SIPROTEC

Distance Protection
7SA6

V4.3

Manual

C53000-G1176-C156-3

Preface

Purpose of this Manual

This manual describes the functions, operation, installation, and placing into service of device 7SA6. In particular, one will find:

- Descriptions of device functions and settings;
- Instructions for mounting and commissioning;
- Compilation of the technical specifications;
- As well as a compilation of the most significant data for experienced users in the Appendix.

General information about design, configuration, and operation of SIPROTEC® 4 devices are laid down in the SIPROTEC ® 4 System Description
(Order no.: E50417-H1176-C151-A1).

Target Audience

Protection engineers, commissioning engineers, personnel concerned with adjustment, checking, and service of selective protective equipment, automatic and control facilities, and personnel of electrical facilities and power plants.

Applicability of this Manual

This manual is valid for: Distance Protection Device SIPROTEC® 4 7SA6; Firmware Version V4.3.

Indication of Conformity

CE	This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Council Directive 89/336/EEC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 73/23 EEC). This conformity is proved by tests conducted by Siemens AG in accordance with Article 10 of the Council Directive in agreement with the generic standards EN 50081 and EN 61 000-6-2 for EMC directive, and with the standard EN 60 255-6 for the low-voltage directive. The product conforms with the international standard of the series IEC 60 255 and the German standard VDE 0435.

Further Standards   IEEE Std C37.90-*

This product is UL-certified according to the Technical Data:

IND. CONT. EQ.
TYPE 1
69CA

IND. CONT. EQ.
TYPE 1

Additional Support Should further information on the System SIPROTEC® 4 be desired or should particular problems arise which are not covered sufficiently for the purchaser's purpose, the matter should be referred to the local Siemens representative.

Training Courses Individual course offerings may be found in our Training Catalogue, or questions may be directed to our training centre in Nuremberg.

Instructions and Warnings The warnings and notes contained in this manual serve for your own safety and for an appropriate lifetime of the device. Please observe them!
The following indicators and standard definitions are used:

DANGER!

indicates that death, severe personal injury or substantial property damage will result if proper precautions are not taken.

Warning

indicates that death, severe personal injury or substantial property damage can result if proper precautions are not taken.

Caution

indicates that minor personal injury or property damage can result if proper precautions are not taken. This particularly applies to damage on or in the device itself and consequential damage thereof.

Note:

indicates information about the device or respective part of the instruction manual which is essential to highlight.

WARNING!

Hazardous voltages are present in this electrical equipment during operation.

Failure to observe these precautions can result in death, personal injury, or serious material damage.

Only qualified personnel shall work on and in the vicinity of this equipment. The personnel must be thoroughly familiar with all warnings and maintenance procedures of this manual as well as the safety regulations.

Successful and safe operation of the device is dependent on proper transportation, storage, mounting and assembly and the observance of the warnings and instructions of the unit manual.

Of particular importance are the general installation and safety regulations for work in a high-voltage environment (for example, VDE, IEC, EN, DIN, or other national and international regulations). These regulations must be observed.

Definition

QUALIFIED PERSONNEL

Prerequisites to proper and safe operation of this product are proper transport, proper storage, setup, installation, operation, and maintenance of the product, as well as careful operation and servicing of the device within the scope of the warnings and instructions of this manual.

- Is trained and authorized to energize, de-energize, clear, ground and tag circuits and equipment in accordance with established safety practices.
- Training and instruction (or other qualification) for switching, grounding, and designating devices and systems.
- Is trained in rendering first aid.

Typographic and Graphical Conventions

To designate terms which refer in the text to information of the device or for the device, the following fonts are used:

`Parameter names`

Designators of configuration or function parameters which may appear word-for-word in the display of the device or on the screen of a personal computer (with operation software DIGSI®), are marked in bold letters of a monospace type style. This also applies to header bars for selection menus.

`1234A`

Parameter addresses have the same character style as parameter names. Parameter addresses contain the suffix **A** in the overview tables if the parameter can only be set in DIGSI ® via the option **Display additional settings**.

`Parameter Conditions`
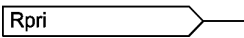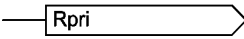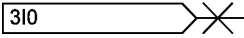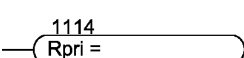
possible settings of text parameters, which may appear word-for-word in the display of the device or on the screen of a personal computer (with operation software DIGSI®), are additionally written in italics. This also applies to header bars for selection menus.

`"Annunciations"`

Designators for information, which may be output by the relay or required from other devices or from the switch gear, are marked in a monospace type style in quotation marks.

Deviations may be permitted in drawings and tables when the type of designator can be obviously derived from the illustration.

The following symbols are used in drawings:

Rpri	device-internal logical input signal
Rpri	device-internal (logical) output signal
3I0	internal input signal of an analogue quantity
2701 Rpri	external binary input signal with number (binary input, input indication)
1114 Rpri =	external binary output signal with number (device indication)

1114 Rpri =	external binary output signal with number (device indication) used as input signal
1234 **FUNCTION** On Off	Example of a parameter switch designated **FUNCTION** with the address 1234 and the possible settings ON and OFF
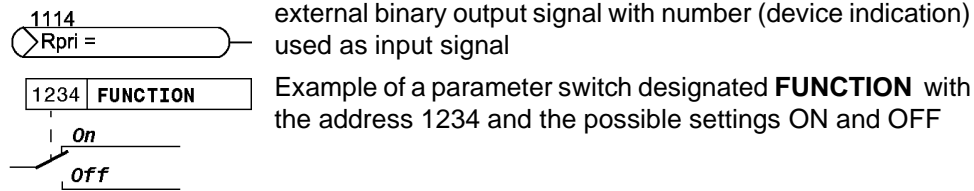
Besides these, graphical symbols are used according to IEC 60 617-12 and IEC 60 617-13 or symbols derived from these standards. Some of the most frequently used are listed below:

	Input signal of an analogue quantity
≥1	OR gate
& signal inversion	AND gate
=1	Exclusive–OR gate (antivalence): output is active, if only **one** of the inputs is active
=	Equivalence: output is active, if **both** inputs are active or inactive at the same time
	Dynamic inputs (edge–triggered) above with positive, below with negative edge
	Formation of one analogue output signal from a number of analogue input signals
2205 **I Max** I Max	Limit stage with setting address and parameter designator (name)
1208 T = T 0	Timer (pickup delay T, example adjustable) with setting address and parameter designator (name)
0 T	Timer (dropout delay T, example non-adjustable)
T	Dynamic triggered pulse timer T (monoflop)
S Q R Q̄	Static memory (RS-flipflop) with setting input (S), resetting input (R), output (Q) and inverted output (Q̄)

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Contents

Introduction   1

The SIPROTEC® 4 7SA6 is introduced in this chapter. The device is presented in its application, characteristics, and scope of functions.

1.1 Overall Operation

The digital Distance Protection SIPROTEC® 4 7SA6 is equipped with a powerful microprocessor system. This provides fully numerical processing of all functions in the device, from the acquisition of the measured values up to the output of commands to the circuit breakers Figure 1-1 shows the basic structure of the 7SA6.

Analog Inputs

The measuring inputs (MI) convert the currents and voltages coming from the transformers and adapt them to the level appropriate for the internal processing of the device. The device has 4 current and 4 voltage inputs. Three current inputs are provided for measurement of the phase currents, a further measuring input (I_4) may be configured to measure the earth current (residual current from the current transformer star-point), the earth current of a parallel line (for parallel line compensation) or the star-point current of a power transformer (for earth fault direction determination).
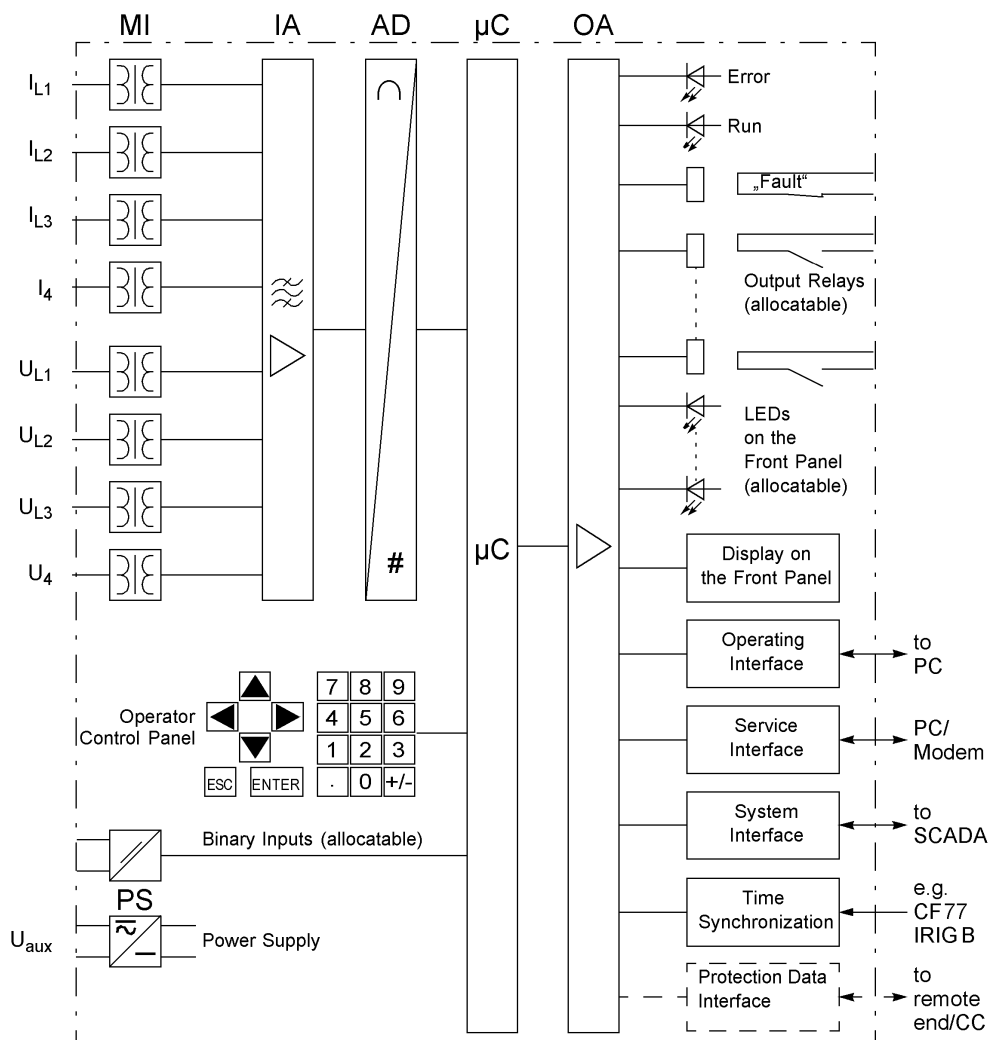
Figure 1-1   Hardware structure of the digital Distance Protection 7SA6

A voltage measuring input is provided for each phase-earth voltage. A further voltage input (U_4) may optionally be used to measure either the displacement voltage (e-n voltage), for a busbar voltage (for synchronism and voltage check) or any other voltage U_X (for overvoltage protection). The analog values are transferred further to the IA input amplifier group.

The input amplifier group IA provides high-resistance termination for the analog input quantities. It consists of filters that are optimized for measured value processing with regard to bandwidth and processing speed.

The AD analog digital converter group contains analog/digital converters and memory components for data transfer to the microcomputer system.

Microcomputer System

Apart from processing the measured values, the microcomputer system µC also executes the actual protection and control functions. They especially consist of:

- Filtering and conditioning of the measured signals,
- Continuous monitoring of the measured quantities
- Monitoring of the pickup conditions for the individual protective functions
- Querying of limit values and time sequences,
- Control of signals for logical functions,
- Reaching trip and close command decisions,
- Stocking messages, fault data and fault values for fault analysis purposes,
- Administration of the operating system and its functions, e.g. data storage, realtime clock, communication, interfaces, etc.

The information is provided via output amplifier OA.

Binary Inputs and Outputs

Binary inputs and outputs from and to the computer system are routed via the I/O modules (inputs and outputs). The computer system obtains the information from the system (e.g remote resetting) or the external equipment (e.g. blocking commands). Additional outputs are mainly commands that are issued to the switching devices and messages for remote signalling of events and states.

Front Elements

LEDs and an LC display provide information on the function of the device and indicate events, states and measured values.

Integrated control and numeric keys in conjunction with the LCD facilitate local interaction with the device. Thereby, all information on the device such as configuration and setting parameters, operation and fault indications and measured values can be retrieved or changed, (see also Chapter 2 and SIPROTEC® 4 System Description, order no. E50417-H1176-C151.

Devices with control functions also allow station control on the front panel.

Serial Interfaces

Via the serial interface in the front panel the communication with a personal computer using the operating program DIGSI® is possible. This facilitates a comfortable handling of all device functions.

The service interface can also be used for communication with a personal computer using DIGSI®. This interface is especially well suited for the fixed wiring of the devices to the PC or operation via a modem.

Via the serial system interface all device data can be transferred to a central evaluation unit or to a control centre. This interface may be provided with various protocols and physical transmission schemes to suit the particular application.

A further interface is provided for <u>time synchronization</u> of the internal clock through external synchronization sources.

Further communication protocols can be realized via additional interface modules.

Protection Data Interface (optional)   Depending on the version one <u>protection data interface</u> can be available. Via these interfaces the data for the teleprotection scheme and further information such as closing the local circuit breaker, other external trip commands coupled via binary inputs and binary information can be transmitted to other ends.

Power Supply   These described functional units are supplied by a power supply PS with the necessary power in the different voltage levels. Brief supply voltage dips which may occur on short circuits in the auxiliary voltage supply of the power system are usually bridged by a capacitor (see also Technical Data, Sub-section 4.1).

1.2 Application Scope

The digital distance protection SIPROTEC® 4 7SA6 is a selective and quick protection for overhead lines and cables with single- and multi-ended infeeds in radial, ring or any type of meshed systems of any voltage levels. The network neutral can be earthed, compensated or isolated.

The device incorporates the functions which are normally required for the protection of an overhead line feeder and is therefore capable of universal application. It may also be applied as time-graded back-up protection to all types of comparison protection schemes used on lines, transformers, generators, motors and busbars of all voltage levels.

The devices located at the ends of the protected zone exchange measuring information via teleprotection functions with conventional connections (contacts) or via optional protection data interfaces using dedicated communication links (usually fibre optic cables) or a communication network. If the 7SA6 devices are equipped with a protection data interface, they can be used for a protection object with 2 ends. Lines with three terminals (teed feeders) require at least one device with two protection data interfaces (7SA522).

Protective Elements
The basic function of the device is the recognition of the distance to the fault with distance protection measurement. In particular for complex multiphase faults, the distance protection has a non-switched 6-impedance-loops design (full scheme). Different pickup schemes enable a good adaption to system conditions and the user philosophy. The network neutral can be isolated, compensated or earthed (with or without earth current limiting). The use on long, heavily-loaded lines is possible with or without series compensation.

The distance protection may be supplemented by teleprotection using various signal transmission schemes (for fast tripping on 100 % of the line length). In addition, an earth fault protection for high resistance earth faults (ordering option) is available, which may be directional, non-directional and may also be incorporated in signal transmission. On lines with weak or no infeed at one line end, it is possible to achieve fast tripping at both line ends by means of the signal transmission schemes. Subsequent to energizing the line onto a fault which may be located along the entire line length, it is possible to achieve a non-delayed trip signal.

In the event of a failure of the measured voltages due to a fault in the secondary circuits (e.g. trip of the voltage transformer mcb or a fuse) the device can automatically revert to an emergency operation with an integrated overcurrent protection, until the measured voltage again becomes available. This time overcurrent protection has three definite-time overcurrent stages and one inverse-time stage; a number of characteristics based on various standards is available for the inverse-time stage. The stages can be combined in any way. Alternatively, the time delayed overcurrent protection may be used as back-up time delayed overcurrent protection, i.e. it functions independent and parallel to the distance protection.

Depending on the version ordered, most short-circuit protection functions may also trip single-pole. They may work in co-operation with an integrated automatic reclosure (available as an option) which enables single-pole, three-pole or single and three-pole automatic reclosure as well as several interrupt cycles on overhead lines. Before reclosure after three-pole tripping, the device can check the validity of the reclosure through voltage and/or synchronism check (can be ordered optionally). It is also possible to connect an external automatic reclosure and/or synchronism check as well as double protection with one or two automatic reclosure functions.

Apart from the mentioned fault protection functions additional protection functions are possible, such as earth fault detection (for isolated or compensated systems), multi-stage overvoltage, undervoltage and frequency protection, circuit breaker failure protection and protection against effects of power swings (for impedance pickup simultaneously active as power swing blocking for the distance protection) and a thermal overload protection which protects the equipment (especially cables) from unpermissible heating due to overload. For the rapid location of the damage to the line after a fault, a fault locator is integrated which also may compensate the influence of parallel lines.

Digital Transmission of Protection Data (optional)
If the distance protection is to be complemented by digital teleprotection schemes, the data required for this purpose can be transmitted via the protection data interface by employing a digital communication link. Communication via the protection data interfaces can be used for transmitting further information. Besides measured values also binary commands or other information can be transmitted.

Control Functions
Depending on the ordered variant the device provides control functions which can be accomplished for activating and deactivating switchgears via the integrated operator panel, the system interface, binary inputs and a personal computer with the operating software DIGSI®. The status of the primary equipment can be transmitted to the device via auxiliary contacts connected to binary inputs. The current status (or position) of the primary equipment can be read out at the device, and used for interlocking or plausibility monitoring. The number of the operating equipment to be switched is limited by the binary inputs and outputs available in the device or the binary inputs and outputs allocated for the switch position indications. Depending on the equipment used one (single point indication) or two (double point indication) binary inputs may be used. The capability of switching primary equipment can be restricted by a setting associated with the switching authority (remote or local), and by the operating mode (interlocked/non-interlocked, with or without password request). Processing of interlocking conditions for switching (e.g. switching error protection) can be established with the aid of integrated, user-configurable logic functions.

Messages and Measured Values; Fault Recording
The operating messages provide information about conditions in the power system and the device. Measurement quantities and values that are calculated can be displayed locally and communicated via the serial interfaces.

Device messages can be assigned to a number of LEDs on the front cover (allocatable), can be externally processed via output contacts (allocable), linked with user-definable logic functions and/or issued via serial interfaces (see Communication below).

During a fault (fault in the system) important events and status changes are stored in the fault logs. Instantaneous fault values are also saved in the device and may be analyzed subsequently.

Communication
Serial interfaces are available for the communication with operating, control and memory systems.

A 9-pin DSUB socket on the front cover is used for local communication with a personal computer. By means of the SIPROTEC® operating software DIGSI® 4, all operational and evaluation tasks can be executed via this operating interface, such as specifying and modifying configuration parameters and settings, configuration of user-specific logic functions, retrieving operational messages and measured values, inquiring device conditions and measured values, issuing control commands.

To establish an extensive communication with other digital operating, control and memory components the device may be provided with further interfaces depending on the order variant.

The service interface can be operated through data lines. Also, a modem can be connected to this interface. For this reason, remote operation is possible via personal computer and the DIGSI® operating software, e.g. to operate several devices via a central PC.

The system interface ensures the central communication between the device and the substation controller. The service interface can be operated through data cables or optical fibres. For data transmission there are several standardized protocols available. The integration of the devices into automation systems from other manufacturers can also take place with this profile.

1.3　Characteristics

General Features
- Powerful 32-bit microprocessor system
- Complete digital processing of measured values and control, from the sampling of the analog input values up to the closing and tripping commands to the circuit breakers
- Complete galvanic and reliable separation between internal processing circuits from the measurement, control, and power supply circuits by analog input transducers, binary inputs and outputs and the DC/DC or AC/DC converters
- Complete scope of functions which are normally required for the protection of a line feeder
- Digital protection data transmission, may be used for teleprotection with permanent monitoring of disturbance, fault or transfer time deviations in the communication network with automatic runtime re-adjustment
- Distance protection system realizable for 3 ends
- Simple device operation using the integrated operator panel or a connected personal computer with operator guidance
- Storage of fault indications as well as instantaneous values for fault recording

Distance Protection
- Protection for all types of faults in systems with earthed, compensated or isolated starpoint
- Different pickup schemes enable the adaption to different system conditions and the user philosophy: Either overcurrent pickup, voltage and phase-angle controlled pickup or impedance pickup (with polygonal characteristic)
- Reliable differentiation between load and fault conditions also on long, high-loaded lines
- High sensitivity in the case of a weakly loaded system, extreme stability against load jumps and power swings
- Optimal adapting to the line conditions by polygonal tripping characteristic with separated setting along the X-axis (reach) and R-axis (arc resistance reserve), for earth faults separated R setting
- Six measuring systems for each distance zone
- Six distance zones, selectable as forward, reverse or non-directional reaching, one may be used as an overreach zone
- Nine time stages for the distance zones
- Direction determination (with polygon) is done with unfaulted loop (quadrature) voltages and voltage memory, thereby achieving unlimited directional sensitivity, and not affected by capacitive voltage transformer transients
- Suitable for lines with series compensation
- Insensitive to current transformer saturation
- Compensation against the influence of a parallel line
- Shortest tripping time is approx. 17 ms (for f_N = 50 Hz) or 15 ms (for f_N = 60 Hz)
- Phase segregated tripping (in conjunction with single-pole or single- and three-pole auto-reclosure)

- Non-delayed tripping following switch onto fault

- Two sets of earth impedance compensation

Power Swing Supplement (optionally for impedance pickup)

- Power swing detection with dZ/dt measurement with three measuring systems

- Power swing detection up to a maximum of 7 Hz swing frequency;

- In service also during single-pole dead times

- Settable power swing programs

- Prevention of undesired tripping by the distance protection during power swings

- Tripping for out-of-step conditions can also be configured

Teleprotection Supplement

- Different procedures may be set:

- Permissive Underreach Transfer Trip = PUTT (directly, via pickup or a separately settable overreach zone);

- Comparison schemes (Permissive Overreach Transfer Trip = POTT or blocking schemes, with separate overreach zone or directional pickup)

- Pilot wire comparison / reverse interlocking (with direct voltage for local connections or extremely short lines)

- Suitable for lines with two or three ends

- Phase segregated transmission possible in lines with two ends

- Optionally signal exchange of the devices via dedicated communication links (in general optical fibres) or a communication network, in this case a phase-segregated transmission with two or three line ends and continuous monitoring of the communication paths and the signal propagation delay with automatic re-adjustment.

Earth Fault Protection (optional)

- Time overcurrent protection with maximally three definite time stages (DT) and one inverse time stage (IDMT) for high resistance earth faults in earthed systems

- For inverse time protection a selection from various characteristics based on several standards can be made

- The inverse time stage can also be set as fourth definite time stage

- High sensitivity (depending on the version from 3 mA);

- Phase current stabilization against fault currents during current transformer saturation

- Second harmonic inrush restraint

- Optionally earth fault protection with zero sequence voltage tripping time or inverse time tripping

- Each stage can be set to be non-directional or directional in the forward or reverse direction

- Single-pole tripping enabled by integrated phase selector

- Direction determination with automatic selection of the larger of zero sequence voltage or negative sequence voltage (U_0, I_y or U_2), with zero sequence system quantities (I_0, U_0), with zero sequence current and transformer starpoint current (I_0, I_Y). or with negative sequence system quantities (I_2, U_2) or with zero sequence power ($3I_0 \cdot 3U_0$);

- One or more stages may function in conjunction with a signal transmission supplement; also suited for lines with three ends

- Instantaneous tripping by any stage when switching onto a fault

Transmission of Information (only with numerical protection data transmission)

- Transmission of the measured values from all ends of the protected object

- Transmission of 4 commands to all ends

- Transmission of 24 additional binary signals to all ends

Tripping at Line Ends with no or Weak Infeed

- Possible in conjunction with teleprotection schemes

- Allows fast tripping at both line ends, even if there is no or only weak infeed available at one line end

- Phase segregated tripping and single-pole automatic reclosure (version with single-pole tripping)

External Direct and Remote Tripping

- Tripping at the local line end from an external device via a binary input

- Tripping of the remote line end by internal protection functions or an external device via a binary input (with teleprotection)

Time Overcurrent Protection

- Selectable as emergency function in the case of measured voltage failure, or as backup function independent of the measured voltage

- Maximally two definite time stages (DT) and one inverse time stage (IDMT), each for phase currents and earth current

- For IDMT protection a selection from various characteristics based on several standards is possible

- Blocking capability e.g. for reverse interlocking with any element

- Instantaneous tripping by any stage when switching onto a fault

- Stub fault protection: Additional stage for fast tripping of faults between the current transformer and line isolator (when the isolator switching status feed back is available); particularly suited to substations with $1^1/_2$ circuit breaker arrangements.

Instantaneous High-Current Switch-onto-Fault Protection

- Fast tripping for all faults on total line length

- Selectable for manual closure or following each closure of the circuit breaker

- With integrated line energization detection

Sensitive Earth Fault Detection (optional)

- For compensated or isolated networks

- Detection of the displacement voltage

- Determination of earth-faulted phases

- Sensitive earth fault directional determination

- Angle error correction for current transformers

Automatic Reclosure Function (optional)

- For reclosure after single-pole, three-pole or single-pole and three-pole tripping

- Single or multiple reclosure (up to 8 reclosure attempts)

- With separate action times for every reclosure attempt, optionally without action times

- With separate dead times after single-pole and three-pole tripping, separate for the first four reclosure attempts

- Controlled optionally by protection pickup with separate dead times after single, two-pole and three-pole pickup

- Optionally with adaptive dead time, reduced dead time and dead line check.

Synchronism and Voltage Check (optional)

- Verification of the synchronous conditions before reclosing after three-pole tripping

- Fast measuring of voltage difference U_{diff} of the phase angle difference φ_{diff} and frequency difference f_{diff};

- Alternatively, check of the de-energized state before reclosing

- Closing at asynchronous system conditions with prediction of the synchronization time

- Settable minimum and maximum voltage

- Verification of the synchronous conditions or de-energized state also possible before the manual closing of the circuit breaker, with separate limit values

- Also measurement via transformer

- Measuring voltages optionally phase-phase or phase-earth

Voltage Protection (optional)

- Overvoltage and undervoltage detection with different stages

- Two overvoltage stages for the phase-earth voltages, with common time delay

- Two overvoltage stages for the phase-phase voltages, with common time delay

- Two overvoltage stages for the positive sequence voltage, with a time delay each, optionally with compounding

- Two overvoltage stages for the negative sequence voltage, with a time delay each

- Two overvoltage stages for the zero sequence voltage or any other single-phase voltage, with a time delay each

- Settable drop-off to pick-up ratios for the overvoltage protection functions

- Two undervoltage stages for the phase-earth voltages, with common time delay

- Two undervoltage stages for the phase-phase voltages, with common time delay

- Two undervoltage stages for the positive sequence voltage, with a time delay each

- Settable current criterion for undervoltage protection functions

Frequency Protection (optional)

- Monitoring on underfrequency (f<) and/or overfrequency (f>) with 4 frequency limits and delay times that are independently adjustable

- Very insensitive to phase angle changes

- Large frequency range (approx. 25 Hz to 70 Hz)

Fault Location

- Initiated by trip command or reset of the pickup

- Computation of the distance to fault with dedicated measured value registers

- Fault location output in ohm, kilometers or miles and % of line length

- Parallel line compensation can be selected

- Taking into consideration the load current in case of single-phase earth faults fed from both sides (settable)

- Output of the fault location in the BCD code or as analog value (depending on the order variant)

Circuit Breaker Failure Protection (optional)

- With definite time current stages for monitoring current flow through every pole of the circuit breaker

- With definite time monitoring time steps for single-pole and three-pole tripping

- Start by trip command of every internal protection function

- Start by external trip functions possible

- Single-stage or two-stage

- Short dropout and overshoot times

Thermal Overload Protection (optional)

- Thermal replica of the current heat losses of the protected object

- R.M.S. measurement of all three conductor currents

- Settable thermal and current-dependent warning stages

Analog Outputs (optional)

- Output of up to four analog measured values (depending on the variant ordered): Measured values, fault location, breaking fault current

User-defined Functions

- Freely programmable combination of internal and external signals for the implementation of user-defined logic functions;

- All common logic functions

- Time delays and set point interrogation

Commissioning; Operation (only with digital transmission of protection data)

- Display of magnitude and phase angle of local and remote measured values

- Display of measured values of the communication link, such as runtime and availability

Command Processing

- Switchgears can be energized and de-energized manually via local control keys, the programmable function keys on the front panel, via the system interface (e.g. by SICAM® or LSA), or via the operating interface using a personal computer and the operating software DIGSI®)

- Feedback on switching states via the circuit breaker auxiliary contacts (for commands with feedback)

- Plausibility monitoring of the circuit breaker position and monitoring of interlocking conditions for switching operations

Monitoring Functions

- Availability of the device is greatly increased by monitoring of the internal measurement circuits, auxiliary power supply, hardware, and software

- Current transformer and voltage transformer secondary circuits are monitored using summation and symmetry check techniques

- Trip circuit supervision

- Checking for the load impedance, the measured direction and the phase sequence

- Monitoring the signal transmission of the optional digital communication path

Additional Functions

- Battery buffered real time clock, which may be synchronized via a synchronization signal (e.g. DCF77, IRIG B via satellite receiver), binary input or system interface

- Continuous calculation and display of measured quantities on the front display. Indication of measured values of the remote end or of all ends (for devices with protection data interfaces);

- Fault event memory (trip log) for the last 8 network faults (faults in the power system), with real time stamps

- Earth fault protocols for up to 8 earth faults (devices with sensitive earth fault detection)

- Fault recording and data transfer for fault recording for a maximum time range of 15 s

- Statistics: Counter with the trip commands issued by the device, as well as recording of the fault current data and accumulation of the interrupted fault currents

- Communication with central control and memory components possible via serial interfaces (depending on the individual ordering variant), optionally via data line, modem or fibre optics

- Commissioning aids such as connection and direction checks as well as circuit breaker test functions

■

Functions

2

This chapter describes the numerous functions available on the SIPROTEC® 4 7SA6. It shows the setting possibilities for all the functions in maximum configuration. Instructions for deriving setting values and formulae, where required are provided.

Additionally it may be defined which functions are to be used.

2.1 General

A few seconds after the device is switched on, the initial display appears in the LCD. Depending on the device version either measured values (four-line display) or a single-phase switching diagram of the feeder status (graphic display) is displayed in the 7SA6.

Configuration of the device functions are made via the DIGSI® software from your PC. The procedure is described in detail in the SIPROTEC® 4 System Description, Order No. E50417-H1176-C151. Entry of password No. 7 (for setting modification) is required to modify configuration settings. Without the password, the settings may be read, but may not be modified and transferred to the device.

The function parameters, i.e. settings of function options, threshold values, etc., can be entered via the keypad and display on the front of the device, or by means of a personal computer connected to the front or service interface of the device utilising the DIGSI® software package. The level 5 password (individual parameters) is required.

2.1.1 Functional Scope

2.1.1.1 Configuration of the Functional Scope

The 7SA6 relay contains a series of protective and additional functions. The hardware and firmware provided is designed for this scope of functions. In addition the command functions can be matched to the system conditions. Individual functions can be activated or deactivated during the configuration procedure. The interaction of functions may also be modified.

Example for the configuration of functional scope:

A substation has overhead line and transformer feeders. You want to perform fault location on overhead lines only. For the devices on the transformer feeders you therefore "suppress" this function during configuration.

The available protective and additional functions must be configured as *Enabled* or *Disabled*. For some functions a choice between several alternatives is possible, as described below.

Functions configured as *Disabled* are not processed by the 7SA6. There are no indications, and corresponding settings (functions, limit values) are not displayed during setting.

Note

The functions and default settings available depend on the order variant of the device.

2.1.1.2 Setting Notes

Configuration of Function Scope

Configuration settings can be entered using a PC and the software program DIGSI® and transferred via the operating interface on front cover of the device or via the service interface. Operation using DIGSI® is described in the SIPROTEC® 4 System Description, Order No. E50417-H1176-C151.

For changing configuration parameters in the device, password no.7 is required (for parameter set). Without the password, the settings may be read, but may not be modified and transmitted to the device.

The functional scope with the available options is set in the **Device Configuration** dialog box to match system requirements.

Special Cases

Most settings are self-explanatory. The special cases are described below.

If use of the setting group change function is desired, address 103 **Grp Chge OPTION** should be set to *Enabled*. In this case, up to four different groups of settings may be changed quickly and easily during device operation (see also Subsection 2.1.4). Only one setting group may be selected and used if the setting is *Disabled*.

Address 110 **Trip mode** is only valid for devices that trip single-pole or three-pole. Set *1-/3pole* to enable also single-pole tripping i.e., if you want to utilize single-pole or single-pole / multi-pole automatic reclosure. This requires an internal automatic reclosing function to be available or an external reclosing device. Furthermore, the circuit breaker must be capable of single pole tripping.

Note

If you have changed address 110, save your changes first via **OK** and reopen the dialog box since the other setting options depend on the selection in Address 110.

You can select from various pickup procedures for the distance protection relay: The properties of these procedures are described in detail in Subsection 2.2.1. If the fault current magnitude is a reliable criterion for distinction between a fault occurrence and load operation (incl. tolerable overload), set Address 114 **Dis. PICKUP** = *I> (overcurr.)* (overcurrent pickup). If the voltage decay is required as another pickup criterion, set *U/I* (voltage-dependent current pickup). For heavily loaded high-voltage lines and very-high-voltage lines the setting *U/I*/φ (voltage and phase-angle dependent current pickup) may be required. With setting *Z< (quadrilat.)* (... pickup) the R and X reaches of the distance zones which are set highest establish the pickup criteria. If you set 114 **Dis. PICKUP** = *Disabled*, the distance protection function and all associated functions will not be available.

Please note that the power swing supplement (see also Subsection 2.3) only works together with the *Z< (quadrilat.)* pickup. In all other cases it is ineffective, even though you have set address 120 **Power Swing** = *Enabled*.

To complement the distance protection by teleprotection schemes, you can select the desired scheme at address 121 **Teleprot. Dist.**. You can select the permissive underreach transfer trip with pickup *PUTT (Pickup)* and with overreach zone *PUTT (Z1B)*, the teleprotection scheme *POTT*, directional comparison pickup *Dir.Comp.Pickup*, unblocking with Z1B *UNBLOCKING* blocking scheme *BLOCKING*, and the schemes with pilot wire comparison *Pilot wire comp* and *Rev. Interlock*. If the device features a protection data interface for communication via a digital transmission lines, set *SIGNALv.ProtInt* here. The procedures are

described in detail in Section 2.6. If you don't want to use teleprotection in conjunction with distance protection set **Disabled**.

For communication of the protection signal the device may feature a protection data interface (depending on the ordered version). To communicate via this protection data interface, instruct the device at address 145 to use the protection data interface **P. INTERFACE 1** (**Enabled**). A protected object with two terminals requires one protection data interface for each of the two relays. If there are more line terminals, it must be ensured that all associated devices are connected directly or indirectly (via other devices) which means that at least one of the devices must be equipped with 2 protection data interfaces (e.g. 7SA522). Subsection 2.4 Communication Topology provides more information.

With address 125 **Weak Infeed** you can select a supplement to the teleprotection schemes. Set **Enabled** to apply the classic scheme for echo and weak infeed tripping. The setting **Logic no. 2** switches this function to the French specification. This setting is available in the device variants for the region France (only version 7SA6***-**D** or 10th digit of order number = D).

At Address 126 **Back-Up O/C** you can select the type of characteristic which the time overcurrent protection uses for operation. In addition to the definite time overcurrent protection, an inverse time overcurrent protection may be configured depending on the ordered version. The latter operates either according to an IEC-characteristic (**TOC IEC**) or an ANSI-characteristic (**TOC ANSI**). For the characteristics please refer to the Technical Data. You can also disable the time overcurrent protection (**Disabled**).

At address 131 **Earth Fault O/C** you can select the type of characteristic which the earth fault protection uses for operation. In addition to the definite time overcurrent protection, which provides up to three stages, an inverse-time earth fault protection function may be configured depending on the ordered version. The latter operates either according to an IEC-characteristic (**TOC IEC**) or an ANSI-characteristic (**TOC ANSI**) or according to a logarithmic-inverse characteristic (**TOC Logarithm.**). If an inverse-time characteristic is not required, the stage usually designated "inverse time" can be used as the fourth definite-time stage (**Definite Time**). Alternatively, it is possible to select an earth fault protection with inverse-time characteristic **UO inverse** (only for region German, 10th digit of the ordering code = A) or a zero-sequence power protection **Sr inverse** (only for region French, 10th digits of ordering code = D). For the characteristics please refer to the Technical Data. You can also disable the earth fault protection (**Disabled**).

When using the earth fault protection, it can be complemented by teleprotection schemes. Select the desired scheme at address 132 **Teleprot. E/F**. You can select the direction comparison scheme **Dir.Comp.Pickup**, the unblocking scheme **UNBLOCKING** and the blocking scheme **BLOCKING**. The procedures are described in detail in Section 2.8. If the device features a protection data interface for communication via a digital link, set **SIGNALv.ProtInt** here. If you do not want to use teleprotection in conjunction with earth fault protection set **Disabled**.

Address 145 **P. INTERFACE 1** is also valid for communication of the teleprotection for earth fault protection via teleprotection interface, as described above.

If the device features an automatic reclosing function, address 133 and 134 are of importance. If no automatic reclosing function is desired for the feeder at which 7SA6 operates, or if an external device is used for reclosure, set address 133 **Auto Reclose** to **Disabled**. Automatic reclosure is only allowed on overhead lines. It should not be used in any other case. If the protected object consists of a mixture of overhead lines and other equipment (e.g. overhead line in block with a transformer or overhead line/cable), it must be ensured that reclosure can only be performed in the event of a fault on the overhead line.

Otherwise set the number of desired reclosing attempts there. You can select *1 AR-cycle* to *8 AR-cycles*. You can also set *ADT* (adaptive dead times). In this case the behaviour of the automatic reclosing function is determined by the cycles of the remote end. The number of cycles must however be configured at least in one of the line ends which must have a reliable infeed. The other end — or other ends, if there are more than two line ends — may operate with adaptive dead time. Section 2.14 provides detailed information on this topic.

The **AR control mode** at address134 allows a maximum of four options. Firstly, it can be determined whether the auto-reclose cycles are carried out according to the fault type detected by **pickup** of the starting protective function(s) (only three-pole tripping), or according to the type of **trip command**. Secondly, the automatic reclosing function can be operated **with** or **without** action time.

The setting *Trip with T-action / Trip without T-action ...* (default setting = Trip with T-action ...) is preferred if single-pole or single-pole/three-pole auto-reclose cycles are provided for and possible. In this case different dead times after single-pole tripping on the one hand and after three-pole tripping on the other hand are possible (for every reclose cycle). The protective function that issues the trip command determines the type of trip: single-pole or three-pole. Depending on the latter the dead time is selected.

The setting *Pickup with T-action / Pickup without T-action ...* (Pickup with T-action ...) is only possible and visible if only three-pole tripping is desired. This is the case when either the ordering number of the device model indicates that it is only suited for three-pole tripping, or when only three-pole tripping is configured (address 110 **Trip mode** = *3pole only*, see above). In this case you can set different dead times for the auto-reclose cycles following single-pole, two-pole and three-pole faults. The decisive factor here is the **pickup** situation of the protective functions at the instant the trip command disappears. This control mode enables also the dead times to be made dependent on the type of fault in the case of three-pole reclosure cycles. Tripping is always three-pole.

The setting *Trip with T-action* provides an action time for each reclose cycle. The action time is started by a general pickup of all protection functions. If no trip command is present before the action time expires, the corresponding reclose cycle is not carried out. Section 2.14 provides detailed information on this topic. This setting is recommended for time-graded protection. If the protection function which is to operate with automatic reclosure, does not have a general pickup signal for starting the action times, select *... Trip without T-action*.

Address 137 allows the voltage protection function to be activated using various undervoltage and overvoltage elements. Particularly, the overvoltage protection with the positive sequence system of the measured voltages provides the option to calculate the voltage at the other line end via integrated compounding. This is particularly useful for long transmission lines where no-load or low-load conditions prevail and an overvoltage at the other line end (Ferranti effect) is to cause tripping of the local circuit breaker. In this case set address 137 **U/O VOLTAGE** to *Enabl. w. comp.* (available with compounding). Do not use compounding in lines with series capacitors!

For the fault location you can determine at address 138 **Fault Locator**, *Enabled* and *Disabled* and that the fault distance is output in BCD code (4 bit units, 4 bit tens and 1 bit hundreds and "data valid") via binary outputs (*with BCD-output*). A corresponding number of output relays (FNo 1143 to 1152) must be made available and allocated for this purpose.

For the trip circuit supervision set at address 140 **Trip Cir. Sup.** the number of trip circuits to be monitored: *1 trip circuit*, *2 trip circuits* or *3 trip circuits*, unless you omit it (*Disabled*).

Depending on the ordered version, the device features a number of analog outputs (0 to 20 mA). 2 outputs can be available at port B (mounting location "B"), 2 further outputs at port D (mounting location "D"). You can select for the available analog outputs at address 150 to 153 the kind of analog quantities that are output. Several measured values and the fault location are available.

2.1.1.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
103	Grp Chge OPTION	Disabled Enabled	Disabled	Setting Group Change Option
110	Trip mode	3pole only 1-/3pole	3pole only	Trip mode
114	Dis. PICKUP	Z< (quadrilat.) I> (overcurr.) U/I U/I/φ Disabled	Z< (quadrilat.)	Distance protection pickup program
120	Power Swing	Disabled Enabled	Disabled	Power Swing detection
121	Teleprot. Dist.	PUTT (Z1B) PUTT (Pickup) POTT Dir.Comp.Pickup UNBLOCKING BLOCKING Rev. Interlock Pilot wire comp SIGNALv.ProtInt Disabled	Disabled	Teleprotection for Distance prot.
122	DTT Direct Trip	Disabled Enabled	Disabled	DTT Direct Transfer Trip
124	SOTF Overcurr.	Disabled Enabled	Disabled	Instantaneous HighSpeed SOTF Overcurrent
125	Weak Infeed	Disabled Enabled Logic no. 2	Disabled	Weak Infeed (Trip and/or Echo)
126	Back-Up O/C	Disabled TOC IEC TOC ANSI	TOC IEC	Backup overcurrent
130	Sens. Earth Flt	Disabled Enabled	Disabled	Sensitive Earth Flt.(comp/ isol. starp.)
131	Earth Fault O/C	Disabled TOC IEC TOC ANSI TOC Logarithm. Definite Time U0 inverse Sr inverse	Disabled	Earth fault overcurrent
132	Teleprot. E/F	Dir.Comp.Pickup SIGNALv.ProtInt UNBLOCKING BLOCKING Disabled	Disabled	Teleprotection for Earth fault over-curr.

Addr.	Parameter	Setting Options	Default Setting	Comments
133	Auto Reclose	1 AR-cycle 2 AR-cycles 3 AR-cycles 4 AR-cycles 5 AR-cycles 6 AR-cycles 7 AR-cycles 8 AR-cycles ADT Disabled	Disabled	Auto-Reclose Function
134	AR control mode	Pickup w/ Tact Pickup w/o Tact Trip w/ Tact Trip w/o Tact	Trip w/ Tact	Auto-Reclose control mode
135	Synchro-Check	Disabled Enabled	Disabled	Synchronism and Voltage Check
136	FREQUENCY Prot.	Disabled Enabled	Disabled	Over / Underfrequency Protection
137	U/O VOLTAGE	Disabled Enabled Enabl. w. comp.	Disabled	Under / Overvoltage Protection
138	Fault Locator	Enabled Disabled with BCD-output	Enabled	Fault Locator
139	BREAKER FAILURE	Disabled Enabled	Disabled	Breaker Failure Protection
140	Trip Cir. Sup.	Disabled 1 trip circuit 2 trip circuits 3 trip circuits	Disabled	Trip Circuit Supervision
142	Ther. OVERLOAD	Disabled Enabled	Disabled	Thermal overload protection
145	P. INTERFACE 1	Enabled Disabled	Enabled	Protection Interface 1 (Port D)
147	NUMBER OF RELAY	2 relays 3 relays	2 relays	Number of relays
150	AnalogOutput B1	Disabled IL2 [%] UL23 [%] |P| [%] |Q| [%] d [%] d [km] d [miles] Imax TRIP [pri]	Disabled	Analog Output B1 (Port B)
151	AnalogOutput B2	Disabled IL2 [%] UL23 [%] |P| [%] |Q| [%] d [%] d [km] d [miles] Imax TRIP [pri]	Disabled	Analog Output B2 (Port B)

Addr.	Parameter	Setting Options	Default Setting	Comments
152	AnalogOutput D1	Disabled IL2 [%] UL23 [%] |P| [%] |Q| [%] d [%] d [km] d [miles] Imax TRIP [pri]	Disabled	Analog Output D1 (Port D)
153	AnalogOutput D2	Disabled IL2 [%] UL23 [%] |P| [%] |Q| [%] d [%] d [km] d [miles] Imax TRIP [pri]	Disabled	Analog Output D2 (Port D)

2.1.2 Device

The device requires some general information. This may be, for example, the type of annunciation to be issued in the event a power system fault occurs.

2.1.2.1 Trip Dependent Messages

The indication of messages masked to local LEDs, and the maintenance of spontaneous messages, can be made dependent on whether the device has issued a trip signal. This information is not output if one or more protection functions have picked up due to a fault, but the 7SA6 has not initiated the tripping because the fault was cleared by another device (e.g. on another line). These messages are then limited to faults on the protected line.

The following figure illustrates the creation of the reset command for stored messages. When the relay drops off, stationary conditions (fault display Target on PU / Target on TRIP; Trip / No Trip) decide whether the new fault will be stored or reset.
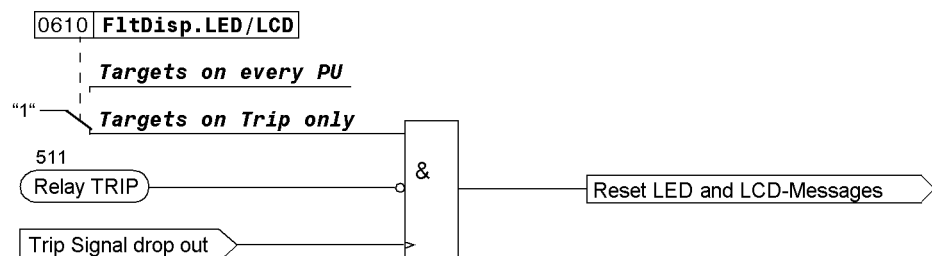
Figure 2-1   Creation of the reset command for the latched LED and LCD messages

2.1.2.2 Spontaneous Annunciations on the Display

You can determine whether or not the most important data of a fault event are displayed automatically after the fault has occurred (see also Subsection "Fault Events" in Section 2.24.1 "Additional functions").

2.1.2.3 Setting Notes

Fault Annuncia-tions

Pickup of a new protective function generally turns off any previously lit LEDs, so that only the latest fault is displayed at any time. It can be selected whether the stored LED displays and the spontaneous annunciations on the display appear upon renewed pickup, or only after a renewed trip signal is issued. In order to enter the desired type of display, select the submenu General Device Settings in the SETTINGS menu. At address 610 **FltDisp.LED/LCD** the two alternatives *Target on PU* and *Target on TRIP* ("No trip - no flag") are offered.

For devices with graphical display use parameter 615 **Spont. FltDisp.** to specify whether or not a spontaneous annunciation will appear automatically on the display (*YES*) or not (*NO*). For devices with text display such messages will appear after a system fault in any case.

After startup of a device featuring a 4-line display, measured values are displayed by default. Use the arrow keys on the device front to select the different represenations of the measured values for the so-called default display. The start page of the default display, which is displayed by default after startup of the device, can be selected via parameter 640 **Start image DD**. The available representation types for the measured values are listed in the appendix .

2.1.2.4 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
610	FltDisp.LED/LCD	Target on PU Target on TRIP	Target on PU	Fault Display on LED / LCD
615	Spont. FltDisp.	NO YES	NO	Spontaneous display of flt.annunciations
640	Start image DD	image 1 image 2 image 3 image 4 image 5	image 1	Start image Default Display

2.1.2.5 Information List

No.	Information	Type of Information	Comments
-	Test mode	IntSP	Test mode
-	DataStop	IntSP	Stop data transmission
-	SynchClock	IntSP_Ev	Clock Synchronization
-	>Light on	SP	>Back Light on

No.	Information	Type of Information	Comments
-	HWTestMod	IntSP	Hardware Test Mode
-	Error FMS1	OUT	Error FMS FO 1
-	Error FMS2	OUT	Error FMS FO 2
-	Brk OPENED	IntSP	Breaker OPENED
-	FdrEARTHED	IntSP	Feeder EARTHED
1	Not configured	SP	No Function configured
2	Non Existent	SP	Function Not Available
3	>Time Synch	SP	>Synchronize Internal Real Time Clock
5	>Reset LED	SP	>Reset LED
11	>Annunc. 1	SP	>User defined annunciation 1
12	>Annunc. 2	SP	>User defined annunciation 2
13	>Annunc. 3	SP	>User defined annunciation 3
14	>Annunc. 4	SP	>User defined annunciation 4
15	>Test mode	SP	>Test mode
16	>DataStop	SP	>Stop data transmission
51	Device OK	OUT	Device is Operational and Protecting
52	ProtActive	IntSP	At Least 1 Protection Funct. is Active
55	Reset Device	OUT	Reset Device
56	Initial Start	OUT	Initial Start of Device
60	Reset LED	OUT_Ev	Reset LED
67	Resume	OUT	Resume
68	Clock SyncError	OUT	Clock Synchronization Error
69	DayLightSavTime	OUT	Daylight Saving Time
70	Settings Calc.	OUT	Setting calculation is running
71	Settings Check	OUT	Settings Check
72	Level-2 change	OUT	Level-2 change
73	Local change	OUT	Local setting change
110	Event Lost	OUT_Ev	Event lost
113	Flag Lost	OUT	Flag Lost
125	Chatter ON	OUT	Chatter ON
126	ProtON/OFF	IntSP	Protection ON/OFF (via system port)
127	AR ON/OFF	IntSP	Auto Reclose ON/OFF (via system port)
128	TelepONoff	IntSP	Teleprot. ON/OFF (via system port)
140	Error Sum Alarm	OUT	Error with a summary alarm
144	Error 5V	OUT	Error 5V
160	Alarm Sum Event	OUT	Alarm Summary Event
177	Fail Battery	OUT	Failure: Battery empty
181	Error A/D-conv.	OUT	Error: A/D converter
182	Alarm Clock	OUT	Alarm: Real Time Clock
183	Error Board 1	OUT	Error Board 1
184	Error Board 2	OUT	Error Board 2
185	Error Board 3	OUT	Error Board 3
186	Error Board 4	OUT	Error Board 4
187	Error Board 5	OUT	Error Board 5
188	Error Board 6	OUT	Error Board 6
189	Error Board 7	OUT	Error Board 7

No.	Information	Type of Information	Comments
190	Error Board 0	OUT	Error Board 0
191	Error Offset	OUT	Error: Offset
192	Error1A/5Awrong	OUT	Error:1A/5Ajumper different from setting
193	Alarm NO calibr	OUT	Alarm: NO calibration data available
194	Error neutralCT	OUT	Error: Neutral CT different from MLFB
4051	Telep. ON	IntSP	Teleprotection is switched ON

2.1.3 Power System Data 1

The device requires certain system and power system data so that it can adapt the implemented functions according to this data. This comprises e.g. nominal system data, nominal data of instrument transformers, polarity and connection type of measured values, in certain cases circuit breaker properties, etc. Furthermore, there are a number of settings associated with all functions rather than a specific protection, control or monitoring function. These data can only be changed from a PC running DIGSI® and are discussed in this Subsection.

2.1.3.1 Setting Notes

General

In DIGSI® double-click Settings to display the available data. A dialog box with tabs CT's, VT's, Power System and Breaker will open under **Power System Data 1** in which you can configure the individual parameters. Thus, the following subsections are structured accordingly.

Current Transformer Polarity

At address 201 **CT Starpoint**, the polarity of the wye-connected current transformers is specified (the following figure also goes for two current transformers). This setting determines the measuring direction of the device (forwards = line direction). Modifying this setting also results in a polarity reversal of the earth current inputs I_E or I_{EE}.
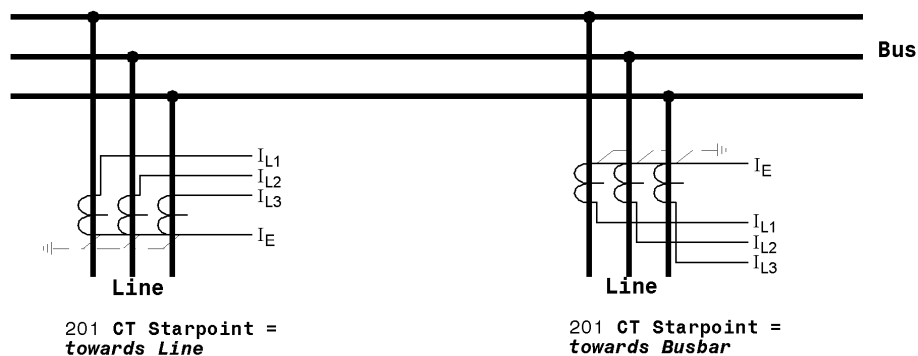
Figure 2-2   Polarity of Current Transformers

Nominal Values of the Transformers

In addresses 203 **Unom PRIMARY** and 204 **Unom SECONDARY** the device obtains information on the primary and secondary rated voltage (phase-to-phase voltage) of the voltage transformers.

It is important to ensure that the rated secondary current of the current transformer matches the rated current of the device, otherwise the device will incorrectly calculate primary amperes.

The correct primary data are required for the calculation of the proper primary information of the operational measured values. If the settings of the device are performed with primary values using DIGSI®, these primary data are an indispensable requirement for the fault-free operation of the device.

Voltage Connection

The device features four voltage measuring inputs, three of which are connected to the set of voltage transformers. Various possibilities exist for the fourth voltage input U_4:

- Connect the U_4 input to the open delta winding e–n of the voltage transformer set:

  Address 210 is then set to: **U4 transformer** = *Udelta transf.*.

  When connected to the e-n winding of a set of voltage transformers, the voltage transformation ratio of the voltage transformers is usually:

$$\frac{VnomPrimary}{\sqrt{3}} \Big/ \frac{VnomSecondary}{\sqrt{3}} \Big/ \frac{VnomSecondary}{3}$$

  The factor Uph/Udelta (secondary voltage, address 211 **Uph / Udelta**) must be set to $3/\sqrt{3} = \sqrt{3} \approx 1.73$. For other transformation ratios, i.e. the formation of the displacement voltage via an interconnected transformer set, the factor must be corrected accordingly. This factor is of importance if the $3U_0$>-protective element is used and for the monitoring of the measured values and the scaling of the measurement and disturbance recording signals.

- Connection of the U_4 input to the busbar voltage in order to perform the synchronism check:

  Address 210 is then set to: **U4 transformer** = *Usync transf.*.

  If the transformation ratio differs from that of the line voltage transformers, this can be adapted with the setting in address 215 **U-line / Usync**. In address 212 **Usync connect.**, the busbar voltage used for synchronism check is configured. The device then selects automatically the appropriate feeder voltage. If the two measuring points used for synchronism check — i.e. feeder voltage transformer and busbar voltage transformer — are not separated by devices that cause a relative phase shift, then the parameter in address 214 φ **Usync-Uline** is not required. This setting is only possible via DIGSI® at "**Additional Settings**". If however a power transformer is switched in between, its vector group must be considered. The phase angle from U_{line} to U_{2bus} is evaluated positively.

Example: (see also Figure 2-3)

Busbar	400 kV primary,
	110 V secondary,
Feeder	220 kV primary,
	100 V secondary,
Transformer	400 kV/220°kV,
	Vector group Yd(n) 5

The transformer vector group is defined from the high side to the low side. In this example, the feeder voltage is connected to the low voltage side of the transformer. If Usync (busbar or high voltage side) is placed at zero degrees, then Uline is at 5 x 30° (according to the vector group) in the clockwise direction, i.e. at −150°. A positive angle is obtained by adding 360°:

Address 214: φ **Usync-Uline** = 360° - 150° = **210°**.

The busbar transformers supply 110 V secondary for primary operation at nominal value while the feeder transformer supplies 100 V secondary. Therefore, this difference must be balanced:

Address 215: **U-line / Usync** = 100 V/110 V = **0.91**.
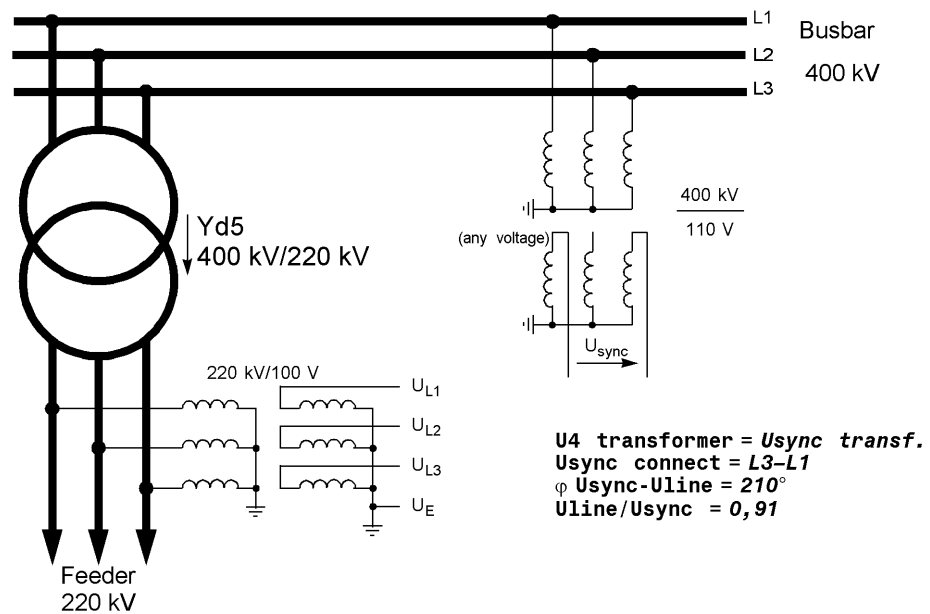
Figure 2-3   Busbar voltage measured via transformer

- Connection of the U_4- input to any other voltage signal U_X, which can be processed by the overvoltage protection function:

  Address 210 is then set to: **U4 transformer** = *Ux transformer*.

- If the input U_4 is not required, set:

  Address 210 **U4 transformer** = *Not connected*.

  Also in this case the factor **Uph / Udelta** (Address 211, see above) is of importance, as it is utilised for the scaling of the measurement and disturbance recording data.

Current Connection The device has four measured current inputs, three of which are connected to the current transformer set. The fourth current measuring input I_4 may be utilised in various ways:

- Connection of the I_4 input to the earth current in the starpoint of the set of current transformers on the protected feeder (normal connection):

  Address 220 is then set to: **I4 transformer** = *In prot. line* and address 221 **I4/Iph CT** = **1**.

- Connection of the I_4 input to a separate earth current transformer on the protected feeder (e.g. a summation CT or core balance CT):

  Address 220 is then set to: **I4 transformer** = *In prot. line* and address 221 **I4/Iph CT** is set:

$$I_4 / I_{ph\ CT} = \frac{\text{Ratio of earth current transformer}}{\text{Ratio of phase current transformers}}$$

This is independent of whether the device has a normal measuring current input for I_4 or a sensitive measuring current input (for sensitive earth fault detection in unearthed power systems).

Example:

Phase current transformers 500 A/5 A

Core balance CT 60 A/1 A

$$I_4 / I_{ph\ CT} = \frac{60 / 1}{500 / 5} = 0.600$$

- Connection of the I_4 input to the earth current of a parallel line (for parallel line compensation of the distance protection and/or fault location):

  Address 220 is then set to: **I4 transformer** = *In paral. line* and usually address 221 **I4/Iph CT** = 1.

  If the set of current transformers on the parallel line however has a different transformation ratio to those on the protected line, this must be taken into account in address 221:

  Address 220 is then set to: **I4 transformer** = *In paral. line* and address 221 **I4/Iph CT** = $I_{N\ paral.\ line}$ / $I_{N\ prot.\ line}$

  <u>Example</u>:

  Current transformers on protected line 1200 A

  Current transformers on parallel line 1500 A

  $$I_4 / I_{ph\ CT} = \frac{1500}{1200} = 1.250$$

- Connection of the I_4 input to the starpoint current of a transformer; this connection is occasionally used for the polarisation of the directional earth fault protection:

  Address 220 is then set to: **I4 transformer** = *IY starpoint*, and address 221 **I4/Iph CT** is according to transformation ratio of the starpoint transformer to the transformer set of the protected line.

- If the I_4 input is not required, set:

  Address 220 **I4 transformer** = *Not connected*,

  Address 221 **I4/Iph CT** is then irrelevant.

  In this case, the neutral current is calculated from the sum of the phase currents.

Rated Frequency

The nominal frequency of the system is set in address 230 **Rated Frequency**. The presetting according to the ordering code (MLFB) only needs to be changed if the device is applied in a region different to the one indicated when ordering. You can set *50 Hz* or *60 Hz*.

System Starpoint

The manner in which the system starpoint is earthed must be considered for the correct processing of earth faults and double earth faults. Accordingly, set for address 207 **SystemStarpoint** = *Solid Earthed*, *Peterson-Coil* or *Isolated*. For low-resistant earthed systems set *Solid Earthed*.

Phase Rotation

Use address 235 **PHASE SEQ.** to change the default setting (*L1 L2 L3* for clockwise rotation) if your power system has a permanent anti-clockwise phase sequence (*L1 L3 L2*).

Distance Unit

Address 236 **Distance Unit** determines the distance unit (*km* or *Miles*) for the fault location indications. This parameter is not relevant if fault detection is not available. Changing the distance unit will not result in an automatic conversion of the setting values which depend on this distance unit. They have to be re-entered into their corresponding valid addresses.

Mode of Earth Impedance (Residual) Compensation   Matching of the earth to line impedance is an essential prerequisite for the accurate measurement of the fault distance (distance protection, fault locator) during earth faults. In address 237 **Format Z0/Z1** the format for entering the residual compensation is determined. It is possible to either use the ratio *RE*/*RL,* *XE*/*XL* or to enter the complex earth (residual) impedance factor *K0*. The actual setting of the earth (residual) impedance factors is done in the power system data 2 (refer to Section 2.1.5).

Operating Time of the Circuit Breaker   The circuit breaker closing time **T-CB close** at address 239 is required if the device is to close also under asynchronous system conditions, no matter whether for manual closing, for automatic reclosing after three-pole tripping, or both. The device will then calculate the time for the close command such that the voltages are phase-synchronous the instant the breaker poles make contact.

Trip Signal Duration   In address 240 the minimum trip command time **TMin TRIP CMD** is set. This setting applies to all protective functions that initiate tripping. It also determines the length of the trip pulse when a circuit breaker trip test is initiated via the device. This setting is only possible via DIGSI® at "**Additional Settings**".

In address 241 the maximum close command duration **TMax CLOSE CMD** is set. This applies to all close commands issued by the device. It also determines the length of the close command pulse when a circuit breaker test cycle is issued via the device. It must be set long enough to ensure that the circuit breaker has securely closed. There is no risk in setting this time too long, as the close command will in any event be terminated following a new trip command from a protection function. This setting is only possible via DIGSI® at "**Additional Settings**".

Circuit Breaker Test   7SA6 allows a circuit breaker test during operation by means of a tripping and a closing command entered on the front panel or via DIGSI®. The duration of the trip command is set as explained above. Address 242 **T-CBtest-dead** determines the duration from the end of the trip command until the start of the close command for this test. It should not be less than 0.1s.

2.1.3.2   Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
201	CT Starpoint	towards Line towards Busbar	towards Line	CT Starpoint
203	Unom PRIMARY	1.0 .. 1200.0 kV	400.0 kV	Rated Primary Voltage
204	Unom SECONDARY	80 .. 125 V	100 V	Rated Secondary Voltage (L-L)
205	CT PRIMARY	10 .. 5000 A	1000 A	CT Rated Primary Current
206	CT SECONDARY	1A 5A	1A	CT Rated Secondary Current
207	SystemStarpoint	Solid Earthed Peterson-Coil Isolated	Solid Earthed	System Starpoint is

Addr.	Parameter	Setting Options	Default Setting	Comments
210	U4 transformer	Not connected Udelta transf. Usync transf. Ux transformer	Not connected	U4 voltage transformer is
211	Uph / Udelta	0.10 .. 9.99	1.73	Matching ratio Phase-VT To Open-Delta-VT
212	Usync connect.	L1-E L2-E L3-E L1-L2 L2-L3 L3-L1	L1-L2	VT connection for sync. voltage
214A	φ Usync-Uline	0 .. 360 °	0 °	Angle adjustment Usync-Uline
215	U-line / Usync	0.50 .. 2.00	1.00	Matching ratio U-line / Usync
220	I4 transformer	Not connected In prot. line In paral. line IY starpoint	In prot. line	I4 current transformer is
221	I4/Iph CT	0.010 .. 5.000	1.000	Matching ratio I4/Iph for CT's
230	Rated Frequency	50 Hz 60 Hz	50 Hz	Rated Frequency
235	PHASE SEQ.	L1 L2 L3 L1 L3 L2	L1 L2 L3	Phase Sequence
236	Distance Unit	km Miles	km	Distance measurement unit
237	Format Z0/Z1	RE/RL, XE/XL K0	RE/RL, XE/XL	Setting format for zero seq.comp. format
239	T-CB close	0.01 .. 0.60 sec	0.06 sec	Closing (operating) time of CB
240A	TMin TRIP CMD	0.02 .. 30.00 sec	0.10 sec	Minimum TRIP Command Duration
241A	TMax CLOSE CMD	0.01 .. 30.00 sec	0.10 sec	Maximum Close Command Duration
242	T-CBtest-dead	0.00 .. 30.00 sec	0.10 sec	Dead Time for CB test-autoreclosure

2.1.4 Setting Group Changeover

2.1.4.1 Purpose of the Setting Groups

Up to four independent setting groups can be created for establishing the device's function settings. During operation, the user can locally switch between setting groups using the operator panel, binary inputs (if so configured), the operator and service interface per PC, or via the system interface. For reasons of safety it is not possible to change between setting groups during a power system fault.

A setting group includes the setting values for all functions that have been selected as **_Enabled_** during configuration (see Subsection 2.1.1.2). In relays 7SA6 four independent setting groups(A to D) are available. Whereas setting values and options may vary, the selected scope of functions is the same for all groups.

Setting groups enable the user to save the corresponding settings for each application. When they are needed, settings may be loaded quickly. All setting groups are stored in the relay. Only one setting group may be active at a given time.

2.1.4.2 Setting Notes

General If multiple setting groups are not required, Group A is the default selection. Then, the rest of this section is not applicable.

If multiple setting groups are desired, the setting group change option must be set to **`Grp Chge OPTION`** = **_Enabled_** in the relay configuration (Subsection 2.1.1.2, address 103). For the setting of the function parameters, you can configure each of the required setting groups A to D, one after the other. A maximum of 4 is possible. Please refer to the SIPROTEC® 4 System Description, Order No. E50417–H1176–C151 to learn how to copy setting groups or reset them to their status at delivery and also what you have to do to change from one setting group to another.

Two binary inputs enable changing between the 4 setting groups from an external source.

2.1.4.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
302	CHANGE	Group A Group B Group C Group D Binary Input Protocol	Group A	Change to Another Setting Group

2.1.4.4 Information List

No.	Information	Type of In-formation	Comments
-	Group A	IntSP	Group A
-	Group B	IntSP	Group B
-	Group C	IntSP	Group C
-	Group D	IntSP	Group D
7	>Set Group Bit0	SP	>Setting Group Select Bit 0
8	>Set Group Bit1	SP	>Setting Group Select Bit 1

2.1.5 Power System Data 2

The general protection data (**P.System Data 2**) include settings associated with all functions rather than a specific protection, monitoring or control function. In contrast to the **P.System Data 1** as discussed before, these can be changed over with the setting groups and can be configured via the operator panel of the device.

2.1.5.1 Setting Notes

Rating of the Pro-tected Object

The rated primary voltage (phase-to-phase) and rated primary current (phases) of the protected equipment are entered in the address 1103 **FullScaleVolt.** and 1104 **FullScaleCurr.**. These settings are required for indication of operational mea-sured values in percent. If these rated values match the primary VT's and CT's, they correspond to the settings in address 203 and 205 (Subsection 2.1.3.1).

General Line Data

The settings of the line data in this case refers to the common data which is independent of the actual distance protection grading.

The line angle (Address 1105 **Line Angle**) may be derived from the line parameters. The following applies:

$$\tan \varphi = \frac{X_L}{R_L} \qquad \text{or} \qquad \varphi = \arctan\left(\frac{X_L}{R_L}\right)$$

where R_L is being the resistance and X_L the reactance of the protected feeder. The line parameters may either apply to the entire line length, or be per unit of line length as the quotient is independent of length. Furthermore it makes no difference if the quo-tients are calculated with primary or secondary values.

The line angle is of major importance e.g. for earth impedance matching according to magnitude and angle or for compounding in overvoltage protection.

Calculation Example:

110 kV overhead line 150 mm^2 with the following data:

$R'_1 = 0.19 \ \Omega/\text{km}$

$X'_1 = 0.42 \ \Omega/\text{km}$

The line angle is computed as follows

$$\tan \varphi = \frac{X_L}{R_L} = \frac{X'_1}{R'_1} = \frac{0.42\ \Omega/km}{0.19\ \Omega/km} = 2.21 \qquad \varphi = 65.7°$$

In address 1105 the setting **Line Angle** = **66**° is entered.

Address 1211 **Distance Angle** specifies the angle of inclination of the R sections of the distance protection polygons. Usually you can also set the line angle here as in address 1105. A slightly smaller angle will usually not be disadvantageous.

The directional values (power, power factor, work and related min., max., mean and setpoint values), calculated in the operational measured values, are usually defined with positive direction towards the protected object. This requires that the connection polarity for the entire device was configured accordingly in the Power System Data 1 (compare also "Polarity of Current Transformers", address 201). But it is also possible to define by setting the "forward" direction for the protection functions and the positive direction for the power etc. differently, e.g so that the active power flow from the line to the busbar is indicated in the positive sense. Set under address 1107 **P,Q sign** the option ***reversed***. If the setting is ***not reversed*** (default), the positive direction for the power etc. corresponds to the "forward" direction for the protection functions.

The reactance value X' of the protected line is entered as reference value **x'** at address 1110 in Ω/km if the distance unit was set as kilometer (address 236, see Subsection 2.1.3.1 at "Distance Unit"), or at address 1112 in $\Omega/mile$ if mile was selected as distance unit. The corresponding line length is entered in address 1111 **Line Length** in kilometres or under address 1113 **Line Length** in miles. After entry of reactance per unit of line length in address 1110 or 1112 or the unit of line length in address 1111 or 1113, the unit of line length is changed in address 236 and the line data must be entered again for the revised distance unit.

The capacitance value C' of the protected line is required for compounding in overvoltage protection. Without compounding it is of no consequence. It is entered as value **c'** at address 1114 in $\mu F/km$ if the distance unit was set to kilometer (address 236, see Subsection 2.1.3.1 at "Distance Unit"), or at address 1115 in $\mu F/mile$ if mile was set as distance unit. After entry of capacitance per unit line length in address 1114 or 1115 or the line length in address 1111 or 1113, the unit of line length is changed in address 236 and the line data must be entered again for the revised distance unit.

When entering the parameters with a personal computer and DIGSI® the values may optionally also be entered as primary values. The following conversion to secondary quantities is then not required.

For conversion of primary values to secondary values the following applies in general:

$$Z_{sec} = \frac{\text{Ratio of current transformers}}{\text{Ratio of voltage transformers}} \cdot Z_{prim}$$

Likewise, the following goes for the reactance setting of a line:

$$X'_{sec} = \frac{N_{CT}}{N_{VT}} \cdot X'_{prim}$$

where

N_{CT} = Current transformer ratio

N_{VT} = Transformation ratio of voltage transformer

The following applies for the capacitance per distance unit:

$$C'_{sec} = \frac{N_{VT}}{N_{CT}} \cdot C'_{prim}$$

Calculation Example:

110 kV overhead line 150 mm^2 as above

R'_1	= 0.19 Ω/km
X'_1	= 0.42 Ω/km
C'	= 0.008 μF/km

Current Transformer   600 A/1 A

Voltage transformer   110 kV / 0.1 kV

The secondary per distance unit reactance is therefore:

$$X'_{sec} = \frac{N_{CT}}{N_{VT}} \cdot X'_{prim} = \frac{600\,A/1\,A}{110\,kV/0.1\,kV} \cdot 0.42\ \Omega/km = 0.229\ \Omega/km$$

In address 1110 the setting **x'** = **0.229** Ω/km is entered.

The secondary per distance unit capacitance is therefore:

$$C'_{sec} = \frac{N_{VT}}{N_{CT}} \cdot C'_{prim} = \frac{110\,kV/0.1\,kV}{600\,A/1\,A} \cdot 0.008\ \mu F/km = 0.015\ \mu F/km$$

In address 1114 the setting **c'** = **0.015** μF/km is entered.

Earth Impedance (Residual) Compensation

Setting of the earth to line impedance ratio is an essential prerequisite for the accurate measurement of the fault distance (distance protection, fault locator) during earth faults. This compensation is either achieved by entering the resistance ratio R_E/R_L and the reactance ratio X_E/X_L or by entry of the complex earth (residual) compensation factor $\underline{K}_0$. Which of these two entry options applies was determined by the setting in address 237 **Format Z0/Z1** (refer to Section 2.1.3.1). Corresponding to the option determined there, only the relevant addresses appear here.

Earth Impedance (Residual) Compensation with Scalar Factors R_E/R_L and X_E/X_L

When entering the resistance ratio R_E/R_L and the reactance ratio X_E/X_L the addresses 1116 to 1119 apply. They are calculated separately, and do not correspond to the real and imaginary components of $\underline{Z}_E/\underline{Z}_L$. A computation with complex numbers is therefore not necessary! The ratios are obtained from system data using the following formulas:

Resistance ratio:	Reactance ratio:
$$\frac{R_E}{R_L} = \frac{1}{3} \cdot \left(\frac{R_0}{R_1} - 1\right)$$	$$\frac{X_E}{X_L} = \frac{1}{3} \cdot \left(\frac{X_0}{X_1} - 1\right)$$

Where

R_0 = Zero sequence resistance of the line

X_0 = Zero sequence reactance of the line

R_1 = Positive sequence resistance of the line

X_1 = Positive sequence reactance of the line

These values may either apply to the entire line length or be based on a per unit of line length, as the quotients are independent of length. Furthermore it makes no difference if the quotients are calculated with primary or secondary values.

Calculation Example:

110 kV overhead line 150 mm^2 with the following data:

   R_1/s = 0.19 Ω/km positive sequence impedance

   X_1/s = 0.42 Ω/km positive sequence impedance

   R_0/s = 0.53 Ω/km zero sequence impedance

   X_0/s = 1.19 Ω/km zero sequence impedance

   (where s   = line length)

For ground impedance ratios, the following emerge:

$$\frac{R_E}{R_L} = \frac{1}{3} \cdot \left(\frac{R_0}{R_1} - 1 \right) = \frac{1}{3} \cdot \left(\frac{0.53\ \Omega/km}{0.19\ \Omega/km} - 1 \right) = 0.60$$

$$\frac{X_E}{X_L} = \frac{1}{3} \cdot \left(\frac{X_0}{X_1} - 1 \right) = \frac{1}{3} \cdot \left(\frac{1.19\ \Omega/km}{0.42\ \Omega/km} - 1 \right) = 0.61$$

The earth impedance (residual) compensation factor setting for the first zone Z1 may be different from that of the remaining zones of the distance protection. This allows the setting of the exact values for the protected line, while at the same time the setting for the back-up zones may be a close approximation even when the following lines have substantially different earth impedance ratios (e.g. cable after an overhead line). Accordingly, the settings for the address 1116 **RE/RL(Z1)** and 1117 **XE/XL(Z1)** are determined with the data of the protected line while the addresses 1118 **RE/RL(Z1B...Z5)** and 1119 **XE/XL(Z1B...Z5)** apply to the remaining zones Z1B and Z2 up to Z5 (as seen from the relay location).

Earth Impedance (Residual) Compensation with Magnitude and Angle ($\underline{K}_0$–Factor)

When the complex earth impedance (residual) compensation factor $\underline{K}_0$ is set, the addresses 1120 to 1123 apply. In this case it is important that the line angle is set correctly (see Address 1105, see paragraph "General Line Data") as the device needs the line angle to calculate the compensation components from the $\underline{K}_0$. These earth impedance compensation factors are defined with their magnitude and angle which may be calculated with the line data using the following equation:

$$\underline{K}_0 = \frac{\underline{Z}_E}{\underline{Z}_L} = \frac{1}{3} \cdot \left(\frac{\underline{Z}_0}{\underline{Z}_1} - 1 \right)$$

Where

$\underline{Z}_0$ = (complex) zero sequence impedance of the line

$\underline{Z}_1$ = (complex) positive sequence impedance of the line

These values may either apply to the entire line length or be based on a per unit of line length, as the quotients are independent of length. Furthermore it makes no difference if the quotients are calculated with primary or secondary values.

For overhead lines it is generally possible to calculate with scalar quantities as the angle of the zero sequence and positive sequence system only differ by an insignificant amount. With cables however, significant angle differences may exist as illustrated by the following example.

<u>Calculation Example</u>:

110 kV single-conductor oil-filled cable $3 \cdot 185$ mm^2 Cu with the following data

$\underline{Z}_1/s$ = $0.408 \cdot e^{j73°}$ Ω/km positive sequence impedance

$\underline{Z}_0/s$ = $0.632 \cdot e^{j18.4°}$ Ω/km zero sequence impedance

(where s = line length)

The calculation of the earth impedance (residual) compensation factor $\underline{K}_0$ results in:

$$\frac{\underline{Z}_0}{\underline{Z}_1} = \frac{0.632}{0.408} \cdot e^{j(18.4°-73°)} = 1.55 \cdot e^{-j54.6°} = 1.55 \cdot (0.579 - j0.815)$$
$$= 0.898 - j1.263$$

$$\underline{K}_0 = \frac{1}{3} \cdot \left(\frac{\underline{Z}_0}{\underline{Z}_1} - 1\right) = \frac{1}{3} \cdot (0.898 - j1.263 - 1) = \frac{1}{3} \cdot (-0.102 - j1.263)$$

The magnitude of K_0 is therefore

$$K_0 = \frac{1}{3} \cdot \sqrt{(-0.102^2) + (-1.263^2)} = 0.42$$

When determining the angle, the quadrant of the result must be considered. The following table indicates the quadrant and range of the angle which is determined by the signs of the calculated real and imaginary part of $\underline{K}_0$.

Table 2-1　　Quadrants and ranges of the angle K_0

Real part	Imaginary part	tan φ(K0)	Quadrant/range	Calculation
+	+	+	I　　0° ... +90°	arc tan (|Im| / |Re|)
+	−	−	IV　−90° ... 0°	−arc tan (|Im| / |Re|)
−	−	+	III　−90° ... −180°	arc tan (|Im| / |Re|) −180°
−	+	−	II　+90° ... +180°	−arc tan (|Im| / |Re|) +180°

In this example the following result is obtained:

$$\varphi(K_0) = \arctan\left(\frac{1.263}{0.102}\right) - 180° = -94.6°$$

The magnitude and angle of the earth impedance (residual) compensation factors setting for the first zone Z1 and the remaining zones of the distance protection may be different. This allows the setting of the exact values for the protected line, while at the same time the setting for the back-up zones may be a close approximation even when the following lines have substantially different earth impedance factors (e.g. cable after an overhead line). Accordingly, the settings for the address 1120 **K0 (Z1)** and 1121 **Angle K0(Z1)** are determined with the data of the protected line while the addresses 1122 **K0 (> Z1)** and 1123 **AngleI K0(> Z1)** apply to the remaining zones Z1B and Z2 up to Z5 (as seen from the relay mounting location).

Note

If a combination of values is set which is not recognized by the device, it operates with preset values $\underline{K}_0 = 1 \cdot e^{0°}$. The information "Dis.ErrorK0(Z1)" (FNo 3654) or "DisErrorK0(>Z1)" (FNo 3655) appears in the event logs.

Parallel Line Mutual Impedance (optional)

If the device is applied to a double circuit line (parallel lines) and parallel line compensation for the distance and/or fault location function is used, the mutual coupling of the two lines must be considered. A prerequisite for this is that the earth (residual) current of the parallel line has been connected to the measuring input I_4 of the device and that this was configured in the power system data (Section 2.1.3.1) by setting the appropriate parameters.

The coupling factors may be determined using the following equations:

Resistance ratio:	Reactance ratio:
$$\frac{R_M}{R_L} = \frac{1}{3} \cdot \frac{R_{0M}}{R_1}$$	$$\frac{X_M}{X_L} = \frac{1}{3} \cdot \frac{X_{0M}}{X_1}$$

where

R_{0M} = Mutual zero sequence resistance (coupling resistance) of the line

X_{0M} = Mutual zero sequence reactance (coupling reactance) of the line

R_1 = Positive sequence resistance of the line

X_1 = Positive sequence reactance of the line

These values may either apply to the entire double circuit line length or be based on a per unit of line length, as the quotient is independent of length. Furthermore it makes no difference whether the quotients are calculated with primary, or secondary values.

These setting values only apply to the protected line and are entered in the addresses 1126 **RM/RL ParalLine** and 1127 **XM/XL ParalLine**.

For earth faults on the protected feeder there is in theory no additional distance protection or fault locator measuring error when the parallel line compensation is used. The setting in address 1128 **RATIO Par. Comp** is therefore only relevant for earth faults outside the protected feeder. It provides the current ratio I_E/I_{EP} for the earth current balance of the distance protection (in Figure 2-4 for the device at location II), above which compensation should take place. In general, a presetting of 85% is sufficient. A more sensitive (larger) setting has no advantage. Only in the case of a severe system asymmetry, or a very small coupling factor (X_M/X_L below approximately 0.4),

may a smaller setting be useful. A more detailed explanation of parallel line compensation can be found in Section 2.2.1 under distance protection.
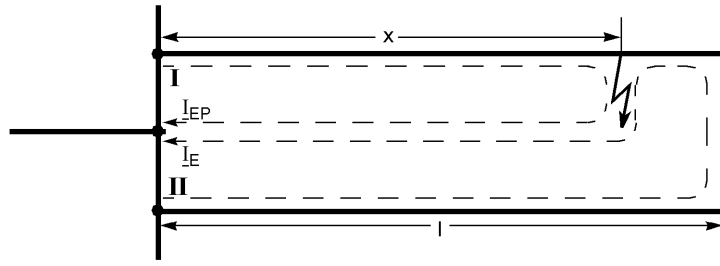
Figure 2-4   Reach with parallel line compensation at II

The current ratio may also be calculated from the desired reach of the parallel line compensation and vice versa. The following applies (refer to Figure 2-4):

$$\frac{I_E}{I_{EP}} = \frac{x \diagup l}{2 - x \diagup l} \qquad \text{or} \qquad \frac{x}{l} = \frac{2}{1 + \dfrac{1}{I_E \diagup I_{EP}}}$$

Current Transformer Saturation

The 7SA6 contains a saturation detector which largely eliminates the measuring errors resulting from the saturation of the current transformers. The threshold above which it picks up can be set in address 1140 **I-CTsat. Thres.**. This is the current level above which saturation may be present. The setting ∞ disables the saturation detector. This setting is only possible via DIGSI® at **Additional Settings**. If current transformer saturation is expected, the following equation may be used as a thumb rule for this setting:

$$\text{Setting value I-CTsat. Thres.} = \frac{n'}{5} \cdot I_{nom}$$

$$\text{With } n' = n \cdot \frac{P_N + P_i}{P' + P_i} = \text{Actual Overcurrent Factor}$$

P_N	= Rated CT burden [VA]
P_i	= Rated CT internal burden [VA]
P'	= Actual connected burden (protection device + connection cable)

Circuit Breaker Status

Information regarding the circuit breaker position is required by various protection and supplementary functions to ensure their optimal functionality. The device has a circuit breaker status recognition which processes the status of the circuit breaker auxiliary contacts and contains also a detection based on the measured currents and voltages for opening and closing (see also Section 2.23.1).

In address 1130 the residual current is set **PoleOpenCurrent**, which will definitely not be exceeded when the circuit breaker pole is open. If parasitic currents (e.g. through induction) can be excluded when the circuit breaker is open, this setting may be very sensitive. Otherwise this setting must be increased correspondingly. Usually

the presetting is sufficient. This setting is only possible via DIGSI® at **Additional Settings**.

The remaining voltage 1131, which will definitely not be exceeded when the circuit breaker pole is open, is set in address **PoleOpenVoltage**. Voltage transformers must be on the line side. The setting should not be too sensitive because of possible parasitic voltages (e.g. due to capacitive coupling). It must in any event be set below the smallest phase-earth voltage which may be expected during normal operation. Usually the presetting is sufficient. This setting is only possible via DIGSI® at **Additional Settings**.

The seal-in time **SI Time all Cl.** (address 1132) determines the activation period for enabling protection functions following each energization of the line (e.g. fast tripping high-current stage). This time is started by the internal circuit breaker switching detection when it recognizes energization of the line or by the circuit breaker auxiliary contacts, if these are connected to the device via binary input to provide information that the circuit breaker has closed. The time should therefore be set longer than the circuit breaker operating time during closing plus the operating time of this protection function plus the circuit breaker operating time during opening. This setting is only possible via DIGSI® at **Additional Settings**.

In address 1134 **Line Closure** the criteria for the internal recognition of line energization are determined. *Manual CLOSE* means that only the manual close signal via binary input or the integrated control is evaluated as closure. *I OR U or ManCl* implies that in addition, the measured current or voltage are used to determine closure of the circuit breaker, whereas *CB OR I or M/C* means that , either CB auxiliary contact status or measured current are used to detect line closure. If the voltage transformer are not situated on the line side, the setting *CB OR I or M/C* must be used. In the case of *I or Man.Close* only the currents or the manual close signals are used to recognize closing of the circuit breaker.

While the time **SI Time all Cl.** (address 1132, refer above) is activated following each recognition of line energization, **SI Time Man.Cl** (address 1150) is the time following <u>manual</u> closure during which special influence of the protection functions is activated (e.g. increased reach of the distance protection). This setting is only possible via DIGSI® at **Additional Settings**.

Note

For CB Test and automatic reclosure the CB auxiliary contact status derived with the binary inputs >CB1 ... (FNo. 366 to 371, 410 and 411) are relevant to indicate the CB switching status. The other binary inputs >CB ... (FNo 351 to 353, 379 and 380) are used for detecting the status of the line (address 1134) and for reset of the trip command (address 1135). Address 1135 is also used by other protection functions, e.g. by the echo function, energization in case of overcurrent etc. For use with one circuit breaker only, both binary input functions e.g. 366 and 351 can be allocated to the same physical input.

For manual closure of the circuit breaker via binary inputs, it can be specified in address 1151 **MAN. CLOSE** whether the integrated manual CLOSE detection checks the synchronism between the busbar voltage and the voltage of the switched feeder. This setting does not apply for a close command via the integrated control functions. If the synchronism check is desired the device must either feature the integrated synchronism check function or an external device for synchronism check must be connected.

In the former case the synchronism check function must be configured as available, a busbar voltage must be connected to the device and this must be correctly parameterized in the power system data (Section 2.1.3.1, address 210 **U4 transformer** = **Usync transf.**, as well as the the associated factors).

If no synchronism check is to be performed with manual closing, set **MAN. CLOSE** = **w/o Sync-check**. If a check is desired, set **with Sync-check**. To not use the MANUAL CLOSE function of the device at, set **MAN. CLOSE** to **NO**. This may be reasonable if the close command is output to the circuit breaker without involving the 7SA6 and the relay itself is not desired to issue a close command.

For commands via the integrated control (local control, DIGSI, serial interface) address 1152 **Man.Clos. Imp.** determines whether a particular close command via the integrated control function should be treated by the protection (like instantaneous re-opening when switching onto a fault) like a MANUAL CLOSE command via binary input. This address also tells the device for which switchgear this applies. You can select from the switching devices which are available for the integrated control. Choose that circuit breaker which usually operates for manual closure and, if required, for automatic reclosure (usually Q0). If **none** is set here, a CLOSE command via the control will not generate a MANUAL CLOSE impulse for the protection function.

Address 1135 **Reset Trip CMD** determines under which conditions a trip command is reset. If **CurrentOpenPole** is set, the trip command is reset as soon as the current disappears. It is important that the value set in address 1130 **PoleOpenCurrent** (see above) is undershot. If **Current AND CB** is set, the circuit-breaker auxiliary contact must send a message that the circuit breaker is open. It is a prerequisite for this setting that the position of the auxiliary contacts is allocated via a binary input.

Three-pole Coupling

Three-pole coupling is only relevant if single-pole auto-reclosures are carried out. If not, tripping is always three-pole. The remainder of this margin heading section is then irrelevant.

Address 1155 **3pole coupling** determines whether any multi-phase pickup leads to a three-pole tripping command, or whether only multi-pole tripping decisions result in a three-pole tripping command. This setting is only relevant with one- and three-pole tripping and therefore only available in this version. More information on this functions is also contained in Subsection 2.23.1 Pickup Logic for the Entire Device.

With the setting **with PICKUP** every fault detection in more than one phase leads to three-pole coupling of the trip outputs, even if only a single-phase earth fault is situated within the tripping region, and further faults only affect the higher zones, or are located in the reverse direction. Even if a single-phase trip command has already been issued, each further fault detection will lead to three-pole coupling of the trip outputs.

If, on the other hand, this address is set to **with TRIP**, three-pole coupling of the trip output (three-pole tripping) only occurs when more than one pole is tripped. Therefore if a single-phase fault is located within the zone of tripping, and a further arbitrary fault is outside the tripping zone, single-phase tripping is possible. Even a further fault during the single-pole tripping will only cause three-pole coupling if it is located within the tripping zone.

This parameter is valid for all protection functions of 7SA6 which are capable of single-pole tripping.

The difference made by this parameter becomes apparent when multiple faults are cleared, i.e. faults occurring almost simultaneously at different locations in the network.

If, for example, two single-phase ground faults occur on different lines — these may also be parallel lines — (Figure 2-5), the protective relays of all four line ends detect a

fault L1–L2–E, i.e. the pickup image is consistent with a two-phase ground fault. If single pole tripping and reclosure is employed, it is therefore desirable that each line only trips and recloses single pole. This is possible with setting 1155 **3pole coupling** = *with TRIP*. In this manner each of the four relays at the four line ends recognises that single pole tripping for the fault on the respective line is required.

Figure 2-5   Multiple fault on a double-circuit line

In some cases, however, three-pole tripping would be preferable for this fault scenario, for example in the event that the double-circuit line is located in the vicinity of a large generator unit (Figure 2-6). This is because the generator considers the two single-phase to ground faults as one double-phase ground fault, with correspondingly high dynamic load on the turbine shaft. With the setting 1155 **3pole coupling** = *with PICKUP*, the two lines are switched off three-pole, since each device detects L1–L2–E on pickup , i.e. a multi-phase fault.
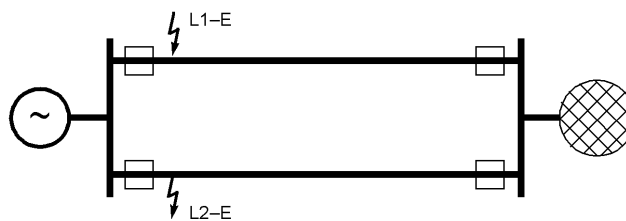
Figure 2-6   Multiple fault on a double-circuit line next to a generator

Address 1156 **Trip2phFlt** determines that the short-circuit protection functions perform only a single-pole trip in case of isolated two-phase faults (clear of ground), provided that single-pole tripping is possible and permitted. This allows a single-pole automatic reclosure cycle for this kind of fault. Thereby you can specify whether the leading phase (*1pole leading Ø*), or the lagging phase *1pole lagging Ø*) is tripped. The parameter is only available in versions with single-pole and three-pole tripping. This setting is only possible via DIGSI® at **Additional Settings**. If this possibility is to be used, you have to bear in mind that the phase selection should be the same throughout the entire network and that it must be the same at all ends of one line. More information on this functions is also contained in Subsection 2.23.1 Pickup Logic for the Entire Device. Usually the presetting *3pole* is used here.

2.1.5.2 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
1103	FullScaleVolt.		1.0 .. 1200.0 kV	400.0 kV	Measurement: Full Scale Voltage (100%)
1104	FullScaleCurr.		10 .. 5000 A	1000 A	Measurement: Full Scale Current (100%)
1105	Line Angle		30 .. 89 °	85 °	Line Angle
1107	P,Q sign		not reversed reversed	not reversed	P,Q operational measured values sign
1110	x'	1A	0.0050 .. 9.5000 Ω/km	0.1500 Ω/km	x' - Line Reactance per length unit
		5A	0.0010 .. 1.9000 Ω/km	0.0300 Ω/km	
1111	Line Length		0.1 .. 1000.0 km	100.0 km	Line Length
1112	x'	1A	0.0050 .. 15.0000 Ω/mi	0.2420 Ω/mi	x' - Line Reactance per length unit
		5A	0.0010 .. 3.0000 Ω/mi	0.0484 Ω/mi	
1113	Line Length		0.1 .. 650.0 Miles	62.1 Miles	Line Length
1114	c'	1A	0.000 .. 100.000 μF/km	0.010 μF/km	c' - capacit. per unit line len. μF/km
		5A	0.000 .. 500.000 μF/km	0.050 μF/km	
1115	c'	1A	0.000 .. 160.000 μF/mi	0.016 μF/mi	c' - capacit. per unit line len. μF/mile
		5A	0.000 .. 800.000 μF/mi	0.080 μF/mi	
1116	RE/RL(Z1)		-0.33 .. 7.00	1.00	Zero seq. comp. factor RE/RL for Z1
1117	XE/XL(Z1)		-0.33 .. 7.00	1.00	Zero seq. comp. factor XE/XL for Z1
1118	RE/RL(Z1B...Z5)		-0.33 .. 7.00	1.00	Zero seq. comp.factor RE/RL for Z1B...Z5
1119	XE/XL(Z1B...Z5)		-0.33 .. 7.00	1.00	Zero seq. comp.factor XE/XL for Z1B...Z5
1120	K0 (Z1)		0.000 .. 4.000	1.000	Zero seq. comp. factor K0 for zone Z1
1121	Angle K0(Z1)		-135.00 .. 135.00 °	0.00 °	Zero seq. comp. angle for zone Z1
1122	K0 (> Z1)		0.000 .. 4.000	1.000	Zero seq.comp.factor K0,higher zones >Z1
1123	AngleI K0(> Z1)		-135.00 .. 135.00 °	0.00 °	Zero seq. comp. angle, higher zones >Z1
1126	RM/RL ParalLine		0.00 .. 8.00	0.00	Mutual Parallel Line comp. ratio RM/RL
1127	XM/XL ParalLine		0.00 .. 8.00	0.00	Mutual Parallel Line comp. ratio XM/XL

Addr.	Parameter	C	Setting Options	Default Setting	Comments
1128	RATIO Par. Comp		50 .. 95 %	85 %	Neutral current RATIO Parallel Line Comp
1130A	PoleOpenCurrent	1A	0.05 .. 1.00 A	0.10 A	Pole Open Current Threshold
		5A	0.25 .. 5.00 A	0.50 A	
1131A	PoleOpenVoltage		2 .. 70 V	30 V	Pole Open Voltage Threshold
1132A	SI Time all Cl.		0.01 .. 30.00 sec	0.05 sec	Seal-in Time after ALL closures
1134	Line Closure		only with ManCl I OR U or ManCl CB OR I or M/C I or Man.Close	only with ManCl	Recognition of Line Closures with
1135	Reset Trip CMD		CurrentOpenPole Current AND CB	CurrentOpenPole	RESET of Trip Command
1140A	I-CTsat. Thres.	1A	0.2 .. 50.0 A; ∞	20.0 A	CT Saturation Threshold
		5A	1.0 .. 250.0 A; ∞	100.0 A	
1150A	SI Time Man.Cl		0.01 .. 30.00 sec	0.30 sec	Seal-in Time after MANUAL closures
1151	MAN. CLOSE		with Sync-check w/o Sync-check NO	NO	Manual CLOSE COMMAND generation
1152	Man.Clos. Imp.		None Breaker Disc.Swit. EarthSwit Q2 Op/Cl Q9 Op/Cl Fan ON/OFF	None	MANUAL Closure Impulse after CONTROL
1155	3pole coupling		with PICKUP with TRIP	with TRIP	3 pole coupling
1156A	Trip2phFlt		3pole 1pole leading Ø 1pole lagging Ø	3pole	Trip type with 2phase faults
1211	Distance Angle		30 .. 90 °	85 °	Angle of inclination, distance charact.

2.1.5.3   Information List

No.	Information	Type of Information	Comments
301	Pow.Sys.Flt.	OUT	Power System fault
302	Fault Event	OUT	Fault Event
303	E/F Det.	OUT	E/Flt.det. in isol/comp.netw.
351	>CB Aux. L1	SP	>Circuit breaker aux. contact: Pole L1
352	>CB Aux. L2	SP	>Circuit breaker aux. contact: Pole L2
353	>CB Aux. L3	SP	>Circuit breaker aux. contact: Pole L3

No.	Information	Type of Information	Comments
356	>Manual Close	SP	>Manual close signal
357	>Close Cmd. Blk	SP	>Block all Close commands from external
361	>FAIL:Feeder VT	SP	>Failure: Feeder VT (MCB tripped)
362	>FAIL:Bus VT	SP	>Failure: Busbar VT (MCB tripped)
366	>CB1 Pole L1	SP	>CB1 Pole L1 (for AR,CB-Test)
367	>CB1 Pole L2	SP	>CB1 Pole L2 (for AR,CB-Test)
368	>CB1 Pole L3	SP	>CB1 Pole L3 (for AR,CB-Test)
371	>CB1 Ready	SP	>CB1 READY (for AR,CB-Test)
378	>CB faulty	SP	>CB faulty
379	>CB 3p Closed	SP	>CB aux. contact 3pole Closed
380	>CB 3p Open	SP	>CB aux. contact 3pole Open
381	>1p Trip Perm	SP	>Single-phase trip permitted from ext.AR
382	>Only 1ph AR	SP	>External AR programmed for 1phase only
383	>Enable ARzones	SP	>Enable all AR Zones / Stages
385	>Lockout SET	SP	>Lockout SET
386	>Lockout RESET	SP	>Lockout RESET
410	>CB1 3p Closed	SP	>CB1 aux. 3p Closed (for AR, CB-Test)
411	>CB1 3p Open	SP	>CB1 aux. 3p Open (for AR, CB-Test)
501	Relay PICKUP	OUT	Relay PICKUP
503	Relay PICKUP L1	OUT	Relay PICKUP Phase L1
504	Relay PICKUP L2	OUT	Relay PICKUP Phase L2
505	Relay PICKUP L3	OUT	Relay PICKUP Phase L3
506	Relay PICKUP E	OUT	Relay PICKUP Earth
507	Relay TRIP L1	OUT	Relay TRIP command Phase L1
508	Relay TRIP L2	OUT	Relay TRIP command Phase L2
509	Relay TRIP L3	OUT	Relay TRIP command Phase L3
510	Relay CLOSE	OUT	Relay GENERAL CLOSE command
511	Relay TRIP	OUT	Relay GENERAL TRIP command
512	Relay TRIP 1pL1	OUT	Relay TRIP command - Only Phase L1
513	Relay TRIP 1pL2	OUT	Relay TRIP command - Only Phase L2
514	Relay TRIP 1pL3	OUT	Relay TRIP command - Only Phase L3
515	Relay TRIP 3ph.	OUT	Relay TRIP command Phases L123
530	LOCKOUT	IntSP	LOCKOUT is active
533	IL1 =	OUT	Primary fault current IL1
534	IL2 =	OUT	Primary fault current IL2
535	IL3 =	OUT	Primary fault current IL3
536	Definitive TRIP	OUT	Relay Definitive TRIP
545	PU Time	OUT	Time from Pickup to drop out
546	TRIP Time	OUT	Time from Pickup to TRIP
560	Trip Coupled 3p	OUT	Single-phase trip was coupled 3phase
561	Man.Clos.Detect	OUT	Manual close signal detected
562	Man.Close Cmd	OUT	CB CLOSE command for manual closing
563	CB Alarm Supp	OUT	CB alarm suppressed
590	Line closure	OUT	Line closure detected
591	1pole open L1	OUT	Single pole open detected in L1

No.	Information	Type of Information	Comments
592	1pole open L2	OUT	Single pole open detected in L2
593	1pole open L3	OUT	Single pole open detected in L3

2.1.6 Oscillographic Fault Records

2.1.6.1 Description

The 7SA6 distance protection is equipped with a fault recording function. The instantaneous values of the measured quantities

i_{L1}, i_{L2}, i_{L3}, i_E or i_{EE}, i_p, i_y and u_{L1}, u_{L2}, u_{L3}, u_{delta} or u_{sync} or u_x or $3 \cdot u_0$

(voltages in accordance with connection) are sampled at intervals of 1 ms (for 50Hz) and stored in a circulating buffer (20 samples per cycle). For a fault, the data are stored for an adjustable period of time, but no more than 5 seconds per fault. A total of 8 records can be saved within 15 s. The fault record memory is automatically updated with every new fault, so no acknowledgment is required. The storage of fault values can also be started by pickup of a protection function, via binary input and via the serial interface.

The data can be retrieved via the serial interfaces by means of a personal computer and evaluated with the protection data processing program DIGSI® and the graphic analysis software SIGRA 4. The latter graphically represents the data recorded during the system fault and calculates additional information such as the impedance or RMS values from the measured values. Currents and voltages can be presented as desired as primary or secondary values. Binary signal traces (marks) of particular events e.g. "fault detection", "tripping" are also represented.

If the device has a serial system interface, the fault recording data can be passed on to a central device via this interface. Data are evaluated by appropriate programs in the central device. Currents and voltages are referred to their maximum values, scaled to their rated values and prepared for graphic presentation. Binary signal traces (marks) of particular events e.g. "fault detection", "tripping" are also represented.

In the event of transfer to a central device, the request for data transfer can be executed automatically and can be selected to take place after each fault detection by the protection, or only after a trip.

2.1.6.2 Setting Notes

General

Other settings pertaining to fault recording (waveform capture) are found in the submenu **Oscillographic Fault Records** of the **Settings** menu. Waveform capture makes a distinction between the trigger instant for an oscillographic record and the criterion to save the record (address 402 **WAVEFORMTRIGGER**). This setting is only possible via DIGSI® at **Additional Settings**. Normally the trigger is the pickup of a protective element, i.e. the time 0 is defined as the instant the first protection function picks up. The criterion for saving may be both the device pickup (*Save w. Pickup*) or the device trip (*Save w. TRIP*). A trip command issued by the device can also be used as trigger instant (*Start w. TRIP*); in this case it is also the saving criterion.

Recording of an oscillographic fault record starts with the pickup by a protective function and ends with the dropout of the last pickup of a protective function. Usually this

is also the extent of a fault recording (address 403 **WAVEFORM DATA** = *Fault event*). If automatic reclosure is implemented, the entire system disturbance — possibly with several reclose attempts — up to the ultimate fault clearance can be stored (address 403 **WAVEFORM DATA** = *Pow.Sys.Flt.*). This facilitates the representation of the entire system fault history, but also consumes storage capacity during the auto-reclosure dead time(s). This setting is only possible via DIGSI® at **Additional Settings**.

The actual storage time encompasses the pre-fault time **PRE. TRIG. TIME** (address 411) ahead of the reference instant, the normal recording time and the post-fault time **POST REC. TIME** (address 412) after the storage criterion has reset. The maximum length of time of a fault record **MAX. LENGTH** is entered in Address 410.

The fault recording can also be triggered via a binary input, via the keypad on the front of the device or with a PC via the operation or service interface. The storage is then dynamically triggered. The length of the fault recording is set in address 415 **BinIn CAPT.TIME** (maximum length however is **MAX. LENGTH**, address 410). Pre-fault and post-fault times will be included. If the binary input time is set for ∞, then the length of the record equals the time that the binary input is activated (static), or the **MAX. LENGTH** setting in address 410, whichever is shorter.

2.1.6.3 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
402A	WAVEFORMTRIGGER R	Save w. Pickup Save w. TRIP Start w. TRIP	Save w. Pickup	Waveform Capture
403A	WAVEFORM DATA	Fault event Pow.Sys.Flt.	Fault event	Scope of Waveform Data
410	MAX. LENGTH	0.30 .. 5.00 sec	2.00 sec	Max. length of a Waveform Capture Record
411	PRE. TRIG. TIME	0.05 .. 0.50 sec	0.25 sec	Captured Waveform Prior to Trigger
412	POST REC. TIME	0.05 .. 0.50 sec	0.10 sec	Captured Waveform after Event
415	BinIn CAPT.TIME	0.10 .. 5.00 sec; ∞	0.50 sec	Capture Time via Binary Input

2.1.6.4 Information List

No.	Information	Type of Information	Comments
-	FltRecSta	IntSP	Fault Recording Start
4	>Trig.Wave.Cap.	SP	>Trigger Waveform Capture
203	Wave. deleted	OUT_Ev	Waveform data deleted

2.2 Distance protection

Distance protection is the main function of the device. It is characterized by high measuring accuracy and the ability to adapt to the given system conditions. It is supplemented by a number of additional functions.

2.2.1 Distance protection, general settings

2.2.1.1 Earth Fault Detection

Functional Description

Recognition of an earth fault is an important element in identifying the type of fault, as the determination of the valid loops for measurement of the fault distance and the shape of the distance zone characteristics substantially depend on whether the fault at hand is an earth fault or not. The 7SA6 has a stabilised earth current measurement, a zero sequence current/negative sequence current comparison as well as a displacement voltage measurement.

Furthermore, special measures are taken to avoid a pickup for single earth faults in an isolated or resonant-earthed system.

Earth Current $3I_0$

For earth current measurement, the fundamental of the summated numerically filtered phase currents is monitored to detect if it exceeds the set value (parameter **3I0> Threshold**). It is stabilized against over-operation resulting from unsymmetrical operating currents and error currents in the secondary circuits of the current transformer due to different degrees of current transformer saturation during short-circuits without earth: the actual pickup threshold automatically increases as the phase current increases (Figure 2-7). The dropout threshold is approximately 95% of the pickup threshold.
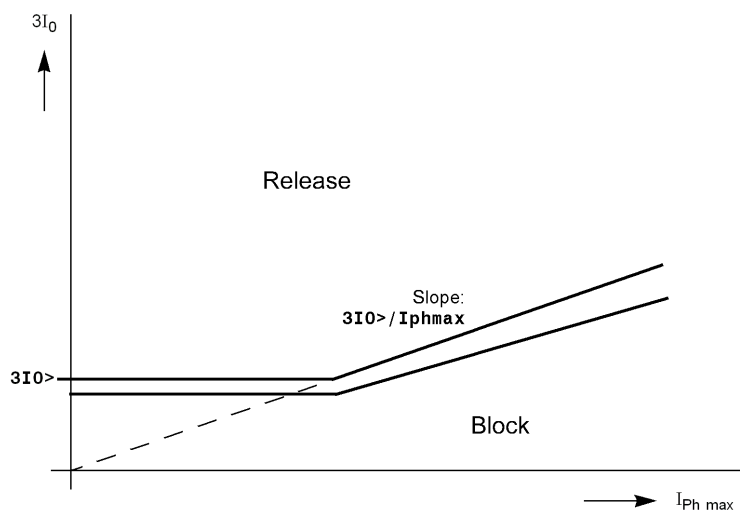
Figure 2-7   Earth current stage: pickup characteristic

Negative Sequence Current $3I_2$

On long, heavily loaded lines, the earth current measurement could be overstabilized by large currents (ref. Figure 2-7). To ensure secure detection of earth faults in this case, a negative sequence comparison stage is additionally provided. In the event of a single-phase fault, the negative sequence current I_2 has approximately the same magnitude as the zero sequence current I_0. When the ratio zero sequence current/negative sequence current exceeds a preset ratio, this stage picks up. It is also stabilized in the event of large negative sequence currents by a parabolic characteristic. Figure 2-8 illustrates this relationship. A release by means of the negative sequence current comparison requires a current of at least 0.2 I_N for $3I_0$ and $3I_2$.
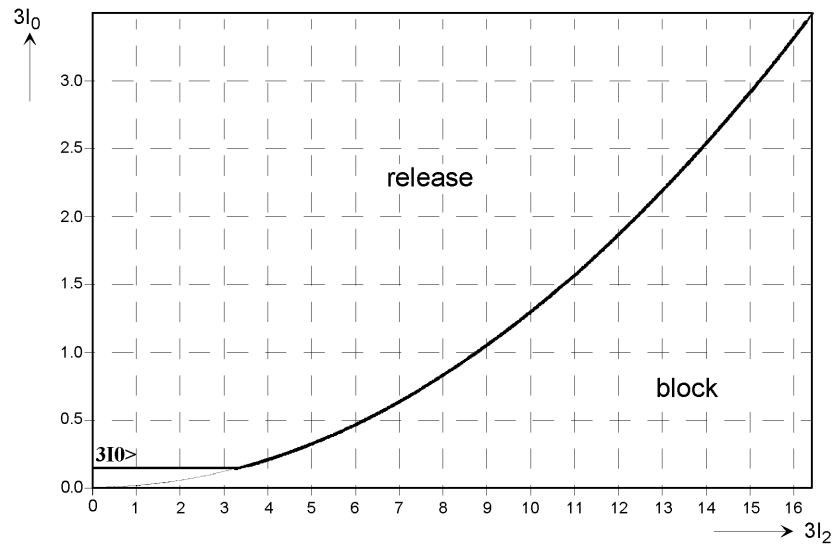
Figure 2-8   Characteristic of the I_0/I_2 stage

Displacement Voltage $3U_0$

For the neutral displacement voltage recognition the displacement voltage $(3 \cdot U_0)$ is numerically filtered and the fundamental frequency is monitored to recognize whether it exceeds the set threshold. The dropout threshold is approximately 95% of the pickup threshold. In earthed networks (**3U0> Threshold**) it may be applied as additional earth fault criterion. For earthed systems, the U_0 criterion may be disabled by applying the ∞ setting.

Logical Combination for Earthed Systems

The current and voltage criteria supplement each other, as the displacement voltage increases when the zero sequence to positive sequence impedance ratio is large, whereas the earth current increases when the zero sequence to positive sequence impedance ratio is smaller. The current and voltage criteria are logically combined with an OR-function for earthed systems. It is however also possible to establish an AND gate of the two criteria (see Figure 2-9). If detection of the displacement voltage has been disabled by setting **3U0> Threshold** to infinite, earth fault detection using the current criterion is still possible in case of CT saturation.

If the relay detects current transformer saturation in any of the phase currents, the voltage criterion is however an indispensable prerequisite for detection of an earth fault since unequal current transformer saturation may cause a faulted secondary zero-sequence current without a primary zero-sequence current flowing in the first place.

The earth fault recognition <u>alone</u> does not cause a general pickup of the distance protection, but merely controls the further fault detection modules. It is only alarmed in case of a general fault detection.
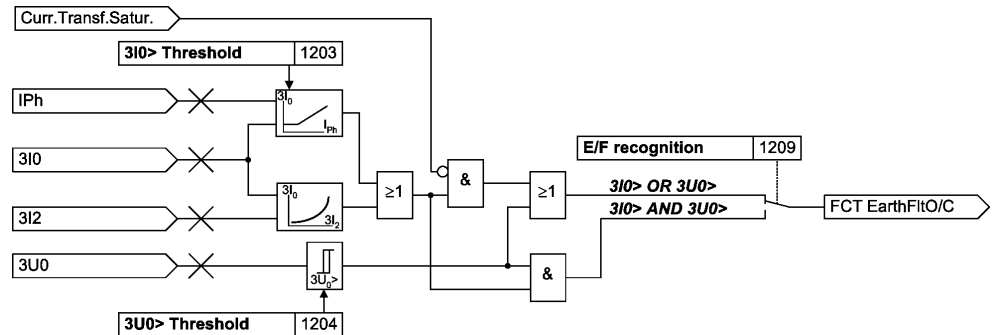
Figure 2-9   Logic of the earth fault detection

Earth Fault Recognition during Single-Pole Open Condition

In order to prevent undesired pickup of the earth fault detection, caused by load currents during single-pole open condition, a modified earth fault detection will take place during single-pole open condition in earthed power systems (Figure 2-10). In this case, the magnitudes of the currents and voltages are monitored in addition to the angles between the currents.
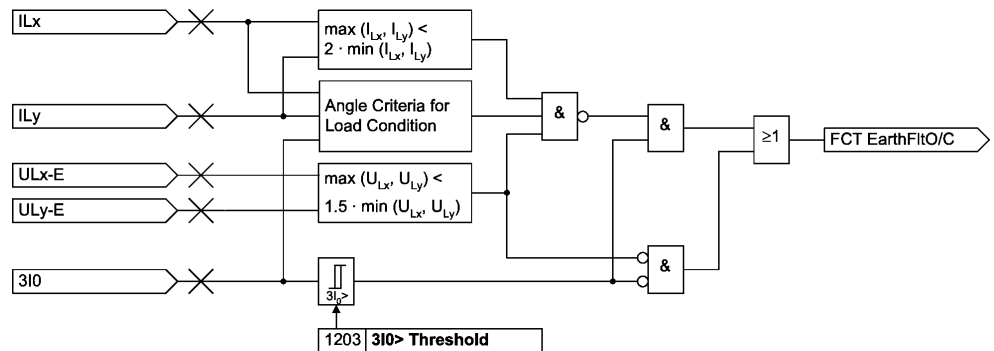
Figure 2-10   Earth fault detection during single-pole open condition

Logical Combination for Non-earthed Systems

In non-earthed systems (isolated system star point or resonant-earthed by means of a Peterson coil) the measured displacement voltage is not used for fault detection. Furthermore, in these systems a simple earth fault is assumed initially in case of a single-phase fault and the fault detection is suppressed in order to avoid an erroneous pickup as a result of the earth fault initiation transients. After a time delay **T3I0 1PHAS** which can be set, the fault detection is released again; this is necessary for the distance protection to still be able to detect a double earth fault with one base point on a dead-end feeder.

If, however, an earth fault is already present in the system, it is detected by the displacement voltage detection (**3U0> COMP/ISOL.**). In this case, there is no delay time: an earth fault occurring now in a different phase can only be a double earth fault. If, apart from the displacement measurement (**3U0> COMP/ISOL.**), there is a fault detection in more than one phase, this is also rated as a double earth fault. In this way, double earth faults can be detected even if no or only little earth current flows via the measuring point.

2.2.1.2 Pickup

Fault detection has to detect a faulty condition in the power system and to initiate all the necessary procedures for selective clearance of the fault:

- start of the delay times for the directional and non-directional final stages,
- determination of the faulted loop(s),
- enabling of impedance calculation and direction determination,
- enabling of tripping command,
- initiation of supplementary functions,
- indication/output of the faulted conductor(s).

Depending on the ordered version, the 7SA6 distance protection features a range of fault detection modes from which the appropriate type for the particular system conditions can be selected. If, according to the ordering code, the device only features impedance fault detection, or if you have set during configuration **Dis. PICKUP** = *Z< (quadrilat.)* (address 114) as detection mode, please continue with Section 2.2.1"Calculation of the Impedances". This type of fault detection works implicitly, i.e the above-mentioned operations are executed automatically as soon as a fault is detected in one of the distance zones.

Overcurrent Pickup

Overcurrent pickup is a phase-selective pickup procedure. After numeric filtering, the currents are monitored in each phase for transgression of a set value. A signal is output for the phase(s) where the set threshold has been exceeded.

For processing the measured values (see Section 2.2.1 "Calculation of the Impedances"), the phase-selective pickup signals are converted into loop information. This depends on the earth fault detection and - in earthed power systems - on the parameter **1ph FAULTS** according to table 2-2. For single-phase pickup without earth fault detection in non-earthed power systems always the phase-phase loop is selected.

The phases that have picked up are signalled. If an earth fault has been detected, it will also be alarmed.

The pickup will drop out if the signal falls below 95% of the pickup value.

Table 2-2   Loops and Phase Indications for Single-phase Overcurrent Pickup

Pickup Module	Earth Fault Detection	Parameter 1ph FAULTS	Valid loop	Alarmed phase(s)
L1	No		L3-L1	L1, L3
L2	No	phase-phase	L1-L2	L1, L2
L3	No		L2-L3	L2, L3
L1	No		L1-E	L1
L2	No	phase-earth [1]	L2-E	L2
L3	No		L3-E	L3
L1	Yes		L1-E	L1, E
L2	Yes	any	L2-E	L2, E
L3	Yes		L3-E	L3, E

[1] only active for earthed power systems

Voltage-dependent Current Pickup U/I (optional)

The U/I pickup is a per phase and per loop pickup mode. Here, the phase currents must exceed a threshold , while the threshold value depends on the magnitude of the loop voltage.

Pickup on earth faults is effectively suppressed in networks with non-earthed neutral points by means of the measures described above in Section "Earth Fault Detection".

The basic characteristics of the U/I pickup can be seen from the current–voltage characteristic shown in Figure 2-11. The first requirement for each phase pickup is that of the minimum current **Iph>** being exceeded. For evaluation of phase–phase loops both relevant phase currents have to exceed this value. Above this current, the current pickup is voltage-dependent with the slope being determined by the settings **U(I>)** and **U(I>>)**. For short-circuits with large currents the overcurrent pickup **Iph>>** is superimposed. The bold dots in Figure 2-11 mark the settings which determine the geometry of the current/voltage characteristic.

The phases that have picked up are signalled. The picked up loops are relevant for processing the measured values.

Loop pickup will drop out if the signal falls below 95 % of the respective current value or exceeds approx. 105 % of the respective voltage value.
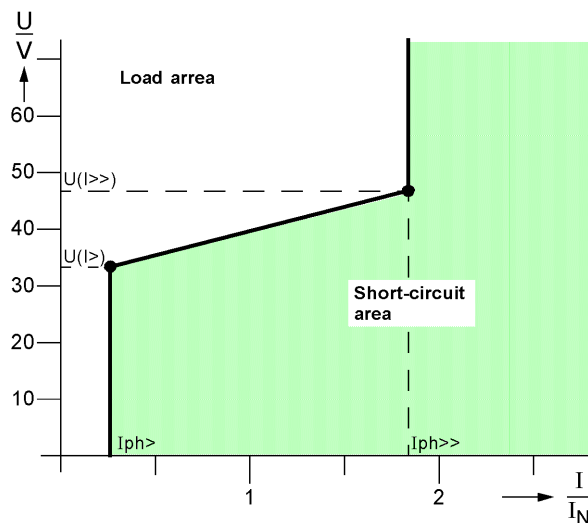
Figure 2-11   U/I characteristic

Pickup Modes

The adaptation to different network conditions is determined by pickup modes.

The setting (**PROGAM U/I**) determines whether the phase–phase loops or the phase–earth loops are always valid, or whether this depends on the earth fault detection. This allows a very flexible adaptation to the network conditions. Optimum control mainly depends on whether the network neutral is not earthed (isolated or compensated), has a low–resistance or effective earthing. Setting notes are given in Section 2.2.1.4.

The evaluation of phase–earth loops is characterized by a high sensitivity in the event of earth faults and is therefore highly advantageous in networks with earthed star points. It automatically adapts to the prevailing infeed conditions; i.e. in the weak-infeed operation mode it becomes more current-sensitive, with high load currents the pickup threshold will be higher. This applies in particular if the network neutral is earthed low–resistance. If only the phase-earth loops are evaluated, it must be ensured that the overcurrent stage **Iph>>** responds in the event of phase-phase faults. If only one measuring system picks up, it can be decided whether this will result

in a pickup of the phase-earth loops or the phase-phase loops in the earthed network (see Table 2-3).

Table 2-3   Loop and Phase Indications for Single-phase U/I pickup; Phase-Earth-Voltages Mode

Pickup module	Measuring current	Measuring voltage	Earth fault detection	Parameter 1ph FAULTS	Valid loop	Alarmed phase(s)
L1	L1	L1-E	No		L3-L1	L1, L3
L2	L2	L2-E	No	phase-phase	L1-L2	L1, L2
L3	L3	L3-E	No		L2-L3	L2, L3
L1	L1	L1-E	No		L1-E	L1
L2	L2	L2-E	No	phase-earth [1]	L2-E	L2
L3	L3	L3-E	No		L3-E	L3
L1	L1	L1-E	Yes		L1-E	L1, E
L2	L2	L2-E	Yes	any	L2-E	L2, E
L3	L3	L3-E	Yes		L3-E	L3, E

[1]   only active for earthed power systems

When evaluating phase–phase loops, the sensitivity towards phase–phase faults is particularly high. In extensive <u>compensated</u> networks this selection is advantageous because it excludes pickup as a result of single earth faults on principle. With two- and three-phase faults it automatically adapts to the prevailing infeed conditions, i.e. in the weak-infeed operation mode it becomes more current-sensitive, with strong infeed and high load currents the pickup threshold will be higher. If only phase-phase faults are evaluated, the measuring loop is independent of the earth-fault detection, therefore this procedure is <u>not suitable for earthed networks</u> (see Table 2-4).

Table 2-4   Loop and Phase Indications for Single-phase U/I pickup; Phase-Phase-Voltages Mode

Pickup module	Measuring current	Measuring voltage	Earth Fault Detection	Parameter 1ph FAULTS	valid loop	alarmed phase(s)
L1	L1	L1-L2			L1-L2	L1, L2
L2	L2	L2-L3	any	any	L2-L3	L2, L3
L3	L3	L3-L1			L3-L1	L1, L3

If the option has been chosen whereby voltage loop selection is dependent on earth-fault detection, then high sensitivity applies to phase-earth faults and to phase–phase faults. On principle, this option is <u>independent of the treatment of the network neutral</u>, however, it requires that the earth–fault criteria according to Section Earth Fault Detection are met for all earth faults or double earth faults (see Table 2-5).

Table 2-5   Loop and Phase Indications for Single-phase U/I pickup; Phase-Earth-Voltages Mode for Earth Faults, Phase-Phase Voltages without Earth Fault

Pickup module	Measuring current	Measuring voltage	Earth Fault Detection	Parameter 1ph FAULTS	Valid loop	Alarmed phase(s)
L1	L1	L1-L2	No		L1-L2	L1, L2
L2	L2	L2-L3	No	any	L2-L3	L2, L3
L3	L3	L3-L1	No		L3-L1	L1, L3
L1	L1	L1-E	Yes		L1-E	L1, E
L2	L2	L2-E	Yes	any	L2-E	L2, E
L3	L3	L3-E	Yes		L3-E	L3, E

Finally, it is also possible to only evaluate phase-earth voltage loops if an earth fault has been detected. For phase-phase faults only the overcurrent **Iph>>**will then pick up. This is advantageous in networks with neutrals that have been <u>earthed low–resistance</u>, i.e. using earth-fault limiting measures. In these cases it is desired to detect earth faults by the U/I pickup only. In these kind of networks it is in most cases even undesirable that phase-phase short-circuits result in a U/I pickup.

The measuring loop is independent of the setting **1ph FAULTS**. Table 2-6 shows the assignment of phase currents, loop voltages and measuring results.

Table 2-6   Loop and Phase Indications for Single-phase U/I pickup; Phase-Earth-Voltages Mode for Earth Faults, I>> without Earth Fault

Pickup module	Measuring current	Measuring voltage	Earth Fault Detection	Parameter 1ph FAULTS	Valid loop	Alarmed phase(s)
L1	L1	L1-E	Yes		L1-E	L1, E
L2	L2	L2-E	Yes	any	L2-E	L2, E
L3	L3	L3-E	Yes		L3-E	L3, E
L1	L1	L1-E	No		no pickup	
L2	L2	L2-E	No	any	no alarm	
L3	L3	L3-E	No		by U_{Ph-E}</I>	

The pickup signals of the loops are converted into phase signals so that the faulted phase(s) can be indicated. If an earth fault has been detected, it will also be alarmed.

Voltage and Angle-dependent Current Pickup U/I/φ (optional)

Phase-angle controlled U/I fault detection can be applied when the U/I characteristic criteria can no longer distinguish reliably between load and short-circuit conditions. This is the case with small source impedances together with long lines or sequence of lines and intermediate infeed. Then the local measured voltage will only drop to a small extent in the event of a short circuit at the line end or in the back-up range of the distance protection so that the phase angle between current and voltage is required as an additional criterion for fault detection.

The U/I/φ pickup is a per phase and per loop pickup mode. It is crucial for the phase currents to exceed the pickup threshold, whereby the pickup value is dependent on the size of the loop voltages and the phase angle between current and voltage.

A precondition for measuring the phase-phase angles is that the associated phase currents as well as the current difference relevant for the loop have exceeded a settable minimum value **Iph>**. The angle is determined by the phase–to–phase voltage and its corresponding current difference.

A precondition for measuring the phase-earth angle is that the associated phase current has exceeded a settable minimum value **Iph>** and that an earth fault has been detected or only phase-to-earth measurements have been stipulated by setting parameters. The angle is determined by the phase-to-earth voltage and its corresponding phase current without considering the earth current.

Pickup on earth faults is effectively suppressed in networks with non-earthed neutral points by means of the measures described in Section "Earth Fault Detection".

The basic characteristics of the U/I/φ pickup can be seen from the current–voltage characteristic shown in Figure 2-12. Initially, it is shaped like the U/I pickup characteristic (Figure 2-11).

For angles in the range of large phase difference, i.e. in the short-circuit angle area above the threshold angle φ**>**, the characteristic between **U(I>)** and **U(Iφ>)** also takes effect; it is cut off by the overcurrent stage **Iφ>**. The bold dots in Figure 2-12 mark the settings which determine the geometry of the current/voltage characteristic. The angle-dependent area, i.e. the area within the short-circuit angle of the characteristic in Figure 2-12, can either be set to affect in forward direction (in direction of line) or in both directions.
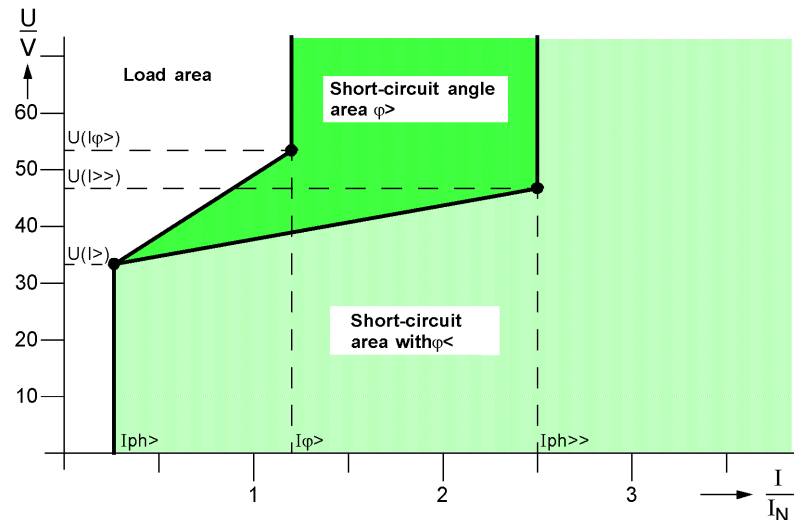
Figure 2-12   U/I/φ characteristic

Loop pickup will drop out if the signal falls below 95% of the respective current value or exceeds approx. 105% of the respective voltage value. A hysteresis of 5° applies to phase-angle measuring.

Pickup programs provide for the matching to different power system conditions. As the U/I/φ pickup is an extension of the U/I pickup, the same program options are available. Tables 2-3 to 2-6 also apply for single–phase pickup.

2.2.1.3 Calculation of the Impedances

A separate measuring system is provided for each of the six possible impedance loops L1-E, L2-E, L3-E, L1-L2, L2-L3, L3-L1. The phase-earth loops are evaluated when an earth fault detection is recognized and the phase current exceeds a settable minimum value **Minimum Iph>**. The phase-phase loops are evaluated when the phase current in both of the affected phases exceeds the minimum value **Minimum Iph>**.

A jump detector synchronizes all the calculations with the fault inception. If a further fault occurs during the evaluation, the new measured values are immediately used for the calculation. The fault evaluation is therefore always done with the measured values of the current fault condition.

Phase-Phase Loops

To calculate the phase-phase loop, for instance during a two-phase short circuit L1-L2 (Figure 2-13), the loop equation is:

$$\underline{I}_{L1} \cdot \underline{Z}_L - \underline{I}_{L2} \cdot \underline{Z}_L = \underline{U}_{L1\text{-}E} - \underline{U}_{L2\text{-}E}$$

with

$\underline{U}, \underline{I}$ the (complex) measured quantities and

$\underline{Z} = R + jX$ the (complex) line impedance.

The line impedance is computed to be

$$\underline{Z}_L = \frac{\underline{U}_{L1-E} - \underline{U}_{L2-E}}{\underline{I}_{L1} - \underline{I}_{L2}}$$
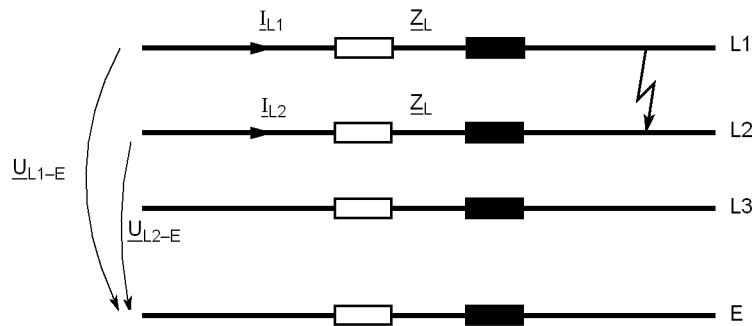
Figure 2-13   Short-circuit of a phase-phase loop

The calculation of the phase-phase loop does not take place as long as one of the concerned phases is switched off (during single-pole dead time), to avoid an incorrect measurement with the undefined measured values existing during this state. A state recognition (refer to section 2.23.1) provides the corresponding block signal. A logic block diagram of the phase-phase measuring system is shown in Figure 2-14.
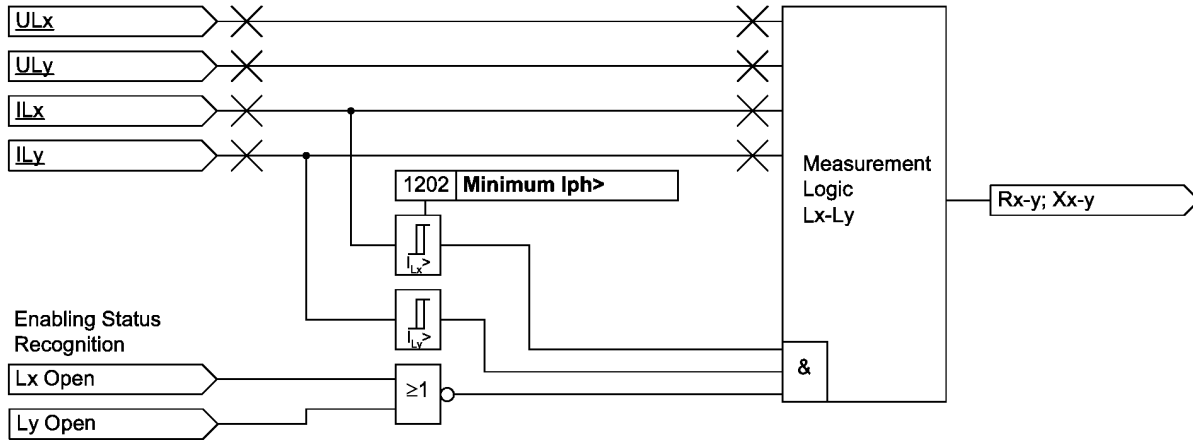
Figure 2-14   Logic of the phase-phase measuring system

Phase-Earth Loops   For the calculation of the phase-earth loop, for example during a L3–E short-circuit (Figure 2-15) it must be noted that the impedance of the earth return path does not correspond to the impedance of the phase. In the loop equation

$$\underline{I}_{L3} \cdot \underline{Z}_L - \underline{I}_E \cdot \underline{Z}_E = \underline{U}_{L3\text{-}E}$$

$\underline{Z}_E$ is replaced by $(\underline{Z}_E/\underline{Z}_L) \cdot \underline{Z}_L$ yielding:

$$I_{L3} \cdot \underline{Z}_L - I_E \cdot \underline{Z}_L \cdot \frac{\underline{Z}_E}{\underline{Z}_L} = \underline{U}_{L3-E}$$

From this the line impedance can be extracted

$$\underline{Z}_L = \frac{\underline{U}_{L3-E}}{I_{L3} - \underline{Z}_E / \underline{Z}_L \cdot I_E}$$
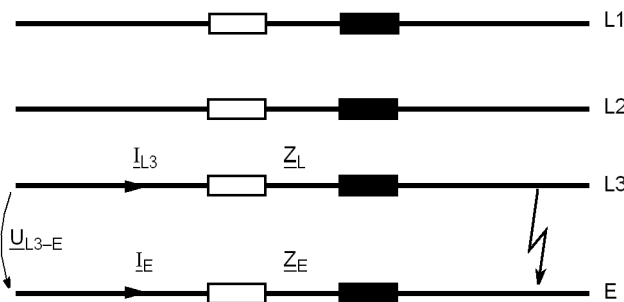
Figure 2-15   Short-circuit of a phase-earth loop

The factor $\underline{Z}_E/\underline{Z}_L$ solely depends on the line parameters and not on the fault distance.

The evaluation of the phase-earth loop does not take place as long as the affected phase is switched off (during single-pole dead time), to avoid an incorrect measurement with the undefined measured values existing in this state. A state recognition provides the corresponding block signal. A logic block diagram of the phase-earth measuring system is shown in Figure 2-16.
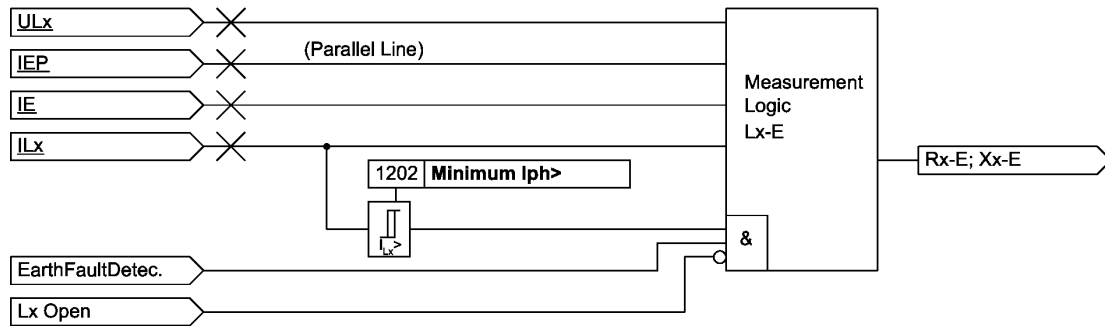
Figure 2-16   Logic of the phase-earth measuring system

Unfaulted Loops   The above considerations apply to the relevant short-circuited loop. A pickup with the current-based fault detection modes (I, U/I, U/I/φ) guarantees that only the faulty loop(s) are released for the distance calculation. All six loops are calculated for the impedance pickup; the impedances of the unfaulted loops are also influenced by the short-circuit currents and voltages in the short-circuited phases. During an L1–E fault for example, the short-circuit current in phase L1 also appears in the measuring loops L1-L2 and L3-L1, the earth current is also measured in loops L2-E and L3-E. Combined with load currents which may flow, the unfaulted loops produce the so-called "apparent impedances" which have nothing to do with the actual fault distance.

These "apparent impedances" in the unfaulted loops are usually larger than the short-circuit impedance of the faulted loop because the unfaulted loop only carries a part of the fault current and always has a larger voltage than the faulted loop. For the selectivity of the zones, they are usually of no consequence.

Apart from the **zone selectivity**, the **phase selectivity** is also important to achieve correct identification of the faulted phases, required to alarm the faulted phase and especially to enable single-pole automatic reclosure. Depending on the infeed conditions, close-in short circuits may cause unfaulted loops to "see" the fault further away than the faulted loop, but still within the tripping zone. This would cause three-pole tripping and therefore void the possibility of single-pole automatic reclosure. As a result power transfer via the line would be lost.

In the 7SA6 this is avoided by the implementation of a "loop verification" function which operates in two steps:

Initially, the calculated loop impedances and its components (phase and/or earth) are used to simulate a replica of the line impedance. If this simulation returns a plausible line image, the corresponding loop pickup is designated as a definitely valid loop.

If the impedances of more than one loop are now located within the range of the zone, the smallest is still declared to be a valid loop. Furthermore, all loops that have an impedance which does not exceed the smallest loop impedance by more than 50% are declared as being valid. Loops with larger impedance are eliminated. Those loops which were declared as being valid in the initial stage, cannot be eliminated by this stage, even if they have larger impedances.

In this manner unfaulted "apparent impedances" are eliminated on the one hand, while on the other hand, unsymmetrical multi-phase faults and multiple short circuits are recognized correctly.

The loops that were designated as being valid are converted to phase information so that the fault detection correctly alarms the faulted phases.

Double Faults in Effectively Earthed Systems

In systems with an effectively or low-resistant earthed starpoint, each connection of a phase with earth results in a short-circuit condition which must be isolated immediately by the closest protection systems. Fault detection occurs in the faulted loop associated with the faulted phase.

With double earth faults, fault detection is generally in two phase-earth loops. If both earth loops are in the same direction, a phase-phase loop may also pick up. It is possible to restrict the fault detection to particular loops in this case. It is often desirable to block the phase-earth loop of the leading phase, as this loop tends to overreach when there is infeed from both ends to a fault with a common earth fault resistance (Parameter 1221 **2Ph-E faults** = *Block leading Ø*). Alternatively, it is also possible to block the lagging phase-earth loop (Parameter **2Ph-E faults** = *Block lagging Ø*). All the affected loops can also be evaluated (Parameter **2Ph-E faults** = *All loops*), or only the phase-phase loop (Parameter **2Ph-E faults** = *Ø-Ø loops only*) or only the phase-earth loops (Parameter **2Ph-E faults** = *Ø-E loops only*).

A prerequisite for these restrictions is that the relevant loops indicate fault locations which are close together and within the reach of the first zone Z1. The loops are considered to be close together when they have the same direction and have both been observed in zone Z1. The loops are considered to be close together when they do not differ by more than a factor 1.5 (largest to smallest impedance). This prevents the elimination, during multiple faults with separate fault location, of the loop relating to the closer fault location by the set restriction. Furthermore a phase-to-phase measurement can only be performed if two earth faults as described above are located close to one another.

In Table 2-7 the measured values used for the distance measurement in earthed systems during double earth faults are shown.

Table 2-7   Evaluation of the measured loops for double loop faults in an earthed system in case both earth faults are close to each other

Loop pickup	Evaluated loop(s)	Setting of parameter 1221
L1-E, L2-E, L1-L2 L2-E, L3-E, L2-L3 L1-E, L3-E, L3-L1	L2-E, L1-L2 L3-E, L2-L3 L1-E, L3-L1	2Ph-E faults = Block leading Ø
L1-E, L2-E, L1-L2 L2-E, L3-E, L2-L3 L1-E, L3-E, L3-L1	L1-E, L1-L2 L2-E, L2-L3 L3-E, L3-L1	2Ph-E faults = Block lagging Ø
L1-E, L2-E, L1-L2 L2-E, L3-E, L2-L3 L1-E, L3-E, L3-L1	L1-E, L2-E, L1-L2 L2-E, L3-E, L2-L3 L1-E, L3-E, L3-L1	2Ph-E faults = All loops
L1-E, L2-E, L1-L2 L2-E, L3-E, L2-L3 L1-E, L3-E, L3-L1	L1-L2 L2-L3 L3-L1	2Ph-E faults = Ø-Ø loops only
L1-E, L2-E, L1-L2 L2-E, L3-E, L2-L3 L1-E, L3-E, L3-L1	L1-E, L2-E L2-E, L3-E L1-E, L3-E	2Ph-E faults = Ø-E loops only

During three phase faults the fault detection of all three phase-phase loops usually occurs. In this case the three phase-phase loops are evaluated. If earth fault detection also occurs, the phase-earth loops are also evaluated.

Double Earth Faults in Non-earthed Systems

In isolated or resonant-earthed networks a single earth fault does not result in a short circuit current flow. There is only a displacement of the voltage triangle (Figure 2-17). For the system operation this state is no immediate danger. The distance protection must not pick up in this case even though the voltage of the phase with the earth fault is equal to zero in the whole galvanically connected system. Any load currents will result in an impedance value that is equal to zero. Therefore a single-phase pickup phase-earth without earth current pickup is avoided in the 7SA6.

a) Healthy System, without Earth Fault   b) Earth Fault in Phase L1
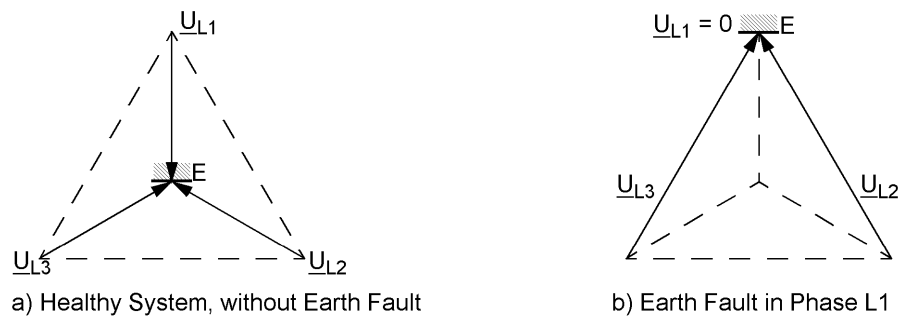
Figure 2-17   Earth fault in non-earthed neutral system

With the occurrence of earth faults — especially in large resonant-earthed systems — large fault inception transient currents can appear that may evoke the earth current pickup. In case of an overcurrent pickup there may also be a phase current pickup. 7SA6 provides special measures against such undesirable pickups.

With the occurrence of a double earth fault in isolated or resonant-earthed systems it is sufficient to switch off one of the faults. The second fault may remain in the system as a simple earth fault. Which of the faults is switched off depends on the double earth fault preference which is set the same in the whole galvanically-connected system. With 7SA6 the following double earth fault preferences (Parameter 1220 **PHASE PREF. 2phe**) can be selected:

acyclic L3 before L1 before L2	L3 (L1) ACYCLIC
acyclic L1 before L3 before L2	L1 (L3) ACYCLIC
acyclic L2 before L1 before L3	L2 (L1) ACYCLIC
acyclic L1 before L2 before L3	L1 (L2) ACYCLIC
acyclic L3 before L2 before L1	L3 (L2) ACYCLIC
acyclic L2 before L3 before L1	L2 (L3) ACYCLIC
cyclic L3 before L1 before L2 before L3	L3 (L1) CYCLIC
cyclic L1 before L3 before L2 before L1	L1 (L3) CYCLIC
all loops are measured	All loops

In all eight preference options, one earth fault is switched off according to the preference scheme. The second fault can remain in the system as a simple earth fault. It can be detected with the Earth Fault Detection in Non-earthed Systems (optional).

The 7SA6 also enables the user to switch off both fault locations of a double earth fault. Set the double earth fault preference to ***All loops***.

Table 2-8 lists all measured values used for the distance measuring in isolated or resonant-earthed systems.

Table 2-8   Evaluation of the Measuring Loops for Multi-phase Pickup in the Non-earthed Network

Loop pickup	Evaluated loop(s)	Setting of parameter 1220
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L1-E L3-E L3-E	PHASE PREF.2phe = L3 (L1) ACYCLIC
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L1-E L3-E L1-E	PHASE PREF.2phe = L1 (L3) ACYCLIC
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L2-E L2-E L1-E	PHASE PREF.2phe = L2 (L1) ACYCLIC
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L1-E L2-E L1-E	PHASE PREF.2phe = L1 (L2) ACYCLIC
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L2-E L3-E L3-E	PHASE PREF.2phe = L3 (L2) ACYCLIC
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L2-E L2-E L3-E	PHASE PREF.2phe = L2 (L3) ACYCLIC
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L1-E L2-E L3-E	PHASE PREF.2phe = L3 (L1) CYCLIC
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L2-E L3-E L1-E	PHASE PREF.2phe = L1 (L3) CYCLIC
L1-E, L2-E, (L1-L2) L2-E, L3-E, (L2-L3) L1-E, L3-E, (L3-L1)	L1-E, L2-E L2-E, L3-E L3-E; L1-E	PHASE PREF.2phe = All loops

Parallel Line Measured Value Correction (optional)

During earth faults on parallel lines, the impedance values calculated by means of the loop equations are influenced by the coupling of the earth impedance of the two conductor systems (Figure 2-18). This causes measuring errors in the result of the impedance computation unless special measures are taken. A parallel line compensation may therefore be activated. In this manner the earth current of the parallel line is taken into consideration by the line equation and thereby allows for compensation of the coupling influence. The earth current of the parallel line must be connected to the device for this purpose. The loop equation is then modified as shown below, refer also to Figure 2-15.

$$\underline{I}_{L3} \cdot \underline{Z}_L - \underline{I}_E \cdot \underline{Z}_E - \underline{I}_{EP} \cdot \underline{Z}_M = \underline{U}_{L3\text{-}E}$$

$$\underline{I}_{L3} \cdot \underline{Z}_L - \underline{I}_E \cdot \underline{Z}_L \cdot \frac{\underline{Z}_E}{\underline{Z}_L} - \underline{I}_{EP} \cdot \underline{Z}_L \cdot \frac{\underline{Z}_M}{\underline{Z}_L} = \underline{U}_{L3-E}$$

where $\underline{I}_{EP}$ is the earth current of the parallel line and the ratio $\underline{Z}_M/\underline{Z}_L$ is a constant line parameter, resulting from the geometry of the double circuit line and the nature of the ground below the line. These line parameters are input to the device — along with all

the other line data — during the parameterisation of the device. The line impedance is calculated similar to the calculation shown earlier.

$$\underline{Z}_L = \frac{\underline{U}_{L3-E}}{\underline{I}_{L3} - \underline{Z}_E / \underline{Z}_L \cdot \underline{I}_E - \underline{Z}_M / \underline{Z}_L \cdot \underline{I}_{EP}}$$
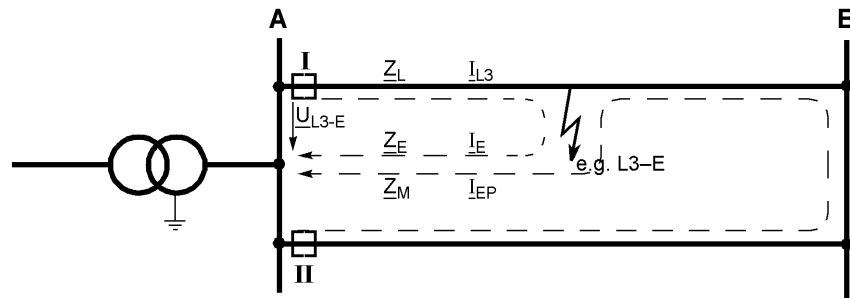
Figure 2-18   Earth fault on a double circuit line

Without parallel line compensation, the earth current on the parallel line will in most cases cause the reach threshold of the distance protection to be shortened (underreach of the distance measurement). In some cases — for example when the two feeders are terminated to different busbars, and the location of the earth fault is on one of the remote busbars (at B in Figure 2-18) — it is possible that an overreach may occur.

The parallel line compensation only applies to faults on the protected feeder. For faults on the parallel line, the compensation may not be carried out, as this would cause severe overreach. The relay located in position II in Figure 2-18 may therefore not be compensated.

Earth current balance is therefore additionally provided in the device, which carries out a cross comparison of the earth currents in the two lines. The compensation is only applied to the line end where the earth current of the parallel line is not substantially larger than the earth current in the line itself. In example Figure 2-18, the current I_E is larger than I_{EP}: Compensation is applied at I by including $\underline{Z}_M \cdot \underline{I}_{EP}$ in the evaluation; at II compensation is not applied.

Switching onto a Fault

When the circuit breaker is switched onto a dead fault with a manual close command, fast tripping by the distance protection is possible. By setting parameters it may be determined which zone(s) is/are released following a manual close (refer to Figure 2-19). The line energization information (input "Line closure") are derived from the line energization recognition.
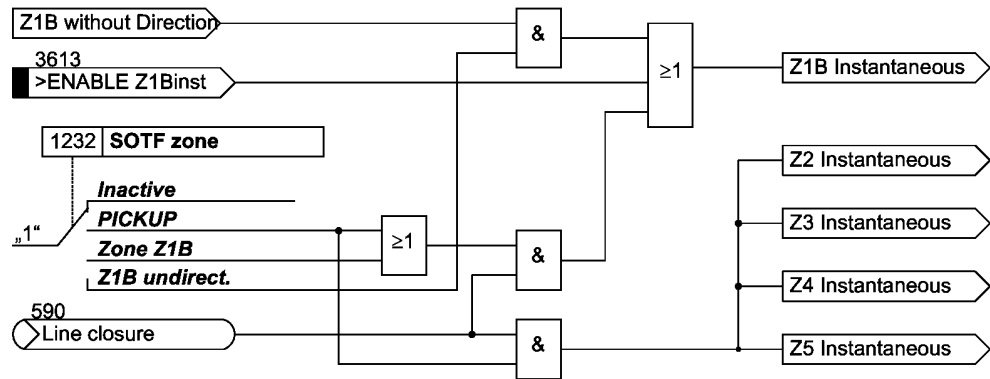
Figure 2-19   Circuit breaker closure onto a fault

2.2.1.4   Setting Notes

At address 1201 **FCT Distance** the distance protection function can be switched *ON* or *OFF*.

Minimum Current

The minimum current for fault detection **Minimum Iph>** (address 1202) in case of impedance pickup is set somewhat (approx. 10 %) below the minimum short-circuit current that may occur. For the other pickup modes it is set at address 1611.

Earth Fault Detection

In systems with earthed star-point, the setting **3IO> Threshold** (address 1203) is set somewhat below the minimum expected earth fault current. $3I_0$ is defined as the sum of the phase currents $|I_{L1} + I_{L2} + I_{L3}|$, which equals the star-point current of the set of current transformers. In non-earthed systems the setting value is recommended to be below the earth current value for double earth faults.

The preset value **3IO>/ Iphmax** = 0.10 (Address 1207) usually is recommended for the slope of the 3I0 characteristic. This setting can only be changed via DIGSI® at **Additional Settings**.

Addresses 1204 and 1209 are only relevant for **earthed** power systems. In non-earthed systems this setting is not relevant and therefore not accessible.

When setting **3UO> Threshold** (address 1204), care must be taken that operational asymmetries do not cause a pickup. $3U_0$ is defined as the sum of the phase-earth voltages $|U_{L1-E} + U_{L2-E} + U_{L3-E}|$. To ignore the U_0–criterion, the address 1204 is set to ∞.

In earthed power systems the earth fault detection can be complemented by a zero sequence voltage detection function. You can determine whether an earth fault is detected when a zero sequence current or a zero sequence voltage threshold is surpassed or when both criteria are met. 1209 (default setting) applies at address **E/F recognition** *3IO> OR 3UO>* if only one of the two criteria is valid. Select *3IO> AND 3UO>* to activate both criteria for earth-fault detection. This setting can only be changed via DIGSI® at **Additional Settings**. If you want to detect only the earth current, set *3IO> OR 3UO>* and also **3UO> Threshold** (address 1204) to ∞.

> *Note*
>
> Do under no circumstances set address 1204 **3U0> Threshold** to ∞, if you have set address 1209 **E/F recognition** = *3I0> AND 3U0>* since earth fault detection will then no longer be possible.

If in isolated or resonant earthed systems the earth fault detection threatens to pick up due to fault inception transients following the occurrence of a single earth fault, the detection can be delayed with setting address 1206 **T3I0 1PHAS**. Set parameter **T3I0 1PHAS** to ∞ if the earth current threshold can also be exceeded during steady-state conditions. Then, even with high earth current, no single-phase pickup is possible anymore. Double earth faults are however correctly detected and measured according to the preference program (also see Section 2.2.1 at margin heading "Double Earth Faults in Non-earthed Systems").

Application with Series-compensated Lines

With series-compensated lines (lines with series capacitors), set address 1208 **SER-COMP.** to *YES* to ensure that the direction determination works correctly in all cases. The effect of series capacitors on direction determination is described in Sub-section 2.2.2 under margin heading "Direction Determination on Series-compensated Lines".

Start of Delay Times

As was mentioned in the description of the measuring technique, each distance zone generates an output signal which is associated with the zone and the affected phase. The zone logic combines these zone fault detections with possible further internal and external signals The delay times for the distance zones can be started either all together on general fault detection by the distance protection function, or individually at the moment the fault enters the respective distance zone. Parameter **Start Timers** (address 1210) is set by default to *on Dis. Pickup*. This setting ensures that all delay times continue to run together even if the type of fault or the selected measuring loop changes, e.g. because an intermediate infeed is switched off. This is also the preferred setting in the case of other distance protection relays in the power system working with this start timing. Where grading of the delay times is especially important, for instance if the fault location shifts from zone Z3 to zone Z2, the setting *on Zone Pickup* should be chosen.

Angle of Inclination of the Tripping Characteristic

The graph of the tripping characteristics is determined, among others, by the inclination angle **Distance Angle** (address 1211). Details about the tripping characteristics can be found in Sub-section 2.2.2 under margin header "Operating Polygons"). Usually the line angle is set here i.e. the same value as at address 1105 **Line Angle** (Sub-section 2.1.5.1). Irrespective of the line angle it is, however, possible to select a different inclination angle of the tripping characteristic.

Parallel Line Measured Value Correction (optional)

The mutual coupling between the two lines of a double-circuit configuration is only relevant to the 7SA6 when it is applied on a double-circuit line and when it is intended to implement parallel line compensation. A prerequisite is that the earth current of the parallel line is connected to the I_4 measuring input of the device and this is entered in the configuration settings. In this case, the setting **Paral.Line Comp** = *YES* must be made at address 1215 (default setting).

The coupling factors were already set as part of the general protection data (Subsection 2.1.5.1), as was the reach of the parallel line compensation.

Double Earth Faults in Effectively Earthed Systems

The loop selection for double earth faults is set in address 1221 **2Ph-E faults** (Phase–Phase–Earth–fault detection). This setting is only possible via DIGSI® at "**Additional Settings**". In most cases, **Block leading Ø** (blocking of the leading phase, default setting) is favourable because the leading phase-earth loop tends to overreach, especially in conjunction with large earth fault resistance. In certain cases (fault resistance phase-phase larger than phase-earth) the setting **Block lagging Ø** (blocking of the lagging phase) may be more favourable. The evaluation of all affected loops with the setting **All loops** allows a maximum degree of redundancy. It is also possible to evaluate as loop **Ø-Ø loops only**. This ensures the most accuracy for two phase to earth faults. Ultimately it is possible to declare the phase-to-earth loops as valid (setting **Ø-E loops only**).

Double Earth Faults in Non-earthed Systems

In isolated or resonant-earthed systems it must be guaranteed that the preference for double earth faults in whole galvanically-connected systems is consistent. The double earth fault preference is set in address 1220 **PHASE PREF.2phe**.

7SA6 enables the user to detect all foot points of a multiple earth fault. **PHASE PREF.2phe** = **All loops** means that each earth fault point on a protected line is switched off independent of the preference. It can also be combined with a different preference. For a transformer feeder, for example, any foot point can be switched off following occurrence of a double earth fault, whereas **L1 (L3) ACYCLIC** is consistently valid for the remainder of the system.

If the earth fault detection threatens to pick up due to fault inception transients following the occurrence of a single earth fault, the detection can be delayed via parameter **T3IO 1PHAS** (address 1206). Usually the presetting (0.04 s) is sufficient. For large resonant-earthed systems the time delay should be increased. Set parameter **T3IO 1PHAS** to ∞ if the earth current threshold can also be exceeded during steady-state conditions. Then, even with high earth current, no single-phase pickup is possible anymore. Double earth faults are, however, detected correctly and evaluated according to the preference mode.

If a double earth fault occurs right after a single earth fault, it is detected and evaluated according to the preference scheme. The already existing earth fault is detected by the zero-sequence voltage (address 1205 **3UO> COMP/ISOL.**). Please note that triple zero-sequence voltage $3U_0$ is relevant here. With a full displacement its value will be $\sqrt{3}$ times the phase-to-phase voltage. Afterwards the delay **T3IO 1PHAS** is not active anymore: an earth fault occurring now in a different phase can only be a double earth fault.

Switching onto a Fault

To determine the reaction of the distance protection during closure of the circuit breaker onto a dead fault, the parameter in address 1232 **SOTF zone** is used. The setting **Inactive** specifies that there is no special reaction, i.e. all distance stages operate according to their set zone parameters. The setting **Zone Z1B** causes all faults inside the overreaching zone Z1B (in the direction specified for these zones) to be cleared without delay following closure of the circuit breaker. If set to **Z1B undirect.**, zone Z1B is also decisive, but it operates in both directions regardless of the direction set at address 1351 **Op. mode Z1B**. The setting **PICKUP** implies that the non-delayed tripping following line energization is activated for all recognized faults in any zone (i.e. with general fault detection of the distance protection).

Load Range (only for Impedance Pickup)

When using the impedance pickup function on long heavily loaded lines, the risk of encroachment of the load impedance into the tripping characteristic of the distance protection may exist. To exclude the risk of unwanted fault detection by the distance protection during heavy load flow, a load trapezoid characteristic may be set for tripping characteristics with large R-reaches, which excludes such unwanted fault detection by

overload. This load trapezoid does not apply for the other pickup modes since the trip polygons are only released after pickup and the pickup function fulfills the task of distinguishing clearly between load operation and short-circuit. This load area is considered in the description of the tripping characteristics (see also Section 2.2.2).

The R-value **R load (Ø-E)** (address 1241) refers to the phase-earth loops, **R load (Ø-Ø)** (address 1243) to the phase-phase loops. The values are set somewhat (approx. 10 %) below the minimum expected load impedance. The minimum load impedance results when the maximum load current and minimum operating voltage exist.

Calculation Example:

110 kV overhead line 150 mm^2 with the following data:

maximum transmittable power

P_{max}	= 100 MVA corresponds to
I_{max}	= 525 A

minimum operating voltage

U_{min}	= 0.9 U_N
Current Transformer	600 A / 5 A
Voltage Transformer	110 kV / 0.1 kV

The resulting minimum load impedance is therefore:

$$R_{Load\ prim} = \frac{U_{min}}{\sqrt{3} \cdot I_{L\ max}} = \frac{0.9 \cdot 110\ kV}{\sqrt{3} \cdot 525\ A} = 108.87\ \Omega$$

This value can be entered as a primary value when parameterizing with a PC and DIGSI®. The conversion to secondary values is

$$R_{Load\ sec} = \frac{N_{CT}}{N_{VT}} \cdot R_{Load\ prim} = \frac{600\ A/5\ A}{110\ kV/0.1\ kV} \cdot 108.87\ \Omega = 11.88\ \Omega$$

when applying a security margin of 10 % the following is set:

primary: **R load (Ø-Ø)** = **97.98** Ω or

secondary: **R load (Ø-Ø)** = **10.69** Ω.

The spread angle of the load trapezoid φ **load (Ø-E)** (address 1242) and φ **load (Ø-Ø)** (address 1244) must be greater (approx. 5°) than the maximum arising load angle (corresponding to the minimum power factor $\cos\varphi$).

Calculation Example:

Minimum power factor

$\cos \varphi_{min}$	= 0.63
φ_{max}	= 51°

Setting value φ **load (Ø-Ø)** = φ_{max} + 5° = **56°**.

Overcurrent, U/I- and U/I/φ-pickup

Depending on the ordered version, the 7SA6 distance protection has a series of pickup modes from which the one matching the respective network conditions best can be selected (also see order data in the Appendix).

If the device does not feature an explicit pickup function or if during configuration of the protection functions (Section 2.1.1.2) you have selected as pickup type **Dis. PICKUP** = *Z< (quadrilat.)* (address 114), the mentioned settings are not relevant and cannot be accessed.

Available pickup modes are described in Section 2.2.1 in detail. If the device has several alternative pickup modes, one option has been selected when configuring in address 114. Below, parameters are given and discussed for all pickup modes. With the following settings, only those parameters will appear that apply for the selected pickup mode.

With the U/I(/φ) pickup mode you can determine the voltage measurement and, if applicable, the phase-angle measurement for phase-to-earth measuring units, and for phase-to-phase measuring loops separately. Address 1601 **PROGAM U/I** indicates which loop voltages apply to phase-to-earth and which to phase-to-phase:

In networks with **earthed** star point, a selection using U_{Ph-E} with earth faults and U_{Ph-Ph} with non-earthed faults is often preferred (address 1601 **PROGAM U/I** = *LE:Uphe/LL:Uphp*). This mode has a maximum sensitivity for all fault types, however it requires the unambiguous detection of earth faults via the earth-fault detection function (also see Section 2.2.1). Otherwise, a mode using U_{Ph-E} for all fault types may be useful (address 1601 **PROGAM U/I** = *LE:Uphe/LL:Uphe*), accepting lesser sensitivity for earth-free faults, since the overcurrent stage Iph>> usually picks up there.

In networks with **low–resistance earthed** starpoint, the U/I/φ pickup should only come into effect on earth faults as phase-to-phase faults are detected by the overcurrent pickup. In this case it is reasonable to set address 1601 **PROGAM U/I** = *LE:Uphe/LL:I>>*.

In **isolated** or **resonant-earthed** power systems it is possible to control the U/I/φ pickup using phase-to-phase voltages only (address 1601 **PROGAM U/I** = *LE:Uphp/LL:Uphp*). Naturally, this excludes pickup by single earth faults, however, it neither allows a correct double earth fault detection, therefore it is suitable only for small isolated cable networks.

Two further general settings refer to the final times, i.e. the tripping times in a worst case scenario for faults outside all distance zones. They should be set above the delay times for distance zones providing a final back-up option (see also configuration of the function settings for the distance zones in Section 2.2.2.2).

The directional final time **DELAY FORW. PU** (address 1602) only works with short circuits in forward (line) direction if there is no impedance within a distance zone after pickup.

The non-directional final time **DEL. NON-DIR PU** (address 1603) works for all faults if there is no impedance within a distance zone after pickup.

Overcurrent Pickup The maximum operational load current that can occur is crucial for the setting of **overcurrent pick-up**. Pickup due to overload must be ruled out! Therefore the pickup value **Iph>>**, (address 1610) must be set above the maximum (over-)load current that is expected (approx. 1.2 times). In this case, it must be ensured that the minimum short-circuit current is above this value. If this is not the case, U/I pick-up is required.

Calculation Example:

Maximum operational current (incl. overload) is 680 A, for current transformers 600 A/5 A, minimum short circuit is 1200 A. The following settings are made:

$\quad$ Iph>> = $I_{L\,max}$ · 1.2 = 680 A · 1.2 = 816 A

This value is sufficiently below the minimum short-circuit current of 1200 A. When configuring via PC and DIGSI® this value can be entered directly as primary value. The conversion to secondary values is

$$\texttt{Iph>>} \ = \ 816 \ \text{A} \cdot \frac{5 \ \text{A}}{600 \ \text{A}} = 6.8 \ \text{A}$$

The condition for minimum short-circuit current also applies to earth faults (in the earthed network) or for double earth faults as long as overcurrent pickup is <u>solely</u> used.

U/I(/φ) Pickup

If U/I pickup is required because the minimum fault current is below the maximum load current (incl. a safety factor of 1.2), the condition for maximum load current in respect to **Iph>>** still has to be observed. Then the <u>minimum current limit</u> **Iph>** (address 1611) is set to below the minimum fault current (approx. 10 %). This also applies to the phase currents during earth faults or double earth faults.

In address 1630 **1ph FAULTS** you can choose whether a phase–to–earth loop shall be selected in an earthed network during single–phase pickup without earth current (I_E release). The setting **1ph FAULTS** = *PHASE‑EARTH* is useful if no or only little earth current can flow via the measuring point in the event of earth faults. With **1ph FAULTS** = *PHASE‑PHASEONLY* the leading phase–phase loop is measured in the event of a single–phase pick-up in the earthed network. This setting is only possible via DIGSI® at "**Additional Settings**".

The meaning of the settings is illustrated in Figure 2-20. **Iph>** (section a, address 1611) is the minimum current as described in the previous section, **Iph>>** (section c) is the overcurrent pickup.
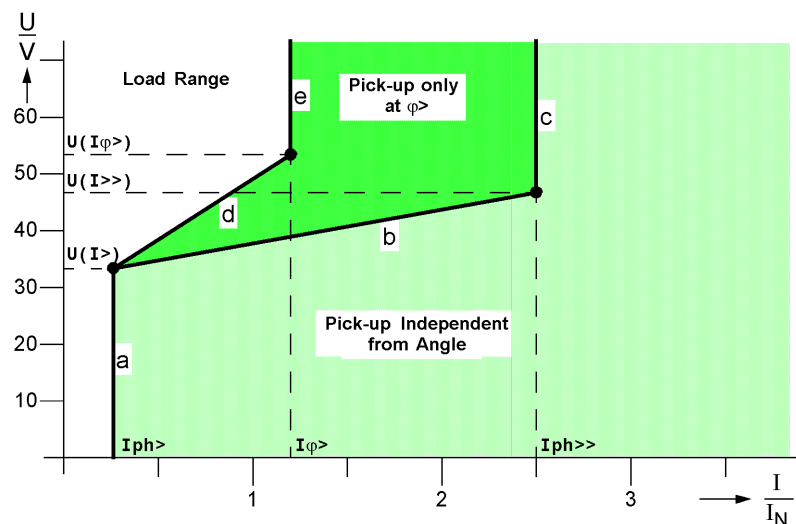
Figure 2-20 Parameters of the U/I/φ pickup

Angular dependence is not needed in the majority of cases. Then the voltage-dependent section b is valid which results in the characteristic a-b-c. When controlling with <u>Uphe</u> the voltages for phase-to-earth current are inserted in address 1612 **Uph‑e (I>>)** and 1613 **Uph‑e (I>)** for the voltage-dependent section b. When controlling with <u>Uphph</u> the voltages for phase-to-phase are set in address 1614 **Uph‑ph (I>>)** and 1615 **Uph‑ph (I>)**. The relevant settings are determined according to the pickup mode (see above).

The characteristic has to be set such that it is just below the minimum expected voltage at the maximum expected load current. If in doubt, check the pick-up conditions in accordance with the U/I characteristic.

Angular Dependence

If a distinction between short-circuit and load conditions is not always possible using the U/I characteristic which is independent of the phase angle, the angular dependent section d-e can additionally be used. This is required for long lines and section of lines with intermediate infeed in combination with small source impedances. Then the local measured voltage will only drop to a small extent in the event of a short circuit at the line end or in the back-up range of the distance protection so that the phase angle between current and voltage is required as an additional criterion for fault detection.

The parameters **Iphi>** (address 1616) and **Uph-e (Iphi>)** (address 1617) or **Uph-ph (Iphi>)** (address 1618) determine the characteristic in the range of large angles φ_K, i.e. in the short-circuit angular range. The threshold angles themselves, which define the short-circuit angle range φ_K, are set in address 1620 φ**>** and 1621 φ**<**. The short-circuit angle range φ_K is between these two angles. Also here the required voltage settings according to the pickup mode (see above) are relevant.

The characteristic for the load angle range has to be set in a way that is just below the minimum expected operating voltage at the maximum expected load current. In the range of the short circuit angles φ_K it must be ensured that load current may not cause pickup in this area. If reactive power has to be transferred via this line, it must be ensured that the maximum reactive current at minimum operating voltage is not within the pickup range, i.e. the short-circuit angle range φ_K. If in doubt, check the pickup conditions in accordance with the U/Iφ characteristic. An arithmetic short-circuit calculation is recommended for extensive networks.

The lower threshold angle φ**>** (address 1620) should be between the load angle and the short-circuit angle. Therefore it must be set smaller than the line angle φ_L = arctan (X_L/R_L) (approx. 10° to 20°). Subsequently, you should check that the angle is not exceeded during load conditions. If this is the case, for instance because the reactive power has to be transferred via this line, it must be ensured that the parameters of the voltage-dependent segment d, that is **Iphi>** and **Uph-e (Iphi>)** or **Uph-ph (Iphi>)** rule out a pickup as the result of reactive power (see above).

The upper threshold angle φ**<** (address 1621) is not critical. 100° to 120° should be sufficient in all cases.

Angular dependence, i.e. increasing the sensitivity for a large short-circuit angle with section d and e in the characteristic, can be limited to the forward direction (line direction) using address 1619 **EFFECT** φ. In this case, **EFFECT** φ is set to *Forward*. Otherwise **EFFECT** φ = *forward&reverse*. This setting is only possible via DIGSI[®] at "**Additional Settings**".

2.2.1.5 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
1201	FCT Distance		ON OFF	ON	Distance protection is
1202	Minimum Iph>	1A	0.05 .. 4.00 A	0.10 A	Phase Current threshold for dist. meas.
		5A	0.25 .. 20.00 A	0.50 A	
1203	3I0> Threshold	1A	0.05 .. 4.00 A	0.10 A	3I0 threshold for neutral current pickup
		5A	0.25 .. 20.00 A	0.50 A	
1204	3U0> Threshold		1 .. 100 V; ∞	5 V	3U0 threshold zero seq. voltage pickup
1205	3U0> COMP/ISOL.		10 .. 200 V	40 V	3U0> pickup (comp/ isol. star-point)
1206	T3I0 1PHAS		0.00 .. 0.50 sec; ∞	0.04 sec	Delay 1ph-faults (comp/isol. star-point)
1207A	3I0>/ Iphmax		0.05 .. 0.30	0.10	3I0>-pickup-stabilisation (3I0> /Iphmax)
1208	SER-COMP.		NO YES	NO	Series compensated line
1209A	E/F recognition		3I0> OR 3U0> 3I0> AND 3U0>	3I0> OR 3U0>	criterion of earth fault recognition
1210	Start Timers		on Dis. Pickup on Zone Pickup	on Dis. Pickup	Condition for zone timer start
1211	Distance Angle		30 .. 90 °	85 °	Angle of inclination, distance charact.
1215	Paral.Line Comp		NO YES	YES	Mutual coupling parall.line compensation
1220	PHASE PREF.2phe		L3 (L1) ACYCLIC L1 (L3) ACYCLIC L2 (L1) ACYCLIC L1 (L2) ACYCLIC L3 (L2) ACYCLIC L2 (L3) ACYCLIC L3 (L1) CYCLIC L1 (L3) CYCLIC All loops	L3 (L1) ACYCLIC	Phase preference for 2ph-e faults
1221A	2Ph-E faults		Block leading Ø Block lagging Ø All loops Ø-Ø loops only Ø-E loops only	Block leading Ø	Loop selection with 2Ph-E faults

Addr.	Parameter	C	Setting Options	Default Setting	Comments
1232	SOTF zone		PICKUP Zone Z1B Inactive Z1B undirect.	Inactive	Instantaneous trip after SwitchOnToFault
1241	R load (Ø-E)	1A	0.100 .. 600.000 Ω; ∞	∞ Ω	R load, minimum Load Impedance (ph-e)
		5A	0.020 .. 120.000 Ω; ∞	∞ Ω	
1242	φ load (Ø-E)		20 .. 60 °	45 °	PHI load, maximum Load Angle (ph-e)
1243	R load (Ø-Ø)	1A	0.100 .. 600.000 Ω; ∞	∞ Ω	R load, minimum Load Impedance (ph-ph)
		5A	0.020 .. 120.000 Ω; ∞	∞ Ω	
1244	φ load (Ø-Ø)		20 .. 60 °	45 °	PHI load, maximum Load Angle (ph-ph)
1305	T1-1phase		0.00 .. 30.00 sec; ∞	0.00 sec	T1-1phase, delay for single phase faults
1306	T1-multi-phase		0.00 .. 30.00 sec; ∞	0.00 sec	T1multi-ph, delay for multi phase faults
1315	T2-1phase		0.00 .. 30.00 sec; ∞	0.30 sec	T2-1phase, delay for single phase faults
1316	T2-multi-phase		0.00 .. 30.00 sec; ∞	0.30 sec	T2multi-ph, delay for multi phase faults
1317A	Trip 1pole Z2		NO YES	NO	Single pole trip for faults in Z2
1325	T3 DELAY		0.00 .. 30.00 sec; ∞	0.60 sec	T3 delay
1335	T4 DELAY		0.00 .. 30.00 sec; ∞	0.90 sec	T4 delay
1345	T5 DELAY		0.00 .. 30.00 sec; ∞	0.90 sec	T5 delay
1355	T1B-1phase		0.00 .. 30.00 sec; ∞	0.00 sec	T1B-1phase, delay for single ph. faults
1356	T1B-multi-phase		0.00 .. 30.00 sec; ∞	0.00 sec	T1B-multi-ph, delay for multi ph. faults
1357	1st AR -> Z1B		NO YES	YES	Z1B enabled before 1st AR (int. or ext.)
1601	PROGAM U/I		LE:Uphe/LL:Uphp LE:Uphp/LL:Uphp LE:Uphe/LL:Uphe LE:Uphe/LL:I>>	LE:Uphe/LL:Uphp	Pickup program U/I
1602	DELAY FORW. PU		0.00 .. 30.00 sec; ∞	1.20 sec	Trip delay for Forward-PICKUP
1603	DEL. NON-DIR PU		0.00 .. 30.00 sec; ∞	1.20 sec	Trip delay for non-directional PICKUP
1610	Iph>>	1A	0.25 .. 10.00 A	1.80 A	Iph>> Pickup (overcurrent)
		5A	1.25 .. 50.00 A	9.00 A	
1611	Iph>	1A	0.10 .. 4.00 A	0.20 A	Iph> Pickup (minimum current)
		5A	0.50 .. 20.00 A	1.00 A	
1612	Uph-e (I>>)		20 .. 70 V	48 V	Undervoltage (ph-e) at Iph>>

Addr.	Parameter	C	Setting Options	Default Setting	Comments
1613	Uph-e (I>)		20 .. 70 V	48 V	Undervoltage (ph-e) at Iph>
1614	Uph-ph (I>>)		40 .. 130 V	80 V	Undervoltage (ph-ph) at Iph>>
1615	Uph-ph (I>)		40 .. 130 V	80 V	Undervoltage (ph-ph) at Iph>
1616	Iphi>	1A	0.10 .. 8.00 A	0.50 A	Iphi> Pickup (minimum current at phi>)
		5A	0.50 .. 40.00 A	2.50 A	
1617	Uph-e (Iphi>)		20 .. 70 V	48 V	Undervoltage (ph-e) at Iphi>
1618	Uph-ph (Iphi>)		40 .. 130 V	80 V	Undervoltage (ph-ph) at Iphi>
1619A	EFFECT φ		forward&reverse Forward	forward&reverse	Effective direction of phi-pickup
1620	φ>		30 .. 60 °	50 °	PHI> pickup (lower set-point)
1621	φ<		90 .. 120 °	110 °	PHI< pickup (upper set-point)
1630A	1ph FAULTS		PHASE-EARTH PHASE-PHASEONLY	PHASE-EARTH	1ph-pickup loop selection (PU w/o earth)

2.2.1.6 Information List

No.	Information	Type of Information	Comments
3603	>BLOCK 21 Dist.	SP	>BLOCK 21 Distance
3611	>ENABLE Z1B	SP	>ENABLE Z1B (with setted Time Delay)
3613	>ENABLE Z1Binst	SP	>ENABLE Z1B instantanous (w/o T-Delay)
3617	>BLOCK Z4-Trip	SP	>BLOCK Z4-Trip
3618	>BLOCK Z5-Trip	SP	>BLOCK Z5-Trip
3619	>BLOCK Z4 Ph-E	SP	>BLOCK Z4 for ph-e loops
3620	>BLOCK Z5 Ph-E	SP	>BLOCK Z5 for ph-e loops
3651	Dist. OFF	OUT	Distance is switched off
3652	Dist. BLOCK	OUT	Distance is BLOCKED
3653	Dist. ACTIVE	OUT	Distance is ACTIVE
3654	Dis.ErrorK0(Z1)	OUT	Setting error K0(Z1) or Angle K0(Z1)
3655	DisErrorK0(>Z1)	OUT	Setting error K0(>Z1) or Angle K0(>Z1)
3671	Dis. PICKUP	OUT	Distance PICKED UP
3672	Dis.Pickup L1	OUT	Distance PICKUP L1
3673	Dis.Pickup L2	OUT	Distance PICKUP L2
3674	Dis.Pickup L3	OUT	Distance PICKUP L3
3675	Dis.Pickup E	OUT	Distance PICKUP Earth
3681	Dis.Pickup 1pL1	OUT	Distance Pickup Phase L1 (only)
3682	Dis.Pickup L1E	OUT	Distance Pickup L1E
3683	Dis.Pickup 1pL2	OUT	Distance Pickup Phase L2 (only)

No.	Information	Type of Information	Comments
3684	Dis.Pickup L2E	OUT	Distance Pickup L2E
3685	Dis.Pickup L12	OUT	Distance Pickup L12
3686	Dis.Pickup L12E	OUT	Distance Pickup L12E
3687	Dis.Pickup 1pL3	OUT	Distance Pickup Phase L3 (only)
3688	Dis.Pickup L3E	OUT	Distance Pickup L3E
3689	Dis.Pickup L31	OUT	Distance Pickup L31
3690	Dis.Pickup L31E	OUT	Distance Pickup L31E
3691	Dis.Pickup L23	OUT	Distance Pickup L23
3692	Dis.Pickup L23E	OUT	Distance Pickup L23E
3693	Dis.Pickup L123	OUT	Distance Pickup L123
3694	Dis.Pickup123E	OUT	Distance Pickup123E
3695	Dis Pickup φ L1	OUT	Dist.: Phi phase L1 Pickup
3696	Dis Pickup φ L2	OUT	Dist.: Phi phase L2 Pickup
3697	Dis Pickup φ L3	OUT	Dist.: Phi phase L3 Pickup
3701	Dis.Loop L1-E f	OUT	Distance Loop L1E selected forward
3702	Dis.Loop L2-E f	OUT	Distance Loop L2E selected forward
3703	Dis.Loop L3-E f	OUT	Distance Loop L3E selected forward
3704	Dis.Loop L1-2 f	OUT	Distance Loop L12 selected forward
3705	Dis.Loop L2-3 f	OUT	Distance Loop L23 selected forward
3706	Dis.Loop L3-1 f	OUT	Distance Loop L31 selected forward
3707	Dis.Loop L1-E r	OUT	Distance Loop L1E selected reverse
3708	Dis.Loop L2-E r	OUT	Distance Loop L2E selected reverse
3709	Dis.Loop L3-E r	OUT	Distance Loop L3E selected reverse
3710	Dis.Loop L1-2 r	OUT	Distance Loop L12 selected reverse
3711	Dis.Loop L2-3 r	OUT	Distance Loop L23 selected reverse
3712	Dis.Loop L3-1 r	OUT	Distance Loop L31 selected reverse
3713	Dis.Loop L1E<->	OUT	Distance Loop L1E selected non-direct.
3714	Dis.Loop L2E<->	OUT	Distance Loop L2E selected non-direct.
3715	Dis.Loop L3E<->	OUT	Distance Loop L3E selected non-direct.
3716	Dis.Loop L12<->	OUT	Distance Loop L12 selected non-direct.
3717	Dis.Loop L23<->	OUT	Distance Loop L23 selected non-direct.
3718	Dis.Loop L31<->	OUT	Distance Loop L31 selected non-direct.
3719	Dis. forward	OUT	Distance Pickup FORWARD
3720	Dis. reverse	OUT	Distance Pickup REVERSE
3741	Dis. Z1 L1E	OUT	Distance Pickup Z1, Loop L1E
3742	Dis. Z1 L2E	OUT	Distance Pickup Z1, Loop L2E
3743	Dis. Z1 L3E	OUT	Distance Pickup Z1, Loop L3E
3744	Dis. Z1 L12	OUT	Distance Pickup Z1, Loop L12
3745	Dis. Z1 L23	OUT	Distance Pickup Z1, Loop L23
3746	Dis. Z1 L31	OUT	Distance Pickup Z1, Loop L31
3747	Dis. Z1B L1E	OUT	Distance Pickup Z1B, Loop L1E
3748	Dis. Z1B L2E	OUT	Distance Pickup Z1B, Loop L2E
3749	Dis. Z1B L3E	OUT	Distance Pickup Z1B, Loop L3E
3750	Dis. Z1B L12	OUT	Distance Pickup Z1B, Loop L12
3751	Dis. Z1B L23	OUT	Distance Pickup Z1B, Loop L23
3752	Dis. Z1B L31	OUT	Distance Pickup Z1B, Loop L31

No.	Information	Type of In-formation	Comments
3755	Dis. Pickup Z2	OUT	Distance Pickup Z2
3758	Dis. Pickup Z3	OUT	Distance Pickup Z3
3759	Dis. Pickup Z4	OUT	Distance Pickup Z4
3760	Dis. Pickup Z5	OUT	Distance Pickup Z5
3771	Dis.Time Out T1	OUT	DistanceTime Out T1
3774	Dis.Time Out T2	OUT	DistanceTime Out T2
3777	Dis.Time Out T3	OUT	DistanceTime Out T3
3778	Dis.Time Out T4	OUT	DistanceTime Out T4
3779	Dis.Time Out T5	OUT	DistanceTime Out T5
3780	Dis.TimeOut T1B	OUT	DistanceTime Out T1B
3781	Dis.TimeOut Tfw	OUT	DistanceTime Out Forward PICKUP
3782	Dis.TimeOut Tnd	OUT	DistanceTime Out Non-directional PICKUP
3801	Dis.Gen. Trip	OUT	Distance protection: General trip
3802	Dis.Trip 1pL1	OUT	Distance TRIP command - Only Phase L1
3803	Dis.Trip 1pL2	OUT	Distance TRIP command - Only Phase L2
3804	Dis.Trip 1pL3	OUT	Distance TRIP command - Only Phase L3
3805	Dis.Trip 3p	OUT	Distance TRIP command Phases L123
3811	Dis.TripZ1/1p	OUT	Distance TRIP single-phase Z1
3813	Dis.TripZ1B1p	OUT	Distance TRIP single-phase Z1B
3816	Dis.TripZ2/1p	OUT	Distance TRIP single-phase Z2
3817	Dis.TripZ2/3p	OUT	Distance TRIP 3phase in Z2
3818	Dis.TripZ3/T3	OUT	Distance TRIP 3phase in Z3
3819	Dis.Trip FD->	OUT	Dist.: Trip by fault detection, forward
3820	Dis.Trip <->	OUT	Dist.: Trip by fault detec, rev/non-dir.
3821	Dis.TRIP 3p. Z4	OUT	Distance TRIP 3phase in Z4
3822	Dis.TRIP 3p. Z5	OUT	Distance TRIP 3phase in Z5
3823	DisTRIP3p. Z1sf	OUT	DisTRIP 3phase in Z1 with single-ph Flt.
3824	DisTRIP3p. Z1mf	OUT	DisTRIP 3phase in Z1 with multi-ph Flt.
3825	DisTRIP3p.Z1Bsf	OUT	DisTRIP 3phase in Z1B with single-ph Flt
3826	DisTRIP3p Z1Bmf	OUT	DisTRIP 3phase in Z1B with multi-ph Flt.
3850	DisTRIP Z1B Tel	OUT	DisTRIP Z1B with Teleprotection scheme

2.2.2 Distance protection with quadrilateral characteristic (optional)

A tripping characteristic in the shape of a polygon is defined for each of the distance zones.

2.2.2.1 Method of Operation

Operating Polygons

In total there are five independent and one additional controlled zone for each fault impedance loop. Figure 2-21 shows the shape of the polygons as example. The first zone is shaded and forward directional. The third zone is reverse directional.

In general, the polygon is defined by means of a parallelogram which intersects the axes with the values R and X as well as the tilt φ_{Dist}. A load trapezoid with the setting R_{Load} and φ_{Load} may be used to cut the area of the load impedance out of the polygon. The axial coordinates can be set individually for each zone; φ_{Dist}, R_{Load} and φ_{Load} are common for all zones. The parallelogram is symmetrical with respect to the origin of the R–X–coordinate system; the directional characteristic however limits the tripping range to the desired quadrants (refer to "Determination of Direction" below).

The R-reach may be set separately for the phase–phase faults and the phase–earth faults to achieve a larger fault resistance coverage for earth faults if this is desired.

For the first zone Z1 an additional settable tilt α exists, which may be used to prevent overreach resulting from angle variance and/or two ended infeed to short-circuits with fault resistance. For Z1B and the higher zones this tilt does not exist.
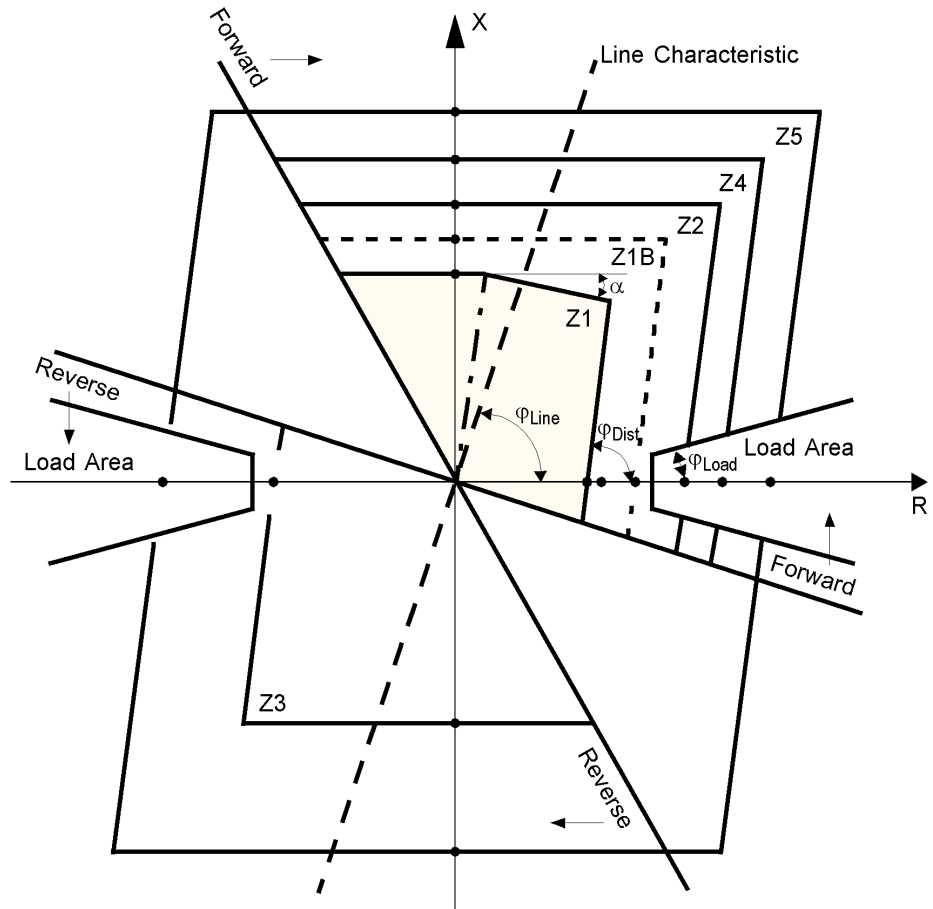
Figure 2-21   Polygonal characteristic (setting values are marked by dots)

Determination of Direction

For each loop an impedance vector is also used to determine the direction of the short-circuit. Usually, $\underline{Z}_L$ is used as for distance calculation. However, depending on the "quality" of the measured values, different computation techniques are used. Immediately after fault inception, the short circuit voltage is disturbed by transients. The voltage memorised prior to fault inception is therefore used in this situation. If the steady-state short-circuit voltage (during a close-in fault) is even too small for direction determination, an unfaulted voltage is used. This voltage is in theory quadrilateral to the actual short-circuit voltage for both phase–earth loops as well as for phase–phase loops (refer to Figure 2-22). This is taken into account when computing the direction vector by means of a 90°–rotation. In Table 2-9 the allocation of the measured values to the six fault loops for the determination of the fault direction is shown.

a) Phase–earth loop (L1–E) b) Phase–phase loop (L2–L3)
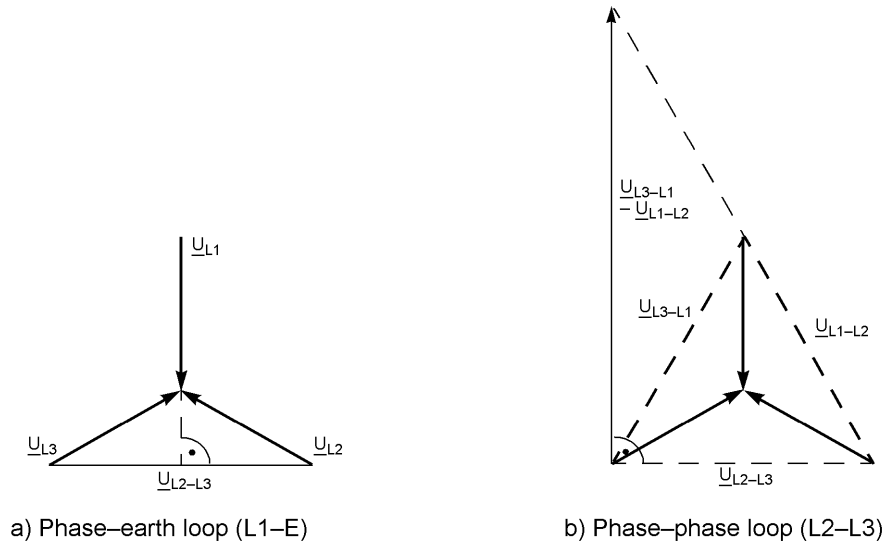
Figure 2-22   Direction determination with quadrature voltages

Table 2-9   Voltage and Current Values for the Determination of Fault Direction

Loop	Measuring Current (Direction)	Actual short-circuit voltage	Quadrature voltage
L1-E	$\underline{I}_{L1}$	$\underline{U}_{L1\text{-}E}$	$\underline{U}_{L2}$ - $\underline{U}_{L3}$
L2-E	$\underline{I}_{L2}$	$\underline{U}_{L2\text{-}E}$	$\underline{U}_{L3}$ - $\underline{U}_{L1}$
L3-E	$\underline{I}_{L3}$	$\underline{U}_{L3\text{-}E}$	$\underline{U}_{L1}$ - $\underline{U}_{L2}$
L1-E[1]	$\underline{I}_{L1}$ - $\underline{k}_E \cdot \underline{I}_E$[1]	$\underline{U}_{L1\text{-}E}$	$\underline{U}_{L2}$ - $\underline{U}_{L3}$
L2-E[1]	$\underline{I}_{L2}$ - $\underline{k}_E \cdot \underline{I}_E$[1]	$\underline{U}_{L2\text{-}E}$	$\underline{U}_{L3}$ - $\underline{U}_{L1}$
L3-E[1]	$\underline{I}_{L3}$ - $\underline{k}_E \cdot \underline{I}_E$[1]	$\underline{U}_{L3\text{-}E}$	$\underline{U}_{L1}$ - $\underline{U}_{L2}$
L1-L2	$\underline{I}_{L1}$ - $\underline{I}_{L2}$	$\underline{U}_{L1}$ - $\underline{U}_{L2}$	$\underline{U}_{L2\text{-}L3}$ - $\underline{U}_{L3\text{-}L1}$
L2-L3	$\underline{I}_{L2}$ - $\underline{I}_{L3}$	$\underline{U}_{L2}$ - $\underline{U}_{L3}$	$\underline{U}_{L3\text{-}L1}$ - $\underline{U}_{L1\text{-}L2}$
L3-L1	$\underline{I}_{L3}$ - $\underline{I}_{L1}$	$\underline{U}_{L3}$ - $\underline{U}_{L1}$	$\underline{U}_{L1\text{-}L2}$ - $\underline{U}_{L2\text{-}L3}$

[1] $\underline{k}_E = \underline{Z}_E/\underline{Z}_L$; if only one phase-earth loop picks up, the earth current $\underline{I}_E$ is taken into account.

If there is neither a current measured voltage nor a memorized voltage available which is sufficient for measuring the direction, the relay selects the ***Forward*** direction. In practice this can only occur when the circuit breaker closes onto a de-energized line, and there is a fault on this line (e.g. closing onto an earthed line).

Figure 2-23 shows the theoretical steady-state characteristic. In practice, the position of the directional characteristic when using memorized voltages is dependent on both the source impedance as well as the load transferred across the line prior to fault inception. Accordingly the directional characteristic includes a safety margin with respect to the limits of the first quadrant in the R–X diagram (Figure 2-23).
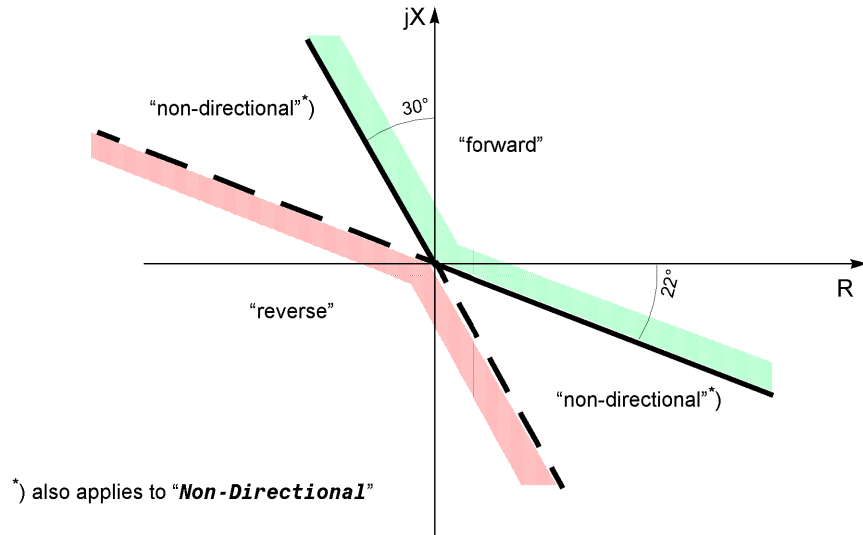
Figure 2-23   Directional characteristic in the R-X-diagram

Since each zone can be set to **Forward**, **Reverse** or **Non-Directional**, different (centrically mirrored) directional characteristics are available for **Forward** and **Reverse**. A non-directional zone has no directional characteristic. The entire tripping region applies here.

Characteristics of the Directional Measurement

The theoretical steady-state directional characteristic shown in Figure 2-23 applies to faulted loop voltages. In the case of quadrature voltages or memorized voltage, the position of the directional characteristic is dependant on both the source impedance as well as the load transferred across the line prior to fault inception.

Figure 2-24 shows the directional characteristic using quadrature or memorized voltage as well as taking the source impedance into account (no load transfer). As these voltages are equal to the corresponding generator voltage $\underline{E}$ and they do not change after fault inception, the directional characteristic is shifted in the impedance diagram by the source impedance $\underline{Z}_{S1} = \underline{E}_1/\underline{I}_1$. For the fault location F_1 (Figure 2-24a) the short-circuit location is in the forward direction and the source impedance is in the reverse direction. For all fault locations, right up to the device location (current transformers), a definite **Forward** decision is made (Figure 2-24b). If the current direction is reversed, the position of the directional characteristic changes abruptly (Figure 2-24c). A reversed current $\underline{I}_2$ now flows via the measuring location (current transformer) which is determined by the source impedance $\underline{Z}_{S2} + \underline{Z}_L$. When load is transferred across the line, the directional characteristic may additionally be rotated by the load angle.
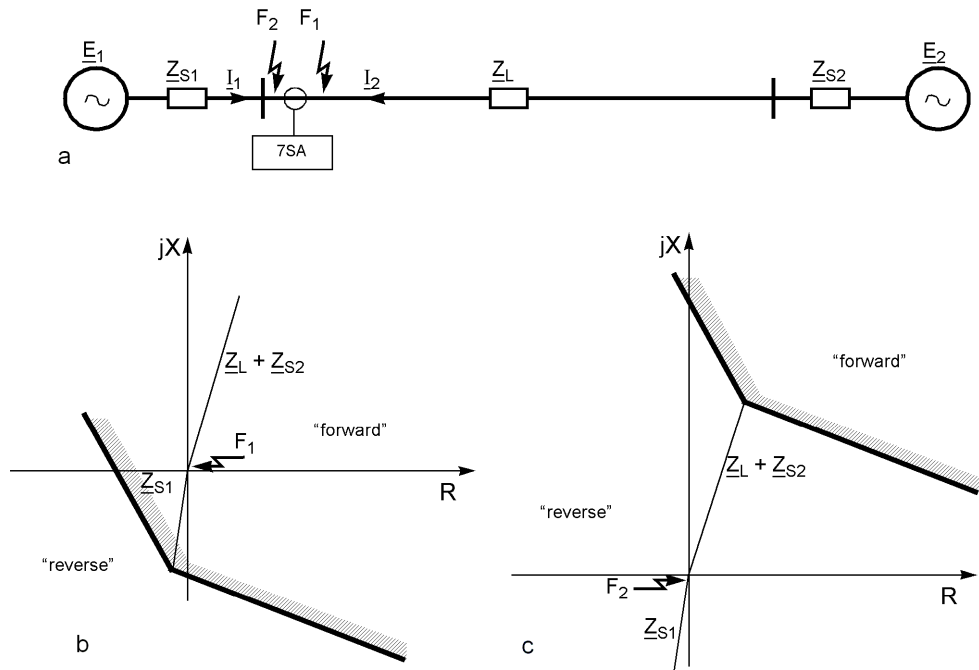
Figure 2-24   Directional characteristic with quadrature or memorized voltages

Determination of Direction in Case of Series-compensated Lines

The directional characteristics and their displacement by the source impedance apply also for lines with series capacitors. If a short-circuit occurs behind the local series capacitors, the short-circuit voltage however reverses its direction until the protective spark gap has picked up (see Figure 2-25).
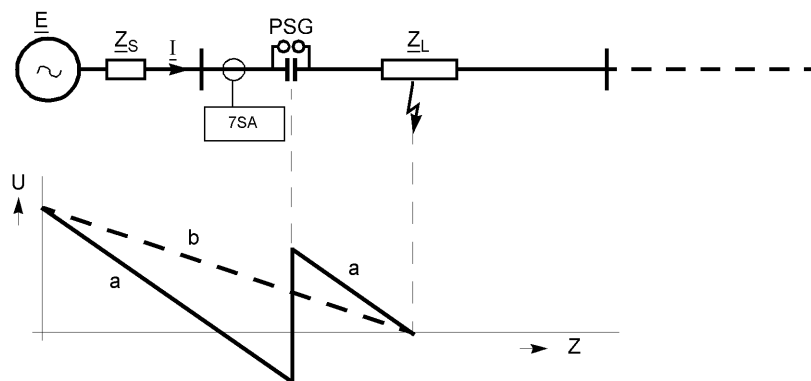
Figure 2-25   Voltage characteristic while a fault occurs after a series capacitor.

a) without pickup of the protective spark gap PSG

b) with pickup of the protective spark gap PSG

The distance protection function would thus detect a wrong fault direction. The use of memorised voltages however ensures that the direction is correctly detected (see Figure 2-26a).

Since the voltage prior to the fault is used for determining the direction, the zeniths of the directional characteristics in dependence of the source impedance and infeed conditions before the fault are thus far displaced that the capacitor reactance — which is

always smaller than the series reactance — does not cause the apparent direction reversal (Figure 2-26b).

If the short-circuit is located before the capacitor, from the relay location (current transformer) in reverse direction, the zeniths of the directional characteristics are shifted to the other direction (Figure 2-26c). A correct determination of the direction is thus also ensured in this case.
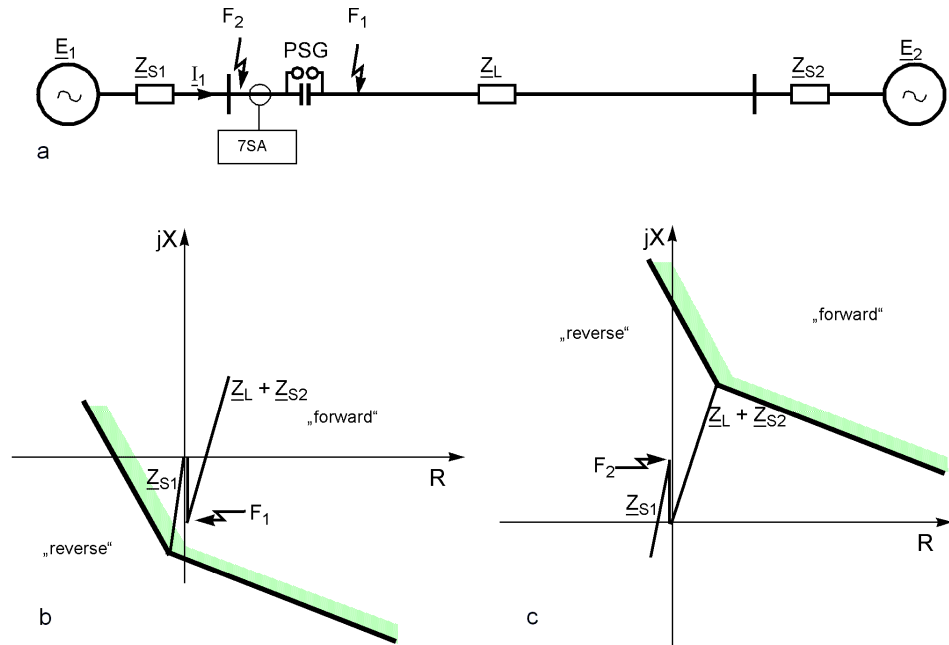
Figure 2-26   Determination of direction in case of series-compensated lines

Pickup and Assignment to the Polygons

Using the fault detection modes I, U/I or U/I/φ the impedances, that were calculated from the valid loops, are assigned, after the pick-up, to the zone characteristics set for the distance protection. To avoid unstable signals at the boundaries of a polygon, the characteristics have a hysteresis of approximately 5% i.e. as soon as it has been determined that the fault impedance lies within a polygon, the boundaries are increased by $5°\%$ in all directions. The loop information is also converted to phase segregated information.

Using the impedance pick-up the calculated loop impedances are also assigned to the zone characteristics set for the distance protection, but without a query of an explicit fault detection scheme. The pick-up range of the distance protection is determined from the thresholds of the largest-set polygon taking into consideration the respective direction. Here the loop information is also converted into faulted phase indication.

"Pickup" signals are generated for each zone and converted into phase information, e.g. "Dis.Z1L1E" (internal message) for zone Z1 and phase L1. This means that each phase and each zone is provided with separate pickup information. The information is then processed in the zone logic and by additional functions (e.g. teleprotection logic, Subsection 2.6). The loop information is also converted to phase-segregated information. Further conditions for "pickup" of a zone are that the direction corresponds to the direction set for the zone, and that the zone is not blocked by the power swing blocking (refer to Subsection 2.3). Furthermore, the distance protection may not be blocked or switched off completely. Figure 2-27 shows these conditions.
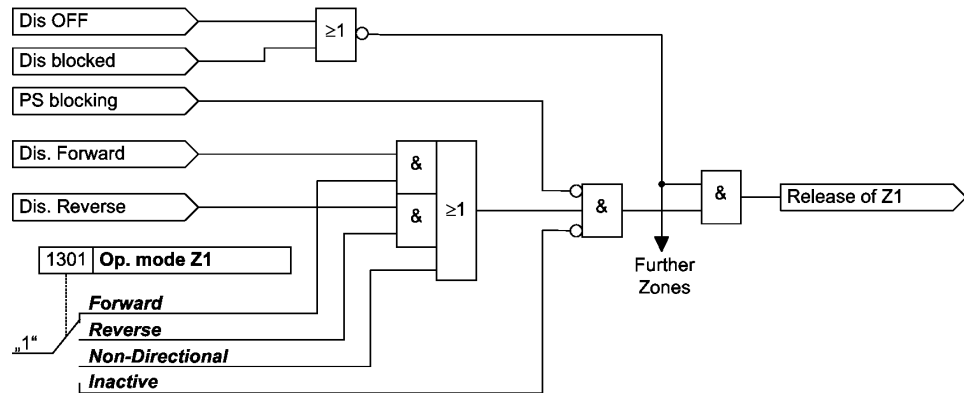
Figure 2-27   Release logic for one zone (example for Z1)

In total, the following zones are available:

Independent zones:

- 1st zone (fast tripping zone) Z1 with **X(Z1)**; **R(Z1) Ø-Ø**, **RE(Z1) Ø-E**; delayable with **T1-1phase** or **T1-multi-phase**,
- 2nd zone (backup zone) Z2 with **X(Z2)**; **R(Z2) Ø-Ø**, **RE(Z2) Ø-E**; may be delayed by **T2-1phase** or **T2-multi-phase**,
- 3rd zone (backup zone) Z3 with **X(Z3)**; **R(Z3) Ø-Ø**, **RE(Z3) Ø-E**; may be delayed by **T3 DELAY**,
- 4th zone (backup zone) Z4 with **X(Z4)**; **R(Z4) Ø-Ø**, **RE(Z4) Ø-E**; may be delayed by **T4 DELAY**,
- 5th zone (backup zone) Z5 with **X(Z5)+** (forward) and **X(Z5)-** (reverse); **R(Z5) Ø-Ø**, **RE(Z5) Ø-E**, delayable with **T5 DELAY**.

Dependent (controlled) Zone:

- Overreaching zone Z1B with **X(Z1B)**; **R(Z1B) Ø-Ø**, **RE(Z1B) Ø-E**; may be delayed by **T1B-1phase** or **T1B-multi-phase**.

2.2.2.2   Setting Notes

Grading Coordination Chart

It is recommended to initially create a grading coordination chart for the entire galvanically interconnected system. This diagram should reflect the line lengths with their primary reactances X in Ω/km. For the reach of the distance zones, the reactances X are the deciding quantity.

The first zone Z1 is usually set to cover 85 % of the protected line without any trip time delay (i.e. T1 = 0.00 s). The protection clears faults in this range without additional time delay, i.e. the tripping time is the relay basic operating time.

The tripping time of the higher zones is sequentially increased by one time grading interval. The grading margin must take into account the circuit breaker operating time including the spread of this time, the resetting time of the protection equipment as well as the spread of the protection delay timers. Typical values are 0.2 s to 0.4 s. The reach is selected to cover up to approximately 80% of the zone with the same set time delay on the shortest neighbouring feeder.

When using a personal computer and DIGSI® to apply the settings, these can be optionally entered as primary or secondary values.

In the case of parameterization with secondary quantities, the values derived from the grading coordination chart must be converted to the secondary side of the current and voltage transformers. In general:

$$Z_{secondary} = \frac{\text{Current transformer ratio}}{\text{Voltage transformer ratio}} \cdot Z_{primary}$$

Accordingly, the reach for any distance zone can be specified as follows:

$$X_{sec} = \frac{N_{CT}}{N_{VT}} \cdot X_{prim}$$

where

N_{CT} = Current transformer ratio

N_{VT} = Transformation ratio of voltage transformer

<u>Calculation Example</u>:

110 kV overhead line 150 mm^2 with the following data:

s (length)   = 35 km

R_1/s = 0.19 Ω/km

X_1/s = 0.42 Ω/km

R_0/s = 0.53 Ω/km

X_0/s = 1.19 Ω/km

Current Transformer   600 A/5 A

Voltage transformer   110 kV / 0.1 kV

The following line data is calculated:

R_L = 0.19 Ω/km · 35 km = 6.65 Ω

X_L = 0.42 Ω/km · 35 km = 14.70 Ω

For the first zone, a setting of 85 % of the line length should be applied, which results in <u>primary</u>:

$X1_{prim}$ = 0.85 · X_L = 0.85 · 14.70 Ω= 12.49 Ω

or <u>secondary</u>:

$$X1_{sec} = \frac{N_{CT}}{N_{VT}} \cdot X1_{prim} = \frac{600 \text{ A/5 A}}{110 \text{ kV/0.1 kV}} \cdot 12.49 \text{ } \Omega = 1.36 \text{ } \Omega$$

Resistance Tolerance

The resistance setting R allows a reserve for fault resistance which appears as an additional resistance at the fault location and is added to the impedance of the line conductors. It comprises, for example, the resistance in arcs, the earth distribution resistance of earth points and others. The setting must consider these fault resistances, but should at the same time not be larger than necessary. On long heavily loaded lines, the setting may extend into the load impedance range. Fault detection due to overload conditions is then prevented with the load trapezoid. Refer to margin heading "Load range (only for impedance pickup)" in Subsection 2.2.1. The resistance tolerance may be separately set for the phase–phase faults on the one hand and the phase–earth

faults on the other hand. It is therefore possible to allow for a larger fault resistance for earth faults for example.

Most important for this setting on overhead lines, is the resistance of the fault arc. In cables on the other hand, an appreciable arc can not exist. On very short cables, care must however be taken that an arc fault on the local cable termination is inside the set resistance of the first zone.

The resistance of the line itself does not have to be considered since it is accounted for through the shape of the polygon provided that the line angle is at least as large as the inclination angle **Distance Angle** (address 1211) of the polygon.

Example:

A maximum arc voltage of 8kV is assumed for phase–phase faults (line data as above). If the minimum primary short-circuit current is assumed to be 1000 A this corresponds to 8 Ω primary. For the resistance setting of the first zone this implies

primary:

$$R1_{prim} = \frac{1}{2} \cdot R_{arc} = \frac{1}{2} \cdot 8\ \Omega = 4\ \Omega$$

or secondary:

$$R1_{sec} = \frac{N_{CT}}{N_{VT}} \cdot R1_{prim} = \frac{600\ A/5\ A}{110\ kV/0.1\ kV} \cdot 4\ \Omega = 0.44\ \Omega$$

Only half the arc resistance was applied in the equation, as it is added to the loop impedance and therefore only half the arc resistance appears in the **per phase** impedance.

A separate resistance tolerance can be set for earth faults. An arc resistance of 6 Ω and a tower footing resistance of 12 Ω is assumed. This results in the following

primary:

$$R1E_{prim} = R_{arc} + R_{tower} = 6\ \Omega + 12\ \Omega = 18\ \Omega$$

or secondary:

$$R1E_{sec} = \frac{N_{CT}}{N_{VT}} \cdot R1_{prim} = \frac{600\ A/5\ A}{110\ kV/0.1\ kV} \cdot 18\ \Omega = 1.96\ \Omega$$

In this case the least favourable condition was assumed, whereby the earth current does not return via the measuring point. If all the earth current, or a portion of the earth current flows via the measuring point, the measured resistance decreases. When there is an infeed from the remote end, the measured resistance may be increased.

Independent Zones Z1 up to Z5

By means of the parameter MODE = *Forward* or *Reverse* or *Non-Directional* each zone can be set (address 1301 **Op. mode Z1**, 1311 **Op. mode Z2**, 1321 **Op. mode Z3**, 1331 **Op. mode Z4** and 1341 **Op. mode Z5**). This allows any combination of reverse, forward, or non-directional graded zones, for example on transformers, generators or bus couplers. In the fifth zone different reach in the X direction can be set for forward or reverse. Zones that are not required are set *Inactive*.

The values derived from the grading coordination chart are set for each of the required zones. The setting parameters are grouped for each zone. For the first zone these are

the parameters **R(Z1) Ø-Ø** (address 1302) for the R intersection of the polygon applicable to phase-phase faults, **X(Z1)** (address 1303) for the X intersection (reach), **RE(Z1) Ø-E** (address 1304) for the R intersection applicable to phase-earth faults and delay time settings.

For the first zone, Z1, an additional tilt α can be set by means of the parameter in address 1307 **Zone Reduction**. This setting is required if short circuits with a large fault resistance (e.g. overhead lines without earth wire) are expected on lines with an infeed at both ends and load transfer in the direction of the line (export).

Different delay times can be set for single- and multiple-phase faults in the first zone: **T1-1phase** (address 1305) and **T1-multi-phase** (address 1306). The first zone is typically set to operate without additional time delay.

For the remaining zones the following correspondingly applies:

X(Z2) (address 1313), **R(Z2) Ø-Ø** (address 1312), **RE(Z2) Ø-E** (address 1314);

X(Z3) (address 1323), **R(Z3) Ø-Ø** (address 1322), **RE(Z3) Ø-E** (address 1324);

X(Z4) (address 1333), **R(Z4) Ø-Ø** (address 1332), **RE(Z4) Ø-E** (address 1334);

X(Z5)+ (address1343) for forward direction, **X(Z5)-** (address 1346) for reverse direction, **R(Z5) Ø-Ø** (address 1342), **RE(Z5) Ø-E** (address 1344).

For the second zone it is also possible to set separate delay times for single- and multi-phase faults. In general the delay times are set the same. If stability problems are expected during multiple-phase faults a shorter delay time can be considered for **T2-multi-phase** (address 1316) while a higher setting for single phase faults may be tolerated **T2-1phase** (address 1315).

The zone timers for the remaining zones are set with the parameters **T3 DELAY** (address 1325), **T4 DELAY** (address 1335) and **T5 DELAY** (address 1345).

If the device is provided with the capability to trip single-pole, single-pole tripping is then possible in the zones Z1 and Z2. While single-pole tripping usually applies to single-phase faults in Z1 (if the remaining conditions for single-pole tripping are satisfied), this may also be selected for the second zone with address 1317 **Trip 1pole Z2**. Single pole tripping in zone 2 is only possible if this address is set to *YES*. The default setting is *NO*.

Note

For instantaneous tripping (undelayed) in the forward direction, the first zone **Z1** should always be used, as only the Z1 and Z1B are guaranteed to trip with the shortest operating time of the device. The further zones should be used sequentially for grading in the forward direction.

If instantaneous tripping (undelayed) is required in the reverse direction, the zone **Z3** should be used for this purpose, as only this zone is ensures instantaneous pickup with the shortest device operating time for faults in the reverse direction. This setting is also recommended in teleprotection *BLOCKING* schemes.

Controlled Zone Z1B

The overreaching zone Z1B is a controlled zone. The normal zones Z1 to Z5 are not influenced by Z1B. There is therefore no zone switching, but rather the overreaching zone is activated or deactivated by the corresponding criteria. At address 1351 **Op. mode Z1B** = *Forward*, it can also be switched *Reverse* or *Non-Directional*. If this stage is not required, it is set to *Inactive* in address 1351. The setting options are similar to those of zone Z1: Address 1352 **R(Z1B) Ø-Ø**, address 1353 **X(Z1B)**,

address 1354 **RE(Z1B) Ø-E**. The delay times for single-phase and multiple-phase faults can again be set separately: **T1B-1phase** (address 1355) and **T1B-multi-phase** (address 1356). If parameter **Op. mode Z1B** is set to *Forward* or *Reverse*, a non-directional trip is also possible in case of closure onto a fault if parameter 1232 **SOTF zone** is set to *Z1B undirect.* (see also Section 2.2.1.4).

Zone Z1B is usually used in combination with automatic reclosure and/or teleprotection schemes. It can be activated internally by the teleprotection functions (see also Section 2.6) or the integrated automatic reclosure (if available, see also Section 2.14) or externally by a binary input. It is generally set to at least 120 % of the line length. On three-terminal line applications ("teed feeders"), it must be set to securely reach beyond the longest line section, even when there is additional infeed via the tee point. The delay times are set in accordance with the type of application, usually to zero or a very small delay. When used in conjunction with teleprotection comparison schemes, the dependence on the fault detection must be considered (refer to margin heading "Distance Protection Prerequisites" in Subsection 2.6.14.

If the distance protection is used in conjunction with an automatic recloser, it can be determined in address 1357 **1st AR -> Z1B** which distance zones are released prior to a rapid automatic reclosure. Usually the overreaching zone Z1B is used for the first cycle (**1st AR -> Z1B** = *YES*). This may be suppressed by changing the setting of **1st AR -> Z1B** to *NO*. In this case the overreaching zone Z1B is not released before and during the 1st automatic reclose cycle. Zone Z1 is always released. The setting only has an effect when the service condition of the automatic reclose function is input to the device via binary input "**>Enable ARzones**" (FNo. 383).

The zones **Z4** and **Z5** can be blocked using a binary input message FNo. 3619 "**>BLOCK Z4 Ph-E**" or FNo. 3620 "**>BLOCK Z5 Ph-E**" for phase-earth loops. To block these zones permanently for phase-earth loops, said binary inputs must be set to the logic value of 1 via CFC.

2.2.2.3   Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
1301	Op. mode Z1		Forward Reverse Non-Directional Inactive	Forward	Operating mode Z1
1302	R(Z1) Ø-Ø	1A	0.050 .. 600.000 Ω	1.250 Ω	R(Z1), Resistance for ph-ph-faults
		5A	0.010 .. 120.000 Ω	0.250 Ω	
1303	X(Z1)	1A	0.050 .. 600.000 Ω	2.500 Ω	X(Z1), Reactance
		5A	0.010 .. 120.000 Ω	0.500 Ω	
1304	RE(Z1) Ø-E	1A	0.050 .. 600.000 Ω	2.500 Ω	RE(Z1), Resistance for ph-e faults
		5A	0.010 .. 120.000 Ω	0.500 Ω	
1305	T1-1phase		0.00 .. 30.00 sec; ∞	0.00 sec	T1-1phase, delay for single phase faults

Addr.	Parameter	C	Setting Options	Default Setting	Comments
1306	T1-multi-phase		0.00 .. 30.00 sec; ∞	0.00 sec	T1multi-ph, delay for multi phase faults
1307	Zone Reduction		0 .. 45 °	0 °	Zone Reduction Angle (load compensation)
1311	Op. mode Z2		Forward Reverse Non-Directional Inactive	Forward	Operating mode Z2
1312	R(Z2) Ø-Ø	1A	0.050 .. 600.000 Ω	2.500 Ω	R(Z2), Resistance for ph-ph-faults
		5A	0.010 .. 120.000 Ω	0.500 Ω	
1313	X(Z2)	1A	0.050 .. 600.000 Ω	5.000 Ω	X(Z2), Reactance
		5A	0.010 .. 120.000 Ω	1.000 Ω	
1314	RE(Z2) Ø-E	1A	0.050 .. 600.000 Ω	5.000 Ω	RE(Z2), Resistance for ph-e faults
		5A	0.010 .. 120.000 Ω	1.000 Ω	
1315	T2-1phase		0.00 .. 30.00 sec; ∞	0.30 sec	T2-1phase, delay for single phase faults
1316	T2-multi-phase		0.00 .. 30.00 sec; ∞	0.30 sec	T2multi-ph, delay for multi phase faults
1317A	Trip 1pole Z2		NO YES	NO	Single pole trip for faults in Z2
1321	Op. mode Z3		Forward Reverse Non-Directional Inactive	Reverse	Operating mode Z3
1322	R(Z3) Ø-Ø	1A	0.050 .. 600.000 Ω	5.000 Ω	R(Z3), Resistance for ph-ph-faults
		5A	0.010 .. 120.000 Ω	1.000 Ω	
1323	X(Z3)	1A	0.050 .. 600.000 Ω	10.000 Ω	X(Z3), Reactance
		5A	0.010 .. 120.000 Ω	2.000 Ω	
1324	RE(Z3) Ø-E	1A	0.050 .. 600.000 Ω	10.000 Ω	RE(Z3), Resistance for ph-e faults
		5A	0.010 .. 120.000 Ω	2.000 Ω	
1325	T3 DELAY		0.00 .. 30.00 sec; ∞	0.60 sec	T3 delay
1331	Op. mode Z4		Forward Reverse Non-Directional Inactive	Non-Directional	Operating mode Z4
1332	R(Z4) Ø-Ø	1A	0.050 .. 600.000 Ω	12.000 Ω	R(Z4), Resistance for ph-ph-faults
		5A	0.010 .. 120.000 Ω	2.400 Ω	
1333	X(Z4)	1A	0.050 .. 600.000 Ω	12.000 Ω	X(Z4), Reactance
		5A	0.010 .. 120.000 Ω	2.400 Ω	
1334	RE(Z4) Ø-E	1A	0.050 .. 600.000 Ω	12.000 Ω	RE(Z4), Resistance for ph-e faults
		5A	0.010 .. 120.000 Ω	2.400 Ω	
1335	T4 DELAY		0.00 .. 30.00 sec; ∞	0.90 sec	T4 delay

Addr.	Parameter	C	Setting Options	Default Setting	Comments
1341	Op. mode Z5		Forward Reverse Non-Directional Inactive	Inactive	Operating mode Z5
1342	R(Z5) Ø-Ø	1A	0.050 .. 600.000 Ω	12.000 Ω	R(Z5), Resistance for ph-ph-faults
		5A	0.010 .. 120.000 Ω	2.400 Ω	
1343	X(Z5)+	1A	0.050 .. 600.000 Ω	12.000 Ω	X(Z5)+, Reactance for Forward direction
		5A	0.010 .. 120.000 Ω	2.400 Ω	
1344	RE(Z5) Ø-E	1A	0.050 .. 600.000 Ω	12.000 Ω	RE(Z5), Resistance for ph-e faults
		5A	0.010 .. 120.000 Ω	2.400 Ω	
1345	T5 DELAY		0.00 .. 30.00 sec; ∞	0.90 sec	T5 delay
1346	X(Z5)-	1A	0.050 .. 600.000 Ω	4.000 Ω	X(Z5)-, Reactance for Reverse direction
		5A	0.010 .. 120.000 Ω	0.800 Ω	
1351	Op. mode Z1B		Forward Reverse Non-Directional Inactive	Forward	Operating mode Z1B (over-rreach zone)
1352	R(Z1B) Ø-Ø	1A	0.050 .. 600.000 Ω	1.500 Ω	R(Z1B), Resistance for ph-ph-faults
		5A	0.010 .. 120.000 Ω	0.300 Ω	
1353	X(Z1B)	1A	0.050 .. 600.000 Ω	3.000 Ω	X(Z1B), Reactance
		5A	0.010 .. 120.000 Ω	0.600 Ω	
1354	RE(Z1B) Ø-E	1A	0.050 .. 600.000 Ω	3.000 Ω	RE(Z1B), Resistance for ph-e faults
		5A	0.010 .. 120.000 Ω	0.600 Ω	
1355	T1B-1phase		0.00 .. 30.00 sec; ∞	0.00 sec	T1B-1phase, delay for single ph. faults
1356	T1B-multi-phase		0.00 .. 30.00 sec; ∞	0.00 sec	T1B-multi-ph, delay for multi ph. faults
1357	1st AR -> Z1B		NO YES	YES	Z1B enabled before 1st AR (int. or ext.)

2.2.3 Tripping Logic of the Distance Protection

2.2.3.1 Method of Operation

General Pickup

When using the pickup procedures I, U/I or U/I/φ the signal "Dis. PICKUP" (general pickup of the distance protection function) is generated after the pickup as soon as one of the conditions for pickup is fulfilled. As soon as any of the distance zones has determined with certainty that the fault is inside the tripping range, the signal "Dis. PICKUP" is generated when using the impedance pickup.

This signal "Dis. PICKUP" is alarmed and made available for the initialisation of internal and external supplementary functions. (e.g. teleprotection signal transmission, automatic reclosure).

Zone Logic of the Independent Zones Z1 up to Z5

As was mentioned in the description of the measuring technique, each distance zone generates an output signal which is associated with the zone and the affected phase. The zone logic combines these zone fault detections with possible further internal and external signals. The delay times of the distance zones can be started either together by a general pickup of the distance protection function or individually upon entry into the corresponding distance zone. Parameter **Start Timers** (address 1210) is set to *on Dis. Pickup* by default. This setting ensures that all delay times continue even when changing the fault type or the measuring loop selection, for example when an intermediate infeed is switched off. This setting is also preferable if other distance protection relays in the network employ this time start scheme. If particular importance is attached to the time grading, for example when the fault location changes from zone Z3 to zone Z2, the setting *on Zone Pickup* should be selected. The simplified zone logic is shown in Figure 2-28 using for zone 1, Figure 2-29 for zone 2 and Figure 2-30 for the third zone. Zones Z4 and Z5 function according to Figure 2-31.

In the case of zones Z1, Z2 and Z1B single-pole tripping is possible for single-phase faults, if the device version includes the single-pole tripping option. Therefore the event output in these cases is provided for each pole. Different trip delay times can be set for single-phase and multiple-phase faults in these zones. For multiple-phase faults and faults in the other zones, the tripping is always three pole.

Note

Binary input ">1p Trip Perm" (FNo. 381) must be activated to achieve single-pole tripping. The internal automatic reclosing function may also grant the single-pole permission. The binary input is usually controlled by an external automatic reclosure device.

The trip delay times of the zones (except for Z1 which is usually always set without delay) can be bypassed. The grading times are started either via zone pickup or general pickup of the distance protection function. The undelayed release results from the line energisation logic, which may be externally initiated via the circuit breaker close signal derived from the circuit breaker control switch or from an internal line energisation detection. Zones Z4 and Z5 may be blocked by external criteria (FNo. 3617 ">BLOCK Z4-Trip", FNo. 3618 ">BLOCK Z5-Trip").

Figure 2-28   Tripping logic for the 1st zone

Figure 2-29   Tripping logic for the 2nd zone
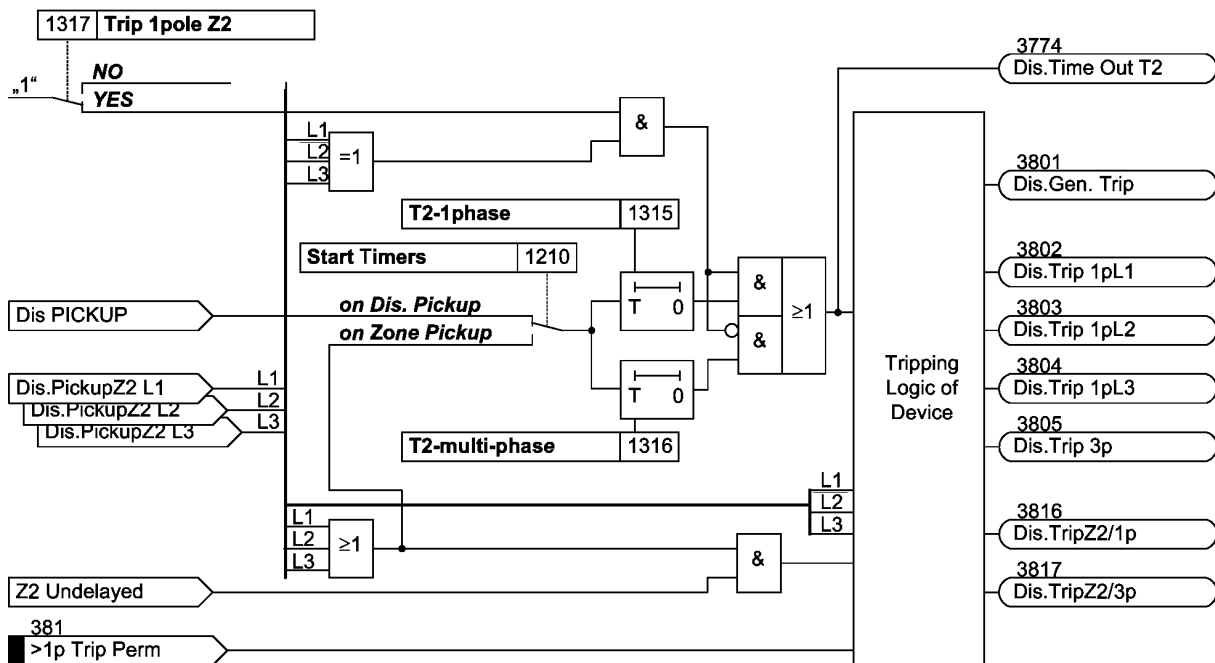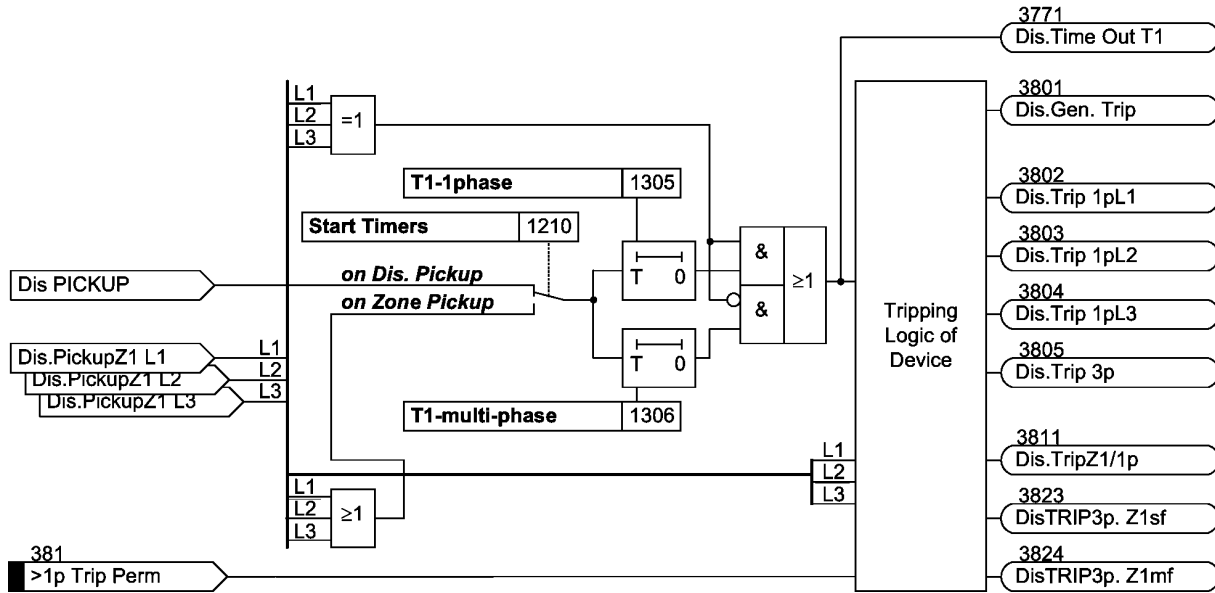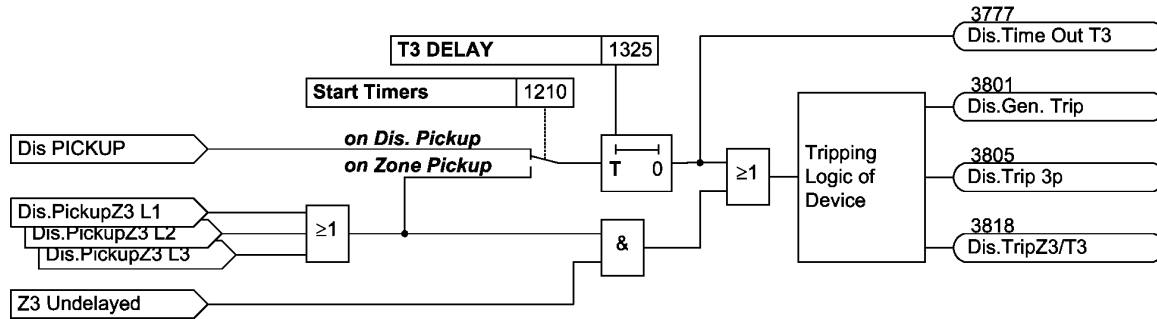
Figure 2-30   Tripping logic for the 3rd zone
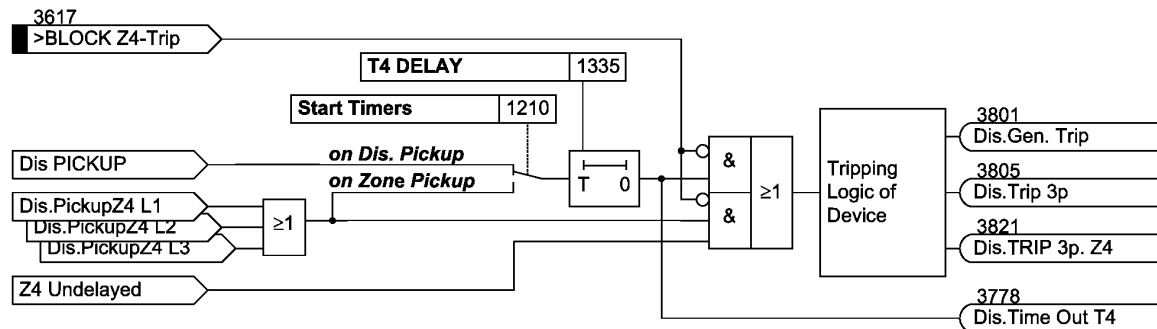
Figure 2-31   Tripping logic for the 4th and 5th zone, shown for Z4

Zone Logic of the Controlled Zone Z1B

The controlled zone Z1B is usually applied as an overreaching zone. The logic is shown in Figure 2-32. It may be activated via various internal and external functions. The binary inputs for external activation of Z1B of the distance protection are "`>ENABLE Z1B`" and "`>Enable ARzones`". The former can for example be from an external teleprotection device, and only affects Z1B of the distance protection. The latter can also be controlled e.g. by an external automatic reclosure device. In addition, it is possible to use the zone Z1B as a rapid autoclosure stage that only operates for single-pole faults, if for example only single-pole automatic reclose cycles are executed.

It is possible for the 7SA6 to trip single-pole during two-phase faults without earth-connection in the overreaching zone when single-pole automatic reclosure is used.

As the device has an integrated teleprotection function, release signals from this function may activate the zone Z1B, provided that the internal teleprotection signal transmission function has been configured to one of the available techniques with parameter 121 **Teleprot. Dist.** i.e., the function has not been set to *Disabled*.
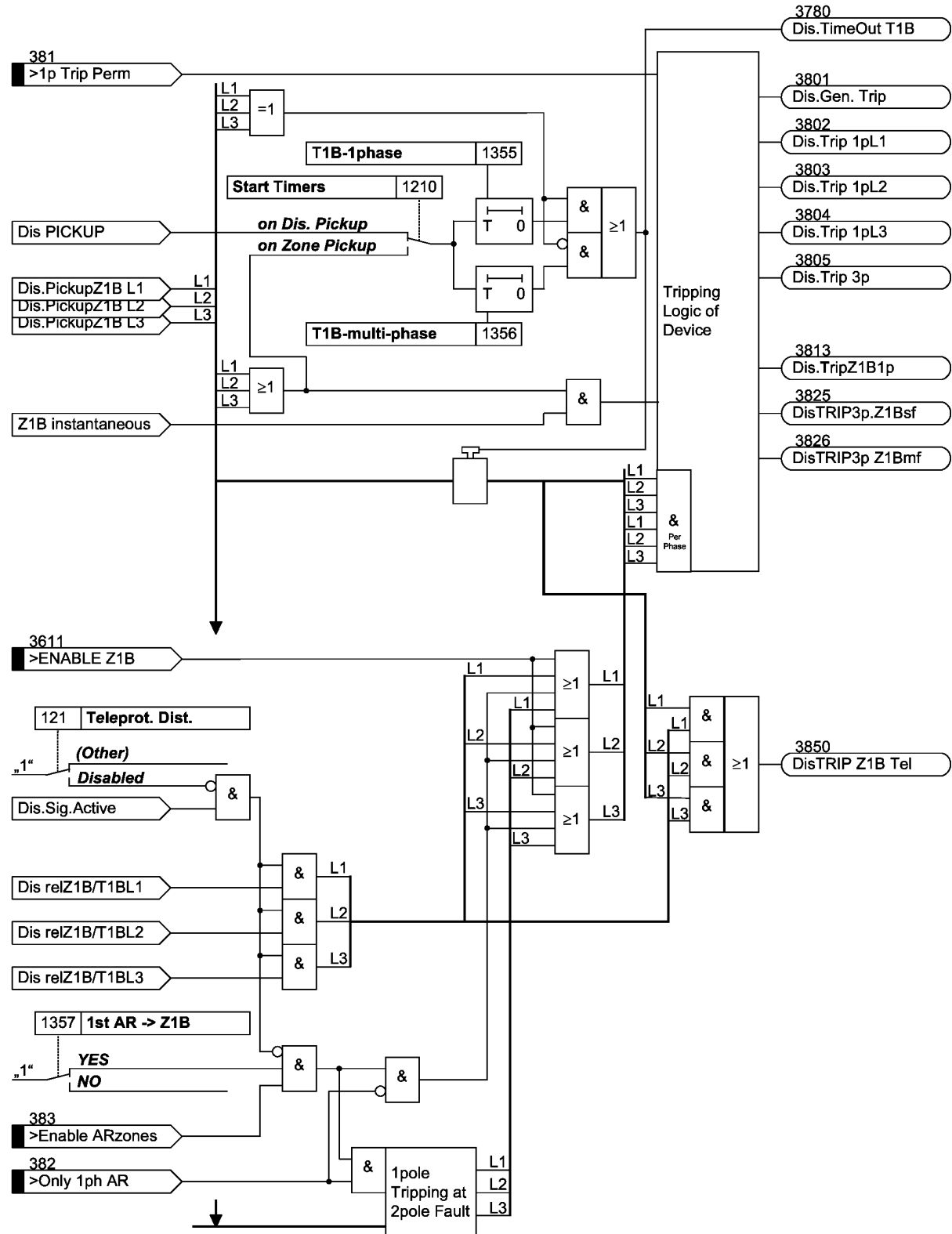
Figure 2-32   Tripping logic for the controlled zone Z1B

Tripping Logic   The output signals generated by the individual zones are logically connected to the output signals "`Dis.Gen. Trip`", "`Dis.Trip 1pL1`", "`Dis.Trip 1pL2`", "`Dis.Trip 1pL3`", "`Dis.Trip 3p`" in the actual tripping logic. The single-pole information implies that tripping will take place single-pole only. Furthermore, the zone that initiated the tripping is identified; if single-pole tripping is possible, this is also alarmed, as shown in the zone logic diagrams (Figures 2-28 up to 2-32). The actual generation of the commands for the tripping (output) relay is executed within the tripping logic of the entire device.

2.2.3.2   Setting Notes

The trip delay times of the distance stages and intervention options which are also processed in the tripping logic of the distance protection were already considered when zones were set.

Further setting options which affect the tripping are described as part of the tripping logic of the device.

2.3 Power swing detection (optional)

The 7SA6 has an integrated power swing supplement which allows both the blocking of trips by the distance protection during power swings (power swing blocking) and the calculated tripping during unstable power swings (out-of-step tripping). To avoid uncontrolled tripping, the distance protection devices are supplemented with power swing blocking functions. At particular locations in the system, out-of-step tripping devices are also applied to split the system into islanded networks at selected locations, when system stability (synchronism) is lost due to severe (unstable) power swings.

2.3.1 Method of Operation

Following dynamic events such as load jumps, short-circuits, reclose dead times or switching actions it is possible that the generators must realign themselves, in an oscillatory manner, with the new load balance of the system. The distance protection registers large transient currents during the power swing and, especially at the electrical centre, small voltages (Figure 2-33). Small voltages with simultaneous large currents apparently imply small impedances, which again could lead to tripping by the distance protection. In expansive networks with large transferred power, even the stability of the energy transfer could be endangered by such power swings.

$$I = \frac{E_1 - E_2}{Z_1 + Z_2} \qquad \text{at the Measuring Location M}$$
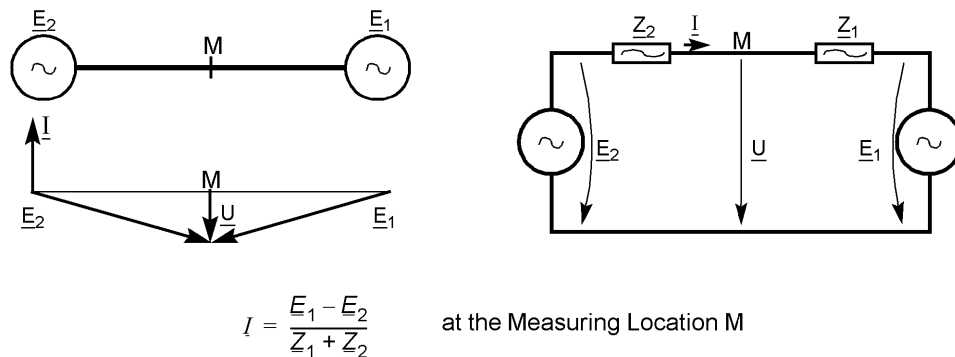
Figure 2-33   Power swing

Note

The power swing supplement works together with the impedance pickup and is only available in this combination.

System power swings are three phase symmetrical processes. Therefore in general a certain degree of measured value symmetry may be assumed. System power swings may however also occur during unsymmetrical processes, e.g. during two-phase short-circuits or during single-pole dead times. The power swing detection in the 7SA6 is therefore based on three measuring systems. For each phase, a dedicated measuring system is available. Even if a power swing has been detected, any subsequent short-circuits will result in the fast cancellation of the power swing block in the affected phases, thereby allowing the tripping of the distance protection.

To detect a power swing, the rate of change of the impedance vectors is measured. The message is triggered when the impedance vector enters the power swing measuring range PPOL (refer to Figure 2-34) and the other criteria of power swing detection are met. The fault detection range APOL is made up of the largest set values for R and X of all the activated zones. The power swing zone has a minimum distance Z_{diff} of 5 Ω (at I_N = 1 A) or 1 Ω (at I_N = 5 A) in all directions from the fault detection zone. In the event of a short-circuit (1), the impedance vector abruptly changes from the load condition into this fault detection range. However, in the event of a power swing, the apparent impedance vector initially enters the power swing range PPOL and only later enters the fault detection range APOL (2). It is also possible that a power swing vector will enter the area of the power swing range and leave it again without coming into contact with the fault detection range (3). If the vector enters the power swing polygon and passes through it leaving on the opposite side, then the sections of the network seen from the relay location have lost synchronism (4): The power transfer is unstable.
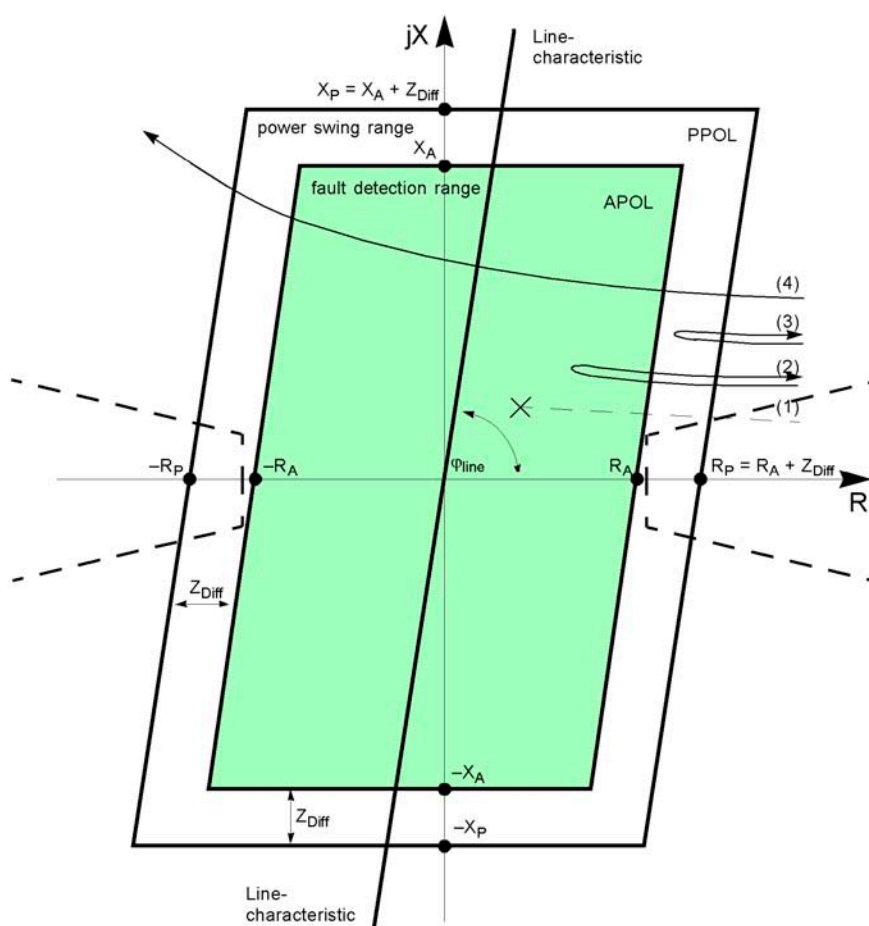
Figure 2-34   Pickup characteristic of the power swing detection for a polygon.

The rate of change of the 3 impedance vectors is monitored in $\frac{1}{4}$ cycle intervals.
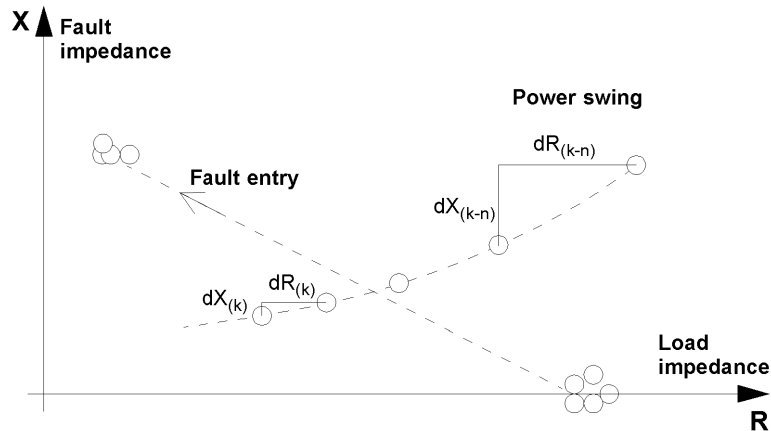
Figure 2-35   Impedance vector during power swing

Trajectory Continuity and Monotony

The rate of change of the impedance vector is very important for the differentiation between faults and power swing conditions. This is shown in Figure 2-35. During the power swing the measured impedance from one sample to the next has a defined change in R and X, referred to as dR(k) and dX(k). Important is also the fact that from one sample to the next the difference is small: i.e. $|dR(k) - dR(k+1)|$ < threshold.

During a fault entry there is a rapid change that will not cause the power swing detection function to pick up.

Trajectory Stability

When the impedance vector enters the impedance characteristic during a power swing this is at a point of the elliptical curve that corresponds to a steady state instability. For release of the power swing detection a further criterion is therefore used. In 2-36 the range for steady state instability is shown. This range is detected in the distance protection relay. This is done by calculating the center of the ellipse and checking if the actual measured X value is less than this value.
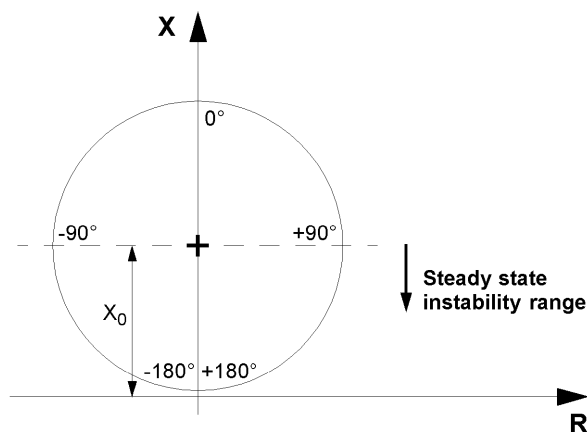
Figure 2-36   Steady state instability range

Trajectory Symmetry

In addition to these measures, a comparison of the three phases is done to ensure that they are symmetrical. During a power swing condition in the single pole open condition, only two of the three phases will have an impedance trajectory. In this case only these 2 remaining phase trajectories are checked to ensure that they are symmetrical.

Power Swing Detection

To ensure stable and secure operation of the power swing detection without risking unwanted power swing blocking during power system faults, a logical combination of a number of measuring criteria are used.
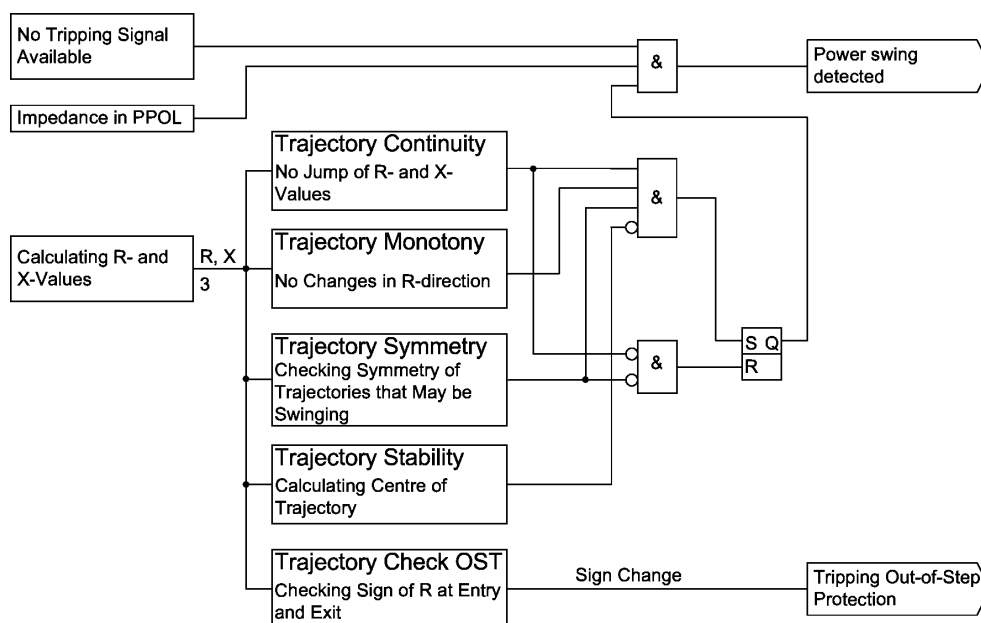
Figure 2-37   Logic diagram of power swing detection

In Figure 2-37 a simplified logic diagram for the power swing function is given. This measurement is done on a per phase basis although 2-37 only shows the logic for one phase. Before a power swing detected signal is generated, the measured impedance must be inside the power swing polygon (PPOL).

In the following 4 measuring criteria are listed:

Trajectory continuity	The calculated R and X values must create a constant line. There must be no jump from one measured value to the next. Refer to Figure 2-35.
Trajectory monotony	The impedance trajectory must initially not change R-direction. Refer to Figure 2-35.
Trajectory symmetry	The trajectory of each phase is evaluated. If no fault is present these 3 trajectories must be symmetrical. During single pole open conditions the remaining 2 trajectories must be symmetrical.
Trajectory stability	When the impedance trajectory enters the PPOL during a swing condition, the system must be in the area of steady state instability. In Figure 2-36 this corresponds to the lower half of the circle.

All these conditions must be true for the generation of a power swing block condition. Once the power swing block condition is set it will remain picked up until the impedance vector leaves the power swing polygon (PPOL). This is unless a fault occurs during this phase. The detection of a jump in the trajectory or non-symmetry of the trajectories will reset the power swing blocking condition. The power swing detection can be blocked via a binary input.

Power Swing Blocking

The power swing blocking affects the distance protection. If the criteria for power swing detection have been fulfilled in at least one phase, the following reactions are possible in relation to the power swing blocking function (set in address 2002 **P/S Op. mode**):

- Block all zones (*All zones block*): All zones of the distance protection are blocked during a power swing.
- Blocking of the first zone only (*Z1/Z1B block*): The first zone (Z1) and the over-reaching zone (Z1B) are blocked during a power swing. Faults in other zones are tripped with the associated grading time.
- Blocking of the higher zone only (*Z2 to Z5 block*): The higher zones (Z2 to Z5) are blocked during a power swing. Only the first and the overreaching zone (Z1 and Z1B) remain active.
- Blocking of the first two zones only (*Z1,Z1B,Z2 block*): The first and second zone (Z1 and Z2) and the overreaching zone (Z1B) are blocked during a power swing. The higher zones Z3 to Z5 remain active.

Only the phases in the configured zones are blocked in which power swings were detected. The associated measures taken apply to all phases when power swing has been detected. They are active for as long as the measured impedance vector is inside the power swing range PPOL, or if due to an abrupt change of the associated impedance vector the power swing criteria are no longer satisfied. But the influence of the power swing block on the distance protection relay will be prolonged for a defined time (address 2007 **Trip DELAY P/S**). Thus transient states (e.g. switching operations) are compensated, which occur during a power swing and cause a jump in the measured quantities.

It is possible with FNo. 4160 ">Pow. Swing BLK" to block the power swing detection via a binary input.

Power Swing Tripping

If tripping in the event of an unstable power swing (out-of-step condition) is desired, the parameter **PowerSwing trip** = *YES* is set. If the criteria for power swing detection are satisfied, the distance protection is initially blocked according to the configured program for power swing blocking, to avoid tripping by the distance protection.

When the impedance vectors identified by the power swing detection exit the power swing characteristic PPOL, the sign of the R components in the vectors are checked to see if they are the same on exiting and entering the pickup polygon. If this is the case, the power swing process is inclined to stabilize. Otherwise, the vector passed through the power swing characteristic (loss of synchronism, case (4) in Figure2-34). Stable power transmission is then no longer possible. The device outputs an alarm to that effect (FNo 4163 "P.Swing unstab."), provided that the parameter at address 2006 **PowerSwing trip** is set to *NO*. The alarm FNo 4163 "P.Swing unstab." is a pulse with a duration of approx. 50 ms, which can also be processed further via output relay, e.g. for a cycle counter or a pulse counter.

Once instability is detected, the device issues a three-pole trip command, thereby isolating the two system segments from each other. Power swing tripping is alarmed.

As the operating range of the power swing supplement depends on the distance protection settings, the power swing <u>tripping</u> can only be active when the distance protection has been activated.

2.3.2 Setting Notes

The power swing supplement is only active if it has been set to **Power Swing** = ***Enabled*** (address 120) during the configuration. For **Power Swing** no other parameters have to be set.

The four possible programs may be set in address 2002 **P/S Op. mode**, as described in Subsection 2.3: ***All zones block***, ***Z1/Z1B block***, ***Z2 to Z5 block*** or ***Z1,Z1B,Z2 block***.

Additionally the tripping function for unstable oscillations (out-of-step condition, loss of system synchronism) can be set with parameter **PowerSwing trip** (address 2006), which should be set to ***YES*** if required (presetting is ***NO***). In the event of power swing <u>tripping</u> it is recommended to set **P/S Op. mode** = ***All zones block*** for the power swing <u>blocking</u>, to avoid premature tripping by the distance protection.

The tripping delay at least effective and following a power swing blocking can be set at address 2007 **Trip DELAY P/S**.

2.3.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
2002	P/S Op. mode	All zones block Z1/Z1B block Z2 to Z5 block Z1,Z1B,Z2 block	All zones block	Power Swing Operating mode
2006	PowerSwing trip	NO YES	NO	Power swing trip
2007	Trip DELAY P/S	0.08 .. 5.00 sec; 0	0.08 sec	Trip delay after Power Swing Blocking

2.3.4 Information List

No.	Information	Type of Information	Comments
4160	>Pow. Swing BLK	SP	>BLOCK Power Swing detection
4163	P.Swing unstab.	OUT	Power Swing unstable
4164	Power Swing	OUT	Power Swing detected
4166	Pow. Swing TRIP	OUT	Power Swing TRIP command
4167	Pow. Swing L1	OUT	Power Swing detected in L1
4168	Pow. Swing L2	OUT	Power Swing detected in L2
4169	Pow. Swing L3	OUT	Power Swing detected in L3

2.4   Protection data interfaces and communication topology (optional)

Where a teleprotection scheme is to be used to achieve 100 % instantaneous protection (Section 2.6), digital communication channels can be used for data transmission between the devices. In addition to the protection data, other data can be transmitted and thus be made available at the line ends. This data includes synchronization and topology data, as well as remote trip signals, remote annunciation signals and measured values. The topology of the protection data communication system is constituted by the allocation of devices to the ends of the protected object and by the allocation of communication paths to the protection data interfaces of the devices.

2.4.1   Method of Operation

Communication Topology

For a standard layout of lines with two ends, you require one protection data interface for each device. The protection data interface is named PI (see also Figure2-38). The corresponding protection data interface must have been set to **_Enabled_** during configuration of the scope of functions (refer to Subsection 2.1.1). In addition, indices must be assigned to the devices (refer to Sub-Section 2.4.2 under margin heading "Communication Topology").
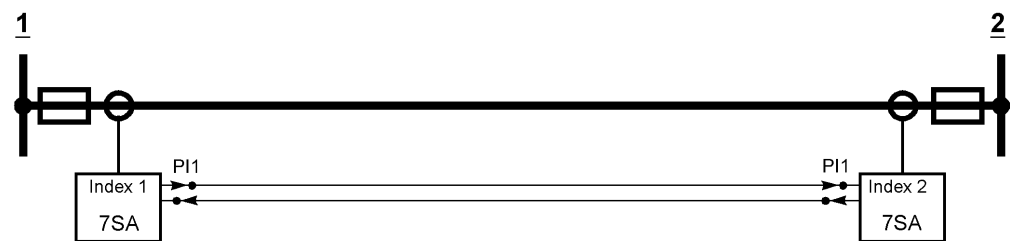
Figure 2-38   Distance protection for two ends with two 7SA6 devices with one protection data interface each (transmitter/ receiver)

Using three ends, at least one 7SA522 device with two protection data interfaces is required. Thus a communication chain can be formed. The number of devices (address 147 **NUMBER OF RELAY**) must correspond to the number of ends of the protected object. Please observe that only current transformer sets that limit the protected object are counted. The line in Figure 2-39, for instance, has **three** ends and **three** devices. It is limited by **three** current transformer sets.

The communication chain begins at the device with index 1 at its protection data interface **P. INTERFACE 1**, continues in the device with index 3 at PI2, runs from device with index 3 from **P. INTERFACE 1** to the device with index 2 at **P. INTERFACE 1**. The example shows that the indexing of the devices must not necessarily have to correspond to the arrangement of the communication chain. Which protection data interface is connected to which protection data interface does not play a role.
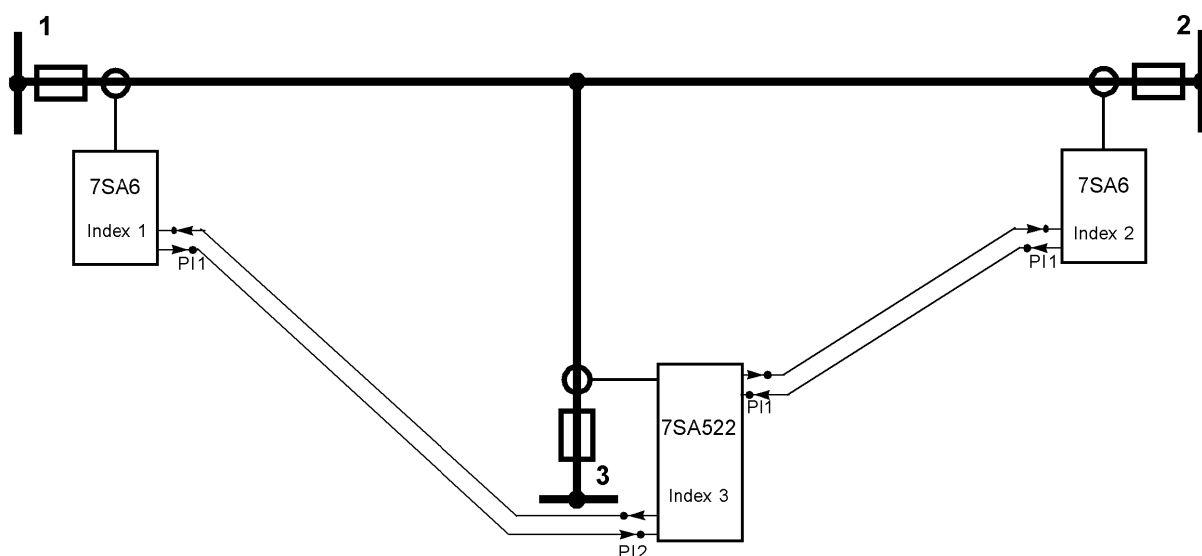
Figure 2-39   Distance protection for three ends with two 7SA6 and one 7SA522, chain topology

Communication Media

The communication is enabled via direct optical fibre connections or communication networks. Which kind of media is used, depends on the distance and on the communication media available. For shorter distances a direct connection via optical fibres having a transmission rate of 512kBit/s is possible. Otherwise we recommend communication converters. A transmission via modem and communication networks can also be realized. Please take into consideration that the responding times of the protection data communication depend on the quality of transmission and that they are prolonged in case of a reduced transmission quality and /or an increased transmission time.

Figure 2-40 shows some examples for communication connections. In case of a direct connection the distance depends on the type of the optical fibre. Table 2-10 lists the options available. Different types of modules can be installed in the device. For ordering information see Appendix, Subsection Accessories.

Table 2-10   Communication via direct connection

Module in the device	Connector type	Fibre type	Optical Wavelength	Perm. path attenuation	Maximum length Optical Fibre
FO5	ST	Multimode 62.5/125 μm	820 nm	8 dB	1.5 km / 0.95 miles
FO6	ST	Multimode 62.5/125 μm	820 nm	16 dB	3.5 km / 2.2 miles
FO7	ST	Monomode 9/125 μm	1300 nm	7 dB	10 km / 6.25 miles
FO8	FC	Monomode 9/125 μm	1300 nm	18 dB	35 km / 22 miles

If a communication converter is used, the device and the communication converter are linked with a FO5 module via optical fibres. The converter itself is equipped with different interfaces for the connection to the communication network. For ordering information see Appendix, Subsection Accessories.
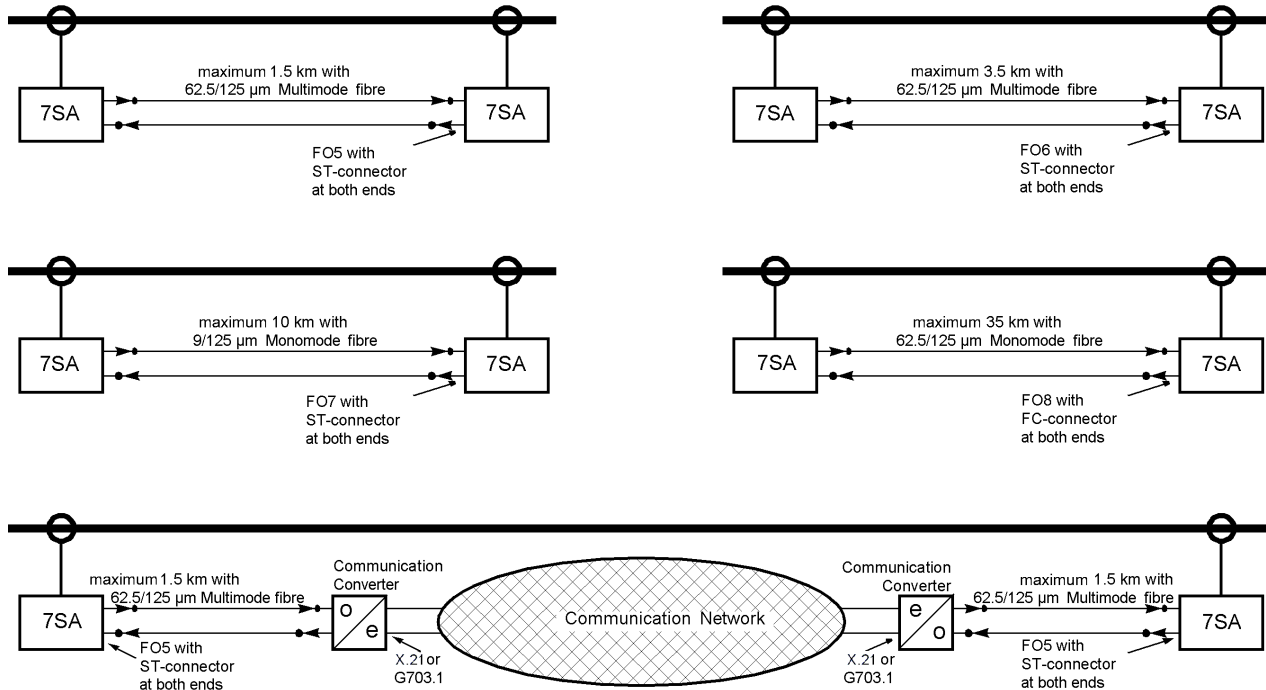
Figure 2-40   Examples for communication connections

Note

The redundancy of different communication connections (for ring topology) requires a consequent separation of the devices connected to the communication network. For example, different communication routes should not be conducted via the same multiplexer card, as there is no alternative which could be used if the multiplexer card should fail.

Functional Logout

In an overall topology up to 3 devices that use teleprotection, it is possible to take out one device, e.g. for maintenance purposes, from the protection function "Teleprotection" without having to re-parameterize the device. A logged out device (in the Functional Logout) no longer participates in the teleprotection, but still sends and receives remote indications and commands (see Section 2.4.2 under "Communication Topology").

Disturbance and Transmission Failure

The communication is continuously monitored by the devices. Single faulty data telegrams are not a direct risk if they occur only occasionally. They are recognized and counted in the device which detects the disturbance and can be read out as statistical information.

If several faulty telegrams or no data telegrams at all are received, this is regarded as a **Disturbance** as soon as a time delay for data disturbance alarm (default setting 100 ms, can be altered) is exceeded. A corresponding alarm is output. When the system

offers no alternative way of communication (as for the ring topology), the teleprotection scheme is disabled. As soon as the data transmission operates properly again, the devices will automatically switch back to the teleprotection scheme.

Transmission time jumps that, for example, can occur in case of switchings in the communication network can be recognized and corrected by the device. After at most 2 seconds the transmission times are measured again.

If the communication is interrupted for a permanent period (which is longer than a settable time period), this can be regarded as a transmission **Failure** of the communication. A corresponding alarm is output. Otherwise the same reactions apply as for the data disturbance.

2.4.2   Setting Notes

General

Protection data interfaces connect the devices with the communication media. The communication is permanently monitored by the devices. Address 4509 **T-DATA DISTURB** defines after which delay time the user is informed about a faulty or missing telegram. Address 4510 **T-DATAFAIL** is used to set the time after which a transmission failure alarm is output.

Protection Data Interface

The protection data interface **P. INTERFACE 1** can be turned *ON* or *OFF* at address 4501 **STATE PROT I 1**. If it is switched *OFF*, this corresponds to a transmission failure. In case of a chain topology the transmission of data can not continue their operation.

In address 4502 **CONNEC. 1 OVER**, set the transmission media that you want to connect to protection data interface **P. INTERFACE 1**. The following selection is possible:

F.optic direct, i.e. communication directly by fibre-optic cable with 512 kBit/s,

Com conv 64 kB, i.e. via communication converters with 64 kBit/s (G703.1 or X.21),

Com conv 128 kB, i.e. via communication converters with 128 kBit/s (X.21, copper cable, bidirectional),

Com conv 512 kB, i.e. via communication converters with 512 kBit/s (X.21).

The possibilities may vary for the different device versions. The data must be identical at both ends of a communication route.

The devices measure and monitor the transmission times. Deviations are corrected, as long as they are within the permissible range.

The maximum permissible signal propagation delay (address 4505 **PROT 1 T-DELAY**) is set to a value that does not exceed the usual value of communication media. This setting is only possible via DIGSI® at **Additional Settings**. If it is exceeded during operation (e.g. because of switchover to a different way of transmission), the message "PI1 TD alarm" will be issued. Once a fault has been detected in the communication of the protection data interface, the time at address 4511 **Td ResetRemote** is started for resetting the remote signals. Please note that only the time of the device is considered whose remote end has failed. Thus the same time is valid for all devices following in a chain.

Communication Topology

First of all, define your communication topology: number the devices consecutively. This numbering is a serial <u>device index</u> that serves for your own overview. It starts for each distance protection system (i.e. for each protected object) with 1. For the dis-

tance protection system the device with index 1 is always the absolute-time master, i.e. the absolute time management of all devices which belong together depends on the absolute time management of this device. As a result the time information of all devices is comparable at all times. The device index serves for unique definition of the devices within the distance protection system (i.e. for one protected object).

An ID number is also to be given to each single device (<u>device-ID</u>). The device–ID is used by the communication system to identify each individual device. It must be between 1 and 65534 and must be unique within the communication system. The ID number identifies the devices in the communication system since the exchange of information between several distance protection systems (thus also for several protected objects) can be executed via the same communication system.

Please make sure that the possible communications links and the existing interfaces are in accordance with each other. If not all devices are equipped with two protection data interfaces, those with only one protection data interface must be located at the ends of the communication chain.

If you work with different physical interfaces and communications links, please make sure that every protection data interface corresponds to the projected communication link.

For a protected object with two ends (e.g. a line) the addresses 4701 **ID OF RELAY 1** and 4702 **ID OF RELAY 2** are set, e.g. for device 1 the device-ID **1** and for device 2 the device-ID **2** (Figure 2-41). The indices of the devices and the device-IDs do not have to match here, as mentioned above.
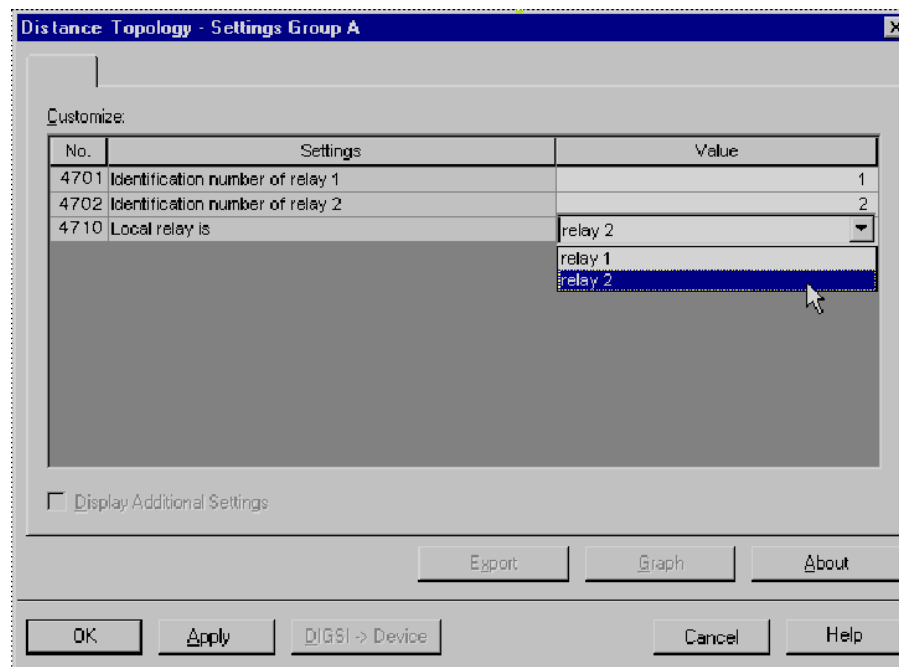
Figure 2-41   Distance protection topology for 2 ends with 2 devices - example

For a protected object with more than two ends (and corresponding devices), the third end is allocated to its device ID at parameter addresses 4703 **ID OF RELAY 3**. A maximum of 3 line ends is possible with 3 devices. Figure 2-42 gives an example with 3 relays. During the configuration of the protection functions the number of devices required for the relevant case of application was set in address 147 **NUMBER OF RELAY**.

Device IDs can be entered for as many devices as were configured under that address, no further IDs are offered during setting.
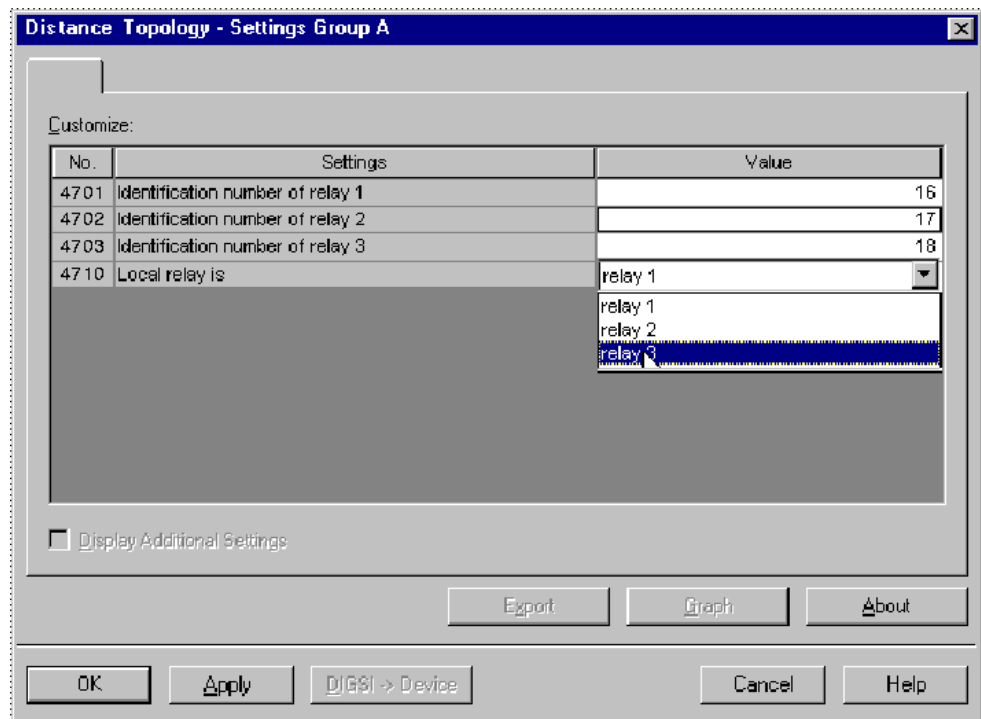
Figure 2-42   Distance protection topology for 3 ends with 3 devices - example

In address 4710 **LOCAL RELAY** you finally indicate the actual local device. Enter the index for each device (according to the consecutive numbering used). Each index from 1 to the entire number of devices must be used once, but may not be used twice.

Make sure that the parameters of the distance protection topology for the distance protection system are conclusive:

• Each device index can only be used once;

• Each device index must be allocated unambiguously to one device ID;

• Each device-index must be the index of a local device once;

• The device with index 1 is the source for the absolute time management (absolute time master).

During startup of the protection system, the above listed conditions are checked. If one out of these conditions is not fulfilled, no protection data can be transmitted. The device signals "DT inconsistent" ("Device table inconsistent").

Device Logout   A device can be removed from the topology via the receive signal 3484 "Logout" so that the remaining relays can still assume their protection function.

If a device logs out functionally (Functional Logout), the number of active protection devices reduces. In this case the teleprotection schemes are automatically switched from 3 to 2 end. If no remote end is available, "Dis.T.Carr.Fail" is signalled.

2.4.3   Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
4501	STATE PROT I 1	ON OFF	ON	State of protection interface 1
4502	CONNEC. 1 OVER	F.optic direct Com conv 64 kB Com conv 128 kB Com conv 512 kB	F.optic direct	Connection 1 over
4505A	PROT 1 T-DELAY	0.1 .. 30.0 ms	30.0 ms	Prot 1: Maximal permissible delay time
4509	T-DATA DISTURB	0.05 .. 2.00 sec	0.10 sec	Time delay for data disturbance alarm
4510	T-DATAFAIL	0.0 .. 60.0 sec	6.0 sec	Time del for transmission failure alarm
4511	Td ResetRemote	0.00 .. 300.00 sec; ∞	0.00 sec	Remote signal RESET DELAY for comm.fail
4701	ID OF RELAY 1	1 .. 65534	1	Identification number of relay 1
4702	ID OF RELAY 2	1 .. 65534	2	Identification number of relay 2
4703	ID OF RELAY 3	1 .. 65534	3	Identification number of relay 3
4710	LOCAL RELAY	relay 1 relay 2 relay 3	relay 1	Local relay is

2.4.4   Information List

No.	Information	Type of Information	Comments
3196	local Teststate	IntSP	Local relay in Teststate
3215	Wrong Firmware	OUT	Incompatible Firmware Versions
3217	PI1 Data reflec	OUT	Prot Int 1: Own Datas received
3227	>PI1 light off	SP	>Prot Int 1: Transmitter is switched off
3229	PI1 Data fault	OUT	Prot Int 1: Reception of faulty data
3230	PI1 Datafailure	OUT	Prot Int 1: Total receiption failure
3233	DT inconsistent	OUT	Device table has inconsistent numbers
3234	DT unequal	OUT	Device tables are unequal
3235	Par. different	OUT	Differences between common parameters
3236	PI1<->PI2 error	OUT	Different PI for transmit and receive
3239	PI1 TD alarm	OUT	Prot Int 1: Transmission delay too high
3243	PI1 with	OUT	Prot Int 1: Connected with relay ID
3457	Ringtopology	OUT	System operates in a closed Ringtopology
3458	Chaintopology	OUT	System operates in a open Chaintopology
3464	Topol complete	OUT	Communication topology is complete

No.	Information	Type of Information	Comments
3475	Rel1Logout	IntSP	Relay 1 in Logout state
3476	Rel2Logout	IntSP	Relay 2 in Logout state
3477	Rel3Logout	IntSP	Relay 3 in Logout state
3484	Logout	IntSP	Local activation of Logout state
3487	Equal IDs	OUT	Equal IDs in constellation
3491	Rel1 Login	OUT	Relay 1 in Login state
3492	Rel2 Login	OUT	Relay 2 in Login state
3493	Rel3 Login	OUT	Relay 3 in Login state

2.5 Remote signals via protection data interface (optional)

2.5.1 Description

7SA6 allows the transmission of up to 28 items of binary information of any type from one device to the other via the communications links provided for protection tasks. Four of 28 information items are transmitted like protection signals with high priority, i.e. very fast, and are therefore especially suitable for the transmission of external protection and trip signals which are generated outside of 7SA6. The other 24 are transmitted in the back-ground and are therefore suitable for any information that does not depend on high-speed transmission, such as information on the events taking place in a substation which may also be useful in other substations as well.

The information is injected into the device via binary inputs and can be output at the other ends again via binary outputs. The integrated user-defined CFC logic allows to perform on both the transmitting and the receiving side logical operations on the signals and on other information from the protection and monitoring functions of the devices.

The binary outputs and the binary inputs to be used must be allocated appropriately during the configuration of the input and output functions (see SIPROTEC® 4 System Description). The 4 high-priority signals are injected into the device via the binary inputs "`>Remote Trip1`" to "`>Remote Trip4`", transmitted to the devices at the other ends and can be processed at each receiving side with the output functions "`RemoteTrip1 rec`" to "`RemoteTrip4 rec`".

If the remote signals are to be used for direct remote tripping, they must be allocated at the send side via CFC with the function that is to perform the transfer trip at the opposite side, and at the receiving side, also via CFC, with the "`>Ext. TRIP ...`" input signals.

The other 24 items of information reach the device via the binary inputs "`>Rem. Signal 1`" to "`>Rem.Signal24`" and are available under "`Rem.Sig 1recv`" etc. at the receiving side.

For the transmission of binary information no settings are required. Each device sends the injected information to all other devices at the ends of the protected object, although the protection data topology is incomplete. Where selection is necessary, it will have to be carried out by appropriate allocation and, if necessary, by a link at the receiving side.

Even devices that have logged out functionally (Functional Logout) can send and receive remote signals and commands.

The annunciations **Dev x available** of the topology detection function can be used to determine whether the signals of the sending devices are still available. They are issued if device x is actively involved in the communication topology and this state is stable.

Once a fault has been detected in the communication of the protection data interface, the time at address 4511 **Td ResetRemote** is started for resetting the remote signals.

2.5.2   Information List

No.	Information	Type of In-formation	Comments
3541	>Remote Trip1	SP	>Remote Trip 1 signal input
3542	>Remote Trip2	SP	>Remote Trip 2 signal input
3543	>Remote Trip3	SP	>Remote Trip 3 signal input
3544	>Remote Trip4	SP	>Remote Trip 4 signal input
3545	RemoteTrip1 rec	OUT	Remote Trip 1 received
3546	RemoteTrip2 rec	OUT	Remote Trip 2 received
3547	RemoteTrip3 rec	OUT	Remote Trip 3 received
3548	RemoteTrip4 rec	OUT	Remote Trip 4 received
3549	>Rem. Signal 1	SP	>Remote Signal 1 input
3550	>Rem.Signal 2	SP	>Remote Signal 2 input
3551	>Rem.Signal 3	SP	>Remote Signal 3 input
3552	>Rem.Signal 4	SP	>Remote Signal 4 input
3553	>Rem.Signal 5	SP	>Remote Signal 5 input
3554	>Rem.Signal 6	SP	>Remote Signal 6 input
3555	>Rem.Signal 7	SP	>Remote Signal 7 input
3556	>Rem.Signal 8	SP	>Remote Signal 8 input
3557	>Rem.Signal 9	SP	>Remote Signal 9 input
3558	>Rem.Signal10	SP	>Remote Signal 10 input
3559	>Rem.Signal11	SP	>Remote Signal 11 input
3560	>Rem.Signal12	SP	>Remote Signal 12 input
3561	>Rem.Signal13	SP	>Remote Signal 13 input
3562	>Rem.Signal14	SP	>Remote Signal 14 input
3563	>Rem.Signal15	SP	>Remote Signal 15 input
3564	>Rem.Signal16	SP	>Remote Signal 16 input
3565	>Rem.Signal17	SP	>Remote Signal 17 input
3566	>Rem.Signal18	SP	>Remote Signal 18 input
3567	>Rem.Signal19	SP	>Remote Signal 19 input
3568	>Rem.Signal20	SP	>Remote Signal 20 input
3569	>Rem.Signal21	SP	>Remote Signal 21 input
3570	>Rem.Signal22	SP	>Remote Signal 22 input
3571	>Rem.Signal23	SP	>Remote Signal 23 input
3572	>Rem.Signal24	SP	>Remote Signal 24 input
3573	Rem.Sig 1recv	OUT	Remote signal 1 received
3574	Rem.Sig 2recv	OUT	Remote signal 2 received
3575	Rem.Sig 3recv	OUT	Remote signal 3 received
3576	Rem.Sig 4recv	OUT	Remote signal 4 received
3577	Rem.Sig 5recv	OUT	Remote signal 5 received
3578	Rem.Sig 6recv	OUT	Remote signal 6 received
3579	Rem.Sig 7recv	OUT	Remote signal 7 received
3580	Rem.Sig 8recv	OUT	Remote signal 8 received
3581	Rem.Sig 9recv	OUT	Remote signal 9 received
3582	Rem.Sig10recv	OUT	Remote signal 10 received
3583	Rem.Sig11recv	OUT	Remote signal 11 received

No.	Information	Type of In-formation	Comments
3584	Rem.Sig12recv	OUT	Remote signal 12 received
3585	Rem.Sig13recv	OUT	Remote signal 13 received
3586	Rem.Sig14recv	OUT	Remote signal 14 received
3587	Rem.Sig15recv	OUT	Remote signal 15 received
3588	Rem.Sig16recv	OUT	Remote signal 16 received
3589	Rem.Sig17recv	OUT	Remote signal 17 received
3590	Rem.Sig18recv	OUT	Remote signal 18 received
3591	Rem.Sig19recv	OUT	Remote signal 19 received
3592	Rem.Sig20recv	OUT	Remote signal 20 received
3593	Rem.Sig21recv	OUT	Remote signal 21 received
3594	Rem.Sig22recv	OUT	Remote signal 22 received
3595	Rem.Sig23recv	OUT	Remote signal 23 received
3596	Rem.Sig24recv	OUT	Remote signal 24 received

2.6 Teleprotection for distance protection

2.6.1 General

Purpose of Teleprotection

Faults which occur on the protected line, beyond the first distance zone, can only be cleared selectively by the distance protection after a delay time. On line sections that are shorter than the smallest sensible distance setting, faults can also not be selectively cleared instantaneously.

To achieve non-delayed and selective tripping on 100% of the line length for all faults by the distance protection, the distance protection can exchange and process information with the opposite line end by means of signal transmission schemes. For this purpose, the device has signal send outputs and receive inputs as well as associated logic functions. This can be done in a conventional way using send and receive contacts. As an alternative, digital communication lines can be used for signal transmission (ordering option).

Teleprotection Schemes

A distinction is made between underreach and overreach schemes.

In underreach schemes, the protection is set with a normal grading characteristic. If a trip command occurs in the first zone, the other line end receives this information via a transmission channel. There the received signal initates a trip, either by activation of overreach zone Z1B or via a direct trip command.

7SA6 allows:
- PUTT (Pickup),
- Permissive Underreach Transfer Trip with Zone Acceleration Z1B (PUTT),
- Direct (Underreach) Transfer Trip

In overreach schemes, the protection works from the start with a fast overreaching zone. This zone, however, can only cause a trip if the opposite end also detects a fault in the overreaching zone. A release (unblock) signal or a block signal can be transmitted. The following teleprotection schemes are differentiated:

Permissive (release) schemes:
- Permissive Overreach Transfer Trip (POTT) (with overreaching zone Z1B).
- Directional comparison,
- Unblocking with overreaching zone Z1B.

Blocking scheme:
- Unblocking with overreaching zone Z1B.

Schemes via pilot wire:
- Pilot Wire Comparison
- Reverse Interlocking

As the distance zones Z1 ... Z5 (without Z1B) function independently, an instantaneous trip in Z1 without a release or blocking signal is always possible. If fast tripping in Z1 is not required (e.g. on very short lines), then Z1 must be delayed with T1.

Transmission Channels

The pilot wire comparison, that is exclusively applied to short lines, enables the user to operate a pilot wire pair (pilot wires or control wires) with direct current to guarantee the exchange of information between the line ends. Also the reverse interlocking operates with DC control signals.

For the signal transmission, one channel in each direction is required. For example, fibre optic connections or voice frequency modulated high frequency channels via pilot cables, power line carrier or microwave radio links can be used for this purpose.

If the device is equipped with an optional protection data interface, digital communication can be used for signal transmission; these include: e.g.: Fibre optic cables, communication networks or dedicated cables.

The following signal transmission schemes are suited for these kinds of transmission:
- Permissive Underreach Transfer Trip with Zone Acceleration Z1B (PUTT),
- Permissive Overreach Transfer Trip (POTT) (with overreaching zone Z1B).

7SA6 allows also the transmission of phase-selective signals. This presents the advantage that single-pole automatic reclosure can be carried out even when two single-phase faults occur on different lines in the system. Where the digital protection data interface is used, the signal transmission is always phase segregated.

The signal transmission schemes are also suited to three terminal lines (teed feeders). In this case, a signal is transmitted from each of the three ends to each of the others in both directions. Phase segregated transmission is only possible for three terminal line applications if digital communication channels are used.

During disturbances in the transmission path, the teleprotection supplement may be blocked without affecting the normal time graded distance protection. The measuring reach control (enable zone Z1B) can be obtained via the binary input "`>Enable ARzones`" from an external reclosure device or from the internal automatic reclose function. With conventional signal transmission schemes, the disturbance is signalled by a binary input, with digital communication it is detected automatically by the protection device.

2.6.2   Method of Operation

Activation and Deactivation

The teleprotection function can be switched on and off by means of the parameter 2101 **FCT Telep. Dis.**, via the system interface (if available) or via binary input (if this is allocated). The switched state is saved internally (refer to Figure 2-43) and secured against loss of auxiliary supply. It is only possible to switch on from the source where previously it had been switched off from. To be active, it is necessary that the function is switched on from all three switching sources.
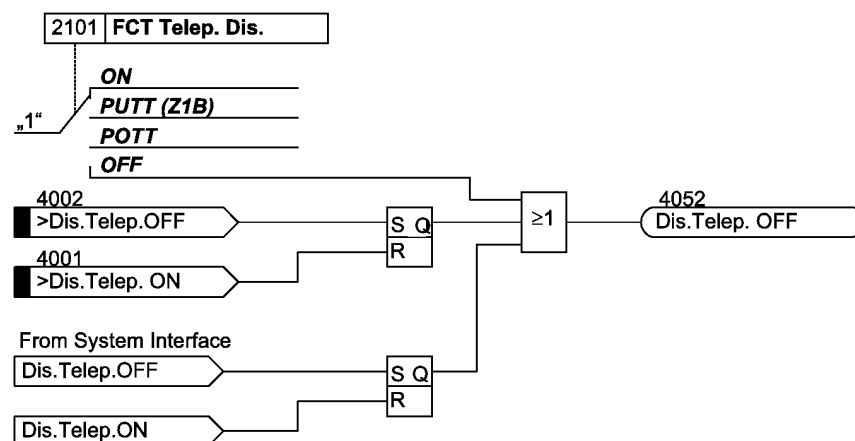
Figure 2-43   Activation and deactivation of the signal transmission logic

2.6.3   PUTT (Pickup)

The following scheme is suited for conventional transmission media.

Principle

The PUTT scheme functionality of is shown in Figure 2-44. In the case of a fault inside zone Z1, the transfer trip signal is sent to the opposite line end. The signal received there initiates the trip, provided that the protection function has picked up. The transmit signal can be prolonged by T_S (settable at address 2103 **Send Prolong.**), to compensate for possible differences in the pick-up time at the two line ends. The distance protection is set such that the first zone reaches up to approximately 85% of the line length. On three terminal lines Z1 is also set to approximately 85% of the shorter line section, but at least beyond the tee off point.

The overreach zone Z1B is without consequence for the teleprotection scheme in this operating mode. It may, however, be controlled by the automatic reclosing function (see also section 2.9.1).
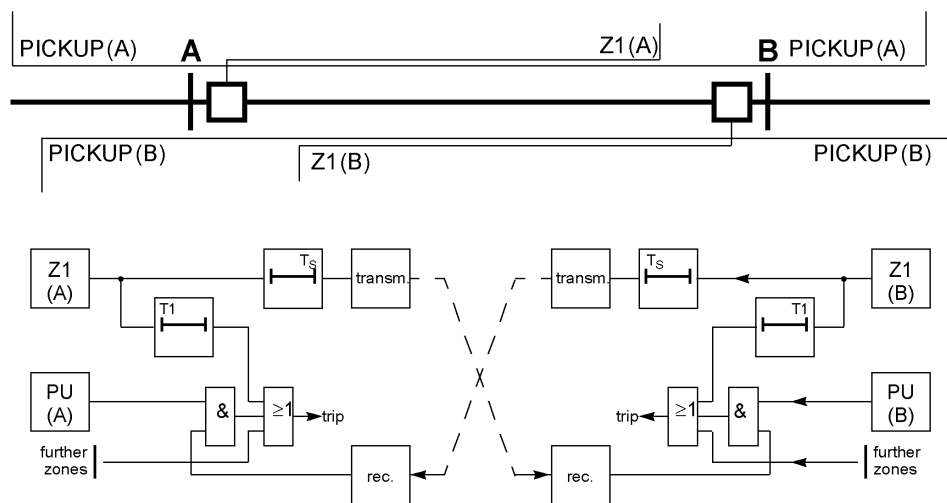
Figure 2-44   Operation scheme of the permissive underreach transfer trip with pickup

Sequence

The permissive transfer trip should only send for faults in the "Forward" direction. Accordingly, the first zone Z1 of the distance protection must definitely be set to *Forward* in addresses 1301 **Op. mode Z1**, refer also to Subsection 2.2.1 under the margin heading "Independent Zones Z1 up to Z5".

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signals are then combined with an OR logic function. With the setting parameter **Type of Line** (address 2102) the device is informed as to whether it has one or two opposite line ends.

If at one line end there is weak or zero infeed, so that the distance protection does not pick up, the circuit breaker can still be tripped. This "Weak-infeed tripping" is referred to in Section 2.9.1.
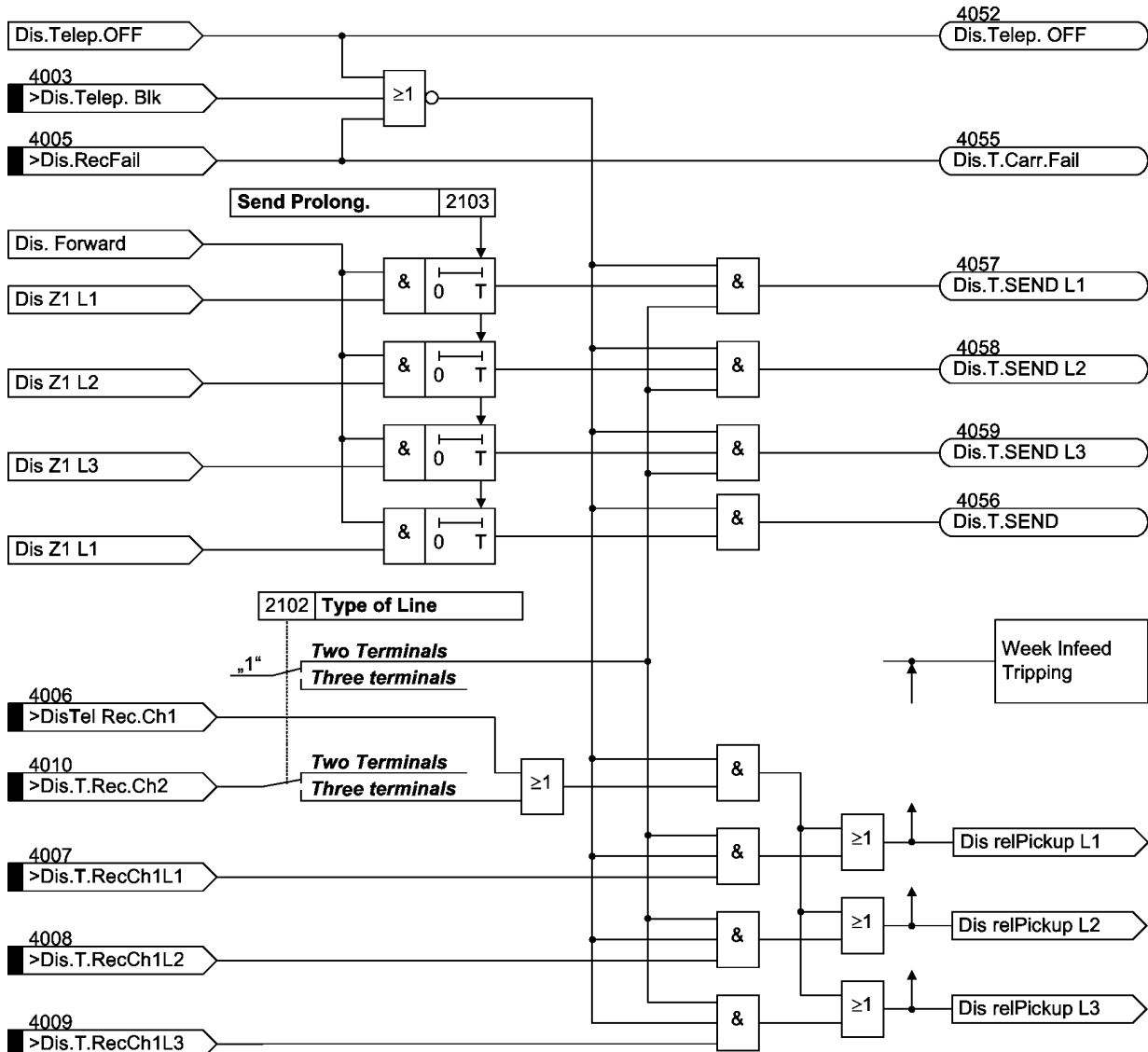
Figure 2-45   Logic diagram of the permissive underreach transfer trip (PUTT) with pickup (one line end)

2.6.4   Permissive Underreach Transfer Trip with Zone Acceleration Z1B (PUTT)

The following procedure is suited for both conventional and digital transmission media.

Principle   Figure 2-46 shows the operation scheme with zone acceleration for this permissive underreach transfer trip scheme. In the case of a fault inside zone Z1, the transfer trip signal is sent to the opposite line end. The signal received there causes tripping if the fault is detected inside the zone Z1B in the set direction. The transmit signal can be prolonged by T_S (settable at address 2103 **Send Prolong.**), to compensate for possible differences in the pick-up time at the two line ends. The distance protection is set such that the first zone reaches up to approximately 85% of the line length, the overreaching zone however is set to reach beyond the opposite substation (approximately 120% of the line length). On three terminal lines Z1 is also set to approximately 85% of the shorter line section, but at least beyond the tee off point. Z1B must securely reach beyond the longer line section, even when additional infeed is possible via the

tee point. For this procedure, transmission via a protection data interface (if provided) is offered.

In protective relays equipped with a protection data interface, address 121 **Teleprot. Dist.** allows to set *SIGNALv.ProtInt*. At address 2101 **FCT Telep. Dis.** *PUTT (Z1B)* can be set.
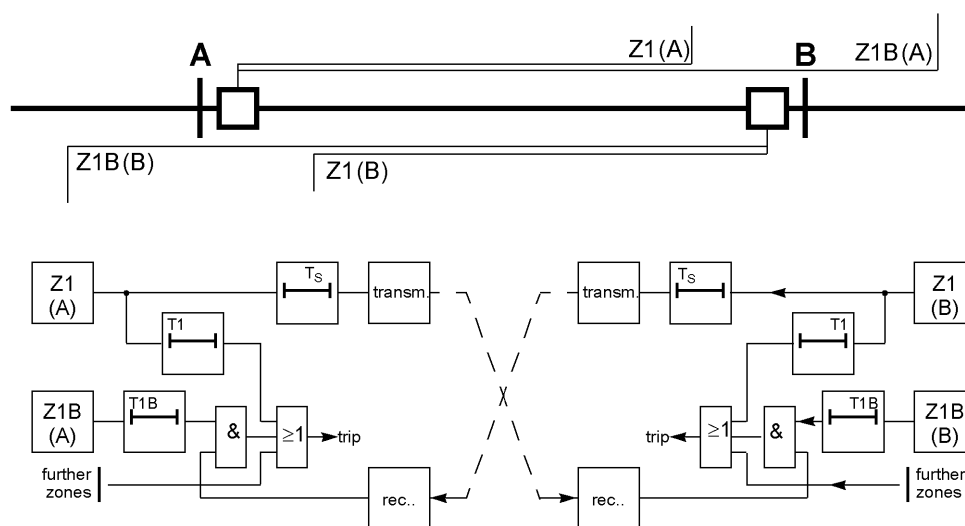
Figure 2-46   Operation scheme of the permissive underreach transfer trip method via Z1B

Sequence
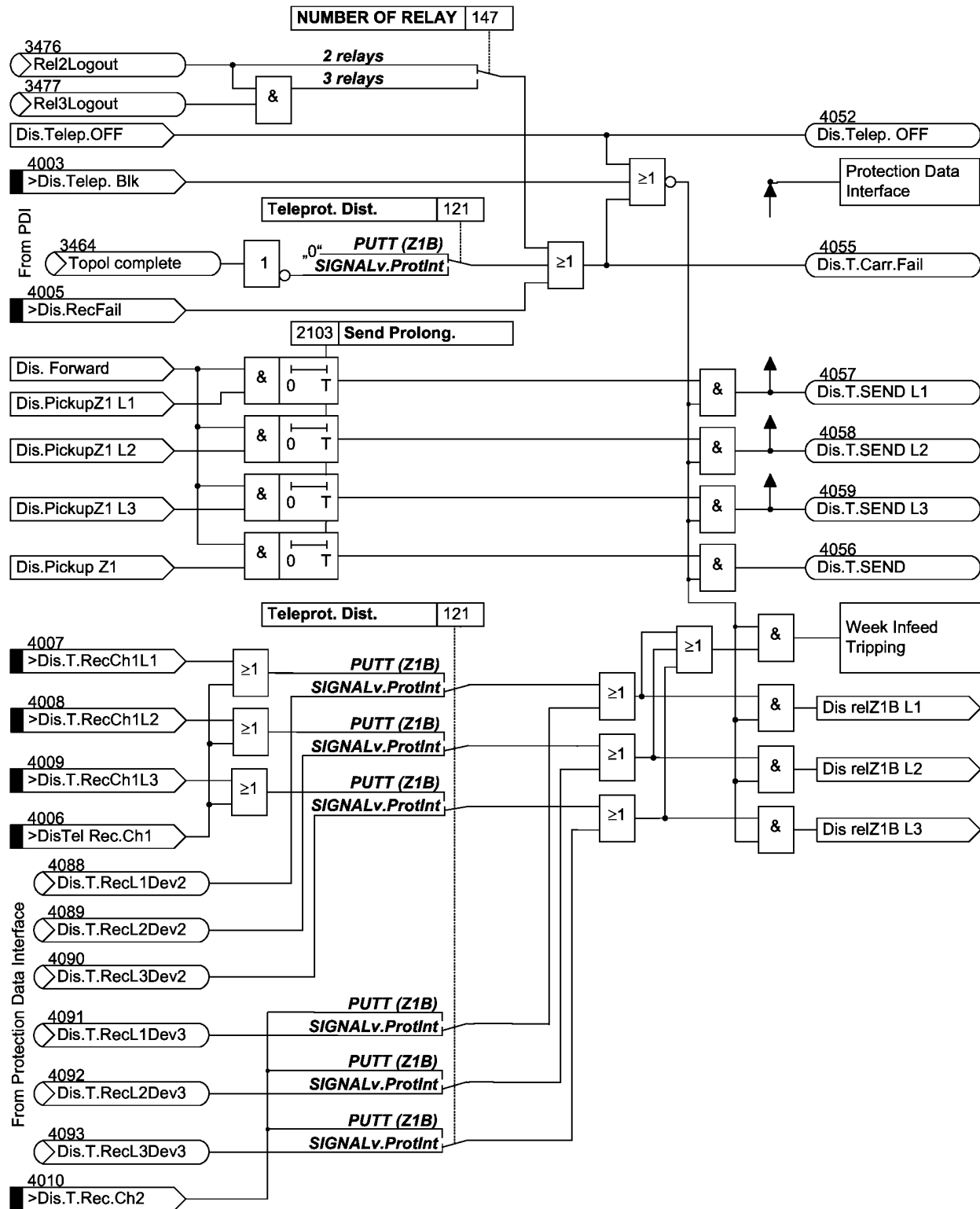
Figure 2-47   Logic diagram of the permissive underreach transfer trip (PUTT) scheme using Z1B (one line end)

The permissive transfer trip only functions for faults in the "forward" direction. Accordingly, the first zone Z1 and the overreach zone Z1B of the distance protection must definitely be set to **Forward** in addresses 1301 **Op. mode Z1** and 1351 **Op. mode Z1B**, refer also to Subsection 2.2.2 under the margin heading "Independent Zones Z1 up to Z5".

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signals are then combined with an OR logic function. If the parameter **Teleprot. Dist.** (address 121) is set to **SIGNALv.ProtInt** and the parameter **NUMBER OF RELAY** (address 147) is set to **3 relays**, the device is informed that it has two remote ends. The default setting is **2 relays**, which corresponds to one remote end. If digital protection transmission is applied and the protection data interface is used, signals will always be transmitted phase-selectively.

If conventional transmission is used, the parameter **Type of Line** (address 2102) informs the device whether it has one or two opposite line ends.

During disturbance of the signal transmission path, the overreaching zone Z1B may be activated by an automatic reclosure (internal or external) via the binary input "`>Enable ARzones`".

If at one line end there is weak or zero infeed, so that the distance protection does not pick up, the circuit breaker can still be tripped. This "Weak-infeed tripping" is referred to in Section 2.9.1.

2.6.5   Direct Underreach Transfer Trip

The following scheme is suited for conventional transmission media.

Principle

As is the case with PUTT (pickup) or PUTT with zone acceleration, a fault in the first zone Z1 is transmitted to the opposite line end by means of a transfer trip signal. The signal received there causes a trip without further queries after a short security margin Tv (settable at address 2202 **Trip Time DELAY**) (Figure 2-48). The transmit signal can be prolonged by T_S (settable at address 2103 **Send Prolong.**), to compensate for possible differences in the pick-up time at the two line ends. The distance protection is set such that the first zone reaches up to approximately 85% of the line length. On three terminal lines Z1 is also set to approximately 85% of the shorter line section, but at least beyond the tee off point. The overreaching zone Z1B is not required here. It may however be activated by internal automatic reclosure or external criteria via the binary input "`>Enable ARzones`".

The advantage compared to the permissive underreach transfer trip with zone acceleration lies in the fact that both line ends are tripped without the necessity for any further measures, even if one line end has no infeed. There is however no further supervision of the trip signal at the receiving end.

The direct underreach transfer trip application is not provided by its own selectable teleprotection scheme setting, but implemented by setting the teleprotection supplement to operate in the permissive underreach transfer trip scheme (address 121 **Teleprot. Dist.** = **PUTT (Z1B)** or **PUTT (Pickup)**), and using the binary inputs for direct external trip at the receiving end. Correspondingly, the transmit circuit in Subsection "The principle of PUTT" (Figure 2-45) applies. For the receive circuit the logic of the "external trip" as described in Section 2.10 applies.

On two terminal lines, the signal transmission may be phase segregated. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signals are then combined with a logical OR function.
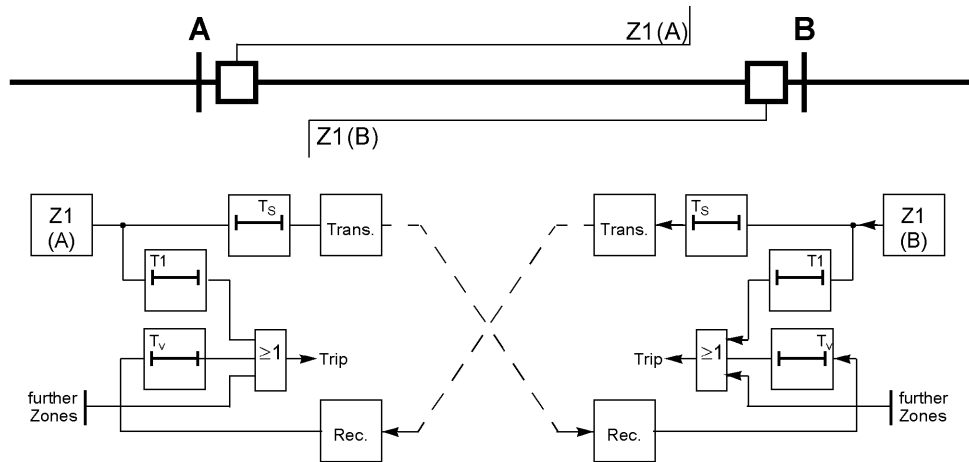
Figure 2-48   Function diagram of the direct underreach transfer trip scheme

2.6.6   Permissive Overreach Transfer Trip (POTT)

The following procedure is suited for both conventional and digital transmission media.

Principle

The permissive overreach transfer mode uses a permissive release principle. The overreaching zone Z1B, set beyond the opposite station, is decisive. This mode can also be used on extremely short lines where a setting of 85% of line length for zone Z1 is not possible and accordingly selective non-delayed tripping could not be achieved. In this case however zone Z1 must be delayed by T1, to avoid non selective tripping by zone Z1 (Figure 2-49).

If the distance protection recognizes a fault inside the overreaching zone Z1B, it initially sends a release signal to the opposite line end. If a release signal is received from the opposite end, a trip signal is forwarded to the trip logic. A prerequisite for fast tripping is therefore that the fault is recognized inside Z1B in the forward direction at both line ends. The distance protection is set such that the overreaching zone Z1B reaches beyond the opposite station (approximately 120% of line length). On three terminal lines, Z1B must be set to reliably reach beyond the longer line section, even if there is an additional infeed via the tee point. The first zone is set in accordance with the usual grading scheme, i.e. approximately 85% of the line length; on three terminal lines at least beyond the tee point.

The transmit signal can be prolonged by T_S (settable under address 2103 **Send Prolong.**). The prolongation of the send signal only comes into effect if the protection has already issued a trip command. This ensures release of the opposite line end even when the short circuit has been switched off rapidly by the independent zone Z1.

For all zones except Z1B, tripping results without release from the opposite line end, allowing the protection to function with the usual grading characteristic independent of the signal transmission.

For this procedure, transmission via a protection data interface (if provided) is offered.

In protective relays equipped with a protection data interface, address 121 **Teleprot. Dist.** allows to set *SIGNALv.ProtInt*. At address 2101 **FCT Telep. Dis.** *POTT* can be set.
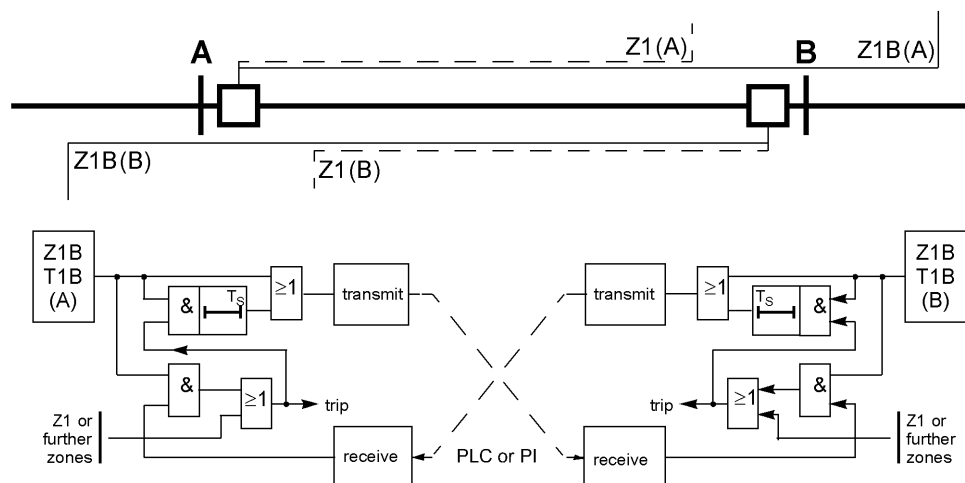
Figure 2-49   Function diagram of the permissive overreach transfer trip method

Sequence

The permissive overreach transfer trip only functions for faults in the "forward" direction. Accordingly, the first overreach zone ZB1 of the distance protection must definitely be set to *Forward* in addresses 1351 **Op. mode Z1B**, refer also to Subsection 2.2.2 under the margin heading "Controlled Zone ZB1".

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signals are then combined with a logical AND gate, as all three line ends must transmit a send signal during an internal fault. If parameter **Teleprot. Dist.** (address 121) is set to *SIGNALv.ProtInt* and parameter **NUMBER OF RELAY** (address 147) to *3 relays*, the device is informed about two remote ends. The default setting is *2 relays*, which corresponds to one remote end. In protective relays equipped with one protection data interface, signal transmission is always phase segregated (Figure 2-51 and 2-52).

If conventional transmission is used, parameter **Type of Line** (address 2102) informs the device whether it has one or two opposite line ends (Figure 2-50).

During disturbance of the signal transmission path, the overreaching zone Z1B may be activated by an automatic reclosure (internal or external) via the binary input "**>Enable ARzones**".

The occurrence of erroneous signals resulting from transients during clearance of external faults or from direction reversal resulting during the clearance of faults on parallel lines, is neutralized by the "Transient Blocking".

On feeders with single-sided infeed, the line end with no infeed cannot generate a release signal, as no fault detection occurs there. To achieve tripping by the permissive overreach transfer scheme even in this case, the device contains a special function. This "Weak Infeed Function" (echo function) is referred to in Subsection "Measures for Weak and Zero Infeed". It is activated when a signal is received from the opposite line end — in the case of three terminal lines from at least one of the opposite line ends — without the device having detected a fault.

The circuit breaker can also be tripped at the line end with no or only weak infeed. This "Weak-infeed tripping" is referred to in Section 2.9.1.
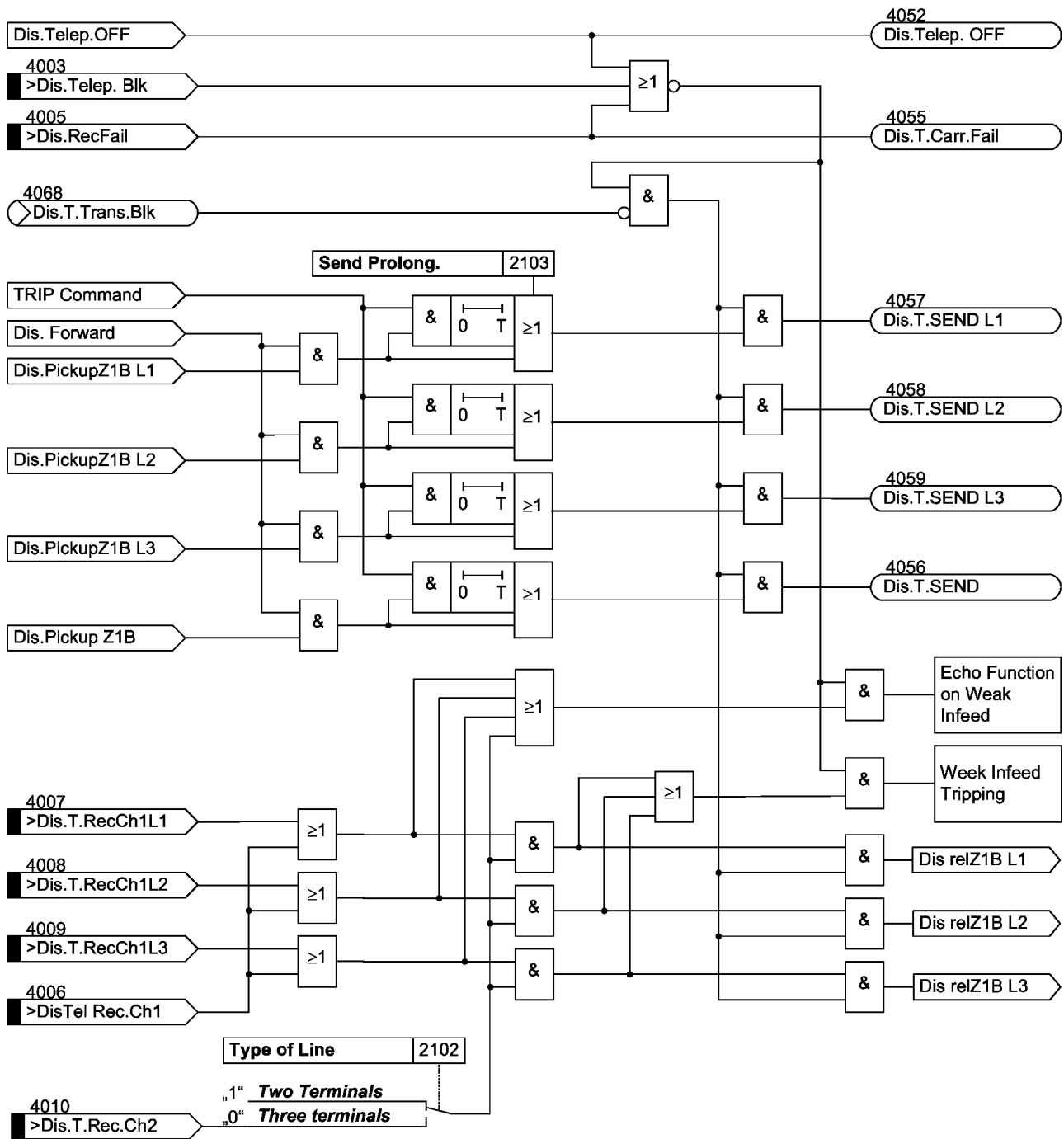
Figure 2-50   Logic diagram of the permissive overreach transfer trip (POTT) scheme (one line end, conventional, no protection data interface)

Figure 2-51   Logic diagram of the permissive overreach transfer trip (POTT) scheme (one line end, with protection data interface)

Continued from Previous Figure

① ②

3476 Rel2Logout		
4088 Dis.T.RecL1Dev2		
4089 Dis.T.RecL2Dev2		
4090 Dis.T.RecL3Dev2		
4091 Dis.T.RecL1Dev3		
4092 Dis.T.RecL2Dev3		
4093 Dis.T.RecL3Dev3		

≥1

Echo Function on Weak Infeed

Week Infeed Tripping

Dis relZ1B L1

Dis relZ1B L2

Dis relZ1B L3

NUMBER OF RELAY | 147

"1" ———— 2 relays

3477 Rel3Logout

3 relays

Figure 2-52   Logic diagram of the permissive overreach transfer trip (POTT) scheme with protection data interface - continued

2.6.7   Directional Comparison Pickup

The following scheme is suited for conventional transmission media.

Principle   The directional comparison scheme is a permissive release scheme. Figure 2-53 shows the operation scheme.

Figure 2-53   Function diagram of the directional comparison method

If the distance protection detects a fault in line direction, it initially sends a release signal to the opposite line end. If a release signal is also received from the opposite line end, a trip signal is transmitted to the trip relay. This is only the case if the opposite line end also detects a fault in line direction. A prerequisite for fast tripping is therefore that the fault is recognized in **both** line ends in forward direction. The distance stages operate independent from the directional comparison pickup.

The transmit signal can be prolonged by T_S (settable under address 2103 **Send Prolong.**). The prolongation of the send signal only comes into effect if the protection has already issued a trip command. This ensures release of the opposite line end even when the short circuit has been switched off rapidly by the independent zone Z1.

Sequence   Figure 2-54 shows the logic diagram of the directional comparison scheme for one line end.

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signals are then combined with a logical AND gate, as all three line ends must transmit a send signal during an internal fault. With the setting parameter **Type of Line** (address 2102) the device is informed as to whether it has one or two opposite line ends.

The occurrence of erroneous signals resulting from transients during clearance of external faults or from direction reversal resulting during the clearance of faults on parallel lines, is neutralized by the "Transient Blocking".

On feeders with single-sided infeed, the line end with no infeed cannot generate a release signal, as no fault detection occurs there. To achieve tripping by the permis-

sive overreach transfer scheme even in this case, the device contains a special function. The "weak-infeed function" (echo function) is activated when a signal is received from the opposite line end — in the case of three terminal lines from at least one of the opposite line ends — without the device having detected a fault.

The circuit breaker can also be tripped at the line end with no or only weak infeed. This "Weak-infeed tripping" is referred to in Section 2.9.1.
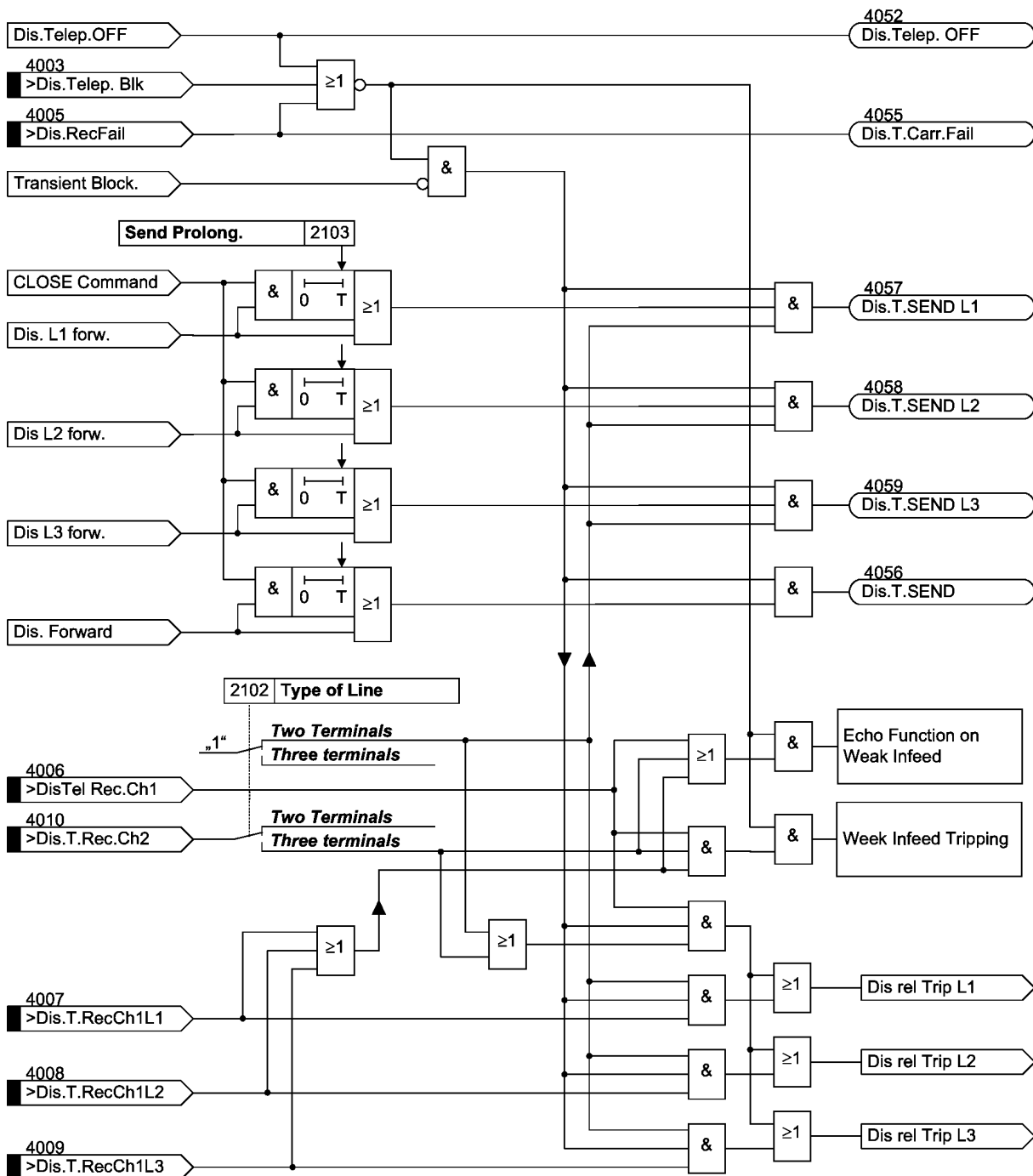
Figure 2-54   Logic diagram of the directional comparison scheme (one line end)

2.6.8 Directional Unblocking Scheme

The following scheme is suited for conventional transmission media.

Principle

The unblocking method is a permissive release scheme. It differs from the permissive overreach transfer scheme in that tripping is possible also when no release signal is received from the opposite line end. It is therefore mainly used for long lines when the signal must be transmitted across the protected line by means of power line carrier (PLC) and the attenuation of the transmitted signal at the fault location may be so severe that reception at the other line cannot necessarily be guaranteed. Here, a special unblocking logic takes effect.

The scheme functionality is shown in Figure 2-55.

Two signal frequencies which are keyed by the transmit output of the 7SA6 are required for the transmission. If the transmission device has a channel monitoring, then the monitoring frequency f_0 is keyed over to the working frequency f_U (unblocking frequency). When the protection recognizes a fault inside the overreaching zone Z1B, it initiates the transmission of the unblock frequency f_U. During the quiescent state or during a fault outside Z1B, or in the reverse direction, the monitoring frequency f_0 is transmitted.

If the release frequency is received from the opposite end, a trip signal is forwarded to the trip logic. Accordingly, it is a prerequisite for fast tripping, that the fault is recognized inside Z1B in the forward direction at both line ends. The distance protection is set such that the overreaching zone Z1B reaches beyond the opposite station (approximately 120% of line length). On three terminal lines, Z1B must be set to reliably reach beyond the longer line section, even if there is an additional infeed via the tee point. The first zone is set in accordance with the usual grading scheme, i.e. approximately 85% of the line length; on three terminal lines at least beyond the tee point.

The transmit signal can be prolonged by T_S (settable under address 2103 **Send Prolong.**). The prolongation of the send signal only comes into effect if the protection has already issued a trip command. This ensures release of the opposite line end even when the short circuit has been switched off rapidly by the independent zone Z1.

Figure 2-55   Function diagram of the directional unblocking method

For all zones except Z1B, tripping results without release from the opposite line end, allowing the protection to function with the usual grading characteristic independent of the signal transmission.

Sequence

Figure 2-56 shows the logic diagram of the unblocking scheme for one line end.

The unblock scheme only functions for faults in the "forward" direction. Accordingly, the overreaching zone Z1B of the distance protection must definitely be set to *Forward* in Address 1351 **Op. mode Z1B**, see also Subsection 2.2.1 at margin heading "Controlled Zone Z1B".

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines the send signal is transmitted to both opposite ends. The receive signals are then combined with a logical AND gate, as all three line ends must transmit a send signal during an internal fault. With the setting parameter **Type of Line** (address 2102) the device is informed as to whether it has one or two opposite line ends.

An unblock logic is inserted before the receive logic, which in essence corresponds to that of the permissive overreach transfer scheme, see Figure 2-57. If an interference free unblock signal is received, a receive signal e.g. ">Dis.T.UB ub 1", appears and the blocking signal e.g. ">Dis.T.UB bl 1" disappears. The internal signal "Unblock 1" is passed on to the receive logic, where it initiates the release of the overreaching zone Z1B of the distance protection (when all remaining conditions have been fulfilled).

If the transmitted signal does not reach the other line end because the short circuit on the protected line causes too much attenuation or reflection of the transmitted signal, neither the unblocking signal e.g., ">Dis.T.UB ub 1", nor the blocking signal ">Dis.T.UB bl 1" will appear on the receiving side. In this case, the release "Unblock 1" is issued after a security delay time of 20 ms and passed onto the receive logic. This release is however removed after a further 100 ms via the timer stage 100/100 ms. When the transmission is functional again, one of the two receive signals must appear again, either ">Dis.T.UB ub 1" or ">Dis.T.UB bl 1"; after a further 100 ms (dropout delay of the timer stage 100/100 ms) the quiescent state is reached again i.e. the direct release path to the signal "Unblock L1" and thereby the usual release is possible.

If none of the signals is received for a period of more than 10 s the alarm "Dis.T.UB Fail1" is generated.

During disturbance of the signal transmission path, the overreaching zone Z1B may be activated by an automatic reclosure (internal or external) via the binary input ">Enable ARzones".

The occurrence of erroneous signals resulting from transients during clearance of external faults or from direction reversal resulting during the clearance of faults on parallel lines, is neutralized by the "Transient Blocking".

On feeders with single-sided infeed, the line end with no infeed cannot generate a release signal, as no fault detection occurs there. To achieve tripping by the permissive overreach transfer scheme even in this case, the device contains a special function. This "Weak-infeed tripping" (echo function) is referred to in Subsection "Measures for Weak and Zero Infeed". It is activated when a signal is received from the opposite line end — in the case of three terminal lines from at least one of the opposite line ends — without the device having detected a fault.

The circuit breaker can also be tripped at the line end with no or only weak infeed. This "Weak-infeed tripping" is referred to in Section 2.9.1.

Figure 2-56　　Logic diagram of the unblocking scheme (one line end)
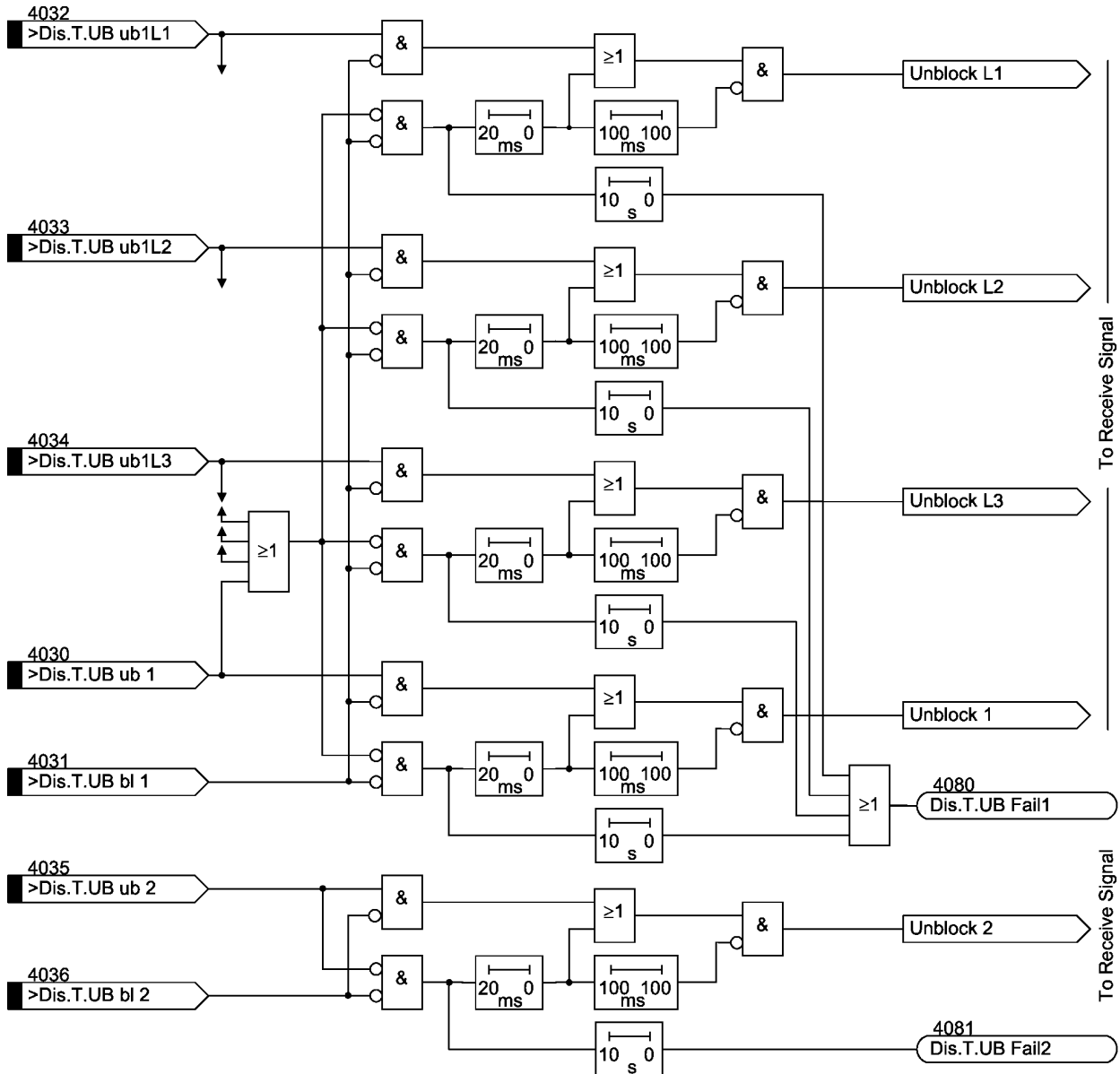
Figure 2-57   Unblock logic

2.6.9   Directional Blocking Scheme

The following scheme is suited for conventional transmission media.

Principle

In the case of the blocking scheme, the transmission channel is used to send a block signal from one line end to the other. The signal may be sent directly after fault inception (jump detector above dotted line in Figure 2-58), and stopped immediately, as soon as the distance protection detects a fault in the forward direction, alternatively the signal is only sent when the distance protection detects the fault in the reverse direction. It is stopped immediately as soon as the distance protection detects a fault in forward direction. Tripping is possible with this scheme even if no signal is received from the opposite line end. It is therefore mainly used for long lines when the signal must be transmitted across the protected feeder by means of power line carrier (PLC)

and the attenuation of the transmitted signal at the fault location may be so severe that reception at the other line cannot necessarily be guaranteed.

The scheme functionality is shown in Figure 2-58.

Faults inside the overreaching zone Z1B, which is set to approximately 120% of the line length, will initiate tripping if a blocking signal is not received from the other line end. On three terminal lines, Z1B must be set to reliably reach beyond the longer line section, even if there is an additional infeed via the tee point. Due to possible differences in the pickup times of the devices at both line ends and due to the signal transmission time delay, the tripping must be somewhat delayed by T_V in this case.

To avoid signal race conditions, a transmit signal can be prolonged by the settable time **T_S** once it has been initiated.
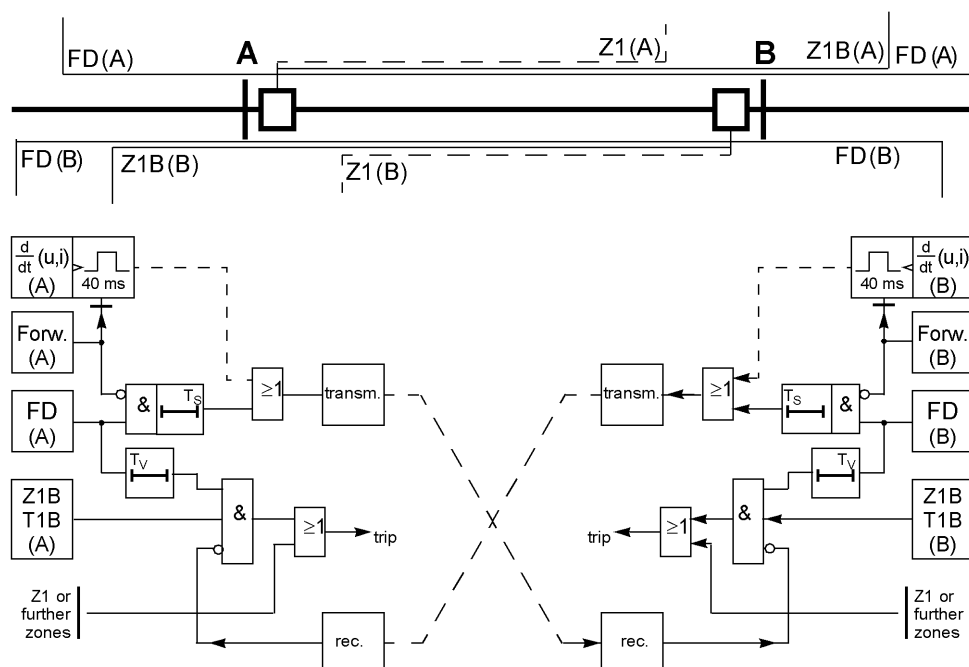
Figure 2-58   Function diagram of the blocking scheme

Sequence   Figure 2-59 shows the logic diagram of the blocking scheme for one line end.

The overreach zone Z1B is blocked which is why it must be set to ***Forward*** (address 1351 **Op. mode Z1B**, see also Subsection 2.2.1 at margin heading "Controlled Zone Z1B").

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signal is then combined with a logical OR gate as no blocking signal must be received from any line end during an internal fault. With the setting parameter **Type of Line** (address 2102) the device is informed as to whether it has one or two opposite line ends.
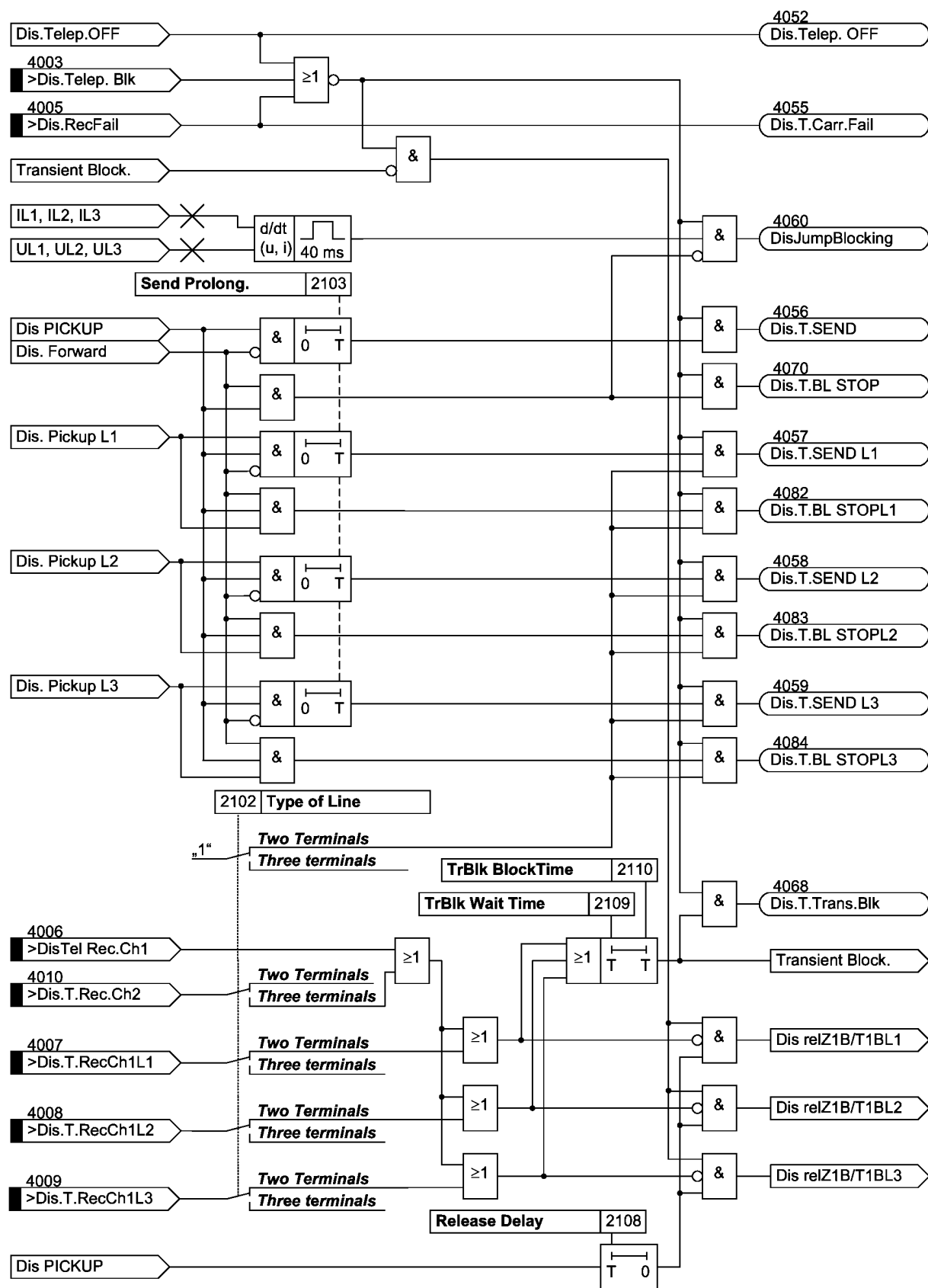
Figure 2-59   Logic diagram of the blocking scheme (one line end)

As soon as the distance protection has detected a fault in the reverse direction, a blocking signal is transmitted (e.g. "`Dis.T.SEND`", FNo 4056). The transmitted signal may be prolonged by setting address 2103 accordingly. The blocking signal is stopped if a fault is detected in the forward direction (e.g. "`Dis.T.BL STOP`", FNo 4070). Very rapid blocking is possible by transmitting also the output signal of the jump detector for measured values. To do so, the output "`DisJumpBlocking`" (FNo 4060) must also be allocated to the transmitter output relay. As this jump signal appears at every measured value jump, it should only be used if the transmission channel can be relied upon to respond promptly to the disappearance of the transmitted signal.

If there is a disturbance in the signal transmission path the overreaching zone can be blocked via a binary input. The distance protection operates with the normal time grading characteristic (non delayed trip in Z1). The overreach zone Z1B may however be activated by internal automatic reclosure or external criteria via the binary input "`>Enable ARzones`".

The occurrence of erroneous signals resulting from transients during clearance of external faults or from direction reversal resulting during the clearance of faults on parallel lines, is neutralized by the "Transient Blocking". It prolongs the blocking signal by the transient blocking time **`TrBlk BlockTime`** (address 2110), if it has been present for the minimum duration equal to the waiting time **`TrBlk Wait Time`** (address 2109).

It lies in the nature of the blocking scheme that single end fed short circuits can also be tripped rapidly without any special measures, as the non feeding end cannot generate a blocking signal.

2.6.10 Pilot Wire Comparison

In the pilot wire comparison the overreaching zone Z1B functions as instantaneous zone at both ends of the protected line. Zone Z1B is set to reach beyond the next station. The pilot wire comparison avoids non-selective tripping.

The information exchange between both line ends is carried out via a closed quiescent current loop (Figure 2-60) that is fed by a substation battery. One NC contact must be allocated for each signal output, the receiving input must be configured to "low-active". As an alternative two auxiliary relay combinations (e.g. 7PA5210-2A) are possible for inverting the contact.

In the quiescent state the pilot wires carry direct current that, at the same time, monitors the healthy state of the connection.

If the distance protection picks up, the following signal appears: "`Dis.T.SEND`". The NC contact is opened and the pilot wire loop is initially interrupted. A trip by Z1B is blocked via the receiving input "`>DisTel Rec.Ch1`". If the protection system then detects a fault within the overreaching zone Z1B, the send signal resets. The NC contact returns to its quiescent state (closed). If the loop in the remote station is also closed after the same sequence, the loop is energized again: the tripping is again released at both ends.

In case the short-circuit occurred outside the protected line the pilot wire loop is also interrupted by the pickup of both devices (both NC contacts "`Dis.T.SEND`" are opened). Since the send signal will not reset at least at one of the line ends (fault is not in line direction in zone Z1B), the loop at that end will remain open. Both receiving inputs are deenergized and block the tripping (because of L-active). The other distance stages including Z1, however, operate independently so that the back-up protection function is not affected.

For lines shorter than the shortest settable line please take into consideration that the first distance zone is either set to disabled or that T1 is delayed for at least one grading time interval.

If the line has single-end infeed an instantaneous trip for the whole line is possible. Since no pick-up occurs on the non-feeding line end, the loop is not interrupted at that point, but only on the feeding line end. After the fault is detected within Z1B, the loop will be closed again and the trip command is executed.

To guarantee that the time period between pickup and tripping of the protection function is sufficient to open and close the pilot wire loop, T1B must be delayed for a short period. If the pilot wire comparison is used with two different types of devices at both line ends (e.g. 7SA6 at one line end and a standard protection relay at the other end) care must be taken that the difference in pick-up and trip delay of the two devices, which may be considerable, does not lead to an unwanted release. This must also be taken into consideration for the delay of T1B.

The quiescent state loop ensures a steady check of the pilot wire connections against interruptions. Since the loop is interrupted during each fault, the signal for pilot wire failure is delayed by 10 s. The pilot wire comparison supplement is then blocked. It does not need to be blocked from external as the pilot wire failure is recognized internally. The other stages of the distance protection continue operating according to the normal grading coordination chart.

Due to the low current consumption of the binary inputs it may be necessary to additionally burden the pilot wire loop with an external shunt connected resistor so that the binary inputs are not hold by the pilot wire capacitance after an interruption of the loop. As an alternative it is possible to connect auxiliary relay combinations (e.g. 7PA5210-2A).
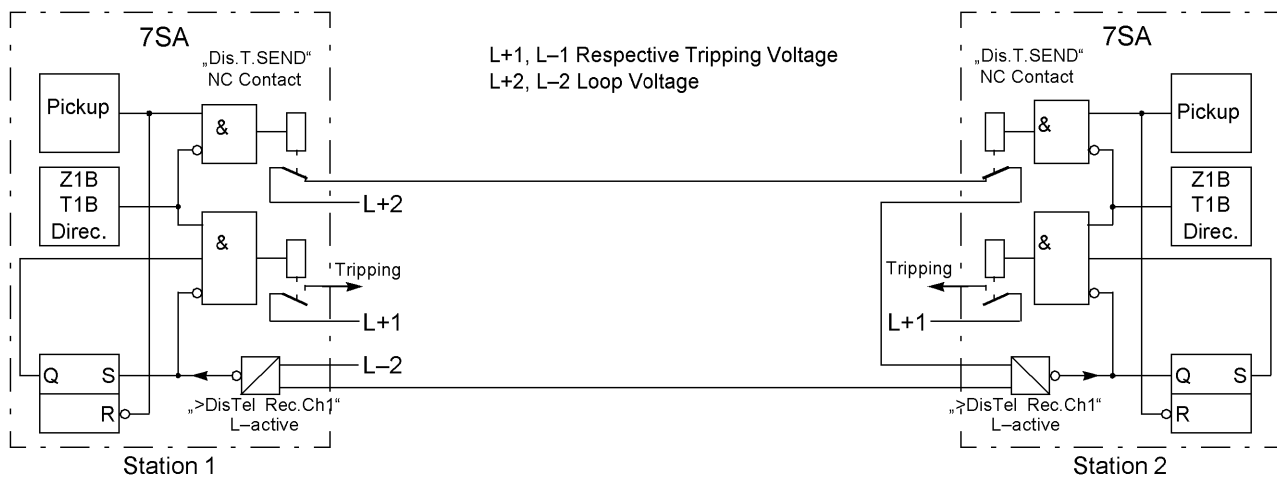
Figure 2-60   Pilot wire comparison - principle

Please take note that both binary inputs are connected in series with each other and the resistance of the pilot wires. Therefore the loop voltage must not be too low or the pickup voltage of the binary inputs must not be too high.

Operation with three terminals is also possible if the device allows it. The following figure shows the logic for two terminals.
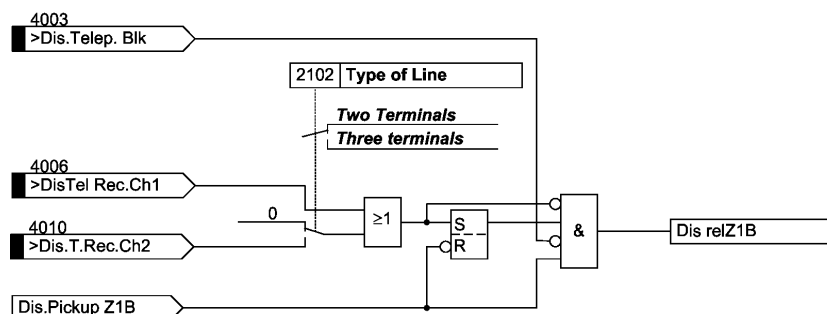
Figure 2-61   Receive circuit of pilot wire comparison logic

The isolation voltage of the pilot wires and the binary inputs and outputs must also be taken into account. In the event of an earth fault the induced longitudinal voltage must neither exceed 60% of the isolation voltage of the pilot wires nor 60% of the isolation of the device. The pilot wire comparison is therefore only suited for short lines.

2.6.11 Reverse Interlocking

If the Distance Protection relay 7SA6 is used as back-up protection in single-end fed transformer feeders, the reverse interlocking function ensures a fast protection of the busbar without endangering the selectivity for faults on the outgoing feeders.

Figure 2-62 shows the logic for reverse interlocking.
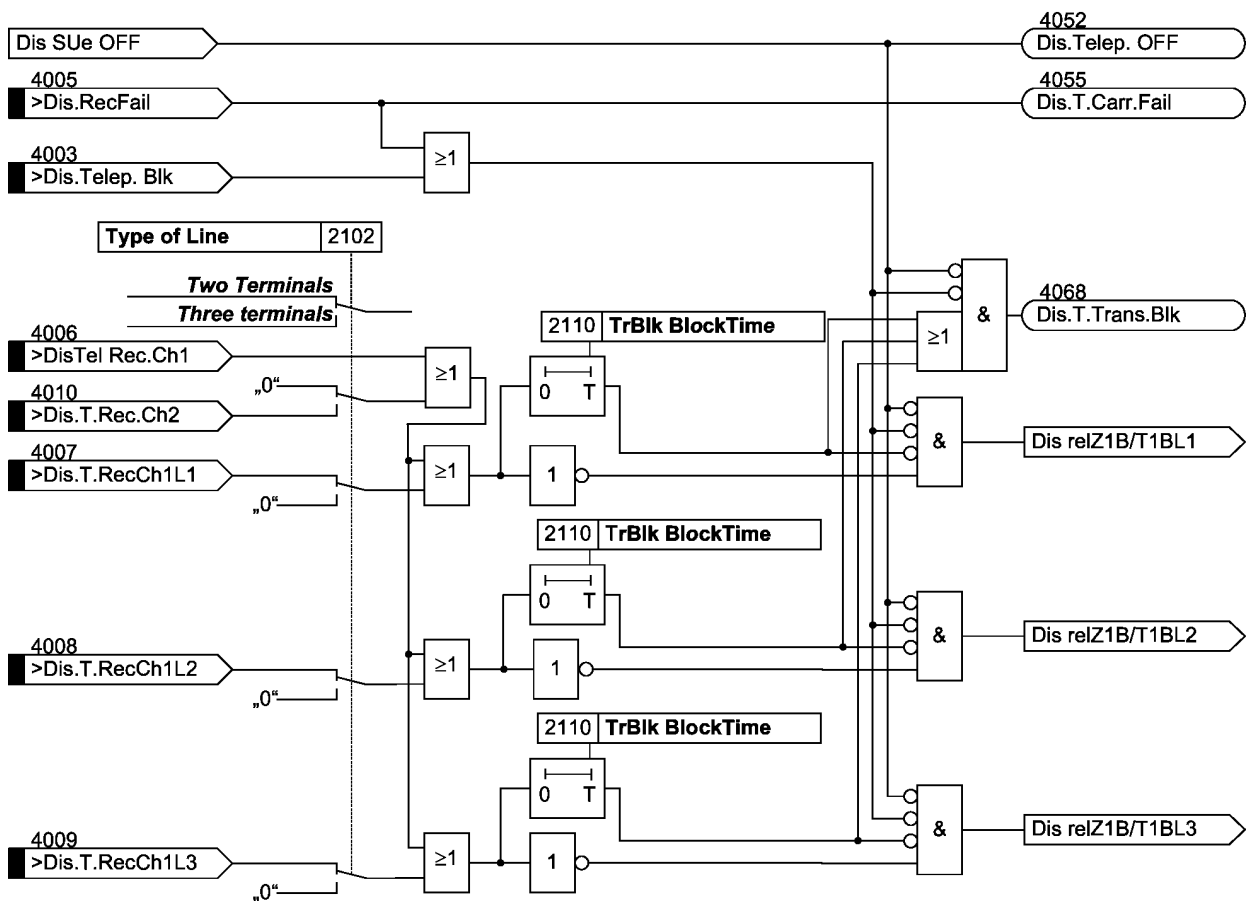
Figure 2-62   Logic diagram of the reverse interlocking

According to Figure 2-63 the distance zones Z1 and Z2 serve as back-up stages for faults on the outgoing lines, for example a fault in **F2**. For distance grading the shortest outgoing line is to be used.

The overreach zone Z1B, whose delay time T1B must be set longer than the pickup time Ta of the protection devices of the outgoing lines, is blocked after the pickup of an inferior protection. The pickup signal is sent (according to Figure 2-63) via the receive input (4006 "`>DisTel Rec.Ch1`") of the distance protection. If no signal is received this zone guarantees fast tripping of the busbar for

- faults on the busbar, such as for example in **F1**,
- failure of the line protection during a fault, such as for example in **F2**.

The reverse interlocking of the distance protection is performed by specific release or blocking of the overreach zone Z1B. It can be realized by the blocking mode (parallel

connection of the NO contacts as illustrated in Figure 2-63) or the release mode (series connection of the NC contacts).

To avoid transient false signals after clearance of external faults, the blocking condition of the reverse interlocking is extended by a transient blocking time (TB in Figure 2-63).
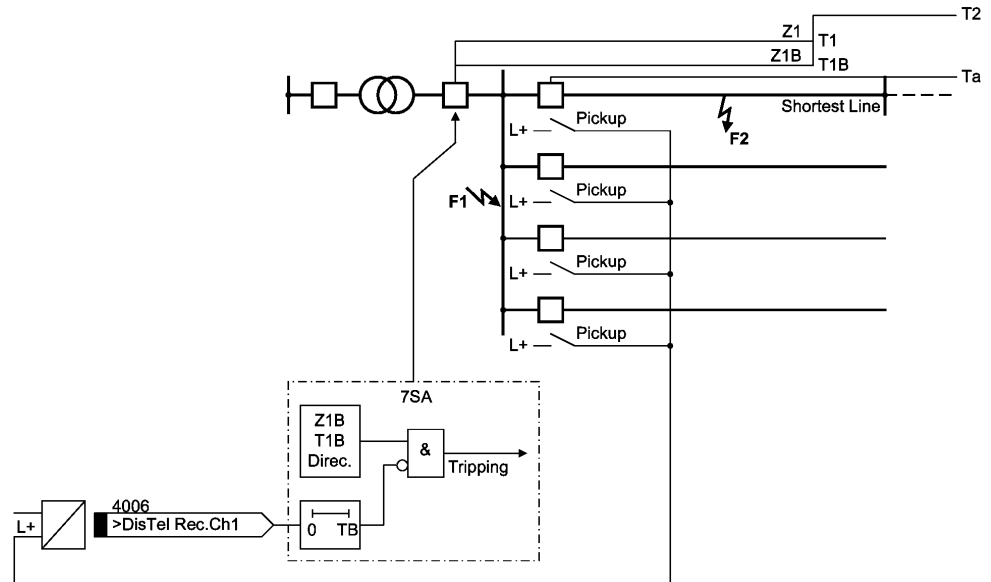
Figure 2-63   Reverse interlocking - functional principle and grading example

2.6.12 Transient Blocking

In the overreach schemes, the transient blocking provides additional security against erroneous signals due to transients caused by clearance of an external fault or by fault direction reversal during clearance of a fault on a parallel line.

The principle of transient blocking scheme is that following the incidence of an external fault, the formation of a release signal is prevented for a certain (settable) time. In the case of permissive schemes, this is achieved by blocking of the transmit and receive circuit.

Figure 2-64 shows the principle of the transient blocking for a directional comparison and for a permissive scheme.

If, following fault detection, a non-directional fault or a fault in the reverse direction is determined within the waiting time **TrBlk Wait Time** (address 2109), the transmit circuit and the release of the overreaching zone Z1B are prevented. This blocking is maintained for the duration of the transient blocking time **TrBlk BlockTime** (address 2110) also after the reset of the blocking criterion. But if a trip command is already present in Z1, the transient blocking time **TrBlk BlockTime** is terminated and thus the blocking of the signal transmission scheme in the event of an internal fault is prevented.

In the case of the blocking scheme, the transient blocking prolongs the received block signal as shown in the logic diagram Figure 2-64.
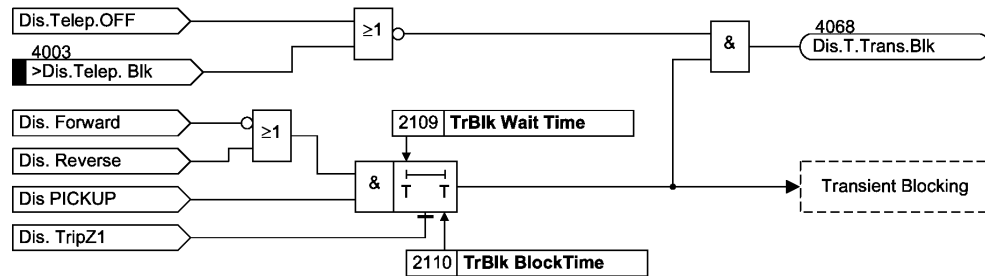
Figure 2-64   Transient blocking for permissive schemes

2.6.13 Measures for Weak and Zero Infeed

In cases where there is weak or no infeed present at one line end, the distance protection will not pick up. Neither a trip nor a send signal can therefore be generated there. With the comparison schemes, using a permissive signal, fast tripping could not even be achieved at the line end with strong infeed without special measures, as the end with weak infeed does not transmit a permissive release signal.

To achieve fast tripping at both line ends in such cases, the distance protection provides special supplements for feeders with weak infeed.

To enable the line end with the weak infeed condition to trip independently, 7SA6 has a special tripping function for weak infeed conditions. As this is a separate protection function with a dedicated trip command, it is described in a separate section (refer to Subsection 2.9.1).

Echo Function

Figure 2-65 shows the method of operation of the echo function. At address 2501 **FCT Weak Infeed** (Weak Infeed FunCTion) can be activated (**ECHO only**) or deactivated (**OFF**). By means of this "switch" the weak infeed tripping function can also be activated (**ECHO and TRIP**, refer also to Section 2.9.1). This setting is common to the teleprotection function for the distance protection and for the earth fault protection.

If there is no fault detection, the echo function causes the received signal to be sent back to the other line end as an "echo", where it is used to initiate permissive tripping.

The detection of the weak infeed condition and accordingly the requirement for an echo are combined in a central AND gate. The distance protection must neither be switched off nor blocked, as it would otherwise always produce an echo due to the missing fault detection. If however the time delayed overcurrent protection is used as an emergency function, an echo is nevertheless possible if the distance protection is out of service, because the fault detection of the emergency overcurrent protection replaces the distance protection fault detection. During this mode of operation, the emergency overcurrent protection must naturally not also be blocked or switched off.

Even when the emergency overcurrent protection does not pick up an echo is created for permissive release scheme during emergency function. The time overcurrent protection at the weaker end must operate with more sensitivity than the distance protection at the end with high infeed. Otherwise the selectivity concerning 100% of the line length is not given.

The essential condition for an echo is the absence of distance protection or overcurrent protection fault detection with the simultaneous reception of a signal from the teleprotection scheme logic, as shown in the corresponding logic diagrams (Figure 2-51 or 2-56).

In case of single- or two-pole pickup of the distance protection, it is nevertheless possible to send an echo if measurement of the phases that have not picked up recognizes a weak-infeed condition.

To avoid an incorrect echo following switching off of the line and reset of the fault detection, the RS flip-flop in Figure 2-65 latches the fault detection condition until the signal receive condition resets, thereby barring the release of an echo. The echo can in any event be blocked via the binary input "`>Dis.T.BlkEcho`".

If the conditions for an echo signal are met, a short delay **Trip/Echo DELAY** is initially activated. This delay is necessary to avoid transmission of the echo if the protection at the weak line end has a longer fault detection time during reverse faults or if it picks up a little later due to unfavourable short-circuit current distribution. If however the circuit breaker at the non-feeding line end is open, this delay of the echo signal is not required. The echo delay time may then be bypassed. The circuit breaker position is provided by the central information control functions. (refer to Section 2.23.1).

The echo impulse is then transmitted (alarm output "ECHO SIGNAL"), the duration of which can be set with the parameter **Trip EXTENSION**. The "ECHO SIGNAL" must be allocated separately to the output relay(s) for transmission, as it is not contained in the transmit signals "`Dis.T.SEND`" or "Dis.T.SEND L*".

Note

The "ECHO SIGNAL" (FNo 4246) must be allocated separately to the output relays for the transmitter actuation, as it is not contained in the transmit signals of the transmission functions. On the digital protection data interface with permissive overreach transfer trip mode, the echo is transmitted as a separate signal without taking any special measures (Figure 2-51).

After output of the echo pulse or during the transmission signal of the distance protection, a new echo can not be sent for at least 50 ms (default setting). This prevents echo repetition after the line has been switched off.

In the case of the blocking scheme and the underreach transfer trip scheme, the echo function is not required and therefore ineffective.
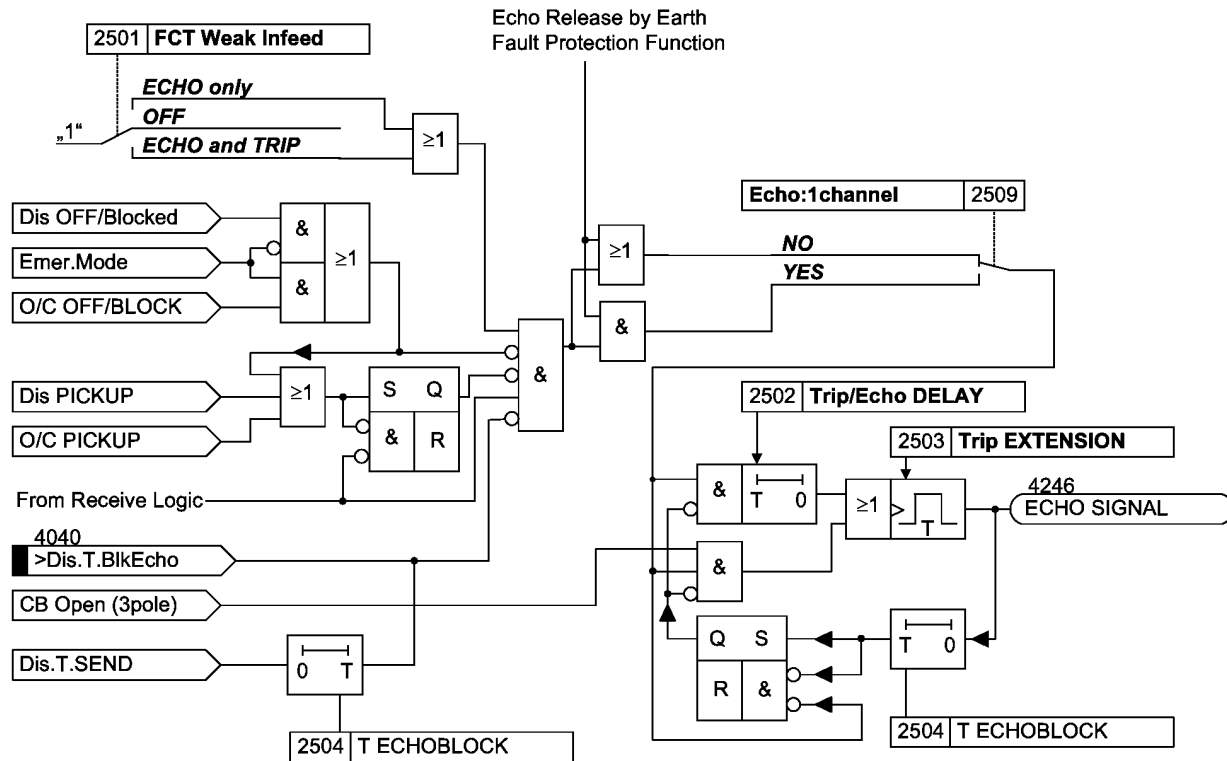
Figure 2-65   Logic diagram of the echo function with distance protection with teleprotection

2.6.14 Setting Notes

General

The teleprotection supplement of distance protection is only in service if it is set during the configuration to one of the possible modes of operation in address 121. Depending on this configuration, only those parameters which are applicable to the selected mode appear here. If the teleprotection supplement is not required the address 121 is set to **Teleprot. Dist.** = *Disabled*.

Conventional Transmission

The following modes are possible with conventional transmission links (as described in Subsection 2.6):

Direct Underreach Transfer Trip   Remote trip without any pickup,

PUTT (Pickup)   PUTT (Pickup)

PUTT (Z1B)   Permissive Underreach Transfer Trip with Zone Acceleration Z1B (PUTT)

POTT   Permissive Overreach Transfer Trip (POTT),

Dir.Comp.Pickup   Directional Comparison Pickup,

UNBLOCKING   Directional Unblocking scheme,

BLOCKING   Directional Blocking scheme,

Pilot wire comp   Pilot Wire Comparison,

Rev. Interlock   Reverse Interlocking

At address 2101 **FCT Telep. Dis.** the use of a teleprotection scheme can be turned *ON* or *OFF*.

If the teleprotection has to be applied to a three terminal line the setting in address 2102 must be **Type of Line** = *Three terminals*, if not, the setting remains *Two Terminals*.

Digital Transmission

The following modes are possible with digital transmission using the protection data interface (described in Subsection 2.6):

PUTT (Z1B)   Permissive Underreach Transfer Trip with Zone Acceleration Z1B (PUTT) via protection interface,

POTT   Permissive Overreach Transfer Trip (POTT).

The desired mode is selected in address 2101 **FCT Telep. Dis.**. The use of a teleprotection scheme can also be turned *ON* or *OFF* here. Address 147 **NUMBER OF RELAY** indicates the number of ends and must be set identically in all devices. The distance protection scheme via the protection data interface is only active if parameter 121 **Teleprot. Dist.** was set to *SIGNALv.ProtInt* for all devices in a constellation.

Distance Protection Prerequisites

For all applications of teleprotection schemes (except PUTT), it must be ensured that the fault detection of the distance protection in the reverse direction has a greater reach than the overreaching zone of the opposite line end (refer to the shaded areas in Figure 2-66 on the right hand side)! This is normally predefined for the U/I/φ–pickup since the local voltage of a reverse fault is smaller than the voltage of the remote supplied end. For impedance pickup at least one of the distance stages must be set to *Reverse* or *Non-Directional*. During a fault in the shaded area (in the left section of the picture), this fault would be in zone Z1B of the protection at B as zone Z1B is set incorrectly. The distance protection at A would not pick up and therefore the protection in B would interpret this as a fault with single end infeed from B (echo from A or no block signal at A). This would result in a false trip!

The blocking scheme needs furthermore a fast reverse stage to generate the blocking signal. Apply zone 3 with non-delayed setting to this end.
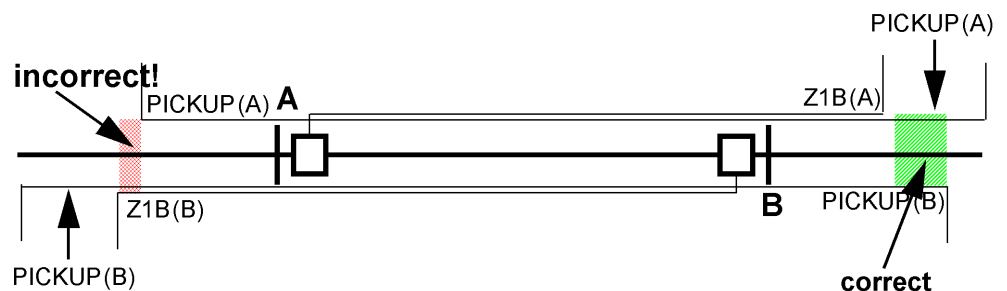
Figure 2-66   Distance protection setting with permissive overreach schemes

Time Settings

The send signal prolongation **Send Prolong.** (address 2103) must ensure that the send signal reliably reaches the opposite line end, even if there is very fast tripping at the sending line end and/or the signal transmission time is relatively long. In the case of the permissive overreaching schemes *POTT*, *Dir.Comp.Pickup* and *UNBLOCKING* this signal prolongation time is only effective if the device has already issued a trip command. This ensures the release of the other line ends even if the short-circuit has been cleared very rapidly by the instantaneous zone Z1. In the case of the blocking scheme *BLOCKING* the transmit signal is always prolonged by this

time. In this case it corresponds to a transient blocking following a reverse fault. This setting is only possible via DIGSI® at **Additional Settings**.

In order to detect steady-state line faults such as open circuits, a monitoring time **Delay for alarm** is started when a fault is detected (address 2107. Upon expiration of this time the fault is considered a permanent failure. This setting is only possible via DIGSI® at **Additional Settings**.

With the release delay **Release Delay** (address 2108) the release of the zone Z1B can be delayed. This is only required for the blocking scheme ***BLOCKING*** to allow sufficient transmission time for the blocking signal during external faults. This delay **only** has an effect on the receive circuit of the teleprotection scheme. Conversely, the permissive signal is not delayed by the set time delay T1B of the overreaching zone Z1B. For ***Pilot wire comp*** and ***Rev. Interlock*** T1B must be delayed so that there is enough time between the pickup of the distance protection function and the trip signal of zone Z1B.

Transient Blocking

The parameters **TrBlk Wait Time** and **TrBlk BlockTime** serve the transient blocking with the permissive overreaching schemes POTT and UNBLOCKING. With permissive underreach transfer trip they are of no consequence.

The time **TrBlk Wait Time** (address 2109) is a waiting time prior to transient blocking. Not before the distance protection recognizes a reverse fault inside this time after fault detection, will the transient blocking become activated in the permissive overreach transfer schemes. In the case of the blocking scheme, the waiting time prevents transient blocking in the event that the blocking signal reception from the opposite line end is very fast. With the setting ∞ there is no transient blocking. This setting is only possible via DIGSI® at **Additional Settings**.

The transient blocking time **TrBlk BlockTime** (address 2110) must be definitely longer than the duration of severe transients resulting from the inception or clearance of external short circuits. The send signal is delayed by this time with the permissive overreach schemes ***POTT*** and ***UNBLOCKING*** if the protection had initially detected a reverse fault. In the case of the blocking scheme ***BLOCKING*** the received (blocking) signal is prolonged by this time. This setting is only possible via DIGSI® at **Additional Settings**.

The preset value should be sufficient in most cases.

Echo Function

In the case of line ends with weak infeed, the echo function is sensible in conjunction with permissive overreach transfer schemes POTT and UNBLOCKING with release signal, so that the feeding line end is also released. The setting lists concerning the weak infeed are listed in Subsection 2.9.2.2. The echo function at address 2501 **FCT Weak Infeed** can be activated (***ECHO only*** or deactivated (***OFF***). By means of this "switch" the weak infeed tripping function can also be activated (***ECHO and TRIP***, refer also to Section 2.9.1).

Please do not fail to observe the notes on the setting of the distance protection stages at margin heading "Distance Protection Prerequisites".

The echo delay time **Trip/Echo DELAY** (address 2502) must be set long enough to avoid incorrect echo signals resulting from the difference in fault detection pick-up time of the distance protection functions at all line ends during external faults (through-fault current). Typical setting is approx. 40 ms (presetting). This setting is only possible via DIGSI® at **Additional Settings**.

The echo impulse duration **Trip EXTENSION** (address 2503) may be matched to the configuration data of the signal transmission equipment. It must be long enough to ensure that the receive signal is recognized even with different pick-up times by the

protection devices at the line ends and different response times of the transmission equipment. In most cases approx. 50 ms (presetting) is sufficient. This setting is only possible via DIGSI® at **Additional Settings**.

An endless echo signal between the line ends can be avoided (e.g. interference coupling in the signal path) by blocking a new echo for a certain time **Echo BLOCK Time** (address 2504) after each output of an echo signal. The typical setting is approx. 50 ms. After the distance protection signal was sent, the echo is equally blocked for the time **Echo BLOCK Time**. This setting is only possible via DIGSI® at **Additional Settings**.

If the distance protection and earth fault protection use a common transmission channel, spurious tripping may occur when the distance protection and the earth fault protection create an echo independently of each other. For this scenario, parameter **Echo:1channel** (address 2509) must be set to *YES*. The default setting is *NO*.

Note

The "ECHO SIGNAL" (FNo. 4246) must be allocated separately to the output relays for the transmitter actuation, as it is not contained in the transmit signals of the transmission functions. On the digital protection data interface with permissive overreach transfer trip mode, the echo is transmitted as a separate signal without taking any special measures.

The echo function settings are common to all weak infeed measures and summarized in tabular form in Section 2.9.1.

2.6.15 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
2101	FCT Telep. Dis.	ON PUTT (Z1B) POTT OFF	ON	Teleprotection for Distance prot. is
2102	Type of Line	Two Terminals Three terminals	Two Terminals	Type of Line
2103A	Send Prolong.	0.00 .. 30.00 sec	0.05 sec	Time for send signal prolongation
2107A	Delay for alarm	0.00 .. 30.00 sec	10.00 sec	Time Delay for Alarm
2108	Release Delay	0.000 .. 30.000 sec	0.000 sec	Time Delay for release after pickup
2109A	TrBlk Wait Time	0.00 .. 30.00 sec; ∞	0.04 sec	Transient Block.: Duration external flt.
2110A	TrBlk BlockTime	0.00 .. 30.00 sec	0.05 sec	Transient Block.: Blk.T. after ext. flt.

2.6.16 Information List

No.	Information	Type of In-formation	Comments
4001	>Dis.Telep. ON	SP	>Distance Teleprotection ON
4002	>Dis.Telep.OFF	SP	>Distance Teleprotection OFF
4003	>Dis.Telep. Blk	SP	>Distance Teleprotection BLOCK
4005	>Dis.RecFail	SP	>Dist. teleprotection: Carrier faulty
4006	>DisTel Rec.Ch1	SP	>Dis.Tele. Carrier RECEPTION Channel 1
4007	>Dis.T.RecCh1L1	SP	>Dis.Tele.Carrier RECEPTION Channel 1,L1
4008	>Dis.T.RecCh1L2	SP	>Dis.Tele.Carrier RECEPTION Channel 1,L2
4009	>Dis.T.RecCh1L3	SP	>Dis.Tele.Carrier RECEPTION Channel 1,L3
4010	>Dis.T.Rec.Ch2	SP	>Dis.Tele. Carrier RECEPTION Channel 2
4030	>Dis.T.UB ub 1	SP	>Dis.Tele. Unblocking: UNBLOCK Channel 1
4031	>Dis.T.UB bl 1	SP	>Dis.Tele. Unblocking: BLOCK Channel 1
4032	>Dis.T.UB ub1L1	SP	>Dis.Tele. Unblocking: UNBLOCK Ch. 1, L1
4033	>Dis.T.UB ub1L2	SP	>Dis.Tele. Unblocking: UNBLOCK Ch. 1, L2
4034	>Dis.T.UB ub1L3	SP	>Dis.Tele. Unblocking: UNBLOCK Ch. 1, L3
4035	>Dis.T.UB ub 2	SP	>Dis.Tele. Unblocking: UNBLOCK Channel 2
4036	>Dis.T.UB bl 2	SP	>Dis.Tele. Unblocking: BLOCK Channel 2
4040	>Dis.T.BlkEcho	SP	>Dis.Tele. BLOCK Echo Signal
4050	Dis.T.on/off BI	IntSP	Dis. Teleprotection ON/OFF via BI
4052	Dis.Telep. OFF	OUT	Dis. Teleprotection is switched OFF
4054	Dis.T.Carr.rec.	OUT	Dis. Telep. Carrier signal received
4055	Dis.T.Carr.Fail	OUT	Dis. Telep. Carrier CHANNEL FAILURE
4056	Dis.T.SEND	OUT	Dis. Telep. Carrier SEND signal
4057	Dis.T.SEND L1	OUT	Dis. Telep. Carrier SEND signal, L1
4058	Dis.T.SEND L2	OUT	Dis. Telep. Carrier SEND signal, L2
4059	Dis.T.SEND L3	OUT	Dis. Telep. Carrier SEND signal, L3
4060	DisJumpBlocking	OUT	Dis.Tele.Blocking: Send signal with jump
4068	Dis.T.Trans.Blk	OUT	Dis. Telep. Transient Blocking
4070	Dis.T.BL STOP	OUT	Dis. Tele.Blocking: carrier STOP signal
4080	Dis.T.UB Fail1	OUT	Dis. Tele.Unblocking: FAILURE Channel 1
4081	Dis.T.UB Fail2	OUT	Dis. Tele.Unblocking: FAILURE Channel 2
4082	Dis.T.BL STOPL1	OUT	DisTel Blocking: carrier STOP signal, L1
4083	Dis.T.BL STOPL2	OUT	DisTel Blocking: carrier STOP signal, L2
4084	Dis.T.BL STOPL3	OUT	DisTel Blocking: carrier STOP signal, L3
4085	Dis.T.RecL1Dev1	OUT	Dis.Tele.Carrier RECEPTION, L1, Device1
4086	Dis.T.RecL2Dev1	OUT	Dis.Tele.Carrier RECEPTION, L2, Device1
4087	Dis.T.RecL3Dev1	OUT	Dis.Tele.Carrier RECEPTION, L3, Device1
4088	Dis.T.RecL1Dev2	OUT	Dis.Tele.Carrier RECEPTION, L1, Device2
4089	Dis.T.RecL2Dev2	OUT	Dis.Tele.Carrier RECEPTION, L2, Device2
4090	Dis.T.RecL3Dev2	OUT	Dis.Tele.Carrier RECEPTION, L3, Device2
4091	Dis.T.RecL1Dev3	OUT	Dis.Tele.Carrier RECEPTION, L1, Device3
4092	Dis.T.RecL2Dev3	OUT	Dis.Tele.Carrier RECEPTION, L2, Device3
4093	Dis.T.RecL3Dev3	OUT	Dis.Tele.Carrier RECEPTION, L3, Device3

2.7 Earth fault overcurrent protection in earthed systems (optional)

In earthed systems, where extremely large fault resistances may exist during earth faults (e.g. overhead lines without earth wire, sandy soil) the fault detection of the distance protection will often not pick up because the resulting earth fault impedance could be outside the fault detection characteristic of the distance protection.

The 7SA6 distance protection features protection functions for high-resistance earth faults in earthed power systems. These options are available — depending on the ordered model:

- Three overcurrent stages with definite time tripping characteristic (definite time),

- One overcurrent stage with inverse time characteristic (IDMT) or

- One zero sequence voltage stage with inverse time characteristic

- One zero sequence power stage with inverse time characteristic

The elements may be configured independently from each other and combined according to the user's requirements. If the fourth current-, voltage or power-dependent stage is not required, it may be employed as a fourth definite time stage.

Each stage may also be set to be non directional or directional — forward or reverse. A signal transmission may be combined with these four stages. For each stage it may be determined if it should coordinate with the teleprotection function. If the protection is applied in the proximity of transformers, an inrush stabilization can be activated. Furthermore, blocking by external criteria is possible via binary inputs (e.g. for reverse interlocking or external automatic reclosure). During energization of the protected feeder onto a dead fault it is also possible to release any stage, or also several, for non-delayed tripping. Stages that are not required, are set inactive.

2.7.1 Method of Operation

Measured Quantities

The zero-sequence current is used as measured variable. According to its definition equation it is obtained from the sum of the three phase currents, i.e.
$3 \cdot \underline{I}_0 = \underline{I}_{L1} + \underline{I}_{L2} + \underline{I}_{L3}$. Depending on the version ordered, and the configured application for the fourth current input I_4 of the device, the zero-sequence current can be measured or calculated.

If the input I_4 is connected in the starpoint of the set of current transformers or to a separate earth current transformer, on the protected feeder, the earth current is directly available as a measured value.

If the device is fitted with the highly sensitive current input for I_4, this current I_4 is used with the factor **I4/Iph CT**(address 221, refer to Subsection 2.1.3.1). As the linear range of this measuring input is severely restricted in the high range, this current is only evaluated up to an amplitude of approx. 1.6 A. In the event of larger currents, the device automatically switches over to the evaluation of the zero sequence current derived from the phase currents. Naturally, all three phase currents obtained from a set of three star-connected current transformers must be available and connected to the device. The processing of the earth current is then also possible if very small as well as large earth fault currents may occur.

If the fourth current input I_4 is otherwise utilized, e.g. for a transformer starpoint current or for the earth current of a parallel line, the device calculates the zero-sequence current from the phase currents. Naturally in this case also all three phase currents

derived from a set of three star connected current transformers must be available and connected to the device.

The zero-sequence voltage is determined by its definition formula $3\,\underline{U}_0 = \underline{U}_{L1\text{-}E} + \underline{U}_{L2\text{-}E} + \underline{U}_{L3\text{-}E}$. Depending on the application for the fourth voltage input U_4 of the device, the zero-sequence voltage can be measured or calculated. If the fourth voltage input is connected to the open delta winding U_{delta} of a voltage transformer and if it is configured accordingly (address 210 **U4 transformer** = *Udelta transf.*, see Subsection 2.1.3.1), this voltage is used — considering the factor **Uph / Udelta** (address 211, see Subsection 2.1.3.1). If not, the device calculates the zero-sequence voltage from the phase voltages. Naturally, all three phase-to-earth voltages obtained from a set of three star-connected voltage transformers must be available and connected to the device.

Definite Time Very High Set Current Stage 3I$_0$>>>

The triple zero-sequence current $3\,I_0$ is passed through a numerical filter and then compared with the set value **3I0>>>**. If this value is exceeded an alarm is issued. After the corresponding delay time **T 3I0>>>** have expired, a trip command is issued which is also alarmed. The reset threshold is approximately 95 % of the pick-up threshold.

Figure 2-67 shows the logic diagram of the 3I$_0$>>>-stage. The function modules "direction determination", "permissive teleprotection", "switch onto fault", and "inrush stabilization" are common to all stages and described below. They may however affect each stage individually. This is accomplished with the following setting parameters:

- **Op. mode 3I0>>>**, determines the operating direction of the stage: *Forward*, *Reverse*, *Non-Directional* or *Inactive*,
- **3I0>>> Telep/BI**, determines whether a non-delayed trip with the teleprotection scheme or binary input 1310 is possible (*YES*) or not possible (*NO*),
- **3I0>>>SOTF-Trip**, determines whether during energization of the feeder onto a fault tripping with this stage shall be non-delayed (*YES*) or not (*NO*) and
- **3I0>>>InrushBlk**, which is used to switch the inrush stabilization (rush blocking) on (*YES*) or off (*NO*).
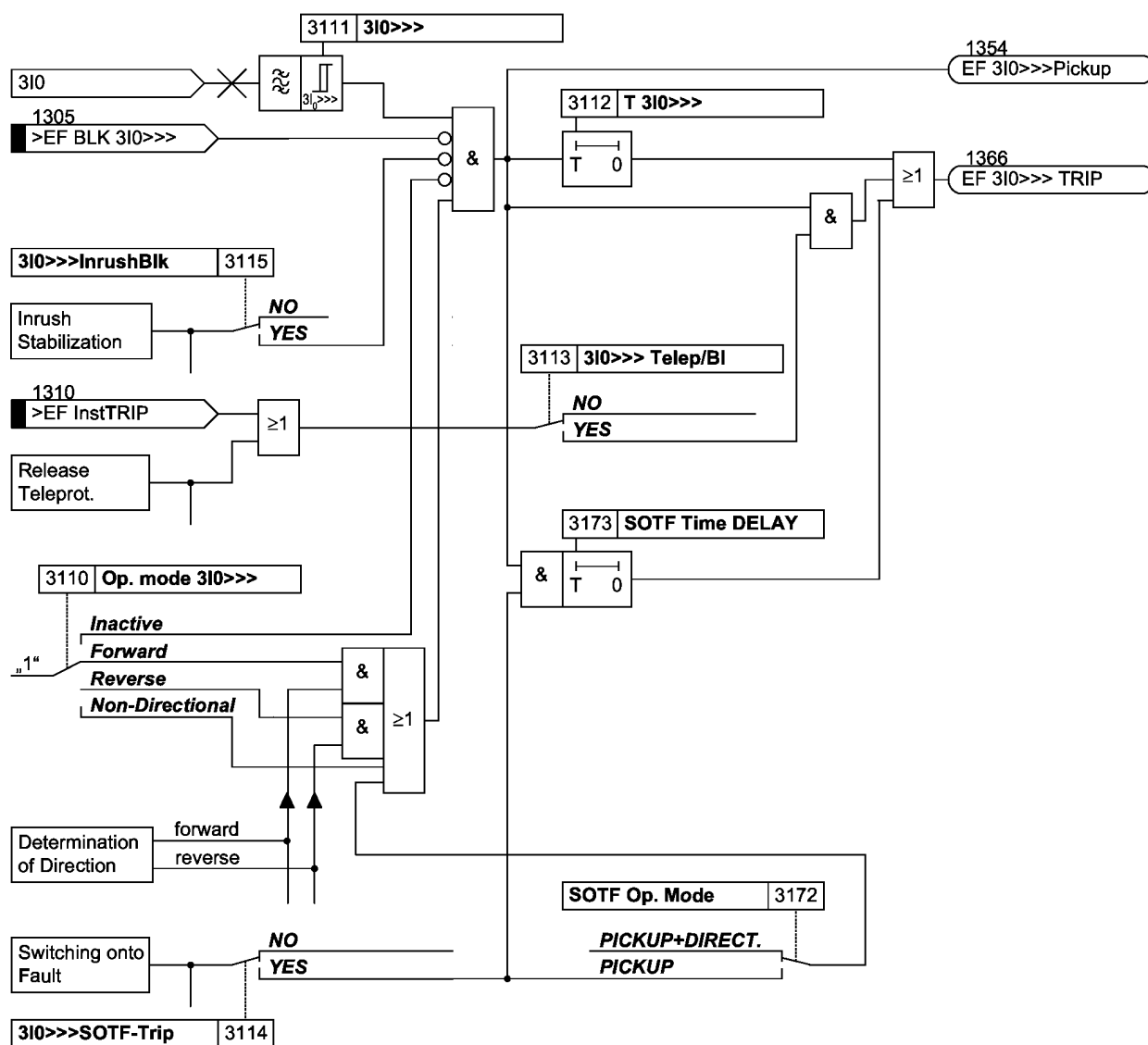
Figure 2-67   Logic diagram of the $3I_0>>>$–stage

Definite Time Very High Set Current Stage $3I_0>>$	The logic of the high set current stage $3I_0>>$ is the same as that of the $3I_0>>>$ stage. In all references **3I0>>>** must merely be replaced with **3I0>>**. In all other respects Figure 2-67 applies.

| **Definite Time Overcurrent Stage $3I_0>$** | The logic of the overcurrent current stage $3I_0>$ is the same as that of the $3I_0>>>$ stage. In all references **3I0>>>** must merely be replaced with **3I0>**. In all other respects Figure 2-67 applies. This stage operates with a specially optimized digital filter that completely suppresses all harmonic components beginning with the 2nd harmonic. Therefore it is particularly suited for a highly-sensitive earth fault detection. |

A fourth, definite time stage can be implemented by setting the "inverse-time" stage (refer to the next paragraph) to a definite-time stage.

| **Inverse Time Overcurrent Stage $3I_{0P}$** | The logic of the stages with inverse time delay functions operate the same as the remaining stages. This stage operates with a specially optimized digital filter that completely suppresses all harmonic components beginning with the 2nd harmonic. Therefore it is particularly suited for a highly-sensitive earth fault detection. However, the |

time delay is calculated here based on the type of the set characteristic, the intensity of the earth current and a time multiplier **3I0p Time Dial** (IEC characteristic, Figure 2-68) or a time multiplier **TimeDial TD3I0p** (ANSI characteristic). A pre-selection of the available characteristics was already done during the configuration of the protection functions. Furthermore, an additional fixed delay **Add.T-DELAY** may be selected. The characteristics are shown in the Technical Data.

Fig. 2-68 shows the logic diagram. The setting addresses of the IEC characteristics are shown by way of an example. In the setting information the different setting addresses are described in detail.

It is also possible to implement this stage equally with a definite time delay. In this case **3I0p PICKUP** is the pickup threshold and **Add.T-DELAY** the definite time delay. The inverse time characteristic is then effectively bypassed.
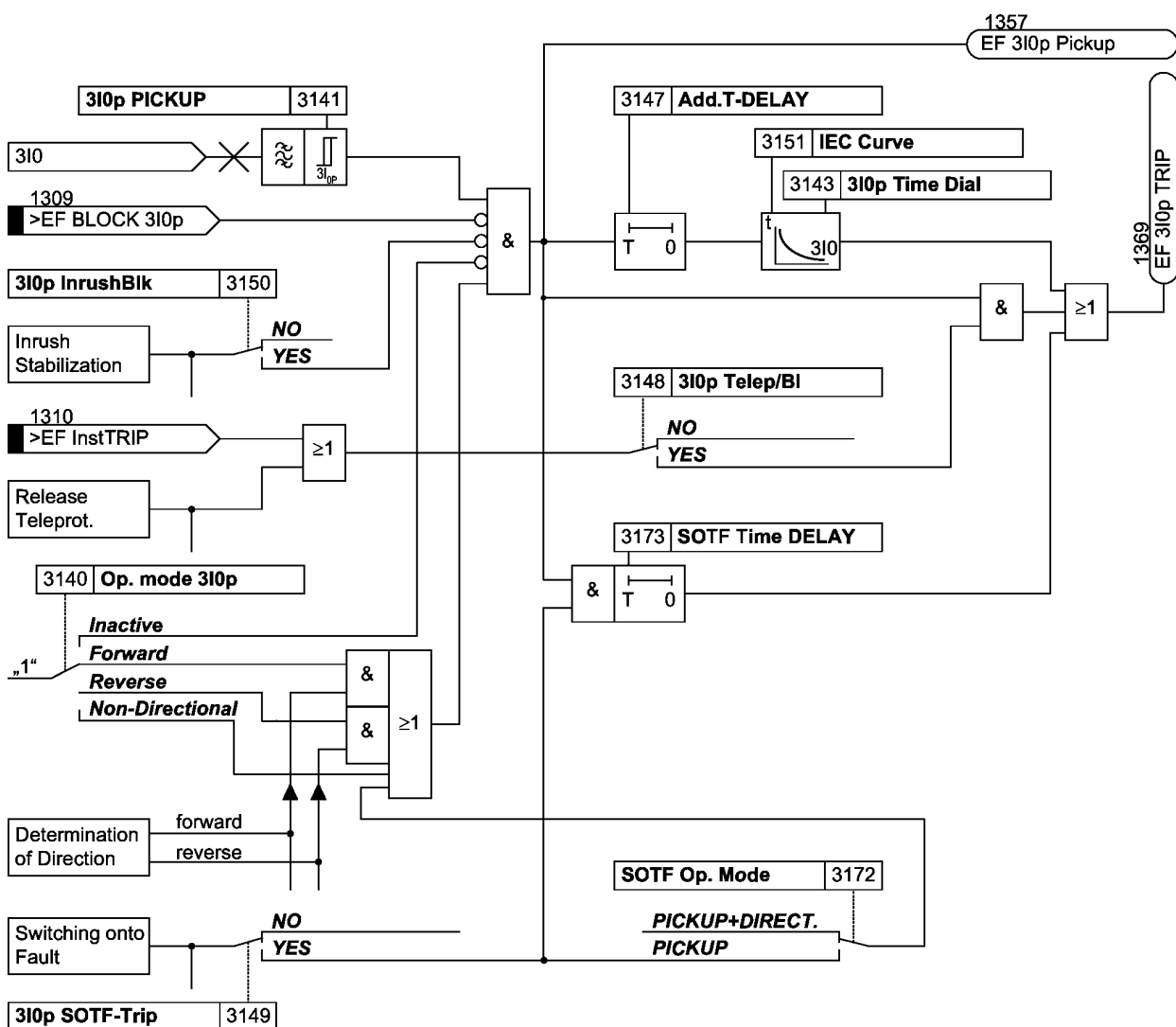
Figure 2-68   Logic diagram of the $3I_{0P}$–stage (inverse time overcurrent protection), example for IEC characteristics

Inverse Time Over-current Stage with Logarithmic–Inverse Characteristic

The inverse logarithmic characteristic differs from the other inverse characteristics mainly by the fact that the shape of the curve can be influenced by a number of parameters. The slope and a time shift **3I0p MaxT-DELAY** which directly affect the curve, can be changed. The characteristics are shown in the Technical Data.

Figure 2-69 shows the logic diagram. In addition to the curve parameters, a minimum time **3I0p MinT-DELAY** can be determined; below this time no tripping can occur. Below a current factor of **3I0p Startpoint**, which is set as a multiple of the basic setting **3I0p PICKUP**, no tripping can take place.

Further information regarding the effect of the various parameters can be found in the setting information of the function parameters in Sub-section 2.7.2.

The remaining setting options are the same as for the other curves.
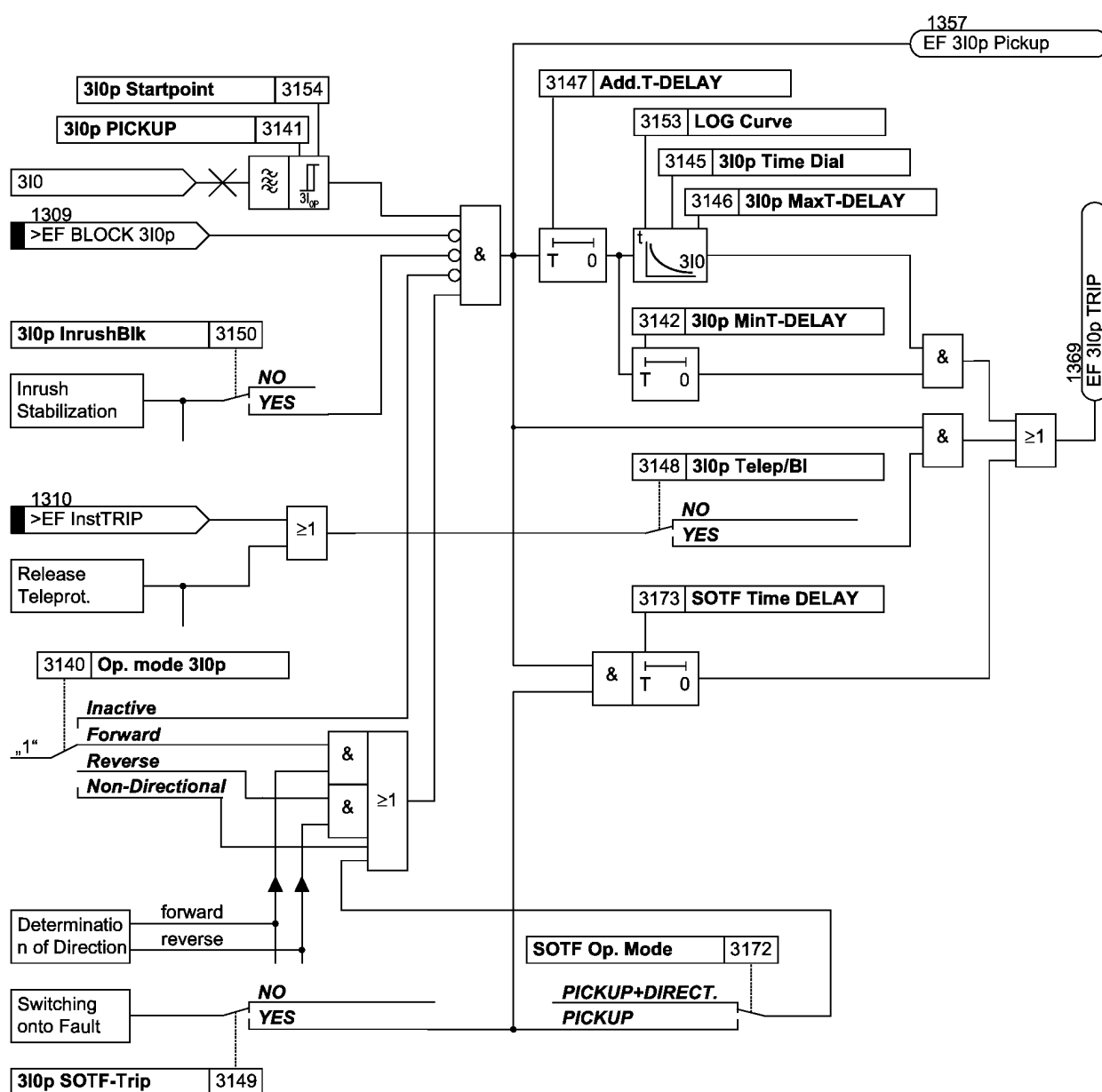
Figure 2-69   Logic diagram of the $3I_{0P}$–stage for the inverse logarithmic characteristic

Zero Sequence Voltage Time Protection (U$_0$-inverse)

The zero sequence voltage time protection operates according to a voltage-dependent trip time characteristic. It can be used instead of the time overcurrent stage with inverse time delay.t

The voltage/time characteristic can be displaced in voltage direction for a determined constant voltage **UOinv. minimum**, valid for t→ ∞ and in time direction by a determined constant time **T forw. (UOinv)**). The characteristics are shown in the Technical Data.

Figure 2-70 shows the logic diagram. The tripping time depends on the level of the zero sequence voltage U$_0$. For meshed earthed systems the zero sequence voltage increases towards the earth fault location. The inverse characteristic results in the shortest command time for the relay closest to the fault. The other relays then reset.

A further time stage **T rev. (UOinv)** provokes non-directional tripping with a voltage-independent delay. This stage can be set above the directional stage. When tripping with this stage it is, however, a prerequisite that the time of the voltage-controlled stage has already expired (without directional check). In case the zero voltage is too low or the voltage transformer circuit-breaker is tripped, this stage is also disabled.
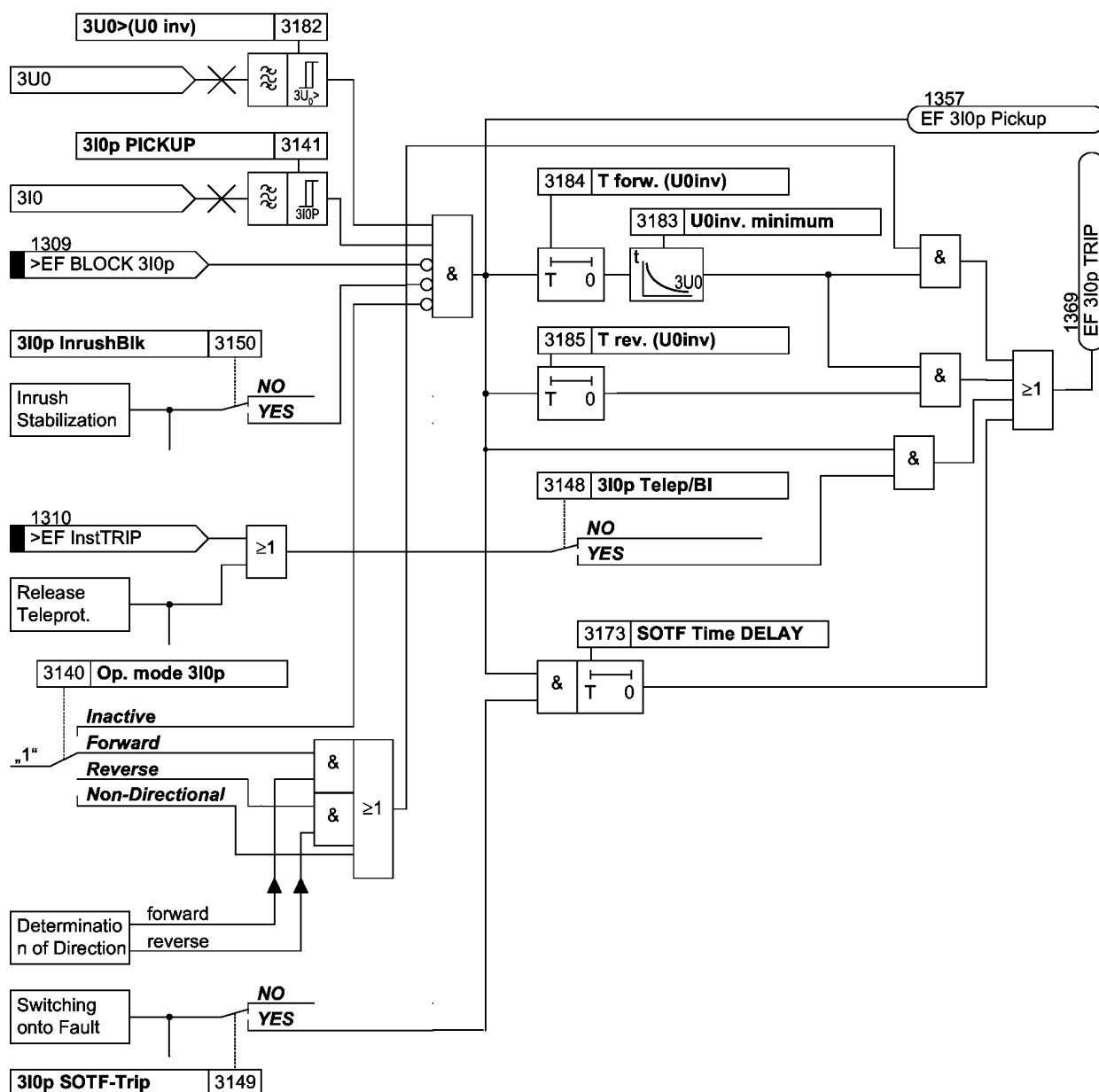
Figure 2-70   Directional zero-sequence voltage time protection with non-directional backup stage

Zero Sequence Power Protection

The zero sequence power protection operates according to a power-dependent trip time characteristic. It can be used instead of an inverse time overcurrent stage.

The power is calculated from the zero sequence voltage and the zero sequence current. The component S_r is decisive in direction of a configurable compensation angle φ_{comp}, which is also referred to as compensated zero sequence power i.e.,

$$S_r = 3\,I_0 \cdot 3\,U_0 \cdot \cos\,(\varphi - \varphi_{comp})$$

where $\varphi = \angle\,(U_0;\,I_0)$. φ_{comp} thus determines the direction of the maximum sensitivity ($\cos\,(\varphi - \varphi_{comp}) = 1$, if $\varphi = \varphi_{comp}$). Due to its sign information the power calculation automatically includes the direction. The power for the reverse direction can be determined by reversing the sign.

The power-time characteristic can be displaced in power direction via a reference value S_{ref} (= basic value for the inverse characteristic for $\varphi = \varphi_{comp}$) and in time direction by a factor k.

Figure 2-71 shows the logic diagram. The tripping time depends on the level of the compensated zero sequence power S_r as defined above. For meshed earthed systems the zero sequence voltage and the zero sequence current increase towards the earth fault location. The inverse characteristic results in the shortest command time for the relay closest to the fault. The other relays then reset.
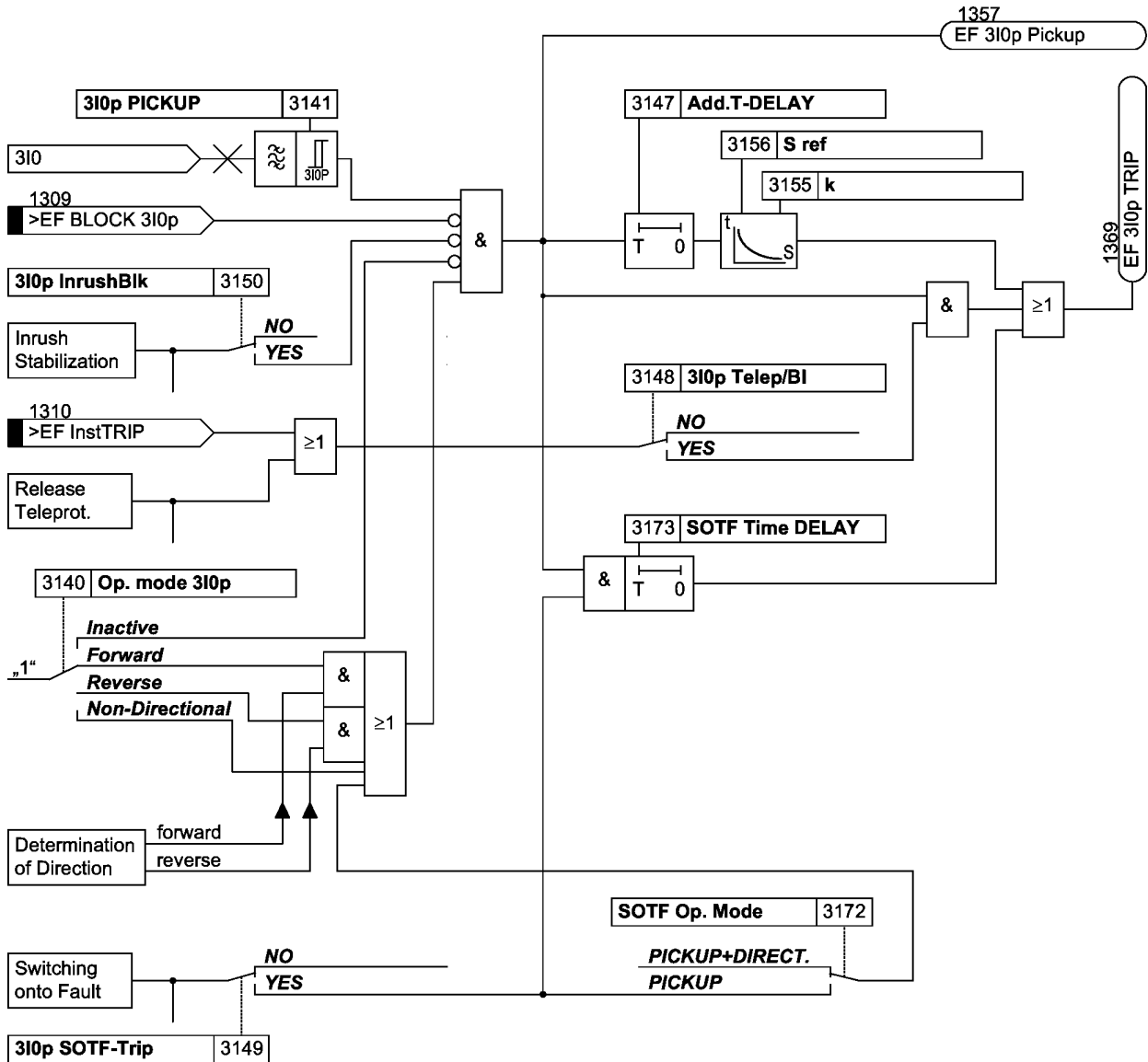
Figure 2-71   Zero-sequence power protection

Phase Current Stabilization   Non-symmetrical load conditions in multiple-earthed systems or different current transformer errors can result in a zero sequence current. This zero sequence current could cause faulty pickup of the earth current stages if low pick-up thresholds are set. To avoid this, the earth current stages are stabilized by the phase current: As the phase currents increase, the pick up thresholds are increased (Figure 2-72). The sta-

bilization factor (= slope) may be changed by means of the parameter **Iph-STAB. Slope** (address 3104). It applies to all stages.
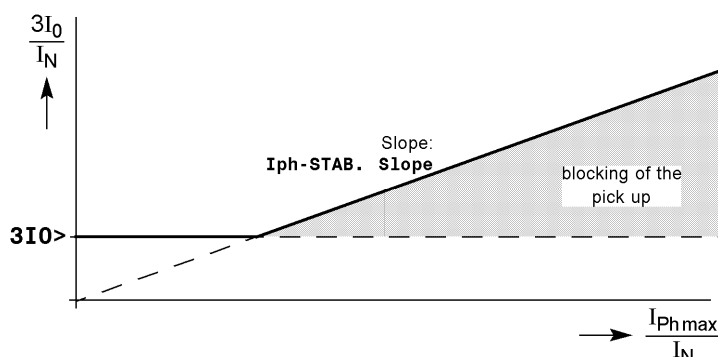
Figure 2-72   Phase current stabilization

Inrush Stabilization	If the device is connected to a transformer feeder, large inrush currents can be expected when the transformer is energized; if the transformer star-point is earthed, also in the zero sequence path. The inrush current may be a multiple of the rated current and flow for several tens of milliseconds up to several minutes.

Although the fundamental current is evaluated by filtering of the measured current, an incorrect pick-up during energization of the transformer may result if very short delay times are set. In the rush current there is a substantial portion of fundamental current depending on the type and size of the transformer that is being energized.

The inrush stabilization blocks tripping of all those stages for which it has been activated, for as long as the rush current is recognized.

The inrush current contains a relatively large second harmonic component (twice the nominal frequency) which is nearly absent during a fault current. Numerical filters that carry out a Fourier analysis of the current are used for the frequency analysis. As soon as the harmonic content is greater than the set value (**2nd InrushRest**), the affected stage is blocked.

Direction Determination with Zero Sequence System

The direction determination is carried out with the measured current $\underline{I}_E$ (= $-3 \cdot \underline{I}_0$), which is compared to the reference voltage $\underline{U}_P$ (= $3 \cdot \underline{U}_0$).

The voltage required for direction determination $\underline{U}_P$ may also be calculated from the starpoint current $\underline{I}_Y$ of an earthed transformer (source transformer) (Figure 2-73), provided that the transformer is available.

It is furthermore possible to polarize with the zero-sequence voltage $3\underline{U}_0$ as well as with the starpoint current $\underline{I}_Y$ of a transformer. The reference value $\underline{U}_P$ then is the sum of the zero-sequence voltage $3\underline{U}_0$ and a value which is proportional to the starpoint current $\underline{I}_Y$. This value is about 20 V for rated current.

The directional polarization using the transformer star-point current is independent of voltage transformers and therefore also functions reliably during a fault in the voltage transformer secondary circuit. It is however a requirement that not all but at least a substantial amount of the earth fault current flows via the transformer, the star-point current of which is measured.

The determination of direction requires a minimum current $3\underline{I}_0$ and a minimum displacement voltage which can be set as $3\underline{U}_0$>. If the displacement voltage is too small,

the direction can only be determined if it is polarized with the transformer starpoint current and this exceeds a minimum value corresponding to the setting $I_Y>$. The direction determination with $3\underline{U}_0$ is inhibited if a "trip of the voltage transformer mcb" is reported via binary input.
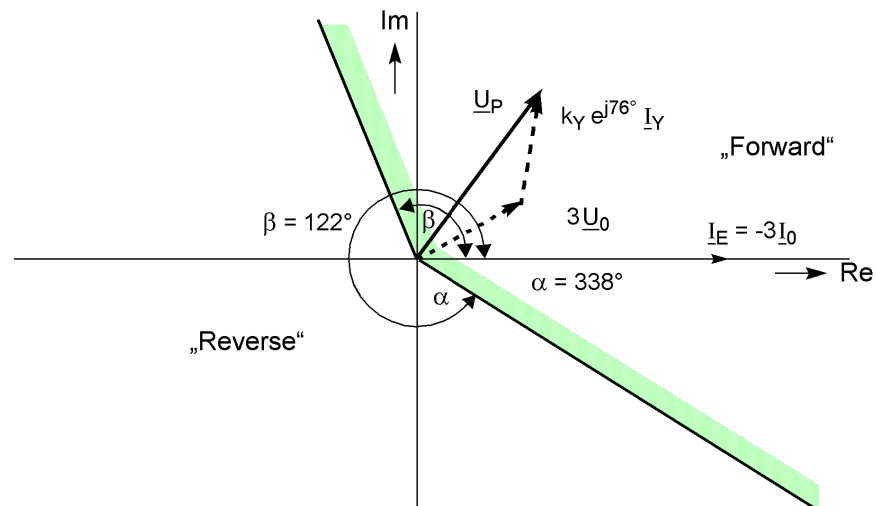
Figure 2-73   Directional characteristic of the earth fault protection

Direction Determination of Negative Sequence System

It is advantageous to use negative sequence system values for the direction determination if the resulting zero sequence voltages during earth faults are too small for an accurate measurement or when the zero sequence values are subject to interference by for example mutual coupling from a parallel line. It can also be used if the zero sequence voltage is not available at the device.

Otherwise this function operates the same as the direction determination with zero sequence current and zero sequence voltage. Instead of $3\underline{I}_0$ and $3\underline{U}_0$ the negative sequence signals $3\underline{I}_2$ and $3\underline{U}_2$ are simply used for the measurement. These signals must also have a minimum magnitude of **3I2>** or **3U2>**.

It is also possible to determine the direction with a zero sequence system or a negative sequence system. In this case the device determines whether the zero sequence quantity (U_P according to Figure 2-73) is larger, or the negative sequence voltage. The direction is determined by the larger of the two values.

Direction Determination with Compensated Zero-Sequence System Power

The zero-sequence power may also be used for direction determination. In this case the sign of the compensated zero-sequence power is decisive. This is the zero-sequence power component as mentioned in the above paragraph "Zero-Sequence Power" S_r in direction of a configurable compensation angle φ_{comp}, i.e.

$$S_r = 3I_0 \cdot 3U_0 \cdot \cos(\varphi - \varphi_{comp}).$$

The direction determination yields

- forward if S_r is positive and **S FORWARD** $< S_r$,
- reverse if S_r is negative and $-$ **S FORWARD** $> S_r$.

For the determination of direction a minimum current I_0 and a minimum displacement voltage which can be set as **3U0>**. The prerequisite is still that the compensated zero-sequence power has a configurable minimum magnitude. The direction determination is also inhibited when a "trip of the voltage transformer mcb" is reported via binary input. Figure 2-74 gives an example for the directional characteristic.
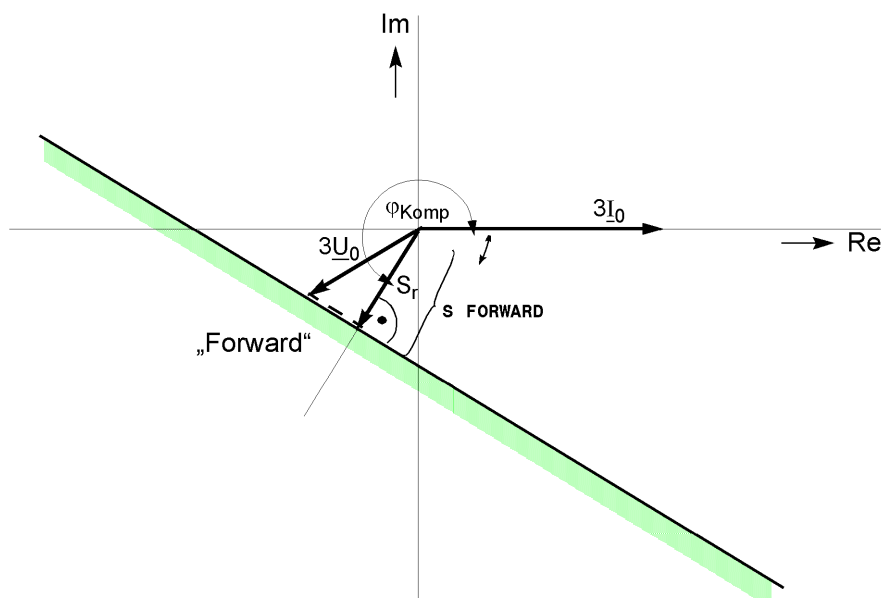
Figure 2-74   Directional characteristic with zero sequence power, example S_r = setting value
S FORWARD

Selecting the Earth-Faulted Phase

Since the earth fault protection employs the quantities of the zero sequence system and the negative sequence system, the faulted phase cannot be determined directly. To enable single-pole automatic reclosure in case of high-resistance earth faults, the earth fault protection function features a phase selector. By means of the distribution of the currents and voltages it detects whether a fault is single-phase or multiple-phase. If the fault is single-phase, it locates the faulted phase.

Once a multi-phase fault has been detected, a three-pole trip command is generated. Three-pole tripping is also initiated if single-pole tripping is not permitted (due to the setting or three-pole coupling of other internal extra functions or external devices via binary input e.g., reclosing device).

The phase selector evaluates the phase-to-earth voltages, the phase currents and the symmetrical components of the currents. If a single-phase fault can be detected with certainty due to a considerable voltage collapse or a high overcurrent, the trip is initiated in the concerned phase. Three-pole tripping is initiated accordingly if the currents and/or voltages indicate a multi-phase fault.

If methods described cannot detect the fault type beyond doubt, the negative sequence system and the zero sequence system are ultimately filtered out of the phase currents. The phase angle between negative sequence current and zero sequence current is used to determine the fault type i.e. whether the fault is single-phase or multi-phase. To this end, the phase currents are also evaluated to rectify the load current if necessary. This method relies on the fact that in the event of a single phase fault the fault-free phases can conduct either no fault currents at all or only such fault currents that are approximately in phase.

The phase selector has an action time of approximately 40°ms. If the phase selector has not made a decision during this time, three-pole tripping is initiated. Three-pole tripping is initiated anyway as soon as a multi-pole fault has been detected, as described above.

Figure 2-75 shows the logic diagram. The phase determined by the phase selector can be processed selectively for each phase, for example the internal information "E/F PICKUP L1" etc. is used for phase-selective signal transmission.

External signaling of the phase-selective pickup is accomplished via the information "E/F L1 selec." etc. They appear only if the phase was clearly detected. Single-pole tripping requires of course the general prerequisites to be fulfilled (device must be suited for single-pole tripping, single-pole tripping allowed).
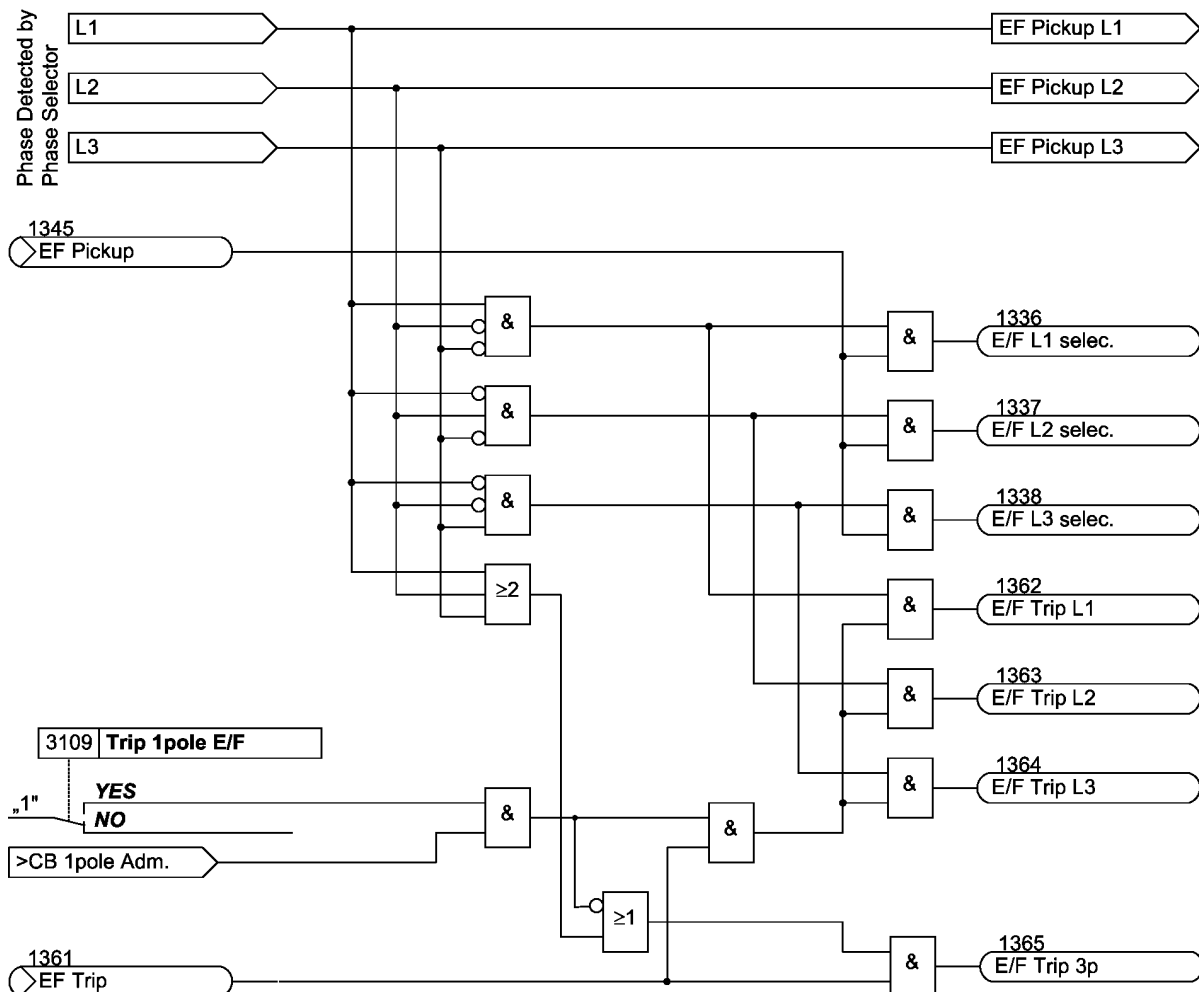
Figure 2-75   Logic diagram of single-pole tripping with phase selector

Blocking

Tripping of the earth fault protection can be blocked by the distance protection. If then the distance protection detects a fault, the earth fault protection will not be tripped. This gives the selective fault clearance by the distance protection preference over tripping by the earth fault protection. The blocking can be restricted by configuration to single-phase or multi-phase faults and to faults in distance zone Z1 or Z1/Z1B. The blocking only affects the time sequence and tripping by the earth fault protection function and after the cause of the blocking has been cleared, it is maintained for approximately 40 ms to prevent signal race conditions. It is issued as fault indication "EF TRIP BLOCK" (FNo 1335).

The earth fault protection can also be blocked during the single-pole dead time of an automatic reclose cycle. This prevents an incorrect measurement resulting from the zero sequence current and voltage signals arising in this state. The blocking affects the entire protection function and is maintained for approximately 40 ms after reclo-

sure to prevent signal race conditions. It is issued as fault indication "E/F BLOCK" (FNo 1332).

If the device is combined with an external automatic reclose device or if single-pole tripping can result from a separate (parallel tripping) protection device, the earth fault protection must be blocked via binary input during the single-pole open condition.

Switching onto an Earth Fault

The line energisation detection can be used to achieve quick tripping when energising the circuit breaker in case of an earth fault. The earth fault protection can then trip three-pole without delay. Parameters can be set to determine for which stage(s) the non-delayed tripping following energization apply (see also logic diagrams from Figure 2-67 to Figure 2-69).

The non-delayed tripping in case of line energization detection is blocked as long as the inrush-stabilization recognizes a rush current. This prevents instantaneous tripping by a stage which, under normal conditions, is sufficiently delayed during energization of a transformer.

2.7.2   Setting Notes

General

During the configuration of the device scope of functions (refer to Section 2.1.1, address 131 **Earth Fault O/C**) it was determined which group of characteristics are to be available. Only those parameters that apply to the available characteristics, according to the selected configuration and the version of the device, are accessible in the procedures described below.

Parameter 3101 **FCT EarthFltO/C** can be used to switch the earth fault protection *ON* or *OFF*. This refers to all functions of the earth fault protection.

If not required, each of the four stages can be deactivated by setting its **MODE...** to *Inactive* (see below).

Blocking

The earth fault protection can be blocked by the distance protection to give preference to the selective fault clearance by the distance protection over tripping by the earth fault protection. In setting address 3102 **BLOCK for Dist.** it is determined whether blocking is done during each fault detection of the distance protection (*every PICKUP*) or only during single-phase fault detection by the distance protection (*1phase PICKUP*) or only during multiple-phase fault detection by the distance protection (*multiph. PICKUP*). If blocking is not desired, set *NO*.

It is also possible to block the earth-fault protection trip only for pickup of the distance protection on the protected line section. To block the earth fault protection for faults occurring within zone Z1, set address 3174 **BLK for DisZone** to *in zone Z1*. To block the earth fault protection for faults occurring within zone Z1 or Z1B, set address 3174 **BLK for DisZone** to *in zone Z1/Z1B*. If, however, blocking of the earth fault protection by the distance protection is to take effect regardless of the fault location, set address 3174 **BLK for DisZone** to *in each zone*.

Address 3102 thus refers to the fault <u>type</u> and address 3174 to the fault <u>location</u>. The two blocking options create an AND condition. To block the earth fault protection only for single-phase faults occurring within zone Z1, set address 3102 **BLOCK for Dist.** = *1phase PICKUP* and 3174 **BLK for DisZone** = *in zone Z1*. To block the earth fault protection for any fault type (any distance protection pickup) occurring within zone Z1, the setting 3102 **BLOCK for Dist.** = *every PICKUP* and 3174 **BLK for DisZone** = *in zone Z1* applies.

The earth fault protection must be blocked during single-pole automatic reclose dead time, to avoid pick-up with the false zero sequence values and, if applicable, the negative sequence values arising during this state (address 3103 **BLOCK 1pDeadTim**). A setting of *YES* (default setting for devices with single-pole tripping) is required if single-pole automatic reclosure is to be carried out. Otherwise set *NO*. Setting parameter 3103 **BLOCK 1pDeadTim** to *YES* completely blocks the earth fault protection if the Open-Pole Detector has recognized a single-pole dead time. If no single-pole tripping is carried out in the protected network, it is absolutely necessary to set this parameter to *NO*.

Regardless of how parameter address 3103 **BLOCK 1pDeadTim** is set, the earth fault protection will always be blocked during the single-pole dead time, if it has issued a trip command itself. This is necessary because otherwise the picked up earth fault protection cannot drop out if the fault current was caused by load current.

Trip

Address 3109 **Trip 1pole E/F** specifies that the earth fault protection trips single pole, provided that the faulted phase can be determined with certainty. This address is only valid for devices that have the option to trip single-pole. If you are using single-pole automatic reclosure, the setting *YES* (default setting) remains valid. Otherwise set *NO*.

Definite Time Stages

First of all, the mode for each stage is set: address 3110 **Op. mode 3I0>>>**, address 3120 **Op. mode 3I0>>** and address 3130 **Op. mode 3I0>**. Each stage can be set to operate *Forward* (usually towards line), *Reverse* (usually towards busbar) or *Non-Directional* (in both directions). If a single stage is not required, set its mode to *Inactive*.

The definite time stages **3I0>>>** (address 3111), **3I0>>** (address 3121) and **3I0>** (address 3131) can be used for a three-stage definite time overcurrent protection. They can also be combined with the inverse time stage **3I0p PICKUP** (address 3141, see below). The pick up thresholds should in general be selected such that the most sensitive stage picks up with the smallest expected earth fault current.

The $3I_0>>$ and $3I_0>>>$ stages are best suited for fast tripping stages (instantaneous), as these stages use an abridged filter with shorter response time. On the other hand, the stages $3I_0>$ and $3I_{0P}$ are best suited for very sensitive earth fault detection due to their effective method of suppressing harmonics.

If no inverse time stage but rather a fourth definite time stage is required, the "inverse time" stage can be implemented as a definite time stage. This must already be taken regard of during the configuration of the protection functions (refer to Section 2.1.1.2, address 131 **Earth Fault O/C** = *Definite Time*). For this stage, the address 3141 **3I0p PICKUP** then determines the current pickup threshold and address 3147 **Add.T-DELAY** the definite time delay.

The values for the time delay settings **T 3I0>>>** (address 3112), **T 3I0>>** (address 3122) and **T 3I0>** (address 3132) are derived from the earth fault grading coordination diagram of the system.

During the selection of the current and time settings, regard must be taken as to whether a stage should be direction dependent and whether it uses teleprotection. Refer also to the margin headings "Determination of Direction" and "Teleprotection with Earth Fault Protection".

The set time delays are pure additional delays, which do not include the operating time (measuring time).

Inverse Time Stage with IEC Characteristic

Also for the inverse time overcurrent stage the operating mode is initially set: address 3140 **Op. mode 3IOp**. The stage can be set to operate *Forward* (usually towards line), *Reverse* (usually towards busbar) or *Non-Directional* (in both directions). If the stage is not required, set its mode to *Inactive*.

For the inverse time overcurrent stage $3I_{0P}$ it is possible to select from a variety of curves depending on the version of the relay and the configuration (Section 2.1.1.2, address 131) that was selected. If an inverse overcurrent stage is not required, set address 131 **Earth Fault O/C = *Definite Time***. The $3I_{0P}$–stage can then be used as a fourth definite time stage (refer to "Definite Time Stages" above) or deactivated. With the IEC characteristics (address 131 **Earth Fault O/C = *TOC IEC***) are available at address 3151 **IEC Curve**:

Normal Inverse (inverse, type A according to IEC 60255–3),

Very Inverse (very inverse, type B according to IEC 60255–3),

Extremely Inv. (extremely inverse, type C according to IEC 60255–3), and

LongTimeInverse (longtime, type B according to IEC 60255–3).

The characteristics and equations they are based on are listed in the Technical Data.

The setting of the pickup threshold **3IOp PICKUP** (address 3141) is similar to the setting of definite time stages (see above). In this case it must be noted that a safety margin between the pickup threshold and the set value has already been incorporated. Pickup only occurs at a current which is approximately 10 % above the set value.

The time multiplier setting **3IOp Time Dial** (address 3143) is derived from the grading coordination chart which was set up for earth faults in the system.

In addition to the inverse current dependant time delay, a constant (fixed length) time delay can also be set if this is required. The setting **Add.T-DELAY** (address 3147) is added to the time of the set curve.

During the selection of the current and time settings, regard must be taken as to whether a stage should be direction dependent and whether it uses teleprotection. Refer also to the margin headings "Determination of Direction" and "Teleprotection with Earth Fault Protection".

Inverse Time Stage with ANSI Characteristic

Also for the inverse time overcurrent stage the operating mode is initially set: address 3140 **Op. mode 3IOp**. The stage can be set to operate *Forward* (usually towards line), *Reverse* (usually towards busbar) or *Non-Directional* (in both directions). If the stage is not required, set its mode to *Inactive*.

For the inverse time overcurrent stage $3I_{0P}$ it is possible to select from a variety of curves depending on the version of the relay and the configuration (Section 2.1.1, address 131) that was selected. If an inverse overcurrent stage is not required, set address 131 **Earth Fault O/C = *Definite Time***. The $3I_{0P}$–stage can then be used as a fourth definite time stage (refer to "Definite Time Stages" above). With the ANSI characteristics (address 131 **Earth Fault O/C = *TOC ANSI***) are available at address 3152 **ANSI Curve**:

Inverse,

Short Inverse,

Long Inverse,

Moderately Inv.,

Very Inverse,

Extremely Inv.,

Definite Inv..

The characteristics and equations they are based on are listed in the Technical Data.

The setting of the pickup threshold **3I0p PICKUP** (address 3141) is similar to the setting of definite time stages (see above). In this case it must be noted that a safety margin between the pickup threshold and the set value has already been incorporated. Pickup only occurs at a current which is approximately 10 % above the set value.

The time multiplier setting **3I0p Time Dial** (address 3144) is derived from the grading coordination chart which was set up for earth faults in the system.

In addition to the inverse time delay, a constant (fixed length) time delay can also be set if this is required. The setting **Add.T-DELAY** (address 3147) is added to the time of the set curve.

During the selection of the current and time settings, regard must be taken as to whether a stage should be direction dependent and whether it uses teleprotection. Refer also to the margin headings "Determination of Direction" and "Teleprotection with Earth Fault Protection".

Inverse Time Stage with Logarithmic Inverse Characteristic

If you have configured the inverse time overcurrent stage with logarithmic inverse characteristic (address 131 **Earth Fault O/C** = *TOC Logarithm.*), the operating mode is initially set:: address 3140 **Op. mode 3I0p**. The stage can be set to operate *Forward* (usually towards line), *Reverse* (usually towards busbar) or *Non-Directional* (in both directions). If the stage is not required, set its mode to *Inactive*.

For the logarithmic inverse characteristic (address 131 **Earth Fault O/C** = *TOC Logarithm.*) the setting of address is 3153 **ANSI Curve** = *Log. inverse*.

The characteristics and equations they are based on are listed in the Technical Data.

Figure 2-76 illustrates the influence of the most important setting parameters on the curve. **3I0p PICKUP** (address 3141) is the reference value for all current values, while **3I0p Startpoint** (address 3154) determines the beginning of the curve, i.e. the lowest operating range on the current axis (referred to **3I0p PICKUP**). The timer setting **3I0p MaxT-DELAY** (address 3146) determines the starting point of the curve (for $3I_0$ = **3I0p PICKUP**). The time factor **3I0p Time Dial** (address 3145) changes the slope of the curve. For large currents, **3I0p MinT-DELAY** (address 3142) determines the lower limit on the time axis. For currents larger than 30 · **3I0p PICKUP** the operating time no longer decreases.

Finally in address 3147 **Add.T-DELAY** a fixed time delay can be set as was done for other curves.

During the selection of the current and time settings, regard must be taken as to whether a stage should be direction dependent and whether it uses teleprotection. Refer also to the margin headings "Determination of Direction" and "Teleprotection with Earth Fault Protection".
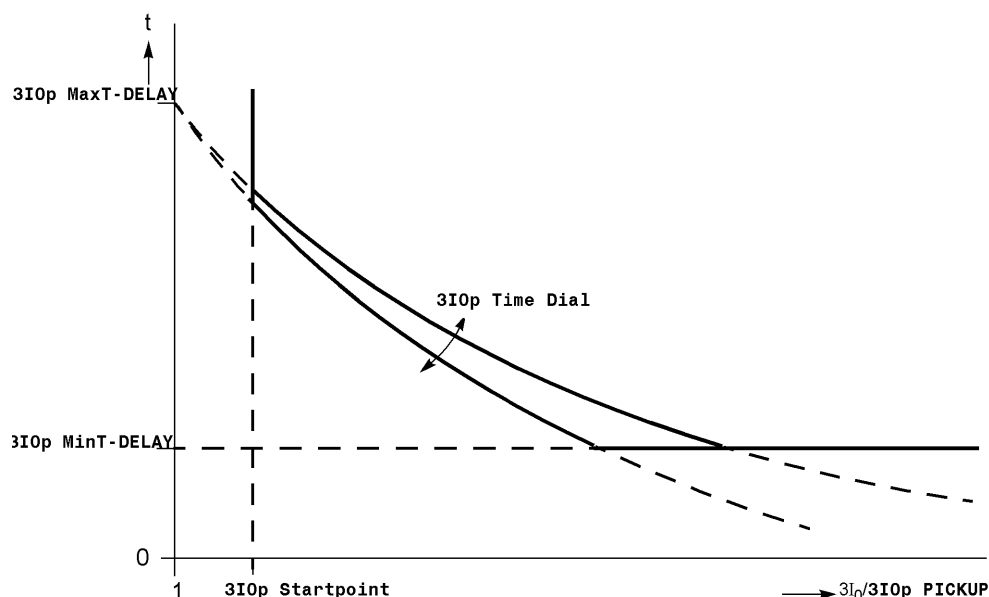
Figure 2-76   Curve parameters in the logarithmic–inverse characteristic

Zero Sequence Voltage Stage with Inverse Characteristic

If you have configured the zero sequence voltage controlled stage (address 131 **Earth Fault O/C** = *UO inverse*) the operating mode is initially set: address 3140 **Op. mode 3IOp**. The stage can be set to operate *Forward* (usually towards line), *Reverse* (usually towards busbar) or *Non-Directional* (in both directions). If the stage is not required, set its mode to *Inactive*.

Address 3141 **3IOp PICKUP** indicates the minimum current value above which this stage is required to operate. The value must be exceeded by the minimum earth fault current value.

The voltage-controlled characteristic is based on the following formula:

$$t = \frac{2 \, s}{0.25 \, U_0 \diagup V - U_{0 \, min} \diagup V}$$

U_0 is the actual zero sequence voltage. $U_{0 \, min}$ is the setting value **UOinv. minimum** (address 3183). Please take into consideration that the equation is based on the zero sequence voltage U_0, not on $3U_0$. The function is illustrated in the Technical Data.

Figure 2-77 shows the most important parameters. **UOinv. minimum** displaces the voltage-controlled characteristic in direction of $3U_0$. The set value is the asymptote for this characteristic ($t \rightarrow \infty$). In Figure 2-77 **a'** shows an asymptote that belongs to the characteristic **a**.

The minimum voltage **3UO>(UO inv)** (address 3182) is the lower voltage threshold. It corresponds to the line **c** in Figure 2-77. In characteristic **b** (asymptote not drawn) the curve is cut by the minimum voltage **3UO>(UO inv)** (line **c**).

An additional time 3184 can be set for directional-controlled tripping at address **T forw. (UOinv)** that is added to the voltage-controlled characteristic.

With the non-directional time **T rev. (UOinv)** (address 3185) a non-directional back-up stage can be generated.
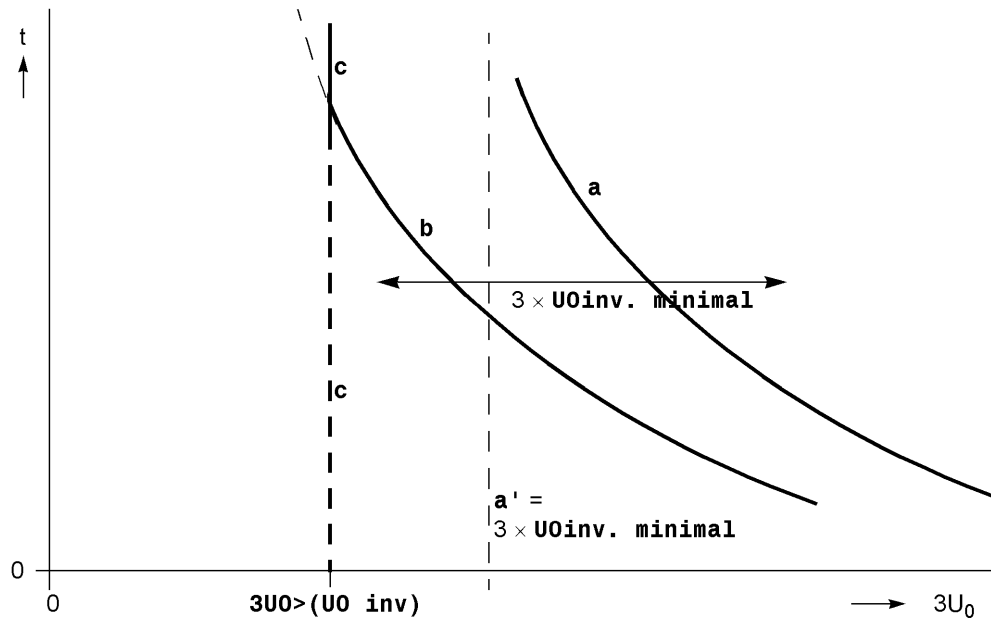
Figure 2-77   Characteristic settings of the zero-sequence voltage time dependent stage —
without additional times

Zero Sequence Power Stage

If you have configured the fourth stage as zero sequence power stage (address 131 **Earth Fault O/C** = *Sr inverse*), set the mode first: Address 3140 **Op. mode 3I0p**. This stage can be set to operate *Forward* (usually towards line) or *Reverse* (usually towards busbar) or *Non-Directional* (in both directions). If the stage is not required, set its mode to *Inactive*. The zero sequence power protection is to operate always in line direction. Mode *Non-Directional* is not reasonable here since it would restrict the stage to mere current measurement.

Address 3141 **3I0p PICKUP** indicates the minimum current value above which this stage is required to operate. The value must be exceeded by the minimum earth fault current value.

The zero-sequence power S_r is calculated according to the formula:

$$S_r = 3I_0 \cdot 3U_0 \cdot \cos(\varphi - \varphi_{comp})$$

The angle φ_{comp} is set as maximum-sensitivity angle at address 3168 **PHI comp**. It refers to the zero sequence voltage in relation to the zero sequence current. The default setting 255° thus corresponds to a zero sequence impedance angle of 75° (255° – 180°). Also refer to Section 2.7 at margin heading "Zero Sequence Power Protection").

The trip time depends on the zero sequence power according to the following formula:

$$t = k \cdot \frac{S_{ref}}{S_r}$$

Where S_r is the compensated power according to above formula. S_{ref} is the setting value **S ref** (address 3156) that indicates the pickup value of the stage at $\varphi = \varphi_{comp}$. Factor **k** (address 3155) can be set to displace the zero sequence time characteristic in time direction, the reference value **S ref** can be set for displacement in power direction.

The time setting **Add.T-DELAY** (address 3147) allows an additional power-independent delay time to be set.

Determination of Direction

The direction of each required stage was already determined when setting the different stages.

According to the requirements of the application, the directionality of each stage is individually selected. If for instance a directional earth fault protection with a non-directional back-up stage is required, this can be implemented by setting the $3I_0>>$ stage directional with a short or no delay time and the $3I_0>$ stage with the same pickup threshold but a longer delay time as directional backup stage. The $3I_0>>>$ stage could be applied as an additional high set instantaneous stage.

If a stage is to operate with teleprotection according to Section 2.8, it may operate without delay in conjunction with a permissive scheme. In the blocking scheme, a short delay equal to the signal transmission time, plus a small reserve margin of approx. 20 ms is sufficient.

Direction determination of the overcurrent stages usually uses the earth current as measured quantity $\underline{I}_E = -3I_0$, whose angle is compared with a reference quantity (Section 2.7). The desired reference quantity is set in **POLARIZATION** (address 3160):

The default setting **U0 + IY or U2** is universal. The device then selects automatically whether the reference quantity is composed of the zero sequence voltage plus the transformer starpoint current, or whether the negative-sequence voltage is used, depending on which quantity prevails. You can even apply this setting when no transformer starpoint current I_Y is connected to the device since an unconnected current does not have any effect.

The setting **U0 + IY** can also be applied with or without transformer starpoint current connected.

If the direction determination must be carried out using only $\underline{I}_Y$ as reference signal, apply the setting **with IY only**. This makes sense if a reliable transformer starpoint current $\underline{I}_Y$ is always available at the device input I_4. The direction determination is then not influenced by disturbances in the secondary circuit of the voltage transformers. This presupposes that the device is equipped with a current input I_4 of normal sensitivity and that the current from the transformer starpoint infeed is connected to I_4.

If direction determination is to be carried out using exclusively the negative sequence system signals $3\,\underline{I}_2$ and $3\,\underline{U}_2$, the setting **with U2 and I2** is applied. In this case only the negative-sequence signals calculated by the device are used for direction determination. In that case, the device does not require any zero-sequence signals for direction determination.

If you are using the zero-sequence power protection (address 131 **Earth Fault O/C = Sr inverse**), it is reasonable to conduct the direction determination also via the zero-sequence power. In this case apply the option **zero seq. power** for **POLARIZATION**.

Finally, the threshold values of the reference quantities must be set. **3U0>** (address 3164) determines the minimum operating voltage for direction determination with U_0. If U_0 is not used for the direction determination, this setting is of no consequence. The set threshold should not be exceeded by asymmetries in the operational measured voltage. The setting value relates to the triple zero-sequence voltage, that is

$$3 \cdot U_0 = |\, \underline{U}_{L1} + \underline{U}_{L2} + \underline{U}_{L3} \,|$$

If the voltage dependent characteristic (U0 inverse) is used as directional stage, it is reasonable for the minimum polarizing voltage to use a value that is equal to or below the minimum voltage of the voltage-controlled characteristic (address 3182).

Only if you have set in the **P.System Data 1** (see Section 2.1.3.1) the connection of the fourth current transformer **I4 transformer** (address 220) = *IY starpoint*, address 3165 **IY>** will appear. It is the lower threshold for the current measured in the starpoint of a source transformer. A relatively sensitive setting can be applied for this value, as the measurement of the starpoint current is quite accurate by nature.

If the direction determination must be done with the negative sequence system signals, the setting values **3U2>** (address 3166) and **3I2>** (address 3167) are decisive for the lower limit of the direction determination. The setting values must in this case also be selected such that operational asymmetry in the system does not lead to a pickup.

If you are using the zero-sequence power protection and the fault direction is determined on the basis of the zero-sequence power, address 3169 **S forward** indicates the value of the compensated zero-sequence power above which the direction is recognized as forward. This value should be smaller than the reference power **S ref** (address 3156, see above paragraph at "Zero-Sequence Power Stage"). This ensures the availability of direction determination even with smaller zero-sequence power conditions.

The position of the directional characteristic can be changed in dependance of the selected method of direction determination (address 3160 **POLARIZATION**, see above). All methods based on angle measurement between measured signal and reference signal (i.e. all methods except **POLARIZATION** = *zero seq. power*), allow the angle range of the direction determination to be changed with the setting angles **Dir. ALPHA** and **Dir. BETA** (addresses 3162 and 3163). This setting is only possible via DIGSI® at "**Additional Settings**". As these set values are not critical, the presettings may be left unchanged. If you want to change these values, refer to Section 2.7, margin heading "Direction Determination with Zero-Sequence System" for the angle determination.

The direction determination **POLARIZATION** with *zero seq. power* determines the directional characteristic by means of the compensation angle **PHI comp** (address 3168) which indicates the symmetry axis of the directional characteristic. This value is also not critical for direction determination. For information on the angle definition, refer to Section 2.7, margin heading "Direction Determination with Zero-Sequence Power". This angle determines at the same time the maximum sensitivity of the zero-sequence power stage thus also affecting indirectly the trip time as described above (margin title "Zero-Sequence Power Stage").

Teleprotection with Earth Fault Protection

The earth fault protection in the 7SA6 may be expanded to a directional comparison protection using the integrated teleprotection logic. Additional information regarding the available teleprotection schemes and their mode of operation may be obtained from Section 2.8. If this is to be used, certain preconditions must already be observed when setting the earth current stage.

Initially it must be determined which stage must operate in conjunction with the teleprotection. This stage must be set directional in the line direction. If for example the $3I_0>$ stage should operate as directional comparison, set address 3130 **Op. mode 3IO>** = *Forward* (see above "Definite Time Stages").

Furthermore, the device must be informed that the applicable stage has to function together with the teleprotection to allow undelayed release of the tripping during internal faults. For the $3I_0>$ stage this means that address 3133 **3IO> Telep/BI** is set to *YES*. The time delay set for this stage **T 3IO>** (address 3132) then functions as a back-up stage, e.g. during failure of the signal transmission. For the remaining stages the corresponding setting parameter is set to *NO*, therefore, in this example:

Address 3123 **3I0>> Telep/BI** for stage $3I_0$>>, address 3113 **3I0>>> Telep/BI** for stage $3I_0$>>>, address 3148 **3I0p Telep/BI** for stage $3I_{0P}$ (if used).

If the echo function is used in conjunction with the teleprotection scheme, or if the weak-infeed tripping function should be used, the additional teleprotection stage **3IoMin Teleprot** (address 3105) must be set to avoid non-selective tripping during through-fault earth current measurement. For further information refer to Section 2.8, margin heading "Earth Fault Protection Prerequisites".

Switching onto an Earth Fault

It is possible to determine with a setting which stage trips without delay following closure onto a dead fault. The parameters **3I0>>>SOTF-Trip** (address 3114), **3I0>> SOTF-Trip** (address 3124), **3I0> SOTF-Trip** (address 3134) and if necessary **3I0p SOTF-Trip** (address 3149) are available for the stages, which can be set to *YES* or *NO* for each stage. Selection of the most sensitive stage is usually not reasonable as a solid short-circuit may be assumed following switching onto a fault, whereas the most sensitive stage often also has to detect high resistance faults. It is important to avoid that the selected stage picks up in a transient way during line energization.

On the other hand, it does not matter if a selected stage may pick up due to inrush conditions on transformers. The switch-onto-fault tripping of a stage is blocked by the inrush stabilization even if it is set as instantaneous switch-onto-fault stage for manual closure.

To avoid a spurious pickup due to transient overcurrents, the delay **SOTF Time DELAY** (address 3173) can be set. Usually, the default setting **0** can be retained. In the case of long cables, where large peak inrush currents can occur, a short delay may be useful. The time delay depends on the severity and duration of the transient overcurrents as well as on which stages were selected for the fast switch onto fault clearance.

With the parameter **SOTF Op. Mode** (address 3172) it is finally possible to determine whether the fault direction must be checked (*PICKUP+DIRECT.*) or not (*PICKUP*), before a switch-onto-fault tripping is generated. It is the direction setting for each stage that applies for this direction check.

Phase Current Stabilization

To avoid a faulty pickup of the stages in the case of asymmetrical load conditions or varying current transformer measuring errors in earthed systems, the earth current stages are stabilized by the phase currents: As the phase currents increase, the pickup thresholds are increased. By means of the setting in address 3104 **Iph-STAB. Slope** the preset value of 10 % for all stages can be jointly changed for all stages. This setting is only possible via DIGSI® at "**Additional Settings**".

Inrush Stabilization

The inrush stabilization is only required if the device is applied to transformer feeders or on lines that end on a transformer; in this case also only for such stages that have a pickup threshold below the inrush current and have a very short or zero delay. The parameters **3I0>>>InrushBlk** (address 3115), **3I0>> InrushBlk** (address 3125), **3I0> InrushBlk** (address 3135) and **3I0p InrushBlk** (address 3150) can be set to *YES* (inrush stabilization active) or *NO* (inrush stabilization inactive) for each stage. If the inrush stabilization has been disabled for all stages, the following parameters are of no consequence.

For the recognition of the inrush current, the portion of second harmonic current content referred to the fundamental current component can be set in address 3170 **2nd InrushRest**. Above this threshold the inrush blocking is effective. The preset value (15 %) should be sufficient in most cases. Lower values imply higher sensitivity of the inrush blocking (smaller portion of second harmonic current results in blocking).

In applications on transformer feeders or lines that are terminated on transformers it may be assumed that, if very large currents occur, a short circuit has occurred in front of the transformer. In the event of such large currents, the inrush stabilization is inhibited. This threshold value which is set in the address 3171 **Imax InrushRest**, should be larger than the maximum expected inrush current (RMS value).

2.7.3 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
3101	FCT EarthFltO/C		ON OFF	ON	Earth Fault overcurrent function is
3102	BLOCK for Dist.		every PICKUP 1phase PICKUP multiph. PICKUP NO	every PICKUP	Block E/F for Distance protection
3103	BLOCK 1pDeadTim		YES NO	YES	Block E/F for 1pole Dead time
3104A	Iph-STAB. Slope		0 .. 30 %	10 %	Stabilisation Slope with Iphase
3105	3IoMin Teleprot	1A	0.01 .. 1.00 A	0.50 A	3Io-Min threshold for Teleprot. schemes
		5A	0.05 .. 5.00 A	2.50 A	
3105	3IoMin Teleprot	1A	0.003 .. 1.000 A	0.500 A	3Io-Min threshold for Teleprot. schemes
		5A	0.015 .. 5.000 A	2.500 A	
3109	Trip 1pole E/F		YES NO	YES	Single pole trip with earth flt.prot.
3110	Op. mode 3I0>>>		Forward Reverse Non-Directional Inactive	Inactive	Operating mode
3111	3I0>>>	1A	0.05 .. 25.00 A	4.00 A	3I0>>> Pickup
		5A	0.25 .. 125.00 A	20.00 A	
3112	T 3I0>>>		0.00 .. 30.00 sec; ∞	0.30 sec	T 3I0>>> Time delay
3113	3I0>>> Telep/BI		NO YES	NO	Instantaneous trip via Teleprot./BI
3114	3I0>>>SOTF-Trip		NO YES	NO	Instantaneous trip after SwitchOnToFault
3115	3I0>>>InrushBlk		NO YES	NO	Inrush Blocking
3120	Op. mode 3I0>>		Forward Reverse Non-Directional Inactive	Inactive	Operating mode

Addr.	Parameter	C	Setting Options	Default Setting	Comments
3121	3I0>>	1A	0.05 .. 25.00 A	2.00 A	3I0>> Pickup
		5A	0.25 .. 125.00 A	10.00 A	
3122	T 3I0>>		0.00 .. 30.00 sec; ∞	0.60 sec	T 3I0>> Time Delay
3123	3I0>> Telep/BI		NO YES	NO	Instantaneous trip via Tele-prot./BI
3124	3I0>> SOTF-Trip		NO YES	NO	Instantaneous trip after SwitchOnToFault
3125	3I0>> InrushBlk		NO YES	NO	Inrush Blocking
3130	Op. mode 3I0>		Forward Reverse Non-Directional Inactive	Inactive	Operating mode
3131	3I0>	1A	0.05 .. 25.00 A	1.00 A	3I0> Pickup
		5A	0.25 .. 125.00 A	5.00 A	
3131	3I0>	1A	0.003 .. 25.000 A	1.000 A	3I0> Pickup
		5A	0.015 .. 125.000 A	5.000 A	
3132	T 3I0>		0.00 .. 30.00 sec; ∞	0.90 sec	T 3I0> Time Delay
3133	3I0> Telep/BI		NO YES	NO	Instantaneous trip via Tele-prot./BI
3134	3I0> SOTF-Trip		NO YES	NO	Instantaneous trip after SwitchOnToFault
3135	3I0> InrushBlk		NO YES	NO	Inrush Blocking
3140	Op. mode 3I0p		Forward Reverse Non-Directional Inactive	Inactive	Operating mode
3141	3I0p PICKUP	1A	0.05 .. 25.00 A	1.00 A	3I0p Pickup
		5A	0.25 .. 125.00 A	5.00 A	
3141	3I0p PICKUP	1A	0.003 .. 25.000 A	1.000 A	3I0p Pickup
		5A	0.015 .. 125.000 A	5.000 A	
3142	3I0p MinT-DELAY		0.00 .. 30.00 sec	1.20 sec	3I0p Minimum Time Delay
3143	3I0p Time Dial		0.05 .. 3.00 sec; ∞	0.50 sec	3I0p Time Dial
3144	3I0p Time Dial		0.50 .. 15.00 ; ∞	5.00	3I0p Time Dial
3145	3I0p Time Dial		0.05 .. 15.00 sec; ∞	1.35 sec	3I0p Time Dial
3146	3I0p MaxT-DELAY		0.00 .. 30.00 sec	5.80 sec	3I0p Maximum Time Delay
3147	Add.T-DELAY		0.00 .. 30.00 sec; ∞	1.20 sec	Additional Time Delay
3148	3I0p Telep/BI		NO YES	NO	Instantaneous trip via Tele-prot./BI
3149	3I0p SOTF-Trip		NO YES	NO	Instantaneous trip after SwitchOnToFault

Addr.	Parameter	C	Setting Options	Default Setting	Comments
3150	3I0p InrushBlk		NO YES	NO	Inrush Blocking
3151	IEC Curve		Normal Inverse Very Inverse Extremely Inv. LongTimeInverse	Normal Inverse	IEC Curve
3152	ANSI Curve		Inverse Short Inverse Long Inverse Moderately Inv. Very Inverse Extremely Inv. Definite Inv.	Inverse	ANSI Curve
3153	LOG Curve		Log. inverse	Log. inverse	LOGARITHMIC Curve
3154	3I0p Startpoint		1.0 .. 4.0	1.1	Start point of inverse characteristic
3155	k		0.00 .. 3.00 sec	0.50 sec	k-factor for Sr-characteristic
3156	S ref		1 .. 100 VA	10 VA	S ref for Sr-characteristic
3160	POLARIZATION		U0 + IY or U2 U0 + IY with IY only with U2 and I2 zero seq. power	U0 + IY or U2	Polarization
3162A	Dir. ALPHA		0 .. 360 °	338 °	ALPHA, lower angle for forward direction
3163A	Dir. BETA		0 .. 360 °	122 °	BETA, upper angle for forward direction
3164	3U0>		0.5 .. 10.0 V	0.5 V	Min. zero seq.voltage 3U0 for polarizing
3165	IY>	1A	0.05 .. 1.00 A	0.05 A	Min. earth current IY for polarizing
		5A	0.25 .. 5.00 A	0.25 A	
3166	3U2>		0.5 .. 10.0 V	0.5 V	Min. neg. seq. polarizing voltage 3U2
3167	3I2>	1A	0.05 .. 1.00 A	0.05 A	Min. neg. seq. polarizing current 3I2
		5A	0.25 .. 5.00 A	0.25 A	
3168	PHI comp		0 .. 360 °	255 °	Compensation angle PHI comp. for Sr
3169	S forward		0.1 .. 10.0 VA	0.3 VA	Forward direction power treshold
3170	2nd InrushRest		10 .. 45 %	15 %	2nd harmonic ratio for inrush restraint
3171	Imax InrushRest	1A	0.50 .. 25.00 A	7.50 A	Max.Current, overriding inrush restraint
		5A	2.50 .. 125.00 A	37.50 A	
3172	SOTF Op. Mode		PICKUP PICKUP+DIRECT.	PICKUP+DIRECT.	Instantaneous mode after SwitchOnToFault
3173	SOTF Time DELAY		0.00 .. 30.00 sec	0.00 sec	Trip time delay after SOTF

Addr.	Parameter	C	Setting Options	Default Setting	Comments
3174	BLK for DisZone		in zone Z1 in zone Z1/Z1B in each zone	in each zone	Block E/F for Distance Protection Pickup
3182	3U0>(U0 inv)		1.0 .. 10.0 V	5.0 V	3U0> setpoint
3183	U0inv. minimum		0.1 .. 5.0 V	0.2 V	Minimum voltage U0min for T->oo
3184	T forw. (U0inv)		0.00 .. 32.00 sec	0.90 sec	T-forward Time delay (U0inv)
3185	T rev. (U0inv)		0.00 .. 32.00 sec	1.20 sec	T-reverse Time delay (U0inv)

2.7.4 Information List

No.	Information	Type of Information	Comments
1305	>EF BLK 3I0>>>	SP	>Earth Fault O/C Block 3I0>>>
1307	>EF BLOCK 3I0>>	SP	>Earth Fault O/C Block 3I0>>
1308	>EF BLOCK 3I0>	SP	>Earth Fault O/C Block 3I0>
1309	>EF BLOCK 3I0p	SP	>Earth Fault O/C Block 3I0p
1310	>EF InstTRIP	SP	>Earth Fault O/C Instantaneous trip
1331	E/F Prot. OFF	OUT	Earth fault protection is switched OFF
1332	E/F BLOCK	OUT	Earth fault protection is BLOCKED
1333	E/F ACTIVE	OUT	Earth fault protection is ACTIVE
1335	EF TRIP BLOCK	OUT	Earth fault protection Trip is blocked
1336	E/F L1 selec.	OUT	E/F phase selector L1 selected
1337	E/F L2 selec.	OUT	E/F phase selector L2 selected
1338	E/F L3 selec.	OUT	E/F phase selector L3 selected
1345	EF Pickup	OUT	Earth fault protection PICKED UP
1354	EF 3I0>>>Pickup	OUT	E/F 3I0>>> PICKED UP
1355	EF 3I0>> Pickup	OUT	E/F 3I0>> PICKED UP
1356	EF 3I0> Pickup	OUT	E/F 3I0> PICKED UP
1357	EF 3I0p Pickup	OUT	E/F 3I0p PICKED UP
1358	EF forward	OUT	E/F picked up FORWARD
1359	EF reverse	OUT	E/F picked up REVERSE
1361	EF Trip	OUT	E/F General TRIP command
1362	E/F Trip L1	OUT	Earth fault protection: Trip 1pole L1
1363	E/F Trip L2	OUT	Earth fault protection: Trip 1pole L2
1364	E/F Trip L3	OUT	Earth fault protection: Trip 1pole L3
1365	E/F Trip 3p	OUT	Earth fault protection: Trip 3pole
1366	EF 3I0>>> TRIP	OUT	E/F 3I0>>> TRIP
1367	EF 3I0>> TRIP	OUT	E/F 3I0>> TRIP
1368	EF 3I0> TRIP	OUT	E/F 3I0> TRIP
1369	EF 3I0p TRIP	OUT	E/F 3I0p TRIP
1370	EF InrushPU	OUT	E/F Inrush picked up

2.8 Teleprotection for earth fault overcurrent protection (optional)

2.8.1 General

With the aid of the integrated comparison logic, the directional earth fault protection according to Section 2.7 can be expanded to a directional comparison protection scheme.

Transmission Modes

One of the stages which must be directional ***Forward*** is used for the directional comparison. This stage can only trip fast if a fault is also recognized in the forward direction at the other line end. A release (unblock) signal or a block signal can be transmitted.

The following permissive schemes exist:

- Directional comparison,
- Directional unblock scheme

and blocking scheme:

- Blocking of the directional stage.

Further stages may be implemented as directional and/or nondirectional backup stages.

Transmission Channels

For the signal transmission, one channel in each direction is required. Fibre optic connections or voice frequency modulated high frequency channels via pilot cables, power line carrier or microwave radio links can be used for this purpose. If the same transmission channel is used as for the transmission by the distance protection, the transmission mode must also be the same!

If the device is equipped with an optional protection data interface, digital communication lines can be used for signal processing; these include: Fibre optic cables, communication networks or dedicated lines. The following teleprotection scheme is suited for these kinds of transmission:

- Directional comparison

7SA6 allows also the transmission of phase-selective signals. This presents the advantage that single-pole automatic reclosure can be carried out even when two single-phase faults occur on different lines in the system. Where the digital protection data interface is used, the signal transmission is always phase segregated. If no single-phase fault is recognized, the signals are transmitted for all three phases. Phase-segregated transmission for the earth fault protection is only reasonable if the faulted phase is detected by the phase selector (address 3109 **Trip 1pole E/F** set to *YES*, see also Section 2.7 at "Tripping").

The signal transmission schemes are also suited to three terminal lines (teed feeders). In this case, signal transmission channels are required from each of the three ends to each of the others in both directions. Phase segregated transmission is only possible for three terminal line applications if digital communication channels are used.

During disturbances on the transmission path, the teleprotection supplement may be blocked. With conventional signal transmission schemes, the disturbance is signalled by a binary input, with digital communication it is detected automatically by the protection device.

Activation and Deactivation

The comparison function can be switched on and off by means of the parameter 3201 **FCT Telep. E/F**, via the system interface (if available) and via binary input (if allocated). The switched state is saved internally (refer to Figure 2-78) and secured against loss of auxiliary supply. It is only possible to switch on from the source where previously it had been switched off from. To be active, it is necessary that the function is not switched off from one of the three switching sources.
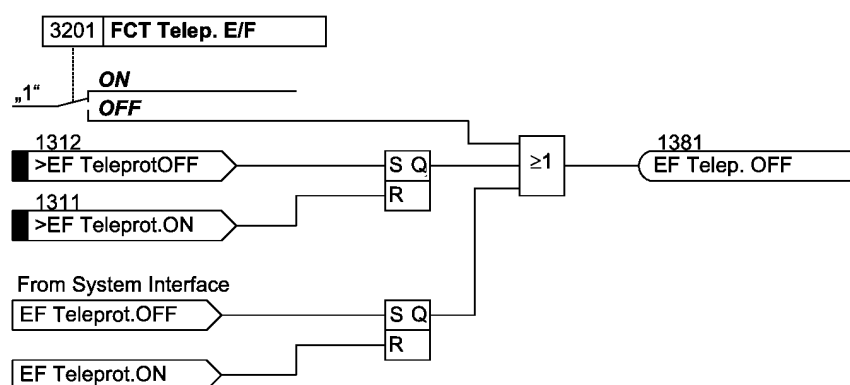
Figure 2-78   Activation and deactivation of the signal transmission logic

2.8.2   Directional Comparison Pickup

The following procedure is suited for both conventional and digital transmission media.

Principle

The directional comparison scheme is a permissive (release scheme). The scheme functionality is shown in Figure 2-79.

When the earth fault protection recognizes a fault in the forward direction, it initially sends a permissive signal to the opposite line end. If a permissive signal is also received from the opposite end, a trip signal is routed to the trip logic. Accordingly it is a prerequisite for fast tripping that the fault is recognized in the forward direction at both line ends.

The send signal can be prolonged by T_S (settable). The prolongation of the send signal only comes into effect if the protection has already issued a trip command. This ensures that the permissive signal releases the opposite line end even if the earth fault is very rapidly cleared by a different independent protection.
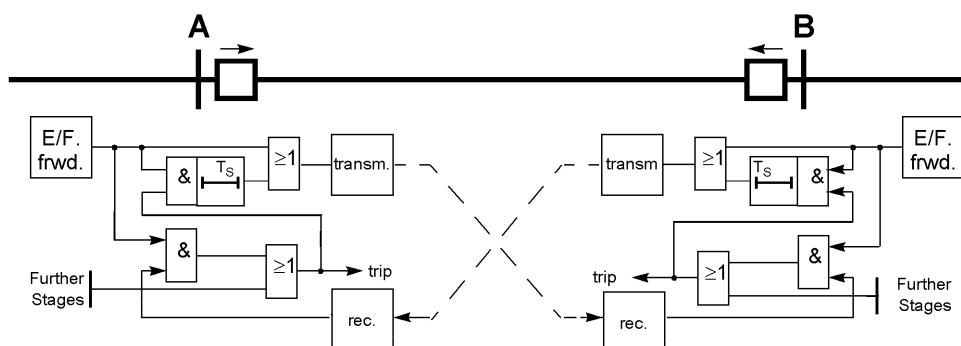
Figure 2-79   Operation scheme of the directional comparison pickup

Sequence Figure 2-80 shows the logic diagram of the directional comparison scheme for one line end.

The directional comparison only functions for faults in the "forward" direction. Accordingly the over current stage intended for operation in the direction comparison mode must definitely be set to *Forward* (*3IO... DIRECTION*); refer also to Subsection 2.7 at the margin heading "Teleprotection with Earth Fault Protection".

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signals are then combined with a logical AND gate, as all three line ends must transmit a send signal during an internal fault. With the setting parameter **Line Config.** (address 3202) the device is informed as to whether it has one or two opposite line ends. If the parameter **Teleprot. E/F** (address 132) is set to *SIGNALv.ProtInt* and the parameter **NUMBER OF RELAY** (address 147) is set to *3 relays*, the device is informed about two remote ends. The default setting is *2 relays*, which corresponds to one remote end.

The occurrence of erroneous signals resulting from transients during clearance of external faults or from direction reversal resulting during the clearance of faults on parallel lines, is neutralized by the "Transient Blocking" (see margin heading "Transient Blocking").

On lines where there is only a single sided infeed or where the star-point is only earthed behind one line end, the line end without zero sequence current cannot generate a permissive signal, as fault detection does not take place there. To also ensure tripping by the directional comparison in this case the device has special features. This "Weak-infeed tripping" (echo function) is referred to at margin heading "Echo Function". It is activated when a signal is received from the opposite line end — in the case of three terminal lines from at least one of the opposite line ends — without the device having detected a fault.

The circuit breaker can also be tripped at the line end with no or only weak infeed. This "Weak-infeed tripping" is referred to in Section 2.9.1.
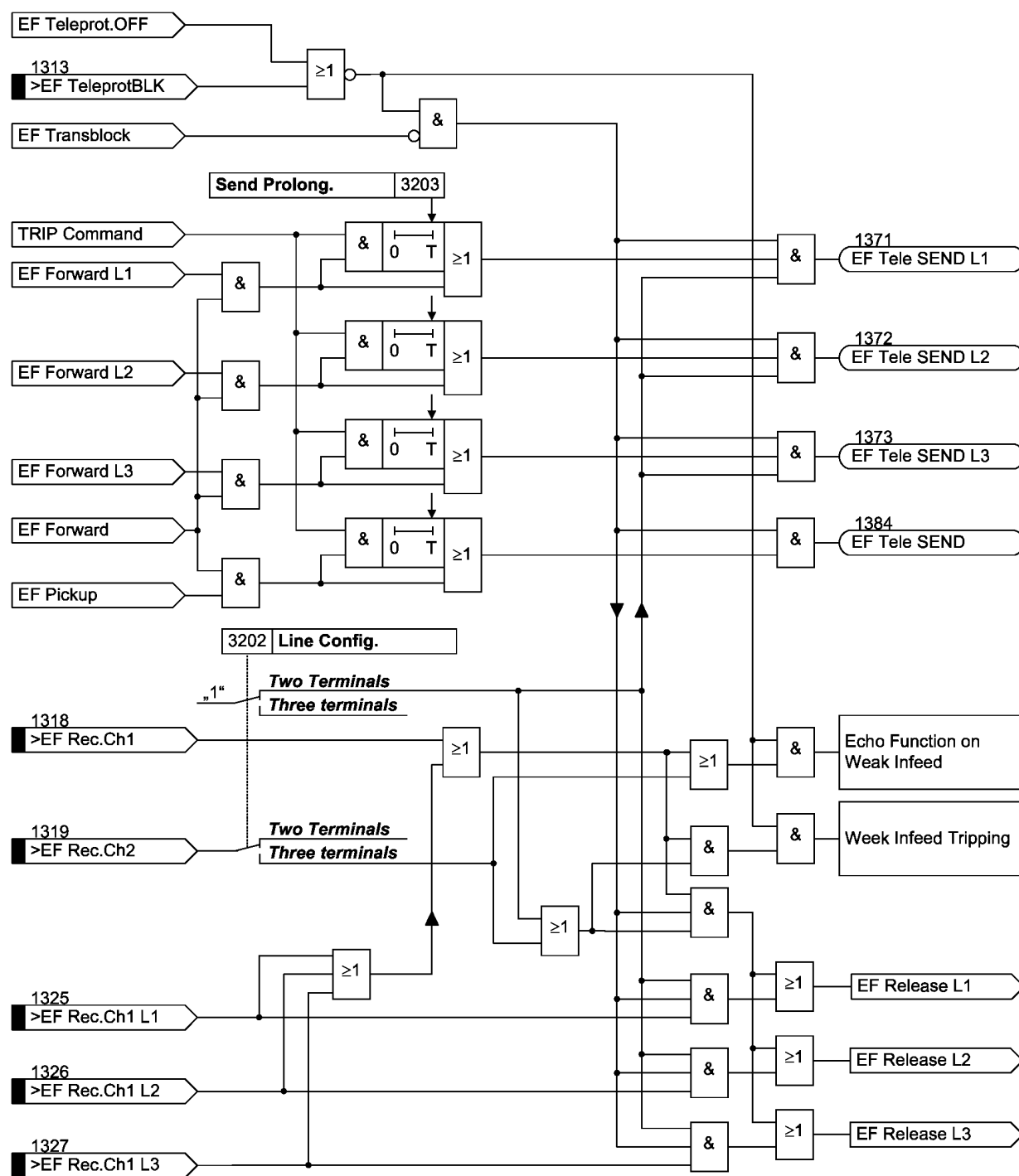
Figure 2-80   Logic diagram of the directional comparison scheme (one line end)

Figure 2-81 and 2-82 shows the logic diagram of the directional comparison scheme for one line end with protection interface.

For earth fault protection, only directional comparison pickup is offered for transmission via protection interface. The directional comparison pickup scheme is only effective if the parameter 132 **Teleprot. E/F** was set to *SIGNALv.ProtInt* in all devices of the setup. In the event of a fault, the indication "Par. different" is output.
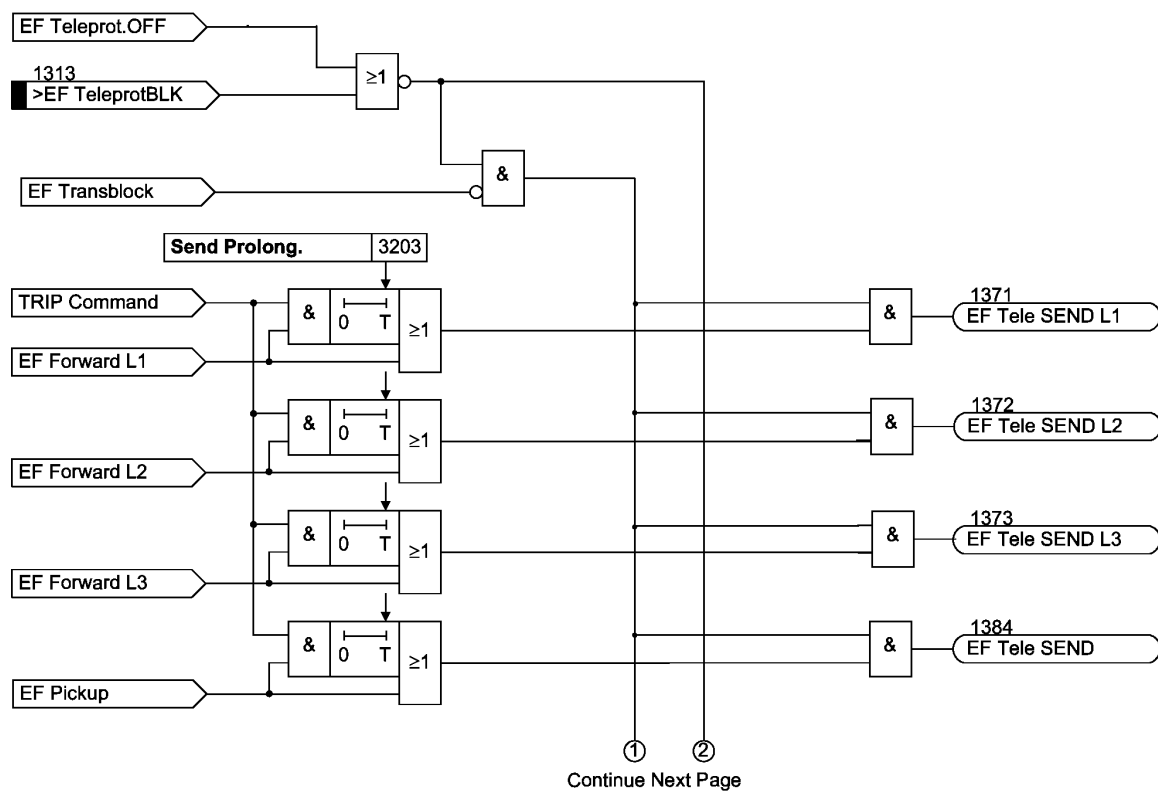
Figure 2-81   Logic diagram of the directional comparison scheme with protection data interface (for one device)
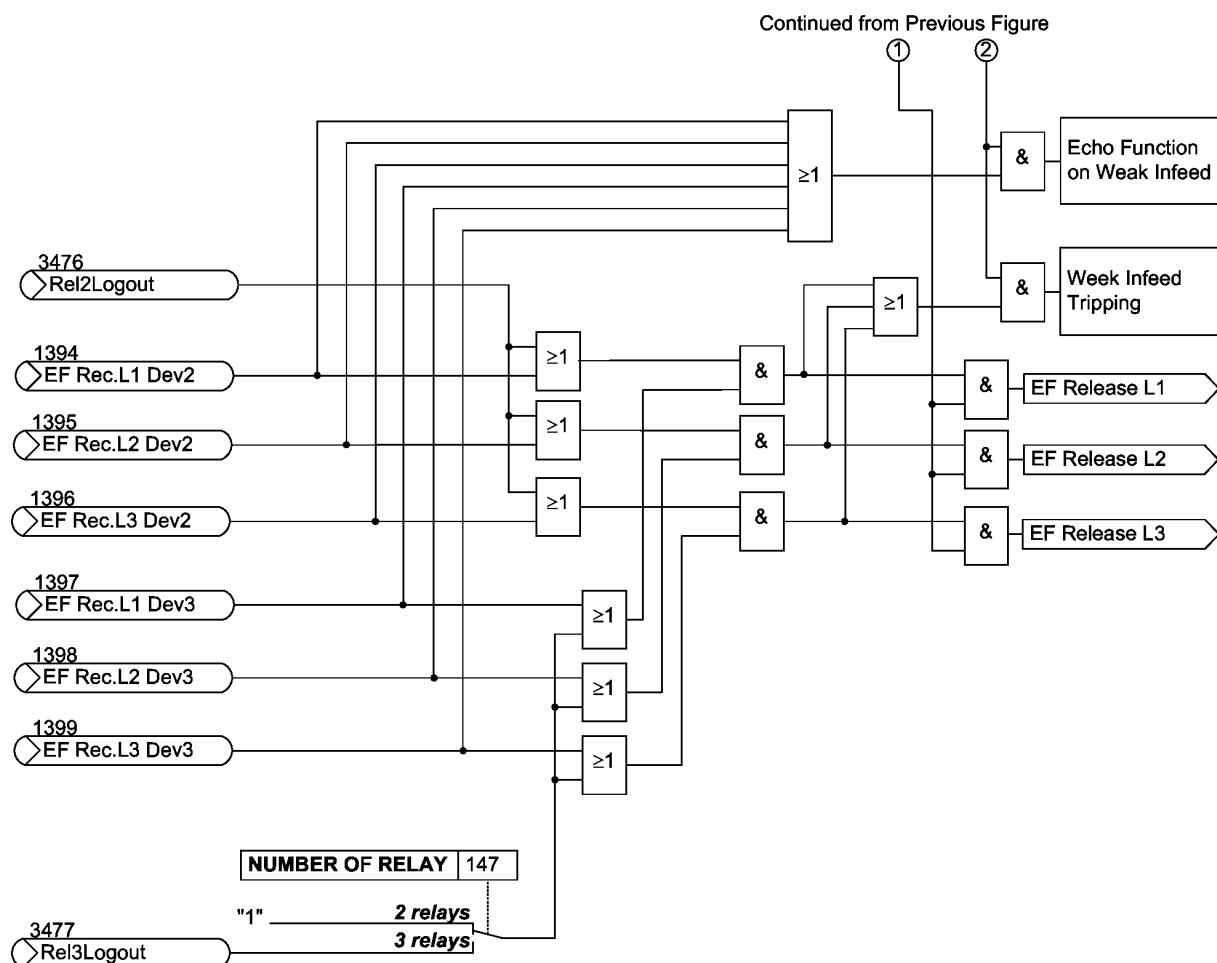
Figure 2-82   Logic diagram of the directional comparison scheme with protection data interface (for one device) — continued

2.8.3   Directional Unblocking Scheme

The following scheme is suited for conventional transmission media.

Principle

The unblocking method is a permissive scheme. It differs from the directional comparison scheme in that tripping is possible also when no release signal is received from the opposite line end. It is therefore mainly used for long lines when the signal must be transmitted across the protected feeder by means of power line carrier (PLC) and the attenuation of the transmitted signal at the fault location may be so severe that reception at the other line cannot necessarily be guaranteed.

The scheme functionality is shown in Figure 2-83.

Two signal frequencies which are keyed by the transmit output of the 7SA6 are required for the transmission. If the transmission device has a channel monitoring, then the monitoring frequency f_0 is keyed over to the working frequency f_U (unblocking frequency). When the protection recognizes an earth fault in the forward direction, it initiates the transmission of the unblock frequency f_U. During the quiescent state or during an earth fault in the reverse direction, the monitoring frequency f_0 is transmitted.

If the unblock frequency is received from the opposite end, a signal is routed to the trip logic. A pre-condition for fast fault clearance is therefore that the earth fault is recognized in the forward direction at both line ends.

The send signal can be prolonged by T_S (settable). The prolongation of the send signal only comes into effect if the protection has already issued a trip command. This ensures that the permissive signal releases the opposite line end even if the earth fault is very rapidly cleared by a different independent protection.

f_0 — quiescent frequency (monit. frequency)   U — unblocking signal
f_U — unblocking frequency (send frequency)   B — blocking signal
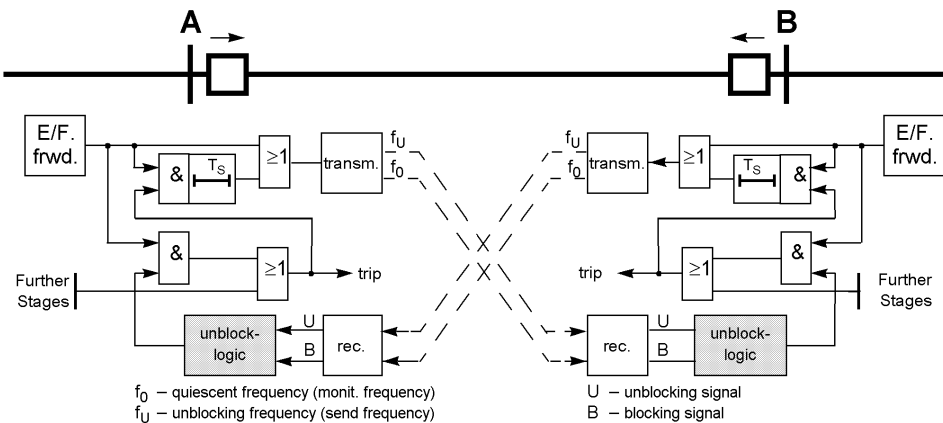
Figure 2-83   Operation scheme of the directional unblocking scheme

Sequence

Figure 2-84 shows the logic diagram of the unblocking scheme for one line end.

The directional unblocking scheme only functions for faults in the "forward" direction. Accordingly the overcurrent stage intended for operation in the directional unblocking scheme must definitely be set to *Forward* (*3IO... DIRECTION*); refer also to Subsection 2.7 at the margin heading "Teleprotection with Earth Fault Protection".

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signals are then combined with a logical AND gate, as all three line ends must transmit a send signal during an internal fault. With the setting parameter **Line Config.** (address 3202) the device is informed as to whether it has one or two opposite line ends.

An unblock logic is inserted before the receive logic, which in essence corresponds to that of the directional comparison scheme, see Figure 2-85. If an interference free unblock signal is received, a receive signal e.g. ">EF UB ub 1", appears and the blocking signal e.g. ">EF UB bl 1" disappears. The internal signal "Unblock 1" is forwarded to the receive logic where it initiates the release of the tripping (when all remaining conditions have been fulfilled).

If the transmitted signal does not reach the other line end because the short circuit on the protected feeder causes too much attenuation or reflection of the transmitted signal, the unblock logic takes effect: Neither the unblocking signal ">EF UB ub 1" nor the monitoring signal ">EF UB bl 1" are received. In this case, the release "Unblock 1" is issued after a security delay time of 20 ms and passed onto the receive logic. This release is however removed after a further 100 ms via the timer stage 100/100 ms. If the interference signal disappears again, one of the two receive signals must appear again, either ">EF UB ub 1" or ">EF UB bl 1"; after a further 100 ms (dropout delay of the timer stage 100/100 ms) the quiescent state is reached again i.e. the direct release path to the signal "Unblock L1" and thereby the usual release is

possible. On three terminal lines, the unblock logic can be controlled via both receive channels.

If none of the signals is received for a period of more than 10 s the alarm "EF TeleUB Fail1" is generated.

The occurrence of erroneous signals resulting from transients during clearance of external faults or from direction reversal resulting during the clearance of faults on parallel lines, is neutralized by the "Transient Blocking".

On lines where there is only a single sided infeed or where the star-point is only earthed behind one line end, the line end without zero sequence current cannot generate a permissive signal, as fault detection does not take place there. To also ensure tripping by the directional comparison in this case the device has special features. This "Weak-infeed tripping" (echo function) is referred to in Subsection "Measures for Weak and Zero Infeed". It is activated when a signal is received from the opposite line end — on three terminal lines, from at least one of the opposite ends — without the device recognizing an earth fault.

The circuit breaker can also be tripped at the line end with no or only weak infeed. This "Weak-infeed tripping" is referred to in Section 2.9.1.
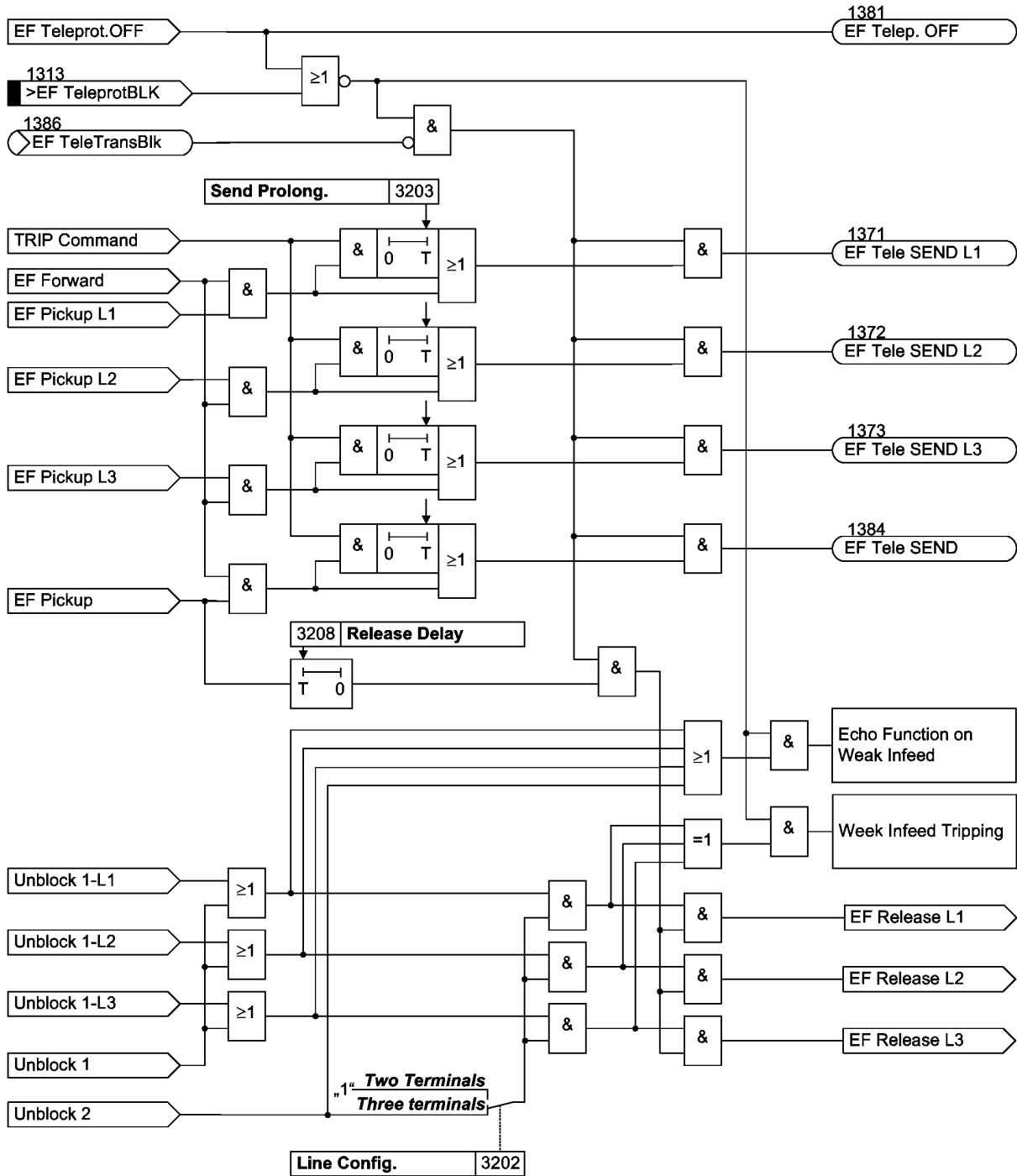
Figure 2-84   Logic diagram of the unblocking scheme (one line end)
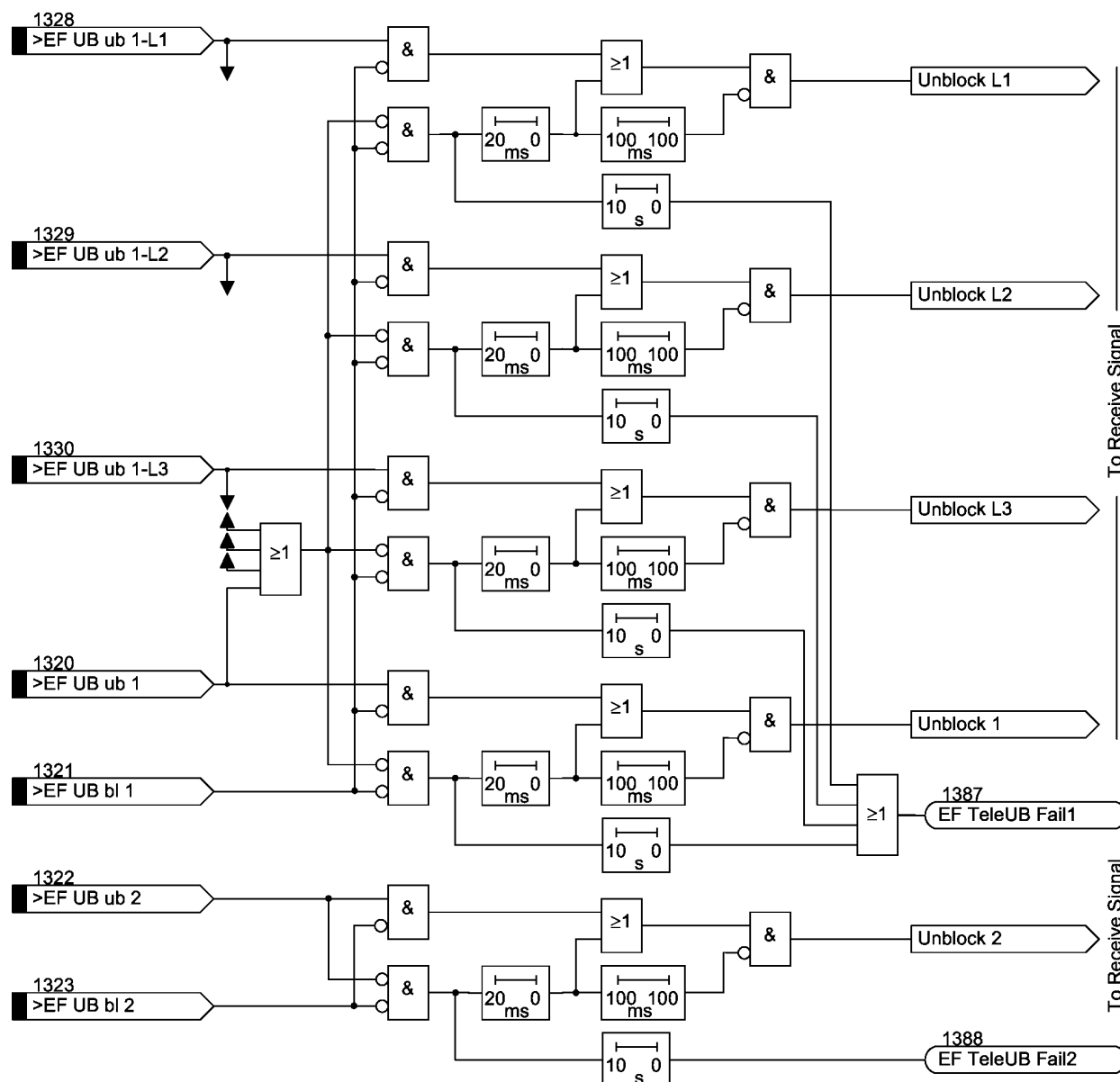
Figure 2-85   Unblock logic

2.8.4   Directional Blocking Scheme

The following scheme is suited for conventional transmission media.

Principle

In the case of the blocking scheme, the transmission channel is used to send a block signal from one line end to the other. The signal may be sent directly after fault inception (jump detector above dotted line), and stopped immediately, as soon as the distance protection detects a fault in the forward direction, alternatively the signal is only sent when the distance protection detects the fault in the reverse direction. It is stopped immediately as soon as the earth fault protection detects an earth fault in forward direction. Tripping is possible with this scheme even if no signal is received from the opposite line end. It is therefore mainly used for long lines when the signal must be transmitted across the protected feeder by means of power line carrier (PLC)

and the attenuation of the transmitted signal at the fault location may be so severe that reception at the other line cannot necessarily be guaranteed.

The scheme functionality is shown in Figure 2-86.

Earth faults in the forward direction cause tripping if a blocking signal is not received from the opposite line end. Due to possible differences in the pick up time delays of the devices at both line ends and due to the signal transmission time delay, the tripping must be somewhat delayed by T_V in this case.

To avoid signal race conditions, a transmit signal can be prolonged by the settable time T_S once it has been initiated.
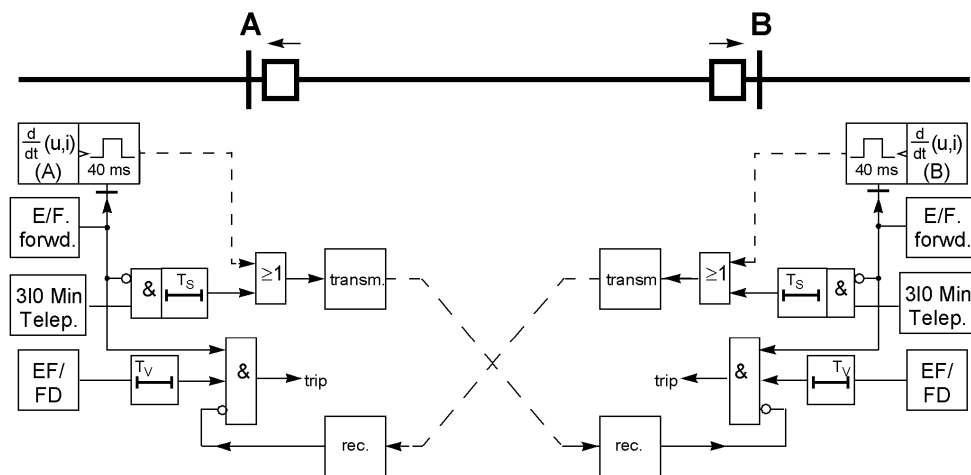
Figure 2-86   Operation scheme of the directional blocking method

Sequence

Figure 2-87 shows the logic diagram of the blocking scheme for one line end.

The stage to be blocked must be set to *Forward* (*3I0... DIRECTION*); refer also to Subsection 2.7 at the margin heading "Teleprotection with Earth Fault Protection".

On two terminal lines, the signal transmission may be phase segregated. Send and receive circuits in this case are built up for each phase. On three terminal lines, the transmit signal is sent to both opposite line ends. The receive signal is then combined with a logical OR gate as no blocking signal must be received from any line end during an internal fault. With the setting parameter *Line Config.* (address 3202) the device is informed as to whether it has one or two opposite line ends.
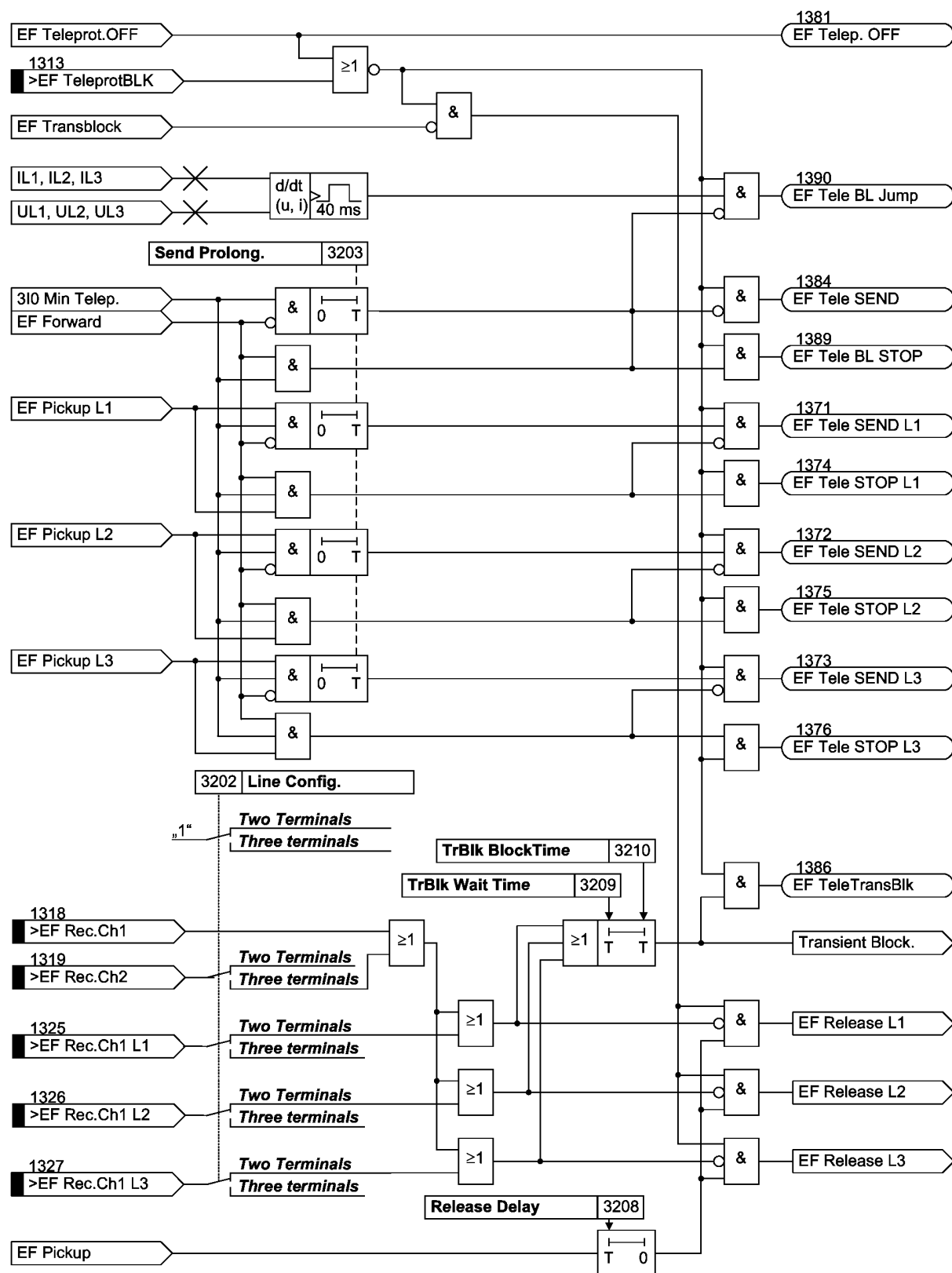
Figure 2-87   Logic diagram of the blocking scheme (one line end)

As soon as the earth fault protection has detected a fault in the reverse direction, a blocking signal is transmitted (e.g. "EF Tele SEND", FNo. 1384). The transmitted signal may be prolonged by setting address 3203 accordingly. The blocking signal is stopped if a fault is detected in the forward direction (e.g. "EF Tele BL STOP", FNo. 1389). Very rapid blocking is possible by transmitting also the output signal of the jump detector for measured values. To do so, the output "EF Tele BL Jump" (FNo. 1390) must also be allocated to the transmitter output relay. As this jump signal appears at every measured value jump, it should only be used if the transmission channel can be relied upon to respond promptly to the disappearance of the transmitted signal.

The occurrence of erroneous signals resulting from transients during clearance of external faults or from direction reversal resulting during the clearance of faults on parallel lines, is neutralized by the "Transient Blocking". It prolongs the blocking signal by the transient blocking time **TrBlk BlockTime** (address 3210), if it has been present for the minimum duration equal to the waiting time **TrBlk Wait Time** (address 3209).

It lies in the nature of the blocking scheme that single end fed short circuits can also be tripped rapidly without any special measures, as the non feeding end cannot generate a blocking signal.

2.8.5   Transient Blocking

Transient blocking provides additional security against erroneous signals due to transients caused by clearance of an external fault or by fault direction reversal during clearance of a fault on a parallel line.

The principle of transient blocking scheme is that following the incidence of an external fault, the formation of a release signal is prevented for a certain (settable) time. In the case of permissive schemes, this is achieved by blocking of the transmit and receive circuit.

Figure 2-88 shows the principle of the transient blocking for a directional comparison and directional unblocking scheme.

If, following fault detection, a non-directional fault or a fault in the reverse direction is determined within the waiting time **TrBlk Wait Time** (address 3209), the transmit circuit and the trip release are prevented. This blocking is maintained for the duration of the transient blocking time **TrBlk BlockTime** (address 3210) also after the reset of the blocking criterion.

In the case of the blocking scheme, the transient blocking prolongs the received blocking signal as shown in the logic diagram Figure 2-87.
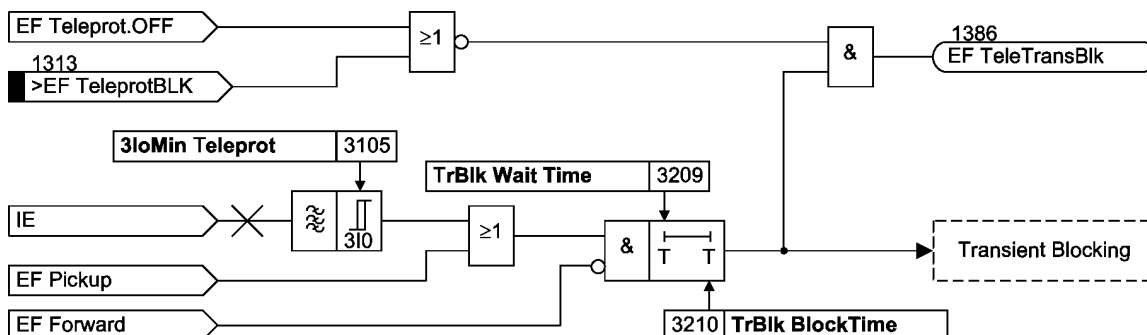
Figure 2-88   Transient blocking for a directional comparison and directional unblocking schemes

2.8.6   Measures for Weak or Zero Infeed

On lines where there is only a single sided infeed or where the star-point is only earthed behind one line end, the line end without zero sequence current cannot generate a permissive signal, as fault detection does not take place there. With the comparison schemes, using a permissive signal, fast tripping could not even be achieved at the line end with strong infeed without special measures, as the end with weak infeed does not transmit a permissive release signal.

To achieve rapid tripping at both line ends under these conditions, the device has a special supplement for lines with weak zero sequence infeed.

To enable even the line end with the weak infeed to trip, 7SA6 provides a weak infeed tripping supplement. Since this is a separate protection function with a dedicated trip command, it is described separately in Section 2.9.1.

Echo Function

Figure 2-89 shows the method of operation of the echo function. At address 2501 **FCT Weak Infeed** (<u>Weak</u> <u>Infeed</u> <u>Fun</u><u>CT</u>ion) can be activated (*ECHO only*) or deactivated (*OFF*). By means of this "switch" the weak infeed tripping function can also be activated (*ECHO and TRIP*, refer also to Section 2.9.1). This setting is common to the teleprotection function for the distance protection and for the earth fault protection.

The received signal at the line end that has no earth current is returned to the other line end as an "echo" by the echo function. The received echo signal at the other line end enables the release of the trip command.

The detection of the weak infeed condition and accordingly the requirement for an echo are combined in a central AND gate. The earth fault protection must neither be switched off nor blocked, as it would otherwise always produce an echo due to the missing fault detection.

The essential condition for an echo is the absence of an earth current (current stage **3IoMin Teleprot**) with simultaneous receive signal from the teleprotection scheme logic, as shown in the corresponding logic diagrams (Figure 2-80 or 2-84).

To prevent the generation of an echo signal after the line has been tripped and the earth current stage **3IoMin Teleprot** reset, it is no longer possible to generate an echo if a fault detection by the earth current stage had already been present (RS flip-flop in Figure 2-89). The echo can in any event be blocked via the binary input "**>EF BlkEcho**".

If the conditions for an echo signal are met, a short delay **Trip/Echo DELAY** is initially activated. This delay is necessary to avoid transmission of the echo if the protection at the weak line end has a longer fault detection time during reverse faults or if it picks up a little later due to unfavourable short-circuit current distribution. If however the circuit breaker at the non-feeding line end is open, this delay of the echo signal is not required. The echo delay time may then be bypassed. The circuit breaker position is provided by the central information control functions. (refer to Section 2.23.1).

The echo impulse is then transmitted (alarm output "**ECHO SIGNAL**"), the duration of which can be set with the parameter **Trip EXTENSION**. The "**ECHO SIGNAL**" must be allocated separately to the output relay for transmission, as it is not contained in the transmission signal "**EF Tele SEND**".

After output of the echo pulse or during the transmission signal of the earth fault protection, a new echo can not be sent for at least 50 ms (default setting). This prevents echo repetition after the line has been switched off.

The echo function is not required for the blocking scheme, and is therefore ineffective.
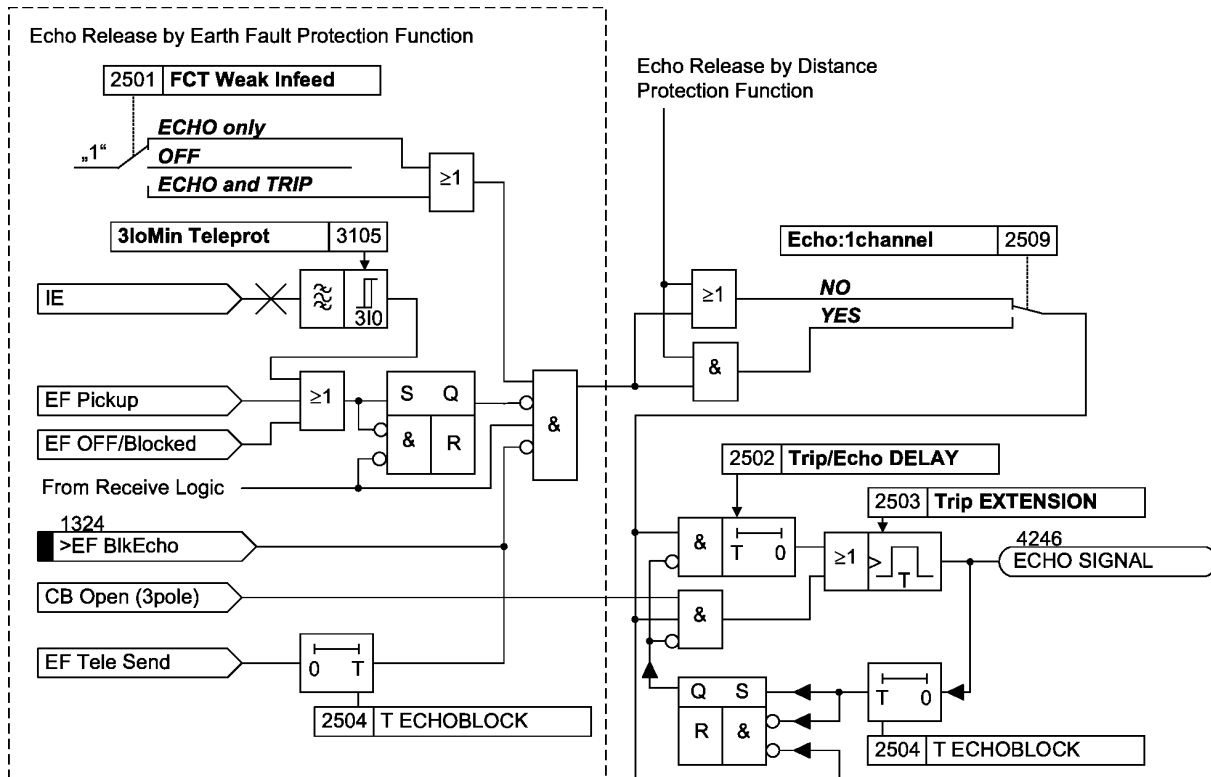
Figure 2-89   Logic diagram of the echo function for the earth fault protection with teleprotection

2.8.7   Setting Notes

General

The teleprotection supplement for earth fault protection is only operational if it was set to one of the available modes during the configuration of the device (address 132). Depending on this configuration, only those parameters which are applicable to the selected mode appear here. If the teleprotection supplement is not required the address 132 is set to **Teleprot. E/F** = *Disabled*. If a protection interface is available, the additional setting text **SIGNALv.ProtInt** is displayed in address 132 **Teleprot. E/F**.

Conventional Transmission

The following modes are possible with conventional transmission links (as described in Subsection 2.8):

Dir.Comp.Pickup   = Directional Comparison Pickup,

UNBLOCKING   = Directional Unblocking Scheme,

BLOCKING   = Directional Blocking Scheme.

At address 3201 **FCT Telep. E/F** the use of a teleprotection scheme can be switched *ON* or *OFF*.

If the teleprotection has to be applied to a three terminal line the setting in address 3202 must be **Line Config.** = *Three terminals*, if not, the setting remains *Two Terminals*.

Digital Transmission

The following mode is possible with digital transmission using the protection data interface:

SIGNALv.ProtInt = Directional Comparison Pickup.

At address 3201 **FCT Telep. E/F** the use of a teleprotection scheme can be switched ***ON*** or ***OFF***. Address 147 **NUMBER OF RELAY** indicates the number of ends and must be set identically in all devices. The earth fault directional comparison pickup scheme via the protection interface is only active if parameter 132 **Teleprot. E/F** was set to ***SIGNALv.ProtInt*** for <u>all</u> devices in a constellation.

Earth Fault Protection Prerequisites

In the application of the comparison schemes, absolute care must be taken that both line ends recognize an external earth fault (earth fault current flowing through) in order to avoid a faulty echo signal in the case of the permissive schemes, or in order to ensure the blocking signal in the case of the blocking scheme. If, during an earth fault according to Figure 2-90, the protection at B does not recognize the fault, this would be interpreted as a fault with single sided infeed from A (echo from B or no blocking signal from B), which would lead to unwanted tripping by the protection at A. Therefore, the earth fault protection features an earth fault stage **3IoMin Teleprot** (address 3105). This stage must be set more sensitive than the earth current stage used for the teleprotection. The larger the capacitive earth current (I_{EC} in Figure 2-90) is the smaller this stage must be set. On overhead lines a setting equal to 70% to 80% of the earth current stage is usually adequate. On cables or very long lines where the capacitive currents in the event of an earth fault are of the same order of magnitude as the earth fault currents the echo function should not be used or restricted to the case where the circuit breaker is open; the blocking scheme should not be used under these conditions at all.
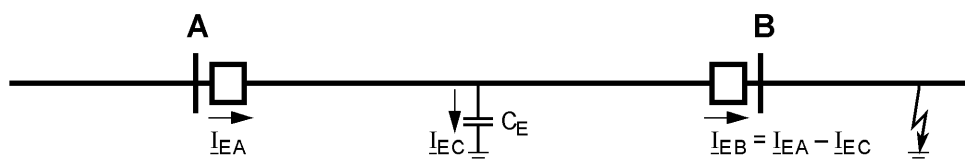
Figure 2-90   Possible current distribution during external earth fault

On three terminal lines (teed feeders) it should further be noted that the earth fault current is not equally distributed on the line ends during an external fault. The most unfavourable case is shown in Figure 2-91. In this case, the earth current flowing in from A is distributed equally on the line ends B and C. The setting value **3IoMin Teleprot** (address 3105), which is decisive for the echo or the blocking signal, must therefore be set smaller than one half of the setting value for the earth current stage used for teleprotection. In addition, the above comments regarding the capacitive earth current which is left out in Figure 2-91 apply. If the earth current distribution is different from the distribution assumed here, the conditions are more favourable as one of the two earth currents I_{EB} or I_{EC} must then be larger than in the situation described previously.
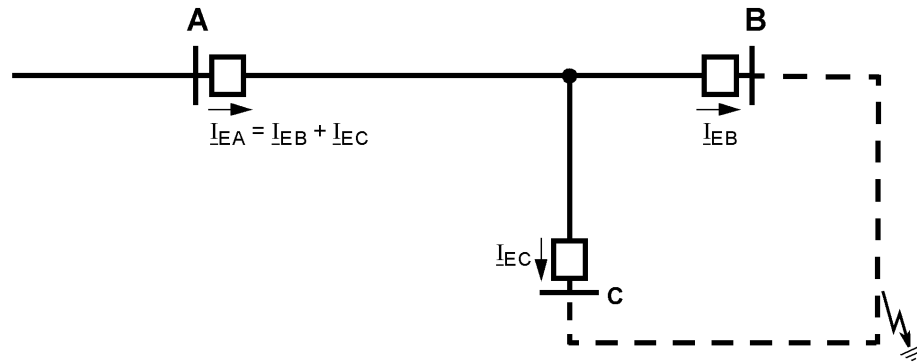
Figure 2-91   Possible unfavourable current distribution on a three terminal line during an external earth fault

Time Settings

The send signal prolongation **Send Prolong.** (address 3203) must ensure that the send signal reliably reaches the opposite line end, even if there is very fast tripping at the sending line end and/or the signal transmission time is relatively long. In the case of the permissive schemes *Dir.Comp.Pickup* and *UNBLOCKING* this signal prolongation time is only effective if the device has already issued a trip command. This ensures the release of the other line end even if the short-circuit is cleared very rapidly by a different protection function or other stage. In the case of the blocking scheme *BLOCKING* the transmit signal is always prolonged by this time. In this case it corresponds to a transient blocking following a reverse fault. This setting is only possible via DIGSI® at **Additional Settings**.

In order to detect steady-state line faults such as open circuits, a monitoring time **Delay for alarm** is started when a fault is detected (address 3207). Upon expiration of this time the fault is considered a permanent failure. This setting is only possible via DIGSI® at **Additional Settings**.

The release of the directional tripping can be delayed by means of the permissive signal delay **Release Delay** (address 3208). In general, this is **only** required for the blocking scheme *BLOCKING* to allow sufficient transmission time for the blocking signal during external faults. This delay only has an effect on the receive circuit of the teleprotection. Conversely, tripping by the comparison protection is **not** delayed by the set time delay of the directional stage.

Transient Blocking

The setting parameters **TrBlk Wait Time** and **TrBlk BlockTime** are for the transient blocking with the comparison schemes. This setting is only possible via DIGSI® at **Additional Settings**.

The time **TrBlk Wait Time** (address 3209) is a waiting time prior to transient blocking. In the case of the permissive schemes, only once the directional stage of the earth fault protection has recognized a fault in the reverse direction, within this period of time after fault detection, will the transient blocking be activated. In the case of the blocking scheme, the waiting time prevents transient blocking in the event that the blocking signal reception from the opposite line end is very fast. With the setting ∞ there is no transient blocking.

The transient blocking time **TrBlk BlockTime** (address 3210) must definitely be set longer than the duration of severe transients resulting from the inception or clearance of external faults. The send signal is delayed by this time with the permissive overreach schemes *Dir.Comp.Pickup* and *UNBLOCKING* if the protection had initially detected a reverse fault. In the case of the blocking scheme *BLOCKING* the received (blocking) signal is prolonged by this time.

The preset value should be sufficient in most cases.

Echo Function   In the case of line ends with weak infeed, or not sufficient earth current, the echo function is sensible for the permissive scheme so that the infeeding line end can be released. The echo function at address 2501 **FCT Weak Infeed** can be activated (*ECHO only*) or deactivated (*OFF*). By means of this "switch" the weak infeed tripping function can also be activated (*ECHO and TRIP*, refer also to Section 2.9.1).

Please do not fail do read the comments regarding the setting of the current stage **3IoMin Teleprot** (address 3105) in the above margin heading "Earth Fault Protection Prerequisites".

The echo delay time **Trip/Echo DELAY** (address 2502) must be set long enough to avoid incorrect echo signals resulting from the difference in fault detection pick-up time of the earth fault protection functions at all line ends during external faults (through-fault current). Typical setting is approx. 40 ms (presetting). This setting is only possible via DIGSI® at **Additional Settings**.

The echo impulse duration **Trip EXTENSION** (address 2503) may be matched to the configuration data of the signal transmission equipment. It must be long enough to ensure that the receive signal is recognized even with different pick-up times by the protection devices at the two line ends and different response times of the transmission equipment. In most cases approx. 50 ms (presetting) is sufficient. This setting is only possible via DIGSI® at **Additional Settings**.

An endless echo signal between the line ends can be avoided (e.g. interference coupling in the signal path) by blocking after each output of an echo signal a new echo for a certain time **Echo BLOCK Time** (address 2504). The typical setting is approx. 50 ms. After the earth fault protection signal was sent, the echo is equally blocked for the time **Echo BLOCK Time**. This setting is only possible via DIGSI® at **Additional Settings**.

If the distance protection and earth fault protection use a common transmission channel, spurious tripping may occur when the distance protection and the earth fault protection create an echo independently of each other. For this scenario, parameter **Echo:1channel** (address 2509) must be set to *YES*. The default setting is *NO*.

Note

The "ECHO SIGNAL" (FNo 4246) must be allocated separately to the output relays for the transmitter actuation, as it is not contained in the transmit signals of the transmission functions. On the digital protection data interface with permissive overreach transfer trip mode, the echo is transmitted as a separate signal without taking any special measures.

The echo function settings are common to all weak infeed measures and summarized in tabular form in Section 2.9.1.

2.8.8   Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
3201	FCT Telep. E/F	ON OFF	ON	Teleprotection for Earth Fault O/C
3202	Line Config.	Two Terminals Three terminals	Two Terminals	Line Configuration
3203A	Send Prolong.	0.00 .. 30.00 sec	0.05 sec	Time for send signal prolongation
3207A	Delay for alarm	0.00 .. 30.00 sec	10.00 sec	Unblocking: Time Delay for Alarm
3208	Release Delay	0.000 .. 30.000 sec	0.000 sec	Time Delay for release after pickup
3209A	TrBlk Wait Time	0.00 .. 30.00 sec; ∞	0.04 sec	Transient Block.: Duration external flt.
3210A	TrBlk BlockTime	0.00 .. 30.00 sec	0.05 sec	Transient Block.: Blk.T. after ext. flt.

2.8.9   Information List

No.	Information	Type of Information	Comments
1311	>EF Teleprot.ON	SP	>E/F Teleprotection ON
1312	>EF TeleprotOFF	SP	>E/F Teleprotection OFF
1313	>EF TeleprotBLK	SP	>E/F Teleprotection BLOCK
1318	>EF Rec.Ch1	SP	>E/F Carrier RECEPTION, Channel 1
1319	>EF Rec.Ch2	SP	>E/F Carrier RECEPTION, Channel 2
1320	>EF UB ub 1	SP	>E/F Unblocking: UNBLOCK, Channel 1
1321	>EF UB bl 1	SP	>E/F Unblocking: BLOCK, Channel 1
1322	>EF UB ub 2	SP	>E/F Unblocking: UNBLOCK, Channel 2
1323	>EF UB bl 2	SP	>E/F Unblocking: BLOCK, Channel 2
1324	>EF BlkEcho	SP	>E/F BLOCK Echo Signal
1325	>EF Rec.Ch1 L1	SP	>E/F Carrier RECEPTION, Channel 1, Ph.L1
1326	>EF Rec.Ch1 L2	SP	>E/F Carrier RECEPTION, Channel 1, Ph.L2
1327	>EF Rec.Ch1 L3	SP	>E/F Carrier RECEPTION, Channel 1, Ph.L3
1328	>EF UB ub 1-L1	SP	>E/F Unblocking: UNBLOCK Chan. 1, Ph.L1
1329	>EF UB ub 1-L2	SP	>E/F Unblocking: UNBLOCK Chan. 1, Ph.L2
1330	>EF UB ub 1-L3	SP	>E/F Unblocking: UNBLOCK Chan. 1, Ph.L3
1371	EF Tele SEND L1	OUT	E/F Telep. Carrier SEND signal, Phase L1
1372	EF Tele SEND L2	OUT	E/F Telep. Carrier SEND signal, Phase L2
1373	EF Tele SEND L3	OUT	E/F Telep. Carrier SEND signal, Phase L3
1374	EF Tele STOP L1	OUT	E/F Telep. Block: carrier STOP signal L1
1375	EF Tele STOP L2	OUT	E/F Telep. Block: carrier STOP signal L2
1376	EF Tele STOP L3	OUT	E/F Telep. Block: carrier STOP signal L3

No.	Information	Type of In-formation	Comments
1380	EF TeleON/offBI	IntSP	E/F Teleprot. ON/OFF via BI
1381	EF Telep. OFF	OUT	E/F Teleprotection is switched OFF
1384	EF Tele SEND	OUT	E/F Telep. Carrier SEND signal
1386	EF TeleTransBlk	OUT	E/F Telep. Transient Blocking
1387	EF TeleUB Fail1	OUT	E/F Telep. Unblocking: FAILURE Channel 1
1388	EF TeleUB Fail2	OUT	E/F Telep. Unblocking: FAILURE Channel 2
1389	EF Tele BL STOP	OUT	E/F Telep. Blocking: carrier STOP signal
1390	EF Tele BL Jump	OUT	E/F Tele.Blocking: Send signal with jump
1391	EF Rec.L1 Dev1	OUT	EF Tele.Carrier RECEPTION, L1, Device1
1392	EF Rec.L2 Dev1	OUT	EF Tele.Carrier RECEPTION, L2, Device1
1393	EF Rec.L3 Dev1	OUT	EF Tele.Carrier RECEPTION, L3, Device1
1394	EF Rec.L1 Dev2	OUT	EF Tele.Carrier RECEPTION, L1, Device2
1395	EF Rec.L2 Dev2	OUT	EF Tele.Carrier RECEPTION, L2, Device2
1396	EF Rec.L3 Dev2	OUT	EF Tele.Carrier RECEPTION, L3, Device2
1397	EF Rec.L1 Dev3	OUT	EF Tele.Carrier RECEPTION, L1, Device3
1398	EF Rec.L2 Dev3	OUT	EF Tele.Carrier RECEPTION, L2, Device3
1399	EF Rec.L3 Dev3	OUT	EF Tele.Carrier RECEPTION, L3, Device3

2.9 Weak-infeed tripping

In cases, where there is no or only weak infeed present at one line end, the distance protection does not pick up there during a short-circuit on the line. The settings and information table at "Weak Infeed" applies for the following functions.

If there is no or only a very small zero sequence current at one line end during an earth fault, the earth fault protection can also not function.

2.9.1 Classical Tripping

2.9.1.1 Method of Operation

Transmission Schemes

By coordinating the weak infeed function with the teleprotection in conjunction with distance protection and/or earth fault protection, fast tripping can also be achieved at both line ends in the above cases.

At the strong infeed line end, the distance protection can always trip instantaneously for faults inside zone Z1. With permissive teleprotection schemes, fast tripping for faults on 100°% of the line length is achieved by activation of the echo function (refer to Subsection 2.6). This provides the permissive release of the trip signal at the strong infeed line end.

The permissive teleprotection scheme in conjunction with the earth fault protection can also achieve release of the trip signal at the strong infeed line end by means of the echo function (refer to Subsection 2.8).

In many cases tripping of the circuit breaker at the weak infeeding line end is also desired. For this purpose the device 7SA6 has a dedicated protection function with dedicated trip command.

Pickup with Under-voltage

In Figure 2-92 the logic diagram of the weak-infeed tripping is shown. At address 2501 **FCT Weak Infeed** (<u>Weak</u> <u>Infeed</u> <u>FunCT</u>ion) can be activated (***ECHO and TRIP***) or deactivated (***OFF***). If this "switch" is set to ***ECHO only***, the tripping is also disabled; however the echo function to release the infeeding line end is activated (refer also to Subsection 2.6 and 2.8). The tripping function can be blocked at any time via the binary input "**>BLOCK Weak Inf**".

The logic for the detection of a weak-infeed condition is built up per phase in conjunction with the distance protection and additionally once for the earth fault protection. Since the undervoltage check is performed for each phase, single-pole tripping is also possible, provided the device version has the single-pole tripping option.

In the event of a short circuit, it may be assumed that only a small voltage appears at the line end with the weak-infeed condition, as the small fault current only produces a small voltage drop in the short-circuit loop. In the event of zero-infeed, the loop voltage is approximately zero. The weak-infeed tripping is therefore dependent on the measured undervoltage **UNDERVOLTAGE** which is also used for the selection of the faulty phase.

If a signal is received from the opposite line end without fault detection by the local protection, this indicates that there is a fault on the protected feeder. In the case of three terminal lines when using a permissive overreach scheme a receive signal from both ends may be present. In case of permissive underreach schemes one receive signal from at least one end is sufficient.

After a security margin time of 40 ms following the start of the receive signal, the weak-infeed tripping is released if the remaining conditions are satisfied: undervoltage, circuit breaker closed and no pickup of the distance protection or of the earth fault protection.

To avoid a faulty pickup of the weak infeed function following tripping of the line and reset of the fault detection, the function cannot pick up anymore once a fault detection in the affected phase was present (RS flip-flop in Figure 2-92).

In the case of the earth fault protection, the release signal is routed via the phase segregated logic modules. Single-phase tripping is therefore also possible if both distance protection and earth fault protection or exclusively earth fault protection issues a release condition.
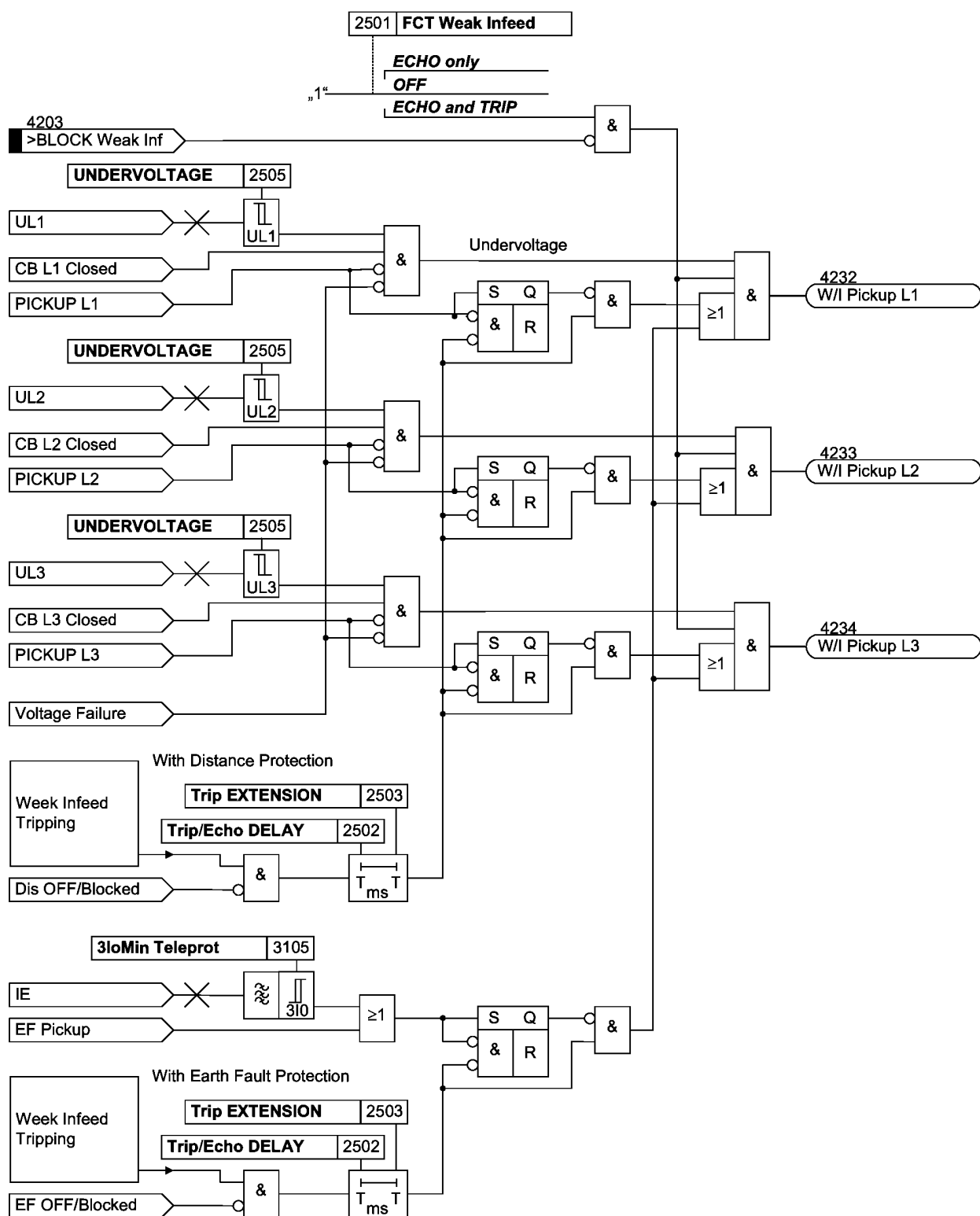
Figure 2-92   Logic diagram of the weak infeed tripping

2.9.1.2 Setting Notes

General

It is a prerequisite for the operation of the weak infeed function that it was enabled during the configuration of the device at address 125 **Weak Infeed** = *Enabled*.

With the parameter **FCT Weak Infeed** (address 2501) it is determined whether the device shall trip during a weak infeed condition or not. With the setting *ECHO and TRIP* both the echo function and the weak infeed tripping function are activated. With the setting *ECHO only* the echo function for provision of the release signal at the in-feeding line end is activated. There is however no tripping at the line end with missing or weak infeed condition. As the weak-infeed measures are dependent on the signal reception from the opposite line end, they only make sense if the protection is coordinated with teleprotection (refer to Section 2.6 and/or 2.8).

The receive signal is a functional component of the trip condition. Accordingly, the weak infeed tripping function must **not be used with the blocking schemes**. It is only permissible with the permissive schemes and the comparison schemes with release signals! In all other cases it should be switched *OFF* at address 2501. In such cases it is better to disable this function from the onset by setting address 125 to *Disabled* during the device configuration. The associated parameters are then not accessible.

The undervoltage setting value **UNDERVOLTAGE** (address 2505) must in any event be set below the minimum expected operational phase–earth voltage. The lower limit for this setting is given by the maximum expected voltage drop at the relay location on the weak-infeed side during a short-circuit on the protected feeder for which the distance protection may no longer pick up.

The remaining settings apply to the echo function and are described in the corresponding sections (2.6 or 2.8).

2.9.2 Tripping According to French Specification

2.9.2.1 Method of Operation

An alternative for detecting weak infeed is only available in the models 7SA6***-**D**.

Pickup with Relative Voltage Jump

In addition to the classical function of weak infeed the so-called *Logic no. 2* (address 125) presents an alternative to the method used so far.

This function operates independently of the teleprotection scheme by using its own receive signal and it is able to trip with delay and without delay.

**Non-delayed Trip-
ping**
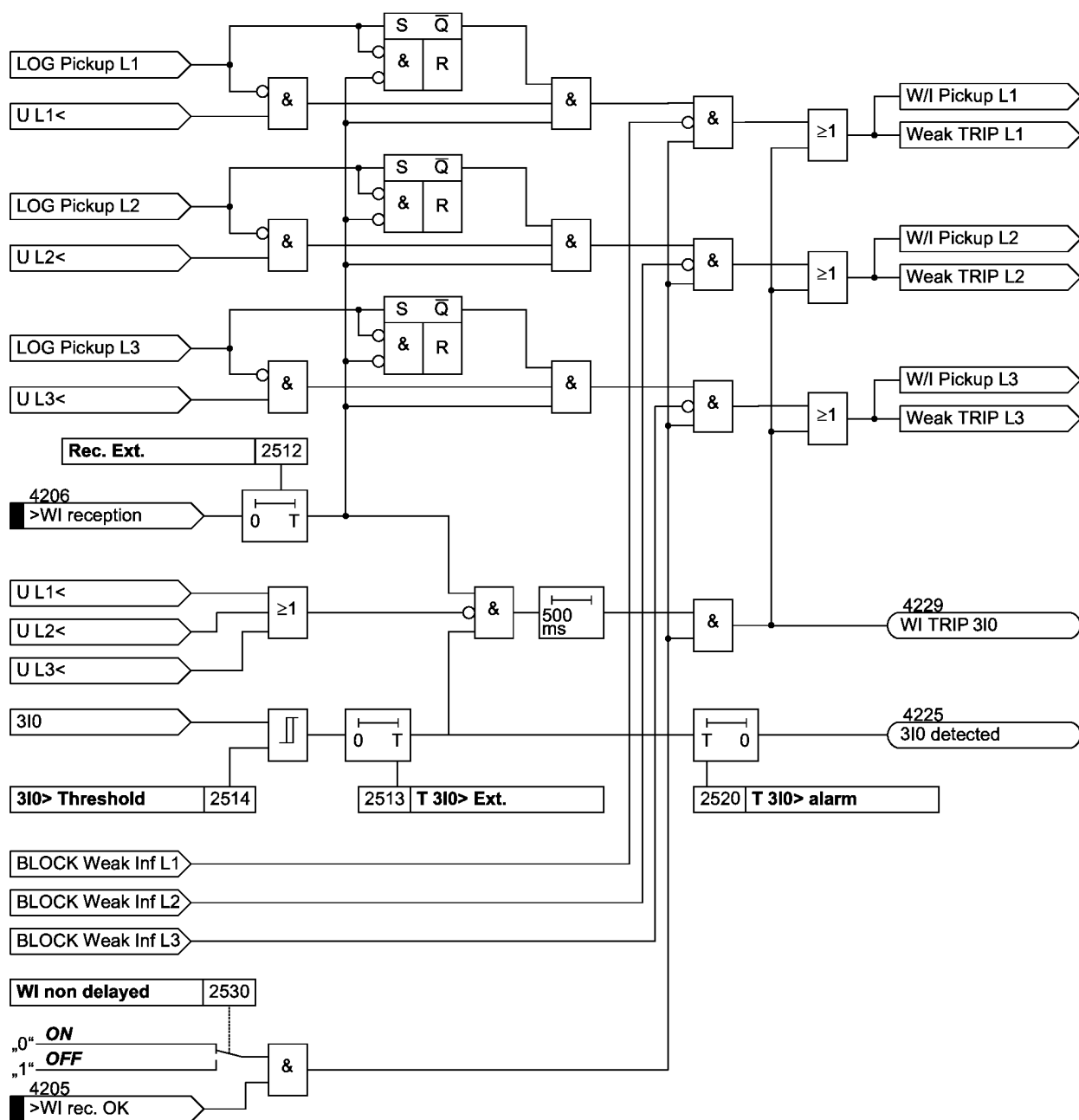
Figure 2-93   Logic diagram for non-delayed tripping

Trip with Delay
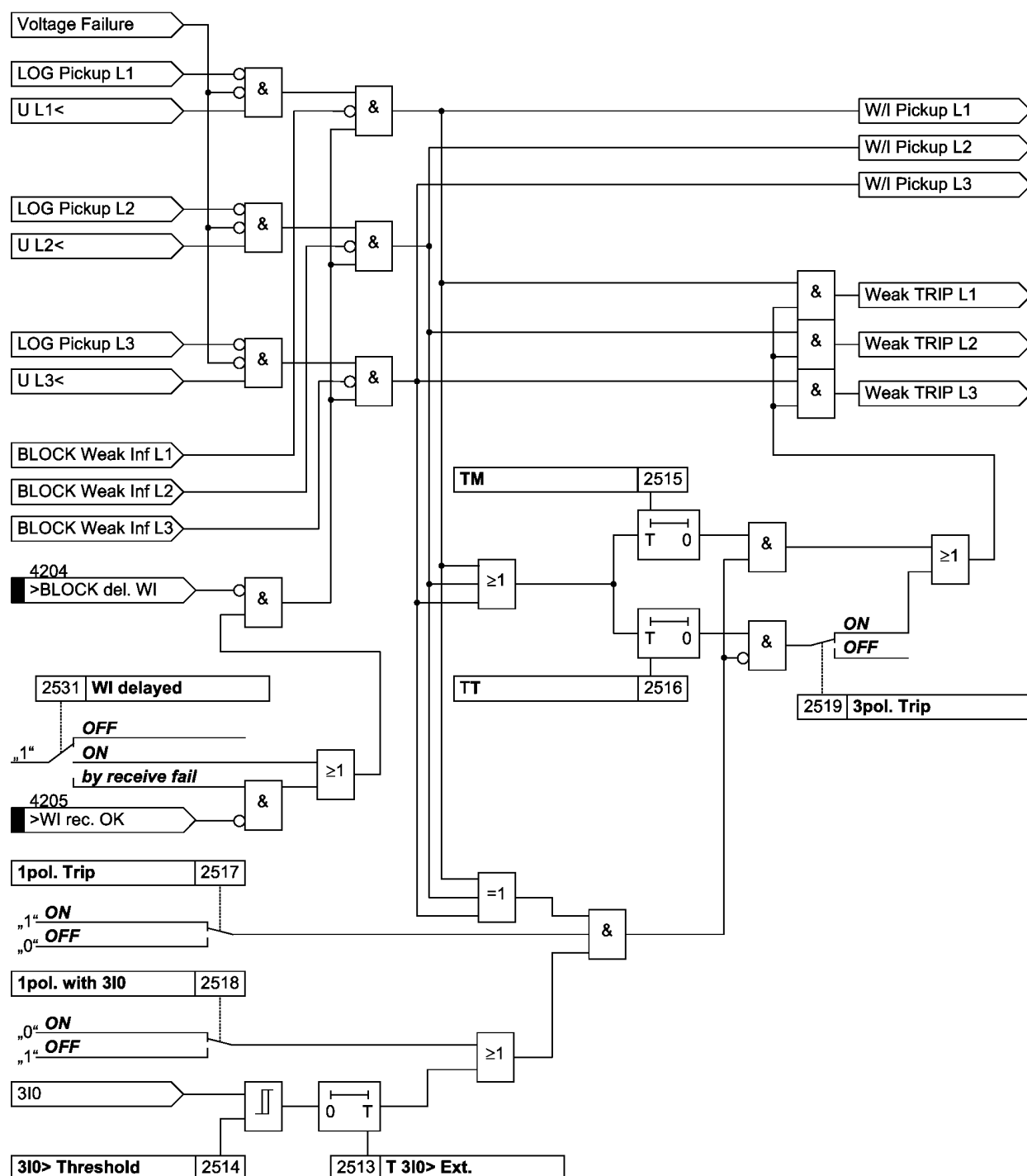
Figure 2-94　　Logic for delayed tripping

2.9.2.2 Setting Notes

Echo Enable   Applications with a transmission channel used by both the distance and the earth fault protection spurious trippings may occur, if distance protection and earth fault protection create an echo independently from each other. In this case parameter **Echo:1channel** (address 2509) has to be set to **YES**. The default setting is **NO**.

Phase Selection   Phase selection is accomplished via undervoltage detection. For this purpose no absolute voltage threshold in volts is parameterized but a factor (address 2510 **Uphe< Factor**), which is multiplied with the measured phase-phase voltage, and yields the voltage threshold. This method accounts for operational deviations from the rated voltage in the undervoltage threshold and adjusts them to the prevailing conditions.

Since a sound positive phase-to-phase voltage is not available in the event of a fault, the undervoltage threshold is delayed. Thus changes in the phase-to-phase voltage affect the threshold only slowly. The time constant can be set at address 2511 **Time const.** τ. The undervoltage is determined for all 3 phases.

If the measured phase-to-phase voltage falls below the threshold (address 1131 **PoleOpenVoltage**), undervoltage is no longer detected in this phase.
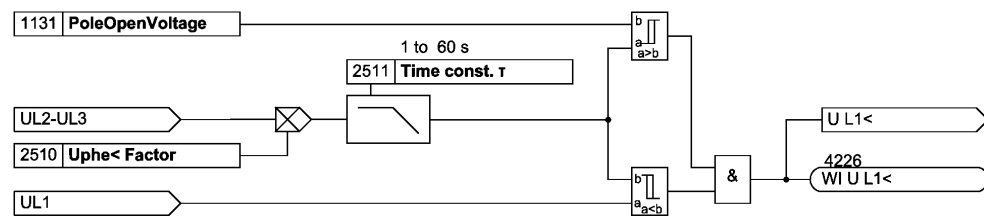
Figure 2-95   Undervoltage Detection for U_{L1-E}

Non-delayed Tripping   An undelayed TRIP command is issued if a receive signal ">WI reception" is present and an undervoltage condition is detected simultaneously. If another protection function capable to detect faults has picked up in the relay, the corresponding phases in the weak-infeed function are blocked. The receive signal is prolonged at address 2512 **Rec. Ext.**, so that a trip command is still possible in the event of a quick dropout of the transmitting line end.

To avoid a faulty pickup of the weak infeed function following tripping of the line and reset of the fault detection, the function cannot pick up any more once an inverse-time overcurrent fault detection in the affected phase was present.

If a receive signal applies and no undervoltage is detected but the zero sequence current threshold **3I0> Threshold** is exceeded, (address 2514) a fault on the line can be assumed. If this state (receive signal, no undervoltage and zero sequence current) applies for longer than 500 ms, 3-pole tripping is initiated. The time delay of "3I0> exceeded" is set at address 2513 **T 3I0> Ext.**. If the zero sequence current exceeds the threshold **3I0> Threshold** for longer than the set time **T 3I0> alarm** (address 2520), the annunciation "3I0 detected" is issued.

The non-delayed stage operates only if binary input ">WI rec. OK" reports the proper functioning of the transmission channel.

Moreover, the phase-selective block signals **BLOCK Weak Inf** affect the non-delayed logic. Faulty pickups are thus prevented, especially after the dedicated line end was shut down.

In address 2530 **WI non delayed** the stage for instantaneous tripping is switched *OFF* or *ON* continuously.

Trip with Delay

The operation of the delayed tripping is determined by three parameters:

- Address 2517 **1pol. Trip** enables a single-pole trip command in case of single-pole faults if set to *ON*.
- If set to *ON*, address 2518 **1pol. with 3I0** allows a single-pole trip command only if the threshold **3I0> Threshold** for the zero current has been surpassed. Position *OFF* allows a single-pole trip command even when **3I0> Threshold** is not exceeded. The time delay of "3I0> exceeded" is set at address 2513 **T 3I0> Ext.**.
- If set to *ON*, address 2519 **3pol. Trip** allows also a three-pole trip command. In position *OFF* the multi-pole pickup is only reported but a three-pole trip command is not issued (only report). But a single-pole trip command can nevertheless be issued.

A delayed tripping stage is implemented to allow tripping the dedicated line end in case the transmission channel is faulted. When undervoltage conditions have been detected, this stage picks up in one or more phases and after a configured time (address 2515 **TM** and address 2516 **TT**) has elapsed it trips without delay.

The delayed-tripping stage **WI delayed** is switched *ON* or *OFF* - permanently at address 2531. The setting *by receive fail* only activates this stage if ">WI rec. OK" is **not** reported as OFF.

To avoid erroneous pickup, phase selection via undervoltage is blocked entirely in the event of voltage failure (pickup of the fuse failure monitor or of the VT mcb). Moreover the corresponding phases are equally blocked if another protection function, capable to detect faults, picks up.

2.9.2.3 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
2501	FCT Weak Infeed		OFF ECHO only ECHO and TRIP	ECHO only	Weak Infeed function is
2502A	Trip/Echo DELAY		0.00 .. 30.00 sec	0.04 sec	Trip / Echo Delay after carrier receipt
2503A	Trip EXTENSION		0.00 .. 30.00 sec	0.05 sec	Trip Extension / Echo Impulse time
2504A	Echo BLOCK Time		0.00 .. 30.00 sec	0.05 sec	Echo Block Time
2505	UNDERVOLTAGE		2 .. 70 V	25 V	Undervoltage (ph-e)
2509	Echo:1channel		NO YES	NO	Echo logic: Dis and EF on common channel
2510	Uphe< Factor		0.10 .. 1.00	0.70	Factor for undervoltage Uphe<

Addr.	Parameter	C	Setting Options	Default Setting	Comments
2511	Time const. τ		1 .. 60 sec	5 sec	Time constant Tau
2512A	Rec. Ext.		0.00 .. 30.00 sec	0.65 sec	Reception extension
2513A	T 3I0> Ext.		0.00 .. 30.00 sec	0.60 sec	3I0> exceeded extension
2514	3I0> Threshold	1A	0.05 .. 1.00 A	0.50 A	3I0 threshold for neutral current pickup
		5A	0.25 .. 5.00 A	2.50 A	
2515	TM		0.00 .. 30.00 sec	0.40 sec	WI delay single pole
2516	TT		0.00 .. 30.00 sec	1.00 sec	WI delay multi pole
2517	1pol. Trip		ON OFF	ON	Single pole WI trip allowed
2518	1pol. with 3I0		ON OFF	ON	Single pole WI trip with 3I0
2519	3pol. Trip		ON OFF	ON	Three pole WI trip allowed
2520	T 3I0> alarm		0.00 .. 30.00 sec	10.00 sec	3I0> exceeded delay for alarm
2530	WI non delayed		ON OFF	ON	WI non delayed
2531	WI delayed		ON OFF by receive fail	OFF	WI delayed

2.9.2.4 Information List

No.	Information	Type of Information	Comments
4203	>BLOCK Weak Inf	SP	>BLOCK Weak Infeed
4204	>BLOCK del. WI	SP	>BLOCK delayed Weak Infeed stage
4205	>WI rec. OK	SP	>Reception (channel) for Weak Infeed OK
4206	>WI reception	SP	>Receive signal for Weak Infeed
4221	WeakInf. OFF	OUT	Weak Infeed is switched OFF
4222	Weak Inf. BLOCK	OUT	Weak Infeed is BLOCKED
4223	Weak Inf ACTIVE	OUT	Weak Infeed is ACTIVE
4225	3I0 detected	OUT	Weak Infeed Zero seq. current detected
4226	WI U L1<	OUT	Weak Infeed Undervoltg. L1
4227	WI U L2<	OUT	Weak Infeed Undervoltg. L2
4228	WI U L3<	OUT	Weak Infeed Undervoltg. L3
4229	WI AUS 3I0	OUT	WI TRIP with zero sequence current
4231	WeakInf. PICKUP	OUT	Weak Infeed PICKED UP
4232	W/I Pickup L1	OUT	Weak Infeed PICKUP L1
4233	W/I Pickup L2	OUT	Weak Infeed PICKUP L2
4234	W/I Pickup L3	OUT	Weak Infeed PICKUP L3
4241	WeakInfeed TRIP	OUT	Weak Infeed General TRIP command
4242	Weak TRIP 1p.L1	OUT	Weak Infeed TRIP command - Only L1
4243	Weak TRIP 1p.L2	OUT	Weak Infeed TRIP command - Only L2

No.	Information	Type of In-formation	Comments
4244	Weak TRIP 1p.L3	OUT	Weak Infeed TRIP command - Only L3
4245	Weak TRIP L123	OUT	Weak Infeed TRIP command L123
4246	ECHO SIGNAL	OUT	ECHO Send SIGNAL

2.10   External direct and remote tripping

Any signal from an external protection or monitoring device can be coupled into the signal processing of the 7SA6 by means of a binary input. This signal may be delayed, alarmed and routed to one or several output relays.

2.10.1 Method of Operation

External Trip of the Local Circuit Breaker

Figure 2-96 shows the logic diagram. If the device and circuit breaker are capable of single-phase operation, it is also possible to trip single phase. The tripping logic of the device in this case ensures that the conditions for single-phase tripping are satisfied (e.g. single-phase tripping enabled, automatic reclosure ready).

The external tripping can be switched on and off with a setting parameter and may be blocked via binary input.
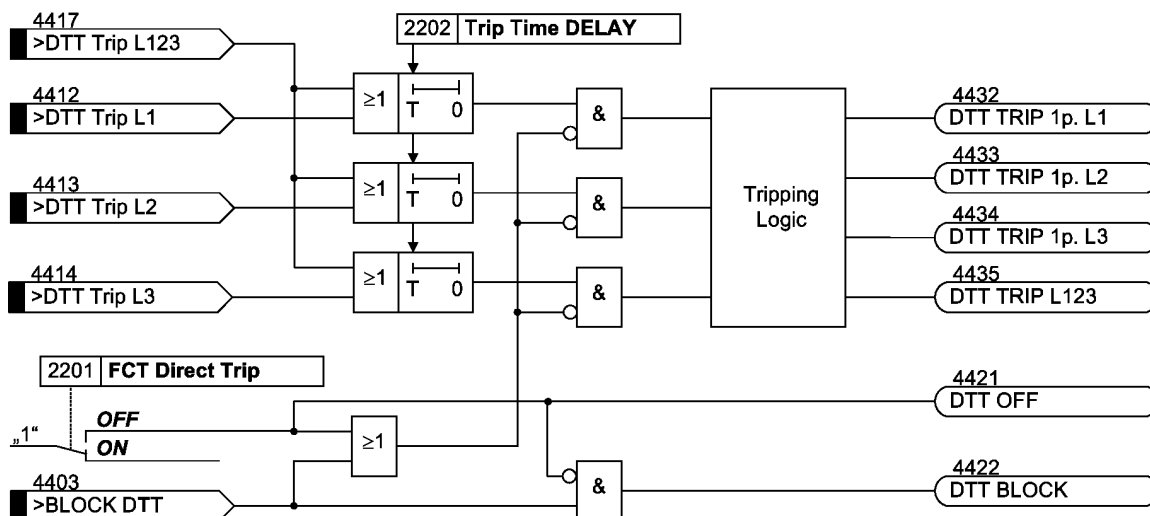
Figure 2-96   Logic diagram of the local external tripping

Remote Trip of the Circuit Breaker at the Opposite Line End

On a digital communication link via protection interface, transmission of up to 4 remote commands is possible, as described in Section 2.5.

On conventional transmission paths, one transmission channel per desired transmission direction is required for remote tripping at the remote end. For example, fibre optic connections or voice frequency modulated high frequency channels via pilot cables, power line carrier or microwave radio links can be used for this purpose in the following ways.

If the trip command of the distance protection is to be transmitted, it is best to use the integrated teleprotection function for the transmission of the signal as this already incorporates the extension of the transmitted signal, as described in Sub-section 2.6. Any of the commands can of course be used to trigger the transmitter to initiate the send signal.

On the receiver side, the local external trip function is used. The receive signal is routed to a binary input which is assigned to the logical binary input function "`>DTT Trip L123`". If single-pole tripping is desired, you can also use binary inputs

">DTT Trip L1", ">DTT Trip L2" and ">DTT Trip L3". Figure 2-96 therefore also applies in this case.

2.10.2 Setting Notes

General   A prerequisite for the application of the direct and remote tripping functions is that during the configuration of the scope of functions in address 122 **DTT Direct Trip** = *Enabled* was applied. At address 2201 **FCT Direct Trip** it can also be switched *ON* or *OFF*.

It is possible to set a trip delay for both the local external trip and the receive side of the remote trip in address 2202 **Trip Time DELAY**. This can be used as a security time margin, especially in the case of local trip.

Once a trip command has been issued, it is maintained for at least as long as the set minimum trip command duration **TMin TRIP CMD**, which was set for the device in general in address 240 (Subsection 2.1.3). Reliable operation of the circuit breaker is therefore ensured, even if the initiating signal pulse is very short. This setting is only possible via DIGSI® at **Additional Settings**.

2.10.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
2201	FCT Direct Trip	ON OFF	OFF	Direct Transfer Trip (DTT)
2202	Trip Time DELAY	0.00 .. 30.00 sec; ∞	0.01 sec	Trip Time Delay

2.10.4 Information List

No.	Information	Type of In-formation	Comments
4403	>BLOCK DTT	SP	>BLOCK Direct Transfer Trip function
4412	>DTT Trip L1	SP	>Direct Transfer Trip INPUT Phase L1
4413	>DTT Trip L2	SP	>Direct Transfer Trip INPUT Phase L2
4414	>DTT Trip L3	SP	>Direct Transfer Trip INPUT Phase L3
4417	>DTT Trip L123	SP	>Direct Transfer Trip INPUT 3ph L123
4421	DTT OFF	OUT	Direct Transfer Trip is switched OFF
4422	DTT BLOCK	OUT	Direct Transfer Trip is BLOCKED
4432	DTT TRIP 1p. L1	OUT	DTT TRIP command - Only L1
4433	DTT TRIP 1p. L2	OUT	DTT TRIP command - Only L2
4434	DTT TRIP 1p. L3	OUT	DTT TRIP command - Only L3
4435	DTT TRIP L123	OUT	DTT TRIP command L123

2.11 Overcurrent protection

The 7SA6 features a time overcurrent protection function which can be used as either a back-up or an emergency overcurrent protection. All elements may be configured independently of each other and combined according to the user's requirements.

2.11.1 General

Whereas the distance protection can only function correctly if the measured voltage signals are available to the device, the emergency overcurrent protection only requires the currents. The emergency overcurrent function is automatically activated when the measured voltage signal is lost, e.g. due to a short circuit or interruption of the voltage transformer secondary circuits (emergency operation). The emergency operation therefore replaces the distance protection as short circuit protection if loss of the measured voltage signal is recognized by one of the following conditions:

- Pickup of the internal measured voltage monitoring ("Fuse–Failure–Monitor", refer to Subsection 2.22.1) or
- If the signal "Failure: Feeder VT (MCB tripped)" is received via binary input, indicating that the measured voltage signal is lost.

If one of these conditions arise, the distance protection is immediately blocked and the emergency operation is activated.

If the overcurrent protection is set as a back-up overcurrent protection, it will work independently of other protection and monitoring functions, i.e. also independently of the distance protection. The back-up overcurrent protection could for instance be used as the only short-circuit protection if the voltage transformers are not yet available when the feeder is initially commissioned.

For the overcurrent protection there are in total four stages for the phase currents and four stages for the earth currents as follows:

- Two overcurrent stages with a definite time characteristic (O/C with DT),
- One overcurrent stage with inverse time characteristic (IDMT),
- One further overcurrent stage which is preferably used as a stub protection, but which can be applied as an additional normal definite time delayed stage.

These four stages are independent of each other and are freely combinable. Blocking by external criteria via binary input is possible as well as rapid (non delayed) tripping (e.g. by an external automatic reclose device). During energization of the protected feeder onto a dead fault it is also possible to release any stage, or also several, for non-delayed tripping. If some stages are not needed, those not needed can be deactivated by setting the pickup value to ∞.

2.11.2   Method of Operation

Measured Values

The phase currents are fed to the device via the input transformers of the measuring input. The earth current 3 I_0 is either measured directly or calculated from the phase currents, depending on the ordered device version and usage of the fourth current input I_4 of the device.

If I_4 is connected in the current transformer star-point connection circuit the earth current is directly available as a measured quantity.

If the device is fitted with the highly sensitive current input for I_4, this current I_4 is used with the factor **I4/Iph CT** (address 221, refer to Subsection 2.1.3 of the **P.System Data 1**. As the linear range of this measuring input is severely restricted in the high range, this current is only evaluated up to an amplitude of approx. 1.6 A. In the event of larger currents, the device automatically switches over to the evaluation of the zero sequence current derived from the phase currents. Naturally, all three phase currents obtained from a set of three star-connected current transformers must be available and connected to the device. The processing of the earth current is then also possible if very small as well as large earth fault currents may occur.

If the fourth current input I_4 is utilized, e.g. for a transformer starpoint current or for the earth current of a parallel line, the device calculates the earth current from the phase currents. Naturally in this case also all three phase currents derived from a set of three star connected current transformers must be available and connected to the device.

Definite Time High-set Current Stage I>>

Each phase current is compared with the setting value **Iph>>** after numerical filtering; the earth current is compared with **3I0>> PICKUP**. Currents above the associated pickup value are detected and signalled. After expiry of the associated time delays **T Iph>>** or **T 3I0>>** a trip command is issued. The dropout value is approximately 5 % less than the pickup value, but at least 1.5 % of the rated current, below the pickup value.

The following figure shows the logic diagram for the I>> stages. The stages can be blocked via a binary input "**>BLOCK O/C I>>**". Binary input "**>O/C InstTRIP**" and the function block "switch onto fault" are common to all stages and described below. They may, however, separately affect the phase and/or earth current stages. This is accomplished with the following setting parameters:

- **I>> Telep/BI** (address 2614)determines whether a non-delayed trip of this stage via binary input "**>O/C InstTRIP**" is possible (***YES***) or impossible (***NO***) and

- **I>> SOTF** (address 2615)determines whether during switching onto a fault tripping shall be instantaneous(***YES***) or not (***NO***) with this stage.
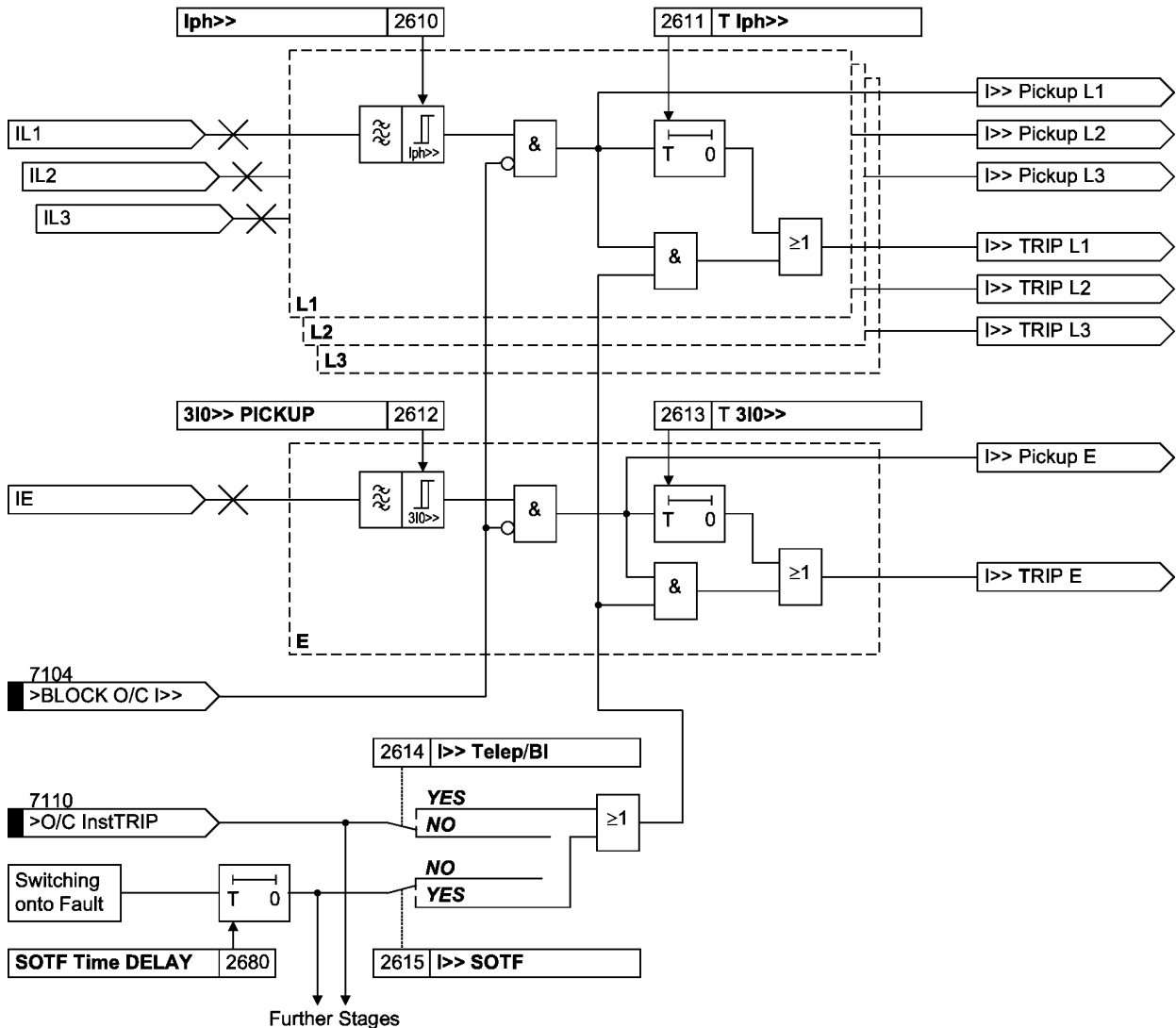
Figure 2-97   Logic diagram of the I>> stage

Definite Time Over-current Stage I>

The logic of the overcurrent stage I> is the same as that of the I>> stages. In all references **Iph>>** must merely be replaced with **Iph>** or. **3I0>> PICKUP** with **3I0>**. In all other respects Figure 2-97 applies.

Inverse Time Over-current Stage Ip

The logic of the inverse overcurrent stage also in principal functions the same as the remaining stages. However, the time delay is calculated here based on the type of the set characteristic, the intensity of the current and a time multiplier (following figure). A pre-selection of the available characteristics was already done during the configuration of the protection functions. Furthermore, an additional constant time delay **T Ip Add** or **T 3I0p Add** may be selected, which is added to the inverse time. The possible characteristics are shown in the Technical Data.

The following figure shows the logic diagram. The setting parameter addresses of the IEC characteristics are shown by way of an example. In the configuration notes (Subsection 2.11.3) the different setting addresses are elaborated upon.
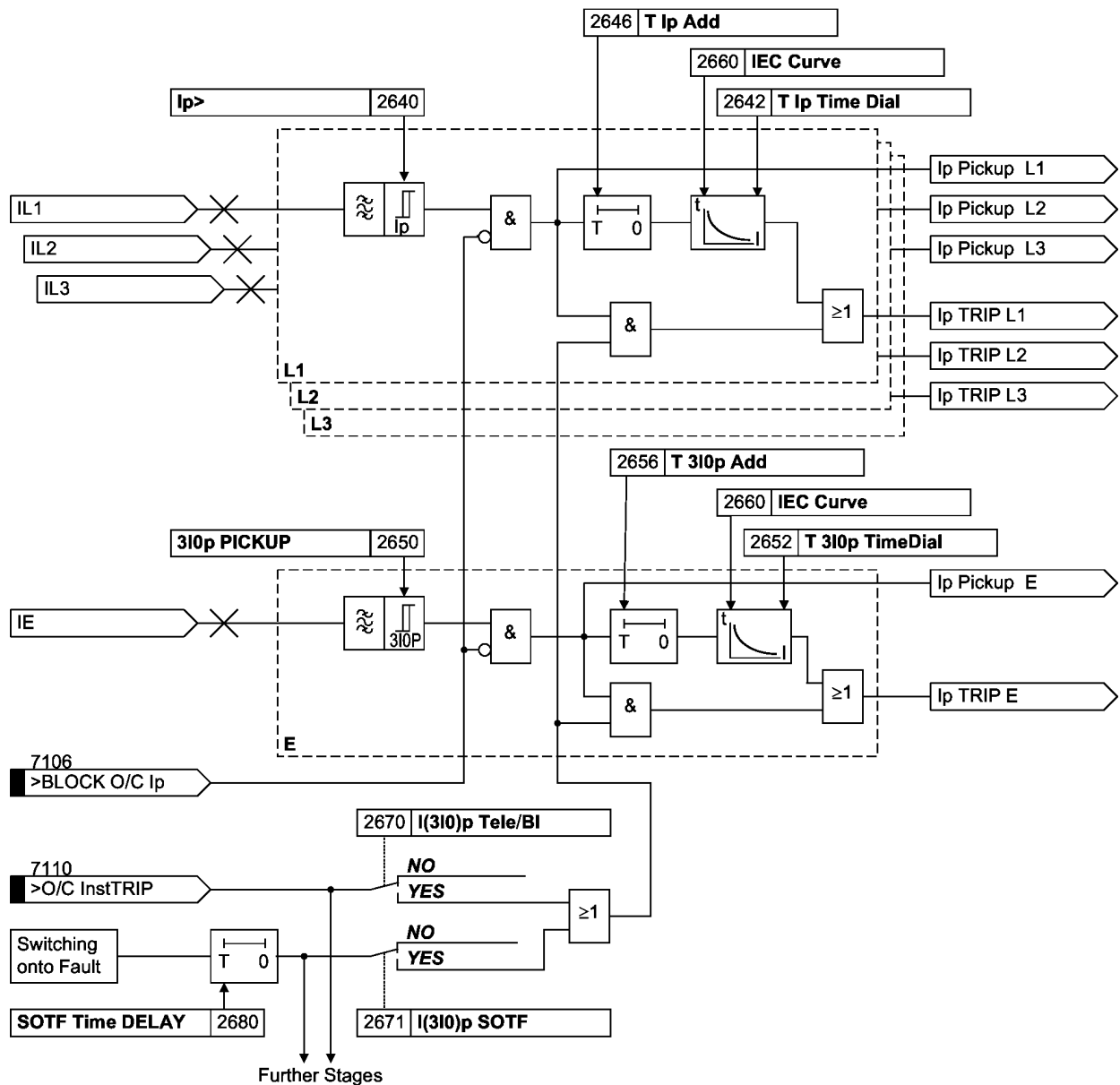
Figure 2-98   Logic diagram of the I_P–stage (inverse time overcurrent protection), example for IEC characteristics

Stub Protection   A further overcurrent stage is the stub protection. It can however also be used as a normal additional definite time overcurrent stage, as it functions independent of the other stages.

A stub fault is a short-circuit located between the current transformer set and the line isolator. It is of particular importance with the $1^1/_2$ circuit breaker arrangements.
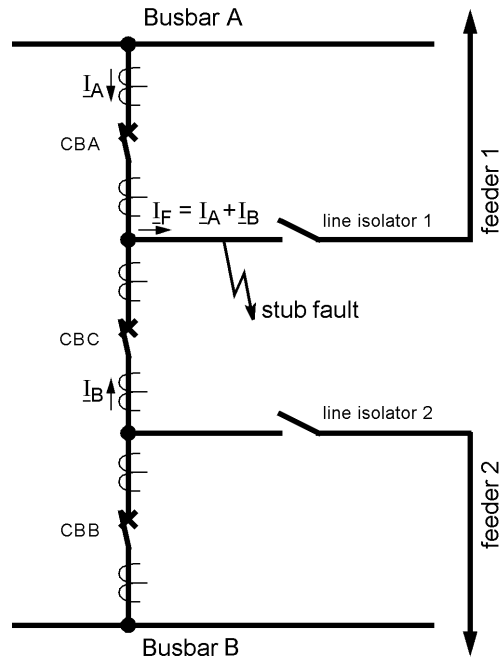
Figure 2-99   Stub fault at an $1^1/_2$ circuit breaker arrangement

If a short circuit current $\underline{I}_A$ and/or $\underline{I}_B$ flows while the line isolator 1 is open, this implies that a fault in the stub range between the current transformers $\underline{I}_A$, $\underline{I}_B$, and the line isolator exists. The circuit breakers CBA and CBC that carry the short-circuit current can be tripped without delay. The two sets of current transformers are connected in parallel such that the current sum $\underline{I}_A + \underline{I}_B$ represents the current flowing towards the line isolator.

The stub protection is an overcurrent protection which is only in service when the state of the line isolator indicates the open condition via a binary input "$>$I-STUB ENABLE". The binary input must therefore be operated via an auxiliary contact of the isolator. In the case of a closed line isolator, the stub protection is out of service. For more information see the next logic diagram.

If the stub protection stage is to be used as a normal definite time overcurrent stage, the binary input "$>$BLOCK I-STUB", should be left without allocation or routing (matrix). The enable input "$>$I-STUB ENABLE", however, has to be constantly activated (either via a binary input or via integrated logic (CFC) functions which can be configured by the user.
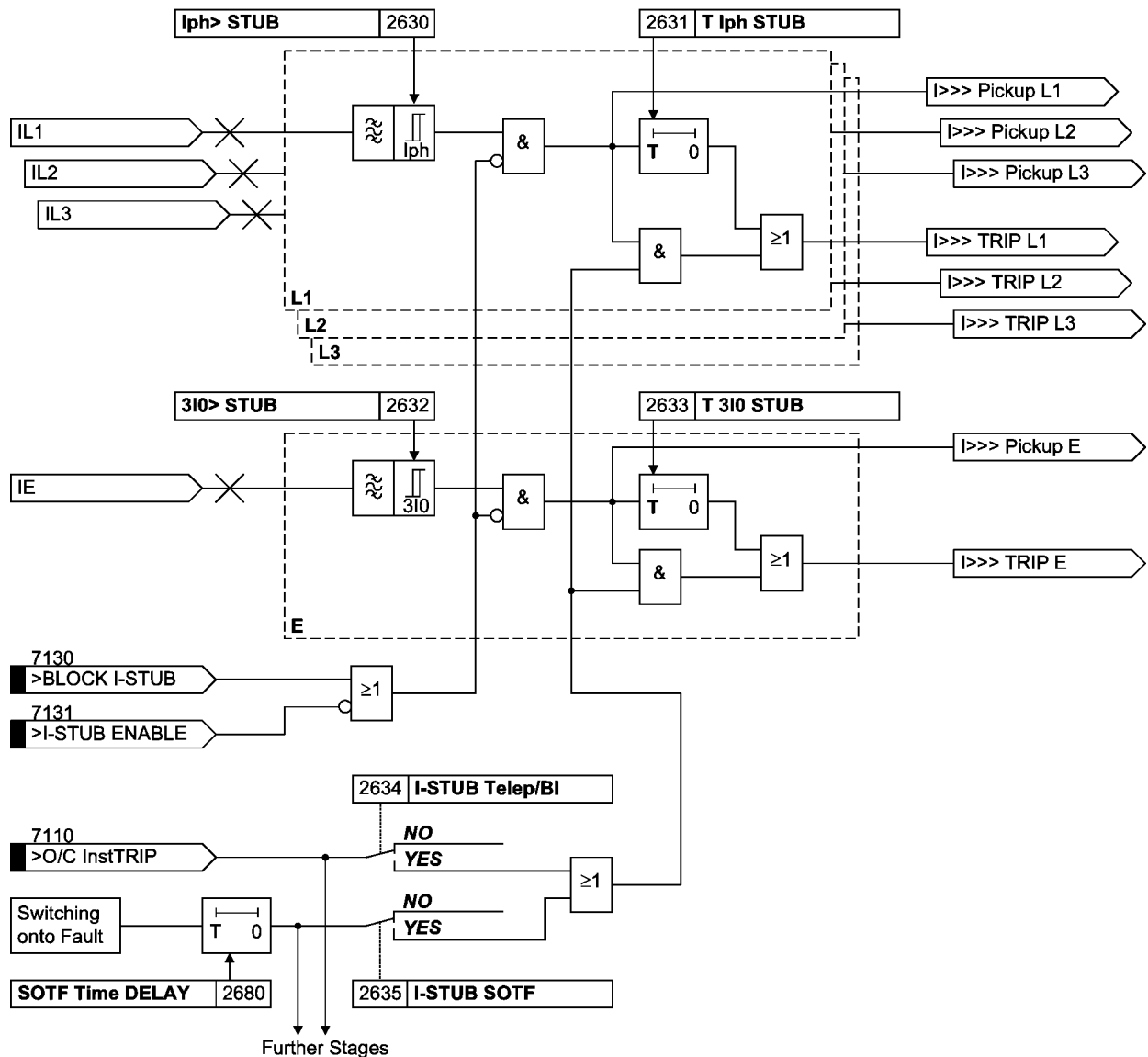
Figure 2-100   Logic diagram of stub fault protection

Instantaneous Tripping before Automatic Reclosure

Automatic reclosure is applied in order to instantaneously remove the fault before automatic reclosure. A release signal from an external automatic reclosure device can be injected via binary input "`>O/C InstTRIP`". The internal automatic reclosure - if available - is also effected by this command. Any stage of the overcurrent protection can thus perform an instantaneous trip before reclosure via the parameter ***Telep***/***BI ....***

Switching onto a Fault

To achieve fast tripping following manual closure of the circuit breaker onto a dead fault, the internal line energization detection feature can be used. The overcurrent protection can then trip three-pole without delay or with a reduced delay. It can be determined via parameter setting for which stage(s) the rapid tripping following closure on to a dead fault applies. (Refer also to the logic diagrams in 2-97, 2-98 and 2-100). This function is independent of the high-current instantaneous tripping described in Subsection 2.12.

Pickup Logic and Tripping Logic

The pickup signals of the individual phases (or the ground) and of the stages are linked in such a way that both the phase information and the stage which has picked up are output (Table 2-11).

Also for the tripping signals the element is indicated which has initiated the tripping. If the device has the option to trip single-pole, and this option has been activated, the pole which has been tripped is also indicated during single-pole tripping (refer also to Subsection 2.23.1 "Tripping Logic of the Entire Device").

Table 2-11   Pickup signals of the individual phases

Internal Annunciation	Figure	Output Annunciation	FNo.
I>> Pickup L1 I> Pickup L1 Ip Pickup L1 I>>> Pickup L1	2-97 2-98 2-100	"O/C Pickup L1"	7162
I>> Pickup L2 I> Pickup L2 Ip Pickup L2 I>>> Pickup L2	2-97 2-98 2-100	"O/C Pickup L2"	7163
I>> Pickup L3 I> Pickup L3 Ip Pickup L3 I>>> Pickup L1	2-97 2-98 2-100	"O/C Pickup L3"	7164
I>> Pickup E I> Pickup E Ip Pickup E I>>> Pickup E	2-97 2-98 2-100	"O/C Pickup E"	7165
I>> Pickup L1 I>> Pickup L2 I>> Pickup L3 I>> Pickup E	2-97 2-97 2-97 2-97	"O/C PICKUP I>>"	7191
I> Pickup L1 I> Pickup L2 I> Pickup L3 I> Pickup E		"O/C PICKUP I>"	7192
Ip Pickup L1 Ip Pickup L2 Ip Pickup L3 Ip Pickup E	2-98 2-98 2-98 2-98	"O/C PICKUP Ip"	7193
I>>> Pickup L1 I>>> Pickup L2 I>>> Pickup L3 I>>> Pickup E	2-100 2-100 2-100 2-100	"I-STUB PICKUP"	7201
(All pickups)		"O/C PICKUP"	7161

2.11.3 Setting Notes

General

During the configuration of the device scope of functions (address 126) the available characteristics were determined. Only those parameters that apply to the available characteristics, according to the selected configuration and the version of the device, are accessible in the procedures described below.

Address 2601 is set according to the desired mode of operation of the overcurrent protection: **Operating Mode** = **ON:always activ** means that the overcurrent protection works independently of other protection functions, i.e. as a backup overcurrent protection. If it is to work only as an emergency function in case of a transmission failure, **ON:with VT loss** must be set. Finally, it can also be set to **OFF**.

If some stages are not needed, those not needed can be deactivated by setting the pickup value to ∞. But if you set only an associated time delay to ∞ this does not suppress the pickup signals but prevents the timers from running.

The stub protection remains in service even if the overcurrent mode of operation setting is **ON:with VT loss**.

One or several stages can be set as instantaneous tripping stages when switching onto a fault. This is chosen during the setting of the individual stages (see below). To avoid a spurious pickup due to transient overcurrents, the delay **SOTF Time DELAY** (address 2680) can be set. Typically, the presetting of **0** is correct. A short delay can be useful in case of long cables for which high inrush currents can be expected, or for transformers. The time delay depends on the severity and duration of the transient overcurrents as well as on which stages were selected for the fast switch onto fault clearance.

High Set Current StagesI_{ph}>>,$3I_0$>>

The I>> stages **Iph>>** (address 2610) and **3I0>> PICKUP** (address 2612) together with the I> stages or I_p stages result in a two-stage characteristic. Of course, all three stages can be combined as well. If one stage is not required, the pickup value has to be set to ∞. The I>> stages always operate with a defined delay.

If the I>> stages are used for instantaneous tripping before the automatic reclosure, the current-setting corresponds to the I> or I_p stages. In this case only the different delay times are of interest. The times **T Iph>>** (address 2611) and **T 3I0>>** (address 2613) can then be set to **0** or a very low value, as the fast clearance of the fault takes priority over the selectivity before the automatic reclosure is initiated. These stages have to be blocked before final trip in order to achieve the selectivity.

For very long lines with a small source impedance or on applications with large reactances (e.g. transformers, series reactors), the I>> stages can also be used for current grading. In this case they must be set in such a way that they do not pick up in case of a fault at the end of the line. The times can then be set to **0** or to a small value.

When using a personal computer and DIGSI® to apply the settings, these can be optionally entered as primary or secondary values. If secondary quantities are used, all currents must be converted to the secondary side of the current transformers.

Calculation Example:

110 kV overhead line 150 mm^2:

s (length)	= 60 km
R_1/s	= 0.19 Ω/km
X_1/s	= 0.42 Ω/km

Short-circuit power at the beginning of the line:

S_k' = 2.5 GVA

Current Transformer   600 A / 5 A

From that the line impedance Z_L and the source impedance Z_S are calculated:

$Z_1/s = \sqrt{0.19^2 + 0.42^2}$ Ω/km = 0.46 Ω/km

Z_L = 0.46 Ω/km · 60 km = 27.66 Ω

$$Z_S = \frac{(110\ kV)^2}{2500\ MVA} = 4.84\ \Omega$$

The three-phase fault current at the line end is $I_{F\ end}$:

$$I_{F\ end} = \frac{1.1 \cdot U_N}{\sqrt{3} \cdot (Z_S + Z_L)} = \frac{1.1 \cdot 110\ kV}{\sqrt{3} \cdot (4.84\ \Omega + 27.66\ \Omega)} = 2150\ A$$

With a safety factor of 10 %, the following primary setting value is calculated:

setting value I>> = 1.1 · 2150 A = 2365 A

or the secondary setting value:

$$\text{Setting value I>>} = 1.1 \cdot \frac{2150\ A}{600\ A} \cdot 5\ A = 19.7\ A$$

i.e. in case of fault currents exceeding 2365 A (primary) or 19.7A (secondary) you can be sure that a short-circuit has occurred on the protected line. This fault can immediately be cleared by the time overcurrent protection.

Note: the calculation was carried out with absolute values, which is sufficiently precise for overhead lines. If the angles of the source impedance and the line impedance vary considerably, a complex calculation will have to be carried out.

A similar calculation can be carried out for earth faults, with the maximum earth current occurring at the line end during a short-circuit being decisive.

The set time delays are pure additional delays, which do not include the operating time (measuring time).

The parameter **I>> Telep/BI** (address 2614) defines whether the time delays "**>O/C InstTRIP**" (address 7110) and **T Iph>>** (address 2611) can be bypassed by the binary input **T 3IO>>** (FNo 2613) or by the operational automatic reclosure function. The binary input (if allocated) is applied to all stages of the time-overcurrent protection. With **I>> Telep/BI** = *YES* you can set the I>> stages to trip immediately after the pickup, only if the binary input is activated. Set time delays for **I>> Telep/BI** = *NO* are always activated.

If the I>> stage is to trip when switching the line on to a fault with or without a short delay, **SOTF Time DELAY** (address 2680, see above and refer to Subsection "General"), the parameter **I>> SOTF** (address 2615) is set to *YES*. Any other stage can be selected as well for this instantaneous tripping.

Overcurrent Stages $I_{ph}>$, $3I_0>$ (O/C with DT)

For the setting of the current pickup value, **Iph>** (address 2620), the maximum operating current is most decisive. Pickup due to overload should never occur, since the device in this operating mode operates as fault protection with correspondingly short tripping times and not as overload protection. For this reason, a pickup value of about 10 % above the expected peak load is recommended for line protection, and a setting of about 20 % above the expected peak load is recommended for transformers and motors.

When using a personal computer and DIGSI® to apply the settings, these can be optionally entered as primary or secondary values. If secondary quantities are used, all currents must be converted to the secondary side of the current transformers.

<u>Calculation Example:</u>

110 kV overhead line 150 mm^2

maximum transmittable power

P_{max}	= 120 MVA

corresponding to

I_{max}	= 630 A
Current Transformer	600 A / 5 A
Safety factor	1.1

With settings in primary quantities the following setting value is calculated:

Setting value I> = 1.1 · 630 A = 693 A

With settings in secondary quantities the following setting value is calculated:

$$\text{Setting value I>} = 1.1 \cdot \frac{630\ A}{600\ A} \cdot 5\ A = 5.8\ A$$

The earth current stage **3I0>** (address 2622) should be set to detect the smallest earth fault current to be expected. For very small earth currents the earth fault protection is most suited (refer to Section 2.7).

The time delay **T Iph>** (address 2621) results from the time grading schedule designed for the network. If implemented as emergency overcurrent protection, shorter tripping times are advisable (one grading time step above the fast tripping stage), as this function is only activated in the case of the loss of the <u>local</u> measured voltage.

The time **T 3I0>** (address 2623) can normally be set shorter, according to a separate time grading schedule for earth currents.

The set times are mere additional delays for the independent stages, which do not include the inherent operating time of the protection. If only the phase currents are to be monitored, set the pickup value of the earth fault stage to ∞.

The parameter **I> Telep/BI** (address 2624) defines whether the time delays **T Iph>>** (address 2611) and **T 3I0>>** (address 2613) can be bypassed by the binary input "**>O/C InstTRIP**" (FNo 7110). The binary input (if allocated) is applied to all stages of the time-overcurrent protection. With **I> Telep/BI** = *YES* you can set the I> stages to trip immediately after the pickup, only if the binary input is activated. Set time delays for **I> Telep/BI** = *NO* are always activated.

If the I> stage is to trip when switching the line on to a fault with or without a short delay, **SOTF Time DELAY** (address 2680, see above and refer to Subsection "General"), the parameter **I> SOTF** (address 2625) is set to *YES*. We recommend, however, not to choose the sensitive setting for the switch on to a fault function as energizing of the

line on to a fault should cause a large fault current. It is important to avoid that the selected stage picks up in a transient way during line energization.

Overcurrent Stages I$_P$, 3I$_{0P}$ (IDMT protection with IEC characteristics)

In the case of the inverse overcurrent stages, various characteristics can be selected, depending on the ordering version of the device and the configuration (address 126), With the IEC characteristics (address 126 **Back-Up O/C** = *TOC IEC*) the following options are available at address 2660 **IEC Curve**:

Normal Inverse (inverse, type A according to IEC 60255-3),

Very Inverse (very inverse, type B according to IEC 60255-3),

Extremely Inv. (extremely inverse, type C according to IEC 60255-3), and

LongTimeInverse (longtime, type B according to IEC 60255-3).

For the setting of the current thresholds **Ip>** (address 2640) and **3I0p PICKUP** (address 2650) the same considerations as for the overcurrent stages of the definite time protection (see above) apply. In this case it must be noted that a safety margin between the pickup threshold and the set value has already been incorporated. Pickup only occurs at a current which is approximately 10 % above the set value.

The above example shows that the maximum expected operating current may directly be applied as setting here.

Primary: Set value IP = 630 ,

Secondary: Set value IP = 5.25 A, i.e. (630 A / 600 A) · 5 A.

The time multiplier setting **T Ip Time Dial** (address 2642) is derived from the grading coordination plan applicable to the network. If implemented as emergency overcurrent protection, shorter tripping times are advisable (one grading time step above the fast tripping stage), as this function is only activated in the case of the loss of the local measured voltage.

The time multiplier setting **T 3I0p TimeDial** (address 2652) can usually be set smaller according to a separate earth fault grading plan. If only the phase currents are to be monitored, set the pickup value of the earth fault stage to ∞.

In addition to the current-dependent delays, a delay of constant length can be set, if necessary. The setting **T Ip Add** (address 2646 for phase currents) and **T 3I0p Add** (address 2656 for earth currents) are in addition to the time delays resulting from the set curves.

The setting parameter **I(3I0)p Tele/BI** (address 2670) determines if it is possible to use the binary input "**>O/C InstTRIP**" (F.No. 7110) to bypass the trip delays **T Ip Time Dial** (address 2642) including the additional time **T Ip Add** (address 2646) and **T 3I0p TimeDial** (address 2652) including the additional time **T 3I0p Add** (address 2656). The binary input (if allocated) is applied to all stages of the time-overcurrent protection. With **I(3I0)p Tele/BI** = *YES* you can set the IP stages to trip immediately after the pickup, only if the binary input is activated. Set time delays for **I(3I0)p Tele/BI** = *NO* are always activated.

If the IP stage is to trip when switching the line on to a fault with or without a short delay, **SOTF Time DELAY** (address 2680, see above and refer to Subsection "General"), the parameter **I(3I0)p SOTF** (address 2671) is set to *YES*. We recommend, however, not to choose the sensitive setting for the switch on to a fault function as energizing of the line on to a fault should cause a large fault current. It is important to avoid that the selected stage picks up in a transient way during line energization.

Overcurrent Stages I$_P$, 3I$_{0P}$ (IDMT protection with ANSI characteristics)

In the case of the inverse overcurrent stages, various characteristics can be selected, depending on the ordering version and the configuration (address 126). With the ANSI characteristics (address 126 **Back-Up O/C** = *TOC ANSI*) are available at address 2661 **ANSI Curve**:

Inverse,

Short Inverse,

Long Inverse,

Moderately Inv.,

Very Inverse,

Extremely Inv. and

Definite Inv..

For the setting of the current thresholds **Ip>** (address 2640) and **3I0p PICKUP** (address 2650) the same considerations as for the overcurrent stages of the definite time protection (see above) apply. In this case it must be noted that a safety margin between the pickup threshold and the set value has already been incorporated. Pickup only occurs at a current which is approximately 10 % above the set value.

The above example shows that the maximum expected operating current may directly be applied as setting here.

Primary: Set value IP = 630 ,

Secondary: Set value IP = 5.25 A, i.e. (630 A / 600 A) · 5 A.

The time multiplier setting **Time Dial TD Ip** (address 2643) is derived from the grading coordination plan applicable to the network. If implemented as emergency overcurrent protection, shorter tripping times are advisable (one grading time step above the fast tripping stage), as this function is only activated in the case of the loss of the <u>local</u> measured voltage.

The time multiplier setting **TimeDial TD3I0p** (address 2653) can usually be set smaller according to a separate earth fault grading plan. If only the phase currents are to be monitored, set the pickup value of the earth fault stage to ∞.

In addition to the current-dependent delays, a delay of constant length can be set, if necessary. The setting **T Ip Add** (address 2646 for phase currents) and **T 3I0p Add** (address 2656 for earth currents) are in addition to the time delays resulting from the set curves.

The setting parameter **I(3I0)p Tele/BI** (address 2670) determines if it is possible to use the binary input ">O/C InstTRIP" (F.No. 7110) to bypass the trip delays **Time Dial TD Ip** (address 2643) including the additional time **T Ip Add** (address 2646) and **TimeDial TD3I0p** (address 2653) including the additional time **T 3I0p Add** (address 2656). The binary input (if allocated) is applied to all stages of the time-overcurrent protection. With **I(3I0)p Tele/BI** = *YES* you can set the IP stages to trip immediately after the pickup, only if the binary input is activated. Set time delays for **I(3I0)p Tele/BI** = *NO* are always activated.

If the IP stage is to trip when switching the line on to a fault with or without a short delay, **SOTF Time DELAY** (address 2680, see above and refer to Subsection "General"), the parameter **I(3I0)p SOTF** (address 2671) is set to *YES*. We recommend, however, not to choose the sensitive setting for the switch on to a fault function as energizing of the line on to a fault should cause a large fault current. It is important to avoid that the selected stage picks up in a transient way during line energization.

Additional Stage
I_stub

When using the Istub protection the pickup thresholds **Iph> STUB** (address 2630) and **3I0> STUB** (address 2632) are usually not critical, as this protection function is only activated when the line isolator is open which implies that every measured current should represents a fault current. With a $1^1/_2$–circuit breaker arrangement it is possible that large short circuit currents flow from busbar A to busbar B or to feeder 2 via the current transformers. These currents could cause different transformation errors in the two current transformer sets I_A and I_B especially in the saturation range. The protection should therefore not be set unnecessarily sensitive. If the minimum short circuit currents on the busbars are known, the pickup threshold **Iph> STUB** is set somewhat (approx. 10 %) below the minimum two phase short circuit current, **3I0> STUB** is set below the minimum single-phase current. If only the phase currents are to be monitored, set the pickup value of the earth fault stage to ∞.

The times **T Iph STUB** (address 2631) and **T 3I0 STUB** (address 2633) are set to **0** for this application to prevent the protection from operating while the line isolator is closed.

If this stage is applied differently, similar considerations as for the other overcurrent stages apply.

The parameter **I-STUB Telep/BI** (address 2634) defines whether the time delays "**>O/C InstTRIP**" (address **T Iph STUB**) and 2631 (address **T 3I0 STUB**) can be bypassed by the binary input 2633. The binary input (if allocated) is applied to all stages of the time-overcurrent protection. With **I-STUB Telep/BI** = **YES** you can set the I>>> stages to trip immediately after the pickup, only if the binary input is activated. Set time delays for **I-STUB Telep/BI** = **NO** are always activated.

If the I>>> stage is to trip when switching the line on to a fault with or without a short delay, **SOTF Time DELAY** (address 2680, see above and refer to Subsection "General"), the parameter **I-STUB SOTF** (address 2635) is set to **YES**. If using the stub protection, then set to **NO** as the effect of this protection function only depends on the position of the isolator.

2.11.4 Settings

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
2601	Operating Mode		ON:with VT loss ON:always activ OFF	ON:with VT loss	Operating mode
2610	Iph>>	1A	0.10 .. 25.00 A; ∞	2.00 A	Iph>> Pickup
		5A	0.50 .. 125.00 A; ∞	10.00 A	
2611	T Iph>>		0.00 .. 30.00 sec; ∞	0.30 sec	T Iph>> Time delay
2612	3I0>> PICKUP	1A	0.05 .. 25.00 A; ∞	0.50 A	3I0>> Pickup
		5A	0.25 .. 125.00 A; ∞	2.50 A	
2613	T 3I0>>		0.00 .. 30.00 sec; ∞	2.00 sec	T 3I0>> Time delay
2614	I>> Telep/BI		NO YES	YES	Instantaneous trip via Teleprot./BI
2615	I>> SOTF		NO YES	NO	Instantaneous trip after SwitchOnToFault

Addr.	Parameter	C	Setting Options	Default Setting	Comments
2620	Iph>	1A	0.10 .. 25.00 A; ∞	1.50 A	Iph> Pickup
		5A	0.50 .. 125.00 A; ∞	7.50 A	
2621	T Iph>		0.00 .. 30.00 sec; ∞	0.50 sec	T Iph> Time delay
2622	3I0>	1A	0.05 .. 25.00 A; ∞	0.20 A	3I0> Pickup
		5A	0.25 .. 125.00 A; ∞	1.00 A	
2623	T 3I0>		0.00 .. 30.00 sec; ∞	2.00 sec	T 3I0> Time delay
2624	I> Telep/BI		NO YES	NO	Instantaneous trip via Tele-prot./BI
2625	I> SOTF		NO YES	NO	Instantaneous trip after SwitchOnToFault
2630	Iph> STUB	1A	0.10 .. 25.00 A; ∞	1.50 A	Iph> STUB Pickup
		5A	0.50 .. 125.00 A; ∞	7.50 A	
2631	T Iph STUB		0.00 .. 30.00 sec; ∞	0.30 sec	T Iph STUB Time delay
2632	3I0> STUB	1A	0.05 .. 25.00 A; ∞	0.20 A	3I0> STUB Pickup
		5A	0.25 .. 125.00 A; ∞	1.00 A	
2633	T 3I0 STUB		0.00 .. 30.00 sec; ∞	2.00 sec	T 3I0 STUB Time delay
2634	I-STUB Telep/BI		NO YES	NO	Instantaneous trip via Tele-prot./BI
2635	I-STUB SOTF		NO YES	NO	Instantaneous trip after SwitchOnToFault
2640	Ip>	1A	0.10 .. 4.00 A; ∞	∞ A	Ip> Pickup
		5A	0.50 .. 20.00 A; ∞	∞ A	
2642	T Ip Time Dial		0.05 .. 3.00 sec; ∞	0.50 sec	T Ip Time Dial
2643	Time Dial TD Ip		0.50 .. 15.00 ; ∞	5.00	Time Dial TD Ip
2646	T Ip Add		0.00 .. 30.00 sec	0.00 sec	T Ip Additional Time Delay
2650	3I0p PICKUP	1A	0.05 .. 4.00 A; ∞	∞ A	3I0p Pickup
		5A	0.25 .. 20.00 A; ∞	∞ A	
2652	T 3I0p TimeDial		0.05 .. 3.00 sec; ∞	0.50 sec	T 3I0p Time Dial
2653	TimeDial TD3I0p		0.50 .. 15.00 ; ∞	5.00	Time Dial TD 3I0p
2656	T 3I0p Add		0.00 .. 30.00 sec	0.00 sec	T 3I0p Additional Time Delay
2660	IEC Curve		Normal Inverse Very Inverse Extremely Inv. LongTimeInverse	Normal Inverse	IEC Curve
2661	ANSI Curve		Inverse Short Inverse Long Inverse Moderately Inv. Very Inverse Extremely Inv. Definite Inv.	Inverse	ANSI Curve

Addr.	Parameter	C	Setting Options	Default Setting	Comments
2670	I(3I0)p Tele/BI		NO YES	NO	Instantaneous trip via Tele-prot./BI
2671	I(3I0)p SOTF		NO YES	NO	Instantaneous trip after SwitchOnToFault
2680	SOTF Time DELAY		0.00 .. 30.00 sec	0.00 sec	Trip time delay after SOTF

2.11.5 Information List

No.	Information	Type of Information	Comments
2054	Emer. mode	OUT	Emergency mode
7104	>BLOCK O/C I>>	SP	>BLOCK Backup OverCurrent I>>
7105	>BLOCK O/C I>	SP	>BLOCK Backup OverCurrent I>
7106	>BLOCK O/C Ip	SP	>BLOCK Backup OverCurrent Ip
7110	>O/C InstTRIP	SP	>Backup OverCurrent InstantaneousTrip
7130	>BLOCK I-STUB	SP	>BLOCK I-STUB
7131	>I-STUB ENABLE	SP	>Enable I-STUB-Bus function
7151	O/C OFF	OUT	Backup O/C is switched OFF
7152	O/C BLOCK	OUT	Backup O/C is BLOCKED
7153	O/C ACTIVE	OUT	Backup O/C is ACTIVE
7161	O/C PICKUP	OUT	Backup O/C PICKED UP
7162	O/C Pickup L1	OUT	Backup O/C PICKUP L1
7163	O/C Pickup L2	OUT	Backup O/C PICKUP L2
7164	O/C Pickup L3	OUT	Backup O/C PICKUP L3
7165	O/C Pickup E	OUT	Backup O/C PICKUP EARTH
7171	O/C PU only E	OUT	Backup O/C Pickup - Only EARTH
7172	O/C PU 1p. L1	OUT	Backup O/C Pickup - Only L1
7173	O/C Pickup L1E	OUT	Backup O/C Pickup L1E
7174	O/C PU 1p. L2	OUT	Backup O/C Pickup - Only L2
7175	O/C Pickup L2E	OUT	Backup O/C Pickup L2E
7176	O/C Pickup L12	OUT	Backup O/C Pickup L12
7177	O/C Pickup L12E	OUT	Backup O/C Pickup L12E
7178	O/C PU 1p. L3	OUT	Backup O/C Pickup - Only L3
7179	O/C Pickup L3E	OUT	Backup O/C Pickup L3E
7180	O/C Pickup L31	OUT	Backup O/C Pickup L31
7181	O/C Pickup L31E	OUT	Backup O/C Pickup L31E
7182	O/C Pickup L23	OUT	Backup O/C Pickup L23
7183	O/C Pickup L23E	OUT	Backup O/C Pickup L23E
7184	O/C Pickup L123	OUT	Backup O/C Pickup L123
7185	O/C PickupL123E	OUT	Backup O/C Pickup L123E
7191	O/C PICKUP I>>	OUT	Backup O/C Pickup I>>
7192	O/C PICKUP I>	OUT	Backup O/C Pickup I>
7193	O/C PICKUP Ip	OUT	Backup O/C Pickup Ip
7201	I-STUB PICKUP	OUT	O/C I-STUB Pickup

No.	Information	Type of In-formation	Comments
7211	O/C TRIP	OUT	Backup O/C General TRIP command
7212	O/C TRIP 1p.L1	OUT	Backup O/C TRIP - Only L1
7213	O/C TRIP 1p.L2	OUT	Backup O/C TRIP - Only L2
7214	O/C TRIP 1p.L3	OUT	Backup O/C TRIP - Only L3
7215	O/C TRIP L123	OUT	Backup O/C TRIP Phases L123
7221	O/C TRIP I>>	OUT	Backup O/C TRIP I>>
7222	O/C TRIP I>	OUT	Backup O/C TRIP I>
7223	O/C TRIP Ip	OUT	Backup O/C TRIP Ip
7235	I-STUB TRIP	OUT	O/C I-STUB TRIP

2.12 Instantaneous high-current switch-on-to-fault protection (SOTF)

The instantaneous high-current switch-onto-fault protection function is provided to disconnect immediately and without delay feeders that are switched onto a high-current fault. It is primarily used as fast protection in the event of energizing the feeder while the earth switch is closed, but can also be used every time the feeder is energized — in other words also following automatic reclosure — (selectable).

The energization of the feeder is reported to the protection by the circuit breaker state recognition function. This function is described in detail in Section 2.23.1.

2.12.1 Method of Operation

Pickup

The high-current pickup function measures each phase current and compares it with the set value **I>>>** (address 2404). The currents are numerically filtered so that only the fundamental frequency is evaluated. If the measured current is more than twice the set value, the protection automatically reverts to the unfiltered measured values, thereby allowing extremely fast tripping. DC current components in the fault current and in the CT secondary circuit following the switching off of large currents virtually have no influence on the high-current pickup operation.

The high-current switch-on-to-fault function can be phase segregated or three-phase.

In case of manual closure of the CB, it operates always in all three phases via the internal release signal "SOTF O/C Release 3ph" supplied by the central function control of the protective relay, provided that the manual closure can be detected there (see Subsection 2.23.1).

If further criteria were determined during configuration of the line energization detection (address 1134 **Line Closure**, refer to Section 2.1.5.1) the release signal "SOTF-O/C Release. Lx" can be initiated selectively for each phase. This only applies to devices that can trip single-pole, and is important in conjunction with single-pole automatic reclosure.

Tripping is always three-pole. The phase selectivity only applies to the pick-up due to the coupling of the high current criterion with the circuit breaker pole which is closed.

In order to generate as quickly as possible a trip command after an energization, the fast switch-on-to-fault protection is released selectively for each phase already when the line is open.

The following figure shows the logic diagram.
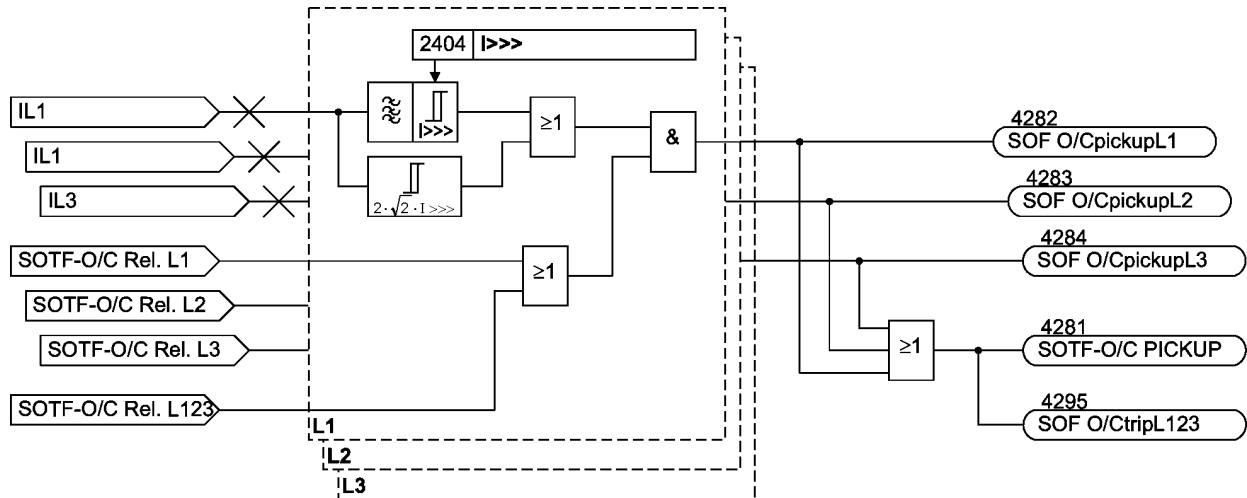
Figure 2-101   Logic diagram of the high current switch on to fault protection

2.12.2 Setting Notes

Requirement   A prerequisite for the operation of the switch-onto-fault protection is that in address 124 **SOTF Overcurr.** = *Enabled* was set during the configuration of the device scope of functions. At address 2401 **FCT SOTF-O/C** it can also be switched *ON* or *OFF*.

Pickup Threshold   The magnitude of the current which causes pick-up of the switch onto fault function is set as **I>>>** in address 2404. The setting value should be selected large enough to ensure that the protection under no circumstances picks up due to an overload condition or due to a current increase resulting from e.g. an automatic reclosure dead time on a parallel feeder. It is recommended to set at least 2.5 times the rated current of the feeder.

2.12.3 Settings

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
2401	FCT SOTF-O/C		ON OFF	ON	Inst. High Speed SOTF-O/C is
2404	I>>>	1A	1.00 .. 25.00 A	2.50 A	I>>> Pickup
		5A	5.00 .. 125.00 A	12.50 A	

2.12.4 Information List

No.	Information	Type of In-formation	Comments
4253	>BLOCK SOTF-O/C	SP	>BLOCK Instantaneous SOTF Overcurrent
4271	SOTF-O/C OFF	OUT	SOTF-O/C is switched OFF
4272	SOTF-O/C BLOCK	OUT	SOTF-O/C is BLOCKED
4273	SOTF-O/C ACTIVE	OUT	SOTF-O/C is ACTIVE
4281	SOTF-O/C PICKUP	OUT	SOTF-O/C PICKED UP
4282	SOF O/CpickupL1	OUT	SOTF-O/C Pickup L1
4283	SOF O/CpickupL2	OUT	SOTF-O/C Pickup L2
4284	SOF O/CpickupL3	OUT	SOTF-O/C Pickup L3
4295	SOF O/CtripL123	OUT	SOTF-O/C TRIP command L123

2.13 Earth fault detection in non-earthed systems (optional)

The earth fault detection function can be applied in power systems whose starpoint is not earthed or earthed through an arc suppression coil (Petersen coil).

2.13.1 Method of Operation

General

Single-phase earth faults are not detected by the earth fault protection since no fault current flows. Furthermore, since network operation is not immediately affected by an earth fault (the voltage triangle is maintained, Figure 2-102) rapid disconnection is usually not desired. It is more important that the earth fault is recognized, indicated and, when possible, localized also. After having performed changes in the system it can finally be cleared. But 7SA6 enables the user to trip on directional earth fault in non-earthed systems.

a) Healthy System, without Earth Fault   b) Earth Fault in Phase L1

Figure 2-102   Earth fault in non-earthed neutral network

Dependent upon the chosen model, the 7SA6 distance protection relay can be fitted with optional earth fault detection module, which includes the following functions:

- Detection of an earth fault (pick-up) by monitoring the displacement voltage,
- Determination of the faulted phase by measuring the phase to earth voltages,
- Determination of the direction of the earth fault (residual) current by high accuracy real and reactive component measurement.

Pickup

The pickup is achieved when the settable threshold for the displacement voltage $3 U_0$ is exceeded. To ensure measurement of stable values, all earth fault detection functions are delayed until 1 second (settable) after inception of voltage displacement. Furthermore, each alteration of the earth fault conditions (e.g. altered direction) is recognized only after this delay. Generally the pickup is only indicated if a fault was detected for sure by the phase determination function (see next margin heading).

Determination of Grounded Phase

After recognition of displaced voltage conditions the first objective of the device is selective detection of the earth-faulted phase. To do this, the individual phase-to-earth voltages are measured. If the voltage magnitude for any given phase is below the setting value U_{min} that phase is detected as the earthed phase as long as the remaining phase-earth voltages are simultaneously above the setting value U_{max}.

Sensitive Earth Fault Directional Determination

The direction of the earth fault can be determined from the direction of the earth fault current in relation to the displacement voltage. The only restriction is that the active or reactive current components must be available with sufficient magnitude at the point of measurement.

In networks with isolated starpoint, the earth fault current flows as capacitive current from the healthy lines via the measuring point to the point of fault. For the determination of the direction the capacitive reactive power is most relevant.

In networks with arc suppression coils, the Petersen coil superimposes a corresponding inductive current on the capacitive earth fault current when an earth fault occurs, so that the capacitive current at the point of fault is compensated. Depending on the measuring point in the system the resultant measured current may be inductive or capacitive. Therefore, the reactive current is not suitable for direction determination of the earth current. In this case, only the ohmic (active) residual current which results from the losses of the Petersen coil can be used for directional determination. This earth fault residual current is only about some per cent of the capacitive earth fault current.

Following the phase determination the earth fault direction is determined from a highly accurate calculation of active and reactive power. The following definitions are used for this purpose:

$$P_E = \frac{1}{T} \cdot \int_t^{t+T} u_E(t) \cdot i_E(t) \cdot dt \qquad \text{and} \qquad Q_E = \frac{1}{T} \cdot \int_t^{t+T} u_E(t - \frac{\pi}{2}) \cdot i_E(t) \cdot dt$$

where T equals period of integration.

The use of an efficient calculation algorithm and simultaneous numerical filtering allows the directional determination to be achieved with high accuracy and sharply defined threshold limits (see Figure 2-103) and insensitivity to harmonic influences — particularly the third and fifth harmonics which are often large in earth fault currents. Direction determination relies on the sign of active and reactive power.
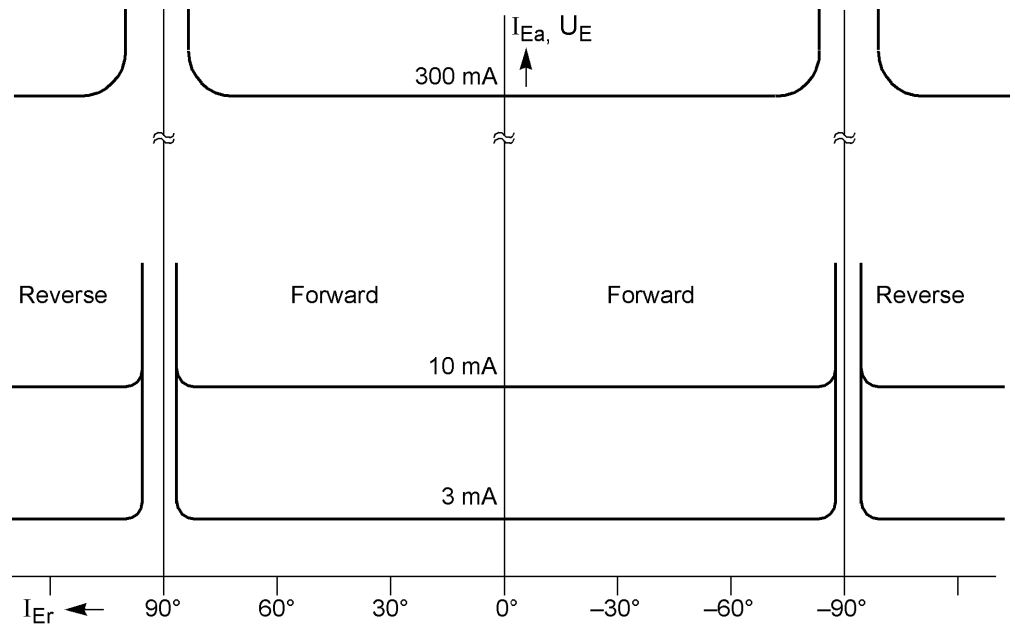
Figure 2-103   Measurement characteristic of the sensitive direction determination for earth fault in a resonant-earthed system

Since the active and reactive component of the current – not the power – determine the earth fault directional decision, these current components are calculated from the power components. Thus for determination of the direction of the earth fault, active and reactive components of the earth fault current as well as the direction of the active and reactive power are evaluated.

In networks with **isolated** starpoint the following criteria apply:

- Earth fault (forward direction), if $Q_E > 0$ and $I_{Eb} >$ setting value,
- Earth fault (reverse direction), if $Q_E < 0$ and $I_{Eb} >$ setting value.

In **resonant-earthed** networks (with **arc suppression coil**) the following criteria apply:

- Earth fault (forward direction), if $P_{Ea} > 0$ and $I_{Ea} >$ setting value (),
- Earth fault (reverse direction), if $P_{Ea} < 0$ and $I_{Ea} >$ setting value.

In the latter case please take into consideration that, according to the mounting location of the device, the active component of the current may be superposed by a large reactive component which is a multiple of the active component (in worse cases it may be 50 times the active component). The accuracy of the calculation algorithm which is extremely high is not sufficient if the transformer is not able to transmit the primary values exactly.

The measurement input circuit of the relay version with earth fault detection is particularly designed for this purpose and permits an extremely high sensitivity for the directional determination of the wattmetric residual current. To be able to use this sensitivity, we recommend toroidal current transformers for earth fault detection in resonant earthed systems. Furthermore, the angle error of the toroidal current transformer can be compensated in the 7SA6. Since the angle error is non-linear, this is done by entering two operating points of the angle error curve of the transformer. The device then calculates the error curve with the accuracy needed.

Earth Fault Location

In radial systems, locating the earth faults is relatively simple. Since all feeders from a common bus (Figure 2-104) deliver a capacitive charging current, nearly the total earth fault current of the system is available at the measuring point of the faulty line in the earthed system. In the non-earthed system it is the residual wattmetric current of the Petersen coil that flows via the measuring point. For the faulted line or cable, a definite "forward" decision will result, whilst in the remaining circuits a "reverse" indication will be given unless the earth current is so small that no measurement can be taken. Definitely the faulty line can be determined clearly.
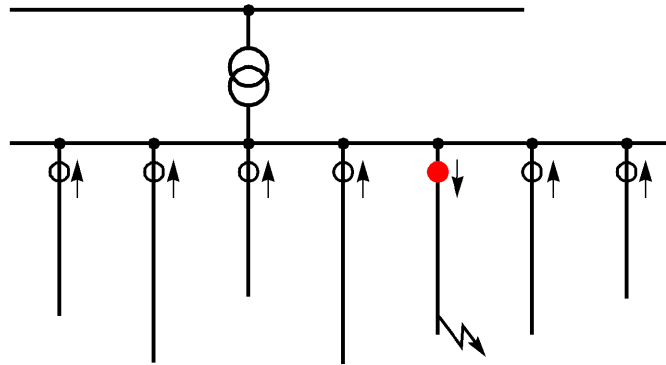
Figure 2-104   Earth fault location in a radial network

In meshed or ring networks the measuring points at the ends of the faulted cable also see a maximum of earth fault (capacitive or ohmic) current. Only in this cable will the direction "forwards" be indicated on both line ends (Figure 2-105). However, also the rest of the direction indications in the system may be useful for earth fault detection. Some indications may not be output when earth current is too low. Further advice can be found in the leaflet "Earth fault detection in isolated neutral or arc-suppression coil earthed high voltage systems".
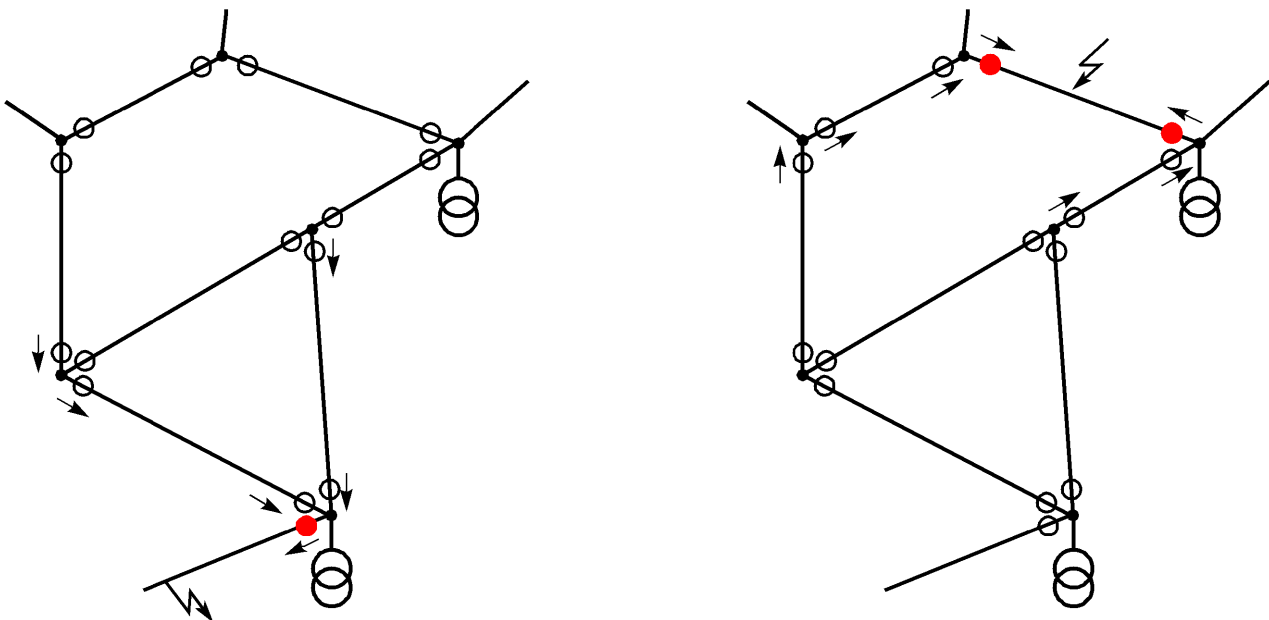
Figure 2-105   Faulted line location in meshed networks using directional indications

2.13.2 Setting Notes

General

This section applies only to relay models with earth fault detection module and only when these are used in networks with isolated or compensated starpoint. In other cases, this section can be passed over.

Earth fault detection is only possible if the function **Sens. Earth Flt** (address 130) was set to *Enabled* during configuration). If the device is equipped with earth fault detector but supposed to operate in an earthed network, address 130 **Sens. Earth Flt** <u>must</u> be set to *Disabled*!

The earth fault detection can be switched *ON: with Trip*, turned *OFF* or set to *Alarm Only* at address 3001 **Sens. Earth Flt**. In the latter case (default setting) the device announces detected earth faults, identifies the faulty phases and the earth fault direction according to the other settings.

If the earth fault detection is switched *ON: with Trip* it also issues a trip command. In this case no earth fault protocol is generated, but a trip log that registers all information about the earth fault and the earth fault tripping. The tripping can be delayed via address 3007 **T 3U0>**.

Voltage Stages

The displacement voltage is the pickup threshold of the earth fault detection and is set in address 3002 **3U0>**.

If the displacement voltage U_{en} of the voltage transformer set is directly connected to the fourth voltage measuring input U_4 of the device and if this was predefined during the configuration, the device will use this voltage, multiplied by the factor **Uph / Udelta** (address 211). For the usual transformation of the voltage transformer with e–n–winding

$$\frac{U_{Nprim}}{\sqrt{3}} \Big/ \frac{U_{Nsec}}{\sqrt{3}} \Big/ \frac{U_{Nsec}}{3}$$

the factor is set to 1.73 ($\sqrt{3}$) (see also Subsection 2.1.3.1, margin heading "Voltage Transformer Connection"). In case of a complete displacement of a healthy voltage triangle the displacement voltage has a value that is $\sqrt{3}$ times the phase-to-phase voltage.

If no displacement voltage is connected to the device, the device calculates the monitored voltage from the total of the voltages:

$3U_0 = |\underline{U}_{L1} + \underline{U}_{L2} + \underline{U}_{L3}|$.

In case of a complete displacement of a healthy voltage triangle the displacement voltage also has a value that is $\sqrt{3}$ times the phase-to-phase voltage.

Since, in case of earth faults in isolated or resonant-earthed systems, the complete displacement voltage emerges, the setting value is uncritical; it should approx. be between 25 % to 50% of the displacement voltage: for $U_N = 100$ V therefore between 50 V to 90 V.

The earth fault is detected and reported only when the displacement voltage has applied for at least the time **T Sens.E/F** (address 3006). This stabilizing period is also enabled if earth fault conditions change (e.g. change of direction).

If tripping is also required for earth faults (address 3001 **Sens. Earth Flt** = *ON: with Trip*), a delay time can be set in address 3007 **T 3U0>**.

For phase determination **Uph-e min** (address 3003) is the criterion for the earth-faulted phase, when simultaneously the other two phase voltages have exceeded **Uph-e max** (address 3004). The setting **Uph-e min** must be set less than the minimum allowable phase-to-earth voltage. This setting is neither critical, 40 V (default setting) should always be correct. **Uph-e max** must be greater than the maximum allowable phase-to-earth voltage, but less than the minimum allowable phase-to-phase voltage. For U_N = 100 V that is for example at 75 V (default setting). The definite detection of the faulted phase is a further prerequisite for alarming an earth fault.

Determination of Direction

The following is valid for determination of direction during earth faults: Pickup current **3I0>** (address 3005) must be set as high as possible to avoid a false pickup of the device provoked by asymmetrical currents in the system and by current transformers (especially in a Holmgreen-connection). Dependent upon the treatment of the network starpoint, the magnitude of the capacitive earth fault current (for isolated networks) or the wattmetric residual current (for compensated networks) is decisive.

In **isolated** networks an earth fault in a cable will allow the total capacitive earth fault currents of the entire electrically connected network, with the exception of the faulted cable itself, to flow through the measuring point. It is normal to use half the value of this earth fault current as the threshold value.

Example: A 25 kV bus-bar feeds seven cable circuits. Each circuit has a current transformer set 300 A/1 A. The earth fault current is 2.5 A/km. The following applies for the cables circuits:

Cable 1	3 km	7.5 A
Cable 2	5 km	12.5 A
Cable 3	2.6 km	6.5 A
Cable 4	5 km	12.5 A
Cable 5	3.4 km	8.5 A
Cable 6	3.4 km	8.5 A
Cable 7	2.6 km	6.5 A
Total	25.0 km	62.5 A

With an earth fault in cable 2, 62.5A – 12.5A = 50A earth fault current will flow through the measuring point, since 12.5A flows directly from cable 2 into the fault. Since that cable is amongst the longest, this is the most unfavourable case (smallest earth fault current flows through the measuring point). On the secondary side, flows:

50 A/300 = 0.167 A.

The relay should be set at approximately half this value for example **3I0>** = **0.080** A.

In **resonant-earthed** networks directional determination is made more difficult since a much larger reactive current (capacitive or inductive) is superimposed on the critical wattmetric (active) current. Therefore, depending on the system configuration and the position of the arc-suppression coil, the total earth current supplied to the device may vary considerably in its values concerning magnitude and phase angle. The relay, however, must evaluate only the active component of the earth fault current, the earth fault residual current, that is $I_E \cdot \cos \varphi$. This demands extremely high accuracy, particularly with regard to phase angle measurement of all the instrument transformers. Furthermore, the device must not be set to operate too sensitive. When applying this function in earthed systems, a reliable direction determination can only be achieved when connecting toroidal current transformers. Here the following rule of thumb applies: setting at half the expected measured current, whereby only the residual wattmetric current is applicable. Residual wattmetric current predominantly derives from losses of the Petersen coil.

Example: The same network, as in the previous example, is considered to be compensated by a Petersen coil. The coil is matched to the total network. The compensation current is thus 62.5 A. The losses should be 4 %. For earth fault directional determination, core balance current transformers 60 A/1 A are fitted.

Since the residual wattmetric current is derived principally from the coil losses, it is, independent of earth fault location, approximately the same:

4 % of 62.5 A = 2.5 A or secondary

2.5 A/60 A = 0.042 A.

As setting value **3IO>** = **0.020**A is selected.

If the earth fault protection is also to trip (address 3001 **Sens. Earth Flt** = *ON: with Trip*), set in address 3008 **TRIP Direction**, whether tripping for earth faults has to be accomplished in *Forward* direction (normally in line direction), *Reverse* direction (normally in direction of busbar) or *Non-Directional*. This setting is only possible via DIGSI® at **Additional Settings**.

Angle Error Compensation

The high reactive current component in resonant-earthed networks and the unavoidable air gap of the core balance type current transformers require a phase angle compensation of the current transformer. This is possible with addresses 3010 to 3013. For the actual connected burden the maximum angle phase displacement**CT Err. F1** (address 3011) of the CT with its associated current **CT Err. I1** (address 3010) as well as a further CT operating point **CT Err. F2**/**CT Err. I2** (address 3013 and 3012), above which the angle displacement remains practically constant (see Figure 2-106). The device thus approximates the transformation curve of the transformer with considerable accuracy. In unearthed systems angle compensation is not required.
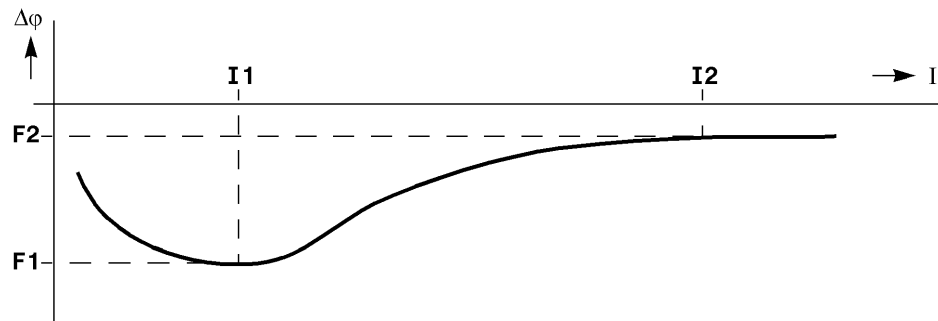
Figure 2-106   Parameters for the phase angle correction

2.13.3 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
3001	Sens. Earth Flt	Alarm Only ON: with Trip OFF	Alarm Only	Sensitive Earth Flt.(comp/ isol. starp.)
3002	3U0>	1 .. 150 V	50 V	3U0> pickup
3003	Uph-e min	10 .. 100 V	40 V	Uph-e min of faulted phase
3004	Uph-e max	10 .. 100 V	75 V	Uph-e max of healthy phases
3005	3I0>	0.003 .. 1.000 A	0.050 A	3I0> Release directional element
3006	T Sens.E/F	0.00 .. 320.00 sec	1.00 sec	Time delay for sens. E/F detection
3007	T 3U0>	0.00 .. 320.00 sec	0.00 sec	Time delay for sens. E/F trip
3008A	TRIP Direction	Forward Reverse Non-Directional	Forward	Direction for sens. E/F trip
3010	CT Err. I1	0.003 .. 1.600 A	0.050 A	Current I1 for CT Angle Error
3011	CT Err. F1	0.0 .. 5.0 °	0.0 °	CT Angle Error at I1
3012	CT Err. I2	0.003 .. 1.600 A	1.000 A	Current I2 for CT Angle Error
3013	CT Err. F2	0.0 .. 5.0 °	0.0 °	CT Angle Error at I2

2.13.4 Information List

No.	Information	Type of Information	Comments
1219	3I0senA=	OUT	Active 3I0sen (sensitive Ie) =
1220	3I0senR=	OUT	Reactive 3I0sen (sensitive Ie) =
1251	>SensEF on	SP	>Switch on sensitive E/F detection
1252	>SensEF off	SP	>Switch off sensitive E/F detection
1253	>SensEF block	SP	>Block sensitive E/F detection
1260	SensEF on/offBI	IntSP	Sensitve E/F detection ON/OFF via BI
1261	SensEF OFF	OUT	Sensitve E/F detection is switched OFF
1262	SensEF BLOCK	OUT	Sensitve E/F detection is BLOCKED
1263	SensEF ACTIVE	OUT	Sensitve E/F detection is ACTIVE
1271	SensEF Pickup	OUT	Sensitve E/F detection picked up
1272	SensEF Phase L1	OUT	Sensitve E/F detection Phase L1
1273	SensEF Phase L2	OUT	Sensitve E/F detection Phase L2
1274	SensEF Phase L3	OUT	Sensitve E/F detection Phase L3
1276	SensEF Forward	OUT	Sensitve E/F detection Forward
1277	SensEF Reverse	OUT	Sensitve E/F detection Reverse
1278	SensEF undefDir	OUT	Sensitve E/F detection Undef. Direction

No.	Information	Type of In-formation	Comments
1281	SensEF TRIP	OUT	Sensitve E/F detection TRIP command
1291	SensEF 3U0>	OUT	Sensitve E/F detection 3U0> pickup

2.14 Automatic reclosure function (optional)

Experience shows that about 85% of the arc faults on overhead lines are extinguished automatically after being tripped by the protection. This means that the line can be re-closed. Reclosure is performed by an automatic reclosure function (AR).

Automatic reclosure is only permitted on overhead lines because the option of automatic extinguishing of a fault arc only exists there. It should not be used in any other case. If the protected object consists of a mixture of overhead lines and other equipment (e.g. overhead line directly connected to a transformer or overhead line/cable), it must be ensured that reclosure can only be performed in the event of a fault on the overhead line.

If the circuit-breaker poles can be operated individually, a single-phase auto-reclosure is usually initiated for single-phase faults and a three-pole auto-reclosure for multiple-phase faults in the network with earthed system starpoint. If the fault still exists after automatic reclosure (arc has not disappeared, there is a metallic fault), then the protective elements will re-trip the circuit breaker. In some systems several reclosing attempts are performed.

In a model with single-pole tripping, the 7SA6 allows phase-selective, single-pole tripping. A single and three-pole, single and multiple shot automatic reclosure function is integrated, depending on the ordered version.

The 7SA6 can also operate in conjunction with an external automatic reclosure device. In this case the signal exchange between 7SA6 and the external reclosure device must be effected via the binary inputs and outputs.

It is also possible to make control of the integrated automatic reclosure by an external protection (e.g. second protection). The use of two 7SA6 with automatic reclosure function or the use of one 7SA6 with an automatic reclosure function and a second protection with its own automatic reclosure function is also possible.

2.14.1 Method of Operation

Reclosure is performed by an automatic reclosure function (AR). An example of the normal time sequence of a double reclosure is shown in the following Figure.
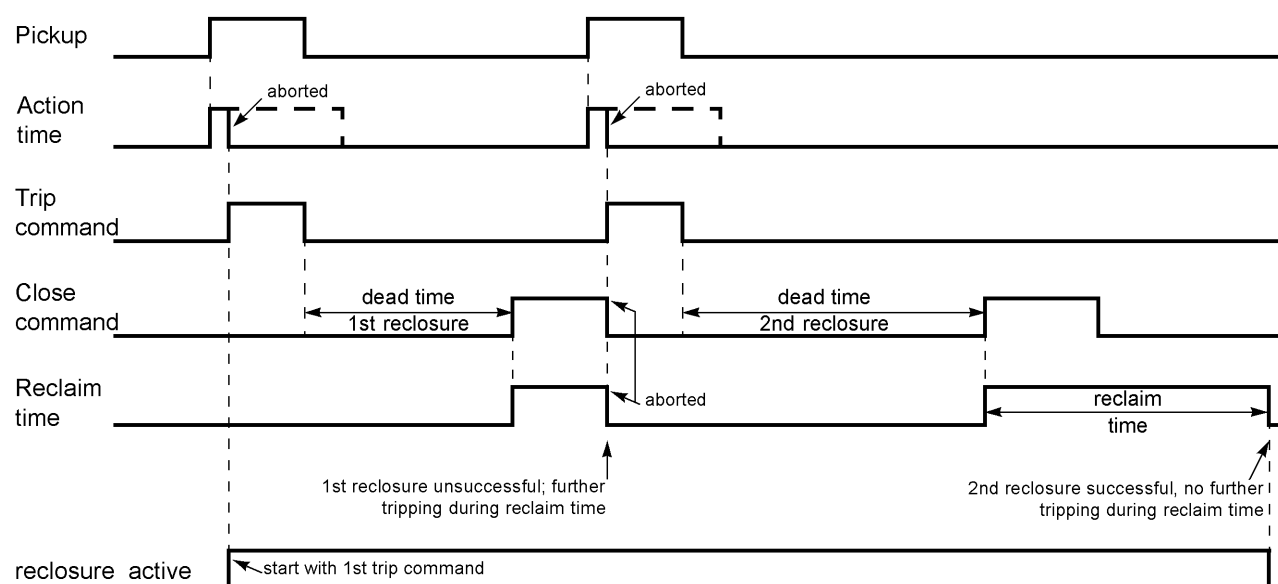
Figure 2-107   Timing diagram of a double-shot reclosure with action time (2nd reclosure successful)

The integrated automatic reclosure circuit allows up to 8 reclosure attempts. The first four interrupt cycles may operate with different parameters (action and dead times, single/three-pole). The parameters of the fourth cycle also apply for the fifth cycle and onwards.

Selectivity before Reclosure

In order for the automatic reclosure to be successful, all faults on the entire overhead line must be cleared at all line ends simultaneously — as fast as possible. In the distance protection, for example, the overreaching zone Z1B may be released before the first reclosure. This implies that faults up to the zone reach limit of Z1B are tripped without delay for the first cycle (Figure 2-108). A limited unselectivity in favour of fast simultaneous tripping is accepted here because a reclosure will be performed in any case. The normal stages of the distance protection (Z1, Z2, etc.) and the normal grading of the other short-circuit functions are independent of the automatic reclosure function.

Reach for 1st tripping before reclosure (overreach zone Z1B enabled)

Reach after 1st reclosure (overreach zone Z1B disabled)
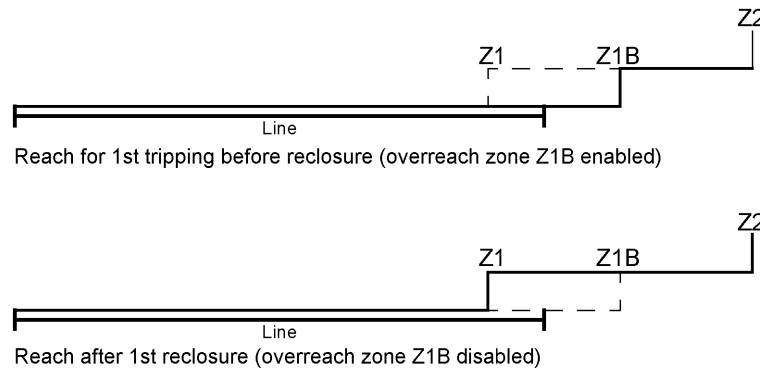
Figure 2-108   Reach control before first reclosure, using distance protection

If the distance protection is operated with one of the signal transmission methods described in Section 2.6 the signal transmission logic controls the overreaching zone, i.e. it determines whether an undelayed trip (or delayed with T1B) is permitted in the event of faults in the overreaching zone (i.e. up to the reach limit of zone Z1B) at both line ends simultaneously. Whether the automatic reclosure device is ready for reclosure or not is irrelevant, because the teleprotection function ensures the selectivity over 100% of the line length and fast, simultaneous tripping. The same applies for the earth fault-direction comparison protection (Section 2.8).

If, however, the signal transmission is switched off or the transmission path is disturbed, the internal automatic reclosure circuit can determine whether the overreaching zone (Z1B in the distance protection) is released for fast tripping. If no reclosure is expected (e.g. circuit-breaker not ready) the normal grading of the distance protection (i.e. fast tripping only for faults in zone Z1) must apply to retain selectivity.

Fast tripping before reclosure is also possible with multiple reclosures. Appropriate links between the output signals (e.g. 2nd reclosure ready: "AR 2.CycZoneRel") and the inputs for enabling/releasing undelayed tripping of the protection functions can be established via the binary inputs and outputs or the integrated user-definable logic functions (CFC).

Mixed Lines Overhead Line/Cable

On mixed lines with cables and overhead lines, it is possible to use the distance zone signals to distinguish between cable and overhead line faults to a certain extent. The automatic reclosure circuit can then be blocked by appropriate signals generated by means of the user-programmable logic functions (CFC) if there is a fault in the cable section.

Initiation

Starting the automatic reclosure function means storing the first trip signal during a network fault that was generated by a protection function which operates with the automatic reclose function. In the case of multiple reclosure, starting therefore only takes place once with the first trip command. The detection of the actual circuit breaker position is necessary for the correct functionality of the auto reclose function.

Starting is important when the first trip command has not appeared before expiry of an action time (see below under "Action times").

Automatic reclosure is not started if the circuit breaker has not been ready for at least one TRIP–CLOSE–TRIP–cycle at the instant of the first trip command. This can be achieved by setting parameters. For further information, please refer to "Interrogation of Circuit Breaker Ready State".

Each short circuit protection function can be parameterized as to whether it should operate with the automatic reclose function or not i.e. whether it should start the reclose function or not. The same goes for external trip commands applied via binary input and/or the trip commands generated by the teleprotection via permissive or intertrip signals.

Those protection and monitoring functions in the device which do not respond to short-circuits or similar conditions do not initiate the automatic reclosure function because a reclosure will be of no use here. For 7SA6 this is e.g. the overvoltage protection.

Action Times

It is often desirable to neutralize the ready–for–reclosure–state if the short-circuit condition was sustained for a certain time, e.g. because it is assumed that the arc has burned in to such an extent that there is no longer any chance of automatic arc extinction during the reclose dead time. Also for the sake of selectivity (see above), faults that are usually cleared after a time delay should not lead to reclosure. It is therefore recommended to use action times in conjunction with the distance protection.

The automatic reclosure function of the 7SA6 can be operated with or without action times (configuration parameter **AR control mode**, address 134, see section 2.1.1.2). No starting signal is necessary from the protection functions or external protection devices that operate without action time. Starting takes place as soon as the first trip command appears.

When operation with action time, an action time is available for each reclose cycle. The action times are always started by the general starting signal (with logic OR combination of all internal and external protection functions which can start the automatic reclosure function). If no trip command is present before the action time expires, the corresponding reclose cycle is not carried out.

For each reclosure cycle, you may set whether or not it allows the initiation. Following the first general pickup, only the action times of those cycles that are set such that they may start off the recloser are considered since the other cycles are not allowed to be the first cycle under any circumstances. By means of the action times and the permission to start the recloser (permission to be the first cycle that is executed) it is possible to determine which reclose cycles are executed depending on the time used by the protection function to trip.

Example 1: 3 cycles are set. Starting of the auto-reclosure is allowed for at least the first cycle. The action times are set as follows:

- 1st Reclosure: T Action = 0.2 s;
- 2nd Reclosure: T Action = 0.8 s;
- 3rd Reclosure: T Action = 1.2 s;

Since reclosure is ready before the fault occurs, the first trip of a time overcurrent protection following a fault is fast, i.e. before the end of any action time. The automatic reclosure function is therefore started (the first cycle is initiated). After unsuccessful reclosure the 2nd cycle would then become active; but the time overcurrent protection would not trip in this example until after 1s according to its grading time. Since the action time for the second cycle was exceeded here, it is blocked. The 3rd cycle with its parameters is therefore now. If the trip command only appeared more than 1.2s after the 1st reclosure, there would have been no further reclosure.

Example 2: 3 cycles are set. Starting is only allowed for the first. The action times are set as in example 1. The first protection trip takes place 0.5s after starting. Since the action time for the 1st cycle has already expired at this time, this cannot start the automatic reclosure function. As the 2nd and 3rd cycles are not permitted to start the reclose function they will also not be initiated. Therefore no reclosure takes place as no starting took place.

Example 3: 3 cycles are set. At least the first two cycles are set such that they can start the recloser. The action times are set as in example 1. The first protection trip takes place 0.5s after starting. Since the action time for the 1st cycle has already expired at this time, it cannot start the automatic reclosure function but the 2nd cycle, for which starting is allowed, is activated immediately. This 2nd cycle therefore starts the automatic reclosure circuit, the 1st cycle is practically skipped.

Control Mode of the Automatic Reclosure

The dead times — these are the times from elimination of the fault (dropout of the trip command or signalling via auxiliary contacts) to the initiation of the automatic close command — may vary, depending on the automatic reclosure control mode selected when determining the functional scope and the resulting signals of the starting protective functions.

In control mode **TRIP...** (With TRIP command) single-pole or single/three-pole reclose cycles are possible if the device and the circuit-breaker are suitable. In this case different dead times after single-pole tripping on the one hand and after three-pole tripping on the other hand are possible (for every reclose cycle). The protective function that issues the trip command determines the type of trip: single-pole or three-pole. Depending on the latter the dead time is selected.

In control mode **PICKUP ...** (With PICKUP...) different dead times can be set for every reclosure cycle after single-phase, two-phase and three-phase faults. Selection of the dead time in this case depends on the type of fault determined by the initiating protection function at the instant that the trip commands reset. This operating mode allows the dead times to be dependent on the type of fault in the case of three-pole reclose cycles.

Reclose Block

Different conditions lead to blocking of the automatic reclosure. No reclosure is for example possible if it is blocked via a binary input. If the automatic reclosure has not yet been started, it cannot be started at all. If a reclose cycle is already in progress, dynamic blocking takes place (see below).

Each individual cycle may also be blocked via binary input. In this case the cycle concerned is declared as invalid and will be skipped in the sequence of permissible cycles. If blocking takes place while the cycle concerned is already running, this leads to aborting of the reclosure, i.e. no reclosure takes place even if other valid cycles have been parameterized.

Internal blocking signals, with a limited duration, arise during the course of the reclose cycles:

The reclaim time **T-RECLAIM** begins with every automatic reclosure command. If the reclosure is successful, all the functions of the automatic reclosure return to the quiescent state at the end of the reclaim time; a fault after expiry of the reclaim time is treated as a new fault in the network. Re-tripping by a protection function during the reclaim time initiates the next reclose cycle in the case of multiple reclosure; if no further reclosure is permitted, the last reclose cycle is declared as unsuccessful if re-tripping within the reclaim time takes place. The automatic reclosure is blocked dynamically.

The dynamic lock-out locks the reclosure for the duration of the dynamic lock-out time (0.5s). This occurs for example after a final tripping or other events which block the automatic reclosure after it has been started. Restarting is locked out for this time. When this time expires, the automatic reclosure function returns to its quiescent state and is ready for a new fault in the power system.

If the circuit breaker is closed manually (by the control discrepancy switch connected to a binary input, the local control functions or via one of the serial interfaces), the au-

tomatic reclosure is blocked for a manual-close-blocking time **T-BLOCK MC**. If a trip command is issued during this time, it can be assumed that a metallic short-circuit is the cause (e.g. closed earth switch). Every trip command within this time is therefore a final trip. With the user definable logic functions (CFC) further control functions can be processed in the same way as a manual–close command.

Interrogation of the Circuit Breaker Ready State

A precondition for automatic reclosure following clearance of a short circuit is that the circuit-breaker is ready for at least one TRIP-CLOSE-TRIP-cycle when the automatic reclosure circuit is started (i.e. at the time of the first trip command). The readiness of the circuit-breaker is signalled to the device through the binary input "**>CB1 Ready**" (FNo. 371). If no such signal is available, the circuit-breaker interrogation can be suppressed (presetting) as automatic reclosure would otherwise not be possible at all.

In the event of a single cycle reclosure this interrogation is usually sufficient. Since, for example, the air pressure or the spring tension for the circuit breaker mechanism drops after the trip, no further interrogation should take place.

Especially when multiple reclosing attempts are programmed, it is recommended to monitor the circuit breaker condition not only prior to the first but also before each following reclosing attempt. Reclosure will be blocked until the binary input indicates that the circuit breaker is ready to complete another CLOSE-TRIP cycle.

The time needed by the circuit-breaker to regain the ready state can be monitored by the 7SA6. This monitoring time **CB TIME OUT** starts as soon as the CB indicates the not ready state. The dead time may be extended if the ready state is not indicated when it expires. However, if the circuit breaker does not indicate its ready status for a longer period than the monitoring time, reclosure is locked out dynamically (see also "Reclose Block", above).

Processing the Circuit Breaker Auxiliary Contacts

If the circuit-breaker auxiliary contacts are connected to the device, the reaction of the circuit-breaker is also checked for plausibility.

In the case of single pole tripping this applies to each individual breaker poles. This assumes that the auxiliary contacts are connected to the appropriate binary inputs for each pole ("**>CB1 Pole L1**", FNo. 366; "**>CB1 Pole L2**", FNo. 367; "**>CB1 Pole L3**", FNo. 368).

If instead of the individual pole auxiliary contacts, the series connections of the normally open and normally closed contacts are used, the CB is assumed to have all three poles open when the series connection of the normally closed contacts is closed (binary input "**>CB1 3p Open**", FNo.411). All 3 poles are assumed closed when the series connection of the normally open contacts is closed (binary input "**>CB1 3p Closed**", FNo. 410). If neither of these conditions are present, it is assumed that the circuit breaker has one pole open (even if this condition also theoretically applies to the two-pole open state).

The device continuously checks the switching state of the circuit-breaker: As long as the auxiliary contacts indicate that the CB is not closed (three-pole), the automatic reclosure function cannot be started. This guarantees that a close command can only be issued if the CB previously tripped (out of the closed state).

The valid dead time begins when the trip command disappears or signals taken from the CB auxiliary contacts indicate that the CB (pole) has opened.

If the CB opens **three-pole** after a **single-pole** trip command, this is considered as a three-pole tripping. If three-pole reclosure cycles are allowed, the dead time for three-pole tripping is activated in the **control mode with trip command** (see margin heading "Control Mode of the Automatic Reclosure")above; in control by pickup, the pickup configuration of the starting protective function(s) is still decisive. If three-pole

cycles are not allowed, the reclosure is locked out dynamically. The trip command is final.

The latter also applies if the CB trips two poles following a single-pole trip command. The device can only detect this if the auxiliary contacts of each pole are connected individually. The device immediately initiates three pole coupling thus resulting in a three-pole trip command.

If the CB auxiliary contacts indicate that at least one further pole has opened during the dead time following a single-pole trip, a three-pole reclose cycle is initiated with the dead time for three-pole reclosure if this is allowed. If the auxiliary contacts are connected for each pole individually, the device can detect a two-pole open CB. In this case the device immediately sends a three-pole trip command provided the forced three-pole trip is activated (see Subsection 2.14.2 at margin heading "Forced Three-Pole Trip").

Sequence of a Three-Pole Reclose Cycle

If the automatic reclosure function is ready, the short-circuit protection trips three pole for all faults inside the stage selected for reclosure. The automatic reclosure function is then started. When the trip command resets or the circuit-breaker opens (auxiliary contact criterion) an (adjustable) dead time starts. At the end of this dead time the circuit-breaker receives a close command. At the same time the (adjustable) reclaim time is started. If during configuration of the protection functions address 134 **AR control mode** = *PICKUP ...* was set, different dead times can be parameterized depending on the type of protection pickup.

If the fault is cleared (successful reclosure), the reclaim time expires and all functions return to their quiescent state. The fault is cleared.

If the fault is not cleared (unsuccessful reclosure), the short-circuit protection issues a final trip with the protection stage that is selected to operate without reclosure. Any fault during the reclaim time leads to a final trip.

After unsuccessful reclosure (final tripping), the automatic reclosure is blocked dynamically (see also margin heading " Reclose Block, above").

The sequence above applies for single reclosure cycles. In 7SA6 multiple reclosure (up to 8 cycles) is also possible (see below).

Sequence of a Single-pole Reclose Cycle

Single-pole reclose cycles are only possible with the appropriate device version and if this was selected during the configuration of the protection functions (address 110 **Trip mode**, see also Section 2.1.1.2). Of course, the circuit-breaker must also be suited for single-pole tripping.

If the automatic reclosure function is ready, the short-circuit protection trips single pole for all single-phase faults inside the stage selected for reclosure. Under the general settings (address 1156 **Trip2phFlt**, see also Section 2.1.5.1) it can also be selected that single-pole tripping takes place for two-phase faults without earth. Single-pole tripping is of course only possible with short-circuit protection functions that can determine the faulty phase.

If only single-pole reclosure is selected then the short-circuit protection issues a final three pole trip with the stage that is valid/selected without reclosure. Every three-pole trip is final. The automatic reclosure is blocked dynamically (see also margin heading " Reclosure Block", above).

The automatic reclosure function is started following a single-pole trip. The (adjustable) dead time for the single-pole reclose cycles starts with reset of the trip command or opening of the circuit-breaker pole (auxiliary contact criterion). After expiry of the dead time the circuit-breaker receives a close command. At the same time the (adjust-

able) reclaim time is started. If the reclosure is blocked during the dead time following a single-pole trip, immediate three-pole tripping can take place as an option (forced three-pole coupling).

If the fault is cleared (successful reclosure), the reclaim time expires and all functions return to their quiescent state. The fault is cleared.

If the fault is not cleared (unsuccessful reclosure), the short-circuit protection issues a final trip with the protection stage that is valid/selected without reclosure. All faults during the reclaim time also lead to the issue of a final three-pole trip.

After unsuccessful reclosure (final tripping), the automatic reclosure is blocked dynamically (see also margin heading " Reclose Block", above).

The sequence above applies for single reclosure cycles. In 7SA6 multiple reclosure (up to 8 cycles) is also possible (see below).

Sequence of a Single and Three-Pole Reclose Cycle

This operating mode is only possible with the appropriate device version and if this was selected during configuration of the protection functions (address 110, see also section 2.1.1.2). Of course, the circuit-breaker must also be suitable for single-pole tripping.

If the automatic reclosure function is ready, the short-circuit protection trips single-pole for single-phase faults and three-pole for multi-phase faults. Under the general settings (address 1156 `Trip2phFlt`, see also Section 2.1.5.1) it can also be selected that single-pole tripping takes place for two-phase faults without earth. Single-pole tripping is of course only possible with short-circuit protection functions that can determine the faulty phase. The valid protection stage selected for reclosure ready state applies for all fault types.

The automatic reclosure function is started in the event of a trip. Depending on the type of fault the (adjustable) dead time for the single-pole reclose cycle or the (separately adjustable) dead time for the three-pole reclose cycle starts following the reset of the trip command or opening of the circuit-breaker (pole). After expiry of the dead time the circuit-breaker receives a close command. At the same time the (adjustable) reclaim time is started. If the reclosure is blocked during the dead time following a single-pole trip, immediate three-pole tripping can take place as an option (forced three-pole coupling).

If the fault is cleared (successful reclosure), the reclaim time expires and all functions return to their quiescent state. The fault is cleared.

If the fault is not cleared (unsuccessful reclosure), the short-circuit protection initiates a final three-pole trip with the protection stage that is valid/selected when reclosure is not ready. All faults during the reclaim time also lead to the issue of a final three-pole trip.

After unsuccessful reclosure (final tripping), the automatic reclosure is blocked dynamically (see also margin heading "Reclose Block", above).

The sequence above applies for single reclosure cycles. In 7SA6 multiple reclosure (up to 8 cycles) is also possible (see below).

Multi-shot Reclosing

If a short-circuit still exists after a reclosure attempt, further reclosure attempts can be made. Up to 8 reclosure attempts are possible with the automatic reclosure function integrated in the 7SA6.

The first four reclosure cycles are independent of each other. Each one has separate action and dead times, can operate single or three pole and can be blocked separately

via binary inputs. The parameters and intervention possibilities of the fourth cycle also apply to the fifth cycle and onwards.

The sequence is the same in principle as in the different reclosure programs described above. However, if the first reclosure attempt was unsuccessful, the reclosure function is not blocked, but instead the next reclose cycle is started. The appropriate dead time starts with the reset of the trip command or opening of the circuit-breaker (pole) (auxiliary contact criterion). The circuit-breaker receives a new close command after expiry of the dead time. At the same time the reclaim time is started.

Until the set maximum number of permissible auto-reclose cycles has been reached, the reclaim time is reset with every new trip command after reclosure and started again with the next close command.

If one of the reclosing attempts is successful, i.e. the fault disappeared after reclosure, the blocking time expires and the automatic reclosing system is reset. The fault is cleared.

If none of the cycles is successful, the short-circuit protection initiates a final three-pole trip after the last permissible reclosure, following a protection stage active without auto-reclosure. The automatic reclosure is blocked dynamically (see also margin heading "Reclose Block", above).

Handling Evolving Faults

When single-pole and single and three-pole reclose cycles are executed in the network, particular attention must be paid to sequential faults.

Sequential faults are faults which occur during the dead time after clearance of the first fault.

There are various ways of handling sequential faults in the 7SA6 depending on the requirements of the network:

For the **Detection** of an evolving fault you can select whether the trip command of a protective function during the dead time or every further pickup is the criterion for an evolving fault.

There are also various selectable possibilities for the **response** of the internal auto-reclose function to a detected evolving fault.

- **EV. FLT. MODE** *blocks AR*:

  The reclosure is blocked as soon as an evolving fault is detected. Tripping as a result of the sequential fault is three-pole. This applies irrespective of whether three-pole cycles are permitted or not. There are no further reclosure attempts; the auto-reclosure is blocked dynamically (see also margin heading "Reclose Block", above).

- **EV. FLT. MODE** *starts 3p AR*:

  As soon as a sequential fault is detected the recloser switches over to a three-pole reclose cycle. All trip commands are now three-pole. The separately settable dead time for sequential faults starts with the clearance of the sequential fault; after the dead time the circuit-breaker receives a close command. The further sequence is the same as for single and three-pole cycles.

  The complete dead time in this case consists of the portion of the single pole dead time up to clearance of the sequential fault plus the dead time for the sequential fault. This makes sense because the duration of the three-pole dead time is most important for the stability of the network.

If reclosure is blocked due to a sequential fault without the protection issuing a three-pole trip command (e.g. for sequential fault detection with starting), the device can

send a three pole trip command so that the circuit-breaker does not remain open with one pole (forced three-pole coupling).

Dead Line Check (DLC)

If the voltage of a disconnected phase does not disappear following a trip, reclosure can be prevented. A prerequisite for this function is that the voltage transformers are connected on the line side of the circuit breaker. To select this function the dead line check must be activated. The automatic reclosure function then checks the disconnected line for no-voltage: The line must have been without voltage for at least an adequate measuring time during the dead time. If this was not the case the reclosure is blocked dynamically.

This no-voltage check on the line is of advantage if a small generator (e.g. wind generator) is connected along the line.

Reduced Dead Time (RDT)

If automatic reclosure is performed in connection with time-graded protection, non-selective tripping before reclosure is often unavoidable in order to achieve fast, simultaneous tripping at all line ends. The 7SA6 has a "reduced dead time (RDT)" procedure which reduces the effect of the short-circuit on healthy line sections to a minimum. The three phase voltages are measured for the reduced dead time. The voltage transformers must be located on the line side of the circuit breaker.

In the event of a short-circuit close to one of the line ends, the surrounding lines can initially be tripped because, for example, a distance protection detects the fault in its overreaching zone Z1B (2-109Figure , relay location III). If the network is meshed and there is at least one other infeed on the busbar B, the voltage there returns immediately after clearance of the fault. For single-pole tripping it is sufficient if there is an earthed transformer with delta winding connected at busbar B which ensures symmetry of the voltages and thus induces a return voltage in the open phase. This allows a distinction between the faulty line and the unfaulted line to be made as follows:

Since line B - C is only tripped singled-ended at C, it receives a return voltage from the end B which is not tripped so that at C the open phase(s) also has(have) voltage. If the device detects this at position III, reclosure can take place immediately or in a shorter time (to ensure sufficient voltage measuring time). The healthy line B - C is then back in operation.

Line A–B is tripped at both ends. No voltage is therefore present identifying the line as the faulted one at both ends. The normal dead time comes into service here.
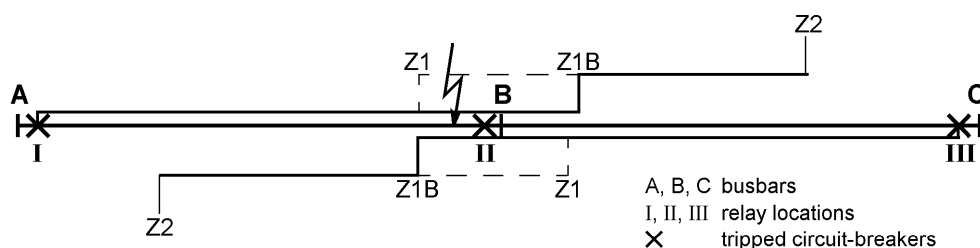
Figure 2-109   Example of a reduced dead time (RDT)

Adaptive Dead Time (ADT)

In all the previous alternatives it was assumed that defined and equal dead times were set at both line ends, if necessary for different fault types and/or reclose cycles.

It is also possible to set the dead times (if necessary different for various fault types and/or reclose cycles) at one line end only and to configure the adaptive dead time at the other end (or ends). This can be done provided that the voltage transformers are

located on the line side of the circuit breaker or that facilities for transfer of a close command to the remote line end exists.

Figure 2-110 shows an example with voltage measurement. It is assumed that the device I is operating with defined dead times whereas the adaptive dead time is configured at position II. It is important that the line is at least fed from busbar A, i.e. the side with the defined dead times.

With the adaptive dead time the automatic reclosure function at line end II decides independently if and when reclosure is sensible and allowed and when it is not. The criterion is the line voltage at end II, which was re-applied from end I following reclosure there. Reclosure therefore takes place at end II as soon as it is apparent that voltage has been re-applied to the line from end I.

In the illustrated example, the lines are disconnected at positions I, II and III. At I reclosure takes place after the parameterized dead time. At III a reduced dead time can take place (see above) if there is also an infeed on busbar B.

If the fault has been cleared (successful reclosure), line A - B is re-connected to the voltage at busbar A through position I. Device II detects this voltage and also recloses after a short delay (to ensure a sufficient voltage measuring time). The fault is cleared.

If the fault has not been cleared after reclosure at I (unsuccessful reclosure), a switch on to fault occurs at I, no healthy voltage appears at II. The device there detects this and does not reclose.

In the case of multiple reclosure the sequence may be repeated several times following an unsuccessful reclosure until one of the reclosures attempts is successful or a final trip takes place.
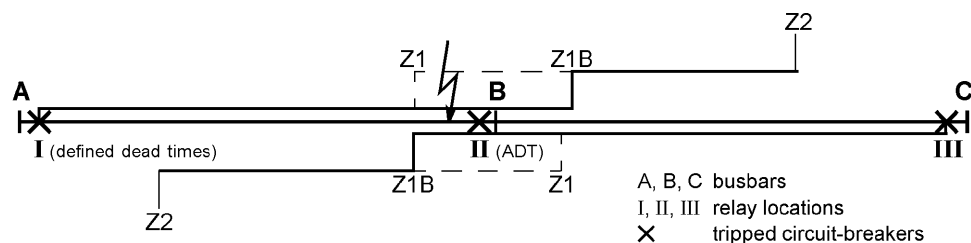
Figure 2-110   Example of adaptive dead time (ADT)

As is shown by the example, the adaptive dead time has the following advantages:

- The circuit-breaker at position II is not reclosed at all if the fault persists and is not unnecessarily stressed as a result.
- With non-selective tripping by overreach at position III no further trip and reclose cycles occur here because the short-circuit path via busbar B and position II remains interrupted even in the event of several reclosure attempts.
- At position I overreach is allowed in the case of multiple reclosures and even in the event of final tripping because the line remains open at position II and therefore no actual overreach can occur at I.

The adaptive dead time also includes the reduced dead time because the criteria are the same. There is no need to set the reduced dead time as well.

CLOSE Command Transmission (Remote-CLOSE)

With close command transmission via the digital connection paths the dead times are only set at one line end. The other line end (or line ends in lines with more than two ends) are set to "Adaptive Dead Time (ADT)". The latter just responds to the received close commands from the transmitting end.

At the sending line end the transmission of the close command is delayed until it is sure that the local reclosure was successful. This means that after reclosure still a possible local pickup is waited for. This delay prevents unnecessary closing at the remote end on the one hand but also increases the time until reclosure takes place there. This is not critical for a single-pole interruption or in radial or meshed networks if no stability problems are expected under these conditions.
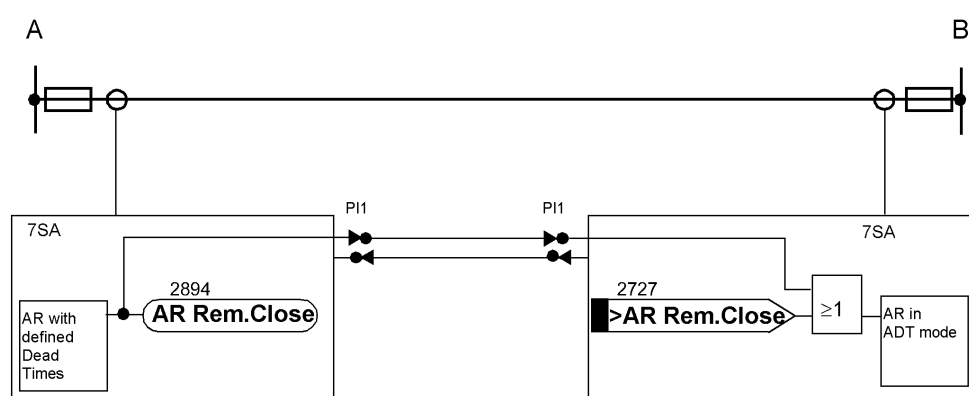
Figure 2-111   AR Remote-Close function via protection data interface

The close command can be transmitted by a teleprotection scheme using the protection interfaces (ordering variant). When the annunciation "AR Remote Close" is output, this information is transmitted at the same time to the remote end via the protection data interface. The information is OR-combined with the information of the binary input ">AR RemoteClose" and made available for the automatic reclosure. (Figure 2-111).

Connecting an External Auto-Reclosure Device

If the 7SA6 has to work with an external reclosure device, the binary inputs and outputs provided for this purpose must be taken into consideration. The following inputs and outputs are recommended:

Binary inputs:

383 ">Enable ARzones" — With this binary input the external reclosure device controls the stages of the individual short-circuit protection functions which are active before reclosure (e.g. overreaching zone in the distance protection). This input is not required if no overreaching stage is used (e.g. differential protection or comparison scheme with distance protection, see also above margin heading "Selectivity before Reclosure").

382 ">Only 1ph AR" — The external reclosure device is only programmed for 1 pole; the stages of the individual protection functions that are activated before reclosure via FNo. 383 only do so in the case of single-phase faults; in the event of multiple phase faults these stages of the individual short-circuit functions do not operate. This input is not required if no overreaching stage is used (e.g. differential protection or comparison scheme with distance protection, see also above at margin heading "Selectivity before Reclosure").

381 ">1p Trip Perm" — The external reclosure device allows 1-pole tripping (logic inversion or 3-pole coupling). If this input is not assigned or not routed (matrix), the protection functions trip 3-pole for all faults. If the external reclosure device cannot supply this signal but sends a "3-pole coupling" signal instead, this must be taken into account in the routing of the binary inputs: The signal must be inverted in this case (L-active = active without voltage).

Binary outputs:

501 "Relay PICKUP" — Start of protection device, general (if required by external recloser device).

512 "Relay TRIP 1pL1" — Trip protective device 1-pole phase L1.

513 "Relay TRIP 1pL2" — Trip protective device 1-pole phase L2.

514 "Relay TRIP 1pL3" — Trip protective device 1-pole phase L3.

515 "Relay TRIP 3ph." — Trip protective device 3-pole,

In order to obtain a phase-segregated trip indication, the respective single-pole trip commands must be combined with the three-pole trip command on one output.

2-112Figure for example, shows the interconnection between a 7SA6 and an external reclosure device with a mode selector switch.

Depending on what the external recloser device requires, the three single-pole outputs (FNo. 512, 513,514) may also be combined to one "single-pole tripping" output; the FNo. 515 provides the "three-pole tripping" signal to the external device.

For exclusively three-pole auto-reclosure cycles, the general pickup (FNo. 501, if required by the external reclosure device) and general trip signal (FNo. 511) from 7SA6 (see Figure2-113) usually suffice.
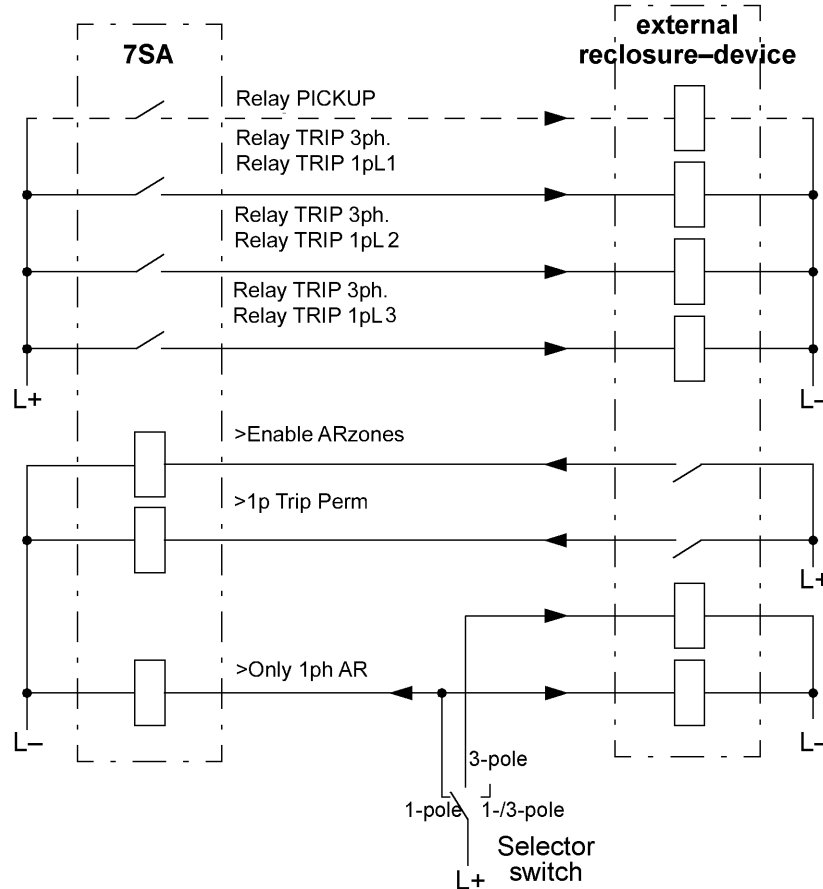
Figure 2-112   Connection example with external auto-reclosure device for 1-/3-pole AR with mode selector switch
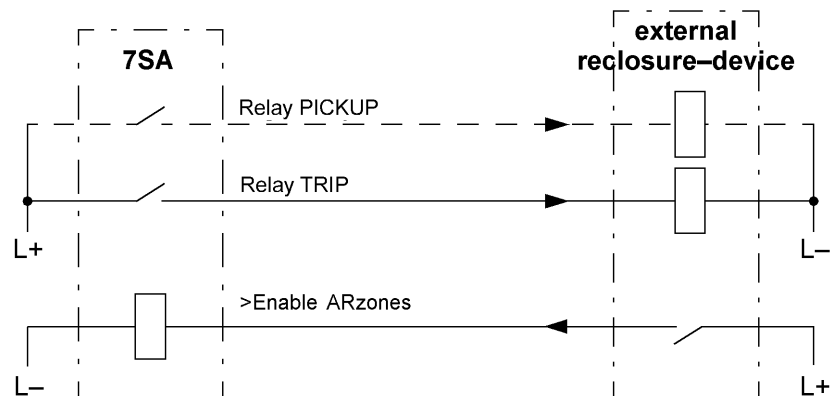
Figure 2-113   Connection example with external reclosure device for 3-pole AR

Controlling the Internal Automatic Reclosure by an External Protection Device

If the 7SA6 is equipped with the internal automatic reclosure function, it may also be controlled by an external protection device. This is of use for example on line ends with redundant protection or additional back-up protection when the second protection is used for the same line end and has to work with the automatic reclosure function integrated in the 7SA6.

The binary inputs and outputs provided for this functionality must be considered in this case. It must be decided whether the internal auto-reclosure is to be controlled by the starting (pickup) or by the trip command of the external protection (see also above under "Control Mode of the Automatic Reclosure").

If the auto-reclosure is controlled by the **trip command**, the following inputs and outputs are recommended to be used:

The automatic reclosure function is started via the <u>Binary inputs</u>:

2711 ">AR Start"	General fault detection for the automatic reclosure circuit (only required for action time),
2712 ">Trip L1 AR"	Trip command L1 for the automatic reclosure circuit,
2713 ">Trip L2 AR"	Trip command L2 for the automatic reclosure circuit,
2714 ">Trip L3 AR"	Trip command L3 for the automatic reclosure circuit,

The general fault detection determines the starting of the action times. It is also necessary if the automatic reclosure circuit is to detect sequential faults by fault detection. In other cases this input information is superfluous.

The trip commands decide whether the dead time for single-pole or three-pole reclose cycles is activated or whether the reclosure is blocked in the event of a three-pole trip (depending on the set dead times).

Figure 2-114 shows the interconnection between the internal automatic reclosure of 7SA6 and an external protection device, as a connection example for single-pole cylces.

To achieve three pole coupling of the external protection and to release, if necessary, its accelerated stages before reclosure the following <u>output</u> functions are suitable:

2864 "AR 1p Trip Perm"	Internal automatic reclosure function ready for 1-pole reclose cycle, i.e. allows 1-pole tripping (logic inversion of the 3-pole coupling).
2889 "AR 1.CycZoneRel"	Internal automatic reclosure function ready for the first reclose cycle, i.e. releases the stage of the external protection device for reclosure, the corresponding outputs can be used for other cycles. This output can be omitted if the external protection does not require an overreaching stage (e.g. differential protection or comparison mode with distance protection).
2820 "AR Program1pole"	Internal automatic reclosure function is programmed for one pole, i.e. only recloses after single-pole tripping. This output can be omitted if no overreaching stage is required (e.g. differential protection or comparison mode with distance protection).

Instead of the three phase-segregated trip commands, the single-pole and three-pole tripping may also be signalled to the internal automatic reclosure function - provided that the external protection device is capable of this -, i.e. assign the following <u>binary inputs</u> of the 7SA6:

2711 ">AR Start"   General fault detection for the internal automatic reclosure function (only required for action time),

2715 ">Trip 1pole AR"   Trip command 1-pole for the internal automatic reclosure,

2716 ">Trip 3pole AR"   Trip command 3-pole for the internal automatic reclosure function,

If only three-pole reclosure cycles are to be executed, it is sufficient to assign the binary input ">Trip 3pole AR" (FNo 2716) for the trip signal. Figure 2-115 shows an example. Any overreaching stages of the external protection are enabled again by "AR 1.CycZoneRel" (FNo. 2889) and of further cycles, if applicable.
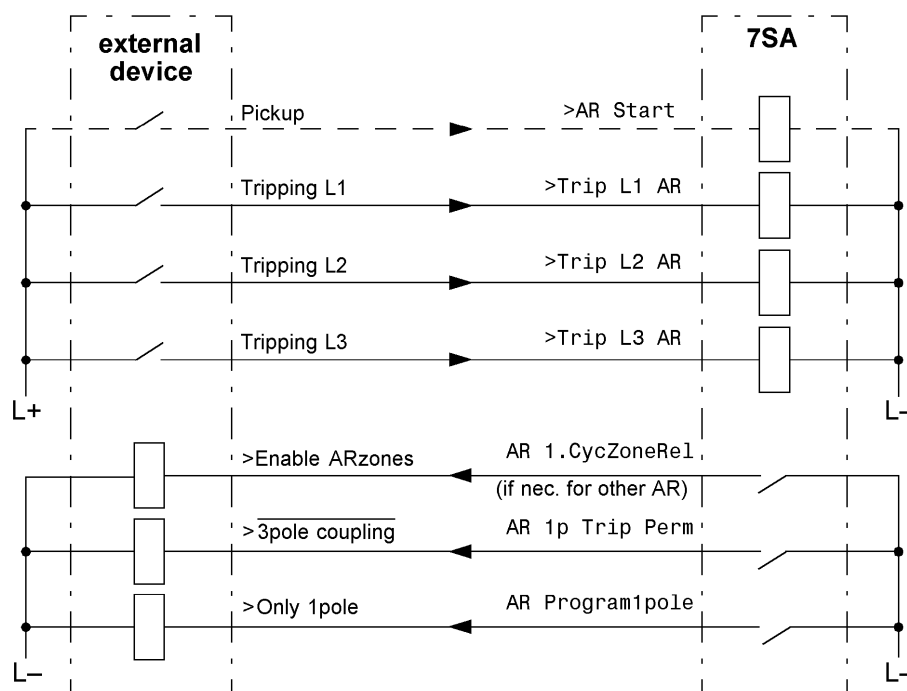
Figure 2-114   Connection example with external protection device for 1-/3-pole reclosure; AR control mode = with TRIP
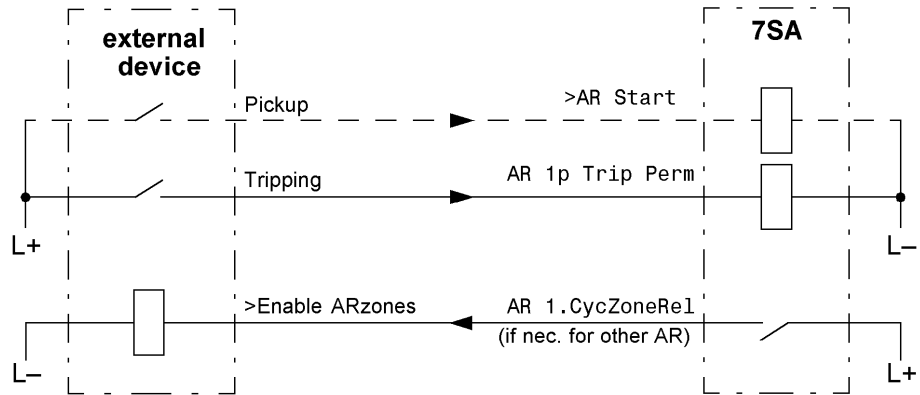
Figure 2-115   Connection example with external protection device for 3-pole reclosure; AR control mode = with TRIP

But if the internal automatic reclose function is controlled by the **pickup** (only possible for 3-pole pickup: 110 **Trip mode** = *3pole only*), the phase-dedicated <u>pickup</u> signals of the external protection must be connected if distinction shall be made between different types of fault. The general trip command then suffices for tripping (FNo. 2746). Figure 2-116 shows a connection example.

Starting signal for each phase

Starting signal 1-phase, 2-phase and 3-phase
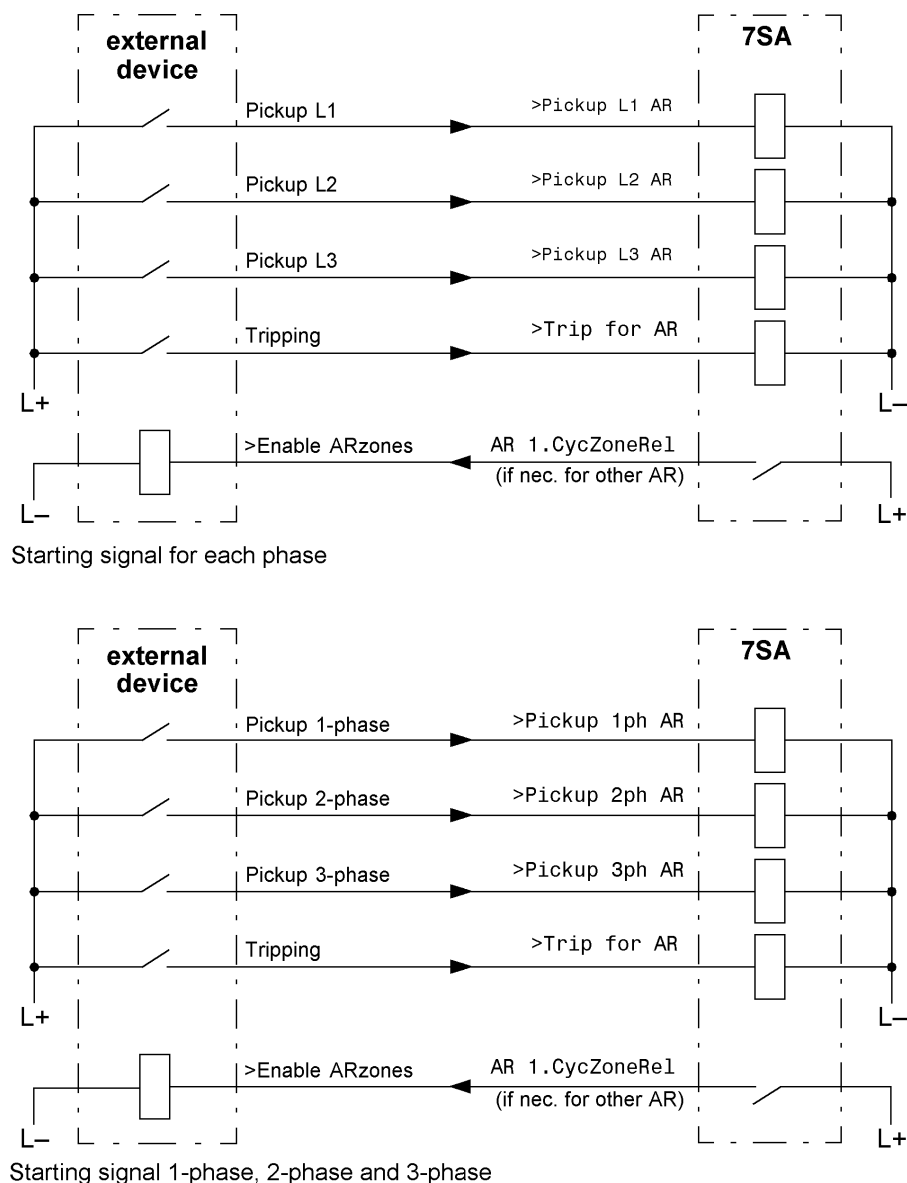
Figure 2-116   Connection example with external protection device for fault detection dependent dead time — dead time control by pickup signals of the protection device; AR control mode = with PICKUP

2 Protection Relays with 2 Automatic Reclosure Circuits

If redundant protection is provided for a line and each protection operates with its own automatic reclosure function, a certain signal exchange between the two combinations is necessary. The connection example in Figure 2-117 shows the necessary cross-connections.

If phase segregated auxiliary contacts of the circuit-breaker are connected, a three-pole coupling by the 7SA6 is guaranteed when more than one CB pole is tripped. This requires activation of the forced three pole trip (see Section 2.14.2 at subtitle "Forced Three-Pole Trip"). An external automatic three-pole coupling is therefore not necessary when the above conditions are satisfied. This rules out two-pole tripping under all circumstances.
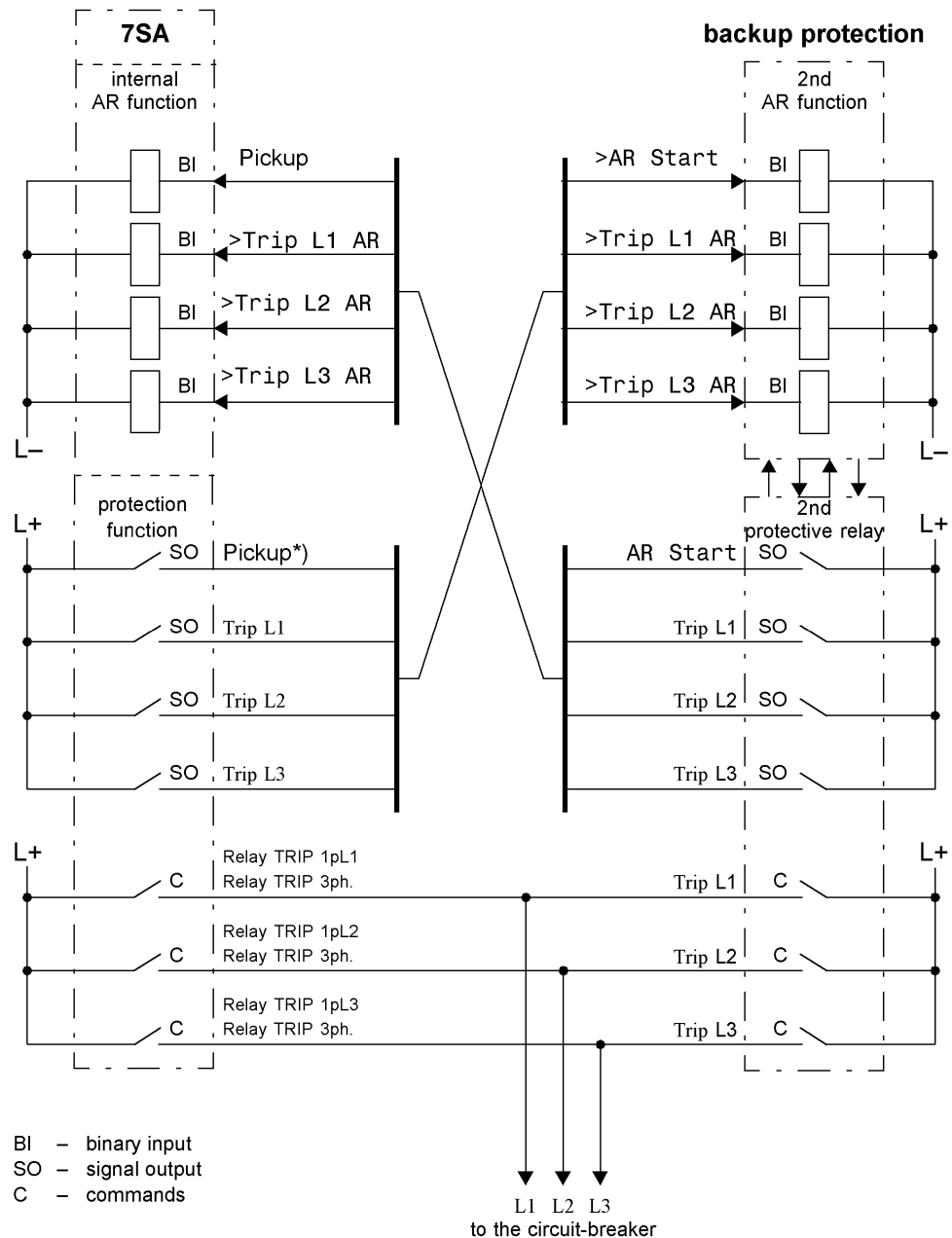
Figure 2-117   Connection example for 2 protection devices with 2 automatic reclosure functions

2.14.2 Setting Notes

General

If no reclosure is required on the feeder to which the 7SA6 distance protection is applied (e.g. for cables, transformers, motors or similar), the automatic reclosure function must be inhibited during configuration of the device (see Section 2.1.1.2, address 133). The automatic reclosure is then totally disabled, i.e. the automatic reclosure is not processed in the 7SA6. No signals regarding the recloser function are generated and the binary inputs for the automatic reclosure function are ignored. All parameters for setting the automatic reclosure function are inaccessible and of no significance. Tripping is always three-pole for all faults.

If, on the other hand, the internal automatic reclosure function is to be used, the type of reclosure must be selected during the configuration of the functions (see Section 2.1.1.2) in address 133 **Auto Reclose** the AR control mode and in address 134 the **AR control mode**.

Up to 8 reclosure attempts are allowed with the integrated automatic reclosure function in the 7SA6. Whereas the settings in the addresses 3401 to 3441 are common to all reclosure cycles, the individual settings of the cycles are made from address 3450 onwards. It is therefore possible to set different individual parameters for the first four reclose cycles. From the fifth cycle onwards the parameters for the fourth cycle apply.

The automatic reclosing function can be turned *ON* or *OFF* under address 3401 **AUTO RECLOSE**.

A prerequisite for automatic reclosure taking place after a trip due to a short-circuit is that the circuit-breaker is ready for at least one TRIP–CLOSE–TRIP–cycle at the time the automatic reclosure circuit is started (i.e. at the time of the first trip command). The readiness of the circuit-breaker is signalled to the device through the binary input "**>CB1 Ready**" (F.No 371). If no such signal is available, leave the setting under address 3402 **CB? 1.TRIP** = *NO* because no automatic reclosure would be possible at all otherwise. If circuit breaker interrogation is possible, set **CB? 1.TRIP** = *YES*.

Furthermore the circuit-breaker ready state can also be interrogated prior to every reclosure. This is set when setting the individual reclose cycles (see below).

To check the ready status of the circuit breaker is regained during the dead times, you can set a circuit breaker ready monitor time under address 3409 **CB TIME OUT**. The time is set slightly longer than the recovery time of the circuit breaker after a TRIP–CLOSE–TRIP–cycle. If the circuit-breaker is not ready again by the time this timer expires, no reclosure takes place, the automatic reclosure function is blocked dynamically.

Waiting for the circuit-breaker to be ready can lead to an increase of the dead times. Interrogation of a sync. check (if used) can also delay reclosure. To avoid uncontrolled prolongation it is possible to set a maximum prolongation of the dead time in this case under address 3411 **T-DEAD EXT.**. This prolongation is unlimited if the setting ∞ is applied. This setting is only possible via DIGSI® at **Additional Settings**. Remember that longer dead times are only permissible after three-pole tripping when no stability problems arise or when a sync. check takes place before reclosure.

The blocking time **T-RECLAIM** (address 3403) defines the time that must elapse, after a <u>successful</u> reclosing attempt, before the automatic reclosing function is reset. Re-tripping of a protection function within this time initiates the next reclose cycle in the event of multiple reclosure; if no further reclosure is permitted, the last reclosure is treated as unsuccessful. The reclaim time must therefore be longer than the longest response time of a protective function which can start the automatic reclosure circuit.

A few seconds are generally sufficient. In areas with frequent thunderstorms or storms, a shorter blocking time may be necessary to avoid feeder lockout due to sequential lightning strikes or cable flashovers.

A longer reclaim time should be chosen if there is no possibility to monitor the circuit breaker (see above) during multiple reclosing (e.g. because of auxiliary contacts missing and information on the circuit breaker ready status). Then the reclaim time must be longer than the recovery time of the circuit-breaker.

The blocking duration following Manual–Close–detection **T-BLOCK MC** (address 3404) must guarantee the circuit breaker to open and close reliably (0.5 s to 1 s). If a fault is detected by a protection function within this time after closing of the circuit

breaker was detected, no reclosure takes place and a final three-pole trip command is issued. If this is not desired, set address 3404 to **0**.

The options for handling evolving faults are described in Subsection 2.14 under margin heading "Handling Evolving Faults". The treatment of sequential faults is not necessary on line ends where the adaptive dead time is applied (address 133 **Auto Reclose** = *ADT*). The addresses 3406 and 3407 are then of no consequence and therefore not accessible.

The detection of an evolving fault can be defined under address 3406 **EV. FLT. RECOG.**.**EV. FLT. RECOG.** *with PICKUP* means that, during a dead time, every **pickup** of a protective function will be interpreted as an evolving fault. With **EV. FLT. RECOG.** *with TRIP* a fault during a dead time is only interpreted as a evolving fault if it has led to a **trip command** by a protection function. This may also include trip commands which are coupled in externally via a binary input or which have been transmitted from an opposite end of the protected object. If an external protection device operates together with the auto-reclosure, evolving fault detection with pickup presupposes that a pickup signal of the external device is also connected to the 7SA6; otherwise an evolving fault can only be detected with the external trip command even if *with PICKUP* was set here.

The reaction in response to sequential faults can be selected under address 3407. **EV. FLT. MODE** *blocks AR* means that no reclosure takes place after detection of a sequential fault. This is always useful when only single-pole reclosure is to take place or when stability problems are expected due to the subsequent three-pole dead time. If a three-pole reclose cycle is to be initiated by tripping of the evolving fault, set **EV. FLT. MODE** = *starts 3p AR*. In this case a separately adjustable three-pole dead time is started with the three-pole trip command due to the sequential fault. This is only useful if three-pole reclosure is also permitted.

Address 3408 **T-Start MONITOR** monitors the reaction of the circuit-breaker after a trip command. If the CB has not opened during this time (from the beginning of the trip command), the automatic reclosure is blocked dynamically. The criterion for circuit breaker opening is the position of the circuit breaker auxiliary contact or the disappearance of the trip command. If a circuit-breaker failure protection (internal or external) is used on the feeder, this time should be shorter than the delay time of the circuit-breaker failure protection so that no reclosure takes place if the circuit-breaker fails.

If the reclosure command is transmitted to the opposite end, this transmission can be delayed by the time setting in address 3410 **T RemoteClose**. This transmission is only posible if the device operates with adaptive dead time at the remote end (address 133 **Auto Reclose** = *ADT*). This parameter is otherwise irrelevant. On the one hand, this delay serves to prevent the remote end device from reclosing unnecessarily when local reclosure is unsuccessful. On the other hand it should be noted that the line is not available for energy transport until the remote end has also closed. This delay must therefore be added to the dead time for consideration of the network stability.

Configuration of Auto-reclosure

This configuration concerns the interaction between the protection and supplementary functions of the device and the automatic reclosure function. The selection of functions of the device which are to start the automatic reclosure circuit and which are not to, is made here.

Table 2-12   In 7SA6 this concerns:

Address 3420	AR w/ DIST., i.e. with distance protection
Address 3421	AR w/ SOTF-O/C, i.e. with high-current fast tripping

Address 3422	AR w/ W/I, i.e. with weak–infeed trip function
Address 3423	AR w/ EF-O/C, i.e. with transfer trip and remote trip
Address 3424	AR w/ DTT, i.e. with externally fed trip command
Address 3425	AR w/ BackUpO/C, i.e. with time overcurrent protection

For the functions which are to start the auto-reclosure function, the corresponding address is set to *YES*, for the others to *NO*. The other functions (overload protection, frequency protection, breaker failure protection) cannot start the automatic reclosure because reclosure is of little use here.

Forced Three-pole Trip

If reclosure is blocked during the dead time of a single-pole cycle without a three-pole trip command having been initiated, the breaker remains open at one pole. With address 3430 **AR TRIP 3pole** it is possible to determine that the tripping logic of the device issues a three-pole trip command in this case (pole discrepancy prevention for the CB poles). Set this address to *YES* if the CB can be tripped single-pole and has no pole discrepancy protection itself. Nevertheless, the device pre-empts the pole discrepancy supervision of the CB because the forced three-pole trip of the device is immediately initiated as soon as the reclosure is blocked following a single-pole trip or if the CB auxiliary contacts report an implausible breaker state (see also Subsection 2.14 at margin heading "Processing the Circuit Breaker Auxiliary Contacts"). The forced three-pole coupling is also activated when only three-pole cycles are allowed but a single-pole trip is signalled externally via a binary input.

The forced three pole trip is unnecessary if only a common three-pole control of the CB is possible.

Dead Line Check / Reduced Dead Time

Under address 3431 the dead line check or the reduced dead time function can be activated. Either the one or the other can be used as the two options are contradictory. The voltage transformers must be connected to the line side of the circuit breaker if either of these modes is to be used. If this is not the case or if neither of the two functions is used, set **DLC or RDT** = *WITHOUT*. If the adaptive dead time is used (see below), the parameters mentioned here are omitted because the adaptive dead time implies the properties of the reduced dead time.

DLC or RDT = *DLC* means that the dead line check of the line voltage is used. This only enables reclosure after it becomes apparent that the line is dead. In this case, the phase-earth voltage limit is set in address 3441 **U-dead<** below which the line is considered voltage-free (disconnected). The setting is applied in Volts secondary. This value can be entered as a primary value when parameterizing with a PC and DIGSI®. Address 3438 **T U-stable** determines the measuring time available for determining the no-voltage condition. Address 3440 is irrelevant here.

DLC or RDT = *RDT* means that the reduced dead time is used. This is described in detail in Section 2.14 at margin heading "Reduced Dead Time (RDT)". In this case the setting under address 3440 **U-live>** determines the limit voltage, Phase–Earth, above which the line is considered to be fault-free. The setting must be smaller than the lowest expected operating voltage. The setting is applied in Volts secondary. This value can be entered as a primary value when parameterizing with a PC and DIGSI®. Address 3438 **T U-stable** determines the measuring time used to determine that the line is fault free with this return voltage. It should be longer than any transient oscillations resulting from line energization. Address 3441 is irrelevant here.

Adaptive Dead Time (ADT)

When operating with adaptive dead time, it must be ensured in advance that **one** end per line operates with defined dead times and has an infeed. The other (or the others in multi-branch lines) may operate with adaptive dead time. It is essential that the

voltage transformers are located on the line side of the circuit breaker. Details about this function can be found in section 2.14 at margin heading "Adaptive Dead Time (ADT)".

For the line end with defined dead times the number of desired reclose cycles must be set during the configuration of the protective functions under address 133 **Auto Reclose**. For the devices operating with adaptive dead time **Auto Reclose** must be set to *ADT* during the configuration of the protective functions under address 133. Only the parameters described below are interrogated in the latter case. No settings are then made for the individual reclosure cycles. The adaptive dead time implies functionality of reduced dead time.

The adaptive dead time may be voltage-controlled or Remote–CLOSE–controlled. Both is possible at the same time. In the first case reclosure takes place as soon as the return voltage, after reclosure at the remote end, is detected. For this purpose the device must be connected to voltage transformers located on the line side of the circuit breaker. In the case of remote-close, the device waits until the remoteclose command is received before issuing the reclose command.

The action time **T-ACTION ADT** (address 3433) is the time after initiation (fault detection) by any protective function which can start the automatic reclosure function within which the trip command must appear. If the command does not appear until after the action time has expired, there is no reclosure. Depending on the configuration of the protective functions (see section 2.1.1.2) the action time may also be omitted; this applies especially when an initiating protective function has no fault detection signal.

The dead times are determined by the reclosure command of the device at the line end with the defined dead times. In cases where this reclosure command does not appear, e.g. because the reclosure was in the mean time blocked there, the readiness of the local device must return to the quiescent state at some time. This takes place after the maximum wait time **T-MAX ADT** (address 3434). This must be long enough to include the last reclosure of the remote end. In the case of single cycle reclosure, the sum total of maximum dead time plus reclaim time of the other device is sufficient. In the case of multiple reclosure the worst case is that all reclosures of the other end except the last one are unsuccessful. The time of all these cycles must be taken into account. To save having to make exact calculations, it is possible to use the sum of all dead times and all protection operating times plus one reclaim time.

Under address 3435 **ADT 1p allowed** it can be determined whether single-pole tripping is allowed (on condition that single-pole tripping is possible). If *NO*, the protection trips three-pole for all fault types. If *YES* the possible tripping situations of the starting protective functions are decisive.

Under address 3436 **ADT CB? CLOSE** it can be determined whether circuit-breaker ready is interrogated before reclosure after an adaptive dead time. With the setting *YES*, the dead time may be extended if the circuit-breaker is not ready for a CLOSE–OPEN–cycle when the dead time expires. The maximum extension that is possible is the circuit-breaker monitoring time; this was set for all reclosure cycles together under address 3409 (see above). Details about the circuit-breaker–monitoring can be found in the function description, section 2.14, at margin heading "Interrogation of the Circuit Breaker Ready State".

If there is a danger of stability problems in the network during a three-pole reclosure cycle, set address 3437 **ADT SynRequest** to *YES*. In this case the voltage of the line and busbar are checked after a three pole trip and before reclosure to determine if sufficient synchronism exists. This is applicable on condition that either the internal synchronism and voltage check function is available or that an external device is available for synchronism check. If only single-pole reclose cycles are executed or no stability

problems are expected during three-pole dead times (e.g. due to closely meshed networks or in radial networks), set address 3437 to **NO**.

Addresses 3438 and 3440 are only significant if the voltage-controlled adaptive dead time is used. Set under address 3440 **U-live>** the limit voltage phase–earth above which the line is considered to be fault-free. The setting must be smaller than the lowest expected operating voltage. The setting is applied in Volts secondary. This value can be entered as a primary value when parameterizing with a PC and DIGSI®. Address 3438 **T U-stable** determines the measuring time used to determine that the line is fault free with this return voltage. It should be longer than any transient oscillations resulting from line energization.

1st Reclosure Cycle

If working on a line with adaptive dead time, no further parameters are needed for the individual reclose cycles here. All the following parameters assigned to the individual cycles are then superfluous and inaccessible.

Address 3450 **1.AR: START** is only available if the automatic reclosure is configured with action time in the operating mode, i. e. if during configuration of the protection functions (see Section 2.1.1.2) address 134 **AR control mode** = **Pickup w/ Tact** or **Trip w/ Tact** was set (the first setting only applies to three-pole tripping). It determines whether automatic reclosure should be started at all with the first cycle. This address is included mainly for the sake of uniformity of the parameters for every reclosure attempt and is set to **YES** for the first cycle. If several cycles are performed, you can (at **AR control mode** = **Pickup ...**) set this parameter and different action times to control the effectiveness of the cycles. Notes and examples can be found in section 2.14 at margin heading "Action Times".

The action time **1.AR: T-ACTION** (address 3451) is the time after initiation (fault detection) by any protective function which can start the automatic reclosure function within which the trip command must appear. If the command does not appear until after the action time has expired, there is no reclosure. Depending on the configuration of the protective functions the action time may also be omitted; this applies especially when an initiating protective function has no fault detection signal.

Depending on the configured operating mode of the automatic reclosure (address 134 **AR control mode**) only address 3456 and 3457 (if **AR control mode** = **with TRIP...**) are available or address 3453 to 3455 (if **AR control mode** = **with PICKUP ...**).

If **AR control mode** = **with TRIP ...**, you can set different dead times for single-pole and three-pole reclose cycles. Whether single-pole or three-pole tripping takes place depends solely on the initiating protection functions. Single-pole tripping is only possible of course if the device and the corresponding protective function are also capable of single-pole tripping.

Table 2-13   AR control mode = **with TRIP...**

3456	1.AR Tdead1Trip	is the dead time after 1-pole tripping,
3457	1.AR Tdead3Trip	is the dead time after 3-pole tripping,

If only single-pole reclosure cycles are required, set the dead time for three-pole tripping to ∞. If only three-pole reclosure cycles are required, set the dead time for single-pole tripping to ∞; the protection then trips three-pole for every fault type.

The dead time after single-pole tripping (if set) **1.AR Tdead1Trip** (address 3456) should be long enough for the short-circuit arc to be extinguished and the surrounding air to be de-ionized so that the reclosure promises to be successful. The longer the

line, the longer is this time due to the charging of the conductor capacitances. Conventional values are 0.9 s to 1.5 s.

For three-pole tripping (address 3457 **1.AR Tdead3Trip**) the stability of the network is the main concern. Since the de-energized line cannot develop synchronizing forces, only short dead times are allowed. The usual values are 0.3 s to 0.6 s. If the device is operating with a synchronism check (see Section 2.15), a longer time may be tolerated under certain circumstances. Longer three-pole dead times are also possible in radial networks.

For **AR control mode** = *with PICKUP ...* it is possible to make the dead times dependent on the type of fault detected by the initiating protection function(s).

Table 2-14   AR control mode = **with PICKUP ...**

3453	1.AR Tdead 1Flt	is the dead time after 1-phase pickup,
3454	1.AR Tdead 2Flt	is the dead time after 2-phase pickup,
3455	1.AR Tdead 3Flt	is the dead time after 3-phase pickup,

If the dead time is to be the same for all types of faults, set all three parameters the same. Note that these settings only cause different dead times for different pickups. The tripping can only be three-pole.

With the setting in address 3407 **EV. FLT. MODE** *starts 3p AR*, it is possible to apply a separate dead time **1.AR: Tdead EV.** (address 3458) for the three-pole dead time after clearance of the sequential fault (see above at heading "General"). Stability aspects are also decisive here. Normally the setting constraints are similar to address 3457 **1.AR Tdead3Trip**.

Under address 3459 **1.AR: CB? CLOSE** it can be determined whether the readiness of the circuit-breaker ("circuit breaker ready")is interrogated before this first reclosure. With the setting *YES*, the dead time may be extended if the circuit-breaker is not ready for a CLOSE–TRIP–cycle when the dead time expires. The maximum extension that is possible is the circuit-breaker monitoring time; this time was set for all reclosure cycles together under address 3409 **CB TIME OUT** (see above). Details about the circuit-breaker monitoring can be found in the function description, section 2.14, at margin heading "Interrogation of circuit-breaker ready state".

If there is a danger of stability problems in the network during a three-pole reclosure cycle, you should set address 3460 **1.AR SynRequest** to *YES*. In this case a check is made before every reclosure following three-pole tripping whether the voltages of the feeder and busbar are sufficiently synchronized. This is applicable on condition that either the internal synchronism and voltage check function is available or that an external device is available for synchronism check. If only single-pole reclose cycles are executed or no stability problems are expected during three-pole dead times (e.g. due to closely meshed networks or in radial networks), set address 3460 to *NO*.

2nd to 4th Reclosure Cycle

If several cycles have been set in the configuration of the function scope, you can set individual reclosure parameters for the 2nd to 4th cycles. The same options are available as for the first cycle. Again only some of the parameters shown below will be available depending on the selections made during configuration of the scope of protection function.

For the 2nd cycle:

3461	2.AR: START	Start in 2nd cycle generally allowed
3462	2.AR: T-ACTION	Action time for the 2nd cycle
3464	2.AR Tdead 1Flt	Dead time after 1-phase pickup
3465	2.AR Tdead 2Flt	Dead time after 2-phase pickup
3466	2.AR Tdead 3Flt	Dead time after 3-phase pickup
3467	2.AR Tdead1Trip	Dead time after 1-pole tripping
3468	2.AR Tdead3Trip	Dead time after 3-pole tripping
3469	2.AR: Tdead EV.	Dead time after evolving fault
3470	2.AR: CB? CLOSE	CB ready interrogation before reclosing
3471	2.AR SynRequest	Sync. check after 3-pole tripping

For the 3rd cycle:

3472	3.AR: START	Start in 3rd cycle generally allowed
3473	3.AR: T-ACTION	Action time for the 3rd cycle
3475	3.AR Tdead 1Flt	Dead time after 1-phase pickup
3476	3.AR Tdead 2Flt	Dead time after 2-phase pickup
3477	3.AR Tdead 3Flt	Dead time after 3-phase pickup
3478	3.AR Tdead1Trip	Dead time after 1-pole tripping
3479	3.AR Tdead3Trip	Dead time after 3-pole tripping
3480	3.AR: Tdead EV.	Dead time after evolving fault
3481	3.AR: CB? CLOSE	CB ready interrogation before reclosing
3482	3.AR SynRequest	Sync. check after 3-pole tripping

For the 4th cycle:

3483	4.AR: START	Start in 4th cycle generally allowed
3484	4.AR: T-ACTION	Action time for the 4th cycle
3486	4.AR Tdead 1Flt	Dead time after 1-phase pickup
3487	4.AR Tdead 2Flt	Dead time after 2-phase pickup
3488	4.AR Tdead 3Flt	Dead time after 3-phase pickup
3489	4.AR Tdead1Trip	Dead time after 1-pole tripping
3490	4.AR Tdead3Trip	Dead time after 3-pole tripping
3491	4.AR: Tdead EV.	Dead time after evolving fault
3492	4.AR: CB? CLOSE	CB ready interrogation before reclosing
3493	4.AR SynRequest	Sync. check after 3-pole tripping

5th To 8th Reclosure Cycle   If more than four cycles were set during configuration of the functional scope, the dead times preceding the fifth (5th) through the ninth (9th) reclosing attempts are equal to the open breaker time which precedes the fourth (4th) reclosing attempt.

Notes on the Information Overview   The most important information about automatic reclosure is briefly explained insofar as it was not mentioned in the following lists or described in detail in the preceding text.

"**>BLK 1.AR-cycle**" (FNo. 2742) to "**>BLK 4.-n. AR**" (FNo. 2745)

The respective auto-reclose cycle is blocked. If the blocking state already exists when the automatic reclosure function is initiated, the blocked cycle is not executed and may be skipped (if other cycles are permitted). The same applies if the automatic reclosure function is started (running) but not internally blocked. If the block signal of a cycle appears while this cycle is being executed (in progress) the automatic reclosure function is blocked dynamically; no further automatic reclosures cycles are then executed.

"**AR 1.CycZoneRel**" (FNo. 2889) to "**AR 4.CycZoneRel**" (FNo. 2892)

The automatic reclosure is ready for the respective reclosure cycle. This information indicates which cycle will be run next. For example, external protection functions can use this information to release accelerated or overreaching trip stages prior to the corresponding reclose cycle.

"**AR is blocked**" (FNo. 2783)

The automatic reclosure is blocked (e.g. circuit breaker not ready). This information indicates to the operational information system that in the event of an upcoming system fault there will be a final trip, i.e. without reclosure. If the automatic reclosure has been started, this information does not appear.

"**AR not ready**" (FNo. 2784)

The automatic reclosure is not ready for reclosure at the moment. In addition to the "**AR is blocked**" (FNo 2783) mentioned above there are also obstructions during the course of the auto-reclosure cycles such as "action" time run out or "last reclaim time running". This information is particularly helpful during testing because no protection test cycle with reclosure may be initiated during this state.

"**AR in progress**" (FNo. 2801)

This information appears following starting of the automatic reclosure function, i.e. with the first trip command that can start the automatic reclosure function. If this reclosure was successful (or any in the case of more than one), this information resets with the expiry of the last reclaim time. If no reclosure was successful or if reclosure was blocked, it ends with the last — the final — trip command.

"**AR Sync.Request**" (FNo. 2865)

Measuring request to an external synchronism check device. The information appears at the end of a dead time subsequent to three-pole tripping if a synchronism request was parameterized for the corresponding cycle. Reclosure only takes place when the synchronism check device has provided release signal "**>Sync.release**" (FNo 2731).

"**>Sync.release**" (FNo. 2731)

Release of reclosure by an external synchronism check device if this was requested by the output information "**AR Sync.Request**" (FNo 2865).

2.14.3 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
3401	AUTO RECLOSE	OFF ON	ON	Auto-Reclose function
3402	CB? 1.TRIP	YES NO	NO	CB ready interrogation at 1st trip
3403	T-RECLAIM	0.50 .. 300.00 sec	3.00 sec	Reclaim time after successful AR cycle
3404	T-BLOCK MC	0.50 .. 300.00 sec; 0	1.00 sec	AR blocking duration after manual close
3406	EV. FLT. RECOG.	with PICKUP with TRIP	with TRIP	Evolving fault recognition
3407	EV. FLT. MODE	blocks AR starts 3p AR	starts 3p AR	Evolving fault (during the dead time)
3408	T-Start MONITOR	0.01 .. 300.00 sec	0.20 sec	AR start-signal monitoring time
3409	CB TIME OUT	0.01 .. 300.00 sec	3.00 sec	Circuit Breaker (CB) Supervision Time
3410	T RemoteClose	0.00 .. 300.00 sec; ∞	∞ sec	Send delay for remote close command
3411A	T-DEAD EXT.	0.50 .. 300.00 sec; ∞	∞ sec	Maximum dead time extension
3420	AR w/ DIST.	YES NO	YES	AR with distance protection
3421	AR w/ SOTF-O/C	YES NO	YES	AR with switch-onto-fault overcurrent
3422	AR w/ W/I	YES NO	YES	AR with weak infeed tripping
3423	AR w/ EF-O/C	YES NO	YES	AR with earth fault overcurrent prot.
3424	AR w/ DTT	YES NO	YES	AR with direct transfer trip
3425	AR w/ BackUpO/C	YES NO	YES	AR with back-up overcurrent
3430	AR TRIP 3pole	YES NO	YES	3pole TRIP by AR
3431	DLC or RDT	WITHOUT RDT DLC	WITHOUT	Dead Line Check or Reduced Dead Time
3433	T-ACTION ADT	0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3434	T-MAX ADT	0.50 .. 3000.00 sec	5.00 sec	Maximum dead time
3435	ADT 1p allowed	YES NO	NO	1pole TRIP allowed
3436	ADT CB? CLOSE	YES NO	NO	CB ready interrogation before re-closing

Addr.	Parameter	Setting Options	Default Setting	Comments
3437	ADT SynRequest	YES NO	NO	Request for synchro-check after 3pole AR
3438	T U-stable	0.10 .. 30.00 sec	0.10 sec	Supervision time for dead/ live voltage
3440	U-live>	30 .. 90 V	48 V	Voltage threshold for live line or bus
3441	U-dead<	2 .. 70 V	30 V	Voltage threshold for dead line or bus
3450	1.AR: START	YES NO	YES	Start of AR allowed in this cycle
3451	1.AR: T-ACTION	0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3453	1.AR Tdead 1Flt	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1phase faults
3454	1.AR Tdead 2Flt	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 2phase faults
3455	1.AR Tdead 3Flt	0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3phase faults
3456	1.AR Tdead1Trip	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1pole trip
3457	1.AR Tdead3Trip	0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3pole trip
3458	1.AR: Tdead EV.	0.01 .. 1800.00 sec	1.20 sec	Dead time after evolving fault
3459	1.AR: CB? CLOSE	YES NO	NO	CB ready interrogation before re-closing
3460	1.AR SynRequest	YES NO	NO	Request for synchro-check after 3pole AR
3461	2.AR: START	YES NO	NO	AR start allowed in this cycle
3462	2.AR: T-ACTION	0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3464	2.AR Tdead 1Flt	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1phase faults
3465	2.AR Tdead 2Flt	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 2phase faults
3466	2.AR Tdead 3Flt	0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3phase faults
3467	2.AR Tdead1Trip	0.01 .. 1800.00 sec; ∞	∞ sec	Dead time after 1pole trip
3468	2.AR Tdead3Trip	0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3pole trip
3469	2.AR: Tdead EV.	0.01 .. 1800.00 sec	1.20 sec	Dead time after evolving fault
3470	2.AR: CB? CLOSE	YES NO	NO	CB ready interrogation before re-closing
3471	2.AR SynRequest	YES NO	NO	Request for synchro-check after 3pole AR
3472	3.AR: START	YES NO	NO	AR start allowed in this cycle
3473	3.AR: T-ACTION	0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3475	3.AR Tdead 1Flt	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1phase faults
3476	3.AR Tdead 2Flt	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 2phase faults
3477	3.AR Tdead 3Flt	0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3phase faults
3478	3.AR Tdead1Trip	0.01 .. 1800.00 sec; ∞	∞ sec	Dead time after 1pole trip
3479	3.AR Tdead3Trip	0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3pole trip

Addr.	Parameter	Setting Options	Default Setting	Comments
3480	3.AR: Tdead EV.	0.01 .. 1800.00 sec	1.20 sec	Dead time after evolving fault
3481	3.AR: CB? CLOSE	YES NO	NO	CB ready interrogation before re-closing
3482	3.AR SynRequest	YES NO	NO	Request for synchro-check after 3pole AR
3483	4.AR: START	YES NO	NO	AR start allowed in this cycle
3484	4.AR: T-ACTION	0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3486	4.AR Tdead 1Flt	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1phase faults
3487	4.AR Tdead 2Flt	0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 2phase faults
3488	4.AR Tdead 3Flt	0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3phase faults
3489	4.AR Tdead1Trip	0.01 .. 1800.00 sec; ∞	∞ sec	Dead time after 1pole trip
3490	4.AR Tdead3Trip	0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3pole trip
3491	4.AR: Tdead EV.	0.01 .. 1800.00 sec	1.20 sec	Dead time after evolving fault
3492	4.AR: CB? CLOSE	YES NO	NO	CB ready interrogation before re-closing
3493	4.AR SynRequest	YES NO	NO	Request for synchro-check after 3pole AR

2.14.4 Information List

No.	Information	Type of In-formation	Comments
2701	>AR on	SP	>AR: Switch on auto-reclose function
2702	>AR off	SP	>AR: Switch off auto-reclose function
2703	>AR block	SP	>AR: Block auto-reclose function
2711	>AR Start	SP	>External start of internal Auto reclose
2712	>Trip L1 AR	SP	>AR: External trip L1 for AR start
2713	>Trip L2 AR	SP	>AR: External trip L2 for AR start
2714	>Trip L3 AR	SP	>AR: External trip L3 for AR start
2715	>Trip 1pole AR	SP	>AR: External 1pole trip for AR start
2716	>Trip 3pole AR	SP	>AR: External 3pole trip for AR start
2727	>AR RemoteClose	SP	>AR: Remote Close signal
2731	>Sync.release	SP	>AR: Sync. release from ext. sync.-check
2737	>BLOCK 1pole AR	SP	>AR: Block 1pole AR-cycle
2738	>BLOCK 3pole AR	SP	>AR: Block 3pole AR-cycle
2739	>BLK 1phase AR	SP	>AR: Block 1phase-fault AR-cycle
2740	>BLK 2phase AR	SP	>AR: Block 2phase-fault AR-cycle
2741	>BLK 3phase AR	SP	>AR: Block 3phase-fault AR-cycle
2742	>BLK 1.AR-cycle	SP	>AR: Block 1st AR-cycle
2743	>BLK 2.AR-cycle	SP	>AR: Block 2nd AR-cycle
2744	>BLK 3.AR-cycle	SP	>AR: Block 3rd AR-cycle
2745	>BLK 4.-n. AR	SP	>AR: Block 4th and higher AR-cycles

No.	Information	Type of In-formation	Comments
2746	>Trip for AR	SP	>AR: External Trip for AR start
2747	>Pickup L1 AR	SP	>AR: External pickup L1 for AR start
2748	>Pickup L2 AR	SP	>AR: External pickup L2 for AR start
2749	>Pickup L3 AR	SP	>AR: External pickup L3 for AR start
2750	>Pickup 1ph AR	SP	>AR: External pickup 1phase for AR start
2751	>Pickup 2ph AR	SP	>AR: External pickup 2phase for AR start
2752	>Pickup 3ph AR	SP	>AR: External pickup 3phase for AR start
2781	AR off	OUT	AR: Auto-reclose is switched off
2782	AR on	IntSP	AR: Auto-reclose is switched on
2783	AR is blocked	OUT	AR: Auto-reclose is blocked
2784	AR not ready	OUT	AR: Auto-reclose is not ready
2787	CB not ready	OUT	AR: Circuit breaker not ready
2788	AR T-CBreadyExp	OUT	AR: CB ready monitoring window expired
2796	AR on/off BI	IntSP	AR: Auto-reclose ON/OFF via BI
2801	AR in progress	OUT	AR in progress
2809	AR T-Start Exp	OUT	AR: Start-signal monitoring time expired
2810	AR TdeadMax Exp	OUT	AR: Maximum dead time expired
2818	AR evolving Flt	OUT	AR: Evolving fault recognition
2820	AR Program1pole	OUT	AR is set to operate after 1p trip only
2821	AR Td. evol.Flt	OUT	AR dead time after evolving fault
2839	AR Tdead 1pTrip	OUT	AR dead time after 1pole trip running
2840	AR Tdead 3pTrip	OUT	AR dead time after 3pole trip running
2841	AR Tdead 1pFlt	OUT	AR dead time after 1phase fault running
2842	AR Tdead 2pFlt	OUT	AR dead time after 2phase fault running
2843	AR Tdead 3pFlt	OUT	AR dead time after 3phase fault running
2844	AR 1stCyc. run.	OUT	AR 1st cycle running
2845	AR 2ndCyc. run.	OUT	AR 2nd cycle running
2846	AR 3rdCyc. run.	OUT	AR 3rd cycle running
2847	AR 4thCyc. run.	OUT	AR 4th or higher cycle running
2848	AR ADT run.	OUT	AR cycle is running in ADT mode
2851	AR CLOSE Cmd.	OUT	AR: Close command
2852	AR Close1.Cyc1p	OUT	AR: Close command after 1pole, 1st cycle
2853	AR Close1.Cyc3p	OUT	AR: Close command after 3pole, 1st cycle
2854	AR Close 2.Cyc	OUT	AR: Close command 2nd cycle (and higher)
2861	AR T-Recl. run.	OUT	AR: Reclaim time is running
2862	AR successful	OUT	AR successful
2864	AR 1p Trip Perm	OUT	AR: 1pole trip permitted by internal AR
2865	AR Sync.Request	OUT	AR: Synchro-check request
2871	AR TRIP 3pole	OUT	AR: TRIP command 3pole
2889	AR 1.CycZoneRel	OUT	AR 1st cycle zone extension release
2890	AR 2.CycZoneRel	OUT	AR 2nd cycle zone extension release
2891	AR 3.CycZoneRel	OUT	AR 3rd cycle zone extension release
2892	AR 4.CycZoneRel	OUT	AR 4th cycle zone extension release
2893	AR Zone Release	OUT	AR zone extension (general)
2894	AR Remote Close	OUT	AR Remote close signal send

2.15 Synchronism and voltage check (optional)

The synchronism and voltage check function ensures, when switching a line onto a busbar, that the stability of the network is not endangered. The voltage of the feeder to be energized is compared to that of the busbar to check conformances in terms of magnitude, phase angle and frequency within certain tolerances. Optionally, deenergization of the feeder can be checked before it is connected to av energized busbar (or vice versa).

The synchronism check can either be conducted only for automatic reclosure, only for manual closure (this includes also closing via control command) or in both cases. Different close permission (release) criteria can also be programmed for automatic and manual closure.

Synchronism check is also possible without external matching transformers if a power transformer is located between the measuring points.

Closing is released for synchronous or asynchronous system conditions. In the latter case the device determines the time for issuing the close command such that the voltages are identical the instant the breaker poles make contact.

2.15.1 Method of Operation

General

The synchronism and voltage check function uses the feeder voltage — designated with U_{line} — and the bus-bar voltage — designated with U_{bus} — for comparison purposes. The latter may be any convenient phase-to-earth or phase-to-phase voltage derived from the bus-bar voltage transformers.
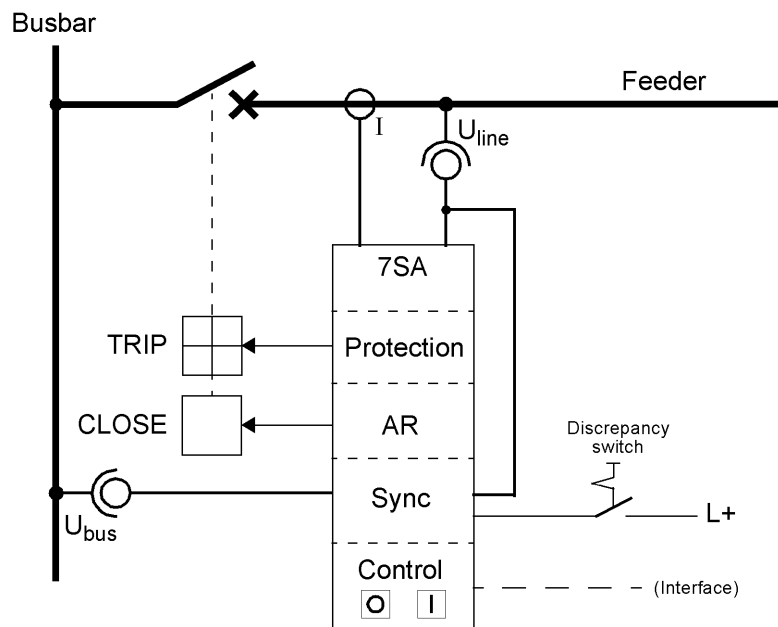
Figure 2-118   Synchronism check on closing

If a power transformer is located between the feeder voltage transformers and the busbar voltage transformers (Figure 2-119), its vector group can be compensated for by the 7SA6 relay, so that no external matching transformers are necessary.
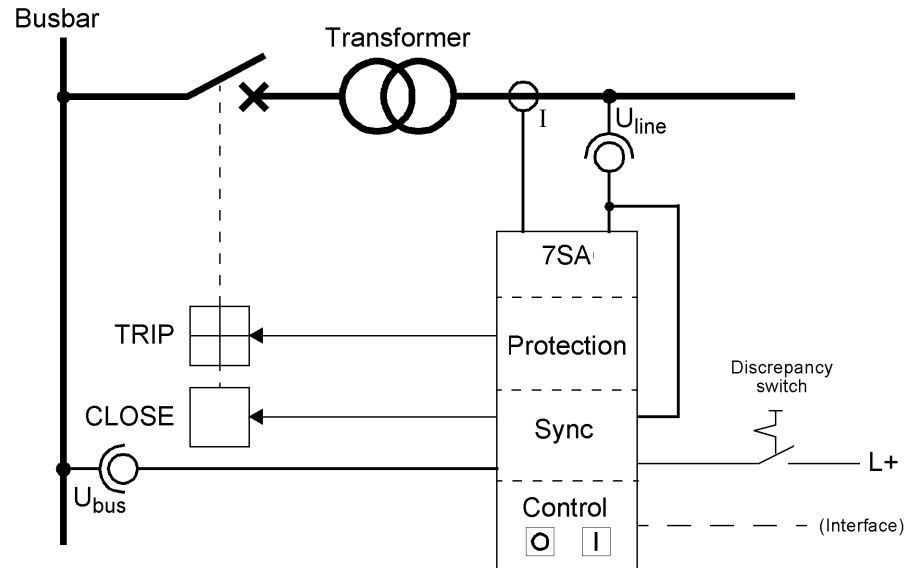
Figure 2-119   Synchronism check across a transformer

The synchronism check function in the 7SA6 usually operates together with the integrated automatic reclose, manual close, and the control functions of the relay. It is also possible to employ an external automatic reclosing system. In such a case signal exchange between the devices is accomplished via binary inputs and outputs.

When closing via the integrated control function, the configured interlocking conditions may have to be verified before checking the conditions for synchronism. After the synchronism check grants the release, the interlocking conditions are not checked a second time.

Furthermore, closing is possible with synchronous or asynchronous system conditions or both. Synchronous closing means that the closing command is issued as soon as the critical values (voltage magnitude difference **Max. Volt. Diff**, angle difference **Max. Angle Diff**, and frequency difference **Max. Freq. Diff**) lie within the set tolerances. For closing with asynchronous system conditions, the device calculates the correct timing of the closing command from the angle difference **Max. Angle Diff** and the frequency difference **Max. Freq. Diff** such that the voltages on the busbar and the feeder circuit have exactly the same phase relationship at the instant that the circuit breaker primary contacts close. For this purpose the device must be informed on the operating time of the circuit breaker for closing. Different frequency limit thresholds apply to closing at synchronism and asynchronous conditions: If closing shall be permitted exclusively under synchronous system conditions, the frequency difference limit for this condition can be set. If closing is permitted under synchronous as well as under asynchronous system conditions, a frequency difference below 0.01 Hz is treated as a synchronous condition, a higher frequency difference value can then be set for closing under asynchronous system conditions.

The synchronism check function only operates when it is requested to do so. Various possibilities exist to this end:

- Measuring request from the internal automatic reclosure device. If the internal automatic reclosing function is set accordingly (one or more reclosing attempts set to synchronism check, see also Section 2.14.2), the measuring request is accomplished internally. The release conditions for automatic reclosing apply.
- Measuring request from an external automatic reclosure device. The measuring request must be activated via the binary input ">Sync. Start AR" (FNo 2906). The release conditions for automatic reclosing apply.
- Measuring request from the internal manual CLOSE detection. The manual CLOSE detection of the central function control (Section 2.23.1) issues a measuring request provided this was configured in the power system data 2 (Section 2.1.5.1, address 1151). This requires the device to be informed of the manual closing via binary input ">Manual Close" (FNo 356). The release conditions for manual reclosing apply.
- Request to execute a check synchronism measurement from an external closing command. Binary input ">Sync. Start MC" FNo. 2905 fulfills this purpose. Unlike the ">Manual Close" (see previous paragraph), this merely affects the measuring request to the synchronism check function, but not other integrated manual CLOSE function such as instantaneous tripping when switching onto a fault (e.g. overreaching zone for distance protection or accelerated tripping of a time overcurrent stage). The release conditions for manual closure apply.
- Measuring request from the integrated control function via control keys or via the serial interace using DIGSI ® on a PC or from a control center. The release conditions for manual closure apply.

The synchronism check function gives permission for passage "Sync. release" (FNo 2951) of the closing command to the required function. Furthermore a separate closing command is available as output indication "Sync.CloseCmd" (FNo 2961).

The check of the release conditions is limited by an adjustable synchronous monitoring time **T-SYN. DURATION**. The configured conditions must be fulfilled within this time. Otherwise synchronism will not be checked. A new synchronism check sequence requires a new request.

The device outputs messages if, after a request to check synchronism, the conditions for release are not fulfilled, i.e. if the absolute voltage difference **Max. Volt. Diff**, the absolute frequency difference **Max. Freq. Diff**, or the absolute phase angle difference **Max. Angle Diff** lie outside the permissible limit values. A precondition for these messages is that voltages within the operating range of the relay are available. When a closing command is handled by the integrated control function and the conditions for synchronism are not fulfilled, the command is cancelled i.e., the control function outputs "CO–" (refer also to Section 2.25.1).

Operating Modes   The closing check procedure can be selected from the following operating modes:

SYNC-CHECK =	Release at synchronism, that is, when the critical values **Max. Volt. Diff**, **Max. Freq. Diff** and **Max. Angle Diff** lie within the set limits.
Usync> U-line< =	Release for energized busbar (Ubus>) and de-energized line (Uline<).
Usync< U-line> =	Release for de-energized busbar (Ubus<) and energized line (Uline>).

Usync< U-line< =   Release for de-energized busbar (Ubus<) and de-energized line (Uline<).

OVERRIDE =   Release without any check.

Each of these conditions can be enabled or disabled individually; combinations are also possible (e.g., release if **Usync> U-line<** or **Usync< U-line>** are fulfilled). Combination of **OVERRIDE** with other parameters is, of course, not reasonable.

The release conditions can be configured individually either for automatic reclosing or for manual closing or for closing via control commands. For example, manual closing and control closing can be allowed in cases of synchronism or dead line, whilst, before an automatic reclose attempt dead line conditions are only checked at one line end and after the automatic reclose attempt only synchronism at the other end.

Dead Line or Dead Bus Closing

For release of the closing command to energize a voltage overhead line from a live busbar, the following conditions are checked:

- Does the feeder voltage U_{line} lie below the set value **Dead Volt. Thr.**?
- Does the busbar voltage U_{bus} lie above the set value **Live Volt. Thr.**, but below the maximum operating voltage **Umax**?
- Is the frequency f_{bus} within the permitted operating range $f_N \pm 3$ Hz?

After successful check the closing command is released.

Corresponding conditions apply when switching a live line onto a dead busbar or a dead line onto a dead busbar.

Closing at Synchronous System Conditions

Before releasing a closing command at synchronous conditions, the following conditions are checked:

- Does the busbar voltage U_{bus} lie above the set value **Live Volt. Thr.**, but below the maximum operating voltage **Umax**?
- Does the feeder voltage U_{line} lie above the set value **Live Volt. Thr.**, but below the maximum operating voltage **Umax**?
- Is the voltage difference $|U_{line} - U_{bus}|$ within the permissible tolerance **Max. Volt. Diff**?
- Are the two frequencies f_{1bus} and f_{line} within the permitted operating range $f_N \pm 3$ Hz?
- Does the frequency difference $|f_{line} - f_{bus}|$ lie within the permissible tolerance **Max. Freq. Diff**?
- Is the angle difference $|\varphi_{line} - \varphi_{bus}|$ within the permissible tolerance **Max. Angle Diff**?

To check whether these conditions are observed for a certain minimum time, you can set this minimum time as **T SYNC-STAB**. Checking the synchronism conditions can also be confined to a maximum monitoring time **T-SYN. DURATION**. This implies that the conditions must be fulfilled within the time **T-SYN. DURATION** for the duration of **T SYNC-STAB**. If this is the case, the closing command is released.

Closing at Asynchronous System Conditions

Before releasing a closing command at asynchronous conditions, the following conditions are checked:

- Does the busbar voltage U_{bus} lie above the set value **Live Volt. Thr.**, but below the maximum operating voltage **Umax**?
- Does the feeder voltage U_{line} lie above the set value **Live Volt. Thr.**, but below the maximum operating voltage **Umax**?

- Is the voltage difference $|U_{line} - U_{bus}|$ within the permissible tolerance **Max. Volt. Diff**?
- Are the two frequencies f_{bus} and f_{line} within the permitted operating range $f_N \pm 3$ Hz?
- Does the frequency difference $|f_{line} - f_{bus}|$ lie within the permissible tolerance **Max. Freq. Diff**?

When the check has been terminated successfully, the device determines the next synchronizing time from the angle difference and the frequency difference. The close command is issued at synchronization time minus the operating time of the circuit breaker.

2.15.2 Setting Notes

Preconditions

When setting the general power system data (Power system data 1, refer to Section 2.1.3.1) a number of parameters regarding the measured quantities and the operating mode of the synchronism check function must be applied.

This concerns the following parameters:

203 **Unom PRIMARY**	rated primary voltage of the feeder voltage transformers (phase-to-phase) in kV;
204 **Unom SECONDARY**	rated secondary voltage of the feeder voltage transformers (phase-to-phase) in V;
210 **U4 transformer**	connection of the additional voltage transformer input U_4, must be **Usync transf.** and connected to a busbar voltage;
212 **Usync connect.**	type of voltage which is connected to the device from the busbar voltage transformer,
214 φ **Usync-Uline**	phase angle displacement between the voltage of the busbar and that of the feeder in case a power transformer is installed inbetween;
215 **U-line / Usync**	the ratio of the secondary feeder voltage to the secondary bus-bar voltage under nominal voltage conditions;
230 **Rated Frequency**	the operating range of the synchronism check refers to the nominal frequency of the power system ($f_N \pm 3$ Hz);
1103 **FullScaleVolt.**	Operational rated voltage of the primary power system (phase-phase) in kV;

and, if closing at asynchronous system conditions is allowed,

239 **T-CB close**	the closing time of the circuit breaker.

WARNING!

Closing at Asynchronous System Conditions!

Closing at asynchronous system conditions requires the closing time of the circuit breaker to be set correctly in the Power system data 1 (address 239).

Otherwise, faulty synchronization may occur.

General

The synchronism check function can only operate if it was configured as *Enabled* (address 135) and **U4 transformer** as *Usync transf.* (address 210) during configuration of the functional scope.

The measured values of the synchronism check (636 "Udiff =", 637 "Uline =" ,638 "Ubus =", 647 "F-diff=", 649 "F-line=", 646 "F-bus =", and 648 " φdif=")are only available or will be only calculated, if the synchronism check was set to *Enabled* and the parameter **U4 transformer**(address 210) has been set to *Usync transf.*.

Different interrogation conditions can be parameterized for automatic reclosure on the one hand and for manual closure on the other hand. Each closing command is considered a manual reclosure if it was initiated via the integrated control function or via a serial interface.

The general limit values for synchronism check are set at address 3501 to 3508. Additionally, addresses 3510 to 3519 are relevant for automatic reclosure, addresses 3530 to 3539 are relevant for manual closure. Moreover, address 3509 is relevant for closure via the integrated control function.

The complete synchronism check function is switched *ON* or *OFF* under address 3501 **FCT Synchronism**. If switched off, the synchronism check does not verify the synchronization conditions and release is not granted. You can also set *ON:w/o CloseCmd*: In this case, the close command is not integrated in the device indication "Relay CLOSE" (FNo 510), but the message "Sync.CloseCmd" (FNo 2961) is generated.

Address 3502 **Dead Volt. Thr.** indicates the voltage threshold below which the feeder or the busbar can safely be considered dead (for checking a de-energized feeder or busbar). The setting is applied in Volts secondary. This value can be entered as a primary value when parameterizing with a PC and DIGSI®. Depending on the connection of the voltages these are phase-to-earth voltages or phase-to-phase voltages.

The voltage above which the feeder or busbar is regarded as being definitely live, is set under address 3503 **Live Volt. Thr.** (for energized line or busbar check and for the lower limit of synchronism check). It must be set below the anticipated operational undervoltage. The setting is applied in Volts secondary. This value can be entered as a primary value when parameterizing with a PC and DIGSI®. Depending on the connection of the voltages these are phase-to-earth voltages or phase-to-phase voltages.

The maximum permissible voltage for the operating range of the synchronism check function is set under address 3504 **Umax**. The setting is applied in Volts secondary. This value can be entered as a primary value when parameterizing with a PC and DIGSI®. Depending on the connection of the voltages these are phase-to-earth voltages or phase-to-phase voltages.

Verification of the release conditions via synchronism check can be limited to a configurable synchronous monitoring time **T-SYN. DURATION** (address 3507). The con-

figured conditions must be fulfilled within this time. If not, closure will not be released. If this time is set to ∞, the conditions will be checked until they are fulfilled or the measurement request is cancelled.

If the conditions for <u>synchronous</u> operation must be checked to be maintained for a certain duration, this minimum duration **T SYNC-STAB** can be set under address 3508 before closing is released.

Synchronism Check Conditions before Automatic Reclosure

Addresses 3510 to 3519 are relevant to the check conditions before automatic reclosure of the circuit breaker. When setting the parameters for the internal automatic reclosing function (Section 2.14.2) it is decided with which automatic reclosing cycle synchronism and voltage check should be carried out.

Address 3510 **Op.mode with AR** determines whether closing under asynchronous system conditions is allowed for automatic reclosure. Set this parameter to *with T-CB close* to allow asynchronous closing; the relay will then consider the circuit breaker operating time before determining the correct instant for the close command. Remember that closing under asynchronous system conditions is allowed only if the circuit breaker closing time is set correctly (see above under "Preconditions")! If you wish to permit automatic reclosure only under synchronous system conditions, set this address to *w/o T-CB close*.

The permissible magnitude difference of the voltages is set at address 3511 **Max. Volt. Diff**. The setting is applied in Volts secondary. This value can be entered as a primary value when parameterizing with a PC and DIGSI®. Depending on the connection of the voltages these are phase-to-earth voltages or phase-to-phase voltages.

The permissible frequency difference between the voltages is set at address 3512 **Max. Freq. Diff**, the permissible phase angle difference at address 3513 **Max. Angle Diff**.

The further release conditions for automatic reclosing are set at addresses 3515 to 3519.

The following addresses mean:

3515 **SYNC-CHECK**	the busbar (Ubus) and the feeder (Uline) must both be live (**Live Volt. Thr.**, address 3503); the conditions for synchronism are checked i.e., **Max. Volt. Diff** (address 3511), **Max. Freq. Diff**(address 3512) and **Max. Angle Diff** (address 3513);
3516 **Usync> U-line<**	the busbar (Ubus) must be live (**Live Volt. Thr.**, address 3503), the feeder (Uline) must be dead (**Dead Volt. Thr.**, address 3502);
3517 **Usync< U-line>**	the busbar (Ubus) must be dead (**Dead Volt. Thr.**, address 3502), the feeder (Uline) must be live (**Live Volt. Thr.**, address 3503);
3518 **Usync< U-line<**	the busbar (Ubus) and the feeder (Uline) must both be de-energized (**Dead Volt. Thr.**, address 3502);
3519 **OVERRIDE**	automatic reclosure is released without any check.

The five possible release conditions are independent of each other and can be combined.

Synchronism Check Conditions before Manual Closing

Addresses 3530 to 3539 are relevant to the check conditions before manual closure and closing via control command of the circuit breaker. When setting the general protection data (Power System Data 2, Section 2.1.5.1) it was already decided at address 1151 whether synchronism and voltage check should be carried out before manual closing. With the following setting in address **MAN. CLOSE** = *w/o Sync-check*, no checks are performed before manual closing.

Address 3509 **SyncCB** determines for commands via the integrated control function (local, DIGSI, serial interface) whether synchronism check is carried out or not. This address also tells the device for which switching device of the control the synchronism check applies. You can select from the switching devices which are available for the integrated control. Choose the circuit breaker to be operated via the synchronism check. This is usually the circuit breaker which is operated in case of manual closing or automatic reclosure. If you set **SyncCB** = *none* here, a CLOSE command via the integrated control will be carried out without synchronism check.

Address 3530 **Op.mode with MC** determines whether closing under asynchronous system conditions is allowed for manual closing or reclosure via control command. Set this parameter to *with T-CB close* to allow asynchronous closing; the relay will then consider the circuit breaker closing time before determining the correct instant for the close command. Remember that closing under asynchronous system conditions is allowed only if the circuit breaker closing time is set correctly (see above under "Preconditions")! If you wish to permit manual closure or closing via control command only under synchronous system conditions, set this address to *w/o T-CB close*.

The permissible magnitude difference of the voltages is set at address 3531 **MC maxVolt.Diff**. The setting is applied in Volts secondary. This value can be entered as a primary value when parameterizing with a PC and DIGSI®. Depending on the connection of the voltages these are phase-to-earth voltages or phase-to-phase voltages.

The permissible frequency difference between the voltages is set at address 3532 **MC maxFreq.Diff**, the permissible phase angle difference at address 3533 **MC maxAngleDiff**.

The further release conditions for manual reclosing or reclosure via control command are set under addresses 3535 to 3539.

The following addresses mean:

3535 **MC SYNCHR**	the busbar (Ubus) and the feeder (Uline) must both be energized (**Live Volt. Thr.**, address 3503); the conditions for synchronism are checked i.e., **MC maxVolt.Diff** (address 3531), **MC maxFreq.Diff** (address 3532) and **MC maxAngleDiff** (address 3533); This setting is only possible via DIGSI® under **Additional Settings**.
3536 **MC Usyn> Uline<**	the busbar (Ubus) must be live (**Live Volt. Thr.**, address 3503), the feeder (Uline) must be dead (**Dead Volt. Thr.**, address 3502);
3537 **MC Usyn< Uline>**	the busbar (Ubus) must be dead (**Dead Volt. Thr.**, address 3502), the feeder (Uline) must be live (**Live Volt. Thr.**, address 3503);
3538 **MC Usyn< Uline<**	the busbar (Ubus) and the feeder (Uline) must both be de-energized (**Dead Volt. Thr.**, address 3502);
3539 **MC O/RIDE**	manual closing or closing via control command is released without any check.

The five possible release conditions are independent of each other and can be combined.

Note

The closing functions of the device issue individual output indications for the corresponding close command. Be sure that the output indications are assigned to the correct output relays.

FNo 2851 "AR CLOSE Cmd." for CLOSE command of the automatic reclosure,

FNo 562 "Man.Close Cmd" for manual CLOSE via binary input,

FNo 2961 "Sync.CloseCmd" for CLOSE by synchronism check (not required if synchronism check releases the other CLOSE commands),

FNo 7329 "CB1-TEST close" for CLOSE via circuit breaker test,

additionally CLOSE command via control e.g. "52 Close",

FNo 510 "Relay CLOSE" general CLOSE command for all CLOSE commands described above.

Notes on the Information List

The most important information of the device is briefly explained in so far as it cannot be interpreted in the following information lists or described in detail in the foregoing text.

">Sync. Start MC" (FNo. 2905)

Binary input which enables direct tripping of the sychnonism check with setting parameters for manual close. This tripping with setting parameter for manual close has always precedence if binary inputs ">Sync. Start MC" (F.No. 2905) and ">Sync. Start AR" (F.No. 2906, see below) are activated at the same time.

">Sync. Start AR" (FNo. 2906)

Measuring request from an external automatic reclosure device. The parameters of synchronism check set for automatic reclosure are valid here.

"Sync. req.CNTRL" (FNo. 2936)

Measurement request of the control function; this request is evaluated on event-triggered basis and only generated if the control issues a measurement request.

"Sync. release" (FNo. 2951)

Release signal to an external automatic reclosure device.

2.15.3 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
3501	FCT Synchronism	ON OFF ON:w/o CloseCmd	ON	Synchronism and Voltage Check function
3502	Dead Volt. Thr.	1 .. 60 V	5 V	Voltage threshold dead line / bus
3503	Live Volt. Thr.	20 .. 125 V	90 V	Voltage threshold live line / bus
3504	Umax	20 .. 140 V	110 V	Maximum permissible voltage
3507	T-SYN. DURATION	0.01 .. 600.00 sec; ∞	1.00 sec	Maximum duration of synchronism-check
3508	T SYNC-STAB	0.00 .. 30.00 sec	0.00 sec	Synchronous condition stability timer
3509	SyncCB	None Breaker Disc.Swit. EarthSwit Q2 Op/Cl Q9 Op/Cl Fan ON/OFF	None	Synchronizable circuit breaker
3510	Op.mode with AR	with T-CB close w/o T-CB close	w/o T-CB close	Operating mode with AR
3511	Max. Volt. Diff	1.0 .. 40.0 V	2.0 V	Maximum voltage difference
3512	Max. Freq. Diff	0.03 .. 2.00 Hz	0.10 Hz	Maximum frequency difference
3513	Max. Angle Diff	2 .. 80 °	10 °	Maximum angle difference
3515A	SYNC-CHECK	YES NO	YES	Live bus / live line and Sync before AR
3516	Usync> U-line<	YES NO	NO	Live bus / dead line check before AR
3517	Usync< U-line>	YES NO	NO	Dead bus / live line check before AR
3518	Usync< U-line<	YES NO	NO	Dead bus / dead line check before AR
3519	OVERRIDE	YES NO	NO	Override of any check before AR
3530	Op.mode with MC	with T-CB close w/o T-CB close	w/o T-CB close	Operating mode with Man.Cl
3531	MC maxVolt.Diff	1.0 .. 40.0 V	2.0 V	Maximum voltage difference
3532	MC maxFreq.Diff	0.03 .. 2.00 Hz	0.10 Hz	Maximum frequency difference
3533	MC maxAngleDiff	2 .. 80 °	10 °	Maximum angle difference
3535A	MC SYNCHR	YES NO	YES	Live bus / live line and Sync before MC
3536	MC Usyn> Uline<	YES NO	NO	Live bus / dead line check before Man.Cl

Addr.	Parameter	Setting Options	Default Setting	Comments
3537	MC Usyn< Uline>	YES NO	NO	Dead bus / live line check before Man.Cl
3538	MC Usyn< Uline<	YES NO	NO	Dead bus / dead line check before Man.Cl
3539	MC O/RIDE	YES NO	NO	Override of any check before Man.Cl

2.15.4 Information List

No.	Information	Type of Information	Comments
2901	>Sync. on	SP	>Switch on synchro-check function
2902	>Sync. off	SP	>Switch off synchro-check function
2903	>BLOCK Sync.	SP	>BLOCK synchro-check function
2905	>Sync. Start MC	SP	>Start synchro-check for Manual Close
2906	>Sync. Start AR	SP	>Start synchro-check for AR
2907	>Sync. synch	SP	>Sync-Prog. Live bus / live line / Sync
2908	> Usyn< U-line>	SP	>Sync-Prog. Dead bus / live line
2909	> Usyn> U-line<	SP	>Sync-Prog. Live bus / dead line
2910	> Usyn< U-line<	SP	>Sync-Prog. Dead bus / dead line
2911	>Sync. o/ride	SP	>Sync-Prog. Override (bypass)
2930	Sync. on/off BI	IntSP	Synchro-check ON/OFF via BI
2931	Sync. OFF	OUT	Synchro-check is switched OFF
2932	Sync. BLOCK	OUT	Synchro-check is BLOCKED
2934	Sync. faulty	OUT	Synchro-check function faulty
2935	Sync.Tsup.Exp	OUT	Synchro-check supervision time expired
2936	Sync. req.CNTRL	OUT	Synchro-check request by control
2941	Sync. running	OUT	Synchronization is running
2942	Sync.Override	OUT	Synchro-check override/bypass
2943	Synchronism	OUT	Synchronism detected
2944	Usyn< U-line>	OUT	Sync. dead bus / live line detected
2945	Usyn> U-line<	OUT	Sync. live bus / dead line detected
2946	Usyn< U-line<	OUT	Sync. dead bus / dead line detected
2947	Sync. Udiff>	OUT	Sync. Voltage diff. greater than limit
2948	Sync. fdiff>	OUT	Sync. Freq. diff. greater than limit
2949	Sync. φ-diff>	OUT	Sync. Angle diff. greater than limit
2951	Sync. release	OUT	Synchronism release (to ext. AR)
2961	Sync.CloseCmd	OUT	Close command from synchro-check
2970	Sync. f-bus>>	OUT	Sync. Bus frequency > (fn + 3Hz)
2971	Sync. f-bus<<	OUT	Sync. Bus frequency < (fn - 3Hz)
2972	Sync. f-line>>	OUT	Sync. Line frequency > (fn + 3Hz)
2973	Sync. f-line<<	OUT	Sync. Line frequency < (fn - 3Hz)
2974	Sync. U-syn>>	OUT	Sync. Bus voltage > Umax (P.3504)
2975	Sync. U-syn<<	OUT	Sync. Bus voltage < U> (P.3503)

No.	Information	Type of Information	Comments
2976	Sync. U-line>>	OUT	Sync. Line voltage > Umax (P.3504)
2977	Sync. U-line<<	OUT	Sync. Line voltage < U> (P.3503)

2.16 Undervoltage and overvoltage protection (optional)

Voltage protection has the function to protect electrical equipment against undervoltage and overvoltage. Both operational states are unfavourable as for example undervoltage may cause stability problems or overvoltage may cause insulation problems.

The overvoltage protection in the 7SA6 detects the phase voltages U_{L1-E}, U_{L2-E} and U_{L3-E}, the phase-to-phase voltages U_{L1-L2}, U_{L2-L3} and U_{L3-L1}, as well as the displacement voltage $3U_0$. Instead of the displacement voltage any other voltage that is connected to the fourth voltage input U_4 of the device can be detected. Furthermore the device calculates the positive sequence system voltage and the negative sequence system voltage so that the symmetrical components are also monitored. Here compounding is also possible which calculates the voltage at the remote line end.

For undervoltage protection the phase voltages U_{L1-E}, U_{L2-E} and U_{L3-E}, the phase-to-phase voltages U_{L1-L2}, U_{L2-L3} and U_{L3-L1}, and the positive-sequence system can be used.

These voltage protection functions can be combined according to the user's requirements. They can be switched on or off separately, or used for alarm purposes only. In the latter case the respective trip commands do not appear. Each voltage protection function is two-stage, i.e. it is provided with two threshold setting stages, each one with its respective time delay.

Abnormally high voltages often occur e.g. in low loaded, long distance transmission lines, in islanded systems when generator voltage regulation fails, or after full load shutdown of a generator from the system. Even if compensation reactors are used to avoid line overvoltages by compensation of the line capacitance and thus reduction of the overvoltage, the overvoltage will endanger the insulation if the reactors fail (e.g. due to fault clearance). The line must be deenergized within very short time.

The undervoltage protection can be applied, for example, for disconnection or load shedding tasks in a system. Furthermore, this protection scheme can detect menacing stability problems. With induction machines undervoltages have an effect on the stability and permissible torque thresholds.

2.16.1 Overvoltage Protection

Overvoltage Phase–Earth

Figure 2-120 depicts the logic diagram of the phase voltage stages. The fundamental frequency is numerically filtered from each of the three measuring voltages so that harmonics or transient voltage peaks are largely eliminated. Two threshold stages **Uph-e>** and **Uph-e>>** are compared with the voltages. If a phase voltage exceeds these thresholds it is indicated phase-segregated. Furthermore, a general pick-up indication "Uph-e> Pickup" "Uph-e>> Pickup" is given. The drop-out to pick-up ratio can be set (**Uph-e>(>) RESET**).

Every stage starts a time delay which is common to all phases. Expiry of the respective time delay **T Uph-e>** or **T Uph-e>>** is signalled and usually results in the trip command "Uph-e>(>) TRIP".

The overvoltage protection phase–earth can be blocked via a binary input ">Uph-e>(>) BLK".
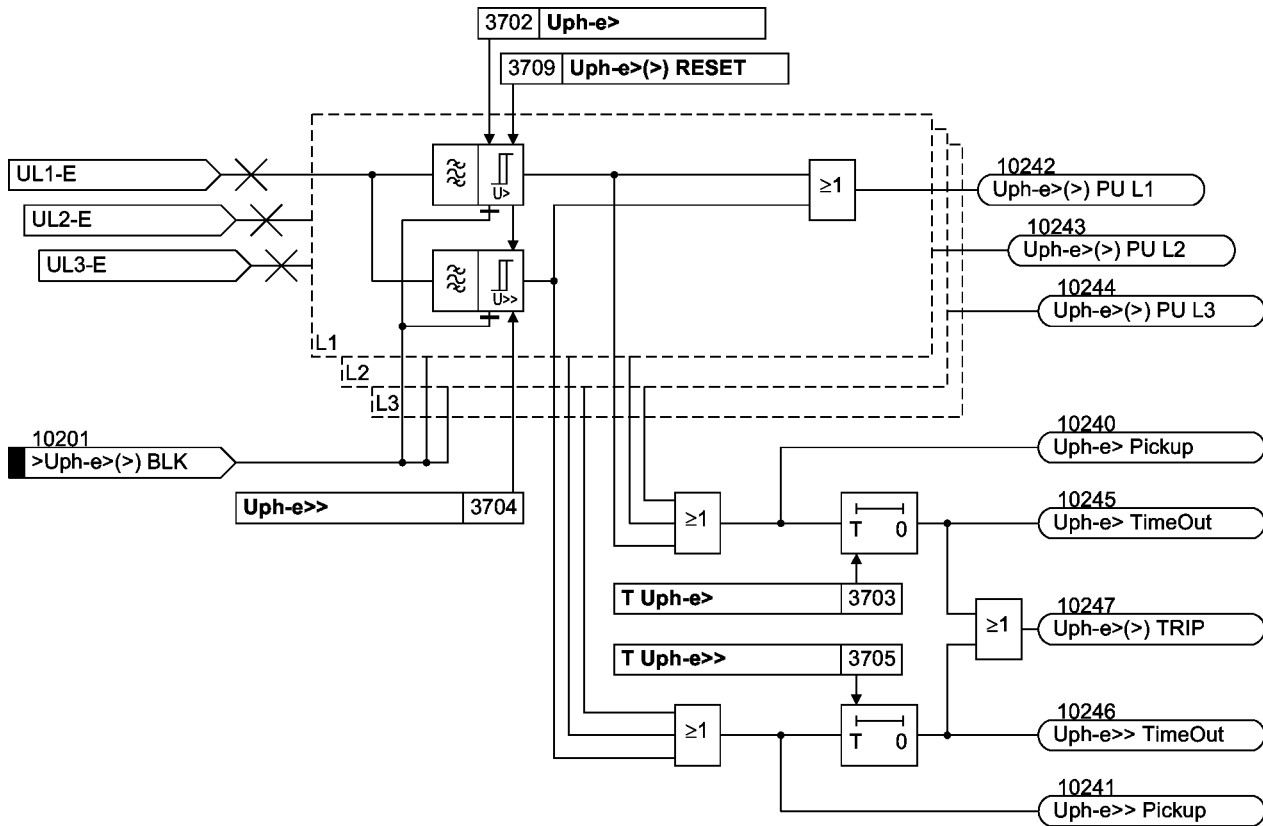
Figure 2-120   Logic diagram of the overvoltage protection for phase voltage

Overvoltage Phase–Phase

The phase–phase overvoltage protection operates just like the phase–earth protection except that it detects phase–to–phase voltages. Accordingly, phase–to–phase voltages which have exceeded one of the stage thresholds **Uph-ph>** or **Uph-ph>>** are also indicated. Beyond this, Figure 2-120 applies in principle.

The phase–phase overvoltage protection can also be blocked via a binary input "**>Uph-ph>(>) BLK**".

Overvoltage Positive Sequence System U$_1$

The device calculates the positive sequence system according to its defining equation

$$\underline{U}_1 = {}^1/_3 \cdot (\underline{U}_{L1} + \underline{a} \cdot \underline{U}_{L2} + \underline{a}^2 \cdot \underline{U}_{L3})$$

where $\underline{a} = e^{j120°}$.

The resulting single–phase AC voltage is fed to the two threshold stages **U1>** and **U1>>** (see Figure 2-121). Combined with the associated time delays **T U1>** and **T U1>>** these stages form a two-stage overvoltage protection for the positive sequence system. Here too, the drop-out to pick-up ratio can be set.

The overvoltage protection for the positive sequence system can also be blocked via a binary input "**>U1>(>) BLK**".
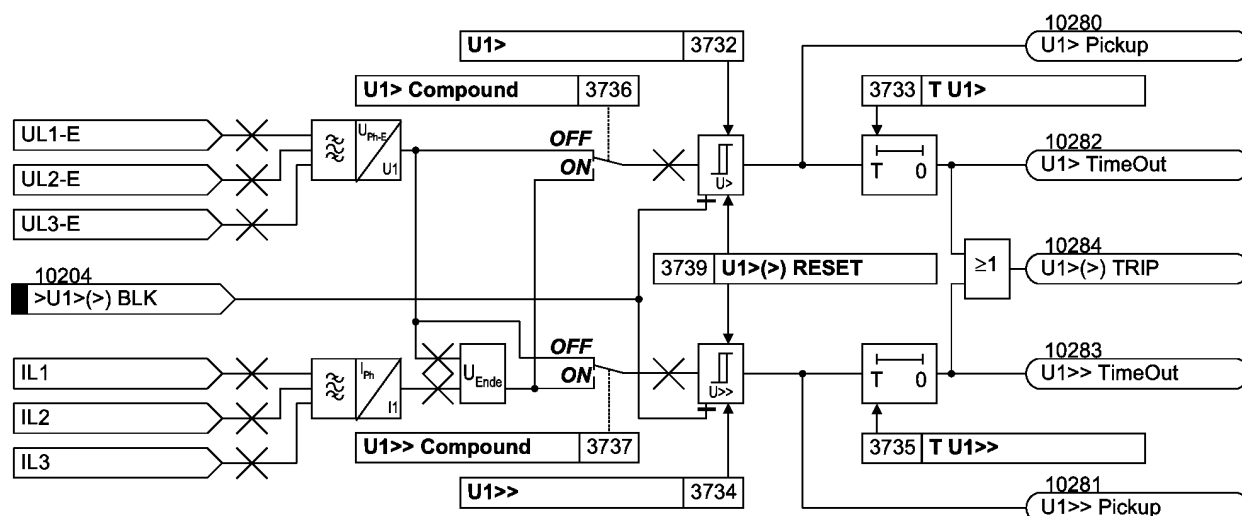
Figure 2-121   Logic diagram of the overvoltage protection for the positive sequence voltage system

Overvoltage U_1 with Configurable Compounding

The overvoltage protection for the positive sequence system may optionally operate with compounding. The compounding calculates the positive sequence system of the voltages at the remote line end. This option is thus particularly well suited for detecting a steady-state voltage increase caused by long transmission lines operating at weak load or no load due to the capacitance per unit length (Ferranti effect). In this case the overvoltage condition exists at the other line end but it can only be removed by switching off the local line end.

For calculating the voltage at the opposite line end the device requires the line data (inductance per unit length, capacitance per unit length, line angle, line length) which were entered in the Power System Data 2 (Section 2.1.5.1) during configuration.

Compounding is only available if address 137 is set to **Enabl. w. comp.**. In this case the calculated voltage at the other line end is also indicated in the operational measured values.

Note

Compounding is not suited for lines with series capacitors.

The voltage at the remote line end is calculated from the voltage measured at the local line end and the flowing current by means of a PI equivalent circuit diagram (refer also to Figure 2-122).

$$\underline{U}_{End} = \underline{U}_{Meas} - \left(\underline{I}_{Meas} - \frac{j\omega C_L}{2} \cdot \underline{U}_{Meas} \right) \cdot (R_L + j\omega L_L)$$

with

$\underline{U}_{End}$	the calculated voltage at the remote line end,
$\underline{U}_{Meas}$	the measured voltage at the local line end,
$\underline{I}_{Meas}$	the measured current at the local line end,
C_L	the line capacitance,

R_L	the ohmic line resistance,
L_L	the line inductance.
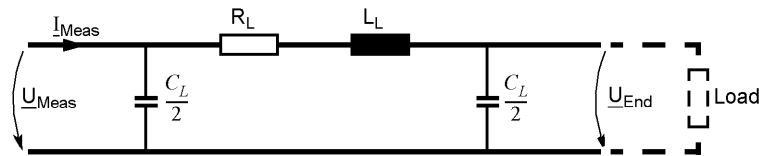
Figure 2-122   PI equivalent diagram for compounding

Overvoltage Negative Sequence System U_2

The device calculates the negative sequence system voltages according to its defining equation:

$$\underline{U}_2 = {}^1\!/_3 \cdot (\underline{U}_{L1} + \underline{a}^2 \cdot \underline{U}_{L2} + \underline{a} \cdot \underline{U}_{L3})$$

where $\underline{a} = e^{j120°}$.

The resulting single–phase AC voltage is fed to the two threshold stages **U2>** and **U2>>**. Figure 2-123 shows the logic diagram. By combining the associated time delays **T U2>** and **T U2>>** a two-stage overvoltage protection for the negative sequence system is formed. Here too, the drop-out to pick-up ratio can be set.
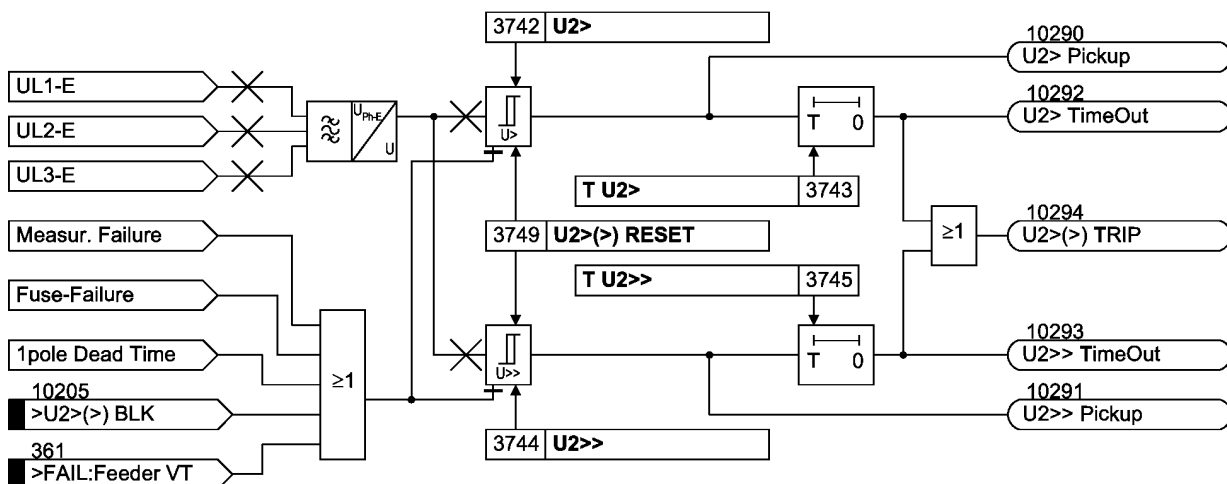
Figure 2-123   Logic diagram of the overvoltage protection for the negative sequence voltage system U_2

The overvoltage protection for the negative sequence system can also be blocked via a binary input "**>U2>(>) BLK**". The stages of the negative sequence voltage protection are automatically blocked as soon as an asymmetrical voltage failure was detected ("Fuse–Failure–Monitor", also see Section 2.22.1, margin heading "Fuse Failure Monitor (Non-symmetrical Voltages)" or when the trip of the mcb for voltage transformers has been signalled via the binary input "**>FAIL:Feeder VT**" (internal indication "internal blocking").

Even during single-pole dead time (with internal automatic reclosure function) the stages of the negative sequence overvoltage protection are automatically blocked since arising negative sequence values are only influenced by the asymmetrical power flow, not by the fault in the system. If the device cooperates with an external automatic reclosure function, or if a single-pole tripping can be triggered by a different

protection system (working in parallel), the overvoltage protection for the negative sequence system must be blocked via a binary input during single-pole tripping.

Overvoltage Zero Sequence System 3U₀

Figure 2-124 depicts the logic diagram of the zero sequence voltage stage. The fundamental frequency is numerically filtered from the measuring voltage so that the harmonics or transient voltage peaks remain largely harmless.

The triple zero sequence voltage $3U_0$ is fed to the two threshold stages **3U0>** and **3U0>>**. Combined with the associated time delays **T 3U0>** and **T 3U0>>** these stages form a two-stage overvoltage protection for the zero sequence system. Here too, the drop-off to pick-up ratio can be set (**3U0>(>) RESET**). Furthermore, a stabilization delay can be configured which is implemented by repeated measuring (approx. 2 periods).

The overvoltage protection for the zero sequence system can also be blocked via a binary input "**>3U0>(>) BLK**". The stages of the zero sequence voltage protection are automatically blocked as soon as an asymmetrical voltage failure was detected ("Fuse–Failure–Monitor", also see Section 2.22.1, margin heading "Fuse Failure Monitor (Non-symmetrical Voltages)" or when the trip of the mcb for voltage transformers has been signalled via the binary input "**>FAIL:Feeder VT**" (internal indication "internal blocking").

The stages of the zero sequence voltage protection are automatically blocked (with the internal automatic reclosure function) during single-pole automatic reclose dead time to avoid pick-up with the asymmetrical power flow arising during this state. If the device operates with an external automatic reclosure function or if single-pole tripping can be triggered by a different protection system (operating in parallel), the overvoltage protection for the zero sequence system must be blocked via a binary input during single-pole tripping.

According to Figure 2-124 the device calculates the voltage to be monitored:

$$3 \cdot \underline{U}_0 = \underline{U}_{L1} + \underline{U}_{L2} + \underline{U}_{L3}.$$

This applies if no suitable voltage is connected to the fourth measuring input U_4.

However, if the displacement voltage U_{en} of the voltage transformer set is directly connected to the fourth measuring input U_4 of the device and this information was entered during configuration, the device will automatically use this voltage and calculate the triple zero sequence voltage.

$$3 \cdot U_0 = \textbf{Uph / Udelta} \cdot U_4$$

Since the voltage transformation ratio of the voltage transformer set is usually

$$\frac{U_{Nprim}}{\sqrt{3}} \Big/ \frac{U_{Nsec}}{\sqrt{3}} \Big/ \frac{U_{Nsec}}{3}$$

the factor is set to **Uph / Udelta** $= 3/\sqrt{3} = \sqrt{3} = 1.73$. For more details, refer to **Power System Data 1** in Section 2.1.5.1 at margin heading "Voltage Connections" via address 211.
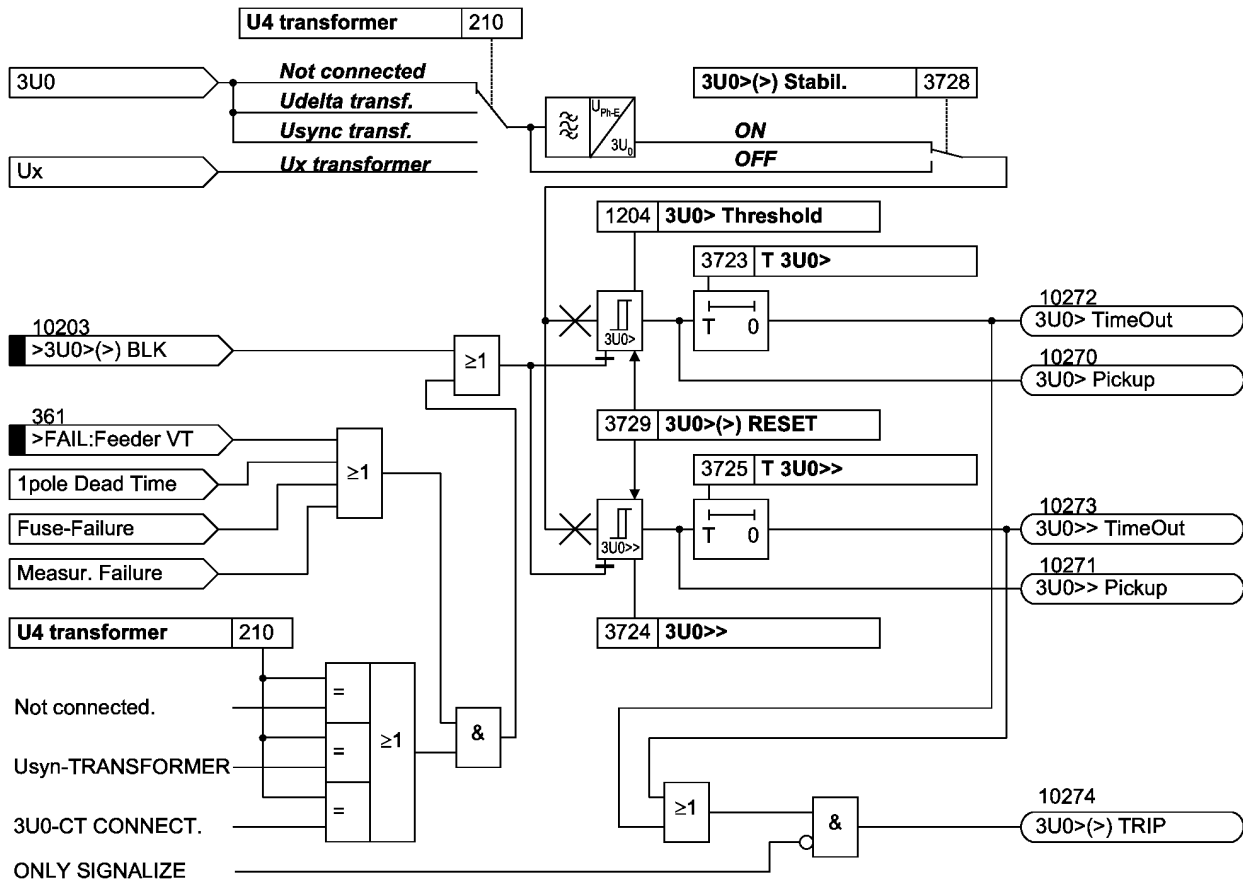
Figure 2-124   Logic diagram of the overvoltage protection for zero sequence voltage

Freely Selectable Single–phase Voltage

As the zero sequence voltage stages operate separately and independent from the other protective overvoltage functions they can be used for any other single–phase voltage. Therefore the fourth voltage input U_4 of the device must be assigned accordingly (also see Section 2.1.3, "Voltage Transformer Connection").

The stages can be blocked via a binary input ">3U0>(>) BLK". Internal blocking is not accomplished in this application case.

2.16.2 Undervoltage Protection

Undervoltage Phase–Earth

Figure 2-125 depicts the logic diagram of the phase voltage stages. The fundamental frequency is numerically filtered from each of the three measuring voltages so that harmonics or transient voltage peaks are largely harmless. Two threshold stages **Uph-e<** and **Uph-e<<** are compared with the voltages. If phase voltage falls below a threshold it is indicated phase-segregated. Furthermore, a general pick-up indication "Uph-e< Pickup" "Uph-e<< Pickup" is given. The drop-out to pick-up ratio is approx. 1.05.

Every stage starts a time delay which is common to all phases. Expiry of the respective time delay **T Uph-e<** or **T Uph-e<<** is signalled and results in the trip command "Uph-e<(<) TRIP".

Depending on the configuration of the substations the voltage transformers are located on the busbar side or on the outgoing feeder side. This results in a different

behaviour of the undervoltage protection when the line is deenergized. While the voltage usually remains present or reappears at the busbar side after a trip command and opening of the circuit breaker, it is switched on at the outgoing side. For the undervoltage protection this results in a pick-up state being present if the voltage transformers are on the outgoing side. If this pick-up must be reset, the current can be used as an additional criterion (current supervision **CURR.SUP. Uphe<**) to achieve this result. Undervoltage will then only be detected if, together with the undervoltage condition, the minimum current **PoleOpenCurrent** of the corresponding phase is also exceeded. This condition is communicated by the central function control of the device.

The undervoltage protection phase–earth can be blocked via a binary input "**Uphe<(<) BLK**". The stages of the undervoltage protection are then automatically blocked if a voltage failure is detected ("Fuse–Failure–Monitor", also see Section 2.22.1) or if the trip of the mcb of the voltage transformers is indicated (internal blocking) via the binary input "**>FAIL:Feeder VT**".

Also during a single-pole automatic reclose dead time (using the internal autoreclosure function) the stages of the undervoltage protection are automatically blocked in the pole open state. If necessary, the current criterion will be considered, so that they do not respond to the undervoltage of the disconnected phase when voltage transformers are located on the outgoing side.
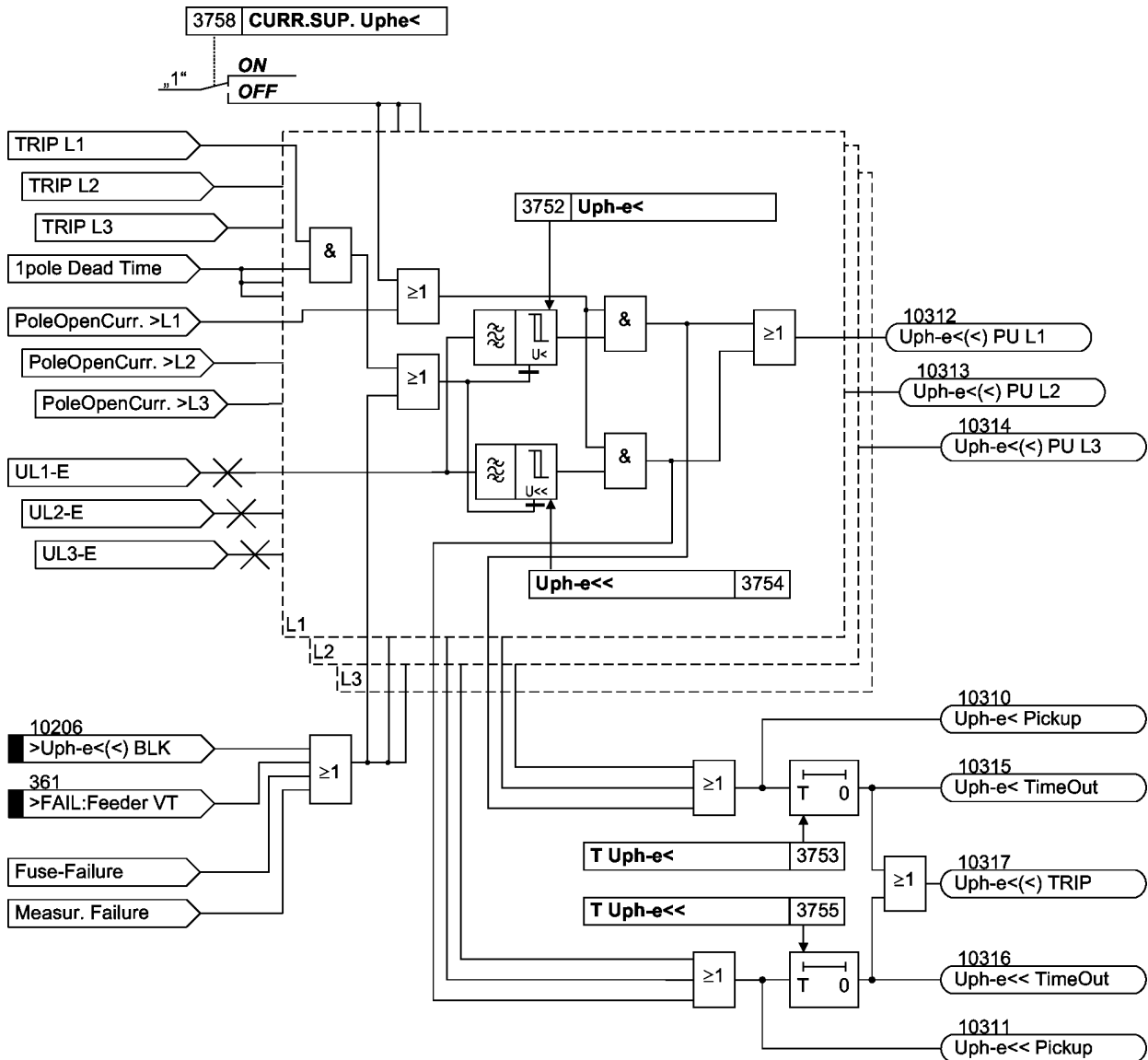
Figure 2-125   Logic diagram of the undervoltage protection for phase voltages

Undervoltage Phase–Phase

Basically, the phase–phase undervoltage protection operates like the phase–earth protection except that it detects phase–to–phase voltages. Accordingly, both phases are indicated during pick-up of an undervoltage stage if one of the stage thresholds **Uph‑ph<** or **Uph‑ph<<** was undershot. Beyond this, Figure 2-125 applies in principle.

It is sufficient for the current criterion that current flow is detected in one of the involved phases.

The phase–phase undervoltage protection can also be blocked via a binary input "**>Uphph<(<) BLK**". There is an automatic blocking if the measuring voltage failure was detected or voltage mcb tripping was indicated (internal blocking of the phases affected by the voltage failure).

During single-pole dead time for automatic reclosure (using the internal automatic re-closure function) the stages of the undervoltage protection are automatically blocked in the disconnected phase so that it does not respond to the undervoltage of the disconnected phase provided that the voltage transformers are located on the outgoing side.

Undervoltage Positive Sequence System U₁

The device calculates the positive sequence system according to its defining equation

$$\underline{U}_1 = \tfrac{1}{3} \cdot (\underline{U}_{L1} + \underline{a} \cdot \underline{U}_{L2} + \underline{a}^2 \cdot \underline{U}_{L3})$$

where $\underline{a} = e^{j120°}$.

The resulting single–phase AC voltage is fed to the two threshold stages **U1<** and **U1<<** (see Figure 2-126). Combined with the associated time delays **T U1<** and **T U1<<** these stages form a two-stage undervoltage protection for the positive sequence system.

Current can be used as an additional criterion for the undervoltage protection of the positive sequence system (current supervision **CURR.SUP.U1<**). An undervoltage is only detected if the current flow is detected in at least one phase together with the undervoltage criterion.

The undervoltage protection for the positive sequence system can be blocked via the binary input "**>U1<(<) BLK**". The stages of the undervoltage protection are automatically blocked if voltage failure is detected ("Fuse–Failure–Monitor", also see Section 2.22.1) or, if the trip of the mcb for the voltage transformer is indicated via the binary input "**>FAIL:Feeder VT**" (internal blocking).
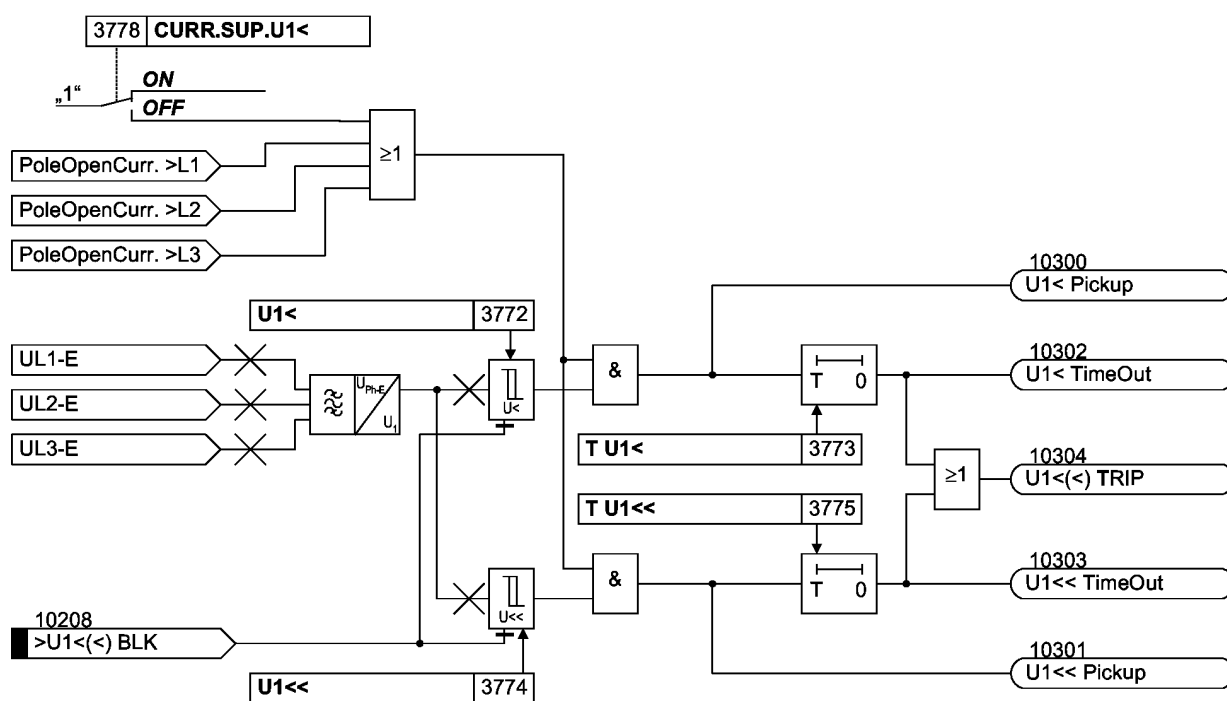
Figure 2-126   Logic diagram of the undervoltage protection for positive sequence voltage system

During single-pole dead time for automatic reclosure (using the internal automatic reclosure function) the stages of the undervoltage protection are automatically blocked in the positive sequence system so that they do not respond to the reduced voltage caused by the disconnected phase in case the voltage transformers are located on the outgoing side.

2.16.3 Setting Notes

General

The voltage protection can only operate if it has been set to ***Enabled*** during the configuration of the device scope (address 137). Compounding is only available if address 137 is set to ***Enabl. w. comp.***.

The overvoltage and undervoltage stages can detect phase-to-earth voltages, phase-to-phase voltages or the symmetrical positive sequence system of the voltages; for overvoltage also the symmetrical negative sequence system, zero sequence voltage or a different single-phase voltage can be used. Any combination is possible. Detection procedures that are not required are switched ***OFF***.

Note

For overvoltage protection it is particularly important to observe the setting hints: NEVER set an overvoltage stage (U_{L-E}, U_{L-L}, U_1) lower than an undervoltage stage. This would put the device immediately into a state of permanent pickup which cannot be reset by any measured value operation. As a result, the device would remain out of service!

Overvoltage Phase-Earth

The phase voltage stages can be set at address 3701 **Uph-e>(>)** to ***ON*** or ***OFF***. In addition to this you can set ***Alarm Only***, i.e. these stages operate and send alarms but do not generate any trip commands.

The settings of the voltage threshold and the timer values depend on the type of application. If steady-state overvoltages are to be detected on long unloaded lines, the **Uph-e>** stage (address 3702) is set to at least 5 % above the maximum stationary phase–to–earth voltage that is to be expected in operation. Additionally, a high drop-off to pick-up ratio is required (address 3709 **Uph-e>(>) RESET** = 0.98 = presetting). This setting is only possible via DIGSI® at "**Additional Settings**". The delay time **T Uph-e>** (address 3703) should be a few seconds so that overvoltages with short duration may not result in tripping.

The **Uph-e>>** stage (address 3704) is provided for high overvoltages with short duration. Here, an adequately high pick-up value is set, e.g. the $1^1/_2$-fold of the nominal phase–earth voltage. 0.1 to 0.2 s are sufficient for the time delay **T Uph-e>>** (address 3705).

Overvoltage Phase–Phase

Basically, the same considerations apply as for the phase undervoltage stages. These stages may be used instead of the phase voltage stages or be used additionally. Depending on your choice, you set address 3711 **Uph-ph>(>)** to ***ON***, ***OFF*** or ***Alarm Only***.

As phase–to–phase voltages are monitored, the phase–to–phase values are used for the settings **Uph-ph>** (address 3712) and **Uph-ph>>** (address 3714).

For the delay times **T Uph-ph>** (address 3713) and **T Uph-ph>>** (address 3715) the same considerations apply as above. The same is true for the drop-off ratios (address 3719 **Uphph>(>) RESET**). This latter setting is only possible via DIGSI® at "**Additional Settings**".

Overvoltage Positive Sequence System U₁

The positive sequence voltage stages can be used instead of or in addition to previously mentioned overvoltage stages. Depending on your choice, you set address 3731 **U1>(>)** to ***ON***, ***OFF*** or ***Alarm Only***.

For symmetrical voltages an increase of the positive sequence system corresponds to an AND gate of the voltages. These stages are particularly suited to the detection of steady-state overvoltages on long, weak-loaded transmission lines (Ferranti effect). Here too, the **U1>** stage (address 3732) with a longer delay time **T U1>** (address 3733) is used for the detection of steady-state overvoltages (some seconds), the **U1>>** stage (address 3734) with the short delay time **T U1>>** (address 3735) is used for the detection of high overvoltages that may jeopardize insulation.

Please note that the positive sequence system is calculated according to its definition equation $U_1 = {}^1/_3 \cdot |\underline{U}_{L1} + \underline{a} \cdot \underline{U}_{L2} + \underline{a}^2 \cdot \underline{U}_{L3}|$. For symmetrical voltages this is equivalent to a phase-to-earth voltage.

If you want the voltage at the remote line end to be decisive for overvoltage detection, you use the compounding feature. To do so, you must have set during the configuration of the protective functions (Section 2.1.1.2) address 137 **U/O VOLTAGE** to *Enabl. w. comp.* (enabled with compounding).

In addition, the compounding feature needs the line data, which have bee set in the **Power System Data 2** (Section 2.1.5.1): at address 1110 or 1112 **x'**, address 1114 or 1115 **c'** and address 1111 or 1113 **Line Length**, and at address 1105 **Line Angle**. These data are vital for a correct compounding calculation. If the values provided here do not correspond to real conditions, the compounding may calculate a too high voltage at the remote end, which causes the protection to pick up immediately as soon as the measured values are applied. In such a case, the pickup state can only be reset by switching off the measuring voltage.

You can activate the compounding separately for each of the U1 voltages *ON* or *OFF*: for the **U1>** stage at address 3736 **U1> Compound** and for the **U1>>** stage at address 3737 **U1>> Compound**.

The drop-off to pick-up ratio (address 3739 **U1>(>) RESET**) is set as high as possible with regard to the detection of even small steady-state overvoltages. This setting is only possible via DIGSI® at "**Additional Settings**".

Overvoltage Negative Sequence System U$_2$

The negative sequence system voltage stages detect asymmetrical voltages. If such voltages shall cause tripping, set the address 3741 **U2>(>)** to *ON*. If such a condition shall only lead to output of an alarm, set the address 3741 **U2>(>)** to *Alarm Only*, in all other cases set it to *OFF*.

This protective function also has two stages, one being **U2>** (address 3742) with a greater time delay **T U2>** (address 3743) for steady-state asymmetrical voltages and the other being **U2>>** (address 3744) with a short delay time **T U2>>** (address 3745) for high asymmetrical voltages.

Please note that the negative sequence system is calculated according to its definition equation $U_2 = {}^1/_3 \cdot |\underline{U}_{L1} + \underline{a}^2 \cdot \underline{U}_{L2} + \underline{a} \cdot \underline{U}_{L3}|$. For symmetrical voltages and two swapped phases this is equivalent to the phase-to-earth voltage value.

The drop-off to pick-up ratio **U2>(>) RESET** can be set in address 3749. This setting is only possible via DIGSI® at "**Additional Settings**".

Zero Sequence System Overvoltage

The zero sequence voltage stages can be activated at address 3721 **3U0>(>) (or Ux)** *ON*- oder *OFF*. They can also be set to *Alarm Only*, i.e. these stages operate and send alarms but do not generate any trip commands. This protection function can be used for any other single-phase voltage which is connected to the fourth voltage measurement input U$_4$. Also refer to Section 2.1.3.1 under margin header "Voltage Transformer Connection".

This protective function also has two stages. The settings of the voltage threshold and the timer values depend on the type of application. Here no general guidelines can be established. The stage **3U0>** (address 3722) is usually set with a high sensitivity and a longer delay time **T 3U0>** (address 3723). The **3U0>>** stage (address 3724) and its delay time **T 3U0>>** (address 3725) allow you to implement a second stage with less sensitivity and a shorter delay time.

Similar considerations apply if this voltage stage is used for a different voltage at the measuring input U_4.

Since the time delays of the zero sequence voltage stages are very stable due to the measurement repetition, the sensitivity can be set quite high. This stabilization can be deactivated at address 3728 **3U0>(>) Stabil.** if a shorter pickup time is required. This setting is only possible via DIGSI® at "**Additional Settings**". Please keep in mind that it does not make sense to combine a sensitive setting with a short pickup time.

The drop-off to pick-up ratio **3U0>(>) RESET** can be set in address 3729. This setting is only possible via DIGSI® at "**Additional Settings**".

When setting the voltage values please observe the following:

- If the voltage U_4 is connected to the voltage U_{en} of the set of voltage transformers and this has been specified when setting the Power System Data 1 (see Section 2.1.3.1 under margin header "Voltage Transformer Connection", address 210 **U4 transformer** = *Udelta transf.*), the device multiplies the voltage connected there with the matching factor **Uph / Udelta** (address 211), i.e. normally with 1.73. The voltage measured is thus $\sqrt{3} \cdot U_{en} = 3 \cdot U_0$. If the symmetrical voltage delta is completely displaced, it will be $\sqrt{3}$ times the phase-phase voltage.

- If the voltage U_4 is connected to any other voltage which is not used for voltage protection, and this has been specified when setting the Power System Data 1 (see Section 2.1.3.1 under margin header "Voltage Transformer Connection", z.B. **U4 transformer** = *Usync transf.* oder **U4 transformer** = *Not connected*), the device calculates the zero sequence voltage from the phase voltages according to their definition $3 \cdot U_0 = |U_{L1} + U_{L2} + U_{L3}|$. If the symmetrical voltage delta is completely displaced, it will be $\sqrt{3}$ times the phase-phase voltage.

- If U_4 is connected to any other AC voltage which is used for voltage protection, and this has been specified when setting the Power System Data 1 (see Section 2.1.3.1 under margin header "Voltage Transformer Connection", **U4 transformer** = *Ux transformer*), this voltage will be used for the voltage stages without any further factors. This "zero sequence voltage" is then actually, a single-phase voltage protection for any kind of voltage at U_4. Please note that with a sensitive setting, i.e. with a setting close to the voltages to be expected in operation, you need to set not only the delay time **T 3U0>** (address 3723) but also the pickup/dropout ratio **3U0>(>) RESET** (address 3729) as high as possible.

Undervoltage Phase–Earth

The phase voltage stages can be switched *ON* or *OFF* under address 3751 **Uph-e<(<)**. In addition to this you can set *Alarm Only*, i.e. these stages operate and send alarms but do not generate any trip commands.

This undervoltage protection function has two stages. The **Uph-e<** stage (address 3752) with a longer setting of the time **T Uph-e<** (address 3753) operates in the case of minor undervoltages. However, the value set here must not be higher than the undervoltage permissible in operation. In the presence of higher voltage dips, the **Uph-e<<** stage (address 3754) with the delay **T Uph-e<<** (address 3755) becomes active

The settings of the voltages and times depend on the intended use; therefore no general recommendations for the settings can be given. For load shedding, for example, the values are often determined by a priority grading coordination chart. In case

of stability problems, the permissible levels and durations of overvoltages must be observed. With induction machines undervoltages have an effect on the permissible torque thresholds.

If the voltage transformers are located on the line side, the measuring voltages will be missing when the line is disconnected. To avoid that the undervoltage levels in these cases are or remain picked up, the current criterion **CURR.SUP. Uphe<** (address 3758) *ON* is switched on. With busbar side voltage transformers it can be switched *OFF*. However, if the busbar is dead, the undervoltage protection will pick up and expire and then remain in a picked-up state. It must therefore be ensured in such cases that the protection is blocked by a binary input.

Undervoltage Phase–Phase

Basically, the same considerations apply as for the phase undervoltage stages. These stages may replace the phase voltage stages or be used additionally. Depending on your choice, you set address 3761 **Uph-ph<(<)** to *ON*, *OFF* or *Alarm Only*.

As phase–to–phase voltages are monitored, the phase–to–phase values are used for the settings **Uph-ph<** (address 3762) and **Uph-ph<<** (address 3764).

The corresponding times delay are **T Uph-ph<** (address 3763) and **T Uphph<<** (address 3765).

If the voltage transformers are located on the line side, the measuring voltages will be missing when the line is disconnected. To avoid that the undervoltage levels in these cases are or remain picked up, the current criterion **CURR.SUP.Uphph<** (address 3768) *ON* is switched on. With busbar side voltage transformers it can be switched *OFF*. However, if the busbar is dead, the undervoltage protection will pick up and expire and then remain in picked-up state. It must therefore be ensured in such cases that the protection is blocked by a binary input.

Undervoltage Positive Sequence System U_1

The positive sequence undervoltage stages can be used instead of or in addition to previously mentioned undervoltage stages. Depending on your choice, you set address 3771 **U1<(<)** to *ON*, *OFF* or *Alarm Only*.

Basically, the same considerations apply as for the other undervoltage stages. Especially in case of stability problems, the positive sequence system is advantageous, since the positive sequence system is relevant for the limit of the stable energy transmission.

To achieve the two-stage condition, the **U1<** stage (address 3772) is combined with a greater time delay **T U1<** (address 3773), and the **U1<<** stage (address 3774) with a shorter time delay **T U1<<** (address 3775).

Please note that the positive sequence system is established according to its defining equation $U_1 = {}^1/_3 \cdot |\underline{U}_{L1} + \underline{a} \cdot \underline{U}_{L2} + \underline{a}^2 \cdot \underline{U}_{L3}|$. For symmetrical voltages this is equivalent to a phase-earth voltage.

If the voltage transformers are located on the line side, the measuring voltages will be missing when the line is disconnected. To avoid that the undervoltage levels in these cases are or remain picked up, the current criterion **CURR.SUP.U1<** (address 3778) *ON* is switched on. With busbar side voltage transformers it can be switched *OFF*. However, if the busbar is dead, the undervoltage protection will pick up and expire and then remain in picked-up state. It must therefore be ensured in such cases that the protection is blocked by a binary input.

2.16.4 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

Addr.	Parameter	Setting Options	Default Setting	Comments
3701	Uph-e>(>)	OFF Alarm Only ON	OFF	Operating mode Uph-e overvoltage prot.
3702	Uph-e>	1.0 .. 170.0 V; ∞	85.0 V	Uph-e> Pickup
3703	T Uph-e>	0.00 .. 100.00 sec; ∞	2.00 sec	T Uph-e> Time Delay
3704	Uph-e>>	1.0 .. 170.0 V; ∞	100.0 V	Uph-e>> Pickup
3705	T Uph-e>>	0.00 .. 100.00 sec; ∞	1.00 sec	T Uph-e>> Time Delay
3709A	Uph-e>(>) RESET	0.30 .. 0.98	0.98	Uph-e>(>) Reset ratio
3711	Uph-ph>(>)	OFF Alarm Only ON	OFF	Operating mode Uph-ph overvoltage prot.
3712	Uph-ph>	2.0 .. 220.0 V; ∞	150.0 V	Uph-ph> Pickup
3713	T Uph-ph>	0.00 .. 100.00 sec; ∞	2.00 sec	T Uph-ph> Time Delay
3714	Uph-ph>>	2.0 .. 220.0 V; ∞	175.0 V	Uph-ph>> Pickup
3715	T Uph-ph>>	0.00 .. 100.00 sec; ∞	1.00 sec	T Uph-ph>> Time Delay
3719A	Uphph>(>) RESET	0.30 .. 0.98	0.98	Uph-ph>(>) Reset ratio
3721	3U0>(>) (or Ux)	OFF Alarm Only ON	OFF	Operating mode 3U0 (or Ux) overvoltage
3722	3U0>	1.0 .. 220.0 V; ∞	30.0 V	3U0> Pickup (or Ux>)
3723	T 3U0>	0.00 .. 100.00 sec; ∞	2.00 sec	T 3U0> Time Delay (or T Ux>)
3724	3U0>>	1.0 .. 220.0 V; ∞	50.0 V	3U0>> Pickup (or Ux>>)
3725	T 3U0>>	0.00 .. 100.00 sec; ∞	1.00 sec	T 3U0>> Time Delay (or T Ux>>)
3728A	3U0>(>) Stabil.	ON OFF	ON	3U0>(>): Stabilization 3U0-Measurement
3729A	3U0>(>) RESET	0.30 .. 0.98	0.95	3U0>(>) Reset ratio (or Ux)
3731	U1>(>)	OFF Alarm Only ON	OFF	Operating mode U1 overvoltage prot.
3732	U1>	2.0 .. 220.0 V; ∞	150.0 V	U1> Pickup
3733	T U1>	0.00 .. 100.00 sec; ∞	2.00 sec	T U1> Time Delay
3734	U1>>	2.0 .. 220.0 V; ∞	175.0 V	U1>> Pickup
3735	T U1>>	0.00 .. 100.00 sec; ∞	1.00 sec	T U1>> Time Delay
3736	U1> Compound	OFF ON	OFF	U1> with Compounding
3737	U1>> Compound	OFF ON	OFF	U1>> with Compounding
3739A	U1>(>) RESET	0.30 .. 0.98	0.98	U1>(>) Reset ratio

Addr.	Parameter	Setting Options	Default Setting	Comments
3741	U2>(>)	OFF Alarm Only ON	OFF	Operating mode U2 overvoltage prot.
3742	U2>	2.0 .. 220.0 V; ∞	30.0 V	U2> Pickup
3743	T U2>	0.00 .. 100.00 sec; ∞	2.00 sec	T U2> Time Delay
3744	U2>>	2.0 .. 220.0 V; ∞	50.0 V	U2>> Pickup
3745	T U2>>	0.00 .. 100.00 sec; ∞	1.00 sec	T U2>> Time Delay
3749A	U2>(>) RESET	0.30 .. 0.98	0.98	U2>(>) Reset ratio
3751	Uph-e<(<)	OFF Alarm Only ON	OFF	Operating mode Uph-e undervoltage prot.
3752	Uph-e<	1.0 .. 100.0 V; 0	30.0 V	Uph-e< Pickup
3753	T Uph-e<	0.00 .. 100.00 sec; ∞	2.00 sec	T Uph-e< Time Delay
3754	Uph-e<<	1.0 .. 100.0 V; 0	10.0 V	Uph-e<< Pickup
3755	T Uph-e<<	0.00 .. 100.00 sec; ∞	1.00 sec	T Uph-e<< Time Delay
3758	CURR.SUP. Uphe<	ON OFF	ON	Current supervision (Uph-e)
3761	Uph-ph<(<)	OFF Alarm Only ON	OFF	Operating mode Uph-ph undervoltage prot.
3762	Uph-ph<	1.0 .. 175.0 V; 0	50.0 V	Uph-ph< Pickup
3763	T Uph-ph<	0.00 .. 100.00 sec; ∞	2.00 sec	T Uph-ph< Time Delay
3764	Uph-ph<<	1.0 .. 175.0 V; 0	17.0 V	Uph-ph<< Pickup
3765	T Uphph<<	0.00 .. 100.00 sec; ∞	1.00 sec	T Uph-ph<< Time Delay
3768	CURR.SUP.Uphph<	ON OFF	ON	Current supervision (Uph-ph)
3771	U1<(<)	OFF Alarm Only ON	OFF	Operating mode U1 undervoltage prot.
3772	U1<	1.0 .. 100.0 V; 0	30.0 V	U1< Pickup
3773	T U1<	0.00 .. 100.00 sec; ∞	2.00 sec	T U1< Time Delay
3774	U1<<	1.0 .. 100.0 V; 0	10.0 V	U1<< Pickup
3775	T U1<<	0.00 .. 100.00 sec; ∞	1.00 sec	T U1<< Time Delay
3778	CURR.SUP.U1<	ON OFF	ON	Current supervision (U1)

2.16.5 Information List

No.	Information	Type of In-formation	Comments
10201	>Uph-e>(>) BLK	SP	>BLOCK Uph-e>(>) Overvolt. (phase-earth)
10202	>Uph-ph>(>) BLK	SP	>BLOCK Uph-ph>(>) Overvolt (phase-phase)

No.	Information	Type of Information	Comments
10203	>3U0>(>) BLK	SP	>BLOCK 3U0>(>) Overvolt. (zero sequence)
10204	>U1>(>) BLK	SP	>BLOCK U1>(>) Overvolt. (positive seq.)
10205	>U2>(>) BLK	SP	>BLOCK U2>(>) Overvolt. (negative seq.)
10206	>Uph-e<(<) BLK	SP	>BLOCK Uph-e<(<) Undervolt (phase-earth)
10207	>Uphph<(<) BLK	SP	>BLOCK Uphph<(<) Undervolt (phase-phase)
10208	>U1<(<) BLK	SP	>BLOCK U1<(<) Undervolt (positive seq.)
10215	Uph-e>(>) OFF	OUT	Uph-e>(>) Overvolt. is switched OFF
10216	Uph-e>(>) BLK	OUT	Uph-e>(>) Overvolt. is BLOCKED
10217	Uph-ph>(>) OFF	OUT	Uph-ph>(>) Overvolt. is switched OFF
10218	Uph-ph>(>) BLK	OUT	Uph-ph>(>) Overvolt. is BLOCKED
10219	3U0>(>) OFF	OUT	3U0>(>) Overvolt. is switched OFF
10220	3U0>(>) BLK	OUT	3U0>(>) Overvolt. is BLOCKED
10221	U1>(>) OFF	OUT	U1>(>) Overvolt. is switched OFF
10222	U1>(>) BLK	OUT	U1>(>) Overvolt. is BLOCKED
10223	U2>(>) OFF	OUT	U2>(>) Overvolt. is switched OFF
10224	U2>(>) BLK	OUT	U2>(>) Overvolt. is BLOCKED
10225	Uph-e<(<) OFF	OUT	Uph-e<(<) Undervolt. is switched OFF
10226	Uph-e<(<) BLK	OUT	Uph-e<(<) Undervolt. is BLOCKED
10227	Uph-ph<(<) OFF	OUT	Uph-ph<(<) Undervolt. is switched OFF
10228	Uph-ph<(<) BLK	OUT	Uphph<(<) Undervolt. is BLOCKED
10229	U1<(<) OFF	OUT	U1<(<) Undervolt. is switched OFF
10230	U1<(<) BLK	OUT	U1<(<) Undervolt. is BLOCKED
10231	U</> ACTIVE	OUT	Over-/Under-Voltage protection is ACTIVE
10240	Uph-e> Pickup	OUT	Uph-e> Pickup
10241	Uph-e>> Pickup	OUT	Uph-e>> Pickup
10242	Uph-e>(>) PU L1	OUT	Uph-e>(>) Pickup L1
10243	Uph-e>(>) PU L2	OUT	Uph-e>(>) Pickup L2
10244	Uph-e>(>) PU L3	OUT	Uph-e>(>) Pickup L3
10245	Uph-e> TimeOut	OUT	Uph-e> TimeOut
10246	Uph-e>> TimeOut	OUT	Uph-e>> TimeOut
10247	Uph-e>(>) TRIP	OUT	Uph-e>(>) TRIP command
10255	Uphph> Pickup	OUT	Uph-ph> Pickup
10256	Uphph>> Pickup	OUT	Uph-ph>> Pickup
10257	Uphph>(>)PU L12	OUT	Uph-ph>(>) Pickup L1-L2
10258	Uphph>(>)PU L23	OUT	Uph-ph>(>) Pickup L2-L3
10259	Uphph>(>)PU L31	OUT	Uph-ph>(>) Pickup L3-L1
10260	Uphph> TimeOut	OUT	Uph-ph> TimeOut
10261	Uphph>> TimeOut	OUT	Uph-ph>> TimeOut
10262	Uphph>(>) TRIP	OUT	Uph-ph>(>) TRIP command
10270	3U0> Pickup	OUT	3U0> Pickup
10271	3U0>> Pickup	OUT	3U0>> Pickup
10272	3U0> TimeOut	OUT	3U0> TimeOut
10273	3U0>> TimeOut	OUT	3U0>> TimeOut
10274	3U0>(>) TRIP	OUT	3U0>(>) TRIP command
10280	U1> Pickup	OUT	U1> Pickup
10281	U1>> Pickup	OUT	U1>> Pickup

No.	Information	Type of Information	Comments
10282	U1> TimeOut	OUT	U1> TimeOut
10283	U1>> TimeOut	OUT	U1>> TimeOut
10284	U1>(>) TRIP	OUT	U1>(>) TRIP command
10290	U2> Pickup	OUT	U2> Pickup
10291	U2>> Pickup	OUT	U2>> Pickup
10292	U2> TimeOut	OUT	U2> TimeOut
10293	U2>> TimeOut	OUT	U2>> TimeOut
10294	U2>(>) TRIP	OUT	U2>(>) TRIP command
10300	U1< Pickup	OUT	U1< Pickup
10301	U1<< Pickup	OUT	U1<< Pickup
10302	U1< TimeOut	OUT	U1< TimeOut
10303	U1<< TimeOut	OUT	U1<< TimeOut
10304	U1<(<) TRIP	OUT	U1<(<) TRIP command
10310	Uph-e< Pickup	OUT	Uph-e< Pickup
10311	Uph-e<< Pickup	OUT	Uph-e<< Pickup
10312	Uph-e<(<) PU L1	OUT	Uph-e<(<) Pickup L1
10313	Uph-e<(<) PU L2	OUT	Uph-e<(<) Pickup L2
10314	Uph-e<(<) PU L3	OUT	Uph-e<(<) Pickup L3
10315	Uph-e< TimeOut	OUT	Uph-e< TimeOut
10316	Uph-e<< TimeOut	OUT	Uph-e<< TimeOut
10317	Uph-e<(<) TRIP	OUT	Uph-e<(<) TRIP command
10325	Uph-ph< Pickup	OUT	Uph-ph< Pickup
10326	Uph-ph<< Pickup	OUT	Uph-ph<< Pickup
10327	Uphph<(<)PU L12	OUT	Uphph<(<) Pickup L1-L2
10328	Uphph<(<)PU L23	OUT	Uphph<(<) Pickup L2-L3
10329	Uphph<(<)PU L31	OUT	Uphph<(<) Pickup L3-L1
10330	Uphph< TimeOut	OUT	Uphph< TimeOut
10331	Uphph<< TimeOut	OUT	Uphph<< TimeOut
10332	Uphph<(<) TRIP	OUT	Uphph<(<) TRIP command

2.17   Frequency protection (optional)

The frequency protection function detects abnormally high and low frequencies in the system or in electrical machines. If the frequency lies outside the allowable range, appropriate actions are initiated, such as load shedding or separating a generator from the system.

<u>Underfrequency</u> is caused by increased real power demand or by a reduction of the generated power e.g., in the event of disconnection from the network, generator failure or faulty operation of the power frequency control. Underfrequency protection is also applied for generators which operate (temporarily) to an island network. This is due to the fact that the reverse power protection cannot operate in case of a drive power failure. The generator can be disconnected from the power system by means of the underfrequency protection. Underfrequency results also in increased reactive power demand of inductive loads.

<u>Overfrequency</u> is caused for instance in case of load shedding, system disconnection or malfunction of the power-frequency control. There is also a risk of self-excitation for generators feeding long lines under no-load conditions.

2.17.1   Method of Operation

Frequency Elements

Frequency protection consists of the four frequency elements f1 to f4. Each element can be set as overfrequency stage (f>) or as underfrequency stage (f<) with individual thresholds and time delays. This ensures variable matching to the application purpose.

- If an element is set to a value <u>above</u> the rated frequency, it is automatically interpreted to be an <u>overfrequency</u> stage f>.
- If an element is set to a value <u>below</u> the rated frequency, it is automatically interpreted to be an <u>underfrequency</u> stage f<.
- If an element is set exactly to the <u>rated frequency</u>, it is <u>inactive</u>.

Each element can be blocked via binary input and also the entire frequency protection function can be blocked.

Frequency Measurement

The largest of the 3 phase-earth currents is used for frequency measurement. This value must be at least 6 V (secondary). Below that value frequency measurement will not take place.

Numerical filters are employed to calculate from the measured voltage a quantity that is proportional to the frequency which is virtually linear in the specified range ($f_N \pm$ 10 %). Filters and repeated measurements ensure that the frequency evaluation is virtually free from harmonic influences and phase jumps.

An accurate and quick measurement result is obtained by considering also the frequency <u>change</u>. When changing the frequency of the power system, the sign of the quotient $\frac{\Delta f}{dt}$ remains unchanged during several repeated measurements. If, however, a phase jump in the measured voltage temporarily simulates a frequency deviation, the sign of $\frac{\Delta f}{dt}$ will subsequently reverse. Thus the measurement results corrupted by a phase jump are quickly discarded.

The dropout value of each frequency element is approximately 20 mHz below (for f>) or above (for f<) of the pickup value.

Operating Ranges   Frequency evaluation requires a measured quantity that can be processed. This implies that at least a sufficiently high voltage is available and that the frequency of this voltage is within the working range of the frequency protection.

The frequency protection selects automatically the largest of the phase-earth voltages. If all three voltages are below the operating range of approx. 6 V (secondary), the frequency cannot be determined. If the voltage sinks below this minimum value after a frequency stage has picked up, the picked up element will drop out. This implies also that all frequency stages will drop out after a line has been switched off (with voltage transformers on line side).

When connecting a measuring voltage with a frequency outside the configured threshold of a frequency stages, the frequency protection is immediately ready to operate. Since the filters of the frequency measurement must first go through a transient state, the command output time may increase slightly (approx. 1 period). This is because a frequency element picks up only if the frequency has been detected outside the configured threshold in five consecutive measurements.

The frequency range is from 25 Hz to 70 Hz. If the frequency leaves this operating range, the frequency elements will drop out. If the frequency returns into the working range, the measurement can be resumed provided that the measuring voltage too is inside the working range. But if the measuring voltage is switched off, the picked up element will drop out immediately.

Power Swings   In interconnected networks, frequency deviations may also be caused by power swings. Depending on the power swing frequency, the mounting location of the device and the setting of the frequency elements, power swings may cause the frequency protection to pick up and even to trip. In such cases out-of-step trips can not be prevented by operating the distance protection with power swing blocking (see also Section 2.3). Rather it is reasonable to block the frequency protection once power swings are detected. This can be accomplished via binary inputs and binary outputs or by corresponding logic operations using the user-defined logic (CFC). If, however, the power swing frequencies are known, tripping of the frequency protection function can also be avoided by adapting the delay times of the frequency protection correspondingly.

Pickup / Tripping   Figure 2-127 shows the logic diagram for the frequency protection function.

Once the frequency was reliably detected to be outside the configured thresholds of a stage (above the setting value for f> elements or below for f< elements), a pickup signal of the corresponding stage is generated. The decision is considered reliable if 5 measurements taken in intervals of $^1/_2$ period yield one frequency outside the set threshold.

After pickup a delay time per element can be started. When the associated time has elapsed, a trip command is issued. A picked up element drops out if the cause of the pickup is no longer valid after 5 measurements or if the measuring voltage was switched off or the frequency leaves the working range. When a frequency elements drops out, the tripping signal of of the corresponding frequency element is immediately reset, but the trip command is maintained for at least the minimum command duration which was set for all tripping functions of the device.

Each of the four frequency elements can be blocked individually by binary inputs. The blocking takes immediate effect. It is also possible to block the entire frequency protection function via binary input.
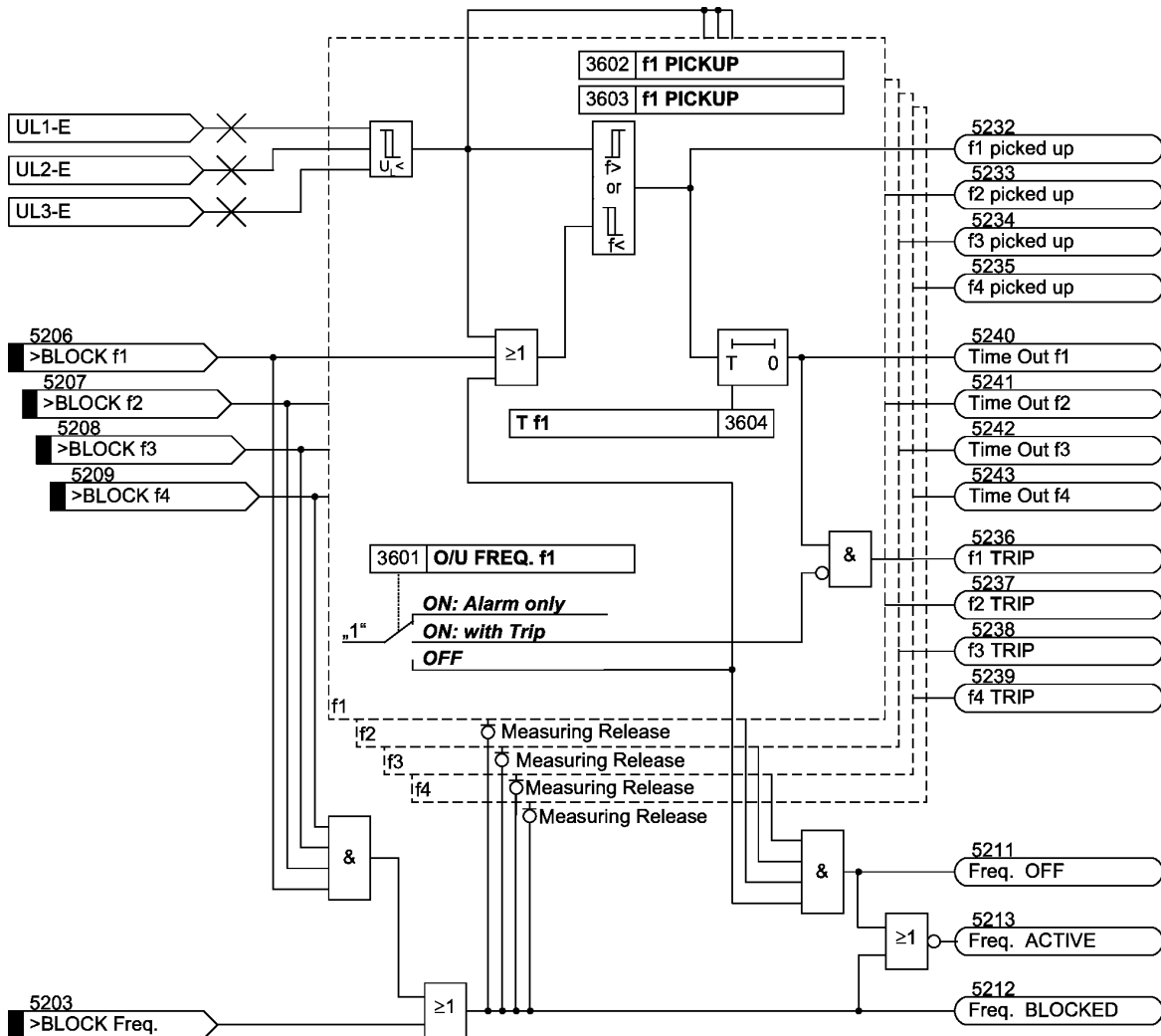
Figure 2-127   Logic diagram of frequency protection for 50 Hz rated frequency

2.17.2 Setting Notes

General

Frequency protection is only in effect and accessible if address 136 **FREQUENCY Prot.** is set to *Enabled* during configuration of protective functions. If the function is not required, *Disabled* is to be set.

The frequency protection function features 4 frequency stages f1 to f4 each of which can function as overfrequency stage or underfrequency stage. Each zone can be set active or inactive. This is set in addresses:

- 3601 **O/U FREQ. f1** for frequency stage f1,
- 3611 **O/U FREQ. f2** for frequency stage f2,
- 3621 **O/U FREQ. f3** for frequency stage f3,
- 3631 **O/U FREQ. f4** for frequency stage f4,

The following 3 options are available:

- Stage *OFF*: The stage is ineffective;
- Stage *ON: with Trip*: The stage is effective and issues an alarm and a trip command (after time has expired) following irregular frequency deviations;
- Stage *ON: Alarm only*: The stage is effective and issues an alarm but no trip command following irregular frequency deviations;

Pickup Values, Delay Time

The configured pickup value determines whether a frequency element is to respond to overfrequency or underfrequency.

- If a stage is set to a value <u>above</u> the rated frequency, it is automatically interpreted to be an <u>overfrequency</u> stage f>.
- If a stage is set to a value <u>below</u> the rated frequency, it is automatically interpreted to be an <u>underfrequency</u> stage f<.
- If a stage is set exactly to the <u>rated frequency</u>, it is <u>inactive</u>.

A pickup value can be set for each stage according to above rules. The addresses and possible setting ranges are determined by the rated frequency as configured in the power system data 1 (Subsection 2.1.3.1) at **Rated Frequency** (address 230).

Please note that none of the frequency stages is set to less than 30 mHz above (for f>) or below (for f<) of the nominal frequency. Since the frequency stages have a hysteresis of approx. 20 mHz, it may otherwise happen that the element does not drop out when returning to the nominal frequency.

Only those addresses are accessible that match the configured nominal frequency. For each element, a trip delay time can be set:

- Address 3602 **f1 PICKUP** pickup value for frequency stage f1 at f_N = 50 Hz, Address 3603 **f1 PICKUP** pickup value for frequency stage f1 at f_N = 60 Hz, Address 3604 **T f1** trip delay for frequency stage f1;
- Address 3612 **f2 PICKUP** pickup value for frequency stage f2 at f_N = 50 Hz, Address 3613 **f2 PICKUP** pickup value for frequency stage f2 at f_N = 60 Hz, Address 3614 **T f2** trip delay for frequency element f2;
- Address 3622 **f3 PICKUP** pickup value for frequency stage f3 at f_N = 50 Hz, Address 3623 **f3 PICKUP** pickup value for frequency stage f3 at f_N = 60 Hz, Address 3624 **T f3** trip delay for frequency stage f3;
- Address 3632 **f4 PICKUP** pickup value for frequency stage f4 at f_N = 50 Hz, Address 3633 **f4 PICKUP** pickup value for frequency stage f4 at f_N = 60 Hz, Address 3634 **T f4** trip delay for frequency stage f4;

The set times are additional delay times not including the operating times (measuring time, drop-out time) of the protective function.

If underfrequency protection is used for load shedding purposes, then the frequency settings relative to other feeder relays are generally based on the priority of the customers served by the protective relay. Normally, it is required for load shedding a frequency / time grading that takes into account the importance of the consumers or consumer groups.

In interconnected networks, frequency deviations may also be caused by power swings. Depending on the power swing frequency, the mounting location of the device and the setting of the frequency stages, it is reasonable to block the entire frequency protection function or single stages once a power swing has been detected. The delay times must then be co-ordinated thus that a power swing is detected before the frequency protection trips.

Further application examples exist in the field of power stations. The frequency values to be set mainly depend, also in these cases, on the specifications of the power system/power station operator. In this context, the underfrequency protection also ensures the power station's own demand by disconnecting it from the power system on time. The turbo regulator regulates the machine set to the nominal speed. Consequently, the station's own demands can be continuously supplied at nominal frequency.

Since the dropout threshold is 20 mHz below or above the trip frequency, the resulting "minimum" trip frequency is 30 mHz above or below the nominal frequency.

A frequency increase can, for example, occur due to a load shedding or malfunction of the speed regulation (e.g. in a stand-alone system). In this way, the frequency protection can, for example, be used as overspeed protection.

2.17.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
3601	O/U FREQ. f1	ON: Alarm only ON: with Trip OFF	ON: Alarm only	Over/Under Frequency Protection stage f1
3602	f1 PICKUP	45.50 .. 54.50 Hz	49.50 Hz	f1 Pickup
3603	f1 PICKUP	55.50 .. 64.50 Hz	59.50 Hz	f1 Pickup
3604	T f1	0.00 .. 600.00 sec	60.00 sec	T f1 Time Delay
3611	O/U FREQ. f2	ON: Alarm only ON: with Trip OFF	ON: Alarm only	Over/Under Frequency Protection stage f2
3612	f2 PICKUP	45.50 .. 54.50 Hz	49.00 Hz	f2 Pickup
3613	f2 PICKUP	55.50 .. 64.50 Hz	57.00 Hz	f2 Pickup
3614	T f2	0.00 .. 600.00 sec	30.00 sec	T f2 Time Delay
3621	O/U FREQ. f3	ON: Alarm only ON: with Trip OFF	ON: Alarm only	Over/Under Frequency Protection stage f3
3622	f3 PICKUP	45.50 .. 54.50 Hz	47.50 Hz	f3 Pickup
3623	f3 PICKUP	55.50 .. 64.50 Hz	59.50 Hz	f3 Pickup
3624	T f3	0.00 .. 600.00 sec	3.00 sec	T f3 Time Delay
3631	O/U FREQ. f4	ON: Alarm only ON: with Trip OFF	ON: Alarm only	Over/Under Frequency Protection stage f4
3632	f4 PICKUP	45.50 .. 54.50 Hz	51.00 Hz	f4 Pickup
3633	f4 PICKUP	55.50 .. 64.50 Hz	62.00 Hz	f4 Pickup
3634	T f4	0.00 .. 600.00 sec	30.00 sec	T f4 Time Delay

2.17.4 Information List

No.	Information	Type of In-formation	Comments
5203	>BLOCK Freq.	SP	>BLOCK frequency protection
5206	>BLOCK f1	SP	>BLOCK frequency protection stage f1
5207	>BLOCK f2	SP	>BLOCK frequency protection stage f2
5208	>BLOCK f3	SP	>BLOCK frequency protection stage f3
5209	>BLOCK f4	SP	>BLOCK frequency protection stage f4
5211	Freq. OFF	OUT	Frequency protection is switched OFF
5212	Freq. BLOCKED	OUT	Frequency protection is BLOCKED
5213	Freq. ACTIVE	OUT	Frequency protection is ACTIVE
5232	f1 picked up	OUT	Frequency protection: f1 picked up
5233	f2 picked up	OUT	Frequency protection: f2 picked up
5234	f3 picked up	OUT	Frequency protection: f3 picked up
5235	f4 picked up	OUT	Frequency protection: f4 picked up
5236	f1 TRIP	OUT	Frequency protection: f1 TRIP
5237	f2 TRIP	OUT	Frequency protection: f2 TRIP
5238	f3 TRIP	OUT	Frequency protection: f3 TRIP
5239	f4 TRIP	OUT	Frequency protection: f4 TRIP
5240	Time Out f1	OUT	Frequency protection: TimeOut Stage f1
5241	Time Out f2	OUT	Frequency protection: TimeOut Stage f2
5242	Time Out f3	OUT	Frequency protection: TimeOut Stage f3
5243	Time Out f4	OUT	Frequency protection: TimeOut Stage f4

2.18   Fault locator

The measurement of the distance to a fault is an important supplement to the protection functions. Availability of the line for power transmission within the system can be increased when the fault is located and cleared faster.

2.18.1   Functional Description

Initiation Conditions

The fault location function in the 7SA6 distance protection is a function which is independent of the distance measurement. It has a separate measured value memory and dedicated filter algorithms. The short-circuit protection merely has to provide a start command to allow the selection of the valid measuring loop and the best suited time interval for the storage of the measured signals.

The fault location function can be triggered by the trip command of the short-circuit protection, or also by each fault detection. In the latter case, a fault location calculation is also possible if a different protection device clears the fault. For a fault outside the protected line, the fault location information is not always correct, as the measured values can be distorted by e.g. intermediate infeeds.

Determination of the Fault Location

The measured value pairs of fault currents and fault voltages (in intervals of 1/20 period) are stored in a cyclic buffer and frozen shortly after the trip command is issued before any distortion of the measured values occurs due to the opening of the circuit breaker even with very fast circuit breakers. Filtering of the measured values and the number of impedance calculations are automatically adapted to the number of stabilized measured value pairs in the determined data window. If a sufficient data window with stabilized values could not be determined, the alarm "Flt.Loc.invalid" is issued.

The evaluation of the measured values in the short-circuit loops is carried out after the short-circuit has been cleared. Short-circuit loops are those which caused the trip. In the event of tripping by the earth fault protection, the three phase–earth loops are evaluated.

At least three result pairs of R and X are calculated from the stored and filtered measured quantities in accordance with the line equations. Average and standard deviations are calculated from the result pairs. After elimination of "deviants", which are recognized by their large deviation from the standard deviation, a new average is calculated. This average for X is the fault reactance which is proportional to the distance to fault. If several loops were evaluated, the loop with the smallest reactance is valid. In this manner, the fault on the protected feeder is in any event determined during multiple faults or in the event of tripping by only the earth fault protection.

Output of the Fault Location

The fault location function issues the following results:
- the short-circuit loop which was used to determine the fault reactance,
- the reactance X per phase in Ω primary and Ω secondary,
- the resistance R per phase in Ω primary and Ω secondary,
- the distance to fault d in kilometres or miles of the line proportional to the reactance, converted on the basis of the set line reactance per unit line length,
- the distance to fault d in % of the line length, calculated on the basis of the set reactance per unit length and the set line length.

The fault location indicated in per cent can, at the same time, be output as BCD-code (Binary Coded Decimal). This, however, must have been preset in address 138 during the configuration of the protection functions (Section 2.1.1.2). A further prerequisite is that the required number of binary outputs is allocated for this purpose.

10 output relays are needed. They are classified as follows:

- 4 outputs for the units ($1 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3$),
- 4 outputs for the tens ($10 \cdot 2^0 + 10 \cdot 2^1 + 10 \cdot 2^2 + 10 \cdot 2^3$),
- 1 output for the hundreds ($100 \cdot 2^0$),
- 1 output for the ready-state annunciation "BCD dist. VALID" (FNo. 1152).

Once a fault was located, the corresponding binary outputs pick up. Then the output "BCD dist. VALID" signals that the data are now valid. The duration can be selected. In the event of a new fault, the data of the former fault are cleared automatically.

The output range extends from 0% to 195%. Output "197" means that a negative fault was detected. Output "199" describes an overflow, i. e. the calculated value is higher than the maximum possible value of 195 %.

The fault location indicated in per cent can also be output as analog value (0 mA to 20 mA). It is a prerequisite that the device is provided with (an) analog output(s) (according to the ordering code) and that an analog output was allocated to the fault location in address 150 to 153 during the configuration of the protection functions (Section 2.1.1.2). For more information about the analog output settings please refer to Subsection 2.21.

Note

The distance can only be applicable in the form of kilometres, miles or percent if the relevant line section is homogeneous. If the line is made up of several sections with different reactances, e.g. overhead line - cable sections, then the reactance calculated by the fault location can be evaluated for a separate calculation of the fault distance.

Parallel Line Measured Value Correction (optional)

In the case of earth faults on double circuit lines, the measured values obtained for calculation of the impedance are influenced by the mutual coupling of the earth impedance of **both** parallel lines. This causes measuring errors in the result of the impedance computation unless special measures are taken. The device is therefore provided with a parallel line compensation function. This function takes the earth current of the parallel line into consideration when solving the line equation, thereby compensating for the coupling influence as was the case with the derivation of the distance by the distance protection (refer to Subsection 2.2.1 at "Correction of Measured Values for Parallel Lines"). The earth current of the parallel line must, of course, be connected to the device and the current input I_4 must be configured correctly in the **Power System Data 1** (Subsection 2.1.3.1 at "Current Transformer Connection").

The parallel line compensation only applies to faults on the protected feeder. For external faults, including those on the parallel line, compensation is impossible.

Correction of Measured Values for Load Current on Double-end fed lines

When faults occur on loaded lines fed from both ends (Figure 2-128), the fault voltage $\underline{U}_{F1}$ is influenced not only by the source voltage $\underline{E}_1$ but also by the source voltage $\underline{E}_2$, if both voltages are applied to the common earth resistance R_F. This causes impedance measuring errors since the current portion $\underline{I}_{F2}$ can not be detected at the measuring point M. This measuring error in the X-component of the fault impedance (decisive for distance calculation) may be considerable in long and heavily loaded lines.

A load compensation feature in 7SA6 is provided for the fault location calculation which largely corrects this measurement inaccuracy for single-phase short-circuits. Correction for the R–component of the fault impedance is not possible; but the resultant inaccuracy is not critical, since only the X–component is critical for the distance to fault indication.

Load compensation is effective for single–phase faults. For single–phase to earth faults, positive and zero phase sequence components of the symmetrical components are used in the compensation.

Load compensation can be switched on or off. Off-switching is useful, for example, during relay testing, in order to avoid influences caused by the test quantities.
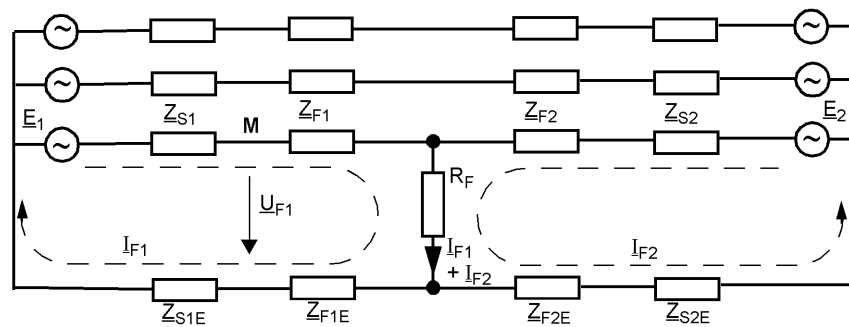
Legend:

M	Measuring location	$\underline{Z}_{S1}$, $\underline{Z}_{S2}$	Source impedances
$\underline{E}_1$, $\underline{E}_2$	Source voltages (EMF)	$\underline{Z}_{S1E}$, $\underline{Z}_{S2E}$	Earth source impedances
$\underline{U}_{F1}$	Fault voltage at the measuring location	$\underline{Z}_{F1}$, $\underline{Z}_{F2}$	Fault impedances
$\underline{I}_{F1}$, $\underline{I}_{F2}$	Part fault currents	$\underline{Z}_{F1E}$, $\underline{Z}_{F2E}$	Earth fault impedances
$\underline{I}_{F1}$ + $\underline{I}_{F2}$	Total fault current	R_F	Common fault resistance

Figure 2-128   Fault currents and voltages on double–end fed lines

2.18.2 Setting Notes

General

The fault location function is only in service if it was selected to *Enabled* during the configuration of the device functions (Section 2.1.1.2, address 138).

If the fault location calculation is to be started by the trip command of the protection, set address 3802 **START** = *TRIP*. In this case a fault location is only output if the device has also issued a trip. The fault location calculation can however also be started with each fault detection of the device (address 3802 **START** = *Pickup*). In this case the fault location is also calculated if for example a different protection device cleared the fault. For a fault outside the protected line, the fault location information is not always correct, as the measured values can be distorted by e.g. intermediate in-feeds.

To calculate the distance to fault in kilometres or miles, the device requires the reactance per unit length data in Ω/km or Ω/mile. For correct indication of the fault location in % of line length, the correct line length has also to be entered. These setting parameters were already applied with the Power System Data 2 (Section 2.1.5.1 at "General Line Data".

A prerequisite for the correct indication of the fault location furthermore is that the other parameters that influence the calculation of the distance to fault have also been set correctly. This concerns the following addresses

1116 **RE/RL(Z1)**,

1117 **XE/XL(Z1)**

or

1120 **KO (Z1)**,

1121 **Angle KO(Z1)**.

If the parallel line compensation is used, set address 3805 **Paral.Line Comp** to *YES* (presetting for devices with parallel line compensation). Further prerequisites are that

- the earth current of the parallel line has been connected to the fourth current input I_4 with the correct polarity and
- the current transformer ratio **I4/Iph CT** (address 221) in the Power System Data 1 has been set correctly (refer also to Subsection 2.1.3.1 at "Current Transformer Connection") and
- the parameter for the fourth current input **I4 transformer** has been set to *In paral. line* (address 220) in the Power System Data 1 (Subsection 2.1.3.1 at "Current Transformer Connection") and
- the mutual impedances **RM/RL ParalLine** and **XM/XL ParalLine** (addresses 1126 and 1127) have been set correctly in the general protection data (Power System Data 2, Sub-section 2.1.5.1).

If load compensation is applied to single-phase faults in double-fed lines of an earthed system, set 3806 in address **Load Compensat. YES**. In case high fault resistances are expected for single-phase faults, e.g. at overhead lines without overhead earth wire or unfavourable footing of the towers, this will improve the accuracy of the distance calculation.

If the fault location is required to be output as BCD-code, set the maximum time period the data should be available at the outputs using address 3811 **Tmax OUTPUT BCD**. If a new fault occurs, the data are terminated immediately even when it occurs before this time has expired. Allocate the corresponding output relays as stored if a longer time period is desired for the output. Once a fault occurred the data will be latched until the memory is reset or a new fault is registered.

2.18.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
3802	START	Pickup TRIP	Pickup	Start fault locator with
3805	Paral.Line Comp	NO YES	YES	Mutual coupling parall.line compensation
3806	Load Compensat.	NO YES	NO	Load Compensation
3811	Tmax OUTPUT BCD	0.10 .. 180.00 sec	0.30 sec	Maximum output time via BCD

2.18.4 Information List

No.	Information	Type of Information	Comments
1114	Rpri =	OUT	Flt Locator: primary RESISTANCE
1115	Xpri =	OUT	Flt Locator: primary REACTANCE
1117	Rsec =	OUT	Flt Locator: secondary RESISTANCE
1118	Xsec =	OUT	Flt Locator: secondary REACTANCE
1119	dist =	OUT	Flt Locator: Distance to fault
1120	d[%] =	OUT	Flt Locator: Distance [%] to fault
1122	dist =	OUT	Flt Locator: Distance to fault
1123	FL Loop L1E	OUT_Ev	Fault Locator Loop L1E
1124	FL Loop L2E	OUT_Ev	Fault Locator Loop L2E
1125	FL Loop L3E	OUT_Ev	Fault Locator Loop L3E
1126	FL Loop L1L2	OUT_Ev	Fault Locator Loop L1L2
1127	FL Loop L2L3	OUT_Ev	Fault Locator Loop L2L3
1128	FL Loop L3L1	OUT_Ev	Fault Locator Loop L3L1
1132	Flt.Loc.invalid	OUT	Fault location invalid
1133	Flt.Loc.ErrorK0	OUT	Fault locator setting error K0,angle(K0)
1143	BCD d[1%]	OUT	BCD Fault location [1%]
1144	BCD d[2%]	OUT	BCD Fault location [2%]
1145	BCD d[4%]	OUT	BCD Fault location [4%]
1146	BCD d[8%]	OUT	BCD Fault location [8%]
1147	BCD d[10%]	OUT	BCD Fault location [10%]
1148	BCD d[20%]	OUT	BCD Fault location [20%]
1149	BCD d[40%]	OUT	BCD Fault location [40%]
1150	BCD d[80%]	OUT	BCD Fault location [80%]
1151	BCD d[100%]	OUT	BCD Fault location [100%]
1152	BCD dist. VALID	OUT	BCD Fault location valid

2.19 Circuit breaker failure protection (optional)

The circuit breaker failure protection provides rapid back-up fault clearance, in the event that the circuit breaker fails to respond to a trip command from a protective function of the local circuit breaker.

2.19.1 Method of Operation

General

Whenever e.g. a short-circuit protection relay of a feeder issues a trip command to the circuit breaker, this is repeated to the breaker failure protection (Figure 2-129). A timer T–BF in the breaker failure protection is started. The timer runs as long as a trip command is present and current continues to flow through the breaker poles.
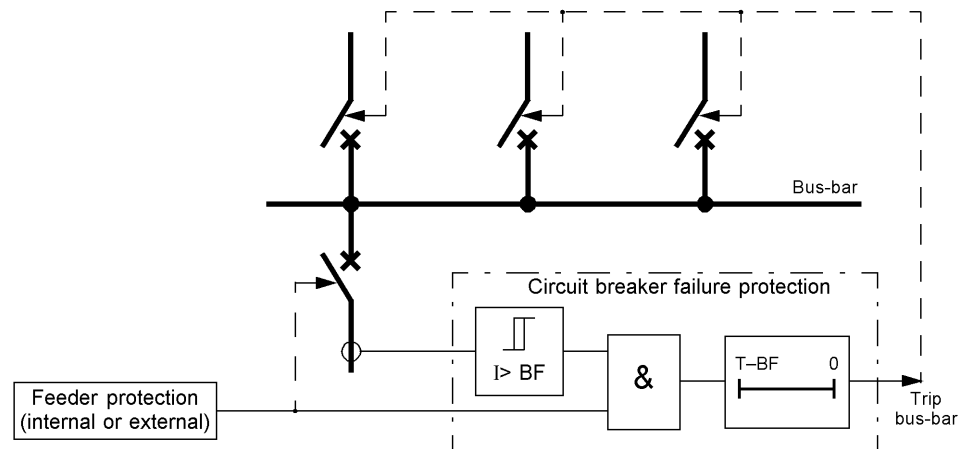
Figure 2-129   Simplified function diagram of circuit breaker failure protection with current flow monitoring

Normally, the breaker will open and interrupt the fault current. The current monitoring stage quickly resets (typical 10 ms) and stops the timer T–BF.

If the trip command is not carried out (breaker failure case), current continues to flow and the timer runs to its set limit. The breaker failure protection then issues a command to trip the back-up breakers and interrupt the fault current.

The reset time of the feeder protection is not relevant because the breaker failure protection itself recognizes the interruption of the current.

For protection functions where the tripping criterion is not dependent on current (e.g. Buchholz protection), current flow is not a reliable criterion for proper operation of the breaker. In such cases, the circuit breaker position can be derived from the auxiliary contacts of the breaker. Therefore, instead of monitoring the current, the condition of the auxiliary contacts is monitored (see Figure 2-130). For this purpose, the outputs from the auxiliary contacts must be fed to binary inputs on the relay (refer also to Section 2.23.1).
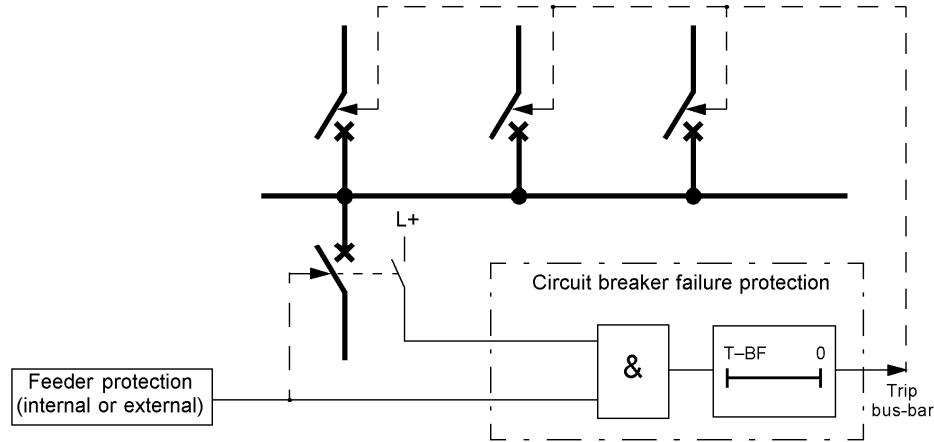
Figure 2-130   Simplified function diagram of circuit breaker failure protection controlled by circuit breaker auxiliary contact

Current Flow Monitoring

Each of the phase currents and an additional plausibility current (see below) are filtered by numerical filter algorithms so that only the fundamental component is used for further evaluation.

Special measures are taken in order to detect a current interruption. In case of sinusoidal currents the current interruption is detected after approximately 10 ms. With aperiodic DC current components in the fault current and/or in the current transformer secondary circuit after interruption (e.g. current transformers with linearized core), or saturation of the current transformers caused by the DC component in the fault current, it can take one AC cycle before the interruption of the primary current is reliably detected.

The currents are monitored and compared with the set threshold. Besides the three phase currents, two further current detectors are provided in order to allow a plausibility check (see Figure 2-131).

The earth current (residual current I_E ($3 \cdot I_0$) is preferably used as plausibility current. If the residual current from the star-point of the current transformer set is connected to the device, then it is used. If the residual current is not available the device calculates it with the formula

$$3 \cdot \underline{I}_0 = \underline{I}_{L1} + \underline{I}_{L2} + \underline{I}_{L3}$$

Additionally, the value calculated by 7SA6 of three times the negative sequence current $3 \cdot I_2$ is used for plausibility check. This is calculated according to the equation:

$$3 \cdot \underline{I}_2 = \underline{I}_{L1} + \underline{a}^2 \cdot \underline{I}_{L2} + \underline{a} \cdot \underline{I}_{L3}$$

where

$$\underline{a} = e^{j120°}.$$

These plausibility currents do not have any direct influence on the basic functionality of the breaker failure protection but they allow a plausibility check in that at least two current thresholds must have been exceeded before any of the breaker failure delay times can be started, thus providing high security against false operation.
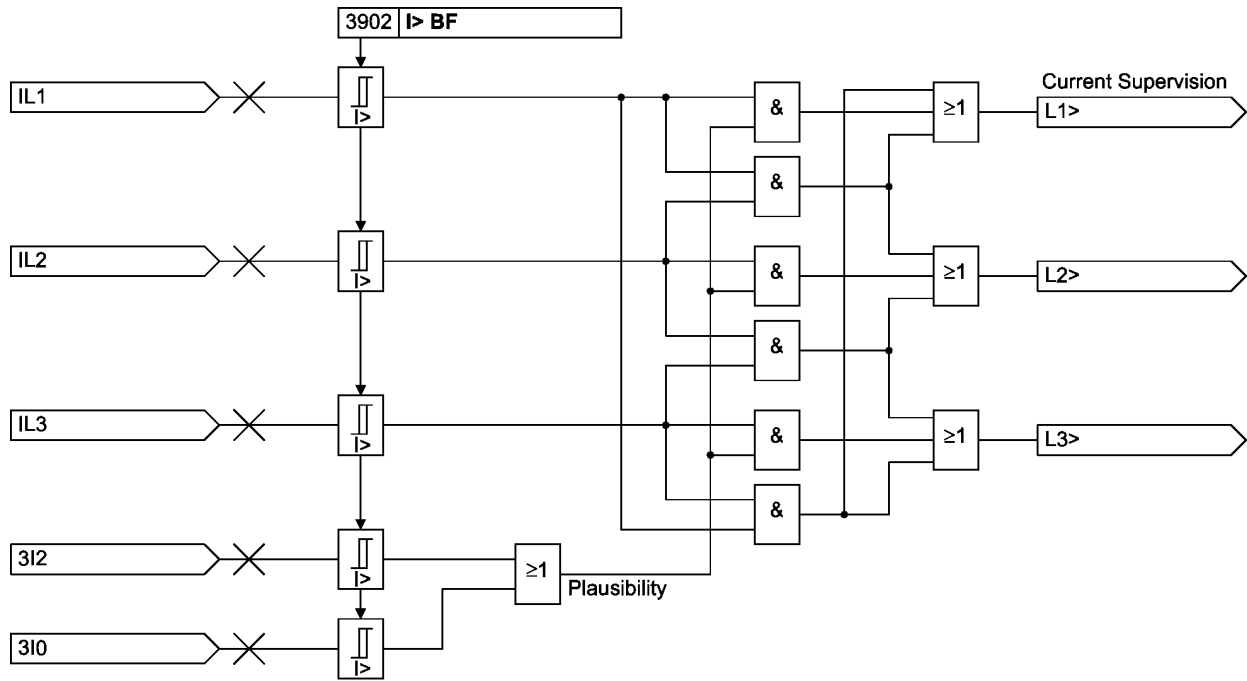
Figure 2-131   Current flow monitoring with plausibility currents $3 \cdot I_0$ and $3 \cdot I_2$

Processing of the Circuit Breaker Auxiliary Contacts

It is the central function control of the device that informs the breaker failure protection on the position of the circuit breaker (refer also to Section 2.23.1). Evaluation of the breaker auxiliary contacts is carried out in the breaker failure protection function only when the current flow monitoring has not picked up. Once the current flow criterion has picked up during the trip signal from the feeder protection, the circuit breaker is assumed to be open as soon as the current disappears, even if the associated auxiliary contact does not (yet) indicate that the circuit breaker has opened (Figure 2-132). This gives preference to the more reliable current criterion and avoids overfunctioning due to a defect e.g. in the auxiliary contact mechanism or circuit. This interlock feature is provided for each individual phase as well as for three-pole trip.

It is possible to disable the auxiliary contact criterion. If you set the parameter switch **Chk BRK CONTACT** (Figure 2-134 top) to *NO*, the breaker failure protection can only be started when current flow is detected. The position of the auxiliary contacts is then not evaluated even if the auxiliary contacts are connected to the device.
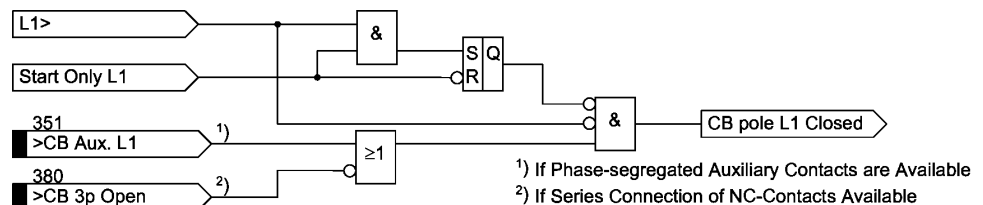
Figure 2-132   Interlock of the auxiliary contact criterion - example for phase L1

On the other hand, current flow is not a reliable criterion for proper operation of the circuit breaker for faults which do not cause detectable current flow (e.g. Buchholz protection). Information regarding the position of the circuit breaker auxiliary contacts is required in these cases to check the correct response of the circuit breaker. This is accomplished through binary input "`>BF Start w/o I`" FNo. 1439

(Figure 2-134 left). This input initiates the breaker failure protection even if no current flow is detected.

Common Phase Initiation

Common phase initiation is used, for example, for lines without automatic reclosure, for lines with only three-pole automatic reclosure, for transformer feeders, or if the busbar protection trips. This is the only available initiation mode if the actual 7SA6 model is able to trip three-pole only.

If the breaker failure protection is intended to be initiated by further external protection devices, it is recommended, for security reasons, to connect two binary inputs to the device. Besides the trip command of the external relay to the binary input ">BF Start 3pole" FNo.1415 it is recommended to connect also the general device pickup to binary input ">BF release" FNo.1432. For Buchholz protection it is recommended that both inputs are connected to the device by two separate wire pairs.

Nevertheless, it is possible to initiate the breaker failure protection in single-channel mode should a separate release criterion not be available. The signal ">BF release" (FNo. 1432) must then not be assigned.

Figure 2-134 shows the operating principle. When the trip signal appears from any internal or external feeder protection and at least one current flow criterion (according to Figure 2-131) is present, the breaker failure protection is initiated and the corresponding delay time(s) is (are) started.

If the current criterion is not fulfilled for any of the phases, the position of the circuit breaker auxiliary contact(s) is queried provided that this is available according to Figure 2-133. If the circuit breaker poles have individual auxiliary contacts, the series connection of the three normally closed (NC) auxiliary contacts is used. The circuit breaker has operated correctly after a three-pole trip command only when none of the phases carries current or when all three NC auxiliary contacts have closed.

Figure 2-133 illustrates how the internal signal "CB pole ≥L1 closed" is created (see Figure 2-134 left) if at least one circuit breaker pole is closed.
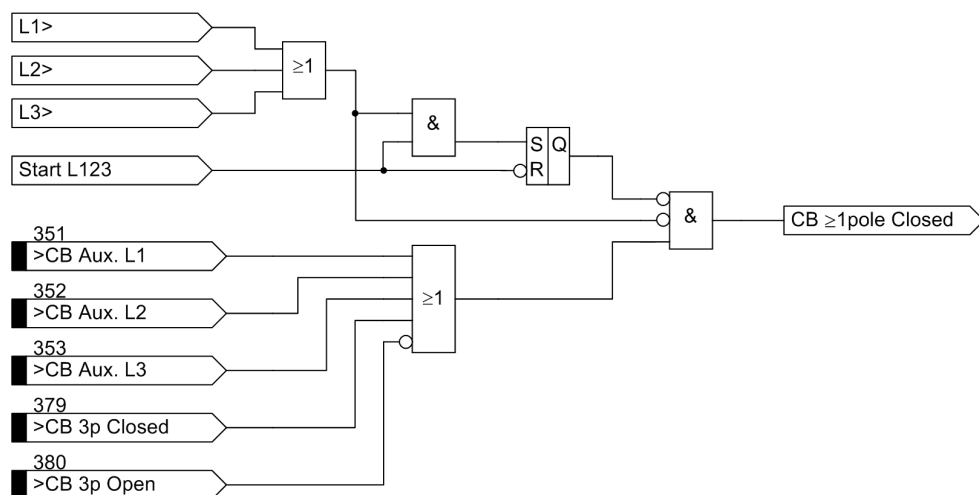
Figure 2-133   Creation of signal "CB ≥ any pole closed"

If an internal protection function or an external protection device trips without current flow, the internal input "Start internal w/o I" or the external input is used to initiate the breaker failure protection via the binary input ">BF Start w/o I". In this case, the

start signal is maintained until the auxiliary contact criterion reports that the circuit breaker is open.

Initiation can be blocked via the binary input ">BLOCK BkrFail" (e.g. during test of the feeder protection relay). Additionally, an internal blocking option is provided.
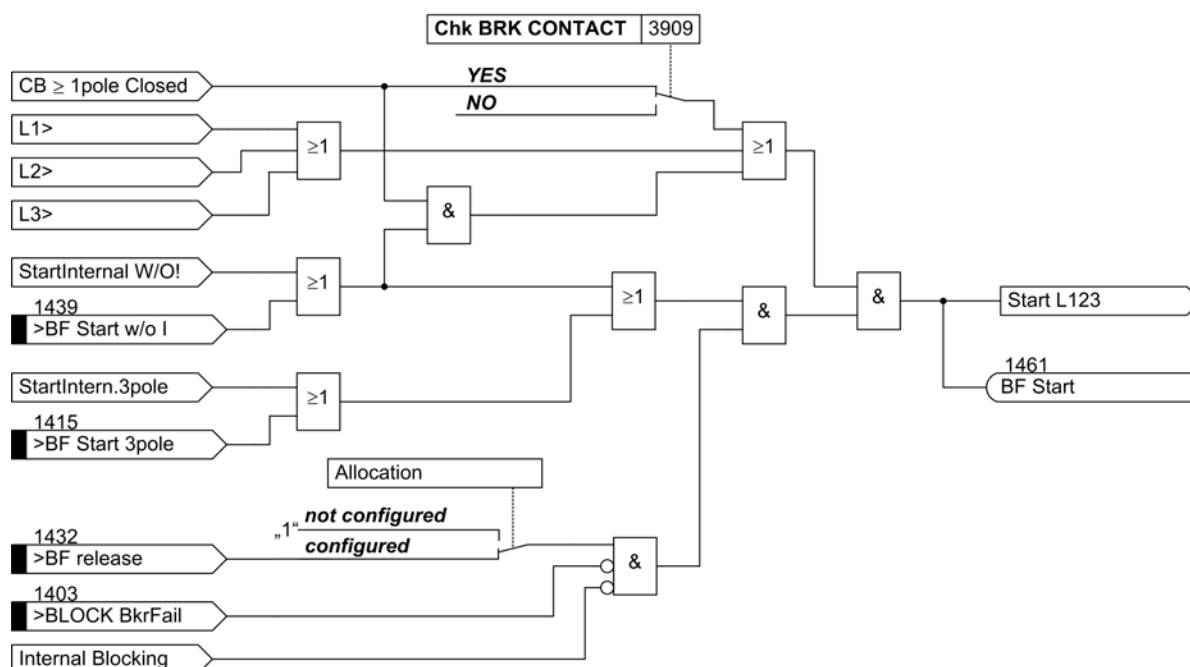
Figure 2-134   Breaker failure protection with common phase initiation

Phase Segregated Initiation

Phase segregated initiation of the breaker failure protection is necessary if the circuit breaker poles can be operated individually, e.g. if single-pole automatic reclosure is used. This is possible if the device is able to trip single-pole.

If the breaker failure protection is intended to be initiated by further external protection devices, it is recommended, for security reasons, to connect two starting criteria to the device. Besides the three trip commands of the external relay to the binary input ">BF Start L1", ">BF Start L2" and ">BF Start L3" it is recommended to connect also for example the general device pickup to binary input ">BF release". Figure 2-135 shows the connections of this dual-channel initiation.

Nevertheless, it is possible to initiate the breaker failure protection in single-channel mode should a separate release criterion not be available. The binary input ">BF release" must then not be assigned to any physical input of the device during configuration.

If the external protection device does not provide a general fault detection signal, a general trip signal can be used instead. Alternatively, the parallel connection of a separate set of trip contacts can produce such a release signal as shown in Figure 2-136.

The starting condition logic for the delay times is shown in Figure 2-137. In principle, it is designed similar to that for the common phase initiation, but individually for each of the three phases. Thus, current flow and initiation conditions are processed for each phase. In case of single-pole interruption before an automatic reclose cycle, current disappearance is reliably monitored for the tripped breaker pole only.
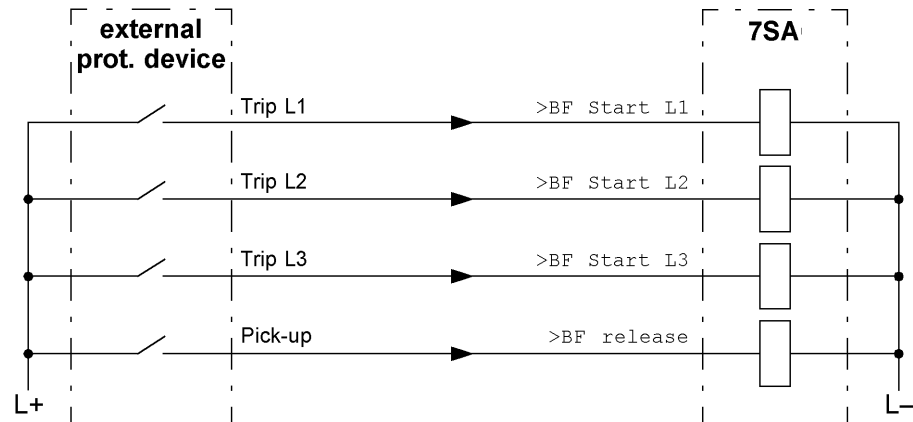
Figure 2-135   Breaker failure protection with phase segregated initiation — example for initiation by an external protection device with release by a fault detection signal
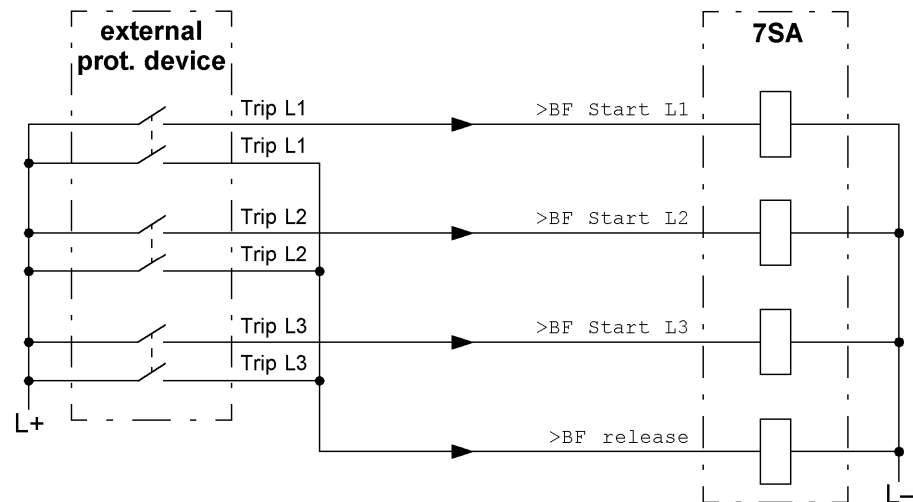
Figure 2-136   Breaker failure protection with phase segregated initiation — example for initiation by an external protection device with release by a separate set of trip contacts

Initiation of a single-phase, e.g. "Start L1 only" is active when the starting input (= trip command of any feeder protection) appears for only this phase and current flow is detected in at least this phase. If current flow is not detected, the auxiliary contact position can be interrogated according to Figure 2-132, dependent on the setting (**Chk BRK CONTACT** = *YES*).

The auxiliary contact criterion is also processed for each individual breaker pole. If however the breaker auxiliary contacts are not available for each individual breaker pole, then a single-pole trip command is assumed to be executed only once the series connection of the normally open (NO) auxiliary contacts is interrupted. This information is provided to the breaker failure protection by the central function control of the device (refer to Section 2.23.1).

The three-phase starting signal "Start L123" is generated if trip signals appear in more than one pole (regardless from which protection function). Phase segregated initiation is then blocked. The input "BF Start w/o I" (e.g. from Buchholz protection) operates in three-phase mode as well. The function is the same as with common phase initiation.

The additional release-signal "`>BF release`" (if assigned to a binary input) affects all starting conditions. Initiation can be blocked via the binary input "`>BLOCK BkrFail`" (e.g. during test of the feeder protection relay). Additionally, an internal blocking option is provided.
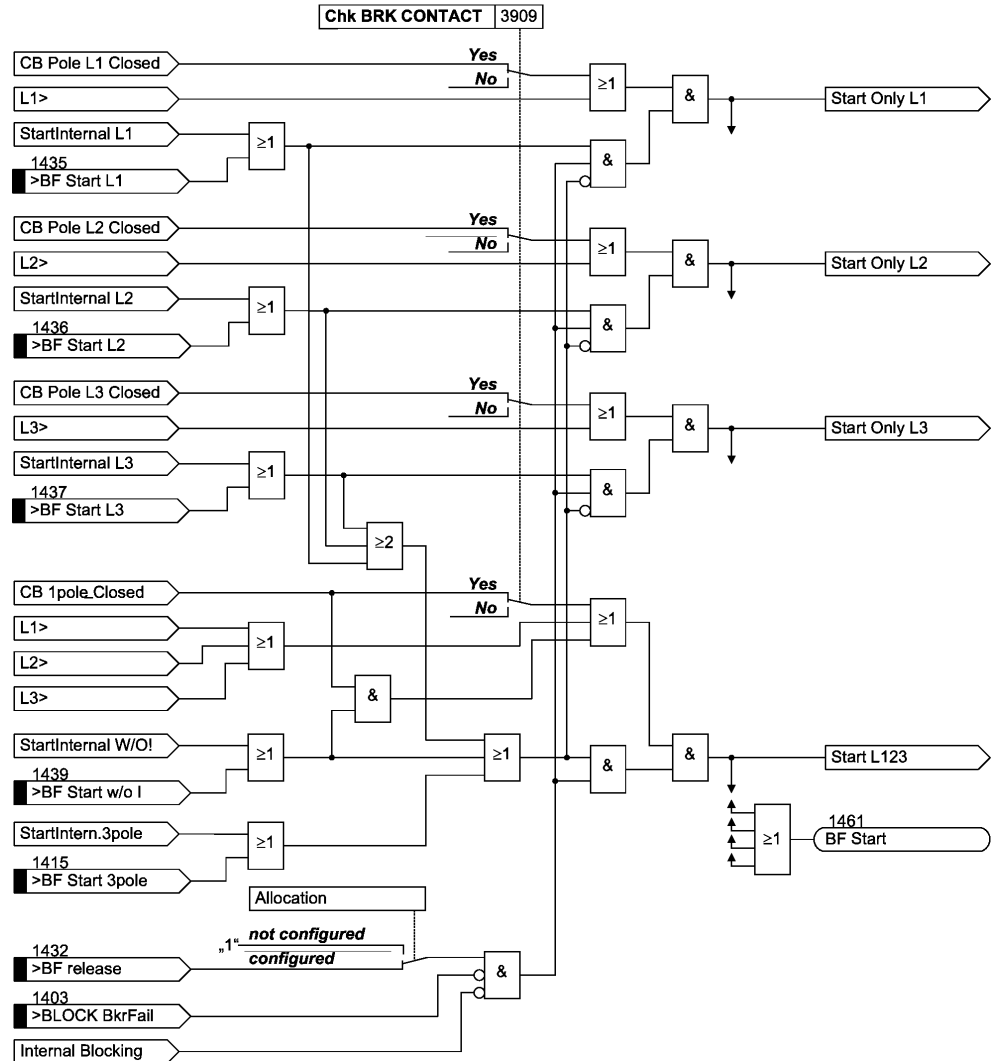
Figure 2-137   Initiation conditions with single-pole trip command

Delay Times

When the initiate conditions are fulfilled, the associated timers are started. The circuit breaker pole(s) must open before the associated time has elapsed.

Different delay timers are provided for operation after common phase initiation and phase segregated initiation. A third time stage can be used for two-stage breaker failure protection.

With single-stage breaker failure protection, the trip command is routed to the adjacent circuit breakers should the local feeder breaker fail (refer to Figure 2-129 or 2-130). The adjacent circuit breakers are those which must trip in order to interrupt the fault current, i.e. the breakers which feed the busbar or the busbar section to which the feeder under consideration is connected. The possible initiation conditions for the breaker failure protection are those discussed above. Depending on the application of

the feeder protection, common phase or phase segregated initiation conditions may occur. Tripping by the breaker failure protection is always three-pole.

The simplest solution is to start the delay timer **T2** (Figure 2-138). The phase-segregated initiation signals are omitted if the feeder protection always trips three-pole or if the circuit breaker is not capable of single-pole tripping.

If different delay times are required after a single-pole trip or three-pole trip it is possible to use the timer stages **T1-1pole** and **T1-3pole** according to Figure 2-139.
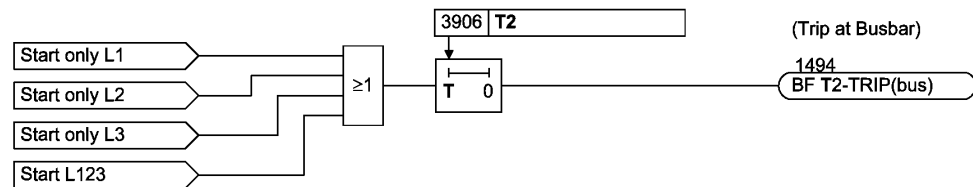
Figure 2-138   Single-stage breaker failure protection with common phase initiation
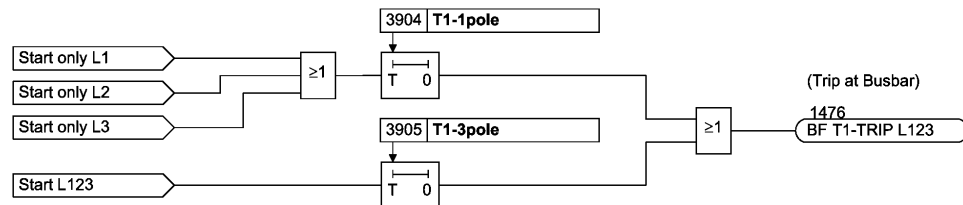
Figure 2-139   Single-stage breaker failure protection with different delay timers

With two-stage breaker failure protection, the trip command of the feeder protection is usually repeated, after a first time stage, to the feeder circuit breaker, often via a second trip coil or set of trip coils, if the breaker has not responded to the original trip command. A second time stage monitors the response to this repeated trip command and trips the breakers of the relevant bus-bar section, if the fault has not yet been cleared after this second time.

For the first time stage, a different time delay **T1-1pole** can be selected for a single-pole trip than for a three-pole trip by the feeder protection. Additionally, you can select (parameter **1p-RETRIP (T1)**) whether this repeated trip should be single-pole or three-pole.
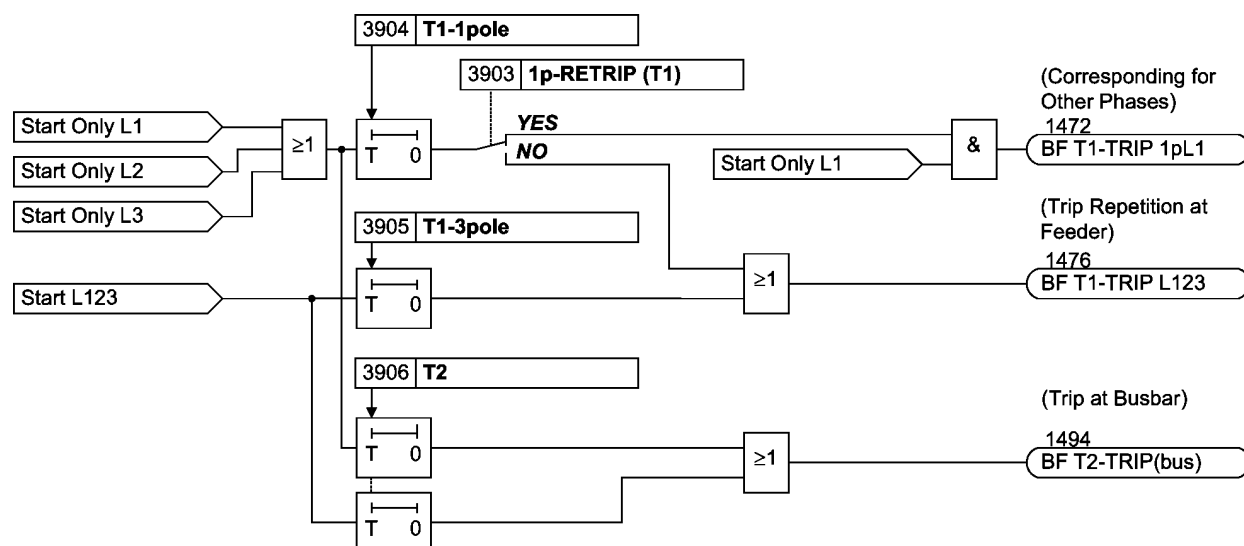
Figure 2-140   Two-stage breaker failure protection with phase segregated initiation

Circuit Breaker not Operational

There may be cases when it is already obvious that the circuit breaker associated with a feeder protection relay cannot clear a fault, e.g. when the tripping voltage or the tripping energy is not available.

In such a case it is not necessary to wait for the response of the feeder circuit breaker. If provision has been made for the detection of such a condition (e.g. control voltage monitor or air pressure monitor), the monitor alarm signal can be fed to the binary input "`>CB faulty`" of the 7SA6. On occurrence of this alarm and a trip command by the feeder protection, a separate timer **T3-BkrDefective**, which is normally set to 0, is started (Figure 2-141). Thus, the adjacent circuit breakers (bus-bar) are tripped immediately in case the feeder circuit breaker is not operational.
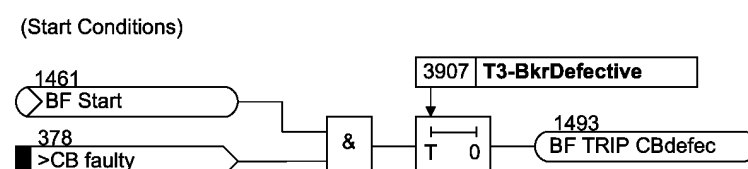
Figure 2-141   Circuit breaker faulty

Transfer Trip to the Remote End Circuit Breaker

The device has the facility to provide an additional intertrip signal to the circuit breaker at the remote line end in the event that the local feeder circuit breaker fails. For this, a suitable protection signal transmission link is required (e.g. via communication cable, power line carrier transmission, radio transmission, or optical fibre transmission). With devices using digital transmission via protection interface, the remote commands can be applied (see also Section 2.5).

To perform this intertrip, the desired command — usually the trip command which is intended to trip the adjacent breakers — is assigned to a binary output of the device. The contact of this output triggers the transmission device. When using digital signal transmission the command is connected to a remote command via the user-defined logic (CFC).

End Fault Protection

An end fault is defined here as a short–circuit which has occurred at the end of a line or protected object, between the circuit breaker and the current transformer set.

This situation is shown in Figure 2-142. The fault is located — as seen from the current transformers (= measurement location) — on the bus-bar side, thus, it will not be regarded by the feeder protection relay as a feeder fault. It can only be detected by either a reverse stage of the feeder protection or by a busbar protection. Nevertheless, a trip command given to the feeder circuit breaker cannot clear the fault since the opposite end continues to feed the fault. Thus, the fault current does not stop flowing even though the feeder circuit breaker has properly responded to the trip command.
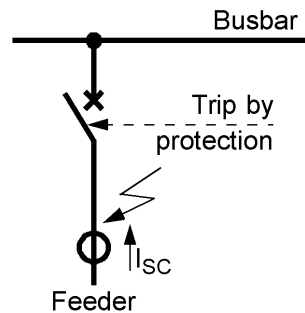
Figure 2-142   End fault between circuit breaker and current transformers

The end fault protection has the task to recognize this situation and to transmit a trip signal to the remote end(s) of the protected object to clear the fault. For this purpose, the output command "BF EndFlt TRIP" is available to trigger a signal transmission device (e.g. power line carrier, radio wave, or optical fibre) — if applicable, together with other commands that need to be transferred or (when using digital signal transmission) as command via the protection interface.

The end fault is recognized when the current continues flowing although the circuit breaker auxiliary contacts indicate that the breaker is open. An additional criterion is the presence of any breaker failure protection initiate signal. Figure 2-143 illustrates the functional principle. If the breaker failure protection is initiated and current flow is detected (current criteria "L*>" according to Figure 2-131), but no circuit breaker pole is closed (auxiliary contact criterion " ≥ any pole closed"), then the timer **T-EndFault** is started. At the end of this time an intertrip signal is transmitted to the opposite end(s) of the protected object.
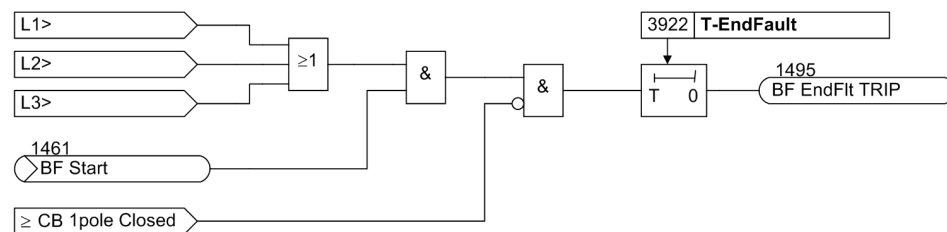
Figure 2-143   Operation scheme of end fault protection

Pole Discrepancy Supervision

The pole discrepancy supervision has the task to detect discrepancies in the position of the three circuit breaker poles. Under steady-state operating conditions, either all three poles of the breaker must be closed, or all three poles must be open. Discrep-

ancy is permitted only for a short time interval during a single-pole automatic reclose cycle.

The scheme functionality is shown in Figure 2-144. The signals which are processed here are the same as those used for the breaker failure protection. The pole discrepancy condition is established when at least one pole is closed (" ≥any pole closed") and at the same time not all three poles are closed (" ≥any pole open").

Additionally, the current criteria (from Figure 2-131) are processed. Pole discrepancy can only be detected when current is not flowing through all three poles (<3), i.e. through only one or two poles. When current is flowing through all three poles, all three poles must be closed even if the breaker auxiliary contacts indicate a different status.

If pole discrepancy of the breaker poles is detected, this is indicated in each phase by a "fault detection signal". This signal identifies the pole which was open before the trip command of the pole discrepancy supervision occurred.
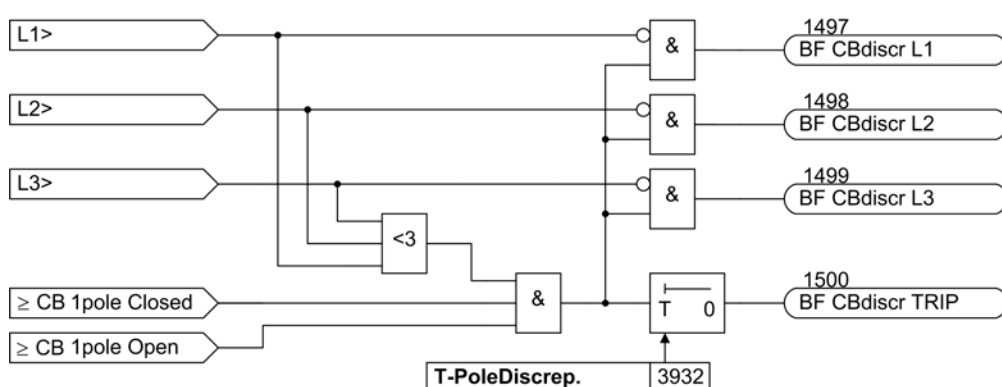
Figure 2-144   Function diagram of pole discrepancy supervision

2.19.2 Setting Notes

General

The breaker failure protection and its ancillary functions (end fault protection, pole discrepancy supervision) can only operate if they were configured as *Enabled* during configuration of the scope of functions (address 139 **BREAKER FAILURE**).

Circuit Breaker Failure Protection

The breaker failure protection is switched *ON* or *OFF* at address 3901 **FCT BreakerFail**.

The current threshold **I> BF** (address 3902) should be selected such that the protection will operate with the smallest expected short-circuit current. A setting of 10 % below the minimum fault current for which breaker failure protection must operate is recommended. On the other hand, the value should not be set lower than necessary.

Normally, the breaker failure protection evaluates the current flow criterion as well as the position of the breaker auxiliary contact(s). If the auxiliary contact(s) status is not available in the device, this criterion cannot be processed. In this case, set address 3909 **Chk BRK CONTACT** to *NO*.

Two-stage Breaker Failure Protection

With two-stage operation, the trip command is repeated after a time delay T1 to the local feeder breaker, normally to a different set of trip coils of this breaker. A choice can be made whether this trip repetition shall be single-pole or three-pole if the initial feeder protection trip was single-pole (provided single-pole trip is possible). This

choice is made in address 3903 **1p-RETRIP (T1)**. Set this parameter to *YES* if you wish single-pole trip for the first stage, otherwise to *NO*.

If the breaker does not respond to this trip repetition, the adjacent circuit breakers are tripped after T2 i.e., the circuit breakers of the busbar or of the concerned busbar section and if necessary also the circuit breaker at the remote end unless the fault has been cleared.

Separate delay times can be set

- for single- or three-pole trip repetition to the local feeder circuit breaker after a **1**-pole trip of the feeder protection **T1-1pole** at address 3904,
- for three-pole trip repetition to the local feeder circuit breaker after **3**-pole trip of the feeder protection **T1-3pole** (address 3905),
- for trip of the adjacent circuit breakers (busbar zone and remote end if applicable) **T2** at address 3906.

The delay times are set dependant on the maximum operating time of the feeder circuit breaker and the reset time of the current detectors of the breaker failure protection, plus a safety margin which allows for any tolerance of the delay timers. Figure 2-145 illustrates the timing of a typical breaker failure scenario. The dropout time for sinusoidal currents is ≤ 15 ms. If current transformer saturation is anticipated, the time should be set to 25 ms.
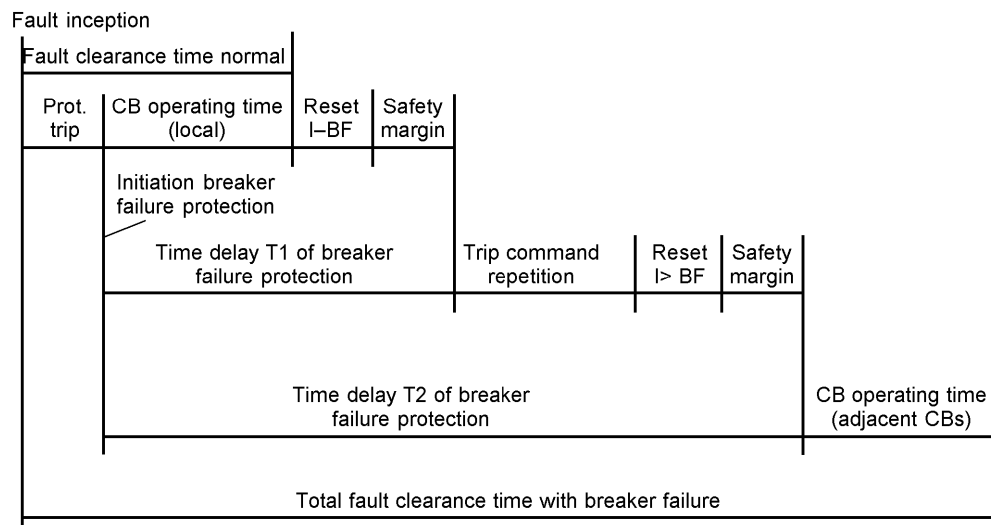
Figure 2-145   Time sequence example for normal clearance of a fault, and with circuit breaker failure, using two-stage breaker failure protection

Single-stage Breaker Failure Protection

With single-stage operation, the adjacent circuit breakers (i.e. the breakers of the busbar zone and, if applicable, the breaker at the remote end) are tripped after a delay time **T2** (address 3906) following initiation, should the fault not have been cleared within this time.

The timers **T1-1pole** (address 3904) and **T1-3pole** (address 3905) are then set to ∞ since they are not needed.

But you may use the T1-timers for single-stage protection if you wish to utilize the facility of setting different delay times after single-pole trip and three-pole trip of the feeder protection. In this case set **T1-1pole** (address 3904) and **T1-3pole** (address 3905) separately but address 3903 **1p-RETRIP (T1)** to *NO*, to avoid a single-

pole trip to the busbar. Set **T2** (address 3906) to ∞ or equal to **T1-3pole** (address 3905) . Be sure that the correct trip commands are assigned to the desired trip relay(s).

The delay times are determined from the maximum operating time of the feeder circuit breaker, the reset time of the current detectors of the breaker failure protection, plus a safety margin which allows for any tolerance of the delay timers. Figure 2-146 illustrates the timing of a typical breaker failure scenario. The dropout time for sinusoidal currents is ≤ 15 ms. If current transformer saturation is anticipated, the time should be set to 25 ms.
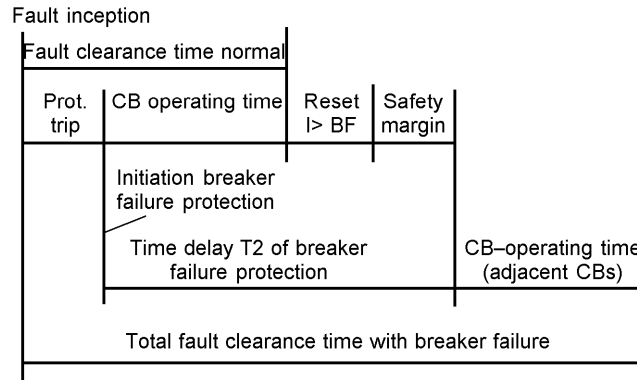
Figure 2-146   Time sequence example for normal clearance of a fault, and with circuit breaker failure, using single-stage breaker failure protection

Circuit Breaker not Operational

If the circuit breaker associated with the feeder is not operational (e.g. control voltage failure or air pressure failure), it is apparent that the local breaker cannot clear the fault. If the relay is informed about this disturbance (via the binary input "**>CB faulty**", the adjacent circuit breakers (busbar and remote end if applicable) are tripped after the time **T3-BkrDefective** (address 3907) which is usually set to **0**.

Address 3908 **Trip BkrDefect.** determines to which output the trip command is routed in the event that the breaker is not operational when a feeder protection trip occurs. Select that output which is used to trip the adjacent breakers (bus-bar trip).

End Fault Protection

The end fault protection can be switched separately *ON* or *OFF* in address 3921 End Flt. stage. An end fault is a short-circuit between the circuit breaker and the current transformer set of the feeder. The end fault protection presumes that the device is informed about the circuit breaker position via breaker auxiliary contacts connected to binary inputs.

If, during an end fault, the circuit breaker is tripped by a reverse stage of the feeder protection or by the bus-bar protection (the fault is a bus-bar fault as determined from the location of the current transformers), the fault current will continue to flow, because the fault is fed from the remote end of the feeder circuit.

The time **T-EndFault** (address 3922) is started when, during the time of pickup condition of the feeder protection, the circuit breaker auxiliary contacts indicate open poles and, at the same time, current flow is still detected (address 3902). The trip command of the end fault protection is intended for the transmission of an intertrip signal to the remote end circuit breaker.

Thus, the delay time must be set such that it can bridge out short transient apparent stub fault conditions which may occur during switching of the breaker.

Pole Discrepancy Supervision

The pole discrepancy supervision can be switched *ON* or *OFF* independently at address 3931 **PoleDiscrepancy**. It is only useful if the breaker poles can be operated individually. It avoids that only one or two poles of the local breaker are open during steady state. It has to be provided that either the auxiliary contacts of each pole or the series connection of the NO auxiliary contacts and the series connection of the NC auxiliary contacts are connected to the device's binary inputs. If these conditions are not fulfilled, switch address 3931 *OFF*.

The delay time **T-PoleDiscrep.** (address 3932) determines how long a breaker pole discrepancy condition of the feeder circuit breaker, i.e. only one or two poles open, may be present before the pole discrepancy supervision issues a three-pole trip command. This time must clearly be longer than the duration of a single-pole automatic reclose cycle. The time should be less than the permissible duration of an unbalanced load condition which is caused by the unsymmetrical position of the circuit breaker poles. Conventional values are 2 s to 5 s.

2.19.3 Settings

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
3901	FCT BreakerFail		ON OFF	ON	Breaker Failure Protection is
3902	I> BF	1A	0.05 .. 20.00 A	0.10 A	Pick-up threshold I>
		5A	0.25 .. 100.00 A	0.50 A	
3903	1p-RETRIP (T1)		NO YES	YES	1pole retrip with stage T1 (local trip)
3904	T1-1pole		0.00 .. 30.00 sec; ∞	0.00 sec	T1, Delay after 1pole start (local trip)
3905	T1-3pole		0.00 .. 30.00 sec; ∞	0.00 sec	T1, Delay after 3pole start (local trip)
3906	T2		0.00 .. 30.00 sec; ∞	0.15 sec	T2, Delay of 2nd stage (busbar trip)
3907	T3-BkrDefective		0.00 .. 30.00 sec; ∞	0.00 sec	T3, Delay for start with defective bkr.
3908	Trip BkrDefect.		NO with T1-trip with T2-trip w/ T1/T2-trip	NO	Trip output selection with defective bkr
3909	Chk BRK CONTACT		NO YES	YES	Check Breaker contacts
3921	End Flt. stage		ON OFF	OFF	End fault stage is
3922	T-EndFault		0.00 .. 30.00 sec; ∞	2.00 sec	Trip delay of end fault stage
3931	PoleDiscrepancy		ON OFF	OFF	Pole Discrepancy supervision
3932	T-PoleDiscrep.		0.00 .. 30.00 sec; ∞	2.00 sec	Trip delay with pole discrepancy

2.19.4 Information List

No.	Information	Type of Information	Comments
1401	>BF on	SP	>BF: Switch on breaker fail protection
1402	>BF off	SP	>BF: Switch off breaker fail protection
1403	>BLOCK BkrFail	SP	>BLOCK Breaker failure
1415	>BF Start 3pole	SP	>BF: External start 3pole
1432	>BF release	SP	>BF: External release
1435	>BF Start L1	SP	>BF: External start L1
1436	>BF Start L2	SP	>BF: External start L2
1437	>BF Start L3	SP	>BF: External start L3
1439	>BF Start w/o I	SP	>BF: External start 3pole (w/o current)
1440	BkrFailON/offBI	IntSP	Breaker failure prot. ON/OFF via BI
1451	BkrFail OFF	OUT	Breaker failure is switched OFF
1452	BkrFail BLOCK	OUT	Breaker failure is BLOCKED
1453	BkrFail ACTIVE	OUT	Breaker failure is ACTIVE
1461	BF Start	OUT	Breaker failure protection started
1472	BF T1-TRIP 1pL1	OUT	BF Trip T1 (local trip) - only phase L1
1473	BF T1-TRIP 1pL2	OUT	BF Trip T1 (local trip) - only phase L2
1474	BF T1-TRIP 1pL3	OUT	BF Trip T1 (local trip) - only phase L3
1476	BF T1-TRIP L123	OUT	BF Trip T1 (local trip) - 3pole
1493	BF TRIP CBdefec	OUT	BF Trip in case of defective CB
1494	BF T2-TRIP(bus)	OUT	BF Trip T2 (busbar trip)
1495	BF EndFlt TRIP	OUT	BF Trip End fault stage
1496	BF CBdiscrSTART	OUT	BF Pole discrepancy pickup
1497	BF CBdiscr L1	OUT	BF Pole discrepancy pickup L1
1498	BF CBdiscr L2	OUT	BF Pole discrepancy pickup L2
1499	BF CBdiscr L3	OUT	BF Pole discrepancy pickup L3
1500	BF CBdiscr TRIP	OUT	BF Pole discrepancy Trip

2.20   Thermal overload protection (optional)

The thermal overload protection prevents damage to the protected object caused by thermal overloading, particularly in case of transformers, rotating machines, power re-actors and cables. It is in general not necessary for overhead lines, since no meaning-ful overtemperature can be calculated because of the great variations in the environ-mental conditions (temperature, wind). In this case, however, a current-dependent alarm stage can signal an imminent overload.

2.20.1 Method of Operation

The unit computes the overtemperature according to a thermal single-body model as per the following thermal differential equation

$$\frac{d\Theta}{dt} + \frac{1}{\tau_{th}} \cdot \Theta = \frac{1}{\tau_{th}} \cdot \left(\frac{I}{k \cdot I_N}\right)^2$$

with

Θ	– Present overtemperature expressed as a percent of the final overtemperature corresponding to the maximum permissible phase current $k \cdot I_N$
τ_{th}	– thermal time constant for the heating
I	– present rms current
k	– k–factor indicating the maximum permissible constant current referred to the nominal current of the current transformers
I_N	– nominal current of the current transformers

The solution of this equation is in steady-state operation is an e-function whose as-ymptote represents the final temperature Θ_{End}. When the overtemperature reaches the first settable temperature threshold Θ_{alarm}, which is below the overtemperature = tripping overtemperature, a warning alarm is given in order to allow an preventive load reduction. When the second temperature threshold, i.e. the final overtemperature = tripping overtemperature, is reached, the protected object is disconnected from the network. It is also possible, however, to set the overload protection to **Alarm Only**. If this option is set, the device only outputs an alarm, even if the end temperature is reached.

The temperature rises are calculated separately for each phase in a thermal replica from the square of the associated phase current. This guarantees a true RMS value measurement and also considers the effect of harmonic content. A choice can be made whether the maximum calculated overtemperature of the three phases, the average overtemperature, or the overtemperature calculated from the phase with maximum current should be decisive for evaluation of the thresholds.

The maximum thermally-permissible continuous current I_{max} is described as a multiple of the nominal current I_N:

$I_{max} = k \cdot I_N$

In addition to the k-factor, the time constant τ_{th} as well as the alarm temperature Θ_{alarm} must be entered as settings of the protection.

Overload protection also features a current warning element I$_{alarm}$ in addition to the temperature warning stage. It reports an overload current prematurely, even if the calculated excessive temperature has not yet attained the warning or tripping temperature levels.

The overload protection can be blocked via a binary input. In doing so, the thermal images are also reset to zero.
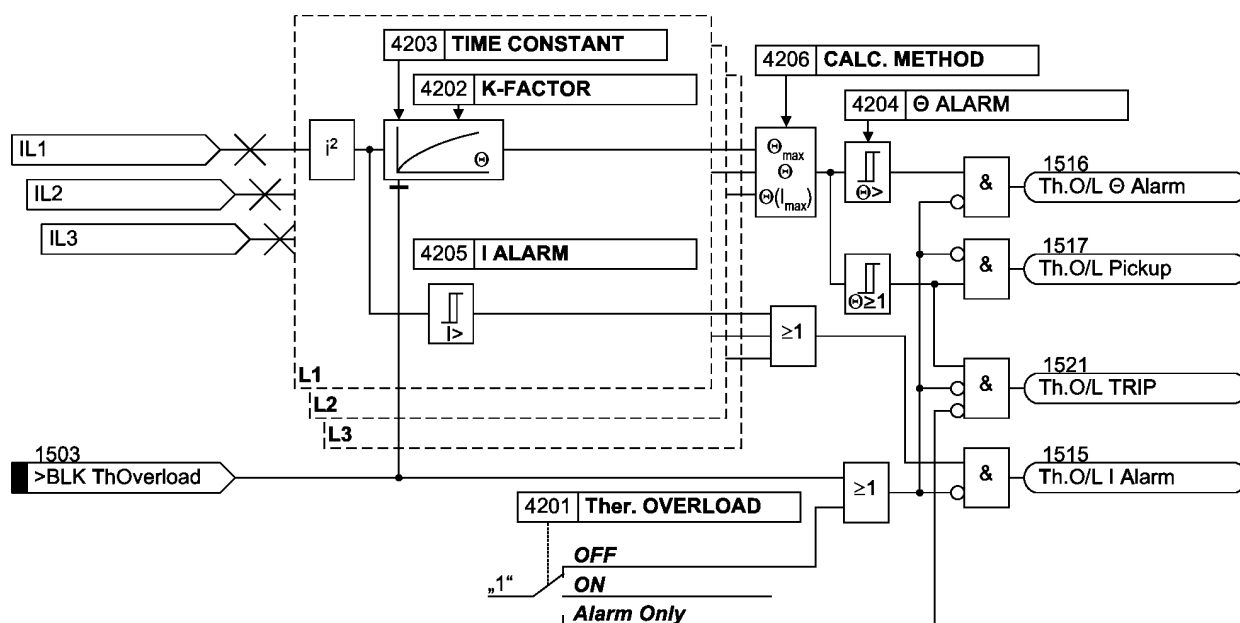
Figure 2-147   Logic diagram of the thermal overload protection

2.20.2 Setting Notes

General   A prerequisite for the application of the thermal overload function is that during the configuration of the scope of functions in address 142 **Ther. OVERLOAD** was set to *Enabled*. The function can be turned *ON* or *OFF* under address 4201 **Ther. OVERLOAD**. Furthermore *Alarm Only* can be set. With that latter setting the protection function is active but only outputs an alarm when the tripping temperature is reached, i.e. the output function "Th.O/L TRIP" is not active.

K- Factor   The nominal device current is used as a basis for overload detection. The setting factor k is set under address 4202 **K-FACTOR**. It is determined by the relation between the permissible thermal continuous current and this rated current:

$$k = \frac{I_{max}}{I_N}$$

The permissible continuous current is at the same time the current at which the e-function of the overtemperature has its asymptote. It is not necessary to determine the tripping temperature since it results automatically from the final rise temperature at $k \cdot I_N$. Manufacturers of electrical machines usually state the permissible continuous current. If no data are available, k is set to 1.1 times the rated current of the protected object. For cables, the permissible continuous current depends on the cross section, the in-

sulation material, the design and the way they are laid, and can be derived from the relevant tables.

Please note that the overload capability of electrical equipment relates to its primary current. This has to be considered if the primary current differs from the rated current of the current transformers.

Example:

Belted cable 10 kV 150 mm^2

Permissible continuous current I_{max} = 322 A

Current transformers 400 A / 5 A

$$k = \frac{322\ A}{400\ A} = 0.805$$

Setting value **K-FACTOR** = **0.80**

Time Constant τ

The thermal time constant τ_{th} is set at address 4203 **TIME CONSTANT**. This is also provided by the manufacturer. Please note that the time constant is set in minutes. Quite often other values for determining the time constant are stated which can be converted into the time constant as follows:

1-s current

$$\frac{\tau_{th}}{min} = \frac{1}{60} \cdot \left(\frac{perm.\ 1\text{-}s\ current}{perm.\ contin.\ current} \right)^2$$

permissible current for application time other than 1°s, e.g. for 0.5°s

$$\frac{\tau_{th}}{min} = \frac{0.5}{60} \cdot \left(\frac{perm.\ 0.5\text{–}s\ current}{perm.\ contin.\ current} \right)^2$$

t_6–time; this is the time in seconds for which a current of 6 times the rated current of the protected object may flow

$$\frac{\tau_{th}}{min} = 0.6 \cdot t_6$$

Example:

Cable as above with

Permissible 1-s current 13.5 kA

$$\frac{\tau_{th}}{min} = \frac{1}{60} \cdot \left(\frac{13\,500\ A}{322\ A} \right)^2 = \frac{1}{60} \cdot 42^2 = 29.4$$

Setting value **TIME CONSTANT** = **29.4 min**

Warning Temperature Levels

By setting a thermal alarm stage Θ **ALARM** (address 4204) an alarm can be provided before the tripping temperature is reached, so that a trip can be avoided by preventive load reduction or by switching over. The percentage is referred to the tripping temperature rise.

The current overload alarm setpoint **I ALARM** (address 4205) is stated as a factor of the rated device current and should be set equal to or slightly below the permissible continuous current $k \cdot I_N$. It can also be used instead of the thermal alarm stage. In this case the thermal alarm stage is set to 100 % and thus practically ineffective.

Calculating the Overtemperature

The thermal replica is calculated individually for each phase. Address 4206 **CALC. METHOD** decides whether the highest of the three calculated temperatures (Θ *max*) or their arithmetic average (*Average* Θ) or the temperature calculated from the phase with maximum current (Θ *from Imax*) should be decisive for the thermal alarm and tripping stage.

Since an overload usually occurs in a balanced way, this setting is of minor importance. If unbalanced overloads are to be expected, however, these options lead to different results.

Averaging should only be used if a rapid thermal equilibrium is possible in the protected object, e.g. with belted cables. If the three phases are, however, more or less thermally isolated (e.g. single conductor cables or overhead lines), one of the maximum settings should be chosen at any rate.

2.20.3 Settings

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
4201	Ther. OVERLOAD		OFF ON Alarm Only	OFF	Thermal overload protection
4202	K-FACTOR		0.10 .. 4.00	1.10	K-Factor
4203	TIME CONSTANT		1.0 .. 999.9 min	100.0 min	Time constant
4204	Θ ALARM		50 .. 100 %	90 %	Thermal Alarm Stage
4205	I ALARM	1A	0.10 .. 4.00 A	1.00 A	Current Overload Alarm setpoint
		5A	0.50 .. 20.00 A	5.00 A	
4206	CALC. METHOD		Θ max Average Θ Θ from Imax	Θ max	Method of Acquiring Temperature

2.20.4 Information List

No.	Information	Type of Information	Comments
1503	>BLK ThOverload	SP	>BLOCK Thermal Overload Protection
1511	Th.Overload OFF	OUT	Thermal Overload Protection OFF
1512	Th.Overload BLK	OUT	Thermal Overload Protection BLOCKED
1513	Th.O/L ACTIVE	OUT	Thermal Overload Protection ACTIVE
1515	Th.O/L I Alarm	OUT	Th. Overload: Current Alarm (I alarm)

No.	Information	Type of In-formation	Comments
1516	Th.O/L Θ Alarm	OUT	Th. Overload Alarm: Near Thermal Trip
1517	Th.O/L Pickup	OUT	Th. Overload Pickup before trip
1521	Th.O/L TRIP	OUT	Th. Overload TRIP command

2.21 Analog outputs (optional)

2.21.1 Method of Operation

Depending on the ordering version of 7SA6 relay up to four analog outputs are available. The values to be transmitted via these analog outputs have been specified during the configuration of the scope of protection functions (see Section 2.1.1.2). A maximum of four of the following analog outputs are available:

- Measured value I_{L2} (current of phase L2) in per cent of the operational nominal current,

- Measured value U_{L2-L3} (phase-to-phase voltage L2-L3) in per cent of the operational nominal voltage

- Measured value $|\underline{P}|$ (absolute value of active power) in percent of operational rated apparent power $\sqrt{3} \cdot U_N \cdot I_N$,

- Measured value $|\underline{P}|$ (absolute value of reactive power) in percent of operational rated apparent power $\sqrt{3} \cdot U_N \cdot I_N$,

- Fault distance d in per cent of line length on the basis of the configured reactance per unit length and the line length (for addresses 1110 to 1113 refer to Section 2.1.5.1),

- Fault distance d in kilometres or miles, depending on the configured length unit (address 236), on the basis of the configured reactance per unit length (for address 1110 or 1112 see also Section 2.1.5),

- Fault current I_{max}, i. e. the maximum of 3 phase currents during clearance of the last fault, in primary Ampere, on the basis of the configured primary and secondary nominal current (for addresses 205 and 206 refer to Section 2.1.3.1).

The operational nominal values are the nominal values configured according to address 1103 and 1104 (refer to Section 2.1.5.1).

Analog values are output as load-independent currents. The analog outputs have a nominal range between 0 mA and 20 mA, their operating range can be up to 22.5 mA. The conversion factor and the valid range can be set.

If measured values are transmitted, they are cyclically updated. Always the last of the event-specific values — i.e. fault distance and fault current, which are only indicated after a fault, — remains unchanged until

- A new value is computed due to a new fault **or**

- Until binary input "`>RES Analog Out`" (FNo. 11000) is activated **or**

- The maximum output time set for the corresponding analog channel has elapsed e.g., **`Tmax OUTPUT(B1)`** (address 5009 for channel B1).

If the maximum output time is set to ∞ only the first two options apply. After the output was reset via the binary input, the output value goes back to 0.

2.21.2 Setting Notes

Measured Values   Once the measured values are selected for the analog outputs (Section 2.1.1.2, Addresses 150 to 153), set the conversion factor and the valid range for the available outputs, as follows:

- For analog output 1 at mounting location "B" (Port B1):

  Address 5001 **20 mA (B1)** = the percent value to be displayed at 20 mA.

  Address 5006 **MIN VALUE (B1)** the smallest valid value.

- For analog output 2 at mounting location "B" (Port B2):

  Address 5011 **20 mA (B2)** = the percent value to be displayed at 20 mA.

  Address 5016 **MIN VALUE (B2)** the smallest valid value.

- For analog output 1 at mounting location "D" (Port D1):

  Address 5021 **20 mA (D1)** = the percent value to be displayed at 20 mA.

  Address 5026 **MIN VALUE (D1)** the smallest valid value.

- For analog output 2 at mounting location "D" (Port D2):

  Address 5031 **20 mA (D2)** = the percent value to be displayed at 20 mA.

  Address 5036 **MIN VALUE (D2)** the smallest valid value.

The maximum value is 22.0mA. In case there is an overflow (value is outside of the maximal permissible threshold), then 22.5mA is output.

Example:

The phase current I_{L2} is to be output as analog output 1 at mounting location "B". 10 mA are the value at nominal operational current, consequently 20 mA mean 200 %. Values below 4 mA are invalid.

Settings

  Address 5001 **20 mA (B1) = 200.0** %,

  Address 5006 **MIN VALUE (B1)** = **4,0** mA,

Fault Location   For the fault location the conversion factor, i. e. the value to be output, is also set to 20 mA. Dependening on whether the fault location should be output in per cent of the line length or in length unit, set the following:

- For analog output 1 at mounting location "B" (Port B1):

  Address 5001 **20 mA (B1)** = the percent value to be displayed at 20 mA.

  or

  Address 5003 or 5004 **20 mA (B1)** = the value in kilometres or miles to be indicated at 20 mA.

- For analog output 2 at mounting location "B" (Port B2):

  Address 5011 **20 mA (B2)** = the percent value to be displayed at 20 mA.

  or

  Address 5013 or 5014 **20 mA (B2)** = the value in kilometres or miles to be indicated at 20 mA.

- For analog output 1 at mounting location "D" (Port D1):

  Address 5021 **20 mA (D1)** = the percent value to be displayed at 20 mA.

  or

  Address 5023 or 5024 **20 mA (D1)** = the value in kilometres or miles to be indicated at 20 mA.

- For analog output 2 at mounting location "D" (Port D2):

  Address 5031 **20 mA (D2)** =the percent value to be displayed at 20 mA.

  or

  Address 5033 or 5034 **20 mA (D2)** = the value in kilometres or miles to be indicated at 20 mA.

Set under Addresses 5007 **NEG VALUE (B1)**, 5017 **NEG VALUE (B2)**, 5027 **NEG VALUE (D1)** or 5037 **NEG VALUE (D2)** which output value is to be indicated in case the fault location is negative (fault in reverse direction). In addresses 5008 **OVERFLOW (B1)**, 5018 **OVERFLOW (B2)**, 5028 **OVERFLOW (D1)** or 5038 **OVERFLOW (D2)** the value of the numerical overflow (fault outside the maximum permissible range) is set.

The values for the negative fault location and the overflow must be set as large as possible since the linear transmission range of the fault location values ends 0.5mA below the smallest of these values.

Set in addresses 5009 **Tmax OUTPUT(B1)**, 5019 **Tmax OUTPUT(B2)**, 5029 **Tmax OUTPUT(D1)** or 5039 **Tmax OUTPUT(D2)** for how long the valid fault location is to be indicated. If a new fault occurs, the fault location is updated. Having set the value to ∞ the transmission of the last fault location will not be interrupted until a new one has been calculated or the output has been reset by activation of binary input "**>RES Analog Out**" (FNo. 11000).

<u>Example</u>:

The fault location is to be output in kilometres at mounting location "B" via the analog output 2; at 20 mA the value 50 kilometres is to be displayed. The output in the event of a fault in reverse direction is 19.84 mA, and 22.50 mA in case of an overflow. The value must be output for a time period of 5 s provided that no other fault occurs in the meantime.

Settings

Address 5013 **20 mA (B2)** = **50.0** km,

Address 5017 **NEG VALUE (B2)** = **19.84** mA,

Address 5018 **OVERFLOW (B2)** = **22.50** mA,

Adresse 5019 **Tmax OUTPUT(B2)** = **5.00** s,

In this case the fault location values can be output up to 19.84mA -0.5mA = 19.34mA. Theoretically, this corresponds to a value of 48.35 km.

Maximum Fault Current

Set the conversion factor and the maximum output time for the maximum fault current:

- For analog output 1 at mounting location "B" (Port B1):

  address 5002 **20 mA (B1)** = value in A, to be displayed at 20 mA,

  address 5009 **Tmax OUTPUT(B1)** maximum output time of the value;

- For analog output 2 at mounting location "B" (Port B2):

  address 5012 **20 mA (B2)** = value in A, to be displayed at 20 mA,

  address 5019 **Tmax OUTPUT(B2)** maximum output time of the value;

- For analog output 1 at mounting location "D" (Port D1):

  address 5022 **20 mA (D1)** = value in A, to be displayed at 20 mA,

  address 5029 **Tmax OUTPUT(D1)** maximum output time of the value;

- For analog output 2 at mounting location "D" (Port D2):

  address 5032 **20 mA (D2)** = value in A, to be displayed at 20 mA,

  address 5039 **Tmax OUTPUT(D2)** maximum output time of the value;

If you set the maximum output time to the value ∞ the transmission of the last fault current will not be interrupted until a new one is calculated or the output is reset by activation of the binary input "**>RES Analog Out**" (FNo. 11000).

The maximum possible value is 22.0 mA; in case of an overflow (a value which surpassed the operating range) 22.5 mA is output.

Example:

The fault current is to be output at mounting location "D" via the analog output 2; at 20 mA will correspond to 20000 A. The value must be output for a time period of 60 s provided that no other fault occurs in the meantime.

Settings

Address 5032 **20 mA (D2)** = **20000** A,

Address 5039 **Tmax OUTPUT(D2)** = **60.00** s

2.21.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
5001	20 mA (B1) =	10.0 .. 1000.0 %	200.0 %	20 mA (B1) correspond to
5002	20 mA (B1) =	10 .. 100000 A	20000 A	20 mA (B1) correspond to
5003	20 mA (B1) =	1.0 .. 1000.0 km	50.0 km	20 mA (B1) correspond to
5004	20 mA (B1) =	1.0 .. 1000.0 Miles	50.0 Miles	20 mA (B1) correspond to
5006	MIN VALUE (B1)	0.0 .. 5.0 mA	4.0 mA	Output value (B1) valid from
5007	NEG VALUE (B1)	1.00 .. 22.50 mA	19.84 mA	Output value (B1) for negative values
5008	OVERFLOW (B1)	1.00 .. 22.50 mA	22.50 mA	Output value (B1) for overflow
5009	Tmax OUTPUT(B1)	0.10 .. 180.00 sec; ∞	5.00 sec	Maximum output time (B1)
5011	20 mA (B2) =	10.0 .. 1000.0 %	200.0 %	20 mA (B2) correspond to
5012	20 mA (B2) =	10 .. 100000 A	20000 A	20 mA (B2) correspond to
5013	20 mA (B2) =	1.0 .. 1000.0 km	50.0 km	20 mA (B2) correspond to
5014	20 mA (B2) =	1.0 .. 1000.0 Miles	50.0 Miles	20 mA (B2) correspond to
5016	MIN VALUE (B2)	0.0 .. 5.0 mA	4.0 mA	Output value (B2) valid from
5017	NEG VALUE (B2)	1.00 .. 22.50 mA	19.84 mA	Output value (B2) for negative values
5018	OVERFLOW (B2)	1.00 .. 22.50 mA	22.50 mA	Output value (B2) for overflow
5019	Tmax OUTPUT(B2)	0.10 .. 180.00 sec; ∞	5.00 sec	Maximum output time (B2)
5021	20 mA (D1) =	10.0 .. 1000.0 %	200.0 %	20 mA (D1) correspond to

Addr.	Parameter	Setting Options	Default Setting	Comments
5022	20 mA (D1) =	10 .. 100000 A	20000 A	20 mA (D1) correspond to
5023	20 mA (D1) =	1.0 .. 1000.0 km	50.0 km	20 mA (D1) correspond to
5024	20 mA (D1) =	1.0 .. 1000.0 Miles	50.0 Miles	20 mA (D1) correspond to
5026	MIN VALUE (D1)	0.0 .. 5.0 mA	4.0 mA	Output value (D1) valid from
5027	NEG VALUE (D1)	1.00 .. 22.50 mA	19.84 mA	Output value (D1) for negative values
5028	OVERFLOW (D1)	1.00 .. 22.50 mA	22.50 mA	Output value (D1) for overflow
5029	Tmax OUTPUT(D1)	0.10 .. 180.00 sec; ∞	5.00 sec	Maximum output time (D1)
5031	20 mA (D2) =	10.0 .. 1000.0 %	200.0 %	20 mA (D2) correspond to
5032	20 mA (D2) =	10 .. 100000 A	20000 A	20 mA (D2) correspond to
5033	20 mA (D2) =	1.0 .. 1000.0 km	50.0 km	20 mA (D2) correspond to
5034	20 mA (D2) =	1.0 .. 1000.0 Miles	50.0 Miles	20 mA (D2) correspond to
5036	MIN VALUE (D2)	0.0 .. 5.0 mA	4.0 mA	Output value (D2) valid from
5037	NEG VALUE (D2)	1.00 .. 22.50 mA	19.84 mA	Output value (D2) for negative values
5038	OVERFLOW (D2)	1.00 .. 22.50 mA	22.50 mA	Output value (D2) for overflow
5039	Tmax OUTPUT(D2)	0.10 .. 180.00 sec; ∞	5.00 sec	Maximum output time (D2)

2.21.4 Information List

No.	Information	Type of Information	Comments
11000	>RES Analog Out	SP	>RESET Analog Outputs

2.22   Monitoring function

The device incorporates extensive monitoring functions of both the device hardware and software; the measured values are also continually checked to ensure their plausibility; the current and voltage transformer secondary circuits are thereby substantially covered by the monitoring function. It is also possible to implement trip circuit monitoring, using appropriate binary inputs as available.

2.22.1   Measurement Supervision

2.22.1.1   Hardware Monitoring

The device is monitored from the measuring inputs up to the command relays. Monitoring checks the hardware for malfunctions and disallowed conditions.

Auxiliary and Reference Voltages

The processor voltage of 5 V is monitored by the hardware, and if the voltage decreases below the minimum value, the processor is no longer operative. If it falls below the minimum value, the device will be put out of service. When the normal voltage returns, the processor system is restarted.

Failure of or switching off the supply voltage puts the device out of operation and a message is immediately generated by a normally closed contact. Brief voltage interruptions of up to 50 ms do not disturb the operational readiness of the device (see for the Technical Data).

The processor monitors the offset and reference voltage of the ADC (analog-digital converter). The protection is suspended if the voltages deviate outside an allowable range, and lengthy deviations are reported.

Battery

The buffer battery, which ensures operation of the internal clock and storage of counters and messages if the auxiliary voltage fails, is periodically checked for charge status. On its undershooting a minimum admissible voltage, the indication "Fail Battery" (FNo. 177) is issued.

If the device is not fed with auxiliary voltage for more than 1 to 2days, the internal clock is switched off automatically, i.e. the time is not registered any more. The data of message buffers and fault record buffers however are kept stored.

Memory Modules

The working memory (RAM) is tested when the system starts up. If a malfunction occurs then, the starting sequence is interrupted, the error LED and LED1 flash while the other LEDs blink at same intervals. During operation, the memory is checked using its checksum.

A checksum of the program memory (EPROM) is cyclically generated and compared with the stored program checksum.

A checksum for the parameter memory (FLASH-EPROM) is cyclically generated and compared with the checksum which is computed after each change of the stored parameters.

If a malfunction occurs, the processor system is restarted.

Scanning Frequency

The sampling frequency and the synchronism of the analog-digital converters is continuously monitored. If any deviations cannot be removed by remedied synchronization, then the processor system is restarted.

Measurement Value Acquisition – Currents

Up to four input currents are measured by the device. If the three phase currents and the earth fault current from the current transformer star point or a separated earth current transformer of the line to be protected are connected to the device, their digitised sum must be zero. Faults in the current circuit are recognised if

$$I_F = |\underline{I}_{L1} + \underline{I}_{L2} + \underline{I}_{L3} + k_I \cdot \underline{I}_E| > \Sigma\text{I THRESHOLD} \cdot I_N + \Sigma\text{I FACTOR} \cdot \Sigma\,|\,I\,|$$

Factor k_I (address **I4/Iph CT**) takes into account a possible different ratio of a separate I_E–transformer (e.g. cable core balance current transformer). Σ**I THRESHOLD** and Σ**I FACTOR** are setting parameters. The component Σ**I FACTOR** $\cdot\,\Sigma\,|\,I\,|$ takes into account the allowable current proportional ratio errors of the input transducers which are particularly prevalent during large fault currents (Figure 2-148). The dropout ratio is about 97 %. $\Sigma\,|\,I\,|$ is the sum of all currents:

$$\Sigma\,|\,I\,| = |\underline{I}_{L1}| + |\underline{I}_{L2}| + |\underline{I}_{L3}| + |k_I \cdot \underline{I}_E|$$

This malfunction is signaled as "Failure Σ I" (FNo. 162).

Note

Current sum monitoring can operate properly only when the residual current of the protected line is fed to the fourth current input (I_4) of the relay.
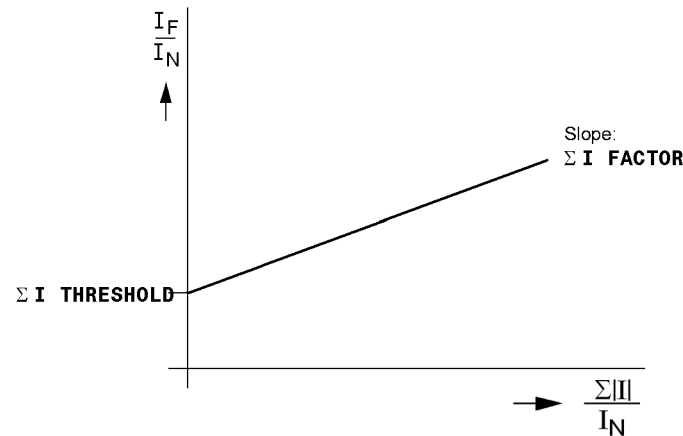
Figure 2-148   Current sum monitoring

Measured Value Acquisition – Voltages

Four measuring inputs are available in the voltage path: three for phase–earth voltages as well as one input for the displacement voltage (e-n voltage of an open delta connection) or a busbar voltage. If the displacement voltage is connected to the device, the sum of the three digitized phase voltages must equal three times the zero sequence voltage. Errors in the voltage transformer circuits are detected when

$$U_F = |\underline{U}_{L1} + \underline{U}_{L2} + \underline{U}_{L3} + k_U \cdot \underline{U}_{EN}| > 25 \text{ V}.$$

The factor k_U allows for a difference of the transformation ratio between the displacement voltage input and the phase voltage inputs (parameter **Uph / Udelta**). The dropout ratio is about 97%.

This malfunction is signaled as "Fail Σ U Ph-E" (FNo. 165).

Note

Voltage sum monitoring can operate properly only when an externally formed open delta voltage is connected to the residual voltage input of the relay.

2.22.1.2 Software Monitoring

Watchdog
For continuous monitoring of the program sequences, a time monitor is provided in the hardware (watchdog for hardware) that expires upon failure of the processor or an internal program, and causes a reset of the processor system with complete restart.

An additional software watchdog ensures that malfunctions during the processing of programs are discovered. This also initiates a restart of the processor system.

To the extent such a malfunction is not cleared by the restart, an additional restart attempt is begun. Following three failed restarts within 30 s the protection takes itself out of service and the red LED "ERROR" is illuminated. The device ready relay resets and alarms the device failure state with its normally closed contact ("life contact").

2.22.1.3 External Transformer Circuits

Interruptions or short circuits in the secondary circuits of the current transformers or voltage transformers, as well as faults in the connections (important for commissioning!), are detected and reported by the device. The measured quantities are periodically checked in the background for this purpose, as long as no system fault is present.

Current Symmetry
During normal system operation (i.e. the absence of a short-circuit fault), symmetry among the input currents is expected. The symmetry is monitored in the device with a magnitude comparison. The smallest phase current is compared to the largest phase current. Asymmetry is recognized if:

$| I_{min} | / | I_{max} | <$ **BAL. FACTOR I** as long as $I_{max} / I_N >$ **BALANCE I LIMIT** $/ I_N$

Thereby I_{max} is the largest of the three phase currents and I_{min} the smallest. The symmetry factor **BAL. FACTOR I** represents the allowable asymmetry of the phase currents while the limit value **BALANCE I LIMIT** is the lower limit of the operating range of this monitoring (see Figure 2-149). Both parameters can be set. The dropout ratio is about 97%.

After a settable time (5-100 s) this malfunction is signaled as "Fail I balance" (FNo. 163).
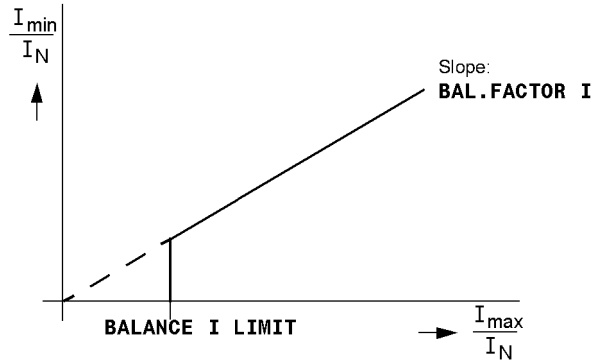
Figure 2-149   Current symmetry monitoring

Broken Conductor   A broken conductor of the protected line or in the current transformer secondary circuit can be detected, if the minimum current **PoleOpenCurrent** flows via the feeder. If the smallest phase currents is below this threshold while the other phase currents are above it, an interruption of a conductor may be assumed. If asymmetric current conditions are also present (see margin heading "Current Symmetry"), the device issues the indication "Fail Conductor" (FNo. 195).

Voltage Symmetry   During normal system operation (i.e. the absence of a short-circuit fault), symmetry among the input voltages is expected. The symmetry is monitored in the device with a magnitude comparison. The smallest phase-to-phase voltage is compared to the largest. Asymmetry is recognized if:

$| U_{min} | / | U_{max} | <$ **BAL. FACTOR U** as long as $| U_{max} | >$ **BALANCE U-LIMIT**

U_{max} is the highest, U_{min} the lowest of the three phase-to-phase voltages. The symmetry factor **BAL. FACTOR U** is the measure for the asymmetry of the conductor voltages; the limit value **BALANCE U-LIMIT** is the lower limit of the operating range of this monitoring (see Figure 2-150). Both settings are adjustable. The dropout ratio is about 97%.

After a settable time, this malfunction is signaled as "Fail U balance" (FNo. 167).
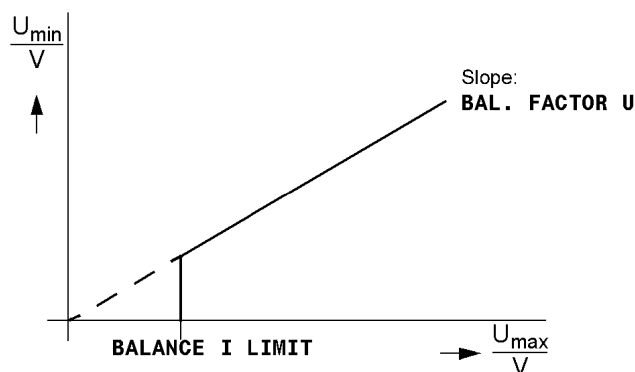
Figure 2-150   Voltage symmetry monitoring

Voltage Phase Sequence   The verification of the faulted phases and the phase preference, direction measurement and polarization with quadrature voltages usually demand clockwise rotation of

the measured values. Phase rotation of measured voltages is checked by verifying the phase sequences of the voltages

$\underline{U}_{L1}$ before$\underline{U}_{L2}$ before$\underline{U}_{L3}$

This check takes place if each measured voltage has a minimum magnitude of

$|U_{L1}|, |U_{L2}|, |U_{L3}| > 40 \ V/\sqrt{3}$

In case of negative phase rotation, the indication "`Fail Ph. Seq.`" (FNo. 171) is output.

If the system has a negative phase rotation, this must have been set during the configuration of the power system data (Subsection 2.1.3.1, address 235). In such event, the phase rotation monitoring applies to the corresponding opposite phase sequence.

Asymmetrical Measuring Voltage Failure "Fuse Failure Monitor"

In the event of measured voltage failure due to a short circuit or broken conductor in the voltage transformer secondary circuit certain measuring loops may mistakenly see a voltage of zero, which due to the load current may result in an unwanted pick-up or even trip.

If fuses are used instead of a secondary miniature circuit breaker (VT mcb) with connected auxiliary contacts, then the "fuse failure monitoring" can detect problems in the voltage transformer secondary circuit. Of course, the miniature circuit breaker and the "fuse failure monitor" can be used at the same time.

The asymmetrical measured voltage failure is characterized by its voltage asymmetrical with simultaneous current symmetry. Figure 2-151 depicts the logic diagram of the "fuse failure monitor" during asymmetrical failure of the measured voltage.

If there is substantial voltage asymmetry of the measured values, without asymmetry of the currents being registered at the same time, this indicates the presence of an asymmetrical failure in the voltage transformer secondary circuit.

The asymmetry of the voltage is detected by the fact that either the zero sequence voltage or the negative sequence voltage exceed a settable value **FFM U>(min)**. The current is assumed to be sufficiently symmetrical if both the zero sequence as well as the negative sequence current are below the settable threshold **FFM I< (max)**.

In non-earthed systems, the zero-sequence system quantities are no reliable criterion since a considerable zero-sequence voltage occurs also in case of a simple earth fault where a significant zero sequence current does not necessarily flow. Therefore, the zero-sequence voltage is not evaluated in such networks but only the negative-sequence voltage (parameter **SystemStarpoint**).

As soon as this state is recognized, the distance protection and all other functions that operate on the basis of undervoltage (e.g. also weak infeed tripping) are blocked. The immediate blocking demands current flow in at least one of the phases. The distance protection may be switched over to definite time overcurrent emergency operation if the overcurrent protection was configured accordingly (refer to Section 2.11).

The fast blocking may not occur as long as one phase is without voltage due to a single-pole dead time condition, as the non-symmetry of the measured values arising in this state is due to the switching state of the line and not due to a failure in the secondary circuits. Accordingly, the fast blocking is disabled when the line is tripped single-pole (internal information "1pole open" in the logic diagram).

If a zero sequence or negative sequence current is detected within approximately 10 s after recognition of this criterion, the protection assumes a short-circuit and removes the blocking by the "fuse failure monitor" for the duration of the fault. If on the other hand the voltage failure criterion is present for longer than approx. 10 s, the blocking is permanently activated (latching of the voltage criterion after 10 s). Only 10 s after

the voltage criterion has been removed by correction of the secondary circuit failure, will the blocking automatically reset, thereby releasing the blocked protection functions again.
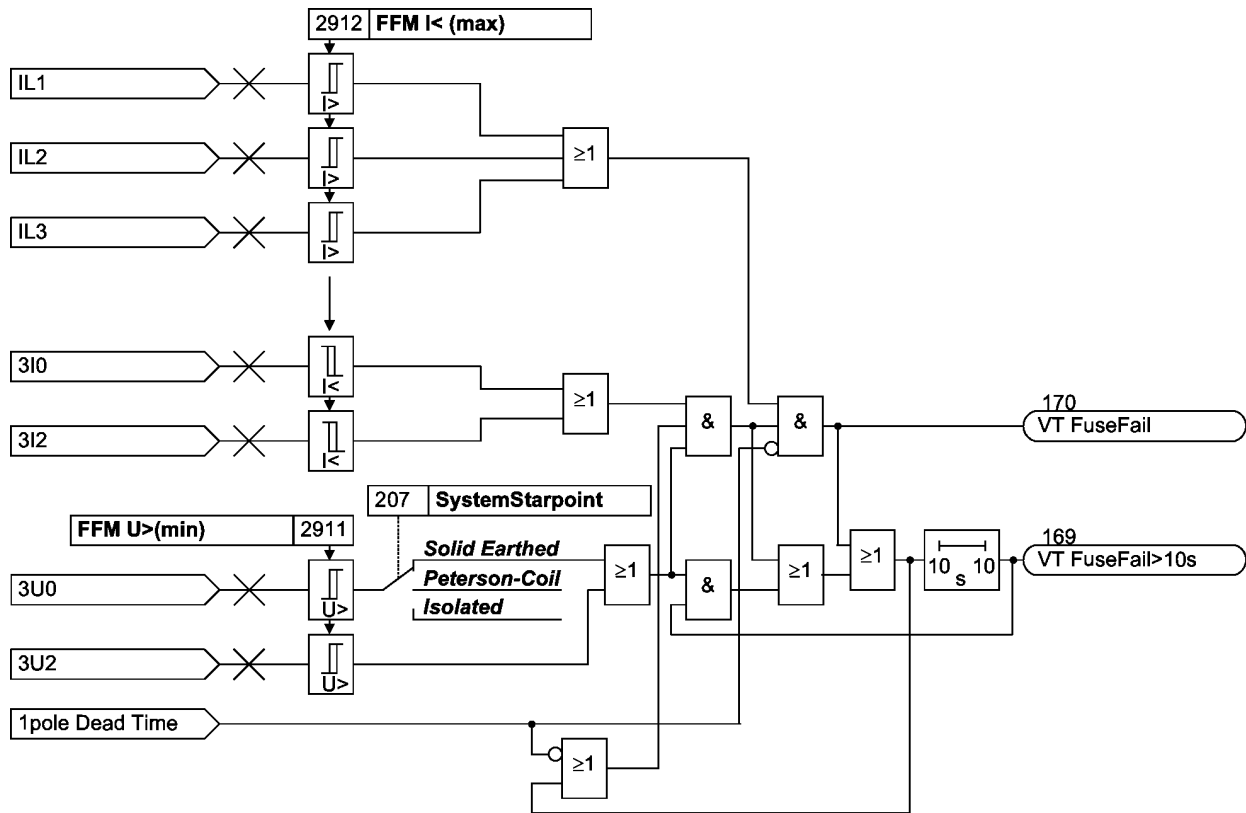
Figure 2-151   Logic diagram of the fuse failure monitor with zero and negative sequence system

Three-Phase Measuring Voltage Failure "Fuse Failure Monitor"

A three-phase failure of the secondary measured voltage can be distinguished from an actual system fault by the fact that the currents have no significant change in the event of a failure in the secondary measured voltage. For this reason, the sampled current values are routed to a buffer, so that the difference between the present and stored current values can be analyzed to recognize the magnitude of the current differential (current differential criterion). A three-pole voltage failure is detected if

- all three phase–earth voltages are smaller than the threshold **FFM U<max (3ph)**,
- the current differential in all three phases is smaller than the threshold **FFM Idelta (3p)**, and
- all three phase current amplitudes are greater than the minimum current **Iph>** for impedance measurement by the distance protection.

If no stored current values are present (yet), the current magnitude criterion is resorted to. A three-pole system voltage failure is detected in this case if

- all three phase–earth voltages are smaller than the threshold **FFM U<max (3ph)**,
- all three phase current amplitudes are smaller than the minimum current **Iph>** for impedance measurement by the distance protection, and
- all three phase current amplitudes are greater than a fixed set noise threshold (40 mA).

If such a voltage failure is recognized, the distance protection and all other functions that operate on the basis of undervoltage (e.g. also weak infeed tripping) are blocked until the voltage failure is removed; thereafter the blocking is automatically removed. Definite time overcurrent emergency operation is possible during the voltage failure if the overcurrent protection was configured accordingly (refer to Section 2.11).

Additional Measured Voltage Failure Monitoring

If no measuring voltage is available after power-on of the device (e.g. because the voltage transformers are not connected), the absence of the voltage can be detected and reported by an additional monitoring function. Where circuit breaker auxiliary contacts are used, they should be used for monitoring as well. Figure 2-152 shows the logic diagram of the measured voltage failure monitoring. A failure of the measured voltage is detected if the following conditions are met at the same time:

- all three phase-to-earth voltages are smaller than **FFM U<max (3ph)**,
- at least one phase current is larger than **PoleOpenCurrent** or at least one breaker pole is closed (can be set),
- no protection function has picked up,
- this condition persists for a settable time **T V-Supervision** (default setting: 3 s).

This time **T V-Supervision** is required to prevent that a voltage failure is detected before the protection picks up.

If a failure is detected by these criteria, the annunciation 168 "Fail U absent" is output, and the device switches to emergency operation (see Section 2.11).
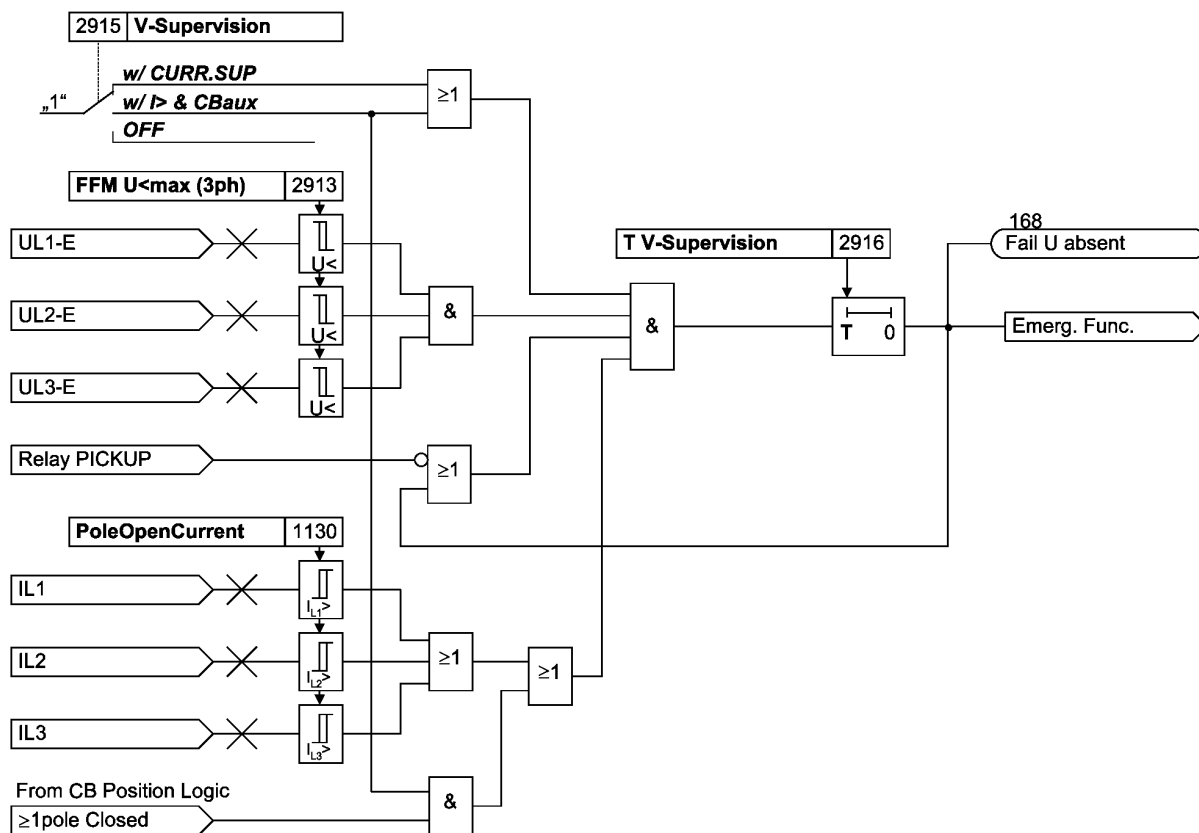
Figure 2-152   Logic diagram of the additional measured voltage failure monitoring

2.22.1.4 Malfunction Responses

Depending on the type of malfunction detected, an indication is sent, a restart of the processor system initiated, or the device is taken out of service. After three unsuccessful restart attempts, the device is also taken out of service. The operational readiness NC contact ("life contact") operates to indicate the device is malfunctioning. The red "ERROR" LED on the device front lights up, provided that there is an internal auxiliary voltage, and the green "RUN" LED goes off. If the internal auxiliary voltage fails, then all LEDs are dark. Table 2-15 shows a summary of the monitoring functions and the malfunction responses of the relay.

Table 2-15   Summary of Malfunction Responses by the Protection Relay

Monitoring	Possible Causes	Malfunction Response	Alarm (FNo.)	Output
Auxiliary Supply Voltage Loss	External (aux. voltage) internal (converter)	Device out of operation or alarm	All LEDs dark "Error 5V" (144)	DOK[2] drops out
Measured Value Acquisition	Internal (converter or reference voltage)	Protection out of operation, alarm	LED "ERROR" "Error A/D-conv." (181)	DOK[2] drops out
Battery	Internal (battery)	Message	"Fail Battery" (177)	as allocated
Hardware Watchdog	Internal (processor failure)	Device not in operation	LED "ERROR"	DOK[2] drops out
Software Watchdog	Internal (program sequence)	Restart attempt [1]	LED "ERROR"	DOK[2] drops out
ROM	Internal (RAM)	Restart attempt [1]), Restart abort Device not in operation	LED flashes	DOK[2] drops out
RAM	Internal (EPROM)	Restart attempt [1]	LED "ERROR"	DOK[2] drops out
Settings memory	internal (Flash-EPROM or RAM)	Restart attempt [1]	LED "ERROR"	DOK[2] drops out
Scanning frequency	Internal (clock generator)	Restart attempt [1]	LED "ERROR"	DOK[2] drops out
1 A/5 A setting	1/5 A jumper wrong	Messages: Protection out of operation	"Error1A/5Awrong" (192) "Error A/D-conv." (181) LED "ERROR"	DOK[2] drops out
Calibration data	Internal (EEPROM or RAM)	Indication: Using default values	"Alarm NO calibr" (193)	As allocated
Earth current transformer sensitive/insensitive	I/O module does not correspond to the order number (MLFB) of the device.	Messages: Protection out of operation	"Error neutralCT" (194)"Error A/D-conv." (181) LED "ERROR"	DOK[2] drops out
Modules	Module does not comply with ordering number (MLFB).	Messages: Protection out of operation	"Error Board 1...7" (FNo. 183 ... 189) and if applicable "Error A/D-conv.". (181)	DOK[2] drops out
Current sum	Internal (measured value acquisition)	Message	"Failure Σ I" (162)	As allocated
Current symmetry	External (power system or current transformer)	Message	"Fail I balance" (163)	as allocated
Broken Conductor	External (power system or current transformer)	Message	"Fail Conductor" (195)	As allocated
Voltage sum	internal (measured value acquisition)	Message	"Fail Σ U Ph-E" (165)	As allocated

Monitoring	Possible Causes	Malfunction Response	Alarm (FNo.)	Output
Voltage Symmetry	External (power system or voltage transformer)	Message	"Fail U balance" (167)	As allocated
Voltage phase sequence	External (power system or connection)	Message	"Fail Ph. Seq." (171)	as allocated
Measuring voltage failure, three-phase "Fuse Failure Monitor"	External (power system or connection)	Message Distance protection is blocked Undervoltage protection is blocked	"VT FuseFail>10s" (169)	as allocated
Voltage failure, one-/two-phase "Fuse Failure Monitor"	External (voltage transformers)	Message Distance protection is blocked Undervoltage protection is blocked	"VT FuseFail>10s" (169)	As allocated
Voltage failure, three-phase	external (power system or connection)	Message Distance protection is blocked Undervoltage protection is blocked	"Fail U absent" (168)	As allocated
Trip Circuit Monitoring	External (trip circuit or control voltage)	Message	"FAIL: Trip cir." (6865)	as allocated

[1] after three unsuccessful restarts, the device is taken out of service.

[2] DOK = "Device OK" = NC contact of the operational readiness relay = life contact

2.22.1.5 Setting Notes

General

The sensitivity of measured value monitor can be modified. Default values are set at the factory, which are sufficient in most cases. If especially high operating asymmetry in the currents and/or voltages is to be expected for the application, or if it becomes apparent during operation that certain monitoring functions activate sporadically, then the setting should be less sensitive.

The measurement supervision can be switched *ON* or *OFF* in address 2901 **MEASURE. SUPERV**.

Symmetry Monitoring

Address 2902 **BALANCE U-LIMIT** determines the limit voltage (Phase-to-Phase), above which the voltage symmetry monitor is effective. Address 2903 **BAL. FACTOR U** is the associated symmetry factor; that is, the slope of the symmetry characteristic curve. The alarm "Fail U balance" (FNo. 167) can be delayed at address 2908 **T BAL. U LIMIT**. These settings can only be changed via DIGSI® at **Additional Settings**.

Address 2904 **BALANCE I LIMIT** determines the limit current, above which the current symmetry monitor is effective. Address 2905 **BAL. FACTOR I** is the associated symmetry factor; that is, the slope of the symmetry characteristic curve. The alarm "Fail I balance" (FNo. 163) can be delayed at address 2909 **T BAL. I LIMIT**. These settings can only be changed via DIGSI® at **Additional Settings**.

Summation Monitoring

Address 2906 Σ**I THRESHOLD** determines the limit current, above which the current sum monitor is activated (absolute portion, only relative to I_N). The relative portion (relative to the maximum conductor current) for activating the current sum monitor is set

at address 2907 Σ**I FACTOR**. These settings can only be changed via DIGSI® at **Additional Settings**.

Note

Current sum monitoring can operate properly only when the residual current of the protected line is fed to the fourth current input (I_4) of the relay.

Asymmetrical Measuring Voltage "Failure Fuse Failure Monitor"

The settings of the "fuse failure monitor" for asymmetrical measured voltage failure must be selected such that on the other hand reliable pickup of the monitoring is ensured in the case of loss of a single-phase voltage (address 2911 **FFM U>(min)**), while on the other hand a pickup due to earth faults in an earthed system is avoided. In accordance with this requirement, address 2912 **FFM I< (max)** must be set sufficiently sensitive (below the smallest fault current due to earth faults). These settings can only be changed via DIGSI® at **Additional Settings**.

In address 2910 **FUSE FAIL MON.**, the "fuse failure monitor" can be switched *OFF* e.g. during asymmetrical testing.

Three-Phase Measuring Voltage Failure "Fuse Failure Monitor"

In address 2913 **FFM U<max (3ph)** the minimum voltage threshold is set. If the measured voltage drops below this threshold and a simultaneous current jump which exceeds the limits according to address 2914 **FFM Idelta (3p)** is not detected while all three phase currents are greater than the minimum current required for the impedance measurement by the distance protection according to address 1202 **Minimum Iph>**, a three phase measured voltage failure is recognized. These settings can only be changed via DIGSI® at **Additional Settings**.

In address 2910 **FUSE FAIL MON.**, the "fuse failure monitor" can be switched *OFF* e.g. during asymmetrical testing.

Additional Measured Voltage Failure Monitoring

At address 2915 **V-Supervision** the measuring voltage failure monitor can be switched to *w/ CURR.SUP*, *w/ I> & CBaux* or *OFF*. Address 2916 **T V-Supervision** is used to set the waiting time of the voltage failure monitoring. This setting can only be changed via DIGSI® at **Additional Settings**.

Circuit Breaker for Voltage Transformers

If a circuit breaker for voltage transformers (VT mcb) is installed in the secondary circuit of the voltage transformers, the status is sent, via binary input, to the device informing it about the position of the VT mcb. If a short-circuit in the secondary side initiates the tripping of the VT mcb, the distance protection function has to be blocked immediately, since otherwise it would be spuriously tripped due to the lacking measured voltage during a load current. The blocking must be faster than the first stage of the distance protection. This requires an extremely short reaction time for VT mcb ($\leq$ 4 ms at 50 Hz, $\leq$ 3 ms at 60 Hz nominal frequency). If this cannot be ensured, the reaction time is to be set under address 2921 **T mcb**.

2.22.1.6 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	C	Setting Options	Default Setting	Comments
2901	MEASURE. SUPERV		ON OFF	ON	Measurement Supervision
2902A	BALANCE U-LIMIT		10 .. 100 V	50 V	Voltage Threshold for Balance Monitoring
2903A	BAL. FACTOR U		0.58 .. 0.95	0.75	Balance Factor for Voltage Monitor
2904A	BALANCE I LIMIT	1A	0.10 .. 1.00 A	0.50 A	Current Balance Monitor
		5A	0.50 .. 5.00 A	2.50 A	
2905A	BAL. FACTOR I		0.10 .. 0.95	0.50	Balance Factor for Current Monitor
2906A	ΣI THRESHOLD	1A	0.05 .. 2.00 A	0.10 A	Summated Current Monitoring Threshold
		5A	0.25 .. 10.00 A	0.50 A	
2907A	ΣI FACTOR		0.00 .. 0.95	0.10	Summated Current Monitoring Factor
2908A	T BAL. U LIMIT		5 .. 100 sec	5 sec	T Balance Factor for Voltage Monitor
2909A	T BAL. I LIMIT		5 .. 100 sec	5 sec	T Current Balance Monitor
2910	FUSE FAIL MON.		ON OFF	ON	Fuse Failure Monitor
2911A	FFM U>(min)		10 .. 100 V	30 V	Minimum Voltage Threshold U>
2912A	FFM I< (max)	1A	0.10 .. 1.00 A	0.10 A	Maximum Current Threshold I<
		5A	0.50 .. 5.00 A	0.50 A	
2913A	FFM U<max (3ph)		2 .. 100 V	5 V	Maximum Voltage Threshold U< (3phase)
2914A	FFM Idelta (3p)	1A	0.05 .. 1.00 A	0.10 A	Delta Current Threshold (3phase)
		5A	0.25 .. 5.00 A	0.50 A	
2915	V-Supervision		w/ CURR.SUP w/ I> & CBaux OFF	w/ CURR.SUP	Voltage Failure Supervision
2916A	T V-Supervision		0.00 .. 30.00 sec	3.00 sec	Delay Voltage Failure Supervision
2921	T mcb		0 .. 30 ms	0 ms	VT mcb operating time

2.22.1.7 Information List

No.	Information	Type of Information	Comments
161	Fail I Superv.	OUT	Failure: General Current Supervision
162	Failure Σ I	OUT	Failure: Current Summation
163	Fail I balance	OUT	Failure: Current Balance
164	Fail U Superv.	OUT	Failure: general Voltage Supervision
165	Fail Σ U Ph-E	OUT	Failure: Voltage summation Phase-Earth
167	Fail U balance	OUT	Failure: Voltage Balance
168	Fail U absent	OUT	Failure: Voltage absent
169	VT FuseFail>10s	OUT	VT Fuse Failure (alarm >10s)
170	VT FuseFail	OUT	VT Fuse Failure (alarm instantaneous)
171	Fail Ph. Seq.	OUT	Failure: Phase Sequence
195	Fail Conductor	OUT	Failure: Broken Conductor
196	Fuse Fail M.OFF	OUT	Fuse Fail Monitor is switched OFF
197	MeasSup OFF	OUT	Measurement Supervision is switched OFF

2.22.2 Trip circuit supervision

2.22.2.1 Method of Operation

Trip Circuit Monitoring

The 7SA6 incorporates an integrated trip circuit supervision function. Depending on the number of available binary inputs (not connected to a common potential), monitoring with one or two binary inputs can be selected. If the routing of the required binary inputs does not comply with the selected monitoring mode, an alarm is issued ("TripC ProgFAIL") with identification of the non-compliant circuit. When using two binary inputs, malfunctions in the trip circuit can be detected under all circuit breaker conditions. When only one binary input is used, malfunctions in the circuit breaker itself cannot be detected. If single-pole tripping is possible, a separate trip circuit supervision can be implemented for each circuit breaker pole provided the required binary inputs are available.

Monitoring with Two Binary Inputs

When using two binary inputs, these are connected according to Figure 2-153, parallel to the associated trip contact on one side, and parallel to the circuit breaker auxiliary contacts on the other.

A precondition for the use of the trip circuit supervision is that the control voltage for the circuit breaker is higher than the total of the minimum voltages drops at the two binary inputs ($U_{Ctrl} > 2 \ U_{BImin}$). Since at least 19 V are needed for each binary input, the monitor can only be used with a system control voltage of over 38 V.
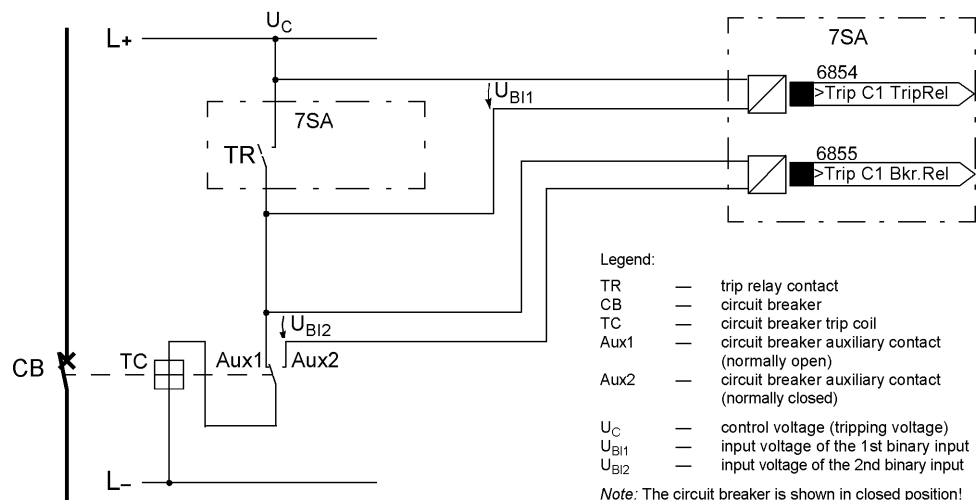
Figure 2-153   Principle of the trip circuit monitoring with two binary inputs

Monitoring with two binary inputs does not only detect interruptions in the trip circuit and loss of control voltage, it also monitors the response of the circuit breaker using the position of the circuit breaker auxiliary contacts.

Depending on the conditions of the trip contact and the circuit breaker, the binary inputs are activated (logical condition "H" in the following table), or short-circuited (logical condition "L").

A state in which both binary inputs are not activated ("L") is only possible in intact trip circuits for a short transition period (trip relay contact closed but circuit breaker not yet open).

A continuous state of this condition is only possible when the trip circuit has been interrupted, a short-circuit exists in the trip circuit, a loss of battery voltage occurs, or malfunctions occur with the circuit breaker mechanism. Therefore, it is used as monitoring criterion.

Table 2-16   Condition Table for Binary Inputs, Depending on RTC and CB Position

No.	Trip contact	Circuit breaker	AuxCont 1	AuxCont 2	BI 1	BI 2
1	Open	ON	Closed	Open	H	L
2	Open	OFF	Open	Closed	H	H
3	Closed	ON	Closed	Open	L	L
4	Closed	OFF	Open	Closed	L	H

The conditions of the two binary inputs are scanned periodically. A query takes place about every 500 ms. If three consecutive conditional checks detect an abnormality, an annunciation is reported (see Figure 2-154). The repeated measurements help to determine the delay of the alarm message and to avoid that an alarm is output during short-time transition periods. After the fault in the trip circuit is removed, the alarm is reset automatically after the same time.
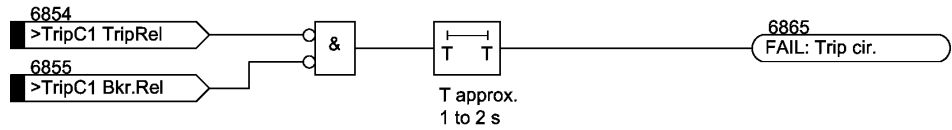
Figure 2-154   Logic diagram of the trip circuit monitoring with two binary inputs

Monitoring with One Binary Input

The binary input is connected in parallel to the respective command relay contact of the protection device according to Figure 2-155. The circuit breaker auxiliary contact is bridged with a high-ohm substitute resistor R.

The control voltage for the circuit breaker should be at least twice as high as the minimum voltage drop at the binary input ($U_{Ctrl} > 2 \cdot U_{BImin}$). Since at least 19 V are needed for the binary input, the monitor can be used with a system control voltage of over 38 V.

A calculation example for the resistance shunt R is shown in the configuration notes in Section "Mounting and Connections", margin "Trip Circuit Supervision".
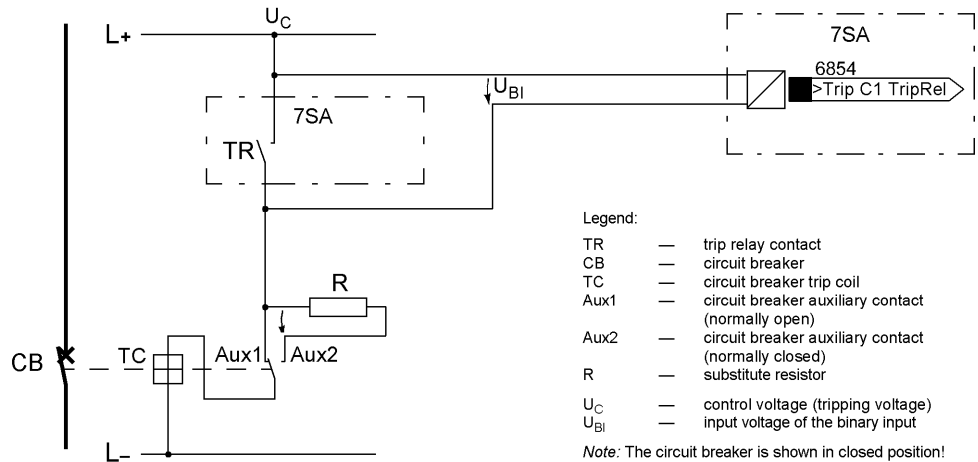
Figure 2-155   Principle of the trip circuit monitoring with one binary input

During normal operation, the binary input is activated (logical condition "H") when the trip contact is open and the trip circuit is intact, because the monitoring circuit is closed by either the circuit breaker auxiliary contact (if the circuit breaker is closed) or through the bypass resistor R. Only as long as the trip contact is closed, the binary input is short circuited and thereby deactivated (logical condition "L").

If the binary input is permanently deactivated during operation, an interruption in the trip circuit or a failure of the (trip) control voltage can be assumed.

The trip circuit monitor does not operate during system faults. A momentary closed tripping contact does not lead to a failure message. If however other trip relay contacts from different devices are connected in parallel in the trip circuit, the failure alarm must be delayed by **Alarm Delay** (refer also to Figure 2-156). After the fault in the trip circuit is removed, the alarm is reset automatically after the same time.
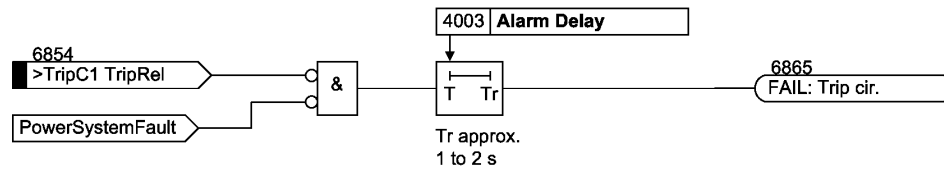
Figure 2-156   Logic diagram for trip circuit monitoring with one binary input

2.22.2.2 Setting Notes

General

The number of circuits to be monitored was set during the configuration in address 140 **Trip Cir. Sup.** (Section 2.1.1.2). If the trip circuit supervision is not used at all, the setting **Disabled** must be applied there.

The trip circuit supervision can be switched **ON** or **OFF** in address 4001 **FCT TripSuperv.**. The number of binary inputs that shall be used in each of the monitored circuits is set in address 4002 **No. of BI**. If the routing of the binary inputs required for this does not comply with the selected supervision mode, the alarm "TripCx ProgFAIL..." is given (with identification of the non-compliant circuit).

Monitoring with One Binary Input

The alarm for monitoring with two binary inputs is always delayed by approx. 1 s to 2 s, whereas the delay time of the alarm for monitoring with one binary input can be set in address 4003 **Alarm Delay**. 1 s to 2 are sufficient if only the 7SA6 device is connected to the trip circuits as the trip circuit supervision does not operate during a system fault. If, however, trip contacts from other devices are connected in parallel in the trip circuit, the alarm must be delayed such that the longest trip command duration can be reliably bridged.

2.22.2.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
4001	FCT TripSuperv.	ON OFF	OFF	TRIP Circuit Supervision is
4002	No. of BI	1 .. 2	2	Number of Binary Inputs per trip circuit
4003	Alarm Delay	1 .. 30 sec	2 sec	Delay Time for alarm

2.22.2.4 Information List

No.	Information	Type of Information	Comments
6854	>TripC1 TripRel	SP	>Trip circuit superv. 1: Trip Relay
6855	>TripC1 Bkr.Rel	SP	>Trip circuit superv. 1: Breaker Relay
6856	>TripC2 TripRel	SP	>Trip circuit superv. 2: Trip Relay
6857	>TripC2 Bkr.Rel	SP	>Trip circuit superv. 2: Breaker Relay
6858	>TripC3 TripRel	SP	>Trip circuit superv. 3: Trip Relay
6859	>TripC3 Bkr.Rel	SP	>Trip circuit superv. 3: Breaker Relay
6861	TripC OFF	OUT	Trip circuit supervision OFF

No.	Information	Type of In-formation	Comments
6865	FAIL: Trip cir.	OUT	Failure Trip Circuit
6866	TripC1 ProgFAIL	OUT	TripC1 blocked: Binary input is not set
6867	TripC2 ProgFAIL	OUT	TripC2 blocked: Binary input is not set
6868	TripC3 ProgFAIL	OUT	TripC3 blocked: Binary input is not set

2.23 Function control and circuit breaker testing

2.23.1 Function Control

The function control is the control centre of the device. It coordinates the sequence of the protection and ancillary functions, processes their decisions and the information coming from the power system.

Applications
- Line energization recognition,
- Processing of the circuit breaker position,
- Open Pole Detector,
- Fault detection logic
- Tripping logic.

2.23.1.1 Line Energization Recognition

During energization of the protected object, several measures may be required or desirable. Following a manual closure onto a short-circuit, immediate trip of the circuit breaker is usually required. In the distance protection for example, this is implemented by activation of the overreaching zone Z1B and the switch on to fault function for a short period following manual closure. In addition at least one stage of each short-circuit protection function can be selected to trip without time delay following manual closure as described in the corresponding sections. Also see Subsection 2.1.5.1 at margin heading "Circuit Breaker Status".

The manual closing command must be indicated to the device via a binary input. In order to be independent of the duration that the switch is closed, the command is set to a defined length in the device (adjustable with the address 1150 **SI Time Man.Cl**). Figure 2-157 shows the logic diagram.
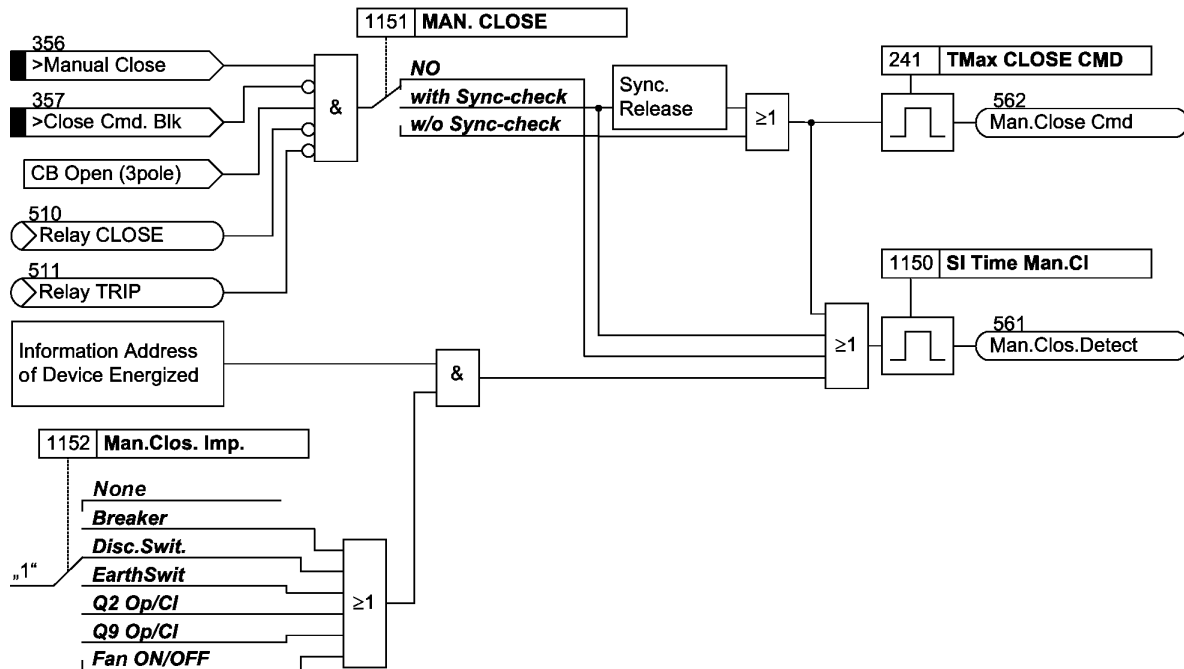
Figure 2-157   Logic diagram of the manual closing procedure

Reclosure via the integrated control functions such as — on-site control, control via DIGSI ®, control via serial interface — can have the same effect as manual reclosure, see parameter 1152.

If the device has an integrated automatic reclosure, the integrated manual closure logic of the 7SA6 automatically distinguishes between an external control command via the binary input and an automatic reclosure by the internal automatic reclosure so that the binary input "`>Manual Close`" can be connected directly to the control circuit of the close coil of the circuit breaker (Figure 2-158). Each reclosure that is not initiated by the internal automatic reclosure function is interpreted as a manual reclosure, even it has been initiated by a control command from the device.
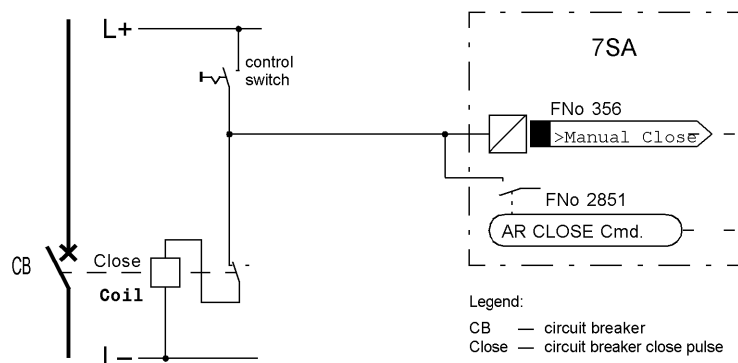
Figure 2-158   Manual closure with internal automatic reclosure

If, however, external close commands which should not activate the manual close function are possible (e.g. external reclosure device), the binary input "`>Manual`"

`Close"` must be triggered by a separate contact at the control discrepancy switch (Figure 2-159).

If in that latter case a manual close command can also be given by means of an internal control command from the device, such a command must be combined with the manual CLOSE function via parameter 1152 **Man.Clos. Imp.** (Figure 2-157).
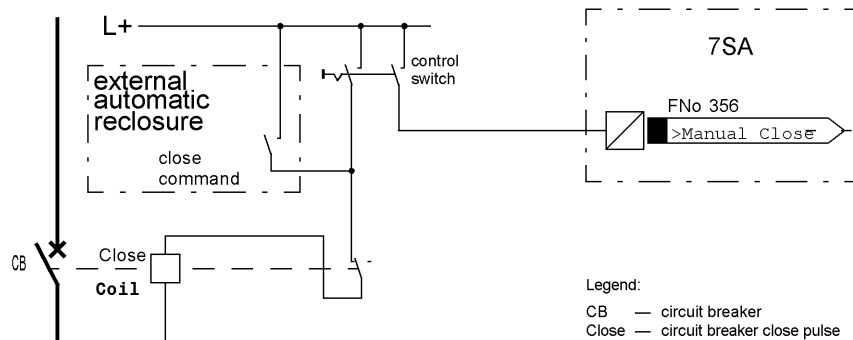
Figure 2-159   Manual closing with external automatic reclosure device

Besides the manual CLOSE detection the device records any energization of the line via the integrated line energization detection. This function processes a change-of-state of the measured quantities as well as the position of the breaker auxiliary contacts. The current status of the circuit breaker is detected, as described in the following Section at "Detection of the Circuit Breaker Position". The criteria for the line energization detection change according to the local conditions of the measuring points and the setting of the parameter address 1134 **Line Closure** (see Section 2.1.5 at margin heading "Circuit Breaker Status").

The phase-phase currents and the phase-earth voltages are available as measuring quantities. A flowing current excludes that the circuit breaker is open (exception: a fault between current transformer and circuit breaker). If the circuit breaker is closed, it may however still occur that no current is flowing. The voltages can only be used as a criterion for the de-energized line if the voltage transformers are installed on the feeder side. Therefore, the device only evaluates those measuring quantities that provide information on the status of the line according to address 1134.

But a change-of-state, such as a voltage jump from zero to a considerable value (address 1131 **PoleOpenVoltage**) or the occurrence of a considerable current (address 1130 **PoleOpenCurrent**) without a line voltage appearing at the same time, can be a reliable indicator for line energization as such changes can neither occur during normal operation nor in case of a fault.

The position of the auxiliary contacts of the circuit breakers indicate directly the position of the circuit breaker. If the circuit breaker is controlled single-pole, the critierion for energization is if at least one contact changes from open to closed.

The detected energization is signaled through the message "Line closure" (FNo 590). In order to be independent of the duration that the switch is closed, the signal is set to a defined length in the device (adjustable with the address 1132 **SI Time all Cl.**). Figure 2-160 shows the logic diagram.
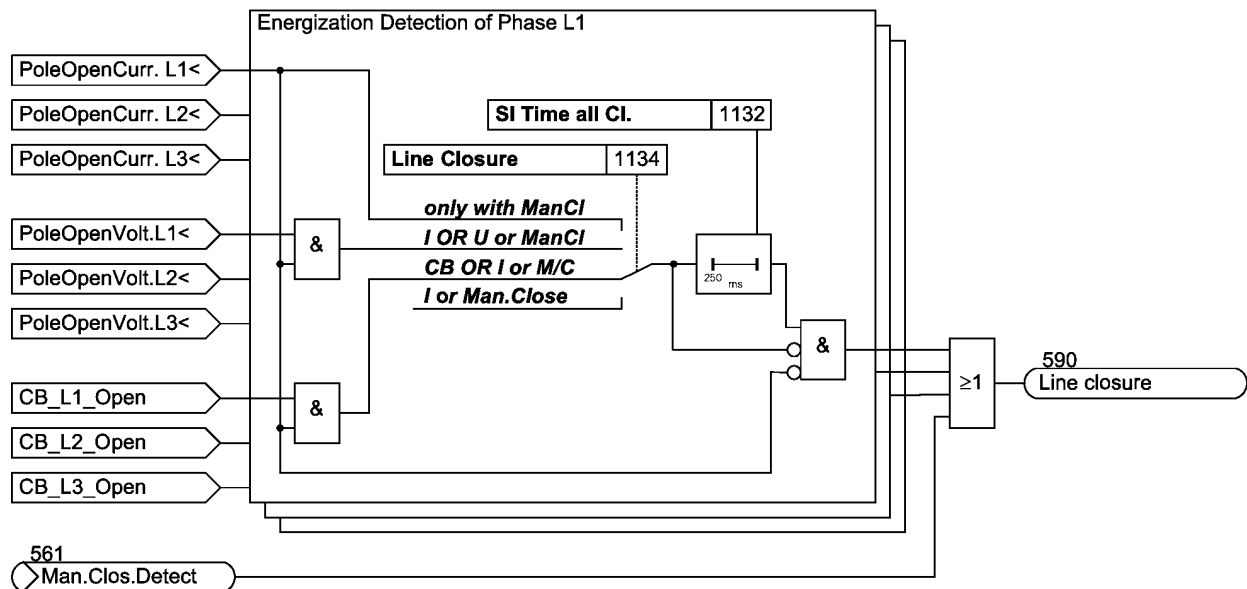
Figure 2-160   Generation of the energisation signal

The line energization detection enables the distance protection, earth fault protection, time-overcurrent protection and high-current switch onto fault protection to trip without delay after energization of their line was detected.

Depending on the configuration of the distance protection, an undelayed trip command can be generated after energization for each pickup or for pickup in zone Z1B. The stages of the earth fault protection and of the time-overcurrent protection together generate an undelayed TRIP command if this was provided for in the configuration. The switch onto fault protection is released phase-selectively and three-pole in case of manual closure after energization detection. In order to generate as quickly as possible a trip command after an energization, the fast switch-on-to-fault protection is released selectively for each phase already when the line is open.

In order to avoid that an energization is detected mistakenly, the state "line open", which precedes any energization, must apply for at least 250 ms.

2.23.1.2 Detection of the Circuit Breaker Position

For Protection Purposes

Information regarding the circuit breaker position is required by various protection and supplementary functions to ensure their optimal functionality. This is for example of assistance for

- the echo function in conjunction with the distance protection with teleprotection (refer to Subsection 2.6),
- the echo function in conjunction with directional earth fault comparison scheme (refer to Subsection 2.8),
- weak infeed tripping (refer to Subsection 2.9.1),
- the high-current instantaneous tripping (refer to Subsection 2.12),
- the circuit breaker failure protection (refer to Subsection 2.19),
- verification of the dropout condition for the trip command (see Subsection "Terminating the Trip Signal").

A circuit breaker position logic is incorporated in the device (Figure 2-161). Depending on the type of auxiliary contact(s) provided by the circuit breaker and the method in which these are connected to the device, there are several alternatives of implementing this logic.

In most cases it is sufficient to furnish the status of the circuit breaker with its auxiliary contacts via a binary input to the device. This always applies if the circuit breaker is only switched three-pole. Then the NO auxiliary contact of the circuit breaker is connected to a binary input which must be configured to the input function "`>CB 3p Closed`" (FNo. 379). The other inputs are then not used and the logic is restricted in principle to simply passing of this input information on.

If the circuit breaker poles can be switched individually, and only a parallel connection of the NO individual pole auxiliary contacts is available, the relevant binary input (BI) is allocated to the function "`>CB 3p Open`" (FNo. 380). The remaining inputs are again not used in this case.

If the circuit breaker poles can be switched individually, and the individual auxiliary contacts are available, an individual binary input should be used for each auxiliary contact if this is possible and if the device can and should trip single-pole. With this configuration, the device can process the maximum amount of information. Three binary inputs are used for this purpose:

- "`>CB Aux. L1`"" (FNo. 351) for the auxiliary contact of pole L1
- "`>CB Aux. L2`"" (FNo. 352) for the auxiliary contact of pole L2
- "`>CB Aux. L3`"" (FNo. 353) for the auxiliary contact of pole L3

The inputs FNo. 379 and FNo 380 are not used in this case.

If the circuit breaker can be switched individually, two binary inputs are sufficient if both the parallel as well as series connection of the auxiliary contacts of the three poles are available. In this case, the parallel connection of the auxiliary contacts is routed to the input function "`>CB 3p Closed`" (FNo 379 and the series connection is routed to the input function "`>CB 3p Open`" (FNo 380).

Please note that Figure 2-161 shows the complete logic for all connection alternatives. For each particular application, only a portion of the inputs is used as described above.

The 8 output signals of the circuit breaker position logic can be processed by the individual protection and supplementary functions. The output signals are blocked if the signals transmitted from the circuit breaker are not plausible: for example, the circuit breaker cannot be open and closed at the same time. Furthermore, no current can flow over an open breaker contact.

The evaluation of the measuring quantities is according to the local conditions of the measuring points (see Section 2.1.5.1 at margin heading "Circuit Breaker Status").

The phase currents are available as measuring quantities. A flowing current excludes that the circuit breaker is open (exception: a fault between current transformer and circuit breaker). If the circuit breaker is closed, it may however still occur that no current is flowing. The decisive setting for the evaluation of the measuring quantities is **PoleOpenCurrent** (address 1130) for the presence of the currents.
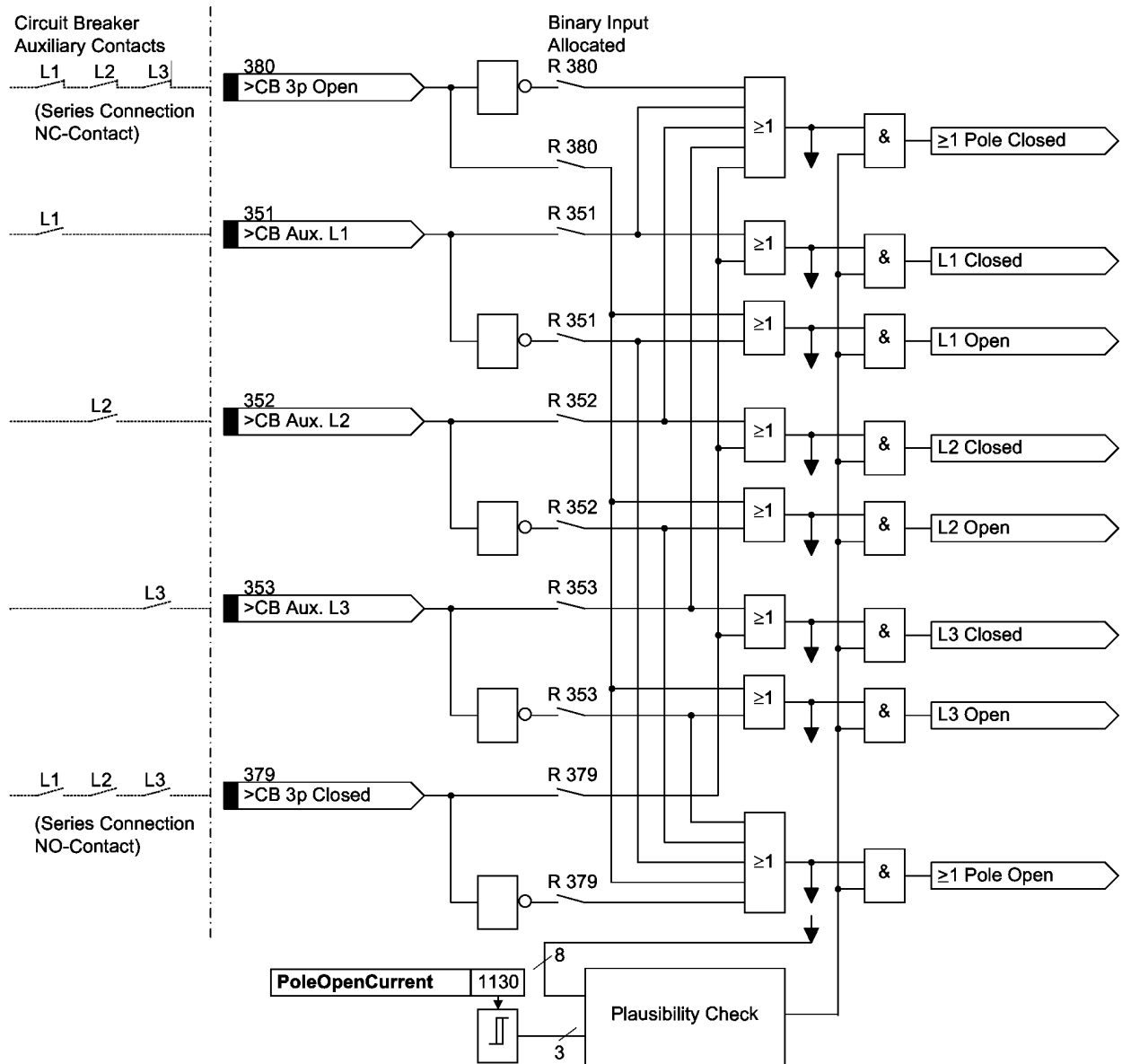
Figure 2-161   Circuit breaker position logic

For Automatic Reclosure and Circuit Breaker Test

Separate binary inputs comprising information on the position of the circuit breaker are available for the automatic reclosure and the circuit breaker test. This is important for

- the plausibility check before automatic reclosure (refer to Subsection 2.14),
- the trip circuit check with the help of the TRIP–CLOSE–test cycle (cf. Subsection 2.23.2).

When using $1^1/_2$ or 2 circuit breakers in each feeder, the automatic reclosure function and the circuit breaker test are referred to **one** circuit breaker. The feedback information of this circuit breaker can be connected separately to the device.

For this, separate binary inputs are available, which should be treated the same and configured additionally if necessary. These have a similar significance as the inputs described above for protection applications and are marked with "CB1 ..." to distinguish them, i.e.:

- "`>CB1 3p Closed`" (FNo. 410) for the series connection of the NO auxiliary contacts of the CB,
- "`>CB1 3p Open`" (FNo. 411) for the series connection of the NC auxiliary contacts of the CB,
- "`>CB1 Pole L1`" (FNo. 366) for the auxiliary contact of pole L1
- "`>CB1 Pole L2`" (FNo. 367) for the auxiliary contact of pole L2
- "`>CB1 Pole L3`" (FNo. 368) for the auxiliary contact of pole L3.

2.23.1.3 Open Pole Detector

Single-pole dead times can be detected and reported via the Open Pole Detector. The corresponding protection and monitoring functions can respond. The following figure shows the logic structure of an Open Pole Detector.
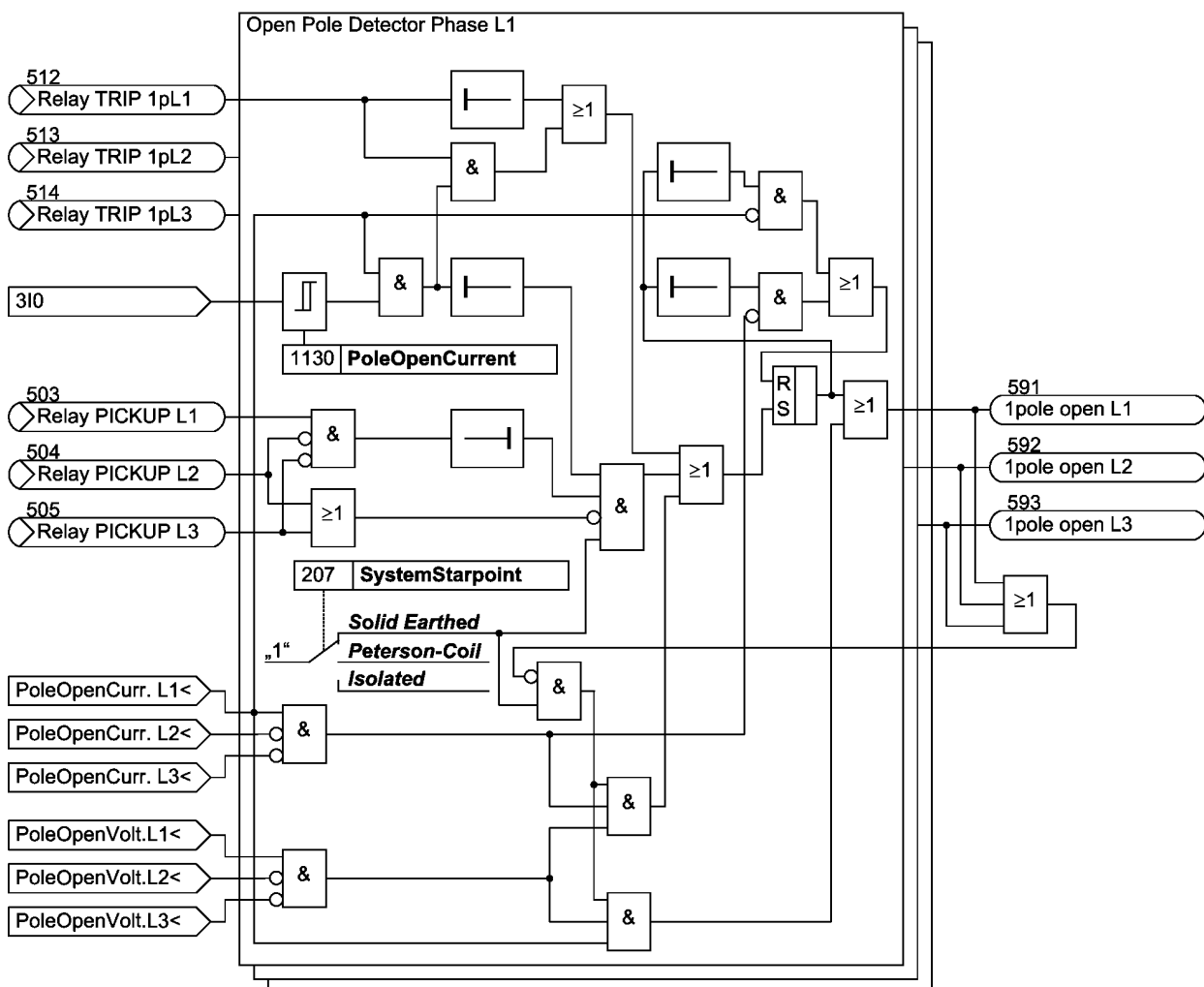
Figure 2-162   Open pole detector logic

Single-pole Dead Time

During a single-pole dead time, the load current flowing in the two healthy phases forces a current flow via earth which may cause undesired pickup. The temporarily applying zero-sequence voltage may also prompt undesired responses of the protection functions.

The messages "1pole open L1" (FNo. 591), "1pole open L2" (FNo. 592) and "1pole open L3" (FNo. 593) are generated in addition if the "Open Pole Detector" recognizes that current and voltage are absent in one phase – but neither in the other phases current is flowing. In this case, the message will be held up only for as long as the condition is fulfilled. This enables a single-pole automatic reclosure to be detected on an unloaded line.

2.23.1.4 Pickup Logic for the Entire Device

Phase Segregated Fault Detection

The fault detection logic combines the fault detection (pick-up) signals of all protection functions. In the case of those protection functions that allow for phase segregated pick-up, the pick-up is output in a phase segregated manner. If a protection function detects an earth fault, this is also output as a common device alarm. Thus the alarms "Relay PICKUP L1", "Relay PICKUP L2", "Relay PICKUP L3" and "Relay PICKUP E" are available.

The annunciations above can be allocated to LEDs or output relays. For the local display of fault event messages and for the transmission of event messages to a personal computer or a centralized control system, several protection functions provide the faulted phase information in a single message, e.g. "Dis.Pickup L12E" for the distance protection fault detection in L1–L2–E only one such message appears. It represents the complete definition of the fault detection.

General Pickup

The pickup signals are combined with OR and lead to a general pickup of the device. It is signaled with the alarm "Relay PICKUP". If no protection function of the device has picked up any longer, "Relay PICKUP" disappears (message: "OFF").

General device pickup is a precondition for a series of internal and external functions that occur subsequently. The following are among the internal functions controlled by general device pickup:

- Opening of fault case: From general device pickup to general device drop out, all fault messages are entered in the trip log.
- Initialization of fault storage: The storage and maintenance of fault values can also be made dependent on the occurrence of a trip command.
- Generation of Spontaneous annunciations: Certain fault messages can be displayed as so called spontaneous messages (see "Spontaneous Indications" below). These display messages can also be made dependent on the general device trip.
- Start action time of automatic reclosure (if available and used)

External functions may be controlled by this indication via an output contact. Examples are:

- Automatic reclose devices,
- Channel boost in conjunction with signal transmission by PLC,
- Further additional devices or similar.

Spontaneous Displays

Spontaneous displays are fault messages which appear in the display automatically following a general fault detection or trip command of the device. For the 7SA6, these messages include:

"Relay PICKUP":	protective function that picked up;
"S/E/F TRIP":	protection function which tripped (only device with graphic display);
"PU Time":	the operating time from the general pickup to the dropout of the device, the time is given in ms;
"TRIP Time":	the operating time from general pickup to the first trip command of the device, in ms;
"dist =":	the distance to fault in kilometres or miles derived by the distance to fault location function (if possible).

2.23.1.5 Tripping Logic of the Entire Device

Three-pole Tripping

In general, the device trips three-pole in the event of a fault. Depending on the version ordered, (13th position of the ordering code = "4" to "7") single-pole tripping is also possible (see below). If, in general, single-pole tripping is not possible or desired, the output function "Relay TRIP 3ph." is used for the trip command output to the circuit breaker. In these cases the following sections regarding single-pole tripping are not of interest.

Single-Pole Tripping

Single-pole tripping only makes sense on overhead lines, on which automatic reclosure shall be carried out and where the circuit breakers at both ends of the line are capable of single-pole tripping. In such cases, the faulted phase may be tripped single-pole and subsequently reclosed; in the case of two-phase and three-phase faults with or without earth, three-pole tripping is usually carried out.

Device prerequisites for phase segregated tripping are:

- that phase segregated tripping is provided by the device (according to the ordering code);
- that phase segregated tripping is provided by the protection function which trips (not provided by e.g. high-current switch-on-to-fault protection, overvoltage protection, overload protection);
- that the binary input ">1p Trip Perm" is configured and activated or the internal automatic reclosure function is ready for reclosure after single-pole tripping.

In all other cases tripping is always three-pole. The binary input ">1p Trip Perm" is the logic inversion of a three-pole coupling and is activated by an external auto-reclosure device as long as this is ready for a single-pole auto-reclosure cycle.

With the 7SA6, it is also possible to trip three-pole when only one phase is subjected to the trip conditions, but more than one phase indicates a fault detection. With distance protection this is the case when two faults at different locations occur simultaneously but only one of them is within the range of the fast tripping zone (Z1 or Z1B). This is selected with the setting parameter **3pole coupling** (address 1155), which is set to **with PICKUP** (every multiple-phase fault detection causes three-pole trip) or **with TRIP** (in the event of multiple-phase trip commands the tripping is three-pole).

The tripping logic combines the trip signals from all protection functions. The trip commands of those protection functions that allow single-pole tripping are phase segre-

gated. The corresponding messages are named "`Relay TRIP L1`", "`Relay TRIP L2`" and "`Relay TRIP L3`".

These alarms can be allocated to LEDs or output relays. In the event of three-pole tripping all three alarms pick up.

If single-pole tripping is possible, the protection functions generates a group signal for the local displaying of alarms and for the transmission of the alarms to a PC or a central control system, e.g. "`Dis.Trip 1pL1`", "`Dis.Trip 1pL2`", for single-pole tripping by the distance protection and "`Dis.Trip 3p`" for three-pole tripping. Only one of these alarms is displayed at a time. These alarms are also intended for the trip command output to the circuit breaker.

Single-pole Tripping after Two-Phase Fault

Single-pole tripping for two-phase faults is a special feature. If a phase-phase fault <u>without earth</u> occurs in an earthed system, this fault can be cleared by single-pole trip and automatic reclosure in one of the faulted phases, as the short-circuit path is interrupted in this manner. The phase selected for tripping must be the same at both line ends (and should be the same for the entire system).

The setting parameter **`Trip2phFlt`** (address 1156) allows to select whether this tripping should be **1pole leading Ø**, i.e. single-pole tripping of the leading phase, or **1pole lagging Ø**, i.e. single-pole tripping of the lagging phase. Standard setting is **3pole**, i.e. three-pole tripping after two-phase faults (default setting).

Table 2-17   One-pole and three-pole trip depending on fault type

Type of Fault (from Protection Function)				Parameter Trip2phFlt	Output signals for trip			
					TRIP 1p. L1	**TRIP 1p. L2**	**TRIP 1p. L3**	**Relay TRIP 3ph.**
L1				(any)	X			
	L2			(any)		X		
		L3		(any)			X	
L1			E	(any)	X			
	L2		E	(any)		X		
		L3	E	(any)			X	
L1	L2			3pole				X
L1	L2			1pole leading Ø	X			
L1	L2			1pole lagging Ø		X		
	L2	L3		3pole				X
	L2	L3		1pole leading Ø		X		
	L2	L3		1pole lagging Ø			X	
L1		L3		3pole				X
L1		L3		1pole leading Ø			X	
L1		L3		1pole lagging Ø	X			
L1	L2		E	(any)				X
	L2	L3	E	(any)				X
L1		L3	E	(any)				X
L1	L2	L3		(any)				X
L1	L2	L3	E	(any)				X
			E	(any)				X

General Trip

All trip signals for the protective functions are connected by OR and generate the message "`Relay TRIP`". This can be allocated to LED or output relay.

Terminating the Trip Signal

Once a trip command is initiated, it is phase segregatedly latched (in the event of three-pole tripping for each of the three poles) (refer to Figure 2-163). At the same time, the minimum trip command duration **`TMin TRIP CMD`** is started. This ensures that the command is transmitted to the circuit breaker for a sufficient amount of time, even if the function which issued the trip signal drops out quickly. The trip commands can only be terminated when the last protection function dropped out (i.e. functions no longer pick up) AND the minimum trip signal duration expired.

A further condition for the reset of the trip command is that the circuit breaker has opened, in the event of single-pole tripping the relevant circuit-breaker pole. In the function control of the device this is checked by means of the circuit-breaker position feedback (Subsection "Detection of the Circuit Breaker Position") and the flow of current. The residual current 1130 that is certainly undershot when the circuit breaker pole is open is set in address **`PoleOpenCurrent`**. Address 1135 **`Reset Trip CMD`** determines under which conditions a trip command is reset. If **`CurrentOpenPole`** is set, the trip command is reset as soon as the current disappears. It is important that the value set in address 1130 **`PoleOpenCurrent`** (see above) is undershot. If **`Current AND CB`** is set, the circuit-breaker auxiliary contact must send a message that the circuit breaker is open. It is a prerequisite for this setting that the position of the auxiliary contacts is allocated via a binary input.
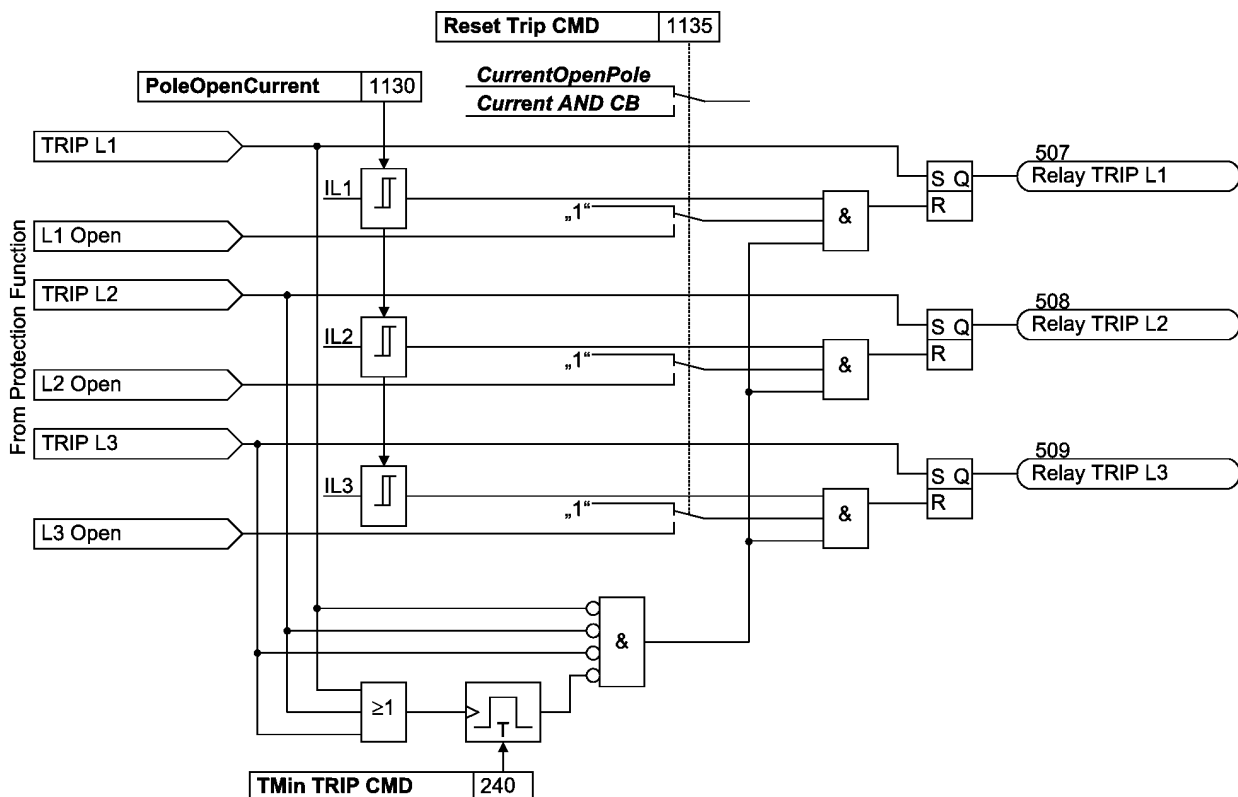
Figure 2-163 Storage and termination of the trip command

Reclosure Inter-locking

When tripping the circuit breaker by a protection function the manual reclosure must often be blocked until the cause for the protection function operation is found. 7SA6 enables this via the integrated reclose interlocking.

The interlocking state ("LOCKOUT") will be realized by a RS flipflop which is protected against auxiliary voltage failure (see Figure 2-164). The RS flipflop is set via binary input ">Lockout SET" (FNo. 385). With the output alarm "LOCKOUT" (FNo. 530), if interconnected correspondingly, a reclosure of the circuit-breaker (e.g. for automatic reclosure, manual close signal, synchronization, closing via control) can be blocked. Only once the cause for the protection operation is known, should the interlocking be reset by a manual reset via binary input ">Lockout RESET" (FNo. 386).
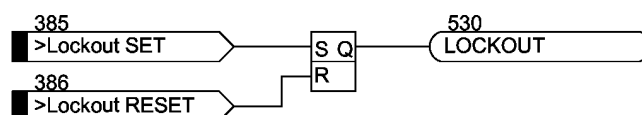
Figure 2-164   Reclosure interlocking

Conditions which cause reclosure interlocking and control commands which have to be interlocked can be set individually. The two inputs and the output can be wired via the correspondingly allocated binary inputs and outputs or be linked via user-defined logic functions (CFC).

If, for example, each trip by the protection function has to cause a closing lock-out, then combine the tripping command "Relay TRIP" (FNo. 511) with the binary input ">Lockout SET". If, however, automatic reclosure is applied, only the final trip of the protection function should activate reclosing lock-out. Please bear in mind that the alarm "Definitive TRIP" (FNo. 536) is only present for 500 ms. Combine the output alarm "Definitive TRIP" (FNo. 536) with the interlocking input ">Lockout SET", so that the interlocking function is not established when an automatic reclosure is still expected to come.

With the output alarm "LOCKOUT" (FNo. 530) it is possible in the most simple case to allocate to the output which trips the circuit-breaker without creating further links. Then the tripping command is maintained until the interlock is reset via the binary reset input. Naturally it has to be ensured in advance that the close coil at the circuit breaker — as is usually done — is blocked as long as a tripping command is maintained.

The output alarm "LOCKOUT" can also be applied to interlock certain closing commands (externally or via CFC), e.g. by combining the output alarm with the binary input ">Close Cmd. Blk" (FNo. 357) or by connecting the inverted alarm with the bay interlocking of the branch.

The reset input ">Lockout RESET" (FNo. 386) resets the interlocking state. This input is initiated by an external device which is protected against unauthorized or unintentional operation. The interlocking state can also be controlled by internal sources using CFC, e.g. a function key, operation of the device or using DIGSI® on a PC.

For each case please make sure the corresponding logical combinations, security measures, etc. are taken into account for the routing of the binary inputs and outputs (Section) and are also considered for the setting of user-defined logic functions, if necessary. See also SIPROTEC® 4 System Description, Order no.. E50417-H1176-C151.

Breaker Tripping Alarm Suppression

While on feeder without automatic reclosure every trip command by a protection function is final, it is desirable, when using automatic reclosure, to prevent the operation detector of the circuit-breaker (transient contact on the breaker) from sending an alarm if the trip of the breaker is not final (Figure 2-165).

For this purpose, the signal from the circuit-breaker is routed via a correspondingly allocated output contact of the 7SA6 (output alarm "CB Alarm Supp", FNo. 563). In the idle state and when the device is turned off, this contact is closed continuosly. Therefore an output contact with a normally closed contact has to be allocated. Which contact is to be allocated is dependent on the device version. Refer to the general views in the Appendix.

Prior to the command, with the internal automatic reclosure in the ready state, the contact opens so that no signal from the circuit-breaker is forwarded. This is only the case if the device is equipped with internal automatic reclosure and if the latter was taken into consideration when configuring the protection functions (address 133).

Also when closing the breaker via the binary input ">Manual Close" (FNo. 356) or via the integrated automatic reclosure the contact is interrupted so that the breaker alarm is inhibited.

Further optional closing commands which are not sent via the device cannot be taken into consideration. Closing commands for control can be linked to the alarm suppression via the user-defined logic functions (CFC).
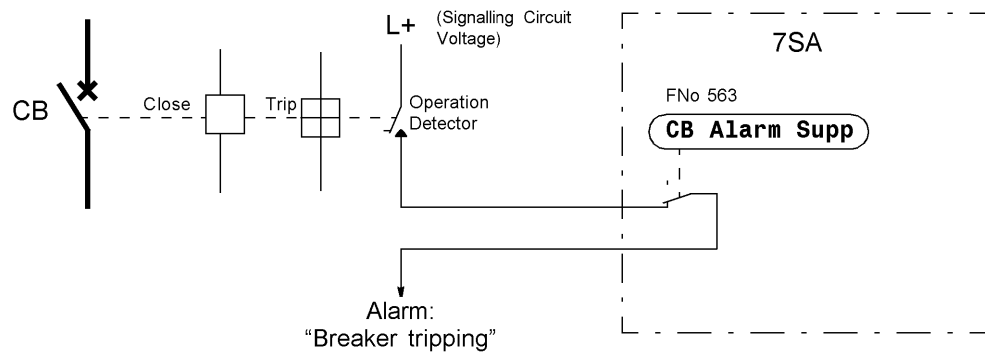
Figure 2-165   Breaker tripping alarm suppression

If the device issues a final trip command, the contact remains closed. This is the case, during the reclaim time of the automatic reclosure cycle, when the automatic reclosure is blocked or switched off or, due to other reasons is not ready for automatic reclosure (e.g. tripping only occurred after the action time expired).

Figure 2-166 shows time diagrams for manual trip and close as well as for short-circuit tripping with a single, failed automatic reclosure cycle.
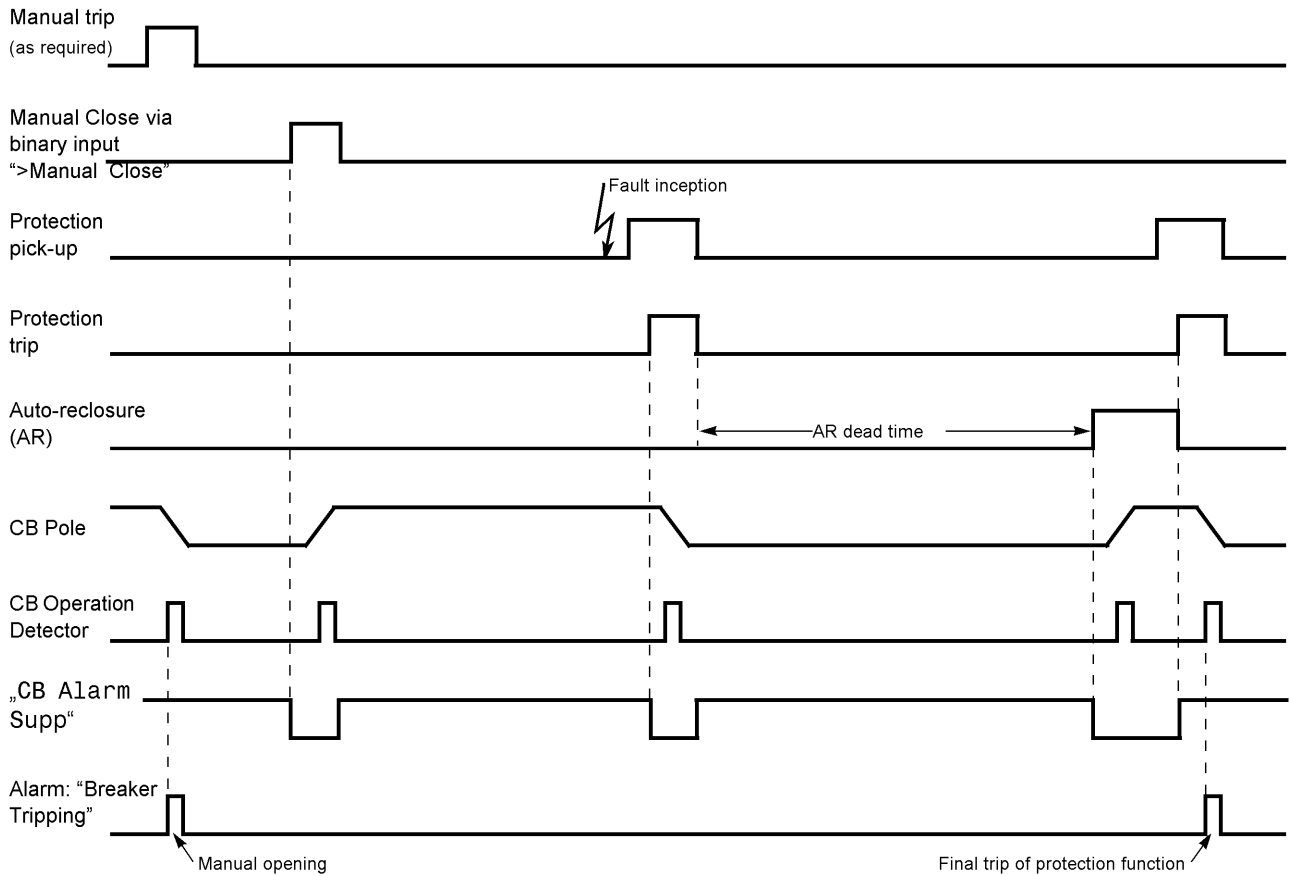
Figure 2-166   Breaker tripping alarm suppression — sequence examples

Trip Dependent Messages

The latching of messages allocated to local LEDs, and the storage of spontaneous messages can be made dependent on whether the device has issued a trip command. This information is then not output if during a system disturbance one or more protection functions have picked up, but no tripping by the 7SA6 resulted because the fault was cleared by a different device (e.g. on another line). These messages are then limited to faults in the line to be protected.
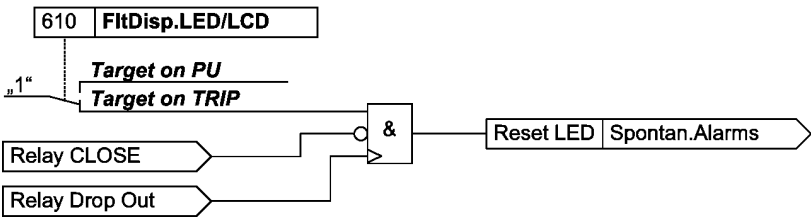
Figure 2-167   Logic diagram of the no–trip–no–flag feature (command-dependent alarms)

Statistics

The number of trips initiated by the device 7SA6 are counted. If the device is capable of single-pole tripping, a separate counter for each circuit breaker pole is provided.

Following each trip command the device registers the value of each current phase that was switched off in each pole. This information is then provided in the trip log and summated in a register. The maximum current that was switched off is also stored.

If the device is equipped with the integrated automatic reclosure, the automatic close commands are also counted, separately for reclosure after single-pole tripping, after three-pole tripping as well as separately for the first reclosure cycle and other reclosure cycles.

The counter and memory levels are secured against loss of auxiliary voltage. They can be set to zero or to any other initial value. For more details, refer to the SIPROTEC® 4 System Description, Order No. E50417-H1176-C151.

2.23.1.6 Setting Notes

Command Duration The setting of the minimum trip signal duration **TMin TRIP CMD** (address 240 was already discussed in Subsection 2.1.3. This setting applies to all protective functions that initiate tripping.

2.23.2 Circuit breaker trip test

The 7SA6 distance protection relay allows for convenient testing of the trip circuits and the circuit breakers.

2.23.2.1 Method of Operation

The test programs as shown in Table 2-18 are available. The single-pole tests are naturally only available if the device at hand allows for single-pole tripping.

The output alarms mentioned must be allocated to the relevant command relays that are used for controlling the circuit breaker coils.

The test is started via the operation panel on the front of the device or via the PC with DIGSI®. The procedure is described in detail in the SIPROTEC® 4 System Description, Order No. E50417-H1176-C151. Figure 2-168 shows the chronological sequence of one TRIP–CLOSE test cycle. The timer setting values are according to Subsection 2.1.3.1 for "command duration" and "circuit breaker test".

Where the circuit breaker auxiliary contacts indicate the status of the circuit breaker or of its poles to the device via binary inputs, the test cycle can only be initiated if the circuit breaker is closed.

The information regarding the position of the circuit breakers is not automatically derived from the position logic according to the above Subsection. For the circuit breaker test function (auto recloser) there are separate binary inputs for the switching status feedback of the circuit breaker position. These must be taken into consideration when allocating the binary inputs as mentioned in the previous Section.

The alarms of the device show the respective state of the test sequence.

Table 2-18   Circuit breaker test programs

Serial No.	Test programs	Circuit Breaker	Output indications (FNo)
1	1-pole TRIP/CLOSE-cycle phase L1		CB1-TESTtrip L1 (7325)
2	1-pole TRIP/CLOSE-cycle phase L2		CB1-TESTtrip L2 (7326)
3	1-pole TRIP/CLOSE-cycle phase L3	CB 1	CB1-TESTtrip L3 (7327)
4	3-pole TRIP/CLOSE-cycle		CB1-TESTtrip 123 (7328)
	Associated close command		CB1-TEST CLOSE (7329)
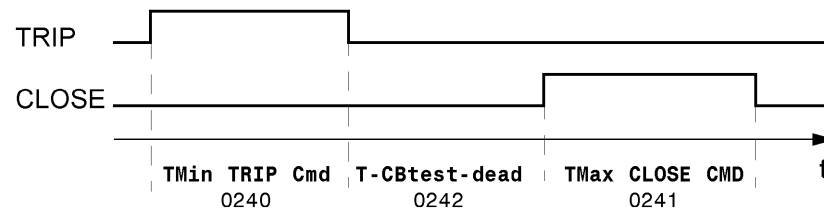
Figure 2-168   TRIP-CLOSE test cycle

2.23.2.2 Setting Notes

The timer setting values are according to Subsection 2.1.3.1 for "command duration" and "circuit breaker test".

2.23.2.3 Information List

No.	Information	Type of Information	Comments
-	CB1tst L1	-	CB1-TEST trip/close - Only L1
-	CB1tst L2	-	CB1-TEST trip/close - Only L2
-	CB1tst L3	-	CB1-TEST trip/close - Only L3
-	CB1tst 123	-	CB1-TEST trip/close Phases L123
7325	CB1-TESTtrip L1	OUT	CB1-TEST TRIP command - Only L1
7326	CB1-TESTtrip L2	OUT	CB1-TEST TRIP command - Only L2
7327	CB1-TESTtrip L3	OUT	CB1-TEST TRIP command - Only L3
7328	CB1-TESTtrip123	OUT	CB1-TEST TRIP command L123
7329	CB1-TEST close	OUT	CB1-TEST CLOSE command
7345	CB-TEST running	OUT	CB-TEST is in progress
7346	CB-TSTstop FLT.	OUT_Ev	CB-TEST canceled due to Power Sys. Fault
7347	CB-TSTstop OPEN	OUT_Ev	CB-TEST canceled due to CB already OPEN
7348	CB-TSTstop NOTr	OUT_Ev	CB-TEST canceled due to CB was NOT READY
7349	CB-TSTstop CLOS	OUT_Ev	CB-TEST canceled due to CB stayed CLOSED
7350	CB-TST .OK.	OUT_Ev	CB-TEST was succesful

2.24 Auxiliary functions

The additional functions of the 7SA6 distance protection relay include:

- processing of messages,
- processing of operational measured values,
- storage of fault record data.

2.24.1 Processing of Messages

After the occurrence of a system fault, data regarding the response of the protective relay and the measured quantities should be saved for future analysis. For this reason message processing is done in three ways:

2.24.1.1 Method of Operation

Displays and Binary Outputs (output relays)

Important events and states are displayed using front panel LEDs. The device furthermore has output relays for remote indication. Most indications and displays can be configured differently to the delivery default settings (for information on the delivery default setting see Appendix). The procedure is described in detail in the SIPROTEC® 4 System Description, (order no. E50417-H1176-C151).

The output relays and the LEDs may be operated in a latched or unlatched mode (each may be individually set).

The latched conditions are protected against loss of the auxiliary voltage. They are reset

- On site by pressing the LED key on the relay,
- Remotely using a binary input configured for that purpose,
- Using one of the serial interfaces,
- Automatically at the beginning of a new pickup.

Status messages should not be stored. Also, they cannot be reset until the criterion to be reported has been cancelled. This applies to e.g. messages from monitoring functions, or the like.

A green LED displays operational readiness of the relay ("RUN"), and cannot be reset. It goes out if the self-check feature of the microprocessor recognizes an abnormal occurrence, or if the auxiliary voltage fails.

When auxiliary voltage is present but the relay has an internal malfunction, the red LED ("ERROR") lights up and the processor blocks the relay.

DIGSI® enables you to control selectively each output relay and LED of the device and, in doing so, check the correct connection to the system. In a dialog box you can, for instance, cause each output relay to pick up, and thus test the wiring between the 7SA6 and the station, without having to create the indications masked to it.

Information on the Integrated Display (LCD) or to a Personal Computer

Events and conditions can be read out on the display on the front cover of the relay. Using the front PC interface or the rear service interface, for instance, a personal computer can be connected, to which the information can be sent.

In the quiescent state, i.e. as long as no system fault is present, the LCD can display selectable operational information (overview of the operational measured values) (de-

fault display). In the event of a system fault, information regarding the fault, the so-called spontaneous messages, are displayed instead. After the fault related indications have been acknowledged, the quiescent data are shown again. Acknowledgement can be performed by pressing the LED buttons on the front panel (see above).

Figure 2-169 shows the default display in a 4-line display as preset. The default display can be configured in the graphic display. For more details, refer to the SIPRO-TEC® 4 System Description, Order No. E50417-H1176-C151 and Display Editor Manual (Order No. E50417-H1176-C095).

Various default displays can be selected via the arrow keys. Parameter 640 can be set to change the presetting for the default display page shown in quiescent state. Two examples of possible default display selections are given below.

```
1    345A   12    121kV
2    341A   23    118kV
3    346A   31    119kV
E    4.7A   U0     2kV
```

Example:

I_{L1}	= 345 A	U_{L1-L2}	= 121 kV
I_{L2}	= 341 A	U_{L2-L3}	= 118 kV
I_{L3}	= 346 A	U_{L3-L1}	= 119 kV
$I_E (3I_0)$	= 4.7 A	U_0	= 2 kV

Figure 2-169   Operational measured values in the default display

Default display 3 shows the measured values U_{L1-L2} and I_{L2}.

```
S:   227MVA   U:  400kV
P:    71MW   I:   401A
Q:   268MVAR
f:50.00Hz cosφ:0.25
```

Example:

S	= 227 MVA	U_{L1-L2}	= 400 kV
P	= 71 MW	I_{L2}	= 401 A
Q	= 268 MVAR		
f	= 50.00 Hz	cosφ	= 0.25

Figure 2-170   Operational measured values in the default display

The device in addition has several event buffers for operational messages, switching statistics, etc., which are saved against loss of auxiliary supply by means of a battery buffer. These messages can be displayed on the LCD at any time by selection via the keypad or transferred to a personal computer via the serial service or PC interface. The retrieval of events/alarms during operation is extensively described in the SIPRO-TEC® 4 System Description, order no. E50417-H1176-C151) .

After a fault on the system, for example, important information about the progression of the fault can be retrieved, such as the pickup of a protective element or the initiation of a trip signal. The time the initial occurrence of the short-circuit fault occurred is accurately provided via the system clock. The progress of the disturbance is output with a relative time referred to the instant of fault detection, so that the duration of the fault until tripping and up to reset of the trip command can be ascertained. The resolution of the time information is 1ms.

With a PC and the DIGSI® protection data processing software it is also possible to retrieve and display the events with the convenience of visualisation on a monitor and a menu-guided dialogue. The data may either be printed or stored for evaluation at a later time and place.

The protection device stores the messages of the last eight system faults; in the event of a ninth fault, the oldest is erased.

A system fault starts with the recognition of the fault by the fault detection of any protection function and ends with the reset of the fault detection of the last protection function or after the expiry of the auto-reclose reclaim time, so that several unsuccessful auto-reclose cycles are also stored cohesively. Accordingly a system fault may contain several individual fault events (from fault detection up to reset of fault detection).

Information to a Control Centre

If the device has a serial system interface, stored information may additionally be transferred via this interface to a centralised control and storage device. Transmission is possible via different transmission protocols.

You may test whether the information is transmitted correctly with DIGSI®.

Also, the information transmitted to the control centre can be influenced during operation or tests. The IEC 60870-5-103 protocol allows to identify all messages and measured values transferred to the central control system with an added message " test operation"- bit while the device is being tested on site (test mode). This identification prevents the messages from being incorrectly interpreted as resulting from an actual power system disturbance or event. Alternatively, you may disable the transmission of annunciations to the system interface during tests ("transmission block").

To influence information at the system interface during test mode ("test mode" and "transmission block"), a CFC logic is required. Default settings already include this logic (see Appendix).

The SIPROTEC® 4 System Description describes in detail how to activate and deactivate test mode and blocked data transmission.

Classification of Messages

Annunciations can be of one of the following types:

- Operational messages: messages generated while the device is in operating: They include information about the status of device functions, measurement data, system data, and similar information.
- Fault Annunciations: messages from the last 8 network faults that were processed by the device.
- Sensitve Ground Fault Logs (when the device has sensitive ground fault detection).
- Messages of the Statistic: they include a counter for the switching actions of the circuit breakers initiated by the device, maybe reclose commands as well as values of interrupted currents and accumulated fault currents.

A complete list of all message and output functions that can be generated by the device with the maximum functional scope can be found in the Appendix. All functions are associated with a information number (FNo). It also indicates where each message can be sent to. If functions are not present in the specific version of the device, or if they are set to **Disabled**, then the associated messages cannot appear.

Operational Messages (Buffer: Event Log)

The operational messages contain information that the device generates during operation and about operational conditions.

Up to 200 operational messages are recorded in chronological order in the device. Newly generated annunciations are added to those already there. If the maximum capacity of the memory is exhausted, the oldest respective indication is lost.

Operational annunciations arrive automatically and can be read out from the device display or a personal computer at any time. Faults in the power system are indicated with "Network Fault" and the present fault number. The fault messages contain detailed information on the behaviour of the power system fault.

Fault Annuncia-tions

Following a system fault, it is possible to for example retrieve important information regarding its progress, such as pickup and trip. The time the initial occurrence of the short-circuit fault occurred is accurately provided via the system clock. The progress of the disturbance is output with a relative time referred to the instant of fault detection, so that the duration of the fault until tripping and up to reset of the trip command can be ascertained. The resolution of the time information is 1ms.

A system fault starts with the recognition of the fault by the fault detection, i.e. first pickup of any protection function, and ends with the reset of the fault detection, i.e. dropout of the last protection function. Where fault causes several protective functions to pick up, the fault is considered to include all that occurred between pickup of the first protective function and dropout of the last protective function.

Spontaneous Annunciations

After a fault, the device displays automatically and without any operator action on its LCD display the most important fault data from the general device pickup in the sequence shown in Figure 2-171.

Protection function that picked up, e.g. distance protection, with phase information;
Protection function that is tripped, e.g. 3pole distance protection (only devices with graphic display);
Elapsed time from pick-up until reset;
Elapsed time from pick-up until the first trip command of a protection function;
Fault distance d in km or miles

Figure 2-171   Display of spontaneous messages in the display — Example

Fault Location Options

Besides the display at the device and in DIGSI® there are additional display option available in particular for the fault location. They depend on the device version, the configuration and allocation:

• If the device features the BCD output for the fault location, the transmitted figures mean the following:

0 to 195: the calculated fault location in % of the line length (if greater than 100%, the error lies outside the protected line in a forward direction);

197: negative fault location (fault in reverse direction);

199   overflow.

• If the device disposes of at least one analog output, the fault location is output via it and is transferred to a suitable display panel where you can immediately read the fault distance after a fault event.

Retrieved Annunciations

The messages for the last eight network faults can be retrieved. In total 600 indications can be recorded. Oldest data are erased for newest data when the buffer is full.

Sensitive Earth Fault Logs

For devices with sensitive earth fault detection, special earth fault records are available. Up to 200 earth fault messages can be recorded for the last 8 faults.

Spontaneous Annunciations

Spontaneous annunciations contain information on new incoming annunciations. Each new incoming message appears immediately, i.e. the user does not have to wait for an update or initiate one. This can be a useful help during operation, testing and commissioning.

Spontaneous annunciations can be read out via DIGSI®. For more details, refer to the SIPROTEC® 4 System Description, Order No. E50417-H1176-C151.

General Interrogation The general interrogation which can be retrieved via DIGSI® enables the current status of the SIPROTEC® device to be read out. It shows all annunciations that are subject to general interrogation with their current value.

2.24.2 Statistics

Counting includes the number of trips initiated by 7SA6, the accumulated breaking currents resulting from trips initiated by protection functions, the number of close commands initiated by the auto-reclosure function.

2.24.2.1 Function Description

Counters and Memories The counters and memories of the statistics are saved by the device. Therefore, the information will not get lost in case the auxiliary voltage supply fails. The counters, however, can be reset to zero or to any value within the setting range.

They can be viewed on the device front and read out using the DIGSI® 4 software on a PC via the operator or service interface.

A password is not required to read counter and stored values but it is necessary to change or delete them. You will find further details in the SIPROTEC® 4 System Description (Order no. E50417-H1176-C151)

Number of Trips The number of trips initiated by the device 7SA6 are counted. If the device is capable of single-pole tripping, a separate counter for each circuit breaker pole is provided.

Number of Automatic Reclosing Commands If the device is equipped with the integrated automatic reclosure, the automatic close commands are also counted, separately for reclosure after single-pole tripping, after three-pole tripping as well as separately for the first reclosure cycle and other reclosure cycles.

Breaking Currents Following each trip command the device registers the value of each current phase that was switched off in each pole. This information is then provided in the trip log and summated in a register. The maximum current that was switched off is also stored. Measured values are indicated in primary values.

Transmission Statistics In 7SA6 the protection communication is registered in statistics. The delay times of the information between the devices via interfaces (transmit and receive) are measured continuously. The values are kept stored in the Statistic folder. The availability of the transmission media is also specified. The availability is indicated in % / min and % / h. This enables an evaluation of the transmission quality.

2.24.2.2 Setting Notes

Reading / Setting / Resetting

The SIPROTEC® 4 System Description describes how to read out the statistical counters via the device front panel or DIGSI®. Setting or resetting of these statistical counters takes place under the menu item **Annunciation** -> **STATISTIC** by overwriting the counter values displayed.

2.24.2.3 Information List

No.	Information	Type of In-formation	Comments
1000	# TRIPs=	OUT	Number of breaker TRIP commands
1001	TripNo L1=	OUT	Number of breaker TRIP commands L1
1002	TripNo L2=	OUT	Number of breaker TRIP commands L2
1003	TripNo L3=	OUT	Number of breaker TRIP commands L3
1027	Σ IL1 =	OUT	Accumulation of interrupted current L1
1028	Σ IL2 =	OUT	Accumulation of interrupted current L2
1029	Σ IL3 =	OUT	Accumulation of interrupted current L3
1030	Max IL1 =	OUT	Max. fault current Phase L1
1031	Max IL2 =	OUT	Max. fault current Phase L2
1032	Max IL3 =	OUT	Max. fault current Phase L3
2895	AR #Close1./1p=	OUT	No. of 1st AR-cycle CLOSE commands,1pole
2896	AR #Close1./3p=	OUT	No. of 1st AR-cycle CLOSE commands,3pole
2897	AR #Close2./1p=	OUT	No. of higher AR-cycle CLOSE commands,1p
2898	AR #Close2./3p=	OUT	No. of higher AR-cycle CLOSE commands,3p
7751	PI1 TD	MV	Prot Int 1:Transmission delay
7753	PI1A/m	MV	Prot Int 1: Availability per min.
7754	PI1A/h	MV	Prot Int 1: Availability per hour
7757	PI1 DTOG	MV	Prot Int 1: DTOG (Device Time Offset)

2.24.3 Measurement

2.24.3.1 Method of Operation

A series of measured values and the values derived from them are available for on-site retrieval or for data transfer.

Precondition for a correct display of primary and percentage values is the complete and correct entry of the nominal values of the instrument transformers and the power system.

Display of Measured Values

Depending on the ordering code, connection type to the device and the configured protection function, only some of the listed operational measured values in Table 2-19 may be available. Only one of the current values I_{EE}, I_Y and I_P can apply, namely the one which is connected to the current measuring input I_4. Phase-to-earth voltages can only be measured if the phase-to-earth voltage inputs are connected. The displacement voltage $3U_0$ is e-n-voltage multiplied by $\sqrt{3}$ — if U_{en} is connected — or calculated

from the phase-to-earth voltages $3U_0 = |\underline{U}_{L1} + \underline{U}_{L2} + \underline{U}_{L3}|$. All three voltage inputs must be phase-earth connected to this end. The zero-sequence voltage U_0 indicates the voltage between the delta center and earth.

For the thermal overload protection the calculated overtemperatures are indicated in relation to the trip overtemperature.

If the device is provided with the earth fault detection function for non-earthed systems, the components of the earth current (active and reactive component) are indicated, as well.

If the device features a synchronism and voltage check function, and provided that these features have been set to 135 during configuration of the scope of the device (address **Enabled**), and that the parameter **U4 transformer** (address 210) has been set to **Usync transf.**, the characteristic values (voltages, frequencies, differences) can be read out.

The power and operating values upon delivery are set such that power in line direction is positive. Active components in line direction and inductive reactive components in line direction are also positive. The same applies for the power factor cosφ. It is occasionally desired to define the power draw from the line (e.g. as seen from the consumer) positively. Using parameter address 1107 **P,Q sign** the signs for these components can be inverted.

The computation of the operational measured values is also executed during an existent system fault in intervals of approx. 0.5s.

Table 2-19   Operational measured values of the local device

Measured Values		primary	secondary	% referred to
I_{L1}, I_{L2}, I_{L3}	Phase currents	S	S	Rated operational current [1]
I_{EE}	Sensitive earth current	S	mA	Rated operational current [3][1]
$3I_0$ — calculated	Earth current	S	S	Rated operational current [1]
$3I_0$ — measured	Earth current	A	A	Rated operational current [3][1]
I_1, I_2	Positive and negative sequence component of currents	S	S	Rated operational current [1]
I_Y, I_P	Transformer Starpoint Current or Earth Current of the Parallel Line	S	S	Rated operational current [3][1]
U_{L1-E}, U_{L2-E}, U_{L3-E}	Phase-to-earth voltages	kV	V	Operational rated voltage / $\sqrt{3}$ [2]
U_{L1-L2}, U_{L2-L3}, U_{L3-L1}	Phase-to-phase voltages	kV	V	Operational rated voltage [2]
$3U_0$	Displacement Voltage	kV	V	Operational rated voltage / $\sqrt{3}$ [2]
U_0	Zero-sequence voltage	kV	V	Operational rated voltage / $\sqrt{3}$ [2]
U_1, U_2	Positive and negative sequence component of voltages	kV	V	Operational rated voltage / $\sqrt{3}$ [2]
U_X	Voltage at measuring input U_4	kV	V	Operational rated voltage / $\sqrt{3}$ [2]
$U_{1compounded}$	Positive sequence component of voltages at the remote end (if compounding is active in voltage protection)	kV	kV	Operational rated voltage / $\sqrt{3}$ [2]
R_{L1-E}, R_{L2-E}, R_{L3-E}, R_{L1-L2}, R_{L1-L2}, R_{L3-L1}	Operational resistance of all loops	Ω	Ω	—
X_{L1-E}, X_{L2-E}, X_{L3-E}, X_{L1-L2}, X_{L2-L3}, X_{L3-L1}	Operational reactance of all loops	Ω	Ω	—

	Measured Values	primary	second-ary	% referred to
S, P, Q	Apparent, active and reactive power	MVA, MW, MVAR	—	$\sqrt{3} \cdot U_N \cdot I_N$ operational rated quantities [1][2]
f	Frequency	Hz	Hz	Rated system frequency
cos φ	Power factor	(abs)	(abs)	—
$\Theta_{L1}/\Theta_{TRIP}$, $\Theta_{L2}/\Theta_{TRIP}$, $\Theta_{L3}/\Theta_{TRIP}$	Thermal value of each phase, referred to the tripping value	—	—	Trip overtemperature
Θ/Θ_{Trip}	Thermal resultant value, referred to the tripping value, calculated according to the set method	—	—	Trip overtemperature
U_{line}, U_{bus}, U_{diff}	Line voltage, busbar voltage and voltage difference (for synchronism check)	kV	—	—
f_{line}, f_{bus}, f_{diff}	Line voltage, busbar frequency and voltage difference (for synchronism check)	Hz	—	—
φ_{diff}	Amount of phase angle difference between line and busbar (for synchronism check)	°	—	—
$I_{3I0senA}$, $I_{3I0senR}$	Active and reactive components of the earth current	S	mA	—

[1] according to address 1104

[2] according to address 1103

[3] considering factor 221 I4/Iph CT

Remote Measured Values   During communication, the data of the other ends of the protected object can also be read out. For each of the devices, the currents and voltages involved as well as phase shifts between the local and transfer measured quantities can be displayed. This is especially helpful for checking the correct and coherent phase allocation and polarity at the different line ends. Furthermore, the device addresses of the other devices are transmitted so that all important data of all ends are available in the substation. All possible data are listed in Table 2-20.

Table 2-20   Operational measured values transmitted from the other ends and compared with the local values

Data		Primary value
Device ADR	Device address of the remote device	(absolute)
I_{L1}, I_{L2}, I_{L3} remote	Phase currents of the remote device	Rated operational current [1]
I_{L1}, I_{L2}, I_{L3} local	Phase currents of the local device	Rated operational current [1]
$\varphi(I_{L1})$, $\varphi(I_{L2})$, $\varphi(I_{L3})$	Phase angles between the remote and the local phase currents	°
U_{L1}, U_{L2}, U_{L3} remote	Voltages of the remote device	Operational rated voltage / $\sqrt{3}$
U_{L1}, U_{L2}, U_{L3} local	Voltages of the local device	Operational rated voltage / $\sqrt{3}$ [2]
$\varphi(U_{L1})$, $\varphi(U_{L2})$ $\varphi(U_{L3})$	Phase angles between the remote and the local voltages	°

[1] for lines according to address 1104

[2] according to address 1103

2.24.3.2 Information List

No.	Information	Type of In-formation	Comments
601	IL1 =	MV	I L1
602	IL2 =	MV	I L2
603	IL3 =	MV	I L3
610	3I0 =	MV	3I0 (zero sequence)
611	3I0sen=	MV	3I0sen (sensitive zero sequence)
612	IY =	MV	IY (star point of transformer)
613	3I0par=	MV	3I0par (parallel line neutral)
619	I1 =	MV	I1 (positive sequence)
620	I2 =	MV	I2 (negative sequence)
621	UL1E=	MV	U L1-E
622	UL2E=	MV	U L2-E
623	UL3E=	MV	U L3-E
624	UL12=	MV	U L12
625	UL23=	MV	U L23
626	UL31=	MV	U L31
627	Uen =	MV	Uen
631	3U0 =	MV	3U0 (zero sequence)
632	Usync =	MV	Usync (synchronism)
633	Ux =	MV	Ux (separate VT)
634	U1 =	MV	U1 (positive sequence)
635	U2 =	MV	U2 (negative sequence)
636	Udiff =	MV	U-diff (line-bus)
637	Uline =	MV	U-line
638	Ubus =	MV	U-bus
641	P =	MV	P (active power)

No.	Information	Type of Information	Comments
642	Q =	MV	Q (reactive power)
643	PF =	MV	Power Factor
644	Freq=	MV	Frequency
645	S =	MV	S (apparent power)
646	F-bus =	MV	Frequency (busbar)
647	F-diff=	MV	Frequency (difference line-bus)
648	φ-diff=	MV	Angle (difference line-bus)
649	F-line=	MV	Frequency (line)
679	U1co=	MV	U1co (positive sequence, compounding)
684	U0 =	MV	U0 (zero sequence)
701	3I0senA	MV	Active 3I0sen (sensitive Ie)
702	3I0senR	MV	Reactive 3I0sen (sensitive Ie)
801	Θ/Θtrip =	MV	Temperat. rise for warning and trip
802	Θ/ΘtripL1=	MV	Temperature rise for phase L1
803	Θ/ΘtripL2=	MV	Temperature rise for phase L2
804	Θ/ΘtripL3=	MV	Temperature rise for phase L3
966	R L1E=	MV	R L1E
967	R L2E=	MV	R L2E
970	R L3E=	MV	R L3E
971	R L12=	MV	R L12
972	R L23=	MV	R L23
973	R L31=	MV	R L31
974	X L1E=	MV	X L1E
975	X L2E=	MV	X L2E
976	X L3E=	MV	X L3E
977	X L12=	MV	X L12
978	X L23=	MV	X L23
979	X L31=	MV	X L31

2.24.4 Demand Measurement Setup

Long-term average values are calculated by 7SA6 and can be read out with the point of time (date and time of the last update).

2.24.4.1 Long-term Average Values

The long-term average values of the three phase currents I_{Lx}, the positive sequence components I_1 for the three phase currents, and the real power P, reactive power Q, and apparent power S are calculated within a set period of time and indicated in primary values.

For the long-term average values mentioned above, the length of the time window for averaging and the frequency with which it is updated can be set. The associated minimum and maximum values can be reset, using binary inputs or by using the integrated control panel in the DIGSI® operating program.

2.24.4.2 Setting Notes

Averages
The time interval for measured value averaging is set at address 2801 **DMD Interval**. The first number specifies the averaging time window in minutes while the second number gives the frequency of updates within the time window. *15 Min., 3 Subs*, for example, means that time averaging occurs for all measured values that arrive within 15 minutes. The output is updated every 15/3 = 5 minutes.

At address 2802 **DMD Sync.Time** you can determine whether the averaging time, selected under address 2801, begins on the hour (*full hour*) or is to be synchronized with another point in time (*a quarter past*, *half hour* or *a quarter to*).

If the settings for averaging are changed, then the measured values stored in the buffer are deleted, and new results for the average calculation are only available after the set time period has passed.

2.24.4.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
2801	DMD Interval	15 Min., 1 Sub 15 Min., 3 Subs 15 Min.,15 Subs 30 Min., 1 Sub 60 Min., 1 Sub	60 Min., 1 Sub	Demand Calculation Intervals
2802	DMD Sync.Time	On The Hour 15 After Hour 30 After Hour 45 After Hour	On The Hour	Demand Synchronization Time

2.24.4.4 Information List

No.	Information	Type of Information	Comments
833	I1dmd =	MV	I1 (positive sequence) Demand
834	Pdmd =	MV	Active Power Demand
835	Qdmd =	MV	Reactive Power Demand
836	Sdmd =	MV	Apparent Power Demand
963	IL1dmd=	MV	I L1 demand
964	IL2dmd=	MV	I L2 demand
965	IL3dmd=	MV	I L3 demand
1052	Pdmd Forw=	MV	Active Power Demand Forward
1053	Pdmd Rev =	MV	Active Power Demand Reverse
1054	Qdmd Forw=	MV	Reactive Power Demand Forward
1055	Qdmd Rev =	MV	Reactive Power Demand Reverse

2.24.5 Min/Max Measurement Setup

Minimum and maximum values are calculated by the 7SA6 and can be read out with the point of time (date and time of the last update).

2.24.5.1 Reset

The minimum and maximum values can be reset, using binary inputs or by using the integrated control panel in the DIGSI® 4 operating program. In addition, the reset can also take place cyclically, beginning with a pre-selected point in time.

2.24.5.2 Setting Notes

The tracking of minimum and maximum values can be reset automatically at a pre-defined point in time. To select this feature, address 2811 **MinMax cycRESET** is set to *YES* (default setting).

The point in time when reset is to take place (the minute of the day in which reset will take place) is set at address 2812 **MiMa RESET TIME**. The reset cycle in days is entered at address 2813 **MiMa RESETCYCLE**, and the beginning date of the cyclical process, from the time of the setting procedure (in days), is entered at address 2814 **MinMaxRES.START**.

2.24.5.3 Settings

Addr.	Parameter	Setting Options	Default Setting	Comments
2811	MinMax cycRESET	NO YES	YES	Automatic Cyclic Reset Function
2812	MiMa RESET TIME	0 .. 1439 min	0 min	MinMax Reset Timer
2813	MiMa RESETCYCLE	1 .. 365 Days	7 Days	MinMax Reset Cycle Period
2814	MinMaxRES.START	1 .. 365 Days	1 Days	MinMax Start Reset Cycle in

2.24.5.4 Information List

No.	Information	Type of Information	Comments
-	ResMinMax	IntSP_Ev	Reset Minimum and Maximum counter
395	>I MinMax Reset	SP	>I MIN/MAX Buffer Reset
396	>I1 MiMaReset	SP	>I1 MIN/MAX Buffer Reset
397	>U MiMaReset	SP	>U MIN/MAX Buffer Reset
398	>UphphMiMaRes	SP	>Uphph MIN/MAX Buffer Reset
399	>U1 MiMa Reset	SP	>U1 MIN/MAX Buffer Reset
400	>P MiMa Reset	SP	>P MIN/MAX Buffer Reset
401	>S MiMa Reset	SP	>S MIN/MAX Buffer Reset
402	>Q MiMa Reset	SP	>Q MIN/MAX Buffer Reset

No.	Information	Type of Information	Comments
403	>Idmd MiMaReset	SP	>Idmd MIN/MAX Buffer Reset
404	>Pdmd MiMaReset	SP	>Pdmd MIN/MAX Buffer Reset
405	>Qdmd MiMaReset	SP	>Qdmd MIN/MAX Buffer Reset
406	>Sdmd MiMaReset	SP	>Sdmd MIN/MAX Buffer Reset
407	>Frq MiMa Reset	SP	>Frq. MIN/MAX Buffer Reset
408	>PF MiMaReset	SP	>Power Factor MIN/MAX Buffer Reset
837	IL1d Min	MVT	I L1 Demand Minimum
838	IL1d Max	MVT	I L1 Demand Maximum
839	IL2d Min	MVT	I L2 Demand Minimum
840	IL2d Max	MVT	I L2 Demand Maximum
841	IL3d Min	MVT	I L3 Demand Minimum
842	IL3d Max	MVT	I L3 Demand Maximum
843	I1dmdMin	MVT	I1 (positive sequence) Demand Minimum
844	I1dmdMax	MVT	I1 (positive sequence) Demand Maximum
845	PdMin=	MVT	Active Power Demand Minimum
846	PdMax=	MVT	Active Power Demand Maximum
847	QdMin=	MVT	Reactive Power Demand Minimum
848	QdMax=	MVT	Reactive Power Demand Maximum
849	SdMin=	MVT	Apparent Power Demand Minimum
850	SdMax=	MVT	Apparent Power Demand Maximum
851	IL1Min=	MVT	I L1 Minimum
852	IL1Max=	MVT	I L1 Maximum
853	IL2Min=	MVT	I L2 Mimimum
854	IL2Max=	MVT	I L2 Maximum
855	IL3Min=	MVT	I L3 Minimum
856	IL3Max=	MVT	I L3 Maximum
857	I1 Min=	MVT	Positive Sequence Minimum
858	I1 Max=	MVT	Positive Sequence Maximum
859	UL1EMin=	MVT	U L1E Minimum
860	UL1EMax=	MVT	U L1E Maximum
861	UL2EMin=	MVT	U L2E Minimum
862	UL2EMax=	MVT	U L2E Maximum
863	UL3EMin=	MVT	U L3E Minimum
864	UL3EMax=	MVT	U L3E Maximum
865	UL12Min=	MVT	U L12 Minimum
867	UL12Max=	MVT	U L12 Maximum
868	UL23Min=	MVT	U L23 Minimum
869	UL23Max=	MVT	U L23 Maximum
870	UL31Min=	MVT	U L31 Minimum
871	UL31Min=	MVT	U L31 Maximum
874	U1 Min =	MVT	U1 (positive sequence) Voltage Minimum
875	U1 Max =	MVT	U1 (positive sequence) Voltage Maximum
880	SMin=	MVT	Apparent Power Minimum
881	SMax=	MVT	Apparent Power Maximum
882	fMin=	MVT	Frequency Minimum
883	fMax=	MVT	Frequency Maximum

No.	Information	Type of In- formation	Comments
1040	Pmin Forw=	MVT	Active Power Minimum Forward
1041	Pmax Forw=	MVT	Active Power Maximum Forward
1042	Pmin Rev =	MVT	Active Power Minimum Reverse
1043	Pmax Rev =	MVT	Active Power Maximum Reverse
1044	Qmin Forw=	MVT	Reactive Power Minimum Forward
1045	Qmax Forw=	MVT	Reactive Power Maximum Forward
1046	Qmin Rev =	MVT	Reactive Power Minimum Reverse
1047	Qmax Rev =	MVT	Reactive Power Maximum Reverse
1048	PFminForw=	MVT	Power Factor Minimum Forward
1049	PFmaxForw=	MVT	Power Factor Maximum Forward
1050	PFmin Rev=	MVT	Power Factor Minimum Reverse
1051	PFmax Rev=	MVT	Power Factor Maximum Reverse
10102	3U0min =	MVT	Min. Zero Sequence Voltage 3U0
10103	3U0max =	MVT	Max. Zero Sequence Voltage 3U0

2.24.6 Set Points (Measured Values)

To recognize extraordinary operational conditions, warning levels can be pro-grammed. When exceeding (with cos φ: undershooting) a programmed limit value a message is generated that can be allocated to both output relays and LEDs. In con-trast to the actual protection functions the monitoring function operates in the back-ground; therefore it may not pick up if measured values are changed spontaneously in the event of a fault and if protection functions are picked up. Also, monitoring does not respond immediately before a trip because an alarm is only output if the setpoint are repeatedly violated.

2.24.6.1 Limit Value Monitoring

Set points can be set for the following measured and metered values:
- IL1dmd>: Exceeding a preset maximum average value in Phase L1.
- IL2dmd>: Exceeding a preset maximum average value in Phase L2.
- IL3dmd>: Exceeding a preset maximum average value in Phase L3.
- I1dmd>: Exceeding a preset maximum average positive sequence current.
- |Pdmd|> : Exceeding a preset maximum average active power.
- |Qdmd|>: Exceeding a preset maximum average reactive power.
- |Sdmd|> : Exceeding a preset maximum average value of the apparent power.
- |cosφ|< Falling below a preset power factor.

2.24.6.2 Setting Notes

Set Points for Measured Values   The settings are entered under **MEASUREMENT** in the sub-menu **SET POINTS (MV) (MV)** by overwriting the existing values.

2.24.6.3 Information List

No.	Information	Type of Information	Comments
-	IL1dmd>	LV	Upper setting limit for IL1dmd
-	IL2dmd>	LV	Upper setting limit for IL2dmd
-	IL3dmd>	LV	Upper setting limit for IL3dmd
-	I1dmd>	LV	Upper setting limit for I1dmd
-	|Pdmd|>	LV	Upper setting limit for Pdmd
-	|Qdmd|>	LV	Upper setting limit for Qdmd
-	Sdmd>	LV	Upper setting limit for Sdmd
-	PF<	LV	Lower setting limit for Power Factor
273	SP. IL1 dmd>	OUT	Set Point Phase L1 dmd>
274	SP. IL2 dmd>	OUT	Set Point Phase L2 dmd>
275	SP. IL3 dmd>	OUT	Set Point Phase L3 dmd>
276	SP. I1dmd>	OUT	Set Point positive sequence I1dmd>
277	SP. |Pdmd|>	OUT	Set Point |Pdmd|>
278	SP. |Qdmd|>	OUT	Set Point |Qdmd|>
279	SP. |Sdmd|>	OUT	Set Point |Sdmd|>
285	cosφ alarm	OUT	Power factor alarm

2.24.7 Energy

Metered values for real and reactive power are determined by the processor system in the background. They can be displayed at the front of the device, read out via the operating interface using a PC with DIGSI®, or transferred to a central operational station via the system interface.

2.24.7.1 Power Metering

7SA6 integrates the calculated power which is then made available with the measured values. The components as listed in table 2-21 can be read out. The signs of the operating values depend on the setting at address 1107 **P,Q sign** (see Subsection 2.24.3 at margin heading "Display of Measured Values").

Please take into consideration that 7SA6 is, above all, a protection device. The accuracy of the measured values depends on the current transformer (normally protection core) and the tolerances of the device. The metering is therefore not suited for tariff purposes.

The counters can be reset to zero or any initial value (see SIPROTEC® 4 System Description, Order No. E50417-H1176-C151).

Table 2-21   Operational metered values

Measured Values		primary
W_{p+}	Real power, output	kWh, MWh, GWh
W_p-	Real power, input	kWh, MWh, GWh
W_q+	Reactive power, output	kVARh, MVARh, GVARh
W_q-	Reactive power, input	kVARh, MVARh, GVARh

2.24.7.2 Setting Notes

Retrieving Parameters   The SIPROTEC® 4 System Description describes how to read out the statistical counters via the device front panel or DIGSI®. The values are added up in direction of the protected object. Provided the direction was set to "forward" (address 201).

2.24.7.3 Information List

No.	Information	Type of Information	Comments
-	Meter res	IntSP_Ev	Reset meter
888	Wp(puls)	PMV	Pulsed Energy Wp (active)
888	Wp(puls)	PMV	Pulsed Energy Wp (active)
889	Wq(puls)	PMV	Pulsed Energy Wq (reactive)
889	Wq(puls)	PMV	Pulsed Energy Wq (reactive)
916	WpΔ=	-	Increment of active energy
917	WqΔ=	-	Increment of reactive energy
924	Wp+=	MVMV	Wp Forward
924	Wp+=	MVMV	Wp Forward
925	Wq+=	MVMV	Wq Forward
925	Wq+=	MVMV	Wq Forward
928	Wp-=	MVMV	Wp Reverse
928	Wp-=	MVMV	Wp Reverse
929	Wq-=	MVMV	Wq Reverse
929	Wq-=	MVMV	Wq Reverse

2.25 Command processing

A control command process is integrated in the SIPROTEC® 4 7SA6 to coordinate the operation of circuit breakers and other equipment in the power system. Control commands can originate from four command sources:

- Local operation using the keypad on the local user interface of the device,
- Operation using DIGSI®,
- Remote operation via network control center or substation controller (e.g. SICAM®),
- Automatic functions (e.g. using a binary inputs, CFC).

The number of switchgear devices that can be controlled is basically limited by the number of available and required binary inputs and outputs. For the output of control commands it has to be ensured that all the required binary inputs and outputs are configured and provided with the correct properties.

If specific interlocking conditions are needed for the execution of commands, the user can program the device with bay interlocking by means of the user-defined logic functions (CFC). The interlocking conditions of the system can be injected via the system interface and must be allocated accordingly.

The procedure during switching operations is described in detail in the SIPROTEC® 4 System Description, Order No. E50417-H1176-C151.

2.25.1 Control Authorization

2.25.1.1 Command Types

Commands to the System

This type of commands are directly output to the switchgear to change their process state:

- Commands for the operation of circuit breakers (asynchronous or synchronous through integration of the the synchronism check and closing control function) as well as commands for the control of isolators and earth switches,
- Step commands, e.g. for raising and lowering transformer taps,
- Set-point commands with configurable time settings, e.g. to control Petersen coils

Device-internal Commands

These commands do not directly operate binary outputs. They serve for initiating internal functions, communicating the detection of status changes to the device or for acknowledging them.

- Manual overriding commands to manually "update" information on process-dependent objects such as indications and switching states, e.g. if the communication with the process is interrupted. Manually overidden objects are marked as such in the information status and can be displayed accordingly.
- Flagging commands (for "setting") the data value of internal objects, e.g. switching authority (remote/local), parameter switchovers, transmission blockages and deletion and presetting of metered values.

- Acknowledgment and resetting commands for setting and resetting internal buffers or data stocks.
- Information status commands to set/delete the additional "Information Status" item of a process object, such as
  - Acquisition blocking,
  - Output blocking.

2.25.1.2 Sequence in the Command Path

Security mechanisms in the command path ensure that a switch command can be carried out only if the test of previously established criteria has been successfully completed. Additionally, user-defined interlocking conditions can be configured separately for each device. The actual execution of the command is also monitored after its release. The entire sequence of a command is described briefly in the following.

Checking a Command

Please observe the following:

- Command entry (e.g. using the keypad on the local user interface of the device)
  - Check password → access rights;
  - Check switching mode (interlocking activated/deactivated) → selection of deactivated interlocking status.
- User configurable interlocking checks:
  - Switching authority,
  - Device position check (set vs. actual comparison);
  - Zone controlled / bay interlocking (logic using CFC);
  - System interlocking (centrally via SICAM);
  - Double operation (interlocking against parallel switching operation);
  - Protection blocking (blocking of switching operations by protective functions);
  - Check (synchronism check before a close command).
- Fixed commands:
  - Internal process time (software watch dog which checks the time for processing the control action between initiation of the control and final close of the relay contact);
  - Configuration in process (if setting modification is in process, commands are rejected or delayed);
  - Equipment not present at output (if controllable equipment is not assigned to a binary output, then the command is denied);
  - Output block (if an output block has been programmed for the circuit breaker, and is active at the moment the command is processed, then the command is denied);
  - Component hardware malfunction;

    – Command in progress (only one command can be processed at a time for each circuit breaker or switch);

    – 1–of–n check (for multiple allocations such as common contact relays it is checked if a command procedure was already initiated for the output relays concerned).

Command Execution Monitoring

The following is monitored:

- Interruption of a command because of a cancel command,
- Running Time Monitor (feedback message monitoring time)

2.25.1.3 Switchgear Interlocking

Interlocking can be executed by the user-defined logic (CFC). System interlocking checks in a SICAM®/SIPROTEC® system are usually categorized as follows:

- System interlocking checked by a central control system (for interbay interlocking),
- Zone controlled/bay interlocking checked in the bay device (for the feeder).

Zone Controlled/Bay Interlocking Zone controlled/bay interlocking relies on the object data base (feedbacks) of the bay unit (here the SIPROTEC® 4 relay) as was determined during configuration (see SIPROTEC® 4 System Description).

The extent of the interlocking checks is determined by the configuration and interlocking logic of the relay.

Switching objects that require system interlocking in a central control system are assigned to a specific parameter inside the bay unit (via configuration matrix).

For all commands, operation with interlocking (normal mode) or without interlocking (test mode) can be selected:

- for local commands by reprogramming the settings with password check,
- for automatic commands, via command processing by CFC and Deactivated Interlocking Recognition,
- for local / remote commands, using an additional interlocking disable command, via Profibus.

Interlocked/ de-interlocked Switching

The configurable command checks in the SIPROTEC® 4 devices are also called "standard interlocking". These checks can be activated via DIGSI ® (interlocked switching / tagging) or deactivated (non-interlocked).

De-interlocked or non-interlocked switching means that the configured interlock conditions are not tested.

Interlocked switching means that all configured interlocking conditions are checked within the command processing. If a condition could not be fulfilled, the command will be rejected by a message with a minus added to it (e.g. "CO–"), followed by an operation response information. The rejection takes also place if a synchronism check is carried out before closing and the conditions for synchronism are not fulfilled. Table 2-22 shows the types of possible commands to switchgear, and the associated annunciations. Indications designated with *) are displayed in the represented form in the device display in the event logs and in DIGSI® on the other hand, they appear in spontaneous indications.

Table 2-22   Command types and corresponding messages

Type of command	Control	Cause	Message
Control issued	Switching	CO	CO+/–
Manual tagging (positive / negative)	Manual tagging	MT	MT+/–
Information state command, Input blocking	Input blocking	ST	ST+/– *)
Information state command, Output blocking	Binary Output Blocking	ST	ST+/– *)
Cancel Command	Cancel	CA	CA+/–

The plus sign indicated in the message is a confirmation of the command execution: The command output has a positive result, as expected. A – sign means a negative, i.e. an unexpected result; the command was rejected. Figure 2-172 shows an example in the operation annunciations command and feedback of a positively run switching action of the circuit breaker.

The check of interlocking can be programmed separately for all switching devices and tags that were set with a tagging command. Other internal commands such as overriding or abort are not tested, i.e. are executed independently of the interlockings.

```
EVENT LOG
--------------------
19.06.01 11:52:05,625
Q0          CO+ close

19.06.01 11:52:06,134
Q0          FB+ close
```

Figure 2-172   Example of an Operational Annunciation for Switching Circuit Breaker 52

Standard Interlocking

The standard interlocking includes the checks for each switchgear which were set during the configuration of inputs and outputs, see SIPROTEC® 4 System Description.

An overview for processing the interlocking conditions in the relay is shown by Figure 2-173.
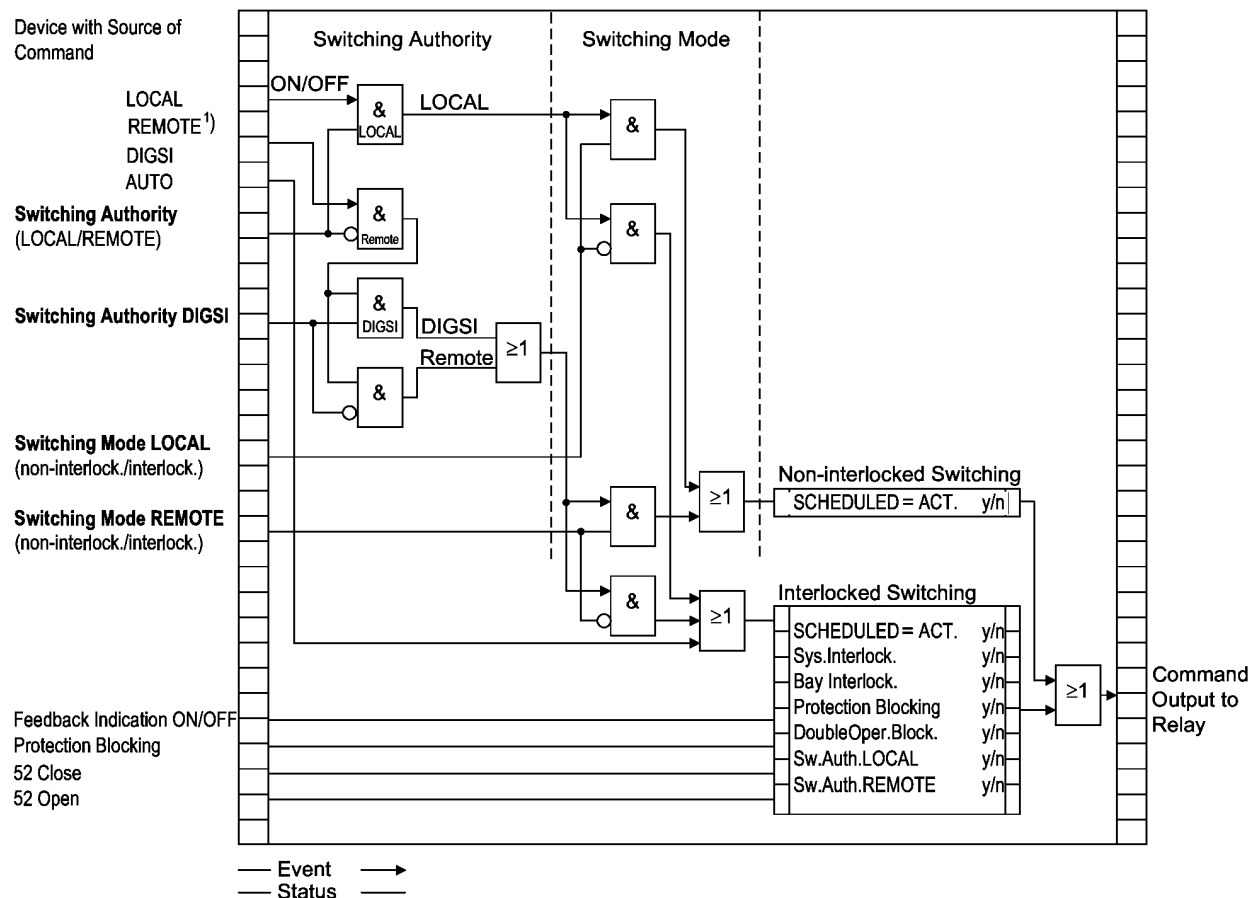
Figure 2-173   Standard interlockings

1)   Source of Command REMOTE includes LOCAL.

LOCAL   command using substation controller

REMOTE   Command using remote source such as SCADA through controller to device

The device display shows the configured interlocking reasons. The are marked by letters explained in 2-23.

Table 2-23   Interlocking Commands

Interlocking Commands	Command	Display
Switching Authority	L	L
System interlocking	S	S
Bay Interlocking	Z	Z
SET = ACTUAL (switch direction check)	P	P
Protection Blockage	B	B

Figure 2-174 shows all interlocking conditions (which usually appear in the display of the device) for three switchgear items with the relevant abbreviations explained in Table 2-23. All parametrized interlocking conditions are shown.

```
Interlocking   01/03
-------------------
Q0 Close/Open S — Z P B
Q1 Close/Open S — Z P B
```

```
Q8 Close/Open S — Z P B
```

Figure 2-174   Example of Configured Interlocking Conditions

Control Logic via CFC   For the bay interlocking an enabling logic can be structured using the CFC. Via specific release conditions the information "released" or "bay interlocked" are available. ON / OFF).

2.25.1.4 Information List

No.	Information	Type of Information	Comments
-	Cntrl Auth	DP	Control Authority
-	ModeLOCAL	DP	Controlmode LOCAL
-	ModeREMOTE	IntSP	Controlmode REMOTE
-	CntrlDIGSI	LV	Control DIGSI
-	Cntrl Auth	IntSP	Control Authority
-	ModeLOCAL	IntSP	Controlmode LOCAL

2.25.2 Control Device

2.25.2.1 Information List

No.	Information	Type of Information	Comments
-	Breaker	CF_D12	Breaker
-	Breaker	DP	Breaker
-	Disc.Swit.	CF_D2	Disconnect Switch
-	Disc.Swit.	DP	Disconnect Switch
-	EarthSwit	CF_D2	Earth Switch
-	EarthSwit	DP	Earth Switch
-	52 Open	IntSP	Interlocking: 52 Open
-	52 Close	IntSP	Interlocking: 52 Close
-	Disc.Open	IntSP	Interlocking: Disconnect switch Open
-	Disc.Close	IntSP	Interlocking: Disconnect switch Close
-	E Sw Open	IntSP	Interlocking: Earth switch Open
-	E Sw Cl.	IntSP	Interlocking: Earth switch Close
-	Q2 Op/Cl	CF_D2	Q2 Open/Close
-	Q2 Op/Cl	DP	Q2 Open/Close

No.	Information	Type of Information	Comments
-	Q9 Op/Cl	CF_D2	Q9 Open/Close
-	Q9 Op/Cl	DP	Q9 Open/Close
-	Fan ON/OFF	CF_D2	Fan ON/OFF
-	Fan ON/OFF	DP	Fan ON/OFF
-	UnlockDT	IntSP	Unlock data transmission via BI

2.25.3 Process Data

During the processing of commands, independently of the further annunciation allocation and processing, command and process feedbacks are sent to the annunciation processing. These messages contain information on the cause. With the corresponding allocation (configuration) these messages are entered in the event log, thus serving as a report.

A listing of possible operating messages and their meaning as well as the command types needed for tripping and closing the switchgear or for raising and lowering of transformer taps and detailed information are described in the SIPROTEC® 4 System Description.

2.25.3.1 Method of Operation

Acknowledgement of Commands to the Device Front

All messages with the source of command LOCAL are transformed into a corresponding response and shown in the display of the device.

Acknowledgement of Commands to Local/Remote/Digsi

The acknowledgement of messages which relate to commands with the origin "Command Issued = Local/ Remote/DIGSI" are sent back to the initiating point independent of the routing (configuration on the serial digital interface).

The acknowledgement of commands is therefore not executed by a response indication as it is done with the local command but by ordinary command and feedback information recording.

Feedback Monitoring

Command processing time-monitors all commands with feedback. Parallel to the command a monitoring time period (command runtime monitoring) is started which checks whether the switchgear has achieved the desired final state within this period. The monitoring time is stopped as soon as the feedback information arrives. If no feedback information arrives, a response "Time Limit Expired" appears and the process is terminated.

Commands and their feedbacks are also recorded as operational annunciations. Normally the execution of a command is terminated as soon as the feedback information (**FB+**) of the relevant switchgear arrives or, in case of commands without process feedback information, the command output resets.

In the feedback the plus sign means that a command has been positively completed. The command has been positively completed, as expected. Accordingly the minus sign means a negative, unexpected, result.

Command Output /
Relay Triggering
The command types needed for tripping and closing of the switchgear or for raising and lowering of transformer taps have been determined during configuration, see also SIPROTEC ® 4 System Description, order no. E50417-H1176-C151.

2.25.3.2 Information List

No.	Information	Type of In-formation	Comments
-	>Door open	SP	>Cabinet door open
-	>CB wait	SP	>CB waiting for Spring charged
-	>Err Mot U	SP	>Error Motor Voltage
-	>ErrCntrlU	SP	>Error Control Voltage
-	>SF6-Loss	SP	>SF6-Loss
-	>Err Meter	SP	>Error Meter
-	>Tx Temp.	SP	>Transformer Temperature
-	>Tx Danger	SP	>Transformer Danger

2.25.4 Protocol

2.25.4.1 Information List

No.	Information	Type of In-formation	Comments
-	SysIntErr.	IntSP	Error Systeminterface

■

Mounting and Commissioning

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3

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This chapter is intended for experienced commissioning staff. The staff must be familiar with the commissioning of protection and control systems, with the management of power systems and with the relevant safety rules and guidelines. Under certain circumstances particular power system adaptations of the hardware are necessary. Some of the primary tests require the protected line or equipment to carry load.

3.1   Mounting and Connections

General

> ⚠️ **WARNING!**
>
> **Warning of improper transport, storage, installation, and application of the device.**
>
> Non–observance can result in death, personal injury or substantial property damage.
>
> Trouble free and safe use of this device depends on proper transport, storage, installation, and application of the device according to the warnings in this instruction manual.
>
> Of particular importance are the general installation and safety regulations for work in a high-voltage environment (for example, VDE, IEC, EN, DIN, or other national and international regulations). These regulations must be observed.

3.1.1   Configuration Information

Prerequisites

For installation and connections the following conditions must be met:

The rated device data is checked as recommended in the SIPROTEC® 4 System Description. The compliance of these data is verified with the Power System Data.

Connection Variants

General Diagrams are shown in Appendix A.2. Connection examples for current transformer and voltage transformer circuits are provided in Appendix A.3. It must be checked that the setting of the **P.System Data 1**, Section 2.1.3.1, was made in accordance to the device connections.

Currents

In Appendix A.3 examples for the possibilities of the current transformer connections in dependence on network conditions are displayed.

For normal connection, address 220 **I4 transformer** = *In prot. line* must be set and furthermore, address 221 **I4/Iph CT** = *1.000*.

When using separate earth current transformers, address 220 **I4 transformer** = *In prot. line* must be set. The factor 221 **I4/Iph CT** may deviate from *1*. For calculation hints, please refer to Section 2.1.3.1 at "Current Transformer Connection". Please observe that 2-CT-connection is permitted only for isolated or compensated networks.

Furthermore, examples for the connection of the earth current of a parallel line (for parallel line compensation) are displayed. Address 220 **I4 transformer** must be set *In paral. line* here. The factor 221 **I4/Iph CT** may deviate from *1*. For calculation hints, please refer to Section 2.1.3.1.

The other figures show examples for the connection of the earth current of a source transformer. Address 220 **I4 transformer** must be set *IY starpoint* here. Hints regarding the factor 221 **I4/Iph CT** can also be found in Section 2.1.3.1.

Voltages

Connection examples for current and voltage transformer circuits are provided in Appendix A.3.

For normal connection the 4th voltage measuring input is not used. Correspondingly, the following setting must be made in address 210 **U4 transformer** = *Not connected*. Nevertheless, the factor in address 211 **Uph / Udelta** must be set to *1.73* (this factor is used internally for the conversion of measured and fault recording values).

For additional connection of an e-n-winding of a set of voltage transformers, address 210 must be set to **U4 transformer** = *Udelta transf.*. The factor address 211 **Uph / Udelta** depends on the transformation ratio of the e–n-winding. Instructions - see Section 2.1.3.1 at "Voltage Transformer Connection".

In further connection examples also the e–n winding of a set of voltage transformers is connected, in this case, however of a central set of transformers at a busbar. For more information refer to the previous paragraph. Observe that 2-CT-connection is permitted only for isolated or compensated networks.

Further figures show examples for the additional connection of a different voltage, in this case the busbar voltage (e.g. for the voltage protection or synchronism check). For voltage protection address 210 **U4 transformer** = *Ux transformer* must be set, for the synchronism check **U4 transformer** = *Usync transf.*. The factor address 215 **U-line / Usync** is unequal to *1*, only if the feeder side VT and busbar side VT have a different transformation ratio. The factor in address 211 **Uph / Udelta** must however be set to *1.73* (this factor is used internally for the conversion of measured and fault recording values).

If there is a power transformer between the set of busbar and the feeder VT's, the phase displacement of the voltages caused by the transformer must be considered for the synchronism check (if used). In this case, also check the addresses 212 **Usync connect.**, 214 φ **Usync-Uline** and 215 **U-line / Usync**. You will find detailed hints and an example in Section 2.1.3.1 under "Voltage Transformer Connection".

Binary Inputs and Outputs

The connections to the system depend on the possible allocation of the binary inputs and outputs, i.e. how they are assigned to the system. The presettings of the device are listed in Tables A.4 in the Appendix. Check also that the labelings on the front correspond to the allocated indication functions.

Changing Setting Groups with Binary Inputs

If binary inputs are used to change setting groups, please observe the following:
- To enable the control of 4 possible setting groups 2 binary inputs have to be available. One binary input must be set for ">Set Group Bit0", the other input for ">Set Group Bit1". If either of these input functions is not assigned, then it is considered as not controlled.
- To control two setting groups, one binary input set for ">Set Group Bit0" is sufficient since the binary input ">Set Group Bit1", which is not assigned, is considered to be not controlled.
- The status of the signals controlling the binary inputs to activate a particular setting group must remain constant as long as that particular group is to remain active.

The following Table shows the relationship between binary inputs and the setting groups A to D. Principal connection diagrams for the two binary inputs are illustrated in the following Figure 3-1. The Figure illustrates an example in which both Set Group Bits 0 and 1 are configured to be controlled (actuated) when the associated binary input is energized (high).

Where:

No   = not energized

Yes   = energized

Table 3-1   Changing Setting Groups with Binary Inputs

Binary Input		Active Group
>Set Group Bit 0	>Set Group Bit 1	
No	No	Group A
Yes	No	Group B
No	Yes	Group C
Yes	Yes	Group D
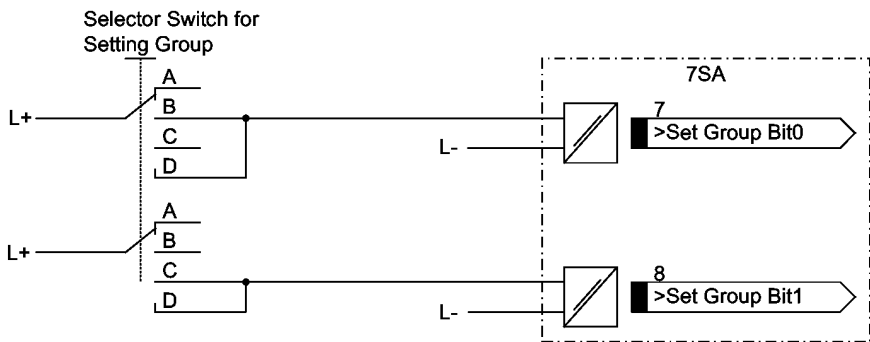
Figure 3-1   Connection diagram (example) for setting group switching with binary inputs

Trip Circuit Supervision

It must be noted that two binary inputs or one binary input and one bypass resistor R must be connected in series. The pick-up threshold of the binary inputs must therefore be substantially below <u>half</u> the rated control DC voltage.

If two binary inputs are used for the trip circuit supervision, these binary inputs must be isolated, i.o.w. not be communed with each other or with another binary input.

If one binary input is used, a bypass resistor R must be used (refer to Figure 3-2). This resistor R is connected in series with the second circuit breaker auxiliary contact (Aux2), to also allow the detection of a trip circuit failure when the circuit breaker auxiliary contact 1 (Aux1) is open, and the command relay contact has reset. The value of this resistor must be such that in the circuit breaker open condition (therefore Aux1 is open and Aux2 is closed) the circuit breaker trip coil (TC) is no longer picked up and binary input (BI1) is still picked up if the command relay contact is open.
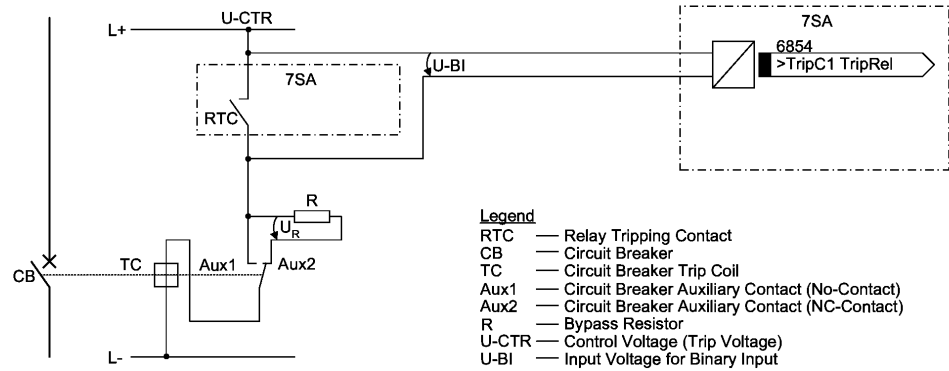
Figure 3-2   Trip circuit supervision with one binary input — Example for trip circuit 1

This results in an upper limit for the resistance dimension, R_{max}, and a lower limit R_{min}, from which the optimal value of the arithmetic mean R should be selected:

$$R = \frac{R_{max} + R_{min}}{2}$$

In order that the minimum voltage for controlling the binary input is ensured, R_{max} is derived as:

$$R_{max} = \left(\frac{U_{CTR} - U_{BI\,min}}{I_{BI\,(High)}} \right) - R_{TC}$$

To keep the circuit breaker trip coil energized in the above case, R_{min} is derived as:

$$R_{min} = R_{TC} \cdot \left(\frac{U_{CTR} - U_{TC\,(LOW)}}{U_{TC\,(LOW)}} \right)$$

$I_{BI\,(HIGH)}$	Constant current with activated BI (= 1.8 mA)
U_{BImin}	Minimum control voltage for BI (19 V for delivery setting for nominal voltages 24/48/60 V; 88 V for delivery setting for nominal voltages 110/125/220/250 V)
U_{CTR}	Control voltage for trip circuit
R_{TC}	DC resistance of circuit breaker trip coil
$U_{TC\,(LOW)}$	Maximum voltage on the circuit breaker trip coil that does not lead to tripping

If the calculation yields that R_{max} R_{min}, the calculation must be repeated using the next lowest switching threshold $U_{BI\,min}$, and this threshold must be implemented in the relay using plug-in jumpers (see Section "Hardware Modifications").

For the power consumption of the resistance:

$$P_R = I^2 \cdot R = \left(\frac{U_{CTR}}{R + R_{TC}} \right)^2 \cdot R$$

Example:

$I_{BI\,(HIGH)}$	1.8 mA (from SIPROTEC® 4 7SA6)
U_{BImin}	19 V for delivery setting for nominal voltages of 24/48/60 V (from the 7SA6); 88 V for delivery setting for nominal voltages 110/125/220/250 V (from 7SA6);
U_{CTR}	110 V (system / trip circuit)
R_{TC}	500 Ω (system / trip circuit)
$U_{TC\,(LOW)}$	2 V (system / trip circuit)

$$R_{max} = \left(\frac{110\ V - 19\ V}{1.8\ mA}\right) - 500\ \Omega = 50.1\ k\Omega$$

$$R_{min} = 500\ \Omega \cdot \left(\frac{110\ V - 2\ V}{2\ V}\right) = 27\ k\Omega$$

$$R = \frac{R_{max} + R_{min}}{2} = 38.6\ k\Omega$$

The closest standard value of 39 kΩ is selected; the power is:

$$P_R = \left(\frac{110\ V}{39\ k\Omega + 0.5\ k\Omega}\right)^2 \cdot 39\ k\Omega \geq 0.3\ W$$

Pilot Wires for Protection

If the distance protection is supplemented with the transmission scheme **Teleprot. Dist.** = *Pilot wire comp* (address 121), it has to be secured that the quiescent state loop is supplied with enough auxiliary voltage. The function itself is described in section 2.6.

Please take note that both binary inputs are interconnected and connected in series with the resistor of the pilot wires. Therefore the loop voltage must not be too low and the pickup voltage of the binary inputs must not be too high. In general, the lowest threshold (19 V) must be selected for the auxiliary voltages of 60 V to 125 V, the threshold of 88 V is selected for voltages of 220 V to 250 V.

Due to the low current consumption of the binary inputs it may be necessary to additionally burden the pilot wire loop with an external shunt connected resistor so that the binary inputs are not blocked by the charge of the pilot wire after an interruption of the loop. As an alternative, auxiliary relay combinations (e.g. 7PA5210-2A) can be introduced.

Pilot wires used as cable connections between stations must always be checked on their effect on high voltage. The pilot wires of the pilot cables must stand external strains.

The worst electrical fault that may occur to the pilot cables is generated in the pilot wire system by an earth fault. The short-circuit current induces a longitudinal voltage into the pilot wires lying parallel to the high voltage line. The induced voltage can be reduced by well-conductive cable jackets and by armouring (low reduction factor, for both high voltage cable and pilot cables).

The induced voltage can be calculated with the following formula:

$U_i = 2\,\pi\,f \cdot M \cdot I_{k1} \cdot l \cdot r_1 \cdot r_2$

with

U_i	= induced longitudinal voltage in V,
f	= nominal frequency in Hz,
M	= mutual inductance between power line and pilot wires in mH/km,
I_{k1}	= maximum earth fault current via power line in kA,
l	= distance between energy line and pilot wires in km,
r_1	= reduction factor of power cable (r_1 = 1 for overhead lines),
r_2	= reduction factor of pilot wire cable.

The calculated induced voltage should neither exceed the 60% rate of the test voltage of the pilot wires nor of the device connections (binary inputs and outputs). Since the latter were produced for a test voltage of 2kV, only a maximum induced longitudinal voltage of 1.2kV is allowed.

3.1.2   Hardware Modifications

3.1.2.1   General

A subsequent adaptation of the hardware to the power system conditions can, for example, become necessary with regard to the control voltage for binary inputs or the termination of bus-capable interfaces. Follow the procedure described in this section, whenever hardware modifications are done.

Auxiliary Voltage

There are different ranges of input voltage for the auxiliary voltage (refer to the Ordering Information in Appendix A.1). The power supplies of the variants for 60/110/125 VDC and 110/125/220/250 VDC, 115 VAC are largely interchangeable by modifying the position of the jumpers. The assignment of these jumpers to the nominal voltage ranges and their spatial arrangement on the PCB are described further below at "Processor Board C-CPU-2" Location and ratings of the miniature fuse and the buffer battery are also shown. When the device is delivered, these jumpers are set according to the name-plate sticker. Generally, they do not need to be altered.

Life Contact

The life contact of the device is a changeover contact from which either the NC contact or the NO contact can be connected to the device terminals via a plug-in jumper (X40). Assignments of the jumpers to the contact type and the spatial layout of the jumpers are described in the following Section at margin heading "Processor Board C-CPU-2".

Nominal Currents

The input transformers of the device are set to a nominal current of 1 A or 5 A with jumpers. The position of the jumpers are set according to the name-plate sticker. The assignments of the jumpers to the nominal current and the spatial layout of the jumpers are described in the following section "Board C-I/O-2" or "Board C-I/O-11". All jumpers must be set for one nominal current, i.e. one jumper (X61 to X64) for each input transformer and additionally the common jumper X60.

Note

If nominal current ratings are changed exceptionally, then the new ratings must be registered in addresses 206 **CT SECONDARY** in the Power System Data (see Subsection 2.1.3.1).

Control Voltage for Binary Inputs

When the device is delivered from the factory, the binary inputs are set to operate with a voltage that corresponds to the rated DC voltage of the power supply. If the rated values differ from the power system control voltage, it may be necessary to change the switching threshold of the binary inputs.

A jumper position is changed to adjust the pickup voltage of a binary input. The assignment of the jumpers to the binary inputs and the spatial layout of the jumpers is described in the following sections at "Processor Board C-CPU-2", "Board(s) C-I/O-1 and C-I/O-10" and "Board C-I/O-11".

Note

If binary inputs are used for trip circuit supervision, note that two binary inputs (or a binary input and a replacement resistor) are connected in series. The switching threshold must lie clearly below <u>one half</u> of the rated control voltage.

Contact Mode for Binary Outputs

Input/output boards can have relays that are equipped with changeover contacts. For this it is necessary to alter a jumper. The following sections at "Switching Elements on Printed Circuit Boards" explain for which relays on which boards this applies.

Exchanging Interfaces

Only serial interfaces of devices for panel flush and cubicle mounting as well as of mounting devices with detached operator panel are replaceable. In the following section under margin heading "Exchanging Interface Modules" it is described which interfaces can be exchanged, and how this is done.

Matching Interfaces with Bus Capability

If the device is equipped with a serial RS485 interface or PROFIBUS, they must be terminated with resistors at the last device on the bus to ensure reliable data transmission. For this purpose, termination resistors are provided on the PCB of the C-CPU-2 processor boards and on the RS485 or PROFIBUS interface module which can be connected via jumpers. The spatial arrangement of the jumpers on the PCB of the processor board C-CPU-2 is described in the following sections at margin heading "Processor board C-CPU-2" and on the interface modules at "RS485-Interface" and "PROFIBUS-Interface". Both jumpers must always be plugged in identically.

The termination resistors are disabled on delivery.

Spare Parts

Spare parts can be the buffer battery that provides for storage of the data in the battery-buffered RAM when the voltage supply fails, and the miniature fuse of the internal power supply. Their spatial arrangement is shown in the figure of the processor board. The ratings of the fuse are printed on the board next to the fuse itself. When exchanging the fuse, please observe the hints given in the SIPROTEC® 4 System Description in the chapter "Maintenance" and "Corrective Action / Repairs".

3.1.2.2   Disassembly

**Work on the Printed
Circuit Boards**

Note

It is assumed for the following steps that the device is not operative.

Caution!

Caution when changing jumper settings that affect nominal values of the device:

As a consequence, the ordering number (MLFB) and the ratings that are stated on the nameplate do no longer match the actual device properties.

If such changes are necessary, the changes should be clearly and fully noted on the device. Self-adhesive labels are provided for this which can be used as supplementary nameplates.

To perform work on the printed circuit boards, such as checking or moving switching elements or exchanging modules, proceed as follows:

- Prepare your workplace: Prepare a suitable underlay for Electrostatically Sensitive Devices (ESD). Also the following tools are required:
  - screwdriver with a 5 to 6 mm wide tip,
  - a crosstip screwdriver for Pz size 1,
  - a nut driver with 4.5 mm socket.
- Unfasten the screw-posts of the D-subminiature connector on the back panel at location "A" and "C". This is not necessary if the device is designed for surface mounting.
- If the device features interfaces at locations "B" and "D" next to the interfaces on location "A" and "C" , the screws located diagonally to the interfaces must be removed. This is not necessary if the device is designed for surface mounting.
- Remove the covers on the front panel and loosen the screws which can then be accessed.
- Remove the front panel and place it carefully to the side. For device versions with detached operator control element, the front cover can directly be lifted off, after the screws have been released.

**Work on the Plug
Connectors**

Caution!

Mind electrostatic discharges:

Non–observance can result in minor personal injury or property damage.

When handling with plug connectors, electrostatic discharges may emerge by previously touching an earthed metal surface must be avoided.

Do not plug or unplug interface connectors under voltage!

For the assembly of the boards for the housing $^1/_3$ refer to Figure 3-3, for the housing $^1/_2$ refer to Figure 3-4, for the housing $^2/_3$ refer to Figure 3-5 and for housing $^1/_1$ refer to Figure 3-6.

- Disconnect the plug connector of the ribbon cable between the front cover and the processor board C-CPU-2 at the front cover side. Press the top latch of the plug connector up and the bottom latch down so that the plug connector of the ribbon cable is pressed out. This action does not apply to the device version with detached operator panel. However, on the central processor unit C–CPU-2 (No. 1 in Figure 3-3 to 3-6) the 7-pole plug connector X16 behind the D-subminiature connector and the plug connector of the ribbon cable (connected to the 68-pole plug connector on the rear side) must be removed.

- Disconnect the ribbon cables between the processor board C-CPU-2 (No. 1 in Figure 3-3 to 3-6) and the input/output board I/O (according to order variant No. 2 to No. 6 in Figure 3-3 to 3-6).

- Remove the boards and put them on the earthed mat to protect them from ESD damage. In the case of the device variant for panel surface mounting please be aware of the fact a certain amount of force is required in order to remove the C-CPU-2 board due to the existing plug connector.

- Check the jumpers according to Figures 3-7 to 3-13, 3-16, 3-17 and the following information. Change or remove the jumpers if necessary.

❶ Processor printed circuit board C–CPU–2
❸ Input/output printed circuit board C–I/O–2
❹ Input/output printed circuit board C–I/O–11

Slot 5   Slot 19
❶   ❸   7SA610∗–∗A/E/J
BI1 to   BI5   ←—— Binary inputs (BI)
BI5

❶   ❹   7SA610∗–∗B/F/K
BI1 to   BI6 and   ←—— Binary inputs (BI)
BI5   BI7
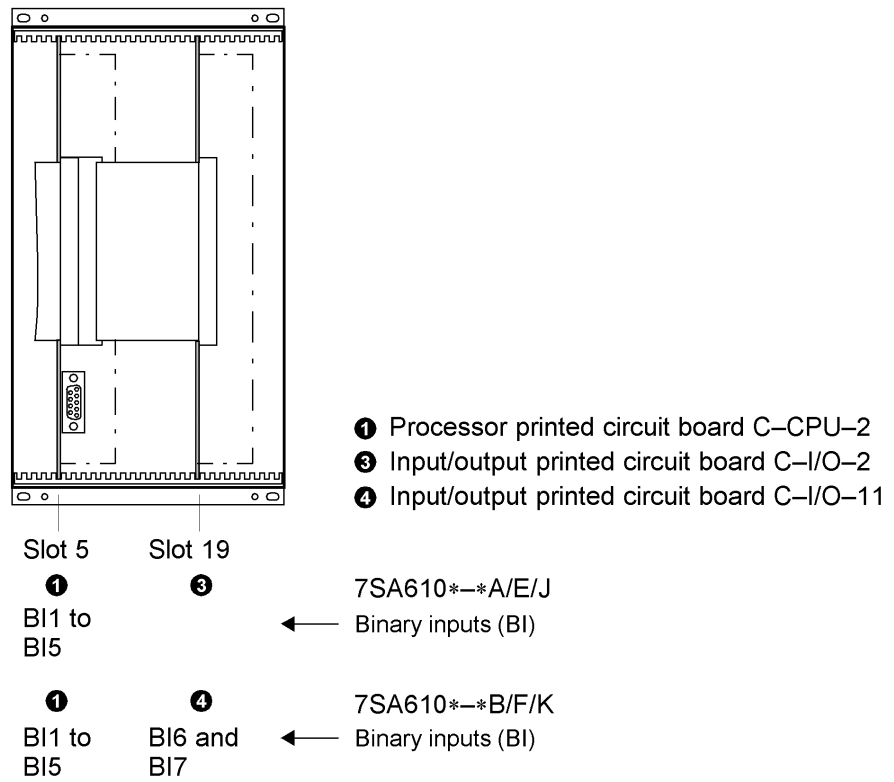
Figure 3-3   Front view with housing size $^1/_3$ after removal of the front cover (simplified and scaled down)

❶ Processor printed circuit board C-CPU-2
❷ Input/output printed circuit board C-I/O-1
❸ Input/output printed circuit board C-I/O-2
❹ Input/output printed circuit board C-I/O-11
❺ Input/output printed circuit board B-I/O-2
❻ Input/output printed circuit board C-I/O-10

Slot 5	Slot 19	Slot 33	
❶	**❷**	**❸**	7SA6∗1∗–∗A/E/J
BI1 to BI5	BI6 to BI13		← Binary Inputs (BI)
❶	**❺**	**❹**	7SA6∗1∗–∗B/F/K
BI1 to BI5	BI8 to BI20	BI6 and BI7	← Binary Inputs (BI)
❶	**❻**	**❸**	7SA6∗1∗–∗M/N/P
BI1 to BI5	BI6 to BI13		← Binary Inputs (BI)

Figure 3-4   Front view with housing size $^1/_2$ after removal of the front cover (simplified and scaled down)

❶ Processor printed circuit board C–CPU–2
❷ Input/output printed circuit board C–I/O–1
❸ Input/output printed circuit board C–I/O–2
❹ Input/output printed circuit board C–I/O–10

Slot 5	Slot 19	Slot 33	Slot 5	
❶	**❷**	**❷**	**❸**	7SA613∗–∗A
BI1 to BI5	BI6 to BI13	BI14 to BI21		← Binary Inputs (BI)
❶	**❹**	**❷**	**❸**	7SA613∗–∗M
BI1 to BI5	BI6 to BI13	BI14 to BI21		← Binary Inputs (BI)
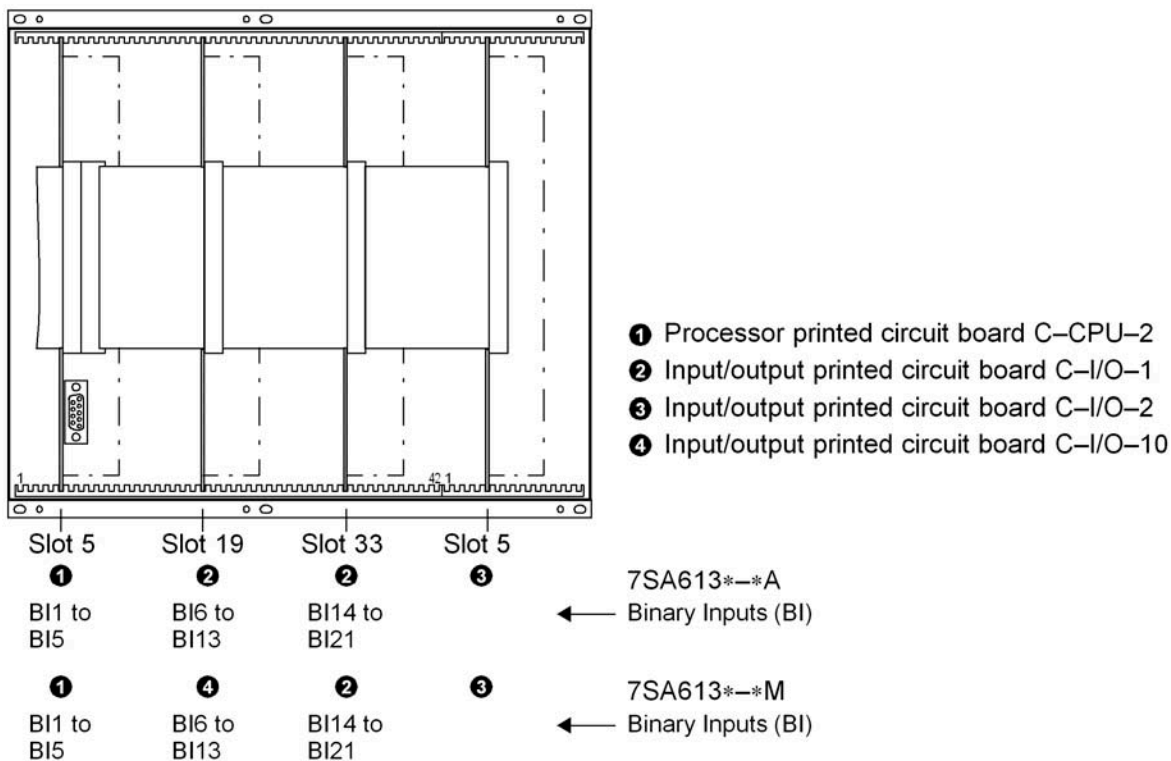
Figure 3-5   Front view with housing size $^2/_3$ after removal of the front cover (simplified and scaled down)

❶ Processor p. c. b. C-CPU-2
❷ Input/Output p. c. b. C-I/O-1
❸ Input/Output p. c. b. C-I/O-2
❹ Input/Output p. c. b. C-I/O-11
❺ Input/Output p. c. b. B-I/O-2
❻ Input/Output p. c. b. C-I/O-10

Slot 5	Slot 19	Slot 33	Slot 19	Slot 33	
❶ BI1 to BI5		❷ BI6 to BI13	❷ BI14 to BI21	❸	7SA6∗2∗−∗A/E/J ← Binary Inputs (BI)
❶ BI1 to BI5	❷ BI22 to BI29	❷ BI6 to BI13	❷ BI14 to BI21	❸	7SA6∗2∗−∗B/F/K ← Binary Inputs (BI)
❶ BI1 to BI5		❺ BI8 to BI20	❺ BI21 to BI33	❹ BI6 and BI7	7SA6∗2∗−∗C/G/L ← Binary Inputs (BI)
❶ BI1 to BI5		❻ BI6 to BI13	❷ BI14 to BI21	❸	7SA6∗2∗−∗M/P/R ← Binary Inputs (BI)
❶ BI1 to BI5	❷ BI22 to BI29	❻ BI6 to BI13	❷ BI14 to BI21	❸	7SA6∗2∗−∗N/Q/S ← Binary Inputs (BI)

Figure 3-6   Front view with housing size $^1/_1$ after removal of the front cover (simplified and scaled down)

3.1.2.3   Switching Elements on Printed Circuit Boards

Processor Board C-CPU-2

The layout of the printed circuit board for the processor board C-CPU-2 is illustrated in the following figure. The set nominal voltage of the integrated supply is checked according to Table 3-2, the quiescent state of the life contact according to Table 3-3 and the selected control voltages of the binary inputs BI1 to BI5 according to Table 3-4 and the integrated interface RS232 / RS485 according to Table 3-5 to 3-7. The location and ratings of the miniature fuse (F1) and the buffer battery (G1) are shown in the following figure.

Before checking the integrated RS232/RS485 interface it may be necessary to remove the interface modules placed above.
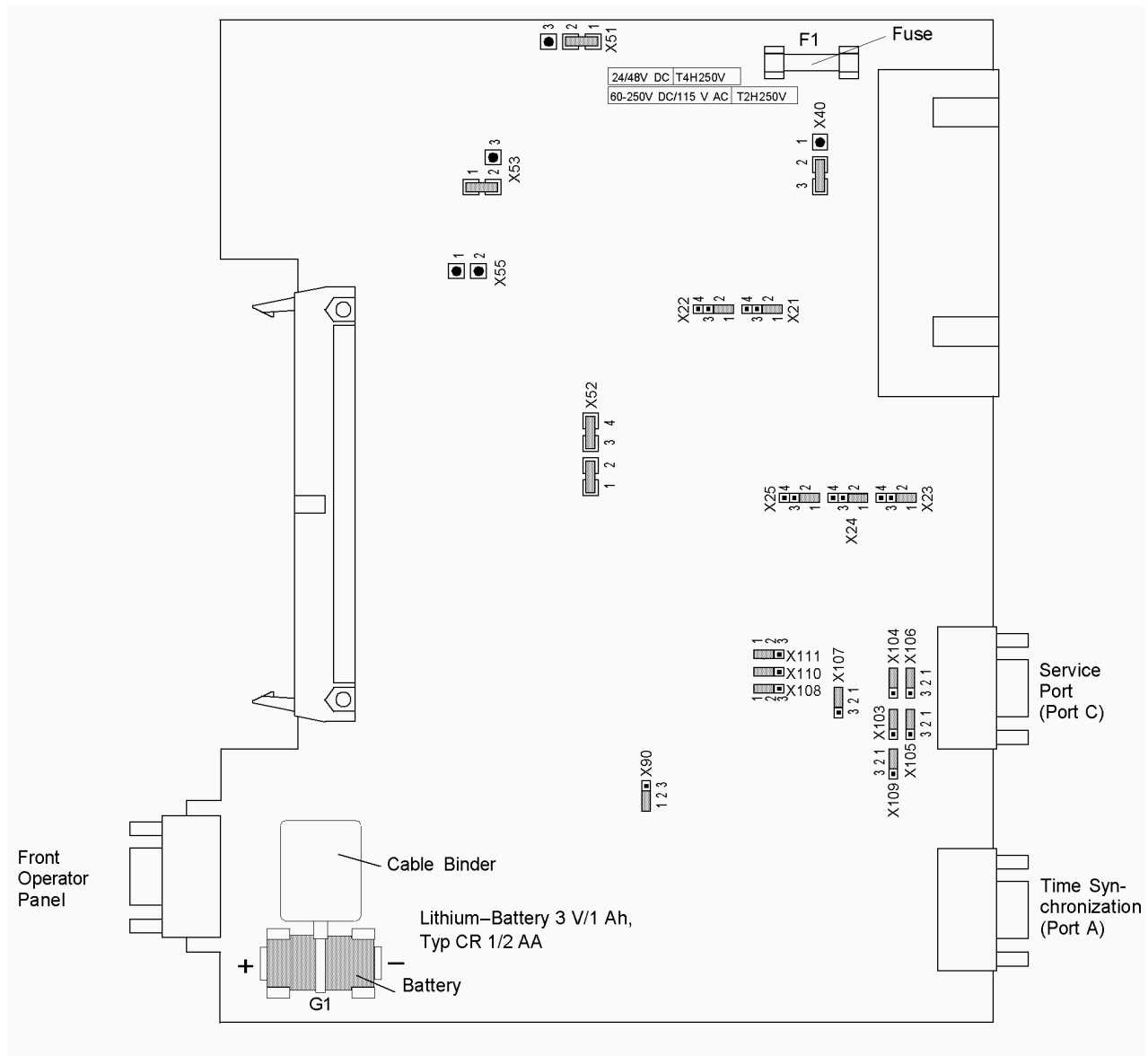
Figure 3-7   Processor printed circuit board C–CPU—2 with jumpers settings required for the board configuration

Table 3-2   Jumper setting of the rated voltage of the integrated **Power Supply** on the C-CPU-2 processor board

Jumper	Nominal voltage		
	24 to 48 VDC	**60 to 125 VDC**	**110 VDC to 250 VDC, 115 VAC**
X51	Not used	1-2	2-3
X52	Not used	1-2 and 3-4	2-3
X53	Not used	1-2	2-3
X55	Not used	Not used	1-2
	cannot be changed	interchangeable	

Table 3-3   Jumper setting of the quiescent state of the **Life Contact** on the processor board C-CPU-2

Jumper	Open in the quiescent state	Closed in the quiescent state	Presetting
X40	1-2	2-3	2-3

Table 3-4   Jumper setting of the **Control Voltages** of the binary inputs BI1 to BI5 on the C-CPU-2 processor board

Binary Inputs	Jumper	17 V Threshold [1]	73 V Threshold [2]	154 V Threshold [3]
BI1	X21	1-2	2-3	3-4
BI2	X22	1-2	2-3	3-4
BI3	X23	1-2	2-3	3-4
BI4	X24	1-2	2-3	3-4
BI5	X25	1-2	2-3	3-4

[1] Factory settings for devices with power supply voltages of 24 VDC to 125 VDC
[2] Factory settings for devices with power supply voltages of 110 VDC to 250 VDC and 115 VAC
[3] Use only with control voltages 220 or 250 VDC

By repositioning jumpers the interface RS485 can be modified into a RS232 interface and vice versa.

Jumpers X105 to X110 must be set to the same position.

Table 3-5   Jumper Settings of the integrated **RS232/RS485 Interface** on the C–CPU-2 processor board

Jumper	RS232	RS485
X103 and X104	1-2	1-2
X105 to X110	1-2	2-3

The jumpers are preset at the factory according to the configuration ordered.

With interface RS232 jumper X111 is needed to activate CTS which enables the communication with the modem.

Table 3-6   Jumper setting for **CTS** (**C**lear **T**o **S**end, flow control) on the C-CPU-2 processor board

Jumper	/CTS from Interface RS232	/CTS controlled by /RTS
X111	1-2	2-3 [1]

[1] Default setting in releases from 7SA6.../**DD**

Jumper setting 2-3: The connection to the modem is usually done with star coupler or optical fibre converter. Therefore the modem control signals according to RS232 standard DIN 66020 are not available. Modem signals are not required since the connection to SIPROTEC® 4 devices is always carried out in the half duplex mode. Please use connection cable with ordering number 7XV5100–4.

Jumper setting 1-2: This setting makes the modem signals available, i. e. for a direct RS232-connection between the SIPROTEC® 4 device and the modem this setting can be selected optionally. We recommend to use a standard RS232 modem connection cable (converter 9-pin to 25-pin).

Note

For a direct connection to DIGSI® with interface RS232 jumper X111 must be plugged in position 2-3.

If there are no external terminating resistors in the system, the last devices on a RS485 bus must be configured via jumpers X103 and X104.

Table 3-7   Jumper settings of the **Terminating Resistors** of interface RS485 on the C-CPU-2 processor board

Jumper	Terminating resistor closed	Terminating resistor open	Presetting
X103	2-3	1-2	1-2
X104	2-3	1-2	1-2

Note: Both jumpers must always be plugged in the same way!

Jumper X90 has no function. The factory setting is 1-2.

Terminating resistors can also be connected externally (e.g. to the terminal block). In this case, the terminating resistors located on the RS485 or PROFIBUS interface module or directly on the PCB of the processor board C-CPU-2 must be de-energized.
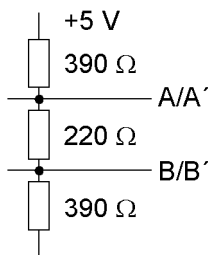
Figure 3-8   Termination of the RS485 interface (external)

Input/Output Board C-I/O-1 and C-I/O-10   The layout of the PCB for the input/output board C-I/O-1 is shown in Figure 3-9, the PCB for the input/output board C-I/O-10 is shown in Figure 3-10.
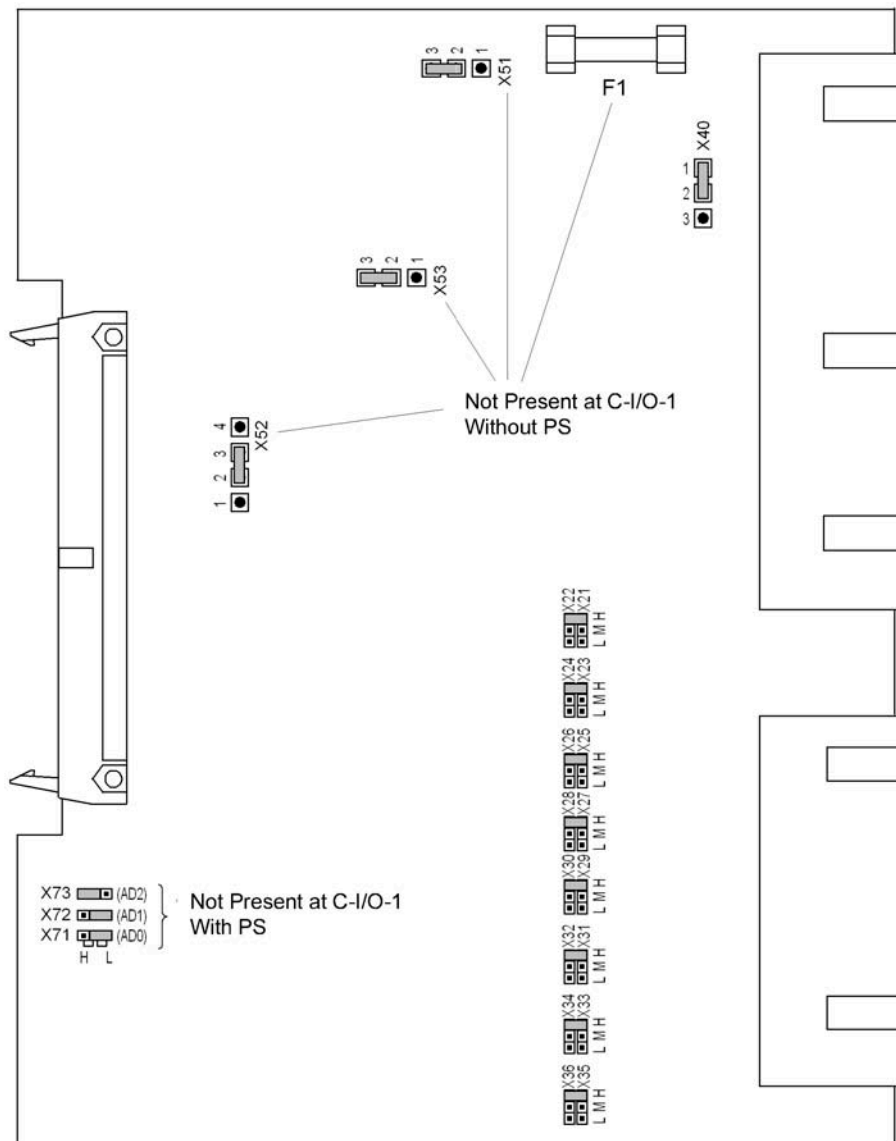
Figure 3-9   Input/output board C-I/O-1 with representation of the jumper settings required for the board configuration
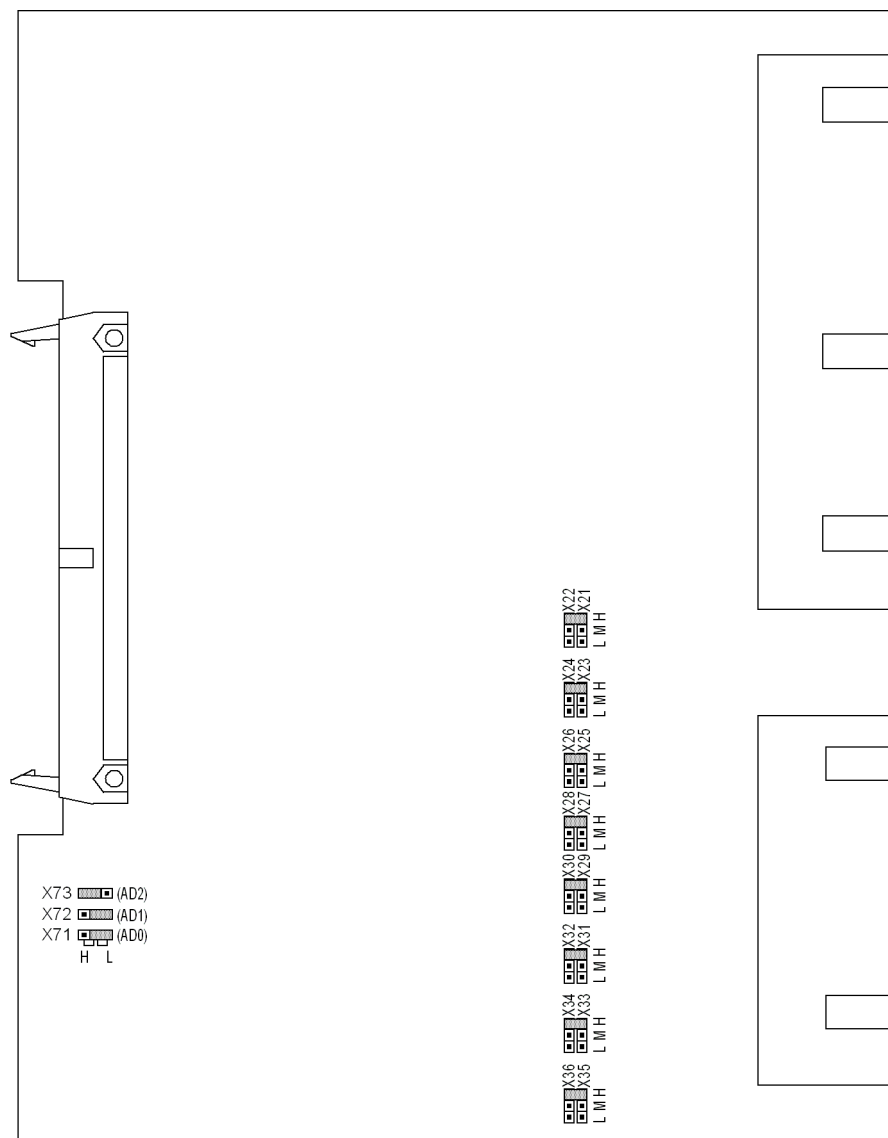
Figure 3-10   Input/output board C–I/O-10 with representation of the jumper settings required for the board configuration

Depending on the device version the contacts of some binary outputs can be changed from from normally open to normally closed (see Appendix, under section A.2).

- In version 7SA6*1*-***A/E/J** (housing size $^1/_2$ with 16 binary outputs) this is valid for the binary output BO9 (Figure 3-4, slot 19);

- In versions 7SA6*2*-***A/E/J** (housing size $^1/_1$ with 24 binary outputs) this is valid for the binary outputs BO9 and BO17 (Figure 3-6, slot 33 left and slot 19 right);

- In versions 7SA6*2*-***B/F/K** (housing size $^1/_1$ with 32 binary outputs) this is valid for the binary outputs BO9, BO17 and BO25 (Figure 3-6, slot 33 left, slot 19 right and slot 19 left);

- In versions 7SA6*2*-***M/P/R** (housing size $^1/_1$ with 24 binary outputs) this is valid for the binary output BO17 (Figure 3-6, slot 19 right);

- In versions 7SA6*2*-***N/Q/S** (housing size $^1/_1$ with 32 binary outputs) this is valid for the binary outputs BO17 and BO25 (Figure 3-6, slot 19 right and slot 19 left),

- In versions 7SA613*-***A** (housing size $^2/_3$ with 24 binary outputs) this is valid for the binary outputs BO9 and BO17 (Figure 3-5, slot 19 and slot 33 left);
- In versions 7SA613*-***M** (housing size $^2/_3$ with 24 binary outputs) this is valid for the binary output BO17 (Figure 3-5, slot 33 left).

The Tables 3-8 and 3-9 show the jumper settings for the contact mode.

Table 3-8   Jumper setting for the **Contact Mode** of the relay for BO9 on the input/output board C-I/O-1 with housing size $^1/_2$

Device 7SA6*1*-*	Printed circuit board	for	Jumper	Open in quies-cent state (NO)	Closed in quiescent state (NC)	Preset-ting
A/E/J	Slot 19	BO9	X40	1-2	2-3	1-2

Table 3-9   Jumper setting for the **Contact Mode** of the relays for BO9, BO17 and BO25 on the input/output board C-I/O-1 with housing size $^1/_1$

Device 7SA6*2*-*	Printed circuit board	for	Jumper	Open in quies-cent state (NO)	Closed in quiescent state (NC)	Preset-ting
A/E/J	Slot 33 left side	BO9	X40	1-2	2-3	1-2
	Slot 19 right side	BO17	X40	1-2	2-3	1-2
B/F/K	Slot 33 left side	BO9	X40	1-2	2-3	1-2
	Slot 19 right side	BO17	X40	1-2	2-3	1-2
	Slot 19 left side	BO25	X40	1-2	2-3	1-2
M/P/R	Slot 19 right side	BO17	X40	1-2	2-3	1-2
N/Q/S	Slot 19 right side	BO17	X40	1-2	2-3	1-2
	Slot 19 left side	BO25	X40	1-2	2-3	1-2

Table 3-10   Jumper setting for the **Contact Mode** of the relay for BO9 and BO17 on the input/output board C-I/O-1 with housing size $^2/_3$

Device 7SA613*-*	Printed Circuit Board	for	Jumper	Open in quies-cent state (NO)	Closed in quiescent state (NC)	Preset-ting
A	Slot 19 left side	BO9	X40	1-2	2-3	1-2
	Slot 33 left side	BO17	X40	1-2	2-3	1-2
M	Slot 33 left side	BO17	X40	1-2	2-3	1-2

Check of the control voltages of the binary inputs:

BI6 to BI13 (with housing size $^1/_2$) according to Table 3-11, BI6 to BI21 (with housing size $^2/_3$) according to Table 3-12, BI6 to BI29 (with housing size $^1/_1$ depending on variant) according to Table 3-13.

Table 3-11   Jumper settings of the **Control Voltages** of the binary inputs BI6 to BI13 on the input/output board C-I/O-1 or C-I/O-10 with housing size $^1/_2$

Binary inputs slot 19	Jumper	17 V Threshold [1]	73 V Threshold [2]	154 V Threshold [3]
BI6	X21/X22	L	M	H
BI7	X23/X24	L	M	H
BI8	X25/X26	L	M	H
BI9	X27/X28	L	M	H
BI10	X29/X30	L	M	H
BI11	X31/X32	L	M	H
BI12	X33/X34	L	M	H
BI13	X35/X36	L	M	H

[1] Factory settings for devices with power supply voltages of 24 VDC to 125 VDC

[2] Factory settings for devices with power supply voltages of 110 VDC to 250 VDC and 115 VAC

[3] Use only with control voltages 220 to 250 VDC

Table 3-12   Jumper settings of the **Control Voltages** of the binary inputs BI6 to BE21 on the input/output board C-I/O-1 or C-I/O-10 with housing size $^2/_3$

Binary Inputs		Jumper	17 V Pickup [1]	73 V Pickup [2]	154 V Pickup [3]
Slot 19 left side	Slot 33 left side				
BI6	BI14	X21/X22	L	M	H
BI7	BI15	X23/X24	L	M	H
BI8	BI16	X25/X26	L	M	H
BI9	BI17	X27/X28	L	M	H
BI10	BI18	X29/X30	L	M	H
BI11	BI19	X31/X32	L	M	H
BI12	BI20	X33/X34	L	M	H
BI13	BI21	X35/X36	L	M	H

[1] Factory settings for devices with rated power supply voltages 24 VDC to 125 VDC

[2] Factory settings for devices with power supply voltages of 110 VDC to 250 VDC and 115 VAC

[3] Use only with control voltages 220 or 250 VDC

Table 3-13 Jumper settings of the **Control Voltages** of the binary inputs BI6 to BI29 on the input/output board C-I/O-1 or C-I/O-10 with housing size $^1/_1$

Binary inputs			Jumper	17 V Threshold [1]	73 V Threshold [2]	154 V Threshold [3]
Slot 33 left side	Slot 19 right side	Slot 19 left side				
BI6	BI14	BI22	X21/X22	L	M	H
BI7	BI15	BI23	X23/X24	L	M	H
BI8	BI16	BI24	X25/X26	L	M	H
BI9	BI17	BI25	X27/X28	L	M	H
BI10	BI18	BI26	X29/X30	L	M	H
BI11	BI19	BI27	X31/X32	L	M	H
BI12	BI20	BI28	X33/X34	L	M	H
BI13	BI21	BI29	X35/X36	L	M	H

[1] Factory settings for devices with power supply voltages of 24 VDC to 125 VDC

[2] Factory settings for devices with power supply voltages of 110 VDC to 250 VDC and 115 VAC

[3] Use only with Control voltages 220 to 250 VDC

The jumpers X71, X72 and X73 on the input/output board C-I/O-1 or C-I/O-10 are for setting the bus address and must not be changed. The following two tables list the jumper presettings.

The mounting locations are shown in Figures 3-3 to 3-6.

Table 3-14 Jumper settings of the **Module Address** of the input/output board C-I/O-1 or C-I/O-10 with housing size $^1/_2$

Jumper	Mounting location slot 19
X71	H
X72	L
X73	H

Table 3-15 Jumper settings of the **Module Address** of the input/output board C-I/O-1 or C-I/O-10 with housing size $^2/_3$

Jumper	Mounting location	
	Slot 33 left side	Slot 19 left side
X71	L	H
X72	H	L
X73	H	H

Table 3-16   Jumper settings of the **PCB Address** of the input/output board C-I/O-1 or C-I/O-10 with housing size $^1/_1$

Jumper	Mounting location		
	Slot 19 left side	Slot 19 right side	Slot 33 left side
X71	H	L	H
X72	H	H	L
X73	H	H	H

Board C-I/O-2   The layout of the PCB for the C-I/O-2 board is shown in Figure 3-11.
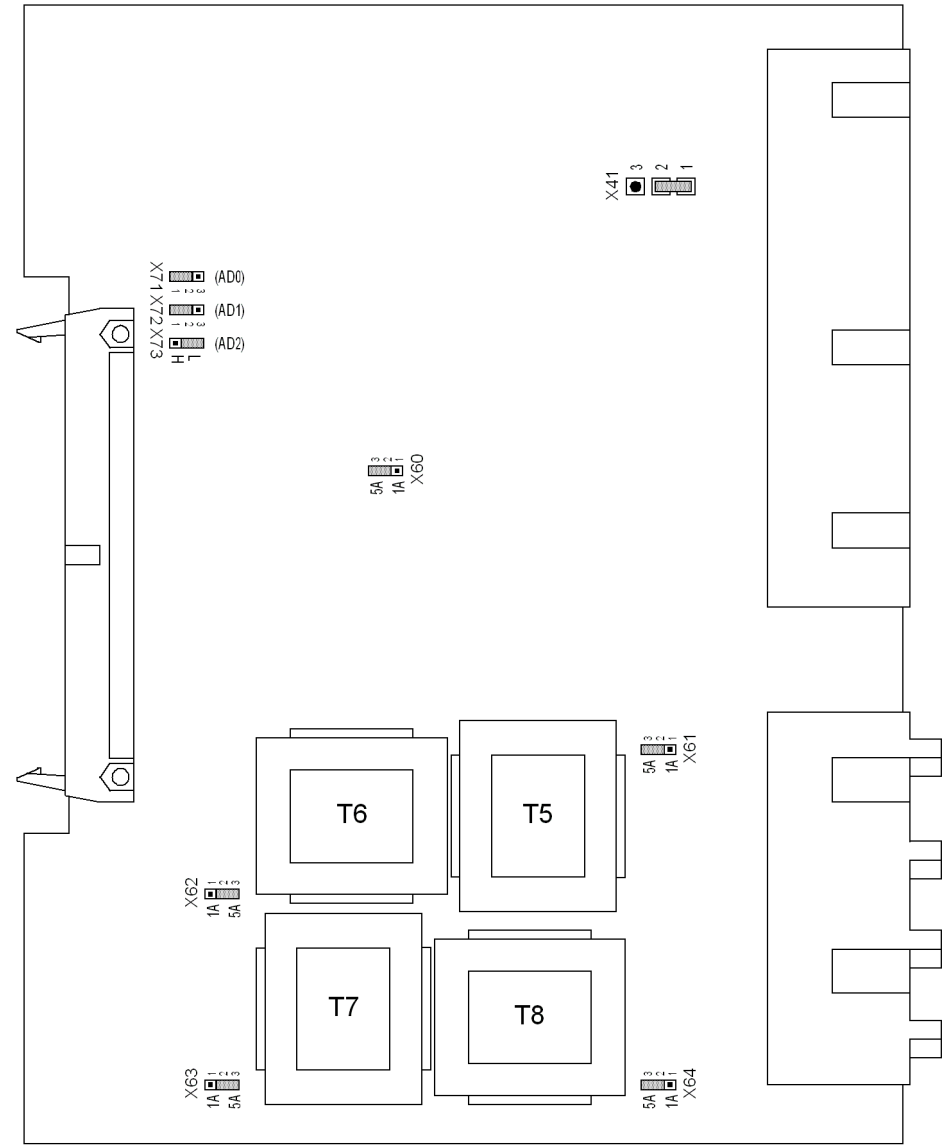
Figure 3-11   Input/output board C–I/O-2 with representation of jumper settings required for checking configuration settings

The contact type of binary output BO6 can be changed from normally open to normally closed (see overview diagrams in section A.2 of the Appendix):

with housing size $^1/_3$: No. 3 in Figure 3-3, slot 19

with housing size $^1/_2$: No. 3 in Figure 3-4, slot 33

with housing size $^2/_3$: No. 3 in Figure 3-5, slot 5 right,

with housing size $^1/_1$: No. 3 in Figure 3-6, slot 33 right.

Table 3-17   Jumper setting for the contact type of binary output BO6

Jumper	Open in quiescent state (NO)	Closed in quiescent state (NC)	Presetting
X41	1-2	2-3	1-2

The set nominal current of the current input transformers are to be checked on the input/output board C-I/O-2. All jumpers must be set for one nominal current, i.e. respectively one jumper (X61 to X64) for each input transformer and additionally the common jumper X60. **But**: In the version with sensitive earth fault current input (input transformer T8) there is no jumper X64.

Jumpers X71, X72 and X73 on the input/output board C-I/O-2 are used to set the bus address and must not be changed. The following Table lists the jumper presettings.

Mounting location:

with housing size $^1/_3$: No. 3 in Figure 3-3, slot 19

with housing size $^1/_2$: No. 3 in Figure 3-4, slot 33

with housing size $^2/_3$: No. 3 in Figure 3-5, slot 5 right,

with housing size $^1/_1$: No. 3 in Figure 3-6, slot 33 right.

Table 3-18   Jumper settings of **PCB Address** of the input/output board C-I/O-2

Jumper	Presetting
X71	1-2(H)
X72	1-2(H)
X73	2-3(L)

C-I/O-11 Input/Output Board
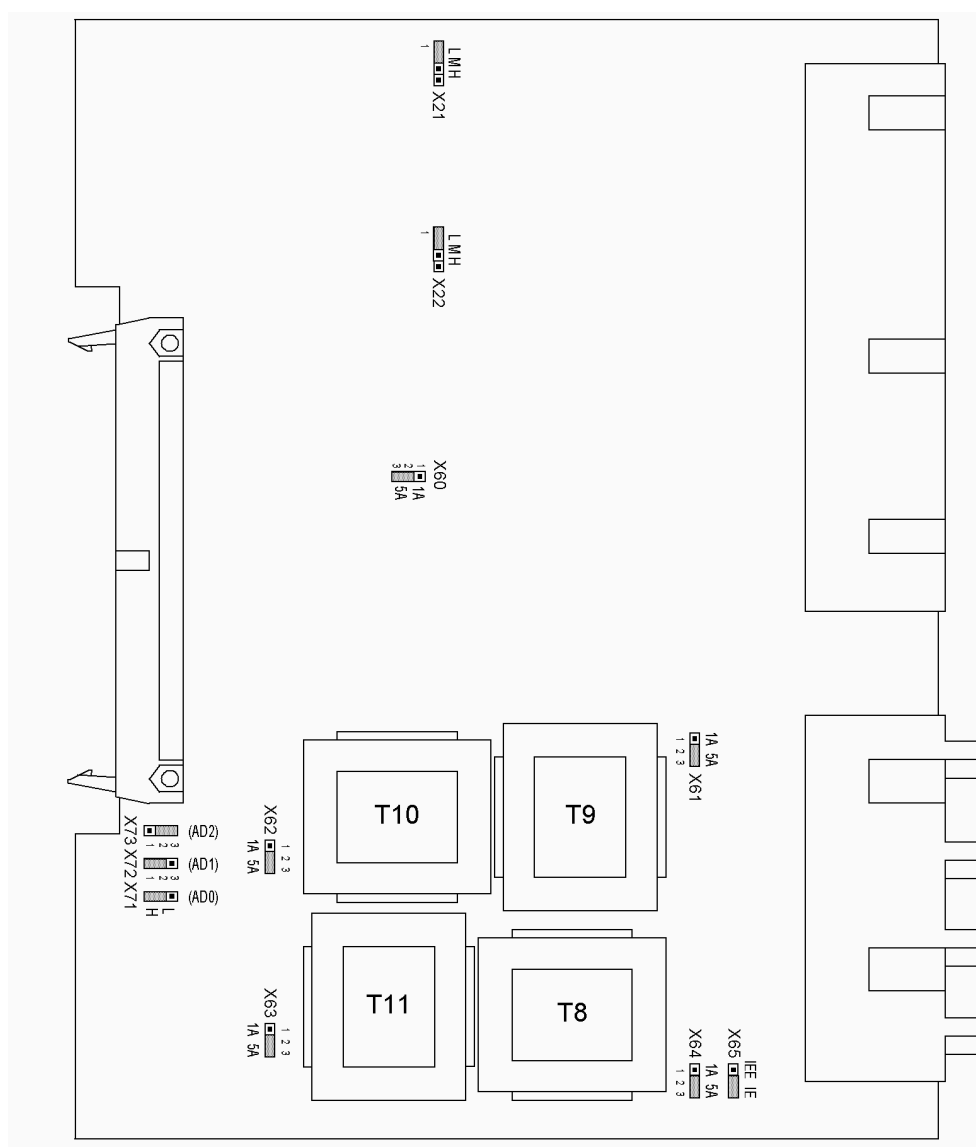
Figure 3-12   C-I/O-11 input/output board with representation of jumper settings required for checking configuration settings

Table 3-19   Jumper settings for **Control Voltages** of the binary inputs BI6 and BI7 on the input/output board C-I/O-11

Binary input	Jumper	17 V Threshold [1]	73 V Threshold [2]	154 V Threshold [3]
BI6	X21	L	M	H
BI7	X22	L	M	H

[1] Factory settings for devices with power supply voltages of 24 VDC to 125 VDC

[2] Factory settings for devices with power supply voltages of 110 VDC to 250 VDC and 115 VAC

[3] Use only with control voltages 220 to 250 VDC

The rated current settings of the input current transformers are to be checked on the input/output board C-I/O-11. The jumpers X60 to X64 must all be set to the same rated

current, i.e. one jumper (X61 to X64) for each input transformer of the phase currents and in addition the common jumper X60. **But**: In the version with sensitive earth fault current input (input transformer T8) there is no jumper X64.

For normal earth current inputs the jumper X65 is plugged in position "IE" and for sensitive earth current inputs in position "IEE".

Jumpers X71, X72 and X73 on the input/output board C-I/O-11 are used for setting the bus address and must not be changed. The following Table lists the jumper presettings.

Mounting location:

with housing size $^1/_3$ No. 4 of Figure 3-3, slot 19

with housing size $^1/_2$:   No. 2 of Figure 3-4, slot 33

with housing size $^1/_1$:   No. 2 of Figure 3-6, slot 33 right.

Table 3-20   Jumper settings of **Bus Address** of the input/output board C-I/O-11

Jumper	Presetting
X71	1-2(H)
X72	1-2 (H)
X73	2-3 (L)

Input/Output Board B-I/O-2   The layout of the PCB for the B-I/O-2 board is shown in Figure 3-13.
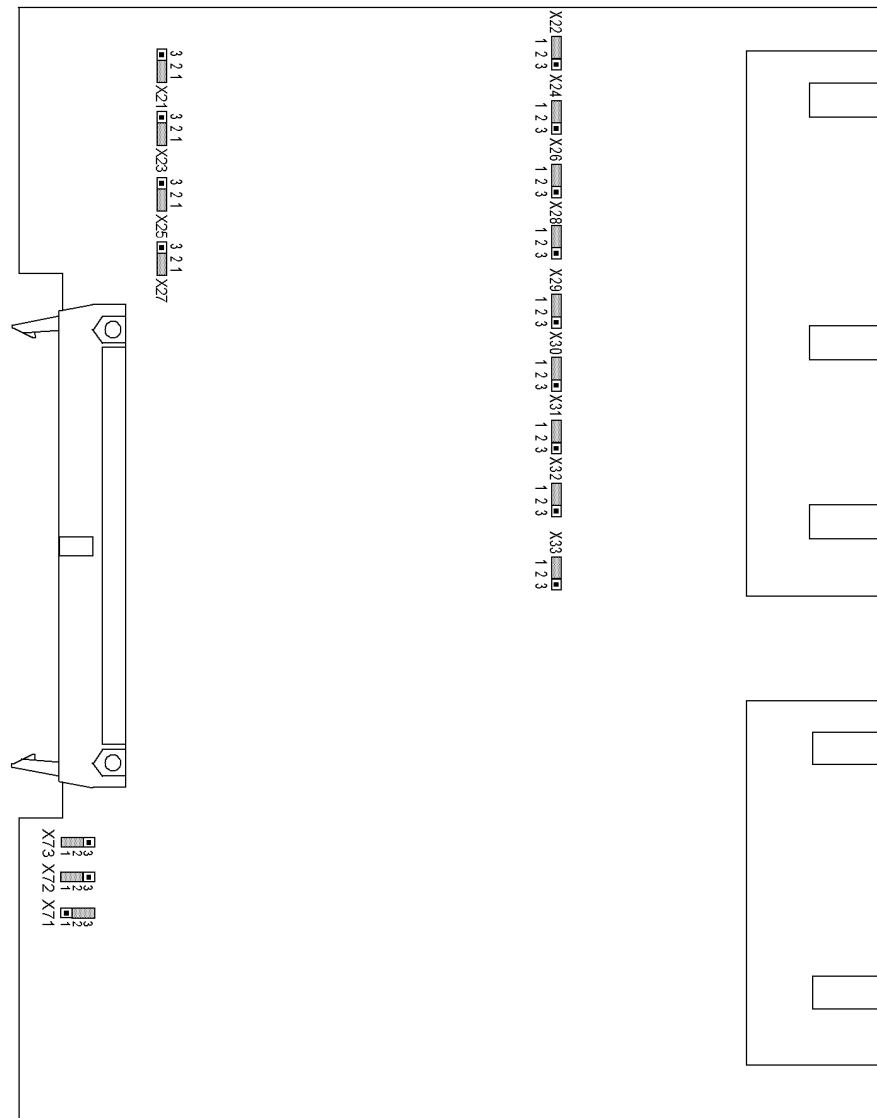
Figure 3-13   Input/output board B-I/O-2 with jumper settings required for the board configuration (representation of the jumpers X71, X72 and X73 for housing size $^1/_1$)

Checking the control voltages of the binary inputs:

BI8 to BI20 (with housing size $^1/_2$) according to Table 3-21

BI8 to BI33 (with housing size $^1/_1$) according to Table 3-22.

Table 3-21   Jumper settings of the **Control Voltages** of the binary inputs BI8 to BI20 on the input/output board B-I/O-2 for variant 7SA6***1***-***B**/**F**/**K**

Binary inputs slot 19	Jumper	17 V Threshold [1]	73 V Threshold [2]
BI8	X21	1-2	2-3
BI9	X22	1-2	2-3
BI10	X23	1-2	2-3
BI11	X24	1-2	2-3
BI12	X25	1-2	2-3
BI13	X26	1-2	2-3
BI14	X27	1-2	2-3
BI15	X28	1-2	2-3
BI16	X29	1-2	2-3
BI17	X30	1-2	2-3
BI18	X31	1-2	2-3
BI19	X32	1-2	2-3
BI20	X33	1-2	2-3

[1] Factory settings for devices with power supply voltages of 24 VDC to 125 VDC
[2] Factory settings for devices with power supply voltages of 110 VDC to 250 VDC and 115 VAC

Table 3-22   Jumper settings of the **Control Voltages** of the binary inputs BI8 to BI33 on the input/output board B-I/O-2 for variant 7SA6***2***-***C**/**G**/**L**

Binary inputs		Jumper	17 V Threshold [1]	73 V Threshold [2]
Slot 33 left side	Slot 19 right side			
BI8	BI21	X21	1-2	2-3
BI9	BI22	X22	1-2	2-3
BI10	BI23	X23	1-2	2-3
BI11	BI24	X24	1-2	2-3
BI12	BI25	X25	1-2	2-3
BI13	BI26	X26	1-2	2-3
BI14	BI27	X27	1-2	2-3
BI15	BI28	X28	1-2	2-3
BI16	BI29	X29	1-2	2-3
BI17	BI30	X30	1-2	2-3
BI18	BI31	X31	1-2	2-3
BI19	BI32	X32	1-2	2-3
BI20	BI33	X33	1-2	2-3

[1] Factory settings for devices with power supply voltages of 24 VDC to 125 VDC
[2] Factory settings for devices with power supply voltages of 110 VDC to 250 VDC and 115 VAC

Jumpers X71, X72 and X73 on the input/output board B-I/O-2 are for setting the **Bus Address**. The jumpers must not be changed. The following two Tables list the jumper presettings.

The mounting locations are shown in Figures 3-3 to 3-6.

Table 3-23   Jumper settings of the **PCB Address** of the input/output boards B-I/O-2 for housing size $^1/_2$

Jumper	Mounting location slot 19
X71	1-2
X72	2-3
X73	1-2

Table 3-24   Jumper settings of the **PCB Address** of the input/output boards B-I/O-2 for housing size $^1/_1$

Jumper	Mounting location	
	Slot 19 right side	**Slot 33 left side**
X71	1-2	2-3
X72	2-3	1-2
X73	1-2	1-2

3.1.2.4   Interface Modules

Exchanging Inter-face Modules   The interface modules are located on the processor board C-CPU-2 (No. 1 in Figure 3-3 to 3-6).
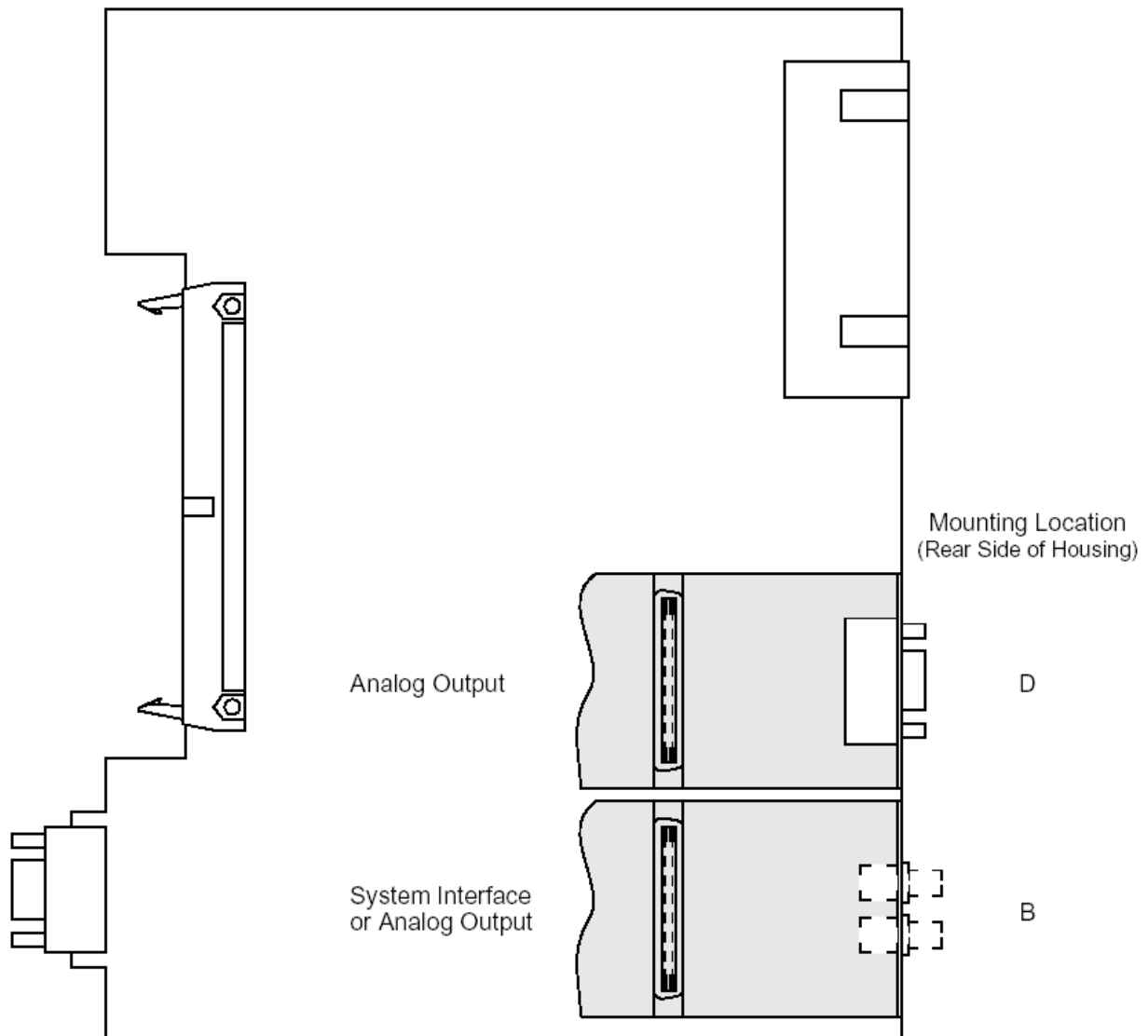
Figure 3-14   C-CPU-2 board with interface modules

Please note the following:

- Only interface modules of devices with panel flush mounting and cubicle mounting as well as of mounting devices with detached operator panel can be exchanged. Devices in surface mounting housings with double-level terminals can be changed only in our manufacturing centre.
- Use only interface modules that can be ordered ex-factory via the ordering code (see also Appendix, Section A.1).
- You may have to ensure the termination of the interfaces featuring bus capability according to the margin heading "RS485 Interface".

Table 3-25   Exchangeable interface modules

Interface	Mounting location / inter-face	Exchange module
System interface or analog output	B	Only interface modules that can be ordered in our facilities via the order key (see also Appendix, Section A.1).
		AN20
Protection data interface or analog output	D	AN20
		FO5 to FO8

The order numbers of the exchange modules can be found in the Appendix in Section A.1, Accessories.

RS232 Interface

Interface RS232 can be modified to interface RS485 and vice versa (see Figures 3-15 and 3-16).

Figure 3-14 shows the C-CPU-2 PCB with the layout of the modules.

The following figure shows the location of the jumpers of interface RS232 on the interface module.

Devices in surface mounting housing with fibre optics connection have their fibre optics module housed in the console housing. The fibre optics module is controlled via a RS232 interface module at the associated CPU interface slot. For this application type the jumpers X12 and X13 on the RS232 module are plugged in position 2-3.

Jumper	Terminating Resistors disconnected
X3	1–2 *)
X4	1–2 *)

*) Default Setting
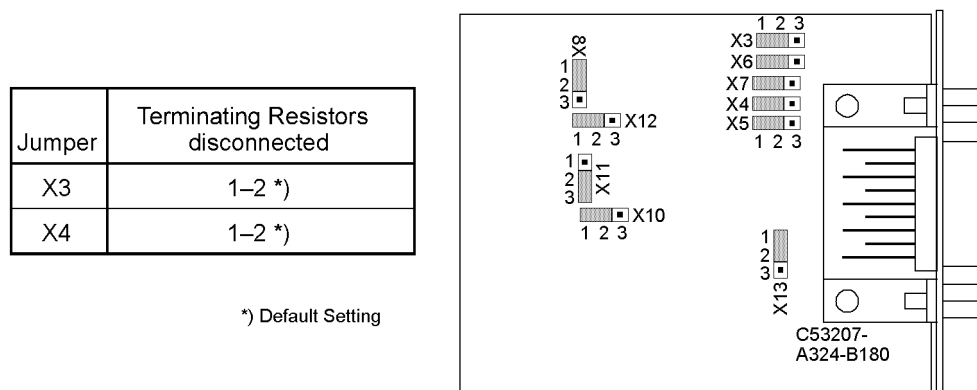
Figure 3-15   Location of the jumpers for configuration of RS232

Terminating resistors are not required for RS232. They are disconnected.

With jumper X11, CTS (Clear-to-Send) is activated which is necessary for modem communication is enabled.

Table 3-26   Jumper setting for **CTS** (**C**lear **T**o **S**end, flow control) on the interface module

Jumper	/CTS from Interface RS232	/CTS controlled by /RTS
X11	1-2	2-3 [1]

[1] Default Setting

Jumper Setting 2-3: The connection to the modem is usually done with star coupler or fibre-optic converter. Therefore the modem control signals according to RS232 standard DIN 66020 are not available. Modem signals are not required since the connection to SIPROTEC® 4 devices is always carried out in the half duplex mode. Please use connection cable with order number 7XV5100-4.

Jumper Setting 1-2: This setting makes the modem signals available, i. e. for a direct RS232-connection between the SIPROTEC® 4 device and the modem this setting can be selected optionally. We recommend to use a standard RS232 modem connection cable (converter 9-pin to 25-pin).

Note

For a direct connection to DIGSI® with Interface RS232, jumper X11 must be plugged in position 2-3.

RS485 Interface   The following figure shows the location of the jumpers of interface RS485 on the interface module.

Interface RS485 can be modified to interface RS232 and vice versa, according to Figure 3-15.

Jumper	Terminating Resistors	
	connected	disconnected
X3	2–3	1–2 *)
X4	2–3	1–2 *)

*) Default Setting
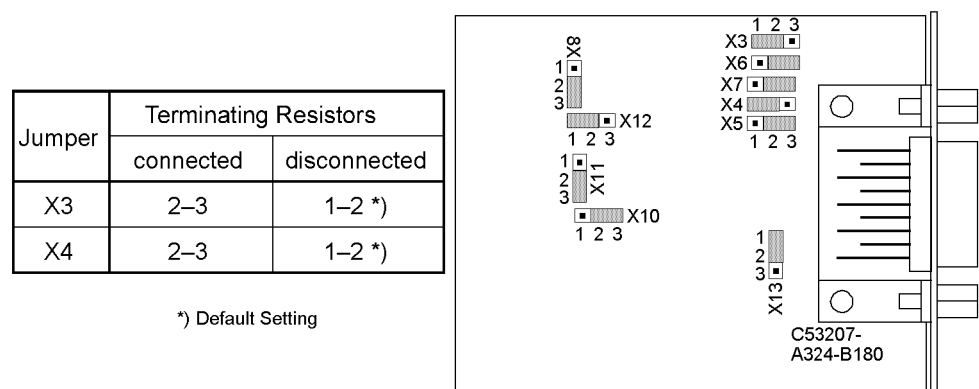
Figure 3-16   Position of terminating resistors and the plug-in jumpers for configuration of the RS485 interface

**Interface
PROFIBUS**

Jump-er	Terminating Resistors	
	connected	disconnected
X3	1–2	2–3 *)
X4	1–2	2–3 *)

*) Default Setting
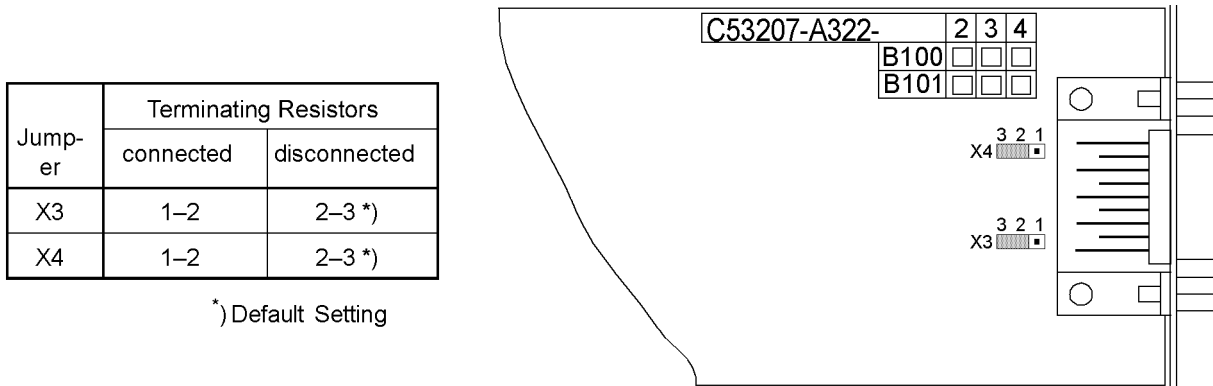
Figure 3-17   Position of the plug-in jumpers for the configuration of the terminating resistors at the interfaces Profibus (FMS and DP) and DNP3.0 interface

RS485 Termination   Busbar capable interfaces always require a termination at the last device to the bus, i.e. terminating resistors must be connected. With the 7SA6 device, this concerns the variants with RS485 or PROFIBUS interfaces.

The terminating resistors are located on the RS485 or PROFIBUS interface module, which is on the board C-CPU-2 (No.1 in Figure 3-3 to 3-6), or directly on the PCB of the processor board C-CPU-2 (see margin heading "Processor Board C-CPU-2", Table 3-7).

Figure 3-14 shows the C-CPU-2 PCB with the layout of the boards.

The board with configuration as RS485 interface is shown in Figure 3-16, the module for the PROFIBUS interface in Figure 3-17.

For the configuration of the terminating resistors both jumpers have to be plugged in the same way.

On delivery the jumpers are set such that the termination resistors are disconnected.

The terminating resistors can also be connected externally (e.g. to the terminal block), see Figure 3-8. In this case, the terminating resistors located on the RS485 or PROFI-BUS interface module or directly on the PCB of the processor board C-CPU-2 must be de-energized.
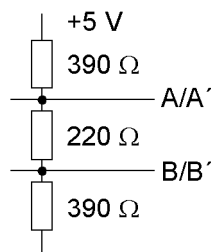
Figure 3-18   Termination of the RS485 interface (external)

Analog Output   The analog output module AN20 is provided with 2 isolated channels with a current range from 0 to 20 mA (unipolar, maximum 350 Ω).

The location on the C-CPU-2 board "B" or/and "D" depends on the ordered variant (see Figure 3-14).
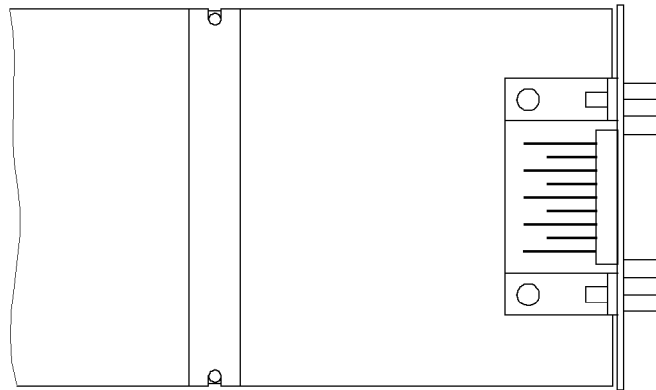
Figure 3-19   AN20 Analog Output Interface Module

3.1.2.5   Reassembly

The assembly of the device is done in the following steps:

- Insert the boards carefully in the housing. The mounting locations of the boards are shown in Figures 3-3 to 3-6. For the variant of the device designed for surface mounting, use the metal lever to insert the processor board C-CPU-2. Installation is easier with the lever.

- First plug in the plug connectors of the ribbon cable onto the input/output board I/O and then onto the processor board C-CPU-2. Be careful that no connector pins are bent! Don't apply force!

- Connect the plug connectors of the ribbon cable between processor board C-CPU-2 and the front panel to the front panel plug connector. These activities are not necessary if the device has a detached operator panel. Instead of this, the connector of the ribbon cable connected to the 68-pin connector on the device rear panel must be plugged on the connector of the processor board C-CPU-2. The 7pole X16 connector belonging to the ribbon cable must be plugged behind the D-subminiature female connector. The plugging position is not relevant in this context as the connection is protected against polarity reversal.

- Press plug connector interlocks together.

- Replace the front panel and screw it tightly to the housing.

- Replace the covers again.

- Re-fasten the interfaces on the rear of the device housing. This activity is not necessary if the device is designed for surface mounting.

3.1.3   Installation

3.1.3.1   Panel Flush Mounting

Depending on the version, the device housing can be $^1/_3$, $^1/_2$, $^2/_3$ or $^1/_1$. For housing size $^1/_3$ (Figure 3-20) and $^1/_2$ (Figure 3-21) there are 4 covers and 4 holes for securing the device, with housing size $^2/_3$ (Figure 3-22) and housing size $^1/_1$ (Figure 3-23) there are 6 covers and 6 securing holes.

- Remove the 4 covers at the corners of the front cover, for housing size $^2/_3$ and $^1/_1$ the 2 covers located centrally at the top and bottom also have to be removed. Thus the 4 respectively 6 elongated holes in the mounting bracket are revealed and can be accessed.

- Insert the device into the panel cut-out and fasten it with four or six screws. For dimensions refer to Section 4.25.

- Mount the four or six covers.

- Connect the ground on the rear plate of the device to the protective ground of the panel. Use at least one M4 screw for the device ground. The cross-sectional area of the earth wire must be equal to the cross-sectional area of any other control conductor connected to the device. The cross-section of the earth wire must be at least 2.5 mm ^{2}.

- Connect the plug terminals and/or the screwed terminals on the rear side of the device according to the wiring diagram of the panel.

  When using forked lugs for direct connections or screw terminal, the screws, before having inserted the lugs and wires, must be tightened in such a way that the screw heads are even with the terminal block.

  A ring lug must be centred in the connection chamber, in such a way that the screw thread fits in the hole of the lug.

  Specifications regarding maximum cross sections, tightening torques, bending radii and tension relief as specified in the SIPROTEC® 4 System Description (Order no. E50417-H1176-C151) must be observed. You will find hints in the short description included in the device.
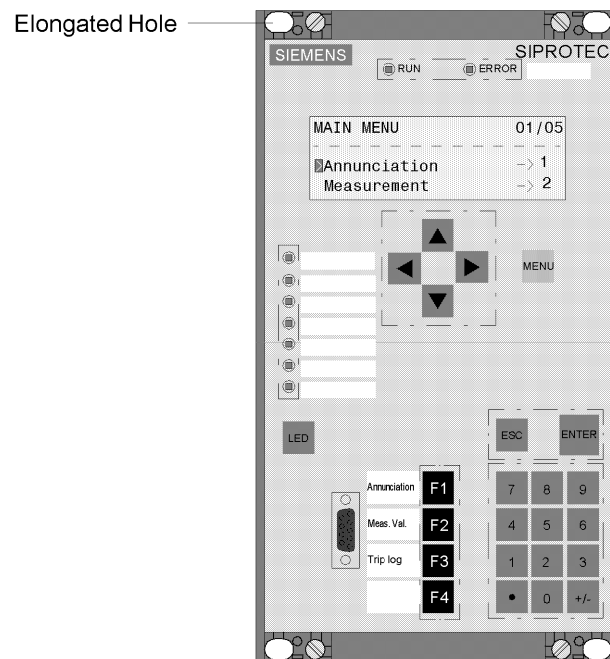
Figure 3-20   Example of panel flush mounting of a unit (housing size $^1\!/_3$)
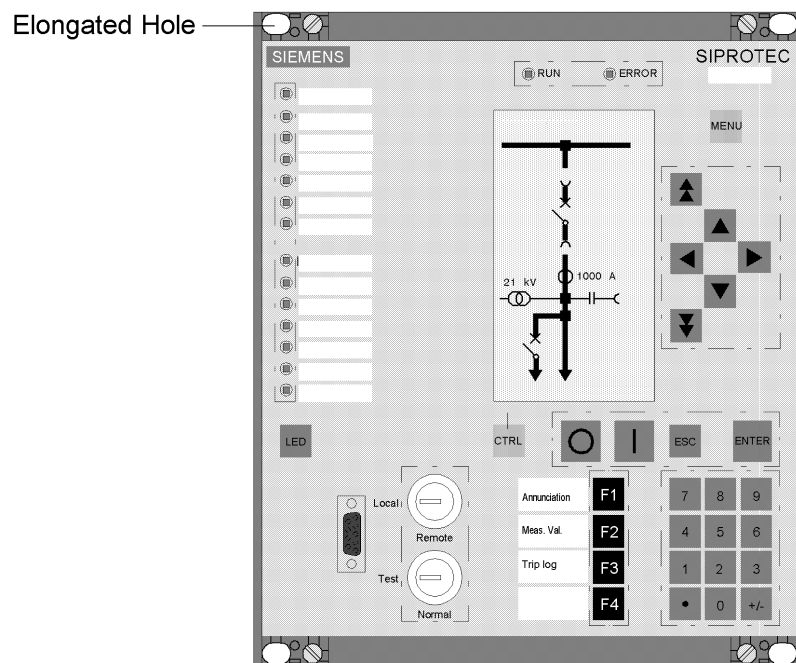
Figure 3-21   Example of panel flush mounting of a unit (housing size $^1\!/_2$)
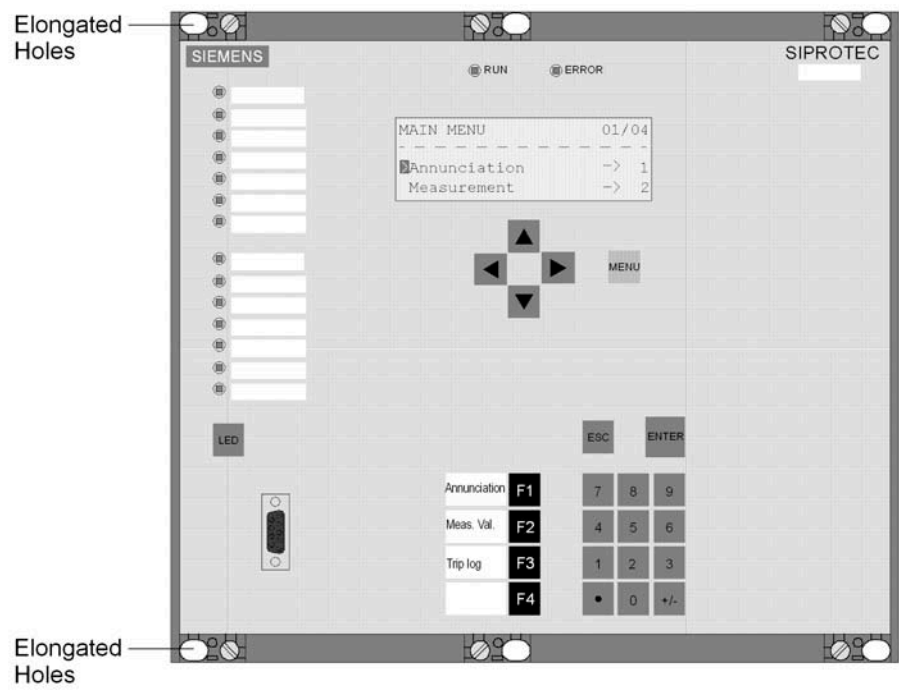
Figure 3-22   Example of panel flush mounting of a device (housing size $^2/_3$)
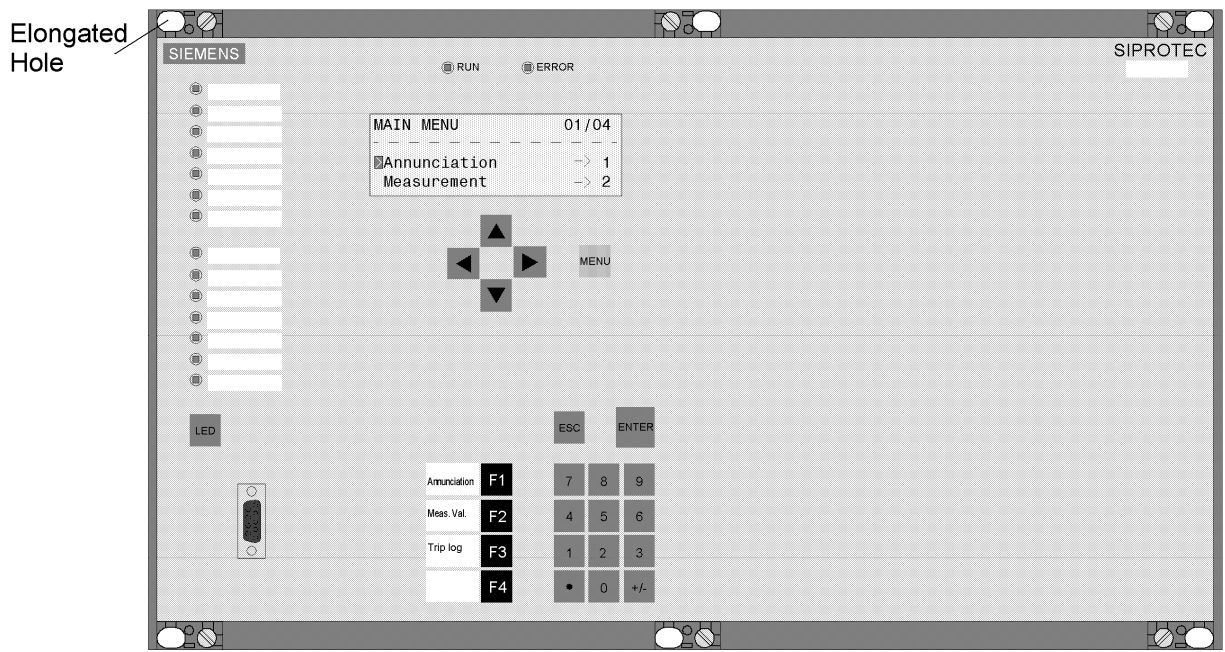
Figure 3-23   Example of panel flush mounting of a unit (housing size $^1/_1$)

3.1.3.2   Rack Mounting and Cubicle Mounting

Two mounting rails are required for installing a device into a frame or cabinet. The ordering codes are stated in the Appendix, Section A.1

For housing size $^1/_3$ (Figure 3-24) and $^1/_2$ (Figure 3-25) there are 4 covers and 4 holes for securing the device, with housing size $^2/_3$ (Figure 3-26) and housing size $^1/_1$ (Figure 3-27)there are 6 covers and 6 securing holes.

- Screw on loosely the two angle brackets in the rack or cabinet, each with four screws.

- Remove the 4 covers at the corners of the front cover, for housing size $^2/_3$ and $^1/_1$ the 2 covers located centrally at the top and bottom also have to be removed. Thus the 4 respectively 6 elongated holes in the mounting bracket are revealed and can be accessed.

- Fasten the device to the mounting brackets with four or six screws.

- Mount the four or six covers.

- Tighten fast the eight screws of the angle brackets in the rack or cabinet.

- Screw down a robust low-ohmic protective earth or station earth to the rear of the device using at least an M4 screw. The cross-sectional area of the earth wire must be equal to the cross-sectional area of any other control conductor connected to the device. The cross-section of the earth wire must be at least 2.5 mm ^{2}.

- Connections use the plug terminals or screw terminals on the rear side of the device in accordance the wiring diagram.

  For screw connections with forked lugs or direct connection, before inserting wires the screws must be tightened so that the screw heads are flush with the outer edge of the connection block.

  A ring lug must be centred in the connection chamber so that the screw thread fits in the hole of the lug.

  Specifications regarding maximum cross sections, tightening torques, bending radii and tension relief as specified in the SIPROTEC® 4 System Description (Order no. E50417-H1176-C151) must be observed. A short description on the device includes information on this matter.
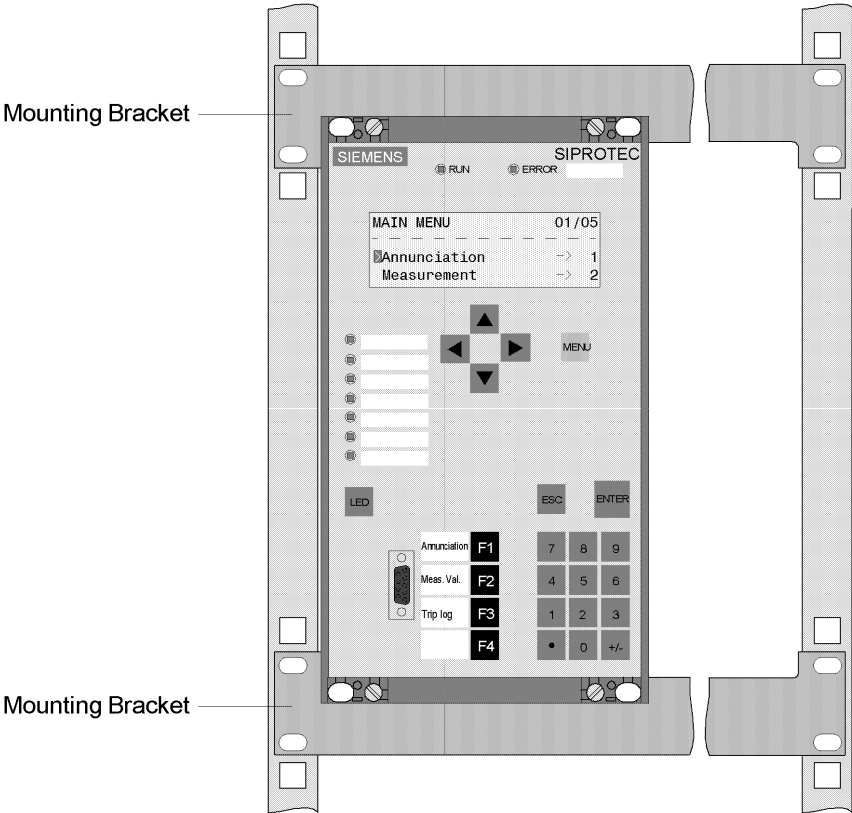
Figure 3-24   Installation example of a unit in a rack or cubicle (housing size $^1/_3$)
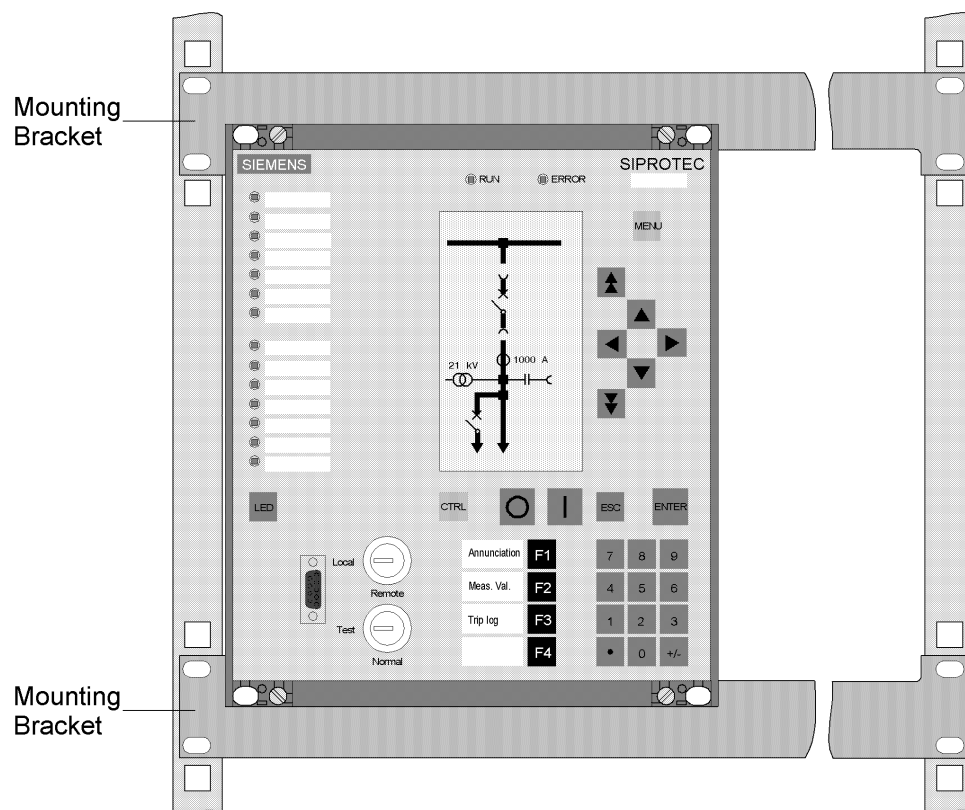
Figure 3-25   Installation example of a unit in a rack or cubicle (housing size $1/2$)
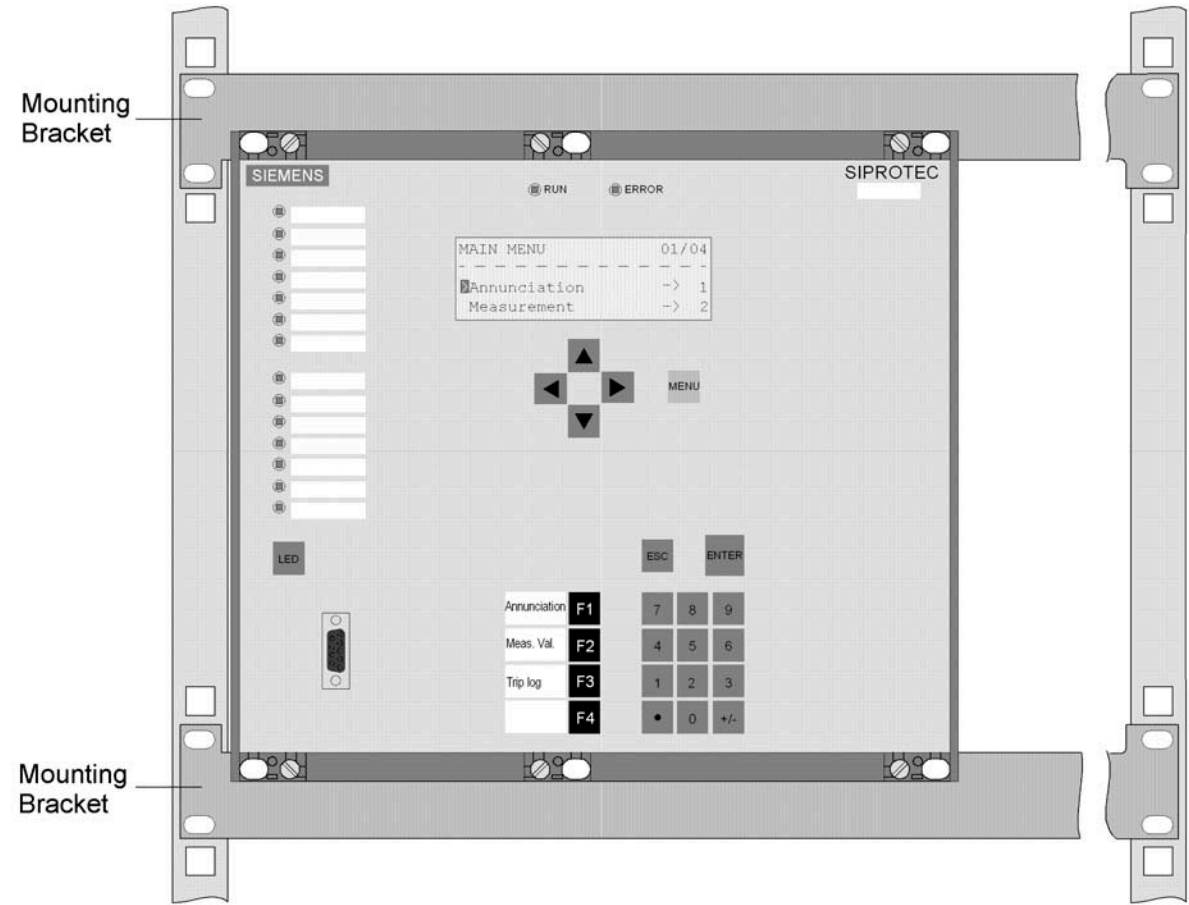
Figure 3-26   Mounting device in a rack or cubicle (housing size $^2/_3$), as an example
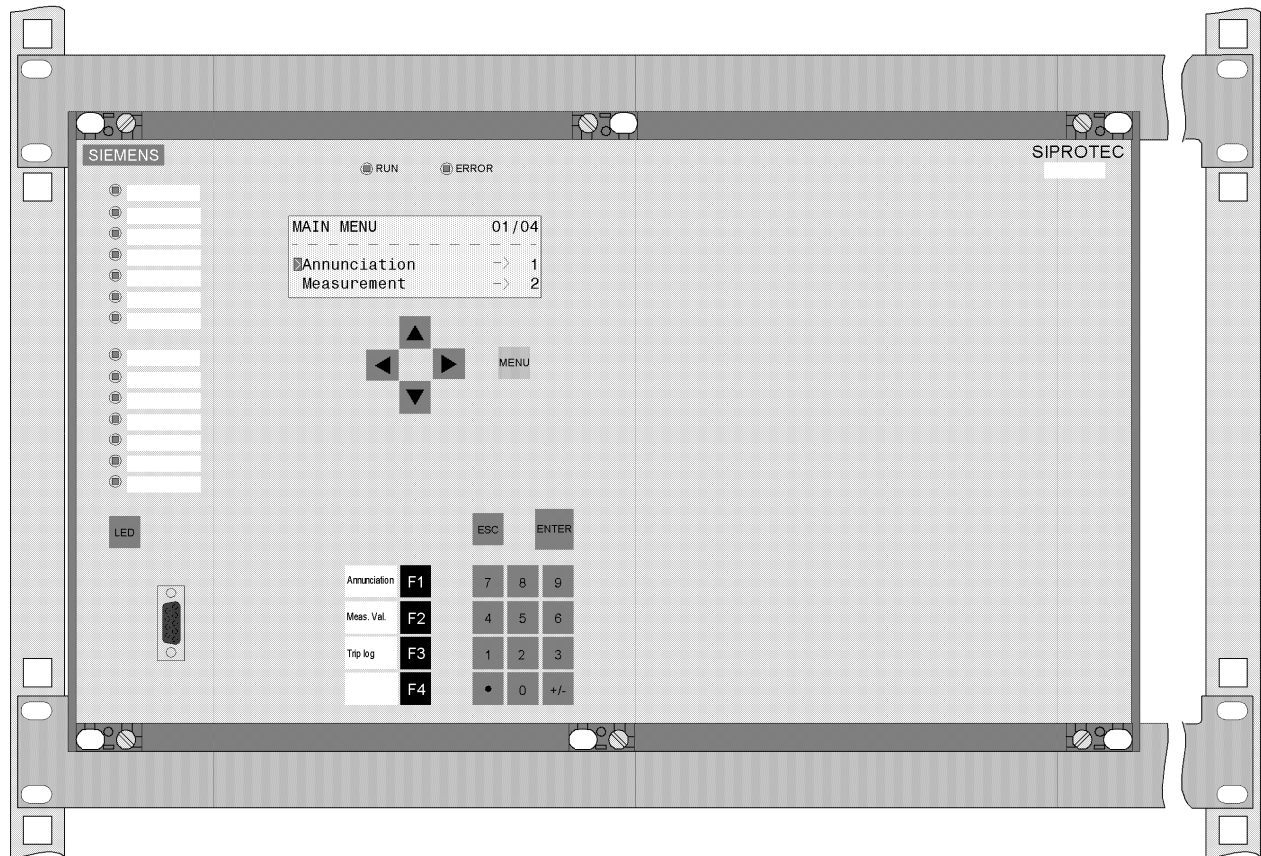
Figure 3-27   Installation example of a unit in a rack or cubicle (housing size $^1/_1$)

3.1.3.3   Panel Surface Mounting

For mounting proceed as follows:

- Secure the device to the panel with four screws. For dimensions see the Technical Data in Section 4.25.

- Connect the earth of the device to the protective earth of the panel. The cross-sectional area of the earth wire must be equal to the cross-sectional area of any other control conductor connected to the device. The cross-section of the earth wire must be at least 2.5 mm ^{2}.

- Connect solid, low-impedance operational earthing (cross-sectional area $\geq$ 2.5 mm^2) to the earthing surface on the side. Use at least one M4 screw for the device earth.

- Connections according to the circuit diagram via screw terminals, connections for optical fibres and electrical communication modules via the inclined housings. Specifications regarding maximum cross sections, tightening torques, bending radii and tension relief as specified in the SIPROTEC® 4 System Description (Order no. E50417-H1176-C151) must be observed. You will find hints in the short description included in the device.

3.1.3.4 Mounting with Detached Operator Panel

Caution!

Be careful when removing or plugging the connector between device and detached operator panel

Non–observance of the following measure can result in property damage. Without the cable the device is not ready for operation!

Do never pull or plug the connector between the device and the detached operator panel during operation while the device is alive!

For mounting the **device** proceed as follows:

- Fasten the device of housing size $^1/_2$ with 6 screws and device of housing size $^1/_1$ with 10 screws. Dimensional drawings are shown in the Technical Data, Section 4.25.
- Screw down a robust low-ohmic protective earth or station earth to the rear of the device using at least a M4. The cross-sectional area of the earth wire must be equal to the cross-sectional area of any other control conductor connected to the device. The cross-section of the earth wire must be at least 2.5 mm ^{2}.
- Connections are realized via plug terminals or screw terminals on the rear side of the device according to the connection diagram.

  When using forked lugs for direct connections or screw terminal, the screws, before having inserted the lugs and wires, must be tightened in such a way that the screw heads are even with the terminal block.

  A ring lug must be centred in the connection chamber, in such a way that the screw thread fits in the hole of the lug.

  Specifications regarding maximum cross sections, tightening torques, bending radii and tension relief as specified in the SIPROTEC® 4 System Description (Order no. E50417-H1176-C151) must be observed. You will find hints in the short description included in the device.

For mounting the **operator panel** please observe the following:

- Remove the 4 covers on the corners of the front plate. Thus, 4 elongated holes are revealed in the mounting bracket and can be accessed.
- Insert the operator panel into the panel cut-out and fasten with four screws. For dimensions see Technical Data.
- Replace the 4 covers.
- Connect the earth on the rear plate of the operator control element to the protective earth of the panel using at least one M4 screw. The cross-sectional area of the ground wire must be equal to the cross-sectional area of any other control conductor connected to the device. The cross-section of the earth wire must be at least 2.5 mm ^{2}.
- Connect the operator panel to the device. Furthermore, plug the 68-pin connector of the cable belonging to the operator panel into the corresponding connection at the rear side of the device (see SIPROTEC® 4 System Description, Order no. E50417-H1176-C151. You will find hints in the short description included in the device).

3.2 Checking Connections

3.2.1 Checking Data Connections of Serial Interfaces

The tables of the following margin headings list the pin-assignments for the different serial interfaces of the device and the time synchronization interface. The position of the connections can be seen in the following Figure.
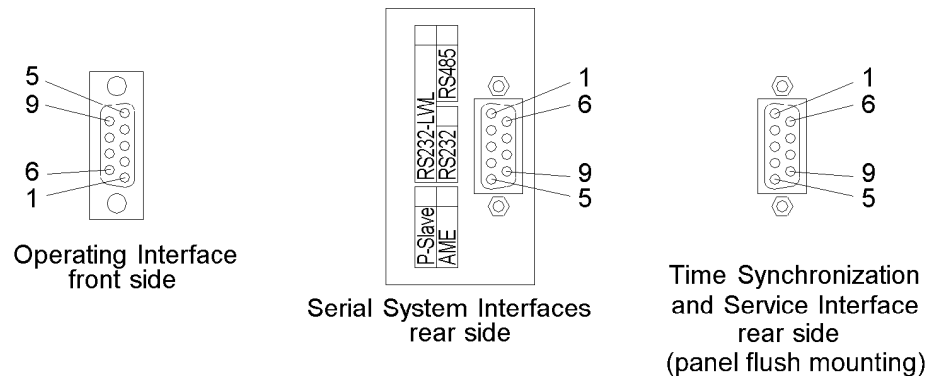
Figure 3-28   9-pin D-subminiature female connectors

Operator Interface

When using the recommended communication cable (see order no. in the Appendix A.1), the correct connection between the SIPROTEC® 4 device and the PC or Laptop is automatically ensured.

Service Interface

Check the data connection if the service interface (Interface C) for communication with the device via fix wiring or a modem.

System Interface

For versions equipped with a serial interface to a control center, the user must check the data connection. The visual check of the assignment of the transmission and reception channels is of particular importance. With RS232 and fibre optic interfaces, each connection is dedicated to one transmission direction. Therefore the output of one device must be connected to the input of the other device and vice versa.

With data cables, the connections are designated according to DIN 66020 and ISO 2110:

- TxD = Data Transmit
- RxD = Data Receive
- $\overline{RTS}$ = Request to Send
- $\overline{CTS}$ = Clear to Send
- GND = Signal / Chassis Ground

The cable shield is to be grounded at **both** line ends. For extremely EMC-prone environments, the Earth may be connected via a separate individually shielded wire pair to improve immunity to interference.

Table 3-27   The assignments of the subminiature connector for the various interfaces

Pin No.	Operator interface	RS232	RS 485	PROFIBUS FMS Slave, RS 485 PROFIBUS DP Slave, RS 485	DNP3.0 RS485
1	Shield (with shield ends electrically connected)				
2	RxD	RxD	-	-	-
3	TxD	TxD	A/A' (RxD/TxD-N)	B/B' (RxD/TxD-P)	A
4	-	-	-	CNTR-A (TTL)	RTS (TTL level)
5	GROUND	GROUND	C/C' (GROUND)	C/C' (GROUND)	GROUND1
6	-	-	-	+5 V (max. load 100 mA)	VCC1
7	$\overline{RTS}$	$\overline{RTS}$	- [1]	-	-
8	$\overline{CTS}$	$\overline{CTS}$	B/B' (RxD/TxD-P)	A/A' (RxD/TxD-N)	B
9	-	-	-	-	-

[1] Pin 7 also carries the RTS signal with RS232 level when operated as RS485 Interface. Pin 7 must therefore not be connected!

Termination

The RS485 interface is capable of half-duplex service with the signals A/A' and B/B' with a common relative potential C/C' (GND). It is necessary to check that the terminating resistors are connected to the bus only at the last unit, and not at all the other devices on the bus. The jumpers for the terminating resistors are located on the interface module RS485 (see Figure 3-15) or PROFIBUS RS485 (see Figure 3-16) or directly on the C-CPU-2 (see Figure 3-7 and Table 3-7). The terminating resistors can also be connected externally (e.g. to the connection module) as illustrated in Figure 3-8. In this case, the terminating resistors located on the module must be disconnected.

If the bus is extended, make sure again that only terminating resistors at the last device to the bus are switched in. The remaining terminating resistors at the bus must not be connected to the system. .

Analog Output

Both analog values are directed as currents via a 9-pin DSUB female connector. The outputs are isolated.

Pin no.	Description
1	Channel 1 positive
2	-
3	-
4	-
5	Channel 2 positive
6	Channel 1 negative
7	-
8	-
9	Channel 2 negative

Time Synchronization Interface

It is optionally possible to process 5-V-, 12-V- or 24-V-time synchronization signals, provided that these are connected to the inputs named in the following Table.

Table 3-28   D-subminiature connector assignment of the time synchronization interface

Pin No.	Designation	Signal meaning
1	P24_TSIG	Input 24 V
2	P5_TSIG	Input 5 V
3	M_TSIG	Return line
4	- [1]	- [1]
5	SHIELD	Shield potential
6	-	-
7	P12_TSIG	Input 12 V
8	P_TSYNC [1]	Input 24 V [1]
9	SHIELD	Shield potential

[1] Assigned, but cannot be used

Optical Fibres

WARNING!

Warning of laser rays!

Non-observance of the following measure can result in death, personal injury or substantial property damage.

Do not look directly into the fibre-optic elements, not even with optical devices! Laser Class 3A according to EN 60825-1.

For the protection data communication, refer to the following section.

Signals transmitted via optical fibres are unaffected by interference. The fibres guarantee electrical isolation between the connections. Transmit and receive connections are identified with the symbols ⟶ for transmit and ⟶ for receive.

The idle state for the optical fiber interface is "Light off". If the idle state is to be changed, use the operating program DIGSI®, as described in the SIPROTEC® 4 System Description, Order No. E50417-H1176-C151.

3.2.2   Checking the Protection Data Communication

If the device features protection data interfaces for digital communication links, the transmission way must be checked. The protection data communication is conducted either directly from device to device via optical fibres or via communication converters and a communication network or a dedicated transmission medium.

Optical Fibres, Directly

WARNING!

Warning of laser rays!

Non-observance of the following measure can result in death, personal injury or substantial property damage.

Do not look directly into the fibre-optic elements, not even with optical devices! Laser Class 3A according to EN 60825-1.

The direct optical fibre connection is visually controlled by means of an optical fibre connector. There is one connection for each direction. Therefore the output of the one device must be connected to the input of the other device and vice versa. Transmission and receiving connections are identified with the symbols ⊶→ for transmit and ⟶• for receive. Important is the visual check of assignment of the transmitter and reception channels.

If using more than one device, the connections of all protection data interfaces are checked according to the topology selected.

Communication Converter

Optical fibres are usually used for the connections between the devices and communication converters. The optical fibres are checked in the same manner as the optical fibre direct connection which means for every protection data interface.

Make sure that under the address 4502 **CONNEC. 1 OVER** the right connection type is parameterized.

Further Connections

For further connections a visual control is sufficient for the time being. Electrical and functional controls are performed during commissioning (see the following main section).

3.2.3 Checking System Connections

WARNING!

Warning of dangerous voltages

Non-observance of the following measures can result in death, personal injury or substantial property damage.

Therefore, only qualified people who are familiar with and adhere to the safety procedures and precautionary measures shall perform the inspection steps.

Caution!

Be careful when operating the device on a battery charger without a battery

Non-observance of the following measure can lead to unusually high voltages and consequently, the destruction of the device.

Do not operate the device on a battery charger without a connected battery. (For limit values see also Technical Data, Section 4.1).

Before the device is energized for the first time, the device should be in the final operating environment for at least 2 hours to equalize the temperature, to minimize humidity and avoid condensation. Connections are checked with the device at its final location. The plant must first be switched off and earthed.

Proceed as follows in order to check the system connections:

- Protective switches for the power supply and the measured voltages must be opened.
- Check the continuity of all current and voltage transformer connections against the system and connection diagrams:
  - Are the current transformers earthed properly?
  - Are the polarities of the current transformers the same?
  - Is the phase relationship of the current transformers correct?
  - Are the voltage transformers earthed properly?
  - Are the polarities of the voltage transformers correct?
  - Is the phase relationship of the voltage transformers correct?
  - Is the polarity for current input I_4 correct (if used)?
  - Is the polarity for voltage input U_4 correct (if used, e.g. for broken delta winding or busbar voltage)?
- Check the functions of all test switches that are installed for the purposes of secondary testing and isolation of the device. Of particular importance are test switches in current transformer circuits. Be sure these switches short-circuit the current transformers when they are in the "test mode".

- The short-circuit feature of the current circuits of the device are to be checked. This may be performed with an ohmmeter or other test equipment for checking continuity. Make sure that terminal continuity is not wrongly simulated in reverse direction via current transformers or their short circuit links.
  - Remove the front panel of the device (see also Figures 3-3 to 3-6).

  - Remove the ribbon cable connected to the input/output board with the measured current inputs (on the front side it is the right PCB, for housing size $1/3$ see Figure 3-3slot 19, for housing size $1/2$ see Figure 3-4slot 33, for housing size $1/1$ see Figure 3-6 slot 33 right). Furthermore, remove the PCB so that there is no more contact anymore with the plug-in terminal.

  - At the terminals of the device, check continuity for each pair of terminals that receives current from the CTs.

  - Firmly re-insert the I/O board. Carefully connect the ribbon cable. Be careful that no connector pins are bent! Don't apply force!

  - At the terminals of the device, again check continuity for each pair of terminals that receives current from the CTs.

  - Attach the front panel and tighten the screws.

- Connect an ammeter in the supply circuit of the power supply. A range of about 2.5 A to 5 A for the meter is appropriate.
- Switch on m.c.b. for auxiliary voltage (supply protection), check the voltage level and, if applicable, the polarity of the voltage at the device terminals or at the connection modules.
- The measured steady-state current should correspond to the quiescent power consumption of the device. Transient movement of the ammeter merely indicates the charging current of capacitors.
- Remove the voltage from the power supply by opening the protective switches.
- Disconnect the measuring test equipment; restore the normal power supply connections.
- Apply voltage to the power supply.
- Close the protective switches for the voltage transformers.
- Verify that the voltage phase rotation at the device terminals is correct.
- Switch off the miniature circuit breakers for the transformer voltage (VT mcb) and the power supply.
- Check tripping circuits to the circuit breakers.
- Check the close circuits to the power system circuit breakers
- Verify that the control wiring to and from other devices is correct.
- Check the signalling connections.
- Check the analog outputs (if available and used).
- Close the protective switches.

3.3 Commissioning

WARNING!

Warning of dangerous voltages when operating an electrical device

Non-observance of the following measures can result in death, personal injury or substantial property damage.

Only qualified people shall work on and around this device. They must be thoroughly familiar with all warnings and safety notices in this instruction manual as well as with the applicable safety steps, safety regulations, and precautionary measures.

Before making any connections, the device must be earthed at the protective conductor terminal.

Hazardous voltages can exist in the power supply and at the connections to current transformers, voltage transformers, and test circuits.

Hazardous voltages can be present in the device even after the power supply voltage has been removed (capacitors can still be charged).

After removing voltage from the power supply, wait a minimum of 10 seconds before re-energizing the power supply. This wait allows the initial conditions to be firmly established before the device is re-energized.

The limit values given in Technical Data must not be exceeded, neither during testing nor during commissioning.

For tests with a secondary test equipment ensure that no other measurement voltages are connected and the trip and close commands to the circuit breakers are blocked, unless otherwise specified.

DANGER!

Hazardous voltages during interruptions in secondary circuits of current transformers

Non-observance of the following measure will result in death, severe personal injury or substantial property damage.

Short-circuit the current transformer secondary circuits before current connections to the device are opened.

During the commissioning procedure, switching operations must be carried out. The tests described require that they can be done without danger. They are accordingly not meant for operational checks.

WARNING!

Warning of dangers evolving from improper primary tests

Non-observance of the following measure can result in death, personal injury or substantial property damage.

Primary tests may only be carried out by qualified persons who are familiar with commissioning protection systems, with managing power systems and the relevant safety rules and guidelines (switching, earthing etc.).

3.3.1 Test Mode / Transmission Block

Activation and Deactivation

If the device is connected to a central control system or a server via the SCADA interface, then the information that is transmitted can be modified with some of the protocols available (see Table "Protocol-dependent functions" in the Appendix A.5).

If **Test mode** is set ON, then a message sent by a SIPROTEC® 4 device to the main control system has an additional test bit. This bit allows the message to be recognized as resulting from testing and not an actual fault or power system event. Furthermore, it can be determined by activating the **Transmission block** that no annunciations at all are transmitted via the system interface during a test mode.

The SIPROTEC® 4 System Description describes in detail how to activate and deactivate test mode and blocked data transmission (Order no. E50417-H1176-C151). Note that when DIGSI® is being used, the program must be in the **Online** operating mode for the test features to be used.

3.3.2 Checking Time Synchronization

If external time synchronization sources are used, the data of the time source (antenna system, time generator) are checked (see Subsection 4 at "Time Synchronization"). A correct function (IRIG B, DCF77) is recognized in such a way that 3 minutes after the startup of the device the clock status is displayed as "synchronized", accompanied by the message "Alarm Clock OFF".

Table 3-29   Time status

No.	Status text	Status
1	– – – – – – – –	synchronized
2	– – – – – – SZ	
3	– – – – ST – –	not synchronized
4	– – – – ST SZ	
5	– – UG ST – –	
6	– – UG – – – –	
	Legend: – – UG – – – – – – – – ST – – – – – – – – SZ	time invalid time fault summertime

3.3.3 Testing the System Interface

Prefacing Remarks If the device features a system interface and uses it to communicate with the control centre, the DIGSI® device operation can be used to test if annunciations are transmitted correctly. This test option should however definitely not be used while the device is in service on a "live" system.

DANGER!

Sending or receiving annunciations via the system interface by means of the test function is a real information exchange between the SIPROTEC device and the control centre. Connected operating equipment such as circuit breakers or disconnectors can be operated in this way!

Non-observance of the following measure will result in death, severe personal injury or substantial property damage.

Equipment used to allow switching such as circuit breakers or disconnectors is to be checked only during commissioning. Do not under any circumstances check them by means of the testing mode during "real" operation performing transmission and reception of messages via the system interface.

Note

After termination of this test, the device will reboot. Thereby, all indication buffers are erased. If required, these buffers should be extracted with DIGSI® prior to the test.

The system interface test is carried out Online using DIGSI®

- Open the **Online** directory by double-clicking; the operating functions for the device appear.
- Click on **Test**; the function selection appears in the right half of the window.
- Double-click in the list view on **Generate indications**. The dialog box **Generate Indications** opens (refer to the following figure).

Structure of the Dialog Box In the column **Indication**, all message texts that were configured for the system interface in the matrix will then appear. In the column **Setpoint** you determine a value for the indications that shall be tested. Depending on the type of message different entering fields are available (e.g. `message ON` / `message OFF`). By clicking on one of the buttons you can select the desired value from the pull-down menu.
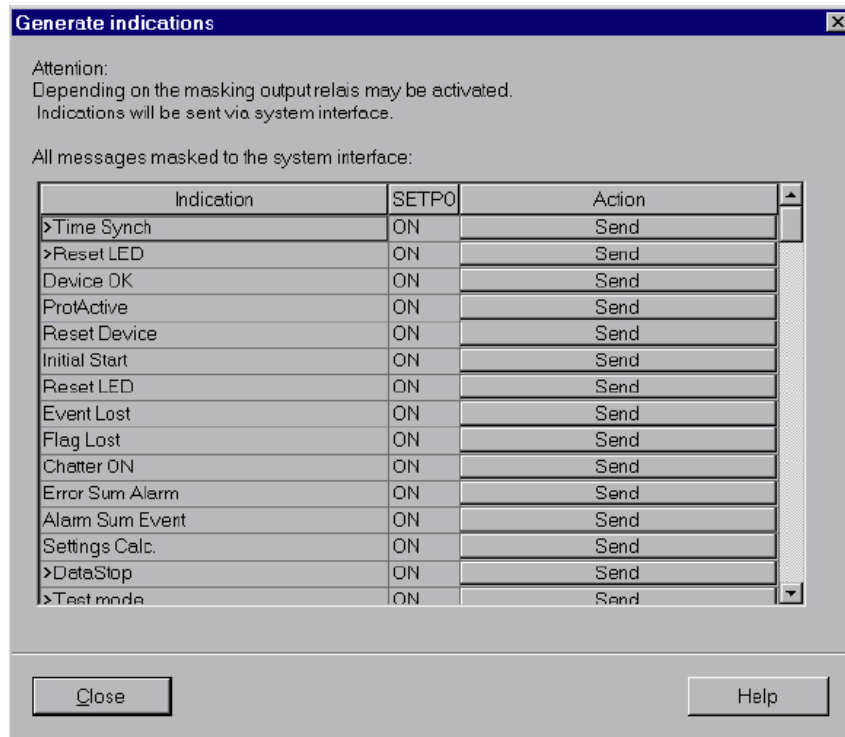
Figure 3-29   System interface test with dialog box: Generate indications — example

Changing the Operating State

By clicking one of the buttons in the column **Action** you will be asked for the password No. 6 (for hardware test menus). After you have entered the password correctly you now can send the indiciations individually. To do so, click on the button **Send** on the corresponding line. The corresponding message is issued and can now be read read out from the event log of the SIPROTEC® 4 device and from the control centre.

Further tests remain enabled, until the dialog box is closed.

Test in Message Direction

For all information that is transmitted to the central station test in **Setpoint** the desired options in the list which appears:

• Make sure that each checking process is carried out carefully without causing any danger (see above and refer to DANGER!)

• Click Send in the function to be tested and check whether the corresponding information reaches the control center and possibly shows the expected effect. Data which are normally linked via binary inputs (first character ">") are likewise indicated to the control center with this procedure. The function of the binary inputs itself is tested separately.

Exiting the Test Mode

To end the system interface test, click on **Close**. The dialog box is closed, the device is not ready for operation during the following startup

Test in Command Direction

The information transmitted in command direction must be indicated by the central station. Check whether the reaction is correct.

3.3.4   Checking the Binary Inputs and Outputs

Prefacing Remarks

The binary inputs, outputs, and LEDs of a SIPROTEC® 4 device can be individually and precisely controlled in DIGSI® 4. This feature is used, for example, to verify control wiring from the device to plant equipment during commissioning. This test option should however definitely not be used while the device is in service on a "live" system.

DANGER!

Sending or receiving annunciations via the system interface by means of the test function is a real information exchange between the SIPROTEC device and the control center. Connected operating equipment such as circuit breakers or disconnectors can be switched in this way!

Non-observance of the following measure will result in death, severe personal injury or substantial property damage.

Equipment used to allow switching such as circuit breakers or disconnectors is to be checked only during commissioning. Do not under any circumstances check them by means of the testing mode during "real" operation performing transmission and reception of messages via the system interface.

Note

After finishing the hardware tests, the device will make an initial startup. Thereby, all inidication buffers are erased. If required, these buffers should be extracted with DIGSI® prior to the test.

The hardware test can be done using DIGSI® in the Online operating mode:

- Open the **Online** directory by double-clicking; the operating functions for the device appear.
- Click on **Test**; the function selection appears in the right half of the window.
- Double-click in the list view on **Hardware Test**. The dialog box of the same name opens (see the following Figure).

Structure of the Dialog Box

The dialog box is classified into three groups: **BI** for binary inputs, **REL** for output relays, and **LED** for light-emitting diodes. On the left of each group is an accordingly labelled panel. By double-clicking these panels you can show or hide the individual information of the selected group.

In the column **Status** the present (physical) state of the hardware component is displayed. It is displayed symbolically. The physical scheduled states of the binary inputs and outputs are indicated by an open or closed switch symbol, the LEDs by a dark or illuminated LED symbol.

The opposite state of each element is displayed in the column **Scheduled**. The display is in plain text.

The right-most column indicates the commands or messages that are configured (masked) to the hardware components.
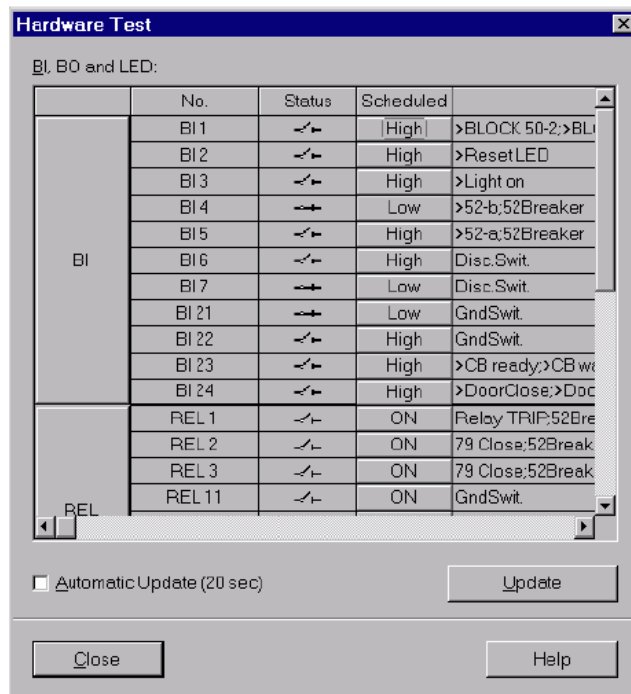
Figure 3-30   Test of the Binary Inputs and Outputs — Example

Changing the Operating State

To change the operating state of a hardware component, click on the associated switching field in the **Scheduled** column.

Before executing the first change of the operating state the password No. 6 will be requested (if activated during configuration). After entry of the correct password a condition change will be executed. Further state changes remain enabled until the dialog box is closed.

Test of the Binary Outputs

Each individual output relay can be energized allowing a check of the wiring between the output relays of the 7SA6 and the plant, without having to generate the message that is assigned to the relay. As soon as the first change of state for any of the output relays is initiated, all output relays are separated from the internal device functions, and can only be operated by the hardware test function. This means, that e.g. a TRIP command coming from a protection function or a control command from the operator panel to an output relay cannot be executed.

Proceed as follows in order to check the output relay :

- Make sure that the switching operations caused by the output relays, can be executed without any danger (see above under DANGER!).
- Each output relay must be tested via the corresponding **Scheduled**-cell in the dialog box.
- Finish the testing (see margin title below "Exiting the Procedure"), so that during further testings no unwanted switching is initiated.

Test of the Binary Inputs

To test the wiring between the plant and the binary inputs of the 7SA6 the condition in the system which initiates the binary input must be generated and the response of the device checked.

To do so, open the dialog box **Hardware Test** again to view the physical position of the binary input. The password is not yet required.

Proceed as follows in order to check the binary inputs:

- Activate in the system each of the functions which cause the binary inputs.
- Check the reaction in the **Status** column of the dialog box. To do this, the dialogue box must be updated. The options may be found below under the margin heading "Updating the Display".
- Finish the testing (see margin heading below "Exiting the Procedure").

If you want to check for the effects a binary input can have, you can do so by controlling individual binary inputs with the hardware test. As soon as the first state change of any binary input is triggered and the password no. 6 has been entered, all binary inputs are separated from the plant and can only be activated via the hardware test function.

Test of the LEDs   The LEDs may be tested in a similar manner to the other input/output components. As soon as the first state change of any LED has been triggered, all LEDs are separated from the internal device functionality and can only be controlled via the hardware test function. This means e.g. that no LED is illuminated anymore by a protection function or by pressing the LED reset button.

Updating the Display   When the dialog box **Hardware Test** is opened, the present conditions of the hardware components at that moment are read in and displayed.

An update is made:

- for the particular hardware component, if a command for change to another state was successful.
- for all hardware components if the **Update** button is clicked,
- for all hardware components with cyclical updating (cycle time is 20 seconds) if the **Automatic Update (20 sec)** field is marked.

Exiting the Procedure   To finish the hardware test, click on **Close**. The dialog box closes. The hardware components are again reset to the original operating state determined by the plant conditions. The device is not ready for operation for a short time during the following startup.

3.3.5   Checking Analog Outputs

7SA6 can be equipped with up to 2 analog outputs. Where analog outputs are provided and used, their functioning should be tested.

Since different measured values or results of the fault location are output, the check depends on the values used. These values must be generated (e.g. with some secondary test equipment).

Make sure that the corresponding values are correctly output at their destination.

3.3.6 Checking the Communication Topology

General

The communication topology can either be checked from the PC using DIGSI®.

You can either connect the PC to the device locally using the operator interface at the front, or the service interface at the back of the PC (Figure 3-31). Or you can log into the device using a modem via the service interface (example in Figure 3-32).
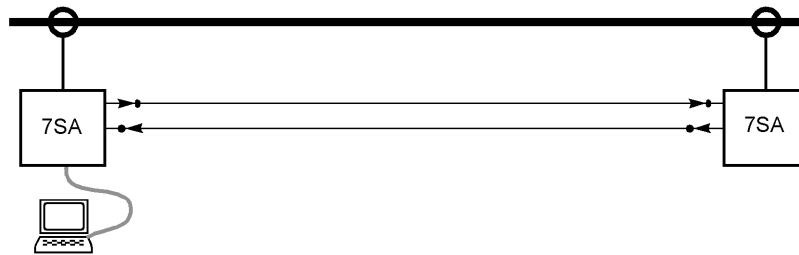
Figure 3-31   PC interfacing directly to the device - example
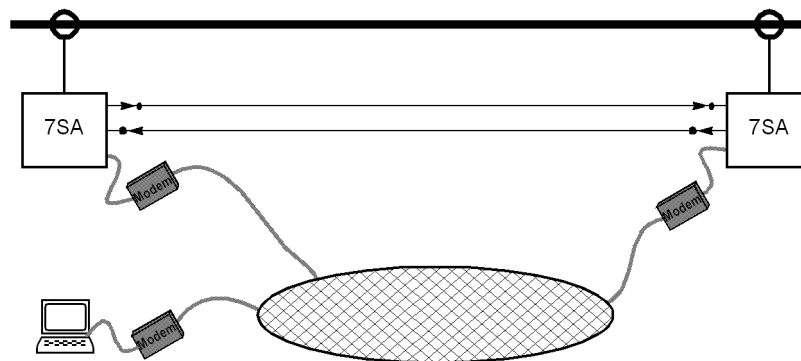
Figure 3-32   PC interfacing via modem — schematic example

Checking a Connection Using Direct Link

For two devices linked with fibre optical cables (as in Figure 3-31 or 3-32), this connection is checked as follows. If two or more devices are linked or, if two devices have been (double-) linked with a ring topology, first check only <u>one</u> link.

- Both devices at the link ends have to be switched on.
- Check in the event log or in the spontaneous annunciations:
  - If the message "PI1 with" (protection data interface 1 connected with FNo. 3243) is provided with the device index of the other device, a link has been established and one device has recognized the other.
- In case of an incorrect communication link, you see the message "PI1 Data fault" (FNo. 3229). In this case, check the fibre optical cable link again.
  - Have the devices been linked correctly and no cables been mixed up?
  - Are the cables free from mechanical damage, intact and the connectors locked?
  - Otherwise repeat check.

Continue with the margin title "Consistency of Topology and Configuration".

Checking a Link with a Communication Converter

If a communication converter is used, please note the instructions enclosed with the device. The communication converter has a test setting where its outputs are looped back to the inputs.

Links via the communication converter are tested by means of local loop-back (Figure 3-33, left).
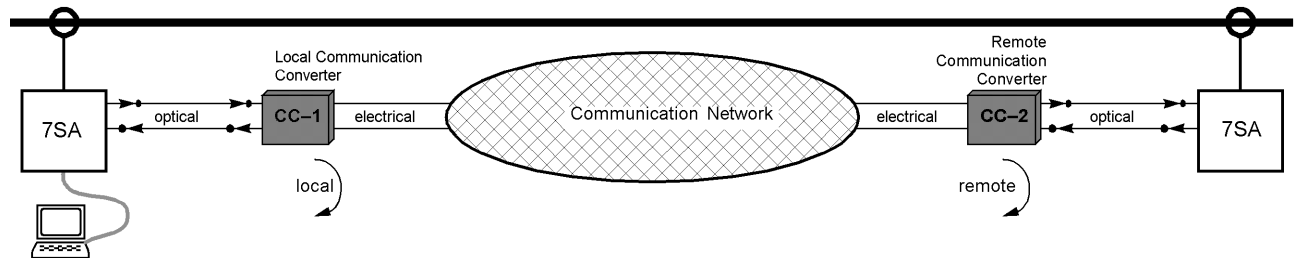
Figure 3-33   Distance protection communication via communication converter and communication network - example

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DANGER!

Opening the communication converter

There is danger to life by energized parts.

Before opening the communication converter, it is absolutely necessary to isolate it from the auxiliary supply voltage at all poles!

- Both devices at the link ends have to be switched on.
- First configure the communication converter CC-1:
  – Open the communication converter.
  – Set the jumpers to the matching position for the correct interface type and transmission rate; they must be identical with the parameterization of the 7SA6 (address 4502 **CONNEC. 1 OVER** for protection data interface 1, see also Subsection 2.4.2).
  – Move the communication converter into test position (jumper X32 in position 2-3).
  – Close the communication converter housing.
- Reconnect the auxiliary supply voltage for the communication converter.
- The system interface (X.21 or G703.1) must be active and connected to the communication converter. Check this by means of the "device ready"-contact of the communication converter (continuity at the NO contact).
  – If the "device ready"-contact of the communication converter doesn't close, check the connection between the communication converter and the net (communication device). The communication device must emit the correct transmitter clock to the communication converter.
- Change the interface parameters at the 7SA6 (at the device front or via DIGSI®):
  – Address 4502 **CONNEC. 1 OVER** = *F.optic direct* when you are testing protection data interface 1,

- Check the operating indications or in the spontaneous annunciations:
  - Message 3217 "PI1 Data reflec" (Protection interface 1 data reflection ON) when you test protection data interface 1,
  - If the indication is not transmitted check for the following:
  - Has the 7SA6 fibre optical transmitting terminal output been correctly linked with the fibre optical receiving terminal input of the communication converter and vice versa (No erroneous interchanging)?
  - Does the 7SA6 device have the correct interface module and is it working correctly?
  - Are the fibre optic cables intact?
  - Are the parameter settings for interface type and transmission rate at the communication converter correct (see above; note the DANGER instruction!)?
  - Repeat the check after correction, if necessary.
- Reset the interface parameters at the 7SA6 correctly:
  - Address 4502 **CONNEC. 1 OVER** = required setting, when you have tested protection data interface 1,
- Disconnect the auxiliary supply voltage of the communication converter at both poles. Note the above DANGER instruction!
- Reset the the communication converter to normal position (X32 in position 1-2) and close the housing again.
- Reconnect the supply voltage of the communication converter.

Perform the above check at the other end with the device being connected there and its corresponding communication converter.

Continue with the margin title "Consistency of Topology and Parameterization".

Consistency of Topology and Configuration

Having performed the above checks, the linking of a device pair, including their communication converters, has been completely tested and connected to auxiliary supply voltage. Now the devices communicate by themselves.

- Check now the Event Log or in the spontaneous annunciations of the device where you are working:
  - Message FNo. 3243 "PI1 with" (protection data interface 1 linked with) followed by the device index of the other device, if interface 1 is applying.
  - If the devices are at least connected once, the message FNo. 3458 "Chaintopology" will appear.
  - If no other devices are involved in the topology as an entity, the message FNo. 3464 "Topol complete" will then be displayed, too.
  - And if the device configuration is also consistent, i.e. the prerequisites for setting the function scope (Section 2.1.1), Power System Data 1 (2.1.3.1), Power System Data 2 (2.1.5.1) topology and protection data interface parameters (Section 2.4.2) have been considered, the fault message, i.e. FNo. 3229 "PI1 Data fault", for the interface just checked will disappear. The communication and consistency test has now been completed.
  - If the fault message of the interface being checked does not disappear, however, the fault must be found and eliminated. Table 3-30 lists messages that indicate such faults.

Table 3-30   Messages on Inconsistencies

FNo.	LCD Text	Meaning / Measures
3233	"DT inconsistent"	"Device table inconsistent": The indexing of the devices is inconsistent (missing numbers or one number used twice, see Section 2.4.2)
3234	"DT unequal"	"Device table unequal": the ID-numbers of the devices are unequal (see Section 2.4.2)
3235	"Par. different"	"Parameterization different": Different functional parameters were set for the devices. They have to be equal at both ends:

Checking Further Links

If all devices involved in the topology communicate properly and all parameters are consistent, the message FNo.3464 "Topol complete" appears.

If there is a ring topology (only in connection with a 7SA522), the message FNo. 3457 "Ringtopology" must also appear after closing the ring.

However, if you are employing a ring topology, which only issues the indication "Chaintopology" instead of "Ringtopology", the protection data communication is functionable, but the ring has not yet been closed. Check the missing links as described above including the consistency test until all links to the ring have been made.

Finally, there should be no more fault messages of the protection data interfaces.

3.3.7   Tests for Circuit Breaker Failure Protection

General

If the device is equipped with the breaker failure protection and this function is used, the integration of this protection function into the system must be tested under practical conditions.

Because of the manifold application facilities and various configuration possibilities of the power plant it is not possible to give detailed description of the necessary test steps. It is important to observe local conditions and protection and system drawings.

Before starting the circuit breaker tests it is recommended to insulate at both ends the feeder which is to be tested, i.e. line disconnectors and busbar disconnectors should be open so that the breaker can be operated without risk.

Caution!

Also for tests on the local circuit breaker of the feeder a trip command to the surrounding circuit breakers can be issued for the busbar.

Non-observance of the following measure can result in minor personal injury or property damage.

Therefore, primarily it is recommended to interrupt the tripping commands to the adjacent (busbar) breakers e.g. by inrupting the corresponding pickup voltage supply.

Before the breaker is closed again for normal operation the trip command of the feeder protection routed to the circuit breaker must be disconnected so that the trip command can only be initiated by the breaker failure protection.

Although the following lists do not claim to be complete, they may also contain points which are to be ignored in the current application.

Auxiliary Contacts of the CB

The circuit breaker auxiliary contact(s) form an essential part of the breaker failure protection system in case they have been connected to the device. Make sure the correct assignment has been checked.

External Initiation Conditions

If the breaker failure protection is intended to be initiated by external protection devices, each of the external initiation conditions must be checked. Single-pole or three-pole tripping is possible depending on the setting of the breaker failure protection. Note that the pole discrepancy supervision of the device or the breaker may lead to a later three-pole trip. Therefore check first how the parameters of the breaker failure protection are set. See Subsection 2.19.2, addresses 3901 onwards.

In order for the breaker failure protection to be started, a current must flow at least via the monitored phase. This may be a secondary injected current.

After every start, the message "BF Start" (FNo 1461) must appear in the spontaneous or fault annunciations.

Only if single-pole starting possible:
- Single-pole starting by trip command of external protection in phase L1:
  Binary input functions ">BF Start L1" and, if necessary, ">BF release" (in or spontaneous or fault messages). Trip command (dependent on settings).
- Single-pole starting by trip command of external protection in phase L2:
  Binary input functions ">BF Start L2" and if necessary ">BF release" (in spontaneous or fault messages). Trip command (dependent on settings).
- Single-pole starting by trip command of external protection in phase L3:
  Binary input functions ">BF Start L3" and, if necessary, ">BF release" (in spontaneous or fault messages). Trip command (dependent on settings).
- Three—pole starting by trip command of the external protection via all three binary inputs L1, L2 and L3:
  Binary input functions ">BF Start L1", ">BF Start L2" and ">BF Start L3" and, if necessary, ">BF release" (in spontaneous or fault messages). Trip command three-pole.

For three-pole starting:
- Three-pole starting by trip command of the external protection:
  Binary input functions ">BF Start 3pole" and, if necessary, ">BF release" (in or spontaneous or fault messages). Trip command (dependent on settings).

Switch off test current.

If start is possible without current flow:
- Starting by trip command of the external protection without current flow:
  Binary input functions ">BF Start w/o I" and, if necessary, ">BF release" (in or spontaneous or fault messages). Trip command (dependent on settings).

Busbar Tripping

The most important thing is the check of the correct distribution of the trip commands to the adjacent circuit breakers in case of breaker failure.

The adjacent circuit breakers are those of all feeders which must be tripped in order to ensure interruption of the fault current should the local breaker fail. These are therefore the circuit breakers of all feeders which feed the busbar or busbar section to which the feeder with the fault is connected.

A general detailed test guide cannot be specified, because the layout of the surrounding circuit breakers largely depends on the system topology.

In particular with multiple busbars the trip distribution logic for the surrounding circuit breakers must be checked. Here check for every busbar section that all circuit breakers which are connected to the same busbar section as the feeder circuit breaker under observation are tripped, and no other breakers.

Tripping of the Remote End

If the trip command of the circuit breaker failure protection must also trip the circuit breaker at the remote end of the feeder under observation, the transmission channel for this remote trip must also be checked. This is done together with transmission of other signals according to Sections "Testing of the Teleprotection Scheme with ..." further below.

Termination of the Checks

All temporary measures taken for testing must be undone, e.g. especially switching states, interrupted trip commands, changes to setting values or individually switched off protection functions.

3.3.8   Current, Voltage, and Phase Rotation Testing

≥ 10 % of Load Current

The connections of the current and voltage transformers are tested using primary quantities. Secondary load current of at least 10 % of the nominal current of the device is necessary. The line is energized and will remain in this state during the measurements.

With proper connections of the measuring circuits, none of the measured-values supervision elements in the device should pick up. If an element detects a problem, the causes which provoked it may be viewed in the Event Log.

If current or voltage summation errors occur, then check the matching factors (see Section 2.1.3.1).

Messages from the symmetry monitoring could occur because there actually are asymmetrical conditions in the network. If these asymmetrical conditions are normal service conditions, the corresponding monitoring functions should be made less sensitive (see Section 2.22.1.5) .

Quantities

Currents and voltages can be viewed in the display field on the front of the device or the operator interface via a PC. They can be compared to the actual measured values, as primary and secondary quantities.

If the measured values are not plausible, the connection must be checked and corrected after the line has been isolated and the current transformer circuits have been short-circuited. The measurements must then be repeated.

Phase Rotation

The phase rotation must correspond to the configured phase rotation, in general a clockwise phase rotation. If the system has a counterclockwise phase sequence, this must have been considered when the power system data was set (address 235 **PHASE SEQ.**). If the phase rotation is incorrect, the alarm "Fail Ph. Seq." (FNo 171) is generated. The measured value phase allocation must be checked and corrected, if required, after the line has been isolated and current transformers have been short-circuited. The measurement must then be repeated.

Voltage Transformer Miniature Circuit Breaker (VT mcb)

Open the miniature circuit breaker of the feeder voltage transformers. The measured voltages in the operational measured values appear with a value close to zero (small measured voltages are of no consequence).

Check in the spontaneous annunciations that the VT mcb trip was entered (message "`>FAIL:Feeder VT`" "ON" in the spontaneous annunciations). Beforehand it has to be assured that the position of the VT mcb is connected to the device via a binary input.

Close the VT mcb again: The above messages appear in the spontaneous messages as "OFF", i.e. "`>FAIL:Feeder VT`" "OFF".

If one of the annunciations does not appear, check the connection and allocation of these signals.

If the "ON" state and "OFF" state are swapped, the contact type (H–active or L–active) must be checked and remedied.

If a busbar voltage is used (for voltage or synchronism check) and the assigned VT mcb is connected to the device, the following function must also be checked:

If the VT mcb is open the message "`>FAIL:Bus VT`" "ON" appears, if it is closed the message "`>FAIL:Bus VT`" "OFF" is displayed.

Switch off the protected power line.

3.3.9   Direction Check with Load Current

$\geq$ 10 % of Load Current

The correct connection of the current and voltage transformers is checked via the protected line using the load current. For this purpose, connect the line. The load current the line carries must be at least $0.1 \cdot I_N$. The load current should be in-phase or lagging the voltage (resistive or resistive-inductive load). The direction of the load current must be known. If there is a doubt, network or ring loops should be opened. The line remains energized during the test.

The direction can be derived directly from the operational measured values. Initially the correlation of the measured load direction with the actual direction of load flow is checked. In this case the normal situation is assumed whereby the forward direction (measuring direction) extends from the busbar towards the line (see the following Figure).

P positive, if active power flows into the line,

P negative, if active power flows towards the busbar,

Q positive, if reactive power flows into the line,

Q negative, if reactive power flows toward the busbar.
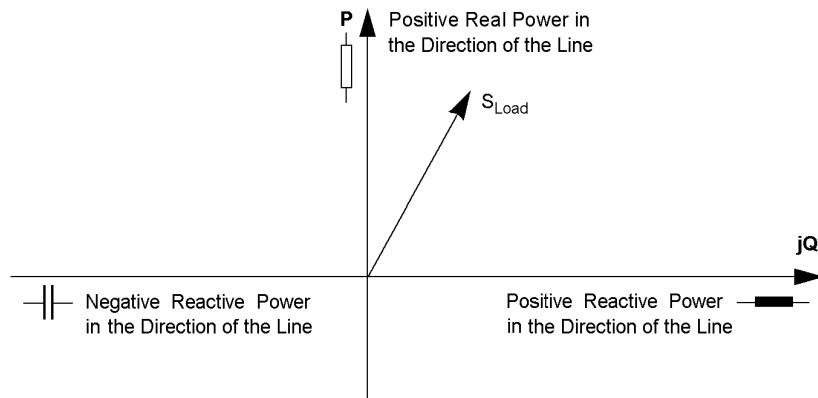
Figure 3-34   Apparent Load Power

The power measurement provides an initial indication as to whether the measured values have the correct polarity. If both the active power as well as the reactive power have the wrong sign, the polarity in address 201 **CT Starpoint** must be checked and rectified.

However, power measurement itself is not able to detect all connection errors. Accordingly, the impedances of all six measuring loops are evaluated. These can also be found as primary and secondary quantities in the operational measured values.

All six measured loops must have the same impedance components (R and X). Small variations may result due to the non-symmetry of the measured values. In addition, the following applies for all impedances when the load is in the first quadrant:

R, **X** both positive, when power flows into the line,

R, **X** both negative, when power flows towards the busbar.

In this case the normal situation is assumed whereby the forward direction (measuring direction) extends from the busbar towards the line In the case of capacitive load, caused by e.g. underexcited generators or charging currents, the X-components may all have the opposite sign.

If significant differences in the values of the various loops are present, or if the individual signs are different, then individual phases in the current or voltage transformer circuits are swapped, not connected correctly, or the phase allocation is incorrect. After isolation of the line and short-circuiting of the current transformers the connections must be checked and corrected. The measurements must then be repeated.

Finally, switch off the protected power line.

3.3.10 Polarity Check for the Voltage Input U$_4$

Depending on the application of the voltage measuring input U$_4$, a polarity check may be necessary. If no measuring voltage is connected to this input, this subsection is irrelevant.

If the input U$_4$ is used for measuring a voltage for overvoltage protection (**P.System Data 1** Address 210 **U4 transformer** = **Ux transformer**), no polarity check is necessary because the polarity is irrelevant here. The voltage magnitude was checked before.

If the input U$_4$ is used for the measurement of the displacement voltage U$_{en}$ (**P.System Data 1** Address 210 **U4 transformer** = **Udelta transf.**), the polarity together with the current measurement is checked (see in the following).

If the input U$_4$ is used for measuring a busbar voltage for synchronism check (**P.System Data 1** Address 210 **U4 transformer** = **Usync transf.**), the polarity must be checked as follows using the synchronism check function.

Only for Synchronism Check

The device must be equipped with the synchronism and voltage check function which must be configured under address 135 **Enabled** (see section 2.1.1.2).

The voltage connected to the busbar must be specified correctly under address 212 **Usync connect.** (see Subsection 2.1.3.1).

If there is no transformer between the two measuring points, address 214 φ **Usync-Uline** must be set to **0°** (see Subsection 2.1.3.1).

If the measurement is made across a transformer, this angle setting must correspond to the phase rotation through which the vector group of the transformer as seen from the feeder in the direction of the busbar rotates the voltage. An example is shown in Subsection 2.1.3.1.

If necessary, different transformation ratios of the transformers on the busbar and the feeder may have to be considered under address 215 **U-line / Usync**.

The synchronism and voltage check must be switched **ON** under address 3501 **FCT Synchronism** .

An additional help for the connection control are the messages 2947 "Sync. Udiff>" and 2949 "Sync. φ-diff>" in the spontaneous annunciations.

- Circuit breaker is open. The feeder is isolated (zero voltage). The VTmcb's of both voltage transformer circuits must be closed.
- For the synchronism check the program **OVERRIDE** = **YES** (Address 3519) is set; the other programs (Addresses 3515 to 3518) are set to **NO**.
- Via binary input (FNo. 2906 ">Sync. Start AR") initiate the measuring request. The synchronism check must release closing (message "Sync. release", FNo. 2951). If not, check all relevant parameters again (synchrocheck configured and enabled correctly, see Sections 2.1.1.2, 2.1.3.1 and 2.15.2).
- Set address 3519 **OVERRIDE** to **NO**.
- Then the circuit breaker is closed while the line isolator is open (see following Figure). Both voltage transformers therefore measure the same voltage.
- The program **SYNC-CHECK** = **YES** (Address 3515) is set for synchronism check.
- Via binary input (FNo. 2906 ">Sync. Start AR") initiate the measuring request. The synchronism check must release closing (message "Sync. release", FNo. 2951).
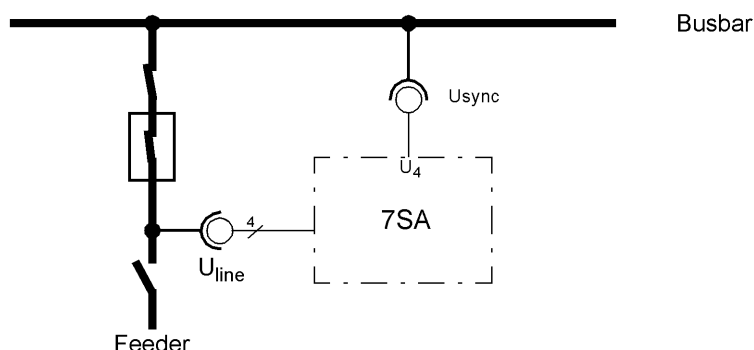
Figure 3-35   Measuring voltages for the synchronism check

- If not, first check whether one of the before named messages 2947 "Sync. Udiff>" or 2949 "Sync. φ-diff>" is available in the spontaneous messages.

  The message "Sync. Udiff>" indicates that the magnitude (ratio) adaptation is incorrect. Check address 215 **U-line / Usync** and recalculate the adaptation factor, if necessary.

  The message "Sync. φ-diff>" indicates that the phase relation of the busbar voltage does not match the setting under address 212 **Usync connect.** (see Section 2.1.3.1). When measuring across a transformer, address 214 φ **Usync-Uline** must also be checked; this must adapt the vector group (see Subsection 2.1.3.1). If these are correct, there is probably a reverse polarity of the voltage transformer terminals for Usync.

- The program **Usync< U-line>** = *YES* (Address 3517) and **SYNC-CHECK** = *YES* (Address 3515) is set for synchronism check.

- Open the VT mcb of the busbar voltage.

- Via binary input (FNo.2906 ">Sync. Start AR") initiate the measuring request. There is no close release. If there is, the VT mcb for the busbar voltage is not allocated. Check whether this is the required state, alternatively check the binary input ">FAIL:Bus VT" (FNo. 362).

- The VT mcb of the busbar voltage is to be closed again.

- Open the circuit breaker.

- The program **Usync> U-line<** = *YES* (Address 3516) and **Usync> U-line<** = *NO* (Address 3517) is set for synchronism check.

- Via binary input (FNo. 2906">Sync. Start AR") initiate the measuring request. The synchronism check must release closing (message "Sync. release", FNo. 2951). Otherwise check all voltage connections and the corresponding parameters again carefully as described in Section 2.1.3.1.

- Open the VT mcb of the feeder voltage.

- Via binary input (FNo.2906 ">Sync. Start AR") initiate the measuring request. No close release is given.

- Open the VT mcb of the feeder voltage again.

Addresses 3515 to 3519 must be restored as they were changed for the test. If the allocation of the LEDs or signal relays was changed for the test, this must also be restored.

3.3.11 Earth Fault Check in a Non-earthed System

The earth fault check is only necessary if the device is connected to an isolated or resonant-earthed system and the earth fault detection is applied. The device must therefore be provided with the earth fault detection function according to its ordering code(16. MLFB position = **2** or **3** or **6** or **7**) and must have been preset during configuration to **Sens. Earth Flt** = *Enabled* (Address 130) . If none of this is the case, this subsection is not relevant.

The primary check serves to find out the correct polarity of the transformer connections for the determination of the earth fault direction.

DANGER!

Energized equipment of the power system ! Capacitive coupled voltages at disconnected equipment of the power system !

Non-observance of the following measure will result in death, severe personal injury or substantial property damage.

Primary measurements must only be carried out on disconnected and earthed equipment of the power system!

Using the primary earth fault method a most reliable test result is guaranteed. Therefore please proceed as follows:

- Isolate the line and earth it on both ends. During the whole testing procedure the line must be open at the remote end.
- Make a test connection between a single phase and earth. On overhead lines it can be connected anywhere, however, it must be located behind the current transformers (looking from the busbar of the feeder to be checked). Cables are earthed on the remote end (sealing end).
- Remove the protective earthing of the line.
- Connect a circuit breaker to the line end that is to be checked.
- Check the direction indication (LED if allocated)
- The faulty phase (FNo 1272 for L1 or 1273 for L2 or 1274 for L3) and the direction of the line, i.e. "SensEF Forward" (FNo. 1276) must be indicated in the earth fault protocol.
- The active and reactive components of the earth current are also indicated, the reactive current ("3I0senR", FNo. 1220) is the most relevant for isolated systems, for resonant-earthed systems it is the active current ("3I0senA", FNo. 1219). If the display shows the message "SensEF Reverse" (FNo. 1277), either the current or voltage transformer terminals are swopped in the neutral path. If message "SensEF undefDir" (FNo 1278) appears, the earth current may be too low.
- Deenergize and earth the line.

The check is then finished.

3.3.12 Polarity Check for the Current Input I$_4$

If the standard connection of the device is used whereby current input I$_4$ is connected in the starpoint of the set of current transformers (refer also to the connection circuit diagram in the Appendix A.3), then the correct polarity of the earth current path in general automatically results.

If, however, the current I$_4$ is derived from a separate summation CT or from a different measuring point, e.g. transformer starpoint current or earth current of a parallel line, an additional polarity check with this current becomes necessary.

If the device is provided with the <u>sensitive</u> current input I$_4$ and it is connected to an isolated or resonant-earthed system, the polarity check for I$_4$ was already carried out with the earth fault check according to the previous section. Then this section can be ignored.

Otherwise the test is done with a disconnected trip circuit and primary load current. It must be noted that during all simulations that do not exactly correspond with situations that may occur in practice, the non-symmetry of measured values may cause the measured value monitoring to pick up. This must therefore be ignored during such tests.

DANGER!

Hazardous voltages during interruptions in secondary circuits of current transformers

Non-observance of the following measure will result in death, severe personal injury or substantial property damage.

Short-circuit the current transformer secondary circuits before current connections to the device are opened.

I$_4$ from Own Line To generate a displacement voltage, the e–n winding of one phase in the voltage transformer set (e.g. L1) is bypassed (refer to Figure 3-36). If no connection on the e–n windings of the voltage transformer is available, the corresponding phase is open circuited on the secondary side. Via the current path only the current from the current transformer in the phase from which the voltage in the voltage path is missing, is connected; the other CTs are short-circuited. If the line carries resistive-inductive load, the protection is in principle subjected to the same conditions that exist during an earth fault in the direction of the line.

At least one stage of the earth fault protection must be set to be directional (address 31x0 of the earth fault protection). The pick-up threshold of this stage must be below the load current flowing on the line; if necessary the pick-up threshold must be reduced. The parameters that have been changed, must be noted.

After switching the line on and off again, the direction indication must be checked: In the fault log the messages "EF Pickup" and "EF forward" must at least be present. If the directional pickup is not present, either the earth current connection or the displacement voltage connection is incorrect. If the wrong direction is indicated, either the direction of load flow is from the line toward the busbar or the earth current path has a swapped polarity. In the latter case, the connection must be rectified after the line has been isolated and the current transformers short-circuited.

In the event that the pick-up alarms were not even generated, the measured earth (residual) current may be too small.
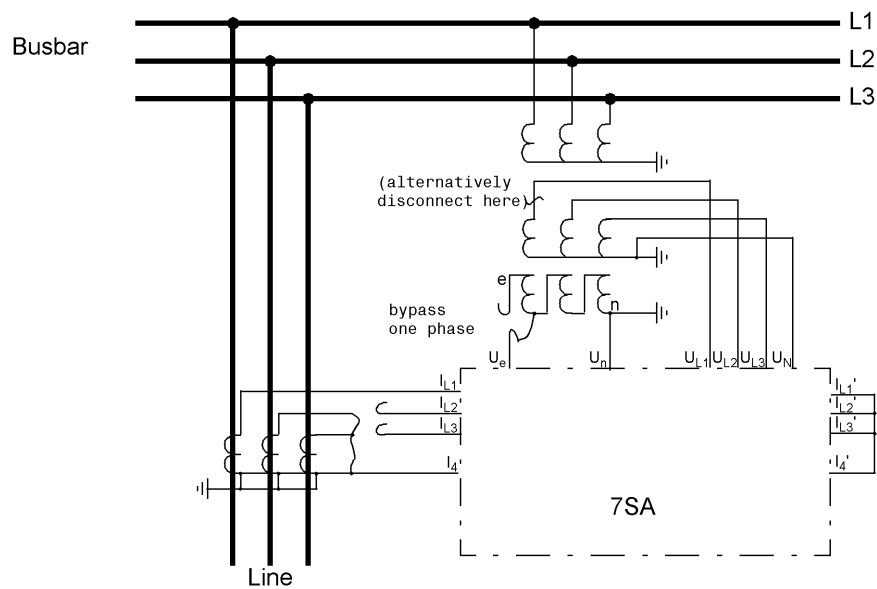
Figure 3-36   Polarity check for the current input I_4, example for current transformer set in Holmgreen circuit

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Note

If parameters were changed for this test, they must be returned to their original state after completion of the test !

I_4 from Parallel Line   If I_4 is the current measured on a parallel line, the above procedure is done with the set of current transformers on the parallel line (Figure 3-37). The same method as above is used here, except that a single phase current from the parallel feeder is measured. The parallel line must and the protected line should carry load. The line remains switched on for the duration of the measurement.

If the polarity of the parallel line earth current measurement is correct, the impedance measured in the tested loop (in the example of Figure 3-37 this is L1–E) should be reduced by the influence of the parallel line. The impedances can be read out as primary or secondary quantities in the list of operational measured values.

If, on the other hand, the measured impedance increases when compared to the value without parallel line compensation, the current measuring input I_4 has a swapped polarity. After isolation of both lines and short-circuiting of the current transformer secondary circuits, the connections must be checked and rectified. Subsequently the measurement must be repeated.
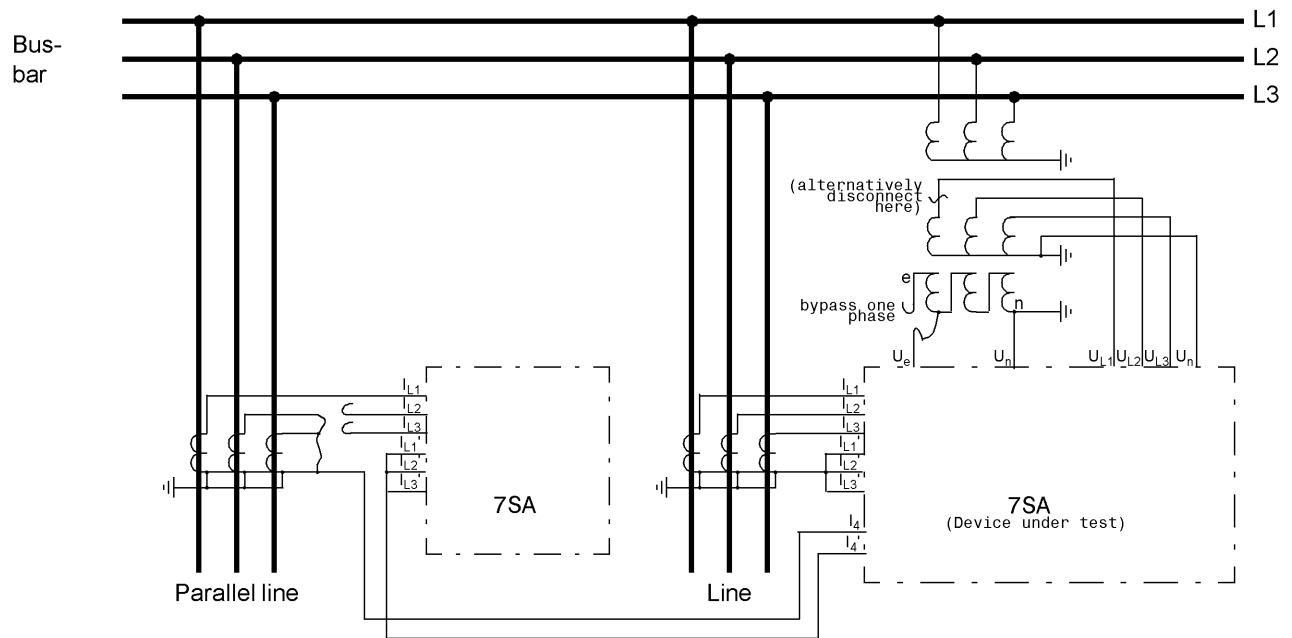
Figure 3-37   Polarity check for the current input I_4, example for earth current of a parallel line

I_4 from a Power Transformer Star-point

If I_4 is the earth current measured in the starpoint of a power transformer and intended for the earth fault protection direction determination (for earthed networks), then the polarity check can only be carried out with a zero sequence current flowing through the transformer. A test voltage source is required for this purpose (single-phase low voltage source).

Caution!

Feeding of zero sequence currents via a transformer without broken delta winding

Inadmissible heating of the transformer is possible!

Zero sequence current should only be routed via a transformer if it has a delta winding, therefore e.g. Yd, Dy or Yy with a compensating winding.

DANGER!

Energized equipment of the power system! Capacitive coupled voltages at disconnected equipment of the power system !

Non-observance of the following measure will result in death, severe personal injury or substantial property damage.

Primary measurements must only be carried out on disconnected and earthed equipment of the power system!

The configuration shown in Figure 3-38 corresponds to an earth current flowing through the line, in other words an earth fault in the forward direction.

At least one stage of the earth fault protection must be set to be directional (address 31xx of the earth fault protection). The test current on the line must exceed the pickup threshold setting of these stages; if necessary the pick-up threshold must be reduced. The parameters that have been changed, must be noted.
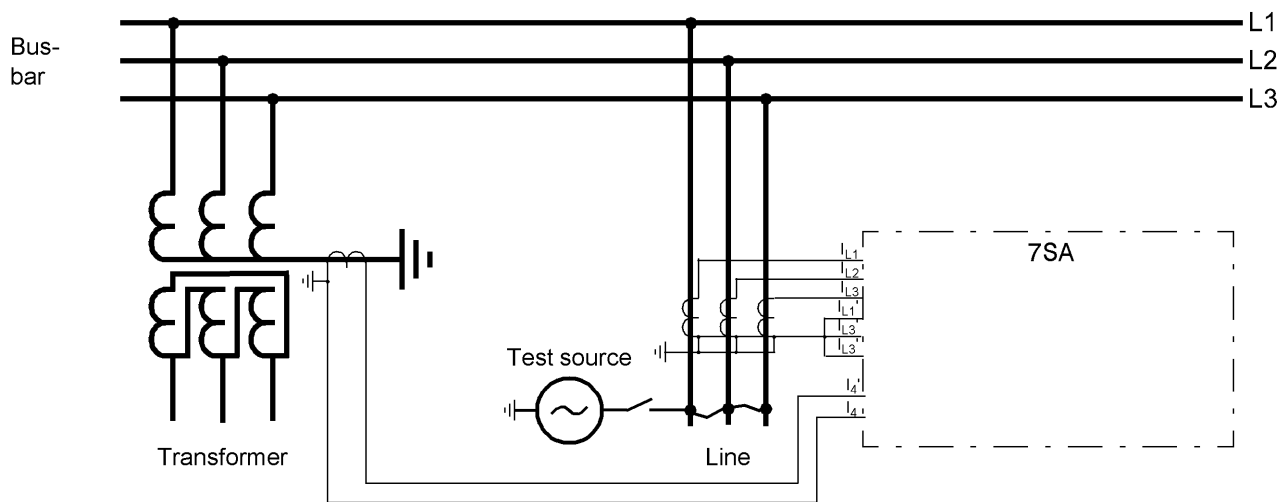
Figure 3-38   Polarity check of I_4, example with earth current from a power transformer star-point

After switching the test source on and off again, the direction indication must be checked: In the fault log the messages "EF Pickup" and "EF forward" must at least be present. If the directional pick-up alarm is missing, a connection error of the earth current connection I_4 is present. If the wrong direction is indicated, the earth current connection I_4 has a swapped polarity. In the previous case the connection must be rectified after the test source has been switched off. The measurements must then be repeated.

If the pick-up alarm is missing altogether, this may be due to the fact that the test current is too small.

Note

If parameters were changed for this test, they must be returned to their original state after completion of the test !

3.3.13 Measuring the Operating Time of the Circuit Breaker

Only for Synchronism Check

If the device is equipped with the function for synchronism and voltage check and it is applied, it is necessary - under asynchronous system conditions - that the operating time of the circuit breaker is measured and set correctly when closing. If the synchronism check function is not used or only for closing under synchronous system conditions, this subsection is irrelevant.

For measuring the operating time a setup as shown in Figure 3-39 is recommended. The timer is set to a range of 1 s and a graduation of 1 ms.

The circuit breaker is closed manually. At the same time the timer is started. After closing the poles of the circuit breaker, the voltage U_{Line} appears and the timer is stopped. The time displayed by the timer is the real circuit breaker closing time.

If the timer is not stopped due to an unfavourable closing moment, the attempt will be repeated.

It is particularly favourable to calculate the mean value from several (3 to 5) successful switching attempts.

Set the calculated time under address 239 as `T-CB close` (under `P.System Data 1`). Select the next lower settable value.

Note

The operating time of the accelerated output relays for command tripping is taken into consideration by the device itself. The tripping command is to be allocated to a such relay. If this is not the case, add 3 ms to the measured circuit-breaker operating time for achieving a greater response time of the "normal" output relay. Subtract 4 ms from the circuit-breaker operating time if high-speed-relays are in service.
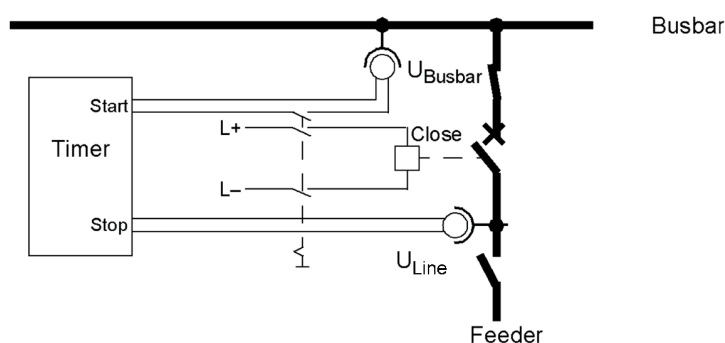
Figure 3-39   Measuring the circuit breaker closing time

3.3.14 Testing of the Teleprotection System with Distance Protection

Note

If the device is intended to operate with teleprotection, all devices used for the transmission of the signals must initially be commissioned according to the corresponding instructions.

The following section applies only for the conventional transmission procedures. It is not relevant for usage with protection data interfaces.

For the functional check of the signal transmission, the earth fault protection should be disabled, to avoid signals from this protection influencing the tests: address 3101 **FCT EarthFltO**/**C** = *OFF*.

Check for Pilot Wire Comparison

The operating mode pilot wire comparison differs considerably from other teleprotection schemes as far as the type of transmission (DC closed circuit-loop) is concerned. The examination is described in the following. If a different transmission scheme is applied, this part can be skipped.

Detailed information on the function of the pilot-wire comparison is available in Section 2.6.

For **Teleprot. Dist.** in address 121 *Pilot wire comp* must be configured and the **FCT Telep. Dis.** must be switched *ON* under address 2101. The protection relays at both line ends must be in operation. Initially, the quiescent current loop of the pilot wire comparison is not yet supplied with auxiliary voltage.

A fault is simulated outside of zone Z1, but within zone Z1B. Since stage Z1B is blocked, the distance protection is only tripped in a higher-leveled zone (usually with T2). This check must be carried out at both line ends.

The direct voltage for the quiescent current loop of the pilot wire comparison is switched to the line. The loop is then fed with quiescent current.

At one line end a fault is simulated outside of the first zone, but within the overreach zone Z1B. The command is tripped to T1B. This check must be carried out at both line ends.

Since the quiescent current loop is part of the nature of the pilot wire comparison, these tests also check if the transmission process is performed correctly. All other tests which are described in this Subsection can be passed over. However, please observe the last margin heading "Important for All Schemes"!

Checking of Reverse Interlocking

The checking of the reverse interlocking is described below. If a different transmission scheme is applied, this part can be skipped.

For more detailed information about the reverse interlocking see Chapter 2.6.

For **Teleprot. Dist.** address 121 must be set to *Rev. Interlock* and the **FCT Telep. Dis.** must be switched *ON* at address 2101. The distance protection of the infeed and switchgear of all outgoing feeders must be in operation. At the beginning no auxiliary voltage is fed to the line for the reverse interlocking.

The following paragraphs describe the testing in a blocked state, i.e. the pick-up signals of the outgoing devices are connected in parallel and block the tested device

of the infeed. In case of release (the NC contacts of the outgoing devices are connected in series) the tests have to be reinterpreted respectively.

A fault is simulated within zone Z1 and overreaching zone Z1B. As a result of the missing blocking signal, the distance protection trips after time delay T1B (slightly delayed).

The direct voltage for reverse interlocking is now switched to the line. The precedent test is repeated, the result will be the same.

At each of the protection devices of the outgoing circuits, a pick-up is simulated. Meanwhile, another short-circuit is simulated as described before for the distance protection of the infeed. Now, the distance protection trips after time T1, which has a longer setting.

These tests also check the proper functioningofthetransmission path. All other tests which are described in this Subsection can be passed over. However, please observe the last margin heading "Important for All Schemes"!

Checking at Permissive Scheme	Requirements: **Teleprot. Dist.** is set in address 121 to one of the comparison schemes using a permissive signal, i.e. *POTT* or *Dir.Comp.Pickup* or *UNBLOCKING*. Furthermore, **FCT Telep. Dis.** is switched *ON* at address 2101. Naturally, the corresponding send and receive signals must also be assigned to the corresponding binary output and input. For the echo function, the echo signal must be assigned separately to the transmit output.

Detailed information on the function of permissive scheme is available in Section 2.6.

A simple check of the signal transmission path from one line end is possible via the echo function if these release techniques are used. The echo function must be activated at both line ends i.e. address 2501 **FCT Weak Infeed** = *ECHO only*; with the setting *ECHO and TRIP* a trip command may occur at the remote end of the check!

A short-circuit is simulated outside Z1, with *POTT* or *UNBLOCKING* inside Z1B, with *Dir.Comp.Pickup* somewhere in forward direction. This may be done with secondary injection test equipment. As the device at the opposite line end does not pick up, the echo function comes into effect there, and consequently a trip command is issued at the line end being tested.

If no trip command appears, the signal transmission path must be checked again, especially also the assignment of the echo signals to the transmit outputs.

In case of a phase-segregated transmission the above-mentioned checks are carried out for each phase. The correct phase allocation is also to be checked.

This test must be performed at both line ends, in the case of three terminal lines at each end for each signal transmission path.

The functioning of the echo delay time and the derivation of the circuit breaker switching status should also be tested at this time (the functioning of the protection at the opposite line end is tested):

The circuit breaker on the protected feeder must be opened, as must be the circuit breaker at the opposite line end. As described above, a fault is again simulated. A receive signal impulse delayed by somewhat more than twice the signal transmission time appears via the echo function at the opposite line end, and the device issues a trip command.

The circuit breaker at the opposite line end is now closed (while the isolators remain open). After simulation of the same fault, the receive and trip command appear again. In this case however, they are additionally delayed by the echo delay time of the device at the opposite line end (0.04 s presetting, address 2502 **Trip/Echo DELAY**).

If the response of the echo delay is opposite to the sequence described here, the operating mode of the corresponding binary input (H–active/L–active) at the <u>opposite</u> line end must be rectified.

The circuit breaker must be opened again.

This test must be performed at both line ends, on a three terminal line at each line end for each transmission path. Finally, please observe the last margin heading "Important for All Schemes"!

Checking in Blocking Scheme

Requirements: **Teleprot. Dist.** is configured in address 121 to one of the comparison schemes with blocking signal, i.e. **BLOCKING**. Furthermore, address **FCT Telep. Dis.** is switched **ON** at address 2101. Naturally, the corresponding send and receive signals must also be assigned to the corresponding binary output and input.

For more details about the function of the blocking scheme refer to Subsection 2.6. In the case of the blocking scheme, communication between the line ends is necessary.

On the transmitting end, a fault in the reverse direction is simulated, while at the receiving end a fault in Z1B but beyond Z1 is simulated. This can be achieved with a set of secondary injection test equipment at each end of the line. As long as the transmitting end is transmitting, the receiving end may not generate a trip signal, unless this results from a higher distance stage. After the simulated fault at the transmitting line end is switched off, the receiving line end remains blocked for the duration of the transmit prolongation time of the transmitting line end (**Send Prolong.**, address 2103). If applicable, the transient blocking time of the receiving line end (**TrBlk BlockTime**, address 2110) appears additionally if a finite delay time **TrBlk Wait Time** (address 2109) has been set and exceeded.

In case of a phase-segregated transmission the above-mentioned checks are performed for each phase. The correct phase allocation is also to be checked.

This test must be performed at both line ends, on a three terminal line at each line end for each transmission path. Finally, please observe the last margin heading "Important for All Schemes"!

Checking at Permissive Underreach Transfer

Requirements: **Teleprot. Dist.** is configured in address 121 to a permissive underreach transfer trip scheme, i.e. **PUTT (Z1B)** or **PUTT (Pickup)**. Furthermore, **FCT Telep. Dis.** is switched **ON** at address 2101. Naturally, the corresponding send and receive signals must also be assigned to the corresponding binary output and input.

Detailed information on the function of permissive underreach transfer is available in Subsection 2.6. Communication between the line ends is necessary.

On the transmitting end, a fault in zone Z1 must be simulated. This may be done with secondary injection test equipment.

Subsequently, on the receiving end, at **PUTT (Z1B)** a fault inside Z1B, but outside Z1 is simulated, at **PUTT (Pickup)** any fault is simulated. Tripping takes place immediately, (or in T1B), without signal transmission only in a higher distance stage. In case of direct transfer trip an immediate trip is always executed at the receiving end.

In case of a phase-segregated transmission the above-mentioned checks are performed for each phase. The correct phase allocation is also to be checked.

This test must be performed at both line ends, on a three terminal line at each line end for each transmission path. Finally, please observe the last margin heading "Important for All Schemes"!

Important for all Schemes

If the earth fault protection was disabled for the signal transmission tests, it may be re-enabled now. If setting parameters were changed for the test (e.g. mode of the echo function or timers for unambiguous observation of sequences), these must now be re-set to the prescribed values.

3.3.15 Testing of the Signal Transmission with Earth-Fault Protection

This section is only relevant if the device is connected to an earthed system and earth fault protection is applied. The device must therefore be provided with the earth fault protection function according to its ordering code (16th MLFB position = 4 or 5 or 6 or 7). Which group of characteristics are to be available must have been preset during configuration to **Earth Fault O/C** (address 131). Furthermore, the teleprotection must be used for the earth fault protection (address 132 **Teleprot. E/F** configured to one of the optional methods). If none of this is the case, this subsection is not relevant.

If the signal transmission path for the earth fault protection is the same path that was already tested in conjunction with the distance protection according to the previous Subsection, then this Subsection is of no consequence and may be omitted.

For the functional check of the earth fault protection signal transmission, the distance protection should be disabled, to avoid interference of the tests by signals from the distance protection: address 1201 **FCT Distance** = *OFF*.

Checking for Permissive Release

Requirements: **Teleprot. E/F** is configured in address 132 to one of the comparison schemes using permissive signal, i.e. *Dir.Comp.Pickup* or *UNBLOCKING*. Furthermore, **FCT Telep. E/F** is switched *ON* at address 3201. Naturally, the corresponding send and receive signals must also be assigned to the corresponding binary output and input. For the echo function, the echo signal must be assigned separately to the transmission output.

Detailed information on the function of permissive release is available in Subsection 2.8.

A simple check of the signal transmission path from one line end is possible via the echo circuit if these release techniques are used. The echo function must be activated at both line ends i.e. address 2501 **FCT Weak Infeed** = *ECHO only*; with the setting *ECHO and TRIP* at the remote end of the check a tripping command may result!

An earth fault is simulated in the direction of the line. This may be done with secondary injection test equipment. As the device at the opposite line end does not pick up, the echo function comes into effect there, and consequently a trip command is issued at the line end being tested.

If no trip command appears, the signal transmission path must be checked again, especially also the assignment of the echo signals to the transmit outputs.

This test must be carried out at both line ends, in the case of three terminal lines at each end for each signal transmission path.

On this occasion, you should also check the functioning of the echo delay time and the monitoring of the circuit breaker status unless this has already been done in the previous section (the operation of the protection at the opposite line end is checked):

The circuit breaker on the protected feeder must be opened, as must be the circuit breaker at the opposite line end. A fault is again simulated as before. A receive signal impulse delayed by somewhat more than twice the signal transmission time appears via the echo function at the opposite line end, and the device issues a trip command.

The circuit breaker at the <u>opposite line end</u> is now closed (while the isolators remain open). After simulation of the same fault, the receive and trip command appear again. In this case however, they are additionally delayed by the echo delay time of the device at the opposite line end (0.04 s presetting, address 2502 `Trip/Echo DELAY`).

If the response of the echo delay is opposite to the sequence described here, the operating mode of the corresponding binary input (H–active/L–active) at the <u>opposite</u> line end must be rectified.

The circuit breaker must be opened again.

This test must also be carried out at both line ends, in the case of three terminal lines at each line end and for each signal transmission path. Finally, please observe the last margin heading "Important for All Schemes"!

Checking for Blocking Scheme

Requirements: `Teleprot. E/F` is configured in address 132 to one of the comparison schemes using blocking signal, i.e. **BLOCKING**. Furthermore, **FCT Telep. E/F** is switched **ON** at address 3201. Naturally, the corresponding send and receive signals must also be assigned to the corresponding binary output and input.

For more details about the function of the blocking scheme refer to Subsection 2.8. In the case of the blocking scheme, communication between the line ends is necessary.

An earth fault in the reverse direction is simulated at the transmitting line end. Subsequently, a fault at the receiving end in the direction of the line is simulated. This can be achieved with a set of secondary injection test equipment at each end of the line. As long as the transmitting end is transmitting, no trip signal must appear at the receiving line end, except in a higher time set as backup stage. After the simulated fault at the transmitting line end has been cleared, the receiving line end remains blocked for the duration of the transmit prolongation time of the transmitting line end (**Send Prolong.**, address 3203). If applicable, the transient blocking time of the receiving line end (**TrBlk BlockTime**, address 3210) appears additionally if a finite delay time **TrBlk Wait Time** (address 3209) has been set and exceeded.

This test must be executed at both line ends, in the case of three terminal lines at each line end and for each transmission path. Finally, please observe the last margin heading "Important for All Schemes"!

Important for all Schemes

If the distance protection was switched off for the signal transmission tests, it may be switched on now. If setting parameters were changed for the test (e.g. mode of the echo function or timers for unambiguous observation of sequences), these must now be re-set to the prescribed values.

3.3.16 Check of the Signal Transmission for Breaker Failure Protection and/or End Fault Protection

If the transfer trip command for breaker failure protection or stub fault protection is to be transmitted to the remote end, this transmission must also be checked.

To check the transmission the breaker failure protection function is initiated by a test current (secondary) with the circuit breaker in the open position. Make sure that the correct circuit breaker reaction takes place at the remote end.

Each transmission path must be checked on lines with more than two ends.

3.3.17 Check of the Signal Transmission for Internal and External Remote Tripping

The 7SA6 provides the possibility to transmit a remote trip signal to the opposite line end if a signal transmission path is available for this purpose. This remote trip signal may be derived from both an internally generated trip signal as well as from any signal coming from an external protection or control device.

If an internal signal is used, the initiation of the transmitter must be checked. If the signal transmission path is the same and has already been checked as part of the previous sections, it need not be checked again here. Otherwise the initiating event is simulated and the response of the circuit breaker at the opposite line end is verified.

In the case of the distance protection, the permissive underreach scheme may be used to trip the remote line end. In this case, the procedure is the same as for permissive underreach (see "Check at Permissive Underreach Scheme"); however the received signal causes a direct trip.

For remote transmission, the external command input is employed on the receiving line end; it is therefore a prerequisite that: **DTT Direct Trip** is set to *Enabled* in address 122 and **FCT Direct Trip** to *ON* at adddress 2201. If the signal transmission path is the same and has already been checked as part of the previous subsections, it need not be checked again here. A function check is sufficient, whereby the externally derived command is executed. For this purpose the external tripping event is simulated and the response of the circuit breaker at the opposite line end is verified.

3.3.18 Testing User-defined Functions

The device has a vast capability for allowing functions to be defined by the user, especially with the CFC logic. Any special function or logic added to the device must be checked.

Naturally, a general procedure is not available. Configuration of these functions and the set associated conditions must be actually known beforehand and tested. Possible interlocking conditions of switching devices (circuit breakers, disconnectors, earth switch) are of particular importance. They must be considered and tested.

3.3.19 Trip and Close Test with the Circuit Breaker

The circuit breaker and tripping circuits can be conveniently tested by the device 7SA6.

The procedure is described in detail in the SIPROTEC® System Description.

If the check does not produce the expected results, the cause may be established from the text in the display of the device or the PC. If necessary, the connections of the circuit breaker auxiliary contacts must be checked:

It must be noted that the binary inputs used for the circuit breaker auxiliary contacts must be assigned separately for the CB test. This means it is not sufficient that the auxiliary contacts are allocated to the binary inputs FNo. 351 to 353, 379 and 380 (according to the possibilities of the auxiliary contacts); additionally, the corresponding FNo. 366 to 368 or 410 and/or 411 must be allocated (according to the possibilities of the auxiliary contacts. In the CB test only the latter ones are analysed. See also

Section 2.23.1.6. Furthermore, the ready state of the circuit breaker for the CB test must be indicated to the binary input with FNo. 371.

3.3.20 Trip/Close Tests for the Configured Operating Devices

Switching by Local Command

If the configured operating devices were not switched sufficiently in the hardware test already described, all configured switching devices must be switched on and off from the device via the integrated control element. The feedback information of the CB position injected via binary inputs should be read out and compared with the actual breaker position. For devices with graphic display this is easy to do with the control display.

The switching procedure is described in the SIPROTEC® 4 System Description (Order no. E50417-H1176-C151) The switching authority must be set in correspondence with the source of commands used. With the switch mode it is possible to select between interlocked and non-interlocked switching. Note that non-interlocked switching constitutes a safety risk.

Switching from a Remote Control Centre

If the device is connected to a remote substation via a system (SCADA) interface, the corresponding switching tests may also be checked from the substation. Please also take into consideration that the switching authority is set in correspondence with the source of commands used.

3.3.21 Triggering Oscillographic Recordings for Test

In order to be able to test the stability of the protection during switchon procedures also, switchon trials can also be carried out at the end. Oscillographic records obtain the maximum information about the behaviour of the protection.

Prerequisite

Along with the capability of storing fault recordings via pickup of the protection function, the 7SA6 also has the capability of capturing the same data when commands are given to the device via the service program DIGSI®, the serial interface, or a binary input. For the latter, event "`>Trig.Wave.Cap.`" must be allocated to a binary input. Triggering of the recording is done e.g. via the binary input on switch-on of the protection object.

Those that are externally triggered (that is, without a protective element pickup) are processed by the device as a normal oscillographic record. For each oscillographic record a fault record is created which is given its individual number to ensure that assignment can be made properly. However, these recordings are not displayed in the fault indication buffer, as they are not fault events.

Start Triggering Oscillographic Recording

In order to start a test measurement recording via DIGSI®, select in the left of the window the operator function **Test**. Double-click in the list view the entry **Test Wave Form** (see Figure 3-40).
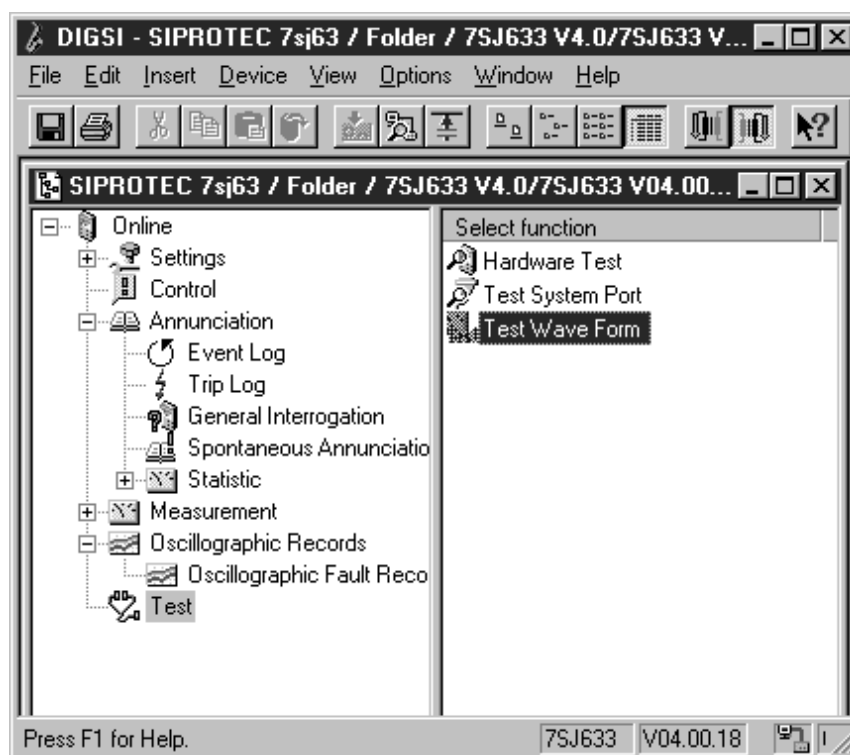
Figure 3-40   Triggering oscillographic recording with DIGSI® — Example

Oscillographic recording is immediately started. During the recording, an annunciation is output in the left area of the status line. Bar segments additionally indicate the progress of the procedure.

The SIGRA or the Comtrade Viewer program is required to view and analyse the oscillographic data.

3.4 Final Preparation of the Device

Firmly tighten all screws. Tighten all terminal screws, including those that are not used.

Caution!

Inadmissable Tightening Torques

Non-observance of the following measure can result in minor personal injury or property damage:

The tightening torques must not be exceeded as the threads and terminal chambers may otherwise be damaged!

The setting values should be checked again, if they were modified during the tests. Check if protection, control and auxiliary functions to be found with the configuration parameters are set correctly (Section 2.1.1, Functional Scope). All desired elements and functions must be set *ON*. Ensure that a copy of the setting values is stored on the PC.

The user should check the device-internal clock and set/synchronize it if necessary, provided that it is not synchronized automatically. For assistance, refer to the SIPROTEC® 4 System Description.

The indication buffers are deleted under **Main Menu** → **Annunciation** → *Set/Reset*, so that in the future they only contain information on actual events and states. The numbers in the switching statistics should be reset to the values that were existing prior to the testing (see also SIPROTEC® 4 System Description).

Reset the counter of the operational measured values (e.g. operation counter, if available) under **Main Menu** → **Measurement** → *Reset* (see also SIPROTEC® 4 System Description).

Press the ESC key, several times if necessary, to return to the default display. The default display appears in the display (e.g. display of operation measured values).

Clear the LEDs on the front panel by pressing the LED key, so that they only show real events and states. In this context, saved output relays are reset, too. Pressing the LED key also serves as a test for the LEDs on the front panel because they should all light when the button is pushed. If the LEDs display states relevant by that moment, these LEDs, of course, stay lit.

The green "RUN" LED must light up, whereas the red "ERROR" must not light up.

Close the protective switches. If test switches are available, then these must be in the operating position.

The device is now ready for operation.

■

Technical Data

4

This chapter provides the technical data of SIPROTEC® 4 device 7SA6 and its individual functions, including the limiting values that under no circumstances may be exceeded. The electrical and functional data for the maximum functional scope are followed by the mechanical specifications with dimension diagrams.

4.1 General

4.1.1 Analog Inputs and Outputs

Nominal Frequency	f_N	50 Hz or 60 Hz	(adjustable)

Current Inputs

Rated current	I_N	1 A or 5 A	
Power Consumption per Phase and Earth Path			
- at I_N = 1 A		Approx. 0.05 VA	
- at I_N = 5 A		Approx. 0.3 VA	
- for sensitive earth fault detection at 1A		Approx. 0.05 VA	
Current Overload Capability per Current Input			
- thermal (rms)		$100 \cdot I_N$ for 1 s $30 \cdot I_N$ for 10 s $4 \cdot I_N$ continuous	
- dynamic (pulse current)		$250 \cdot I_N$ (Half-cycle)	
Current Overload Capability for Sensitive Earth Current Input			
- thermal (rms)		300 A for 1 s	
		100 A for 10 s	
		15 A continuous	
- dynamic (pulse current)		750 A (Half-cycle)	

Voltage Inputs

Rated Voltage U_N		80 V to 125 V	(adjustable)
Power consumption per phase	at 100 V	≤ 0.1 VA	
Voltage Overload Capability in Voltage Path per Input			
- thermal (rms)		230 V continuous	

Analog Output (for measured values and fault location)

Range	0 mA to 24 mA
- Connection for Flush Mounting Housing	Rear panel, mounting location "B" or/and "D" 9-pole D-subminiature female connector
- Connection for Surface Mounting Housing	in console housing at case bottom or/and at the housing top
- Max. burden	350 Ω

4.1.2   Auxiliary Voltage

DC Voltage

Voltage Supply via Integrated Converter			
Rated auxiliary voltage U_{aux} DC	24/48 VDC	60/110/125 VDC	110/125/220/250 V DC
Permissible voltage ranges	19 to 58 VDC	48 to 150 VDC	88 to 300 VDC
Permissible AC ripple voltage, peak to peak	≤ 15 % of the auxiliary nominal voltage		
Power Input			
- quiescent		Approx. 5 W	
- energized	7SA610*-*A/E/J	Approx. 8 W	
	7SA610*-*B/F/K	Approx. 7 W	
	7SA6*1*-*A/E/J/M/N/P	Approx. 14 W	
	7SA6*1*-*B/F/K	Approx. 12 W	
	7SA6*2*-*A/E/J/M/P/R	Approx. 15 W	
	7SA6*2*-*B/K/F/N/Q/S	Approx. 20 W	
	7SA6*2*-*C/G/L	Approx. 16 W	
	7SA613*-*A/M	Approx. 15 W	
Plus approx. 1.5 W per Interface Module			
Bridging time for power supply failure/short circuit	≥ 50 ms at U_{aux} = 48 V and U_{aux} ≥ 110 V		
	≥ 20 ms at U_{aux} = 24 V and U_{aux} = 60 V		

AC Voltage

Voltage Supply via Integrated Converter		
Nominal power supply alternating voltage U_{aux}AC	115 VAC	
Permissible voltage ranges	92 to 132 VAC	
Power Input		
- quiescent		Approx. 7 VA
- energized	7SA610*-*A/E/J	Approx. 14 VA
	7SA610*-*B/F/K	Approx. 12 VA
	7SA6*1*-*A/E/J/M/N/P	Approx. 17 VA
	7SA6*1*-*B/F/K	Approx. 17 VA
	7SA6*2*-*A/E/J/M/P/R	Approx. 20 VA
	7SA6*2*-*B/K/F/N/Q/S	Approx. 23 VA
	7SA6*2*-*C/G/L	Approx. 21 VA
	7SA613*-*A/M	Approx. 20 VA
Plus approx. 1.5 W per Interface Module		
Bridging time for failure/short circuit of alternating auxiliary voltage	≥ 50 ms	

4.1.3 Binary Inputs and Outputs

Binary Inputs

Variant	Quantity	
7SA610*-*A/E/J	5 (configurable)	
7SA610*-*B/F/K	7 (configurable)	
7SA61/31*-*A/E/J/M/N/P	13 (configurable)	
7SA61/31*-*B/F/K	20 (configurable)	
7SA61/32*-*A/E/J/M/P/R	21 (configurable)	
7SA61/32*-*B/F/K/N/Q/S	29 (configurable)	
7SA61/32*-*C/G/L	33 (configurable)	
7SA613*-*A/M	21 (configurable)	
7SA641*-*A/J/M/P	13 (configurable)	
7SA641*-*B/K	20 (configurable)	
7SA642*-*A/J/M/R	21 (configurable)	
7SA642*-*B/K/N/S	29 (configurable)	
7SA642*-*C/L	33 (configurable)	
Rated voltage range	24 VDC to 250 VDC, in 3 ranges, bipolar	
Switching thresholds	Adjustable with jumpers	
- for rated voltages	24/48 VDC and 60/110/125 VDC	$U_{pu} \geq 19$ VDC (pu = pickup) $U_{do} \leq 14$ VDC (do = dropout)
- for rated voltages	110/125/220/250 VDC	$U_{pu} \geq 88$ VDC $U_{do} \leq 66$ VDC
- for rated voltages	220/250 VDC	$U_{pu} \geq 176$ VDC $U_{do} \leq 117$ VDC
Current consumption, energized	Approx. 1.8 mA independent of the control voltage	
Maximum permissible voltage	300 VDC	
Impulse filter on input	220 nF coupling capacitance at 220 V with recovery time > 60 ms	

Binary Outputs

Signalling / Command Relays (see also terminal assigments in Appendix A)						
Quantity and Data	According to the Order Variant (allocatable)					
Order Variant	UL-listed	NO Contact (normal)[1]	NO Contact (fast)[1]	NO or NC Contact (selectable)[1]	NO Contact (high-speed)[1]	High-duty Relay[2]
7SA610*-*A/E/J	x	7	-	1	-	-
7SA610*-*B/F/K	x	5	-	-	-	-
7SA6*1*-*A/E/J	x	7	7	2	-	-
7SA6*1*-*B/F/K	x	8	-	-	-	4
7SA6*1*-*M/N/P	x	7	3	1	5	-

7SA6*2*-*A/E/J	x	14	7	3	-	-
7SA6*2*-*B/F/K	x	21	7	4	-	-
7SA6*2*-*M/P/R	x	14	3	2	5	-
7SA6*2*-*N/Q/S	x	21	3	3	5	-
7SA6*2*-*C/G/L	x	11	-	-	-	8
7SA613*-*A	-	14	7	3	-	-
7SA613*-*M	-	14	3	2	5	-
Switching capability MAKE		1000 W/VA			1000 W/VA	-
Switching capability BREAK		30 W/VA 40 W resistive 25 W/VA at L/R ≤ 50ms			1000 W/VA	- - -
Max. switching capability for 30 s						
At 48 V to 250 V At 24 V		- -				1000 W 500 W
Switching Voltage						
DC		250 V				
AC		250 V			200 V (max.)	250 V
Permissible current per contact (continuous)		5 A				-
Permissible current per contact (close and hold)		30 A for 0.5 s (NO contact)				
Permissible total current on common path		5 A continuous 30 A for 0.5 s				- -
Permissible relative closing time		-				1 %
Operating time, approx.		8 ms	5 ms	8 ms	1 ms	-
Alarm relay [1]		With 1 NC contact or 1 NO contact (switchable)				
Make/break capacity	MAKE	1000 W/VA				
	BREAK	30 VA 40 W resistive 25 VA at L/R ≤ 50 ms				
Switching voltage		250 V				
Permissible current per contact		5 A continuous 30 A for 0.5 s				
[1] UL-listed with the following Nominal Values:						
		120 VAC	Pilot duty, B300			
		240 VAC	Pilot duty, B300			
		240 VAC	5 A General Purpose			
		24 VDC	5 A General Purpose			
		48 VDC	0.8 A General Purpose			
		240 VDC	0.1 A General Purpose			
		120 VAC	1/6 hp (4.4 FLA)			
		240 VAC	1/2 hp (4.9 FLA)			
[2] UL-listed with the following Nominal Values:						
		240 VDC	1.6 FLA			
		120 VDC	3.2 FLA			
		60 VDC	5.5 FLA			

4.1.4   Communication Interfaces

Protection Data Interface

See Section 4.9 "Protection Data Interfaces and Communication Topology"

Operator Interface

Connection	Front side, non-isolated, RS232, 9-pin D-subminiature female connector for connection of a PC
Operation	With DIGSI®
Transmission speed	Min. 4,800 Baud; max. 115,200 Baud; Factory Setting: 38400 Baud; Parity: 8E1
Transmission distance	15 m / 50 feet

Service / Modem Interface

		RS232/RS485 acc. to ordered version	Insulated interface for data transfer
		Operation	With DIGSI®
RS232/RS485			RS232/RS485 according to the order variant
		Connection for panel flush mounting housing	Rear panel, slot "C", 9-pin D-subminiature female connector; Shielded data cable
		Connection for panel surface mounting housing	In the housing on the case bottom; 9-pin D-subminiature female connector; Shielded data cable
		Test voltage	500 VAC; 50 Hz
		Transmission Speed	Min. 4800 Baud; max. 115200 Baud Factory setting 38400 Baud
RS232			
		Transmission distance	15 m / 50 feet
RS485			
		Transmission distance	1 km / 3280 feet / 0.62 miles

System Interface (optional)

RS232/RS485/Optical fibre/ Profibus RS485 / Profibus optical fibre DNP3.0 RS485 DNP3.0 Fibre Optical Link acc. to ordered version	Isolated interface for data transfer to a control terminal	
RS232	Connection for panel flush mounting housing	Rear panel, slot "B", 9-pin D-subminiature female connector
	Connection for panel surface mounting housing	In the housing on the case bottom 9-pin D-subminiature female connector
	Test voltage	500 VAC; 50 Hz
	Transmission speed	Min. 4800 Baud, max. 38400 Baud Factory setting 19200 Baud
	Transmission distance	Max. 15 m / 50 feet
RS485		
	Connection for panel flush mounting housing	Rear panel, slot "B", 9-pin D-subminiature female connector
	Connection for panel surface mounting housing	In console housing at case bottom 9-pin D-subminiature female connector
	Test voltage	500 VAC; 50 Hz
	Transmission speed	Min. 4800 Baud; max. 38400 Baud; Factory setting 19200 Baud
	Transmission distance	Max. 1000 m / 3280 feet / 0.62 miles
Fibre optic cable (FO)		
	FO connector type	ST connector
	Connection for panel flush mounting housing	Rear panel, mounting location "B"
	Connection for panel surface mounting housing	At the housing mounted case at the case bottom
	Optical wavelength	λ = 820 nm
	Laser Class I according to EN 60825-1/-2	Using glass fibre 50/125 μm or for use of FO 62.5/125 μm
	Permissible link signal attenuation	Max. 8 dB, with glass fibre 62.5/125 μm
	Transmission distance	Max. 1.5 km / 0.93 miles
	Character idle state	Selectable: factory setting "Light off"
Profibus RS485 (FMS and DP)		
	Connection for panel flush mounting housing	Rear panel, slot "B", 9-pin D-subminiature female connector
	Connection for panel surface mounting housing	In console housing at case bottom 9-pin D-subminiature female connector
	Test voltage	500 V; 50 Hz
	Transmission speed	Up to 12 MBd
	Transmission distance	1000 m / 3280 feet at $\leq$ 93.75 kBd 500 m / 1640 feet at $\leq$ 187.5 kBd 200 m / 1656 feet at $\leq$ 1.5 MBd 100 m / 328 feet at $\leq$ 12 MBd

Profibus FO (FMS and DP)		
	FO connector type	ST connector single ring / double ring FMS: depending on ordered version; DP: only double ring available
	Connection for panel flush mounting housing	Rear panel, mounting location "B"
	Connection for panel surface mounting housing	Please use version with Profibus RS485 in the console housing as well as separate electrical/optical converter.
	Transmission speed	Conversion by means of external OLM [1] up to 1.5 MBd ≥ 500 kBd for normal version ≤ 57600 Bd with detached operator panel
	Recommended transmission rate:	> 500 KBd
	Optical wavelength	λ = 820 nm
	Laser Class I according to EN 60825-1/-2	Using glass fibre 50/125 μm or for use of FO 62.5/125 μm
	Permissible link signal attenuation	Max. 8 dB, with glass fibre 62.5/125 μm
	Transmission distance between two modules at redundant optical ring topology and optical fiber 62.5/125 μm	2m with plastic fibre 500 kB/s max 1.6 km / 5249 feet / 0.99 miles 1500 kB/s 530 m / 1738 feet / 0.33 miles)
	Neutral light position (status for "No character")	Light OFF
	Max. number of modules in optical rings at 500 kB/s or 1500 kB/s	41
DNP3.0 RS485		
	Connection for flush-mounted housing	Rear panel, slot "B", 9-pin D-subminiature female connector
	Connection for Panel Surface-Mounted Housing	In console housing
	Test Voltage	500 V; 50 Hz
	Transmission Speed	Up to 19200 Baud
	Bridgeable distance	max. 1 km
DNP3.0 Fibre Optical Link		
	FO connector type	ST–connector receiver / transmitter
	Connection for flush-mounted housing	Rear panel, slot "B"
	Connection for Panel Surface-Mounted Housing	In console housing
	Transmission Speed	Up to 19200 Baud
	Optical wavelength	λ = 820 nm
	Laser Class 1 according to EN60825-1/-2	Using glass fibre 50/125 μm or Using glass fibre 62.5/125 μm
	Permissible optical signal attenuation	Max. 8 dB, with glass fibre 62.5/125 μm
	Bridgeable distance	Max. 1.5 km

[1] If the optical interface is required you shall order the following: 11th position 4 (FMS) or L0A (DP) and additionally: For single ring: SIEMENS OLM 6GK1502-3AB10, for double ring: SIEMENS OLM 6GK1502-4AB10

The OLM converter requires an operating voltage of 24 VDC. If the operating voltage is > 24 VDC the additional power supply 7XV5810-0BA00 is required.

Time Synchronization Interface

Time synchronisation	DCF 77/IRIG B-Signal (telegram format IRIG-B000)
Connection for panel flush mounting housing	Rear panel, slot "A" 9-pin D-subminiature female connector
Connection for panel surface mounting housing	At the double-deck terminal on the case bottom
Signal nominal voltages	Selectable 5 V, 12 V or 24 V

Signal Levels and Burdens:		
Nominal Signal Voltage		
5 V	**12 V**	**24 V**
V_{IHigh} 6.0 V	15.8 V	31 V
V_{ILow} 1.0 V at I_{ILow} = 0.25 mA	1.4 V at I_{ILow} = 0.25 mA	1.9 V at I_{ILow} = 0.25 mA
I_{IHigh} 4.5 mA to 9.4 mA	4.5 mA to 9.3 mA	4.5 mA to 8.7 mA
R_I 890 Ω at U_I = 4 V	1930 Ω at U_I = 8.7 V	3780 Ω at U_I = 17 V
640 Ω at U_I = 6 V	1700 Ω at U_I = 15.8 V	3560 Ω at U_I = 31 V

4.1.5   Electrical Tests

Specifications

Standards:	IEC 60255 (product standards) IEEE Std C37.90.0/.1/.2 UL 508 VDE 0435 For more standards see also individual functions

Insulation Test

Standards:	IEC 60255-5 and IEC 60870-2-1
High voltage test (routine test) All circuits except power supply, Binary Inputs, High Speed Outputs, Communication Interface and Time Synchronization Interfaces	2.5 kV (rms), 50 Hz
High voltage test (routine test) Auxiliary voltage, binary inputs and high speed outputs	3.5 kV-
High voltage test (routine test) only isolated communication and time synchronisation interfaces	500 V (rms), 50 Hz
Impulse voltage test (type test) All Circuits Except Communication and Time Synchronization Interfaces, Class III	5 kV (peak): 1.2/50 µs: 0.5 Ws: 3 positive and 3 negative impulses in intervals of 5 s

EMC Tests for Interference Immunity (type tests)

Standards:	IEC 60255-6 and -22 (product standards) EN 61000-6-2 (generic standard) VDE 0435 Teil 301DIN VDE 0435-110
High frequency test IEC 60255-22-1, Class III and VDE 0435 Section 303, Class III	2.5 kV (peak); 1 MHz; τ = 15 μs; 400 surges per s; Test Duration 2 s; R_i = 200 Ω
Electrostatic discharge IEC 60255-22-2, Class IV and IEC 61000-4-2, Class IV	8 kV contact discharge; 15 kV air discharge, both polarities; 150 pF; R_i = 330 Ω
Irradiation with HF field, frequency sweep IEC 60255-22-3, Class III IEC 61000-4-3, Class III	10 V/m; 80 MHz to 1000 MHz; 80 % AM; 1 kHz
Irradiation with HF field, single frequencies IEC 60255-22-3, IEC 61000-4-3 –amplitude-modulated –pulse-modulated	Class III: 10 V/m 80; 160; 450; 900 MHz; 80 % AM 1kHz; duty cycle > 10 s 900 MHz; 50 % PM, repetition frequency 200 Hz
Fast transient disturbances Burst IEC 60255-22-4 and IEC 61000-4-4, Class IV	4 kV; 5/50 ns; 5 kHz; burst length = 15 ms; repetition rate 300 ms; both polarities: R_i = 50 Ω; Test Duration 1 min
High energy surge voltages (SURGE), IEC 61000-4-5 installation Class 3 – Auxiliary voltage – Analog measuring inputs, binary inputs, relay outputs	Impulse: 1.2/50 μs Common mode: 2 kV; 12 Ω; 9 μF diff. mode: 1 kV; 2 Ω; 18 μF Common mode: 2 kV; 42 Ω; 0,5 μF diff. mode: 1 kV; 42 Ω; 0,5 μF
Line conducted HF, amplitude modulated IEC 61000-4-6, Class III	10 V; 150 kHz to 80 MHz; 80 % AM; 1 kHz
Power system frequency magnetic field IEC 60255-6 IEC 61000-4-8	0.5 mT; 50 Hz Class IV: 30 A/m; continuous; 300 A/m for 3 s; 50 Hz
Oscillatory surge withstand capability IEEE Std C37.90.1	2.5 kV (peak); 1 MHz; τ = 15 μs; 400 Surges per s; Test Duration 2 s; R_i = 200 Ω
Fast transient surge withstand cap. IEEE Std C37.90.1	4 kV; 5/50 ns; 5 kHz; burst length = 15 ms; repetition rate 300 ms; both polarities: R_i = 50 Ω; test duration 1 min
Radiated electromagnetic interference IEEE Std C37.90.2	35 V/m; 25 MHz to 1000 MHz
Damped oscillations IEC 60694, IEC 61000-4-12	2.5 kV (peak value), polarity alternating 100 kHz, 1 MHz, 10 MHz and 50 MHz, R_i = 200 Ω

EMC Tests for Noise Emission (type test)

Standard:	EN 50081-* (technical generic standard)
Radio noise voltage to lines, only auxiliary voltage IEC-CISPR 22	150 kHz to 30 MHz Limit class B
Interference field strength IEC-CISPR 22	30 MHz to 1000 MHz Limit class B
Harmonic currents on the network lead at 230 VAC IEC 61000-3-2	Class A limits are observed.
Voltage fluctuations and flicker on the network incoming feeder at 230 V AC IEC 61000-3-3	Limits are observed

4.1.6 Mechanical Stress Tests

Vibration and Shock Stress during Stationary Operation

Standards:	IEC 60255-21 and IEC 60068
Oscillation IEC 60255-21-1, Class 2 IEC 60068-2-6	Sinusoidal 10 Hz to 60 Hz: ± 0.075 mm amplitude; 60 Hz to 150 Hz: 1g acceleration Frequency sweep 1 octave/min 20 cycles in 3 orthogonal axes
Shock IEC 60255-21-2, Class 1 IEC 60068-2-27	Semi-sinusoidal 5 g acceleration, duration 11 ms, each 3 shocks (in both directions of the 3 axes)
Seismic vibration IEC 60255-21-3, Class 1 IEC 60068-3-3	Sinusoidal 1 Hz to 8 Hz: ± 3.5 mm amplitude (horizontal axis) 1 Hz to 8 Hz: ± 1.5 mm amplitude (vertical axis) 8 Hz to 35 Hz: 1 g acceleration (horizontal axis) 8 Hz to 35 Hz: 0.5 g acceleration (vertical axis) Frequency sweep 1 octave/min 1 cycle in 3 orthogonal axes

Vibration and Shock Stress During Transport

Standards:	IEC 60255-21 and IEC 60068
Oscillation IEC 60255-21-1, Class 2 IEC 60068-2-6	Sinusoidal 5 Hz to 8 Hz:± 7.5 mm Amplitude; 8 Hz to 150 Hz: 2 g acceleration frequency sweep 1 octave/min 20 cycles in 3 orthogonal axes
Shock IEC 60255-21-2, Class 1 IEC 60068-2-27	Semi-sinusoidal 15 g acceleration, duration 11 ms, each 3 shocks (in both directions of the 3 axes)
Continuous shock IEC 60255-21-2, Class 1 IEC 60068-2-29	Semi-sinusoidal 10 g acceleration, duration 16 ms, each 1000 shocks (in both directions of the 3 axes)

4.1.7 Climatic Stress Tests

Temperatures

Standards:	IEC 60255-6
Type tested (acc. IEC 60086-2-1 and -2, Test Bd, for 16 h)	−25 °C to +85 °C
Admissible temporary operating temperature (tested for 96 h)	−20 °C to +70 °C or −4 °F to +158 °F (legibility of display may be restricted from +55 °C or 131 °F)
Recommended for permanent operation (according to IEC 60255-6)	−5 °C to +55 °C or 23 °F to +131 °F If max. half of the inputs and outputs are subjected to the max. permissible values
Limit temperatures for storage	−25 °C to +55 °C or −13 °F to +131 °F
Limit temperatures during transport	−25 °C to +70 °C or −13 °F to +158 °F
Storage and transport of the device with factory packaging!	
[1] Limit temperatures for normal operation (i.e. output relays not energized)	−20 °C to +70 °C or −4 °F to +158 °F
[1] Limit temperatures under maximum load (max. cont. admissible input and output values)	−5 °C to +55 °C or −23 °F to +131 °F for $^1/_3$ housing −5 °C to +40 °C or −23 °F to +104 °F for $^1/_2$, $^2/_3$ and $^1/_1$ housing

[1] UL–certified according to Standard 508 (Industrial Control Equipment)

Humidity

Admissible humidity	Annual average ≤ 75 % relative humidity; on 56 days of the year up to 93% relative humidity. Condensation is to be avoided during operation !
It is recommended that all devices be installed so that they are not exposed to direct sunlight nor subject to large fluctuations in temperature that may cause condensation to occur.	

4.1.8 Service Conditions

The protection device is designed for installation in normal relay rooms and plants, so that electromagnetic immunity is ensured if installation is done properly.
In addition the following is recommended:
• Contacts and relays operating within the same cabinet or on the same relay board with digital protection equipment, should be in principle provided with suitable surge suppression components.
• For substations with operating voltages of 100 kV and above, all external cables shall be shielded with a conductive shield earthed at both ends. For substations with lower operating voltages, no special measures are normally required.
• Do not withdraw or insert individual modules/boards while the protective device is energized. In withdrawn condition, some components are electrostatically endangered; during handling the ESD standards (for **E**lectrostatic **S**ensitive **D**evices) must be observed. They are not endangered when inserted into the case.

4.1.9   Certifications

UL Listing		UL Recognition	
7SA6*0-*A***-****		7SA6**-*J***-****	
7SA6*1-*A***-****		7SA6**-*K***-****	
7SA6*2-*A***-****		7SA6**-*L***-****	
7SA6**-*B***-****		7SA641-*P***-****	
7SA6**-*C***-****		7SA6**-*R***-****	
7SA6**-*E***-****		7SA6**-*S***-****	
7SA6**-*F***-****			
7SA6**-*G***-****	Models with threaded terminals		Models with plug–in terminals
7SA6**-*Q***-****			
7SA6*1-*M***-****			
7SA6*2-*M***-****			
7SA6**-*N***-****			
7SA611-*P***-****			
7SA612-*P***-****			
7SA631-*P***-****			
7SA632-*P***-****			

4.1.10 Construction

Housing	7XP20
Dimensions	See dimensional drawings, Section 4.25

Variant	Housing	Size	Weight
			(for maximum number of compo- nents)
7SA61	For panel flush mounting	$^1/_3$	5 kg / 11.02 lb
		$^1/_2$	6 kg / 13.23 lb
		$^2/_3$	8 kg / 17.64 lb
		$^1/_1$	10 kg / 22.04 lb
	For panel surface mounting	$^1/_3$	9.5 kg / 20.94 lb
		$^1/_2$	11 kg / 24.24 lb
		$^1/_1$	19 kg / 41.88 lb
7SA63	For panel flush mounting	$^1/_2$	6 kg / 13.23 lb
		$^1/_1$	10 kg / 22.04 lb
	For panel surface mounting	$^1/_2$	11 kg / 24.24 lb
		$^1/_1$	19 kg / 41.88 lb
7SA64	Mounting with detached operator panel	$^1/_2$	8 kg / 17.64 lb
	Mounting with detached operator panel	$^1/_1$	12 kg / 26.45 lb
	Detached operator panel		2.5 kg / 5.51 lb

Degree of protection according to IEC 60529		
For equipment of the panel surface mounting housing	IP 51	
for device in flush mounted case and in model with detached operator panel		
	Front	IP 51
	Rear	IP 50
For human safety	IP 2x with cover	
UL-certification conditions	"For use on a Flat Surface of a Type 1 Enclosure"	

4.2   Distance Protection

Earth Impedance Ratio

R_E/R_L	-0.33 to 7.00	Increments 0.01
X_E/X_L	-0.33 to 7.00	Increments 0.01
	Separate for first and higher zones	
K_0	0.000 to 4.000	Increments 0.001
PHI (K_0)	-135.00° to +135.00°	
	Separate for first and higher zones	

Mutual Impedance Ratio

R_M/R_L	0.00 to 8.00	Increments 0.01
X_M/X_L	0.00 to 8.00	Increments 0.01
The matching factors for earth impedance and mutual impedance are valid also for fault location.		

Phase Preferences

For double earth fault in earthed net	Block leading phase–earth Block lagging phase–earth Release all associated loops Release only phase-to-earth loops Release of phase-to-phase loops
For double earth fault in isolated or resonant-earthed systems	L3(L1) acyclic L1(L3) acyclic L2(L1) acyclic L1(L2) acyclic L3(L2) acyclic L2(L3) acyclic L3(L1) cyclic L1(L3) cyclic All associated loops

Earth Fault Detection

Earth current 3I$_0$>	for I$_N$ = 1 A	0.05 A to 4.00 A	Increments 0.01 A
	for I$_N$ = 5 A	0.25 A to 20.00 A	
Earth voltage 3U$_0$>		1 V to 100 V; ∞	Increments 1 V
Drop-off to pick-up ratio		Approx. 0.95	
Measuring tolerances for sinusoidal measured values	± 5 %		

Pickup

Overcurrent Pickup			
Overcurrent Iph>>	for I$_N$ = 1 A	0.25 A to 10.00 A	Increments 0.01 A
	for I$_N$ = 5 A	1.25 A to 50.00 A	
Drop-off to pick-up ratio		Approx. 0.95	
Measuring tolerances for sinusoidal measured values	± 5 %		
Voltage and angle-dependent current pickup (U/I/φ) (selectable)			
Characteristic		Different stages with settable inclinations	
Minimum current Iph>	for I$_N$ = 1 A	0.10 A to 4.00 A	Increments 0.01 A
	for I$_N$ = 5 A	0.50 A to 20.00 A	
Current in fault angle range Iφ	for I$_N$ = 1 A	0.10 A to 8.00 A	Increments 0.01 A
	for I$_N$ = 5 A	0.50 A to 40.00 A	
Undervoltage phase–earth Uphe (segregated for Iph>, Iφ> and Iph>>)		20 V to 70 V	Increments 1 V
Undervoltage phase–phase Uphph (segregated for Iph>, Iφ> and Iph>>)		40 V to 130 V	Increments 1 V
Lower threshold angle φ>		30° to 60°	In increments of 1°
Upper threshold angle φ<		90° to 120°	In increments of 1°
Drop-off to pick-up ratio			
Iph>, Iφ>		Approx. 0.95	
Uphe, Uphph		Approx. 1.05	
Measuring tolerances for sinusoidal measured values			
Values of U, I		± 5 %	
Angle φ		± 3°	
Impedance starting (selectable)			
Minimum current Iph>	for I$_N$ = 1 A	0.05 A to 4.00 A	Increments 0.01 A
	for I$_N$ = 5 A	0.25 A to 20.00 A	
The thresholds of the polygon set to the highest level are relevant taking into consideration the corresponding direction			
Dropout/pickup ratio		Approx. 1.05	

Distance Measurement

Characteristic		5 independent and 1 controlled zone	
Setting ranges polygon:			
I_{Ph}> = min. current, phases	for I_N = 1 A	0.05 A to 4.00 A	Increments 0.01 A
	for I_N = 5 A	0.25 A to 20.00 A	
X = reactance reach	for I_N = 1 A	0.050 Ω up to 600.000Ω	Increments 0.001 Ω
	for I_N = 5 A	0.010 Ω up to 120.000Ω	
R = resistance tolerance phase-phase	for I_N = 1 A	0.050 Ω up to 600.000Ω	Increments 0.001 Ω
	for I_N = 5 A	0.010 Ω up to 120.000Ω	
RE = resistance tolerance phase-earth	for I_N = 1 A	0.050 Ω up to 600.000 Ω	Increments 0.001 Ω
	for I_N = 5 A	0.010 Ω up to 120.000 Ω	
φ_{Line} = line angle		30° to 89°	In increments of 1°
φ_{Dist} = angle of distance protection characteristic		30° to 90°	In increments of 1°
α_{Pol} = tilt angle for 1st zone		0° to 30°	In increments of 1°
Direction determination for polygonal characteristic:			
For all types of faults		With phase-true, memorized or cross-polarized voltages	
Directional sensitivity		Dynamically unlimited stationary approx. 1V	
Each zone can be set to operate in forward or reverse direction, non-directional or ineffective.			
Load trapezoid:			
R_{load} = minimum load resistance	for I_N = 1 A	0.050 Ω to 600.000 Ω, ∞	Increments 0.001 Ω
	for I_N = 5 A	0.010 Ω to 120.000 Ω, ∞	
φ_{load} = maximum load angle		20° to 60°	In increments of 1°
Dropout to pickup ratio			
- currents		Approx. 0.95	
- impedances		Approx. 1.06	
Measured value correction		Mutual impedance matching for parallel lines (ordering option)	
Measuring tolerances for sinusoidal measured values		$\left|\dfrac{\Delta X}{X}\right| \leq 5\ \%$ for $30° \leq \varphi_{sc} \leq 90°$ $\left|\dfrac{\Delta R}{R}\right| \leq 5\ \%$ for $0° \leq \varphi_{sc} \leq 60°$	

Times

Shortest trip time	Approx. 17 ms (50 Hz) / 15 ms (60 Hz) with fast relay and approx. 11 ms (50 Hz) / 10 ms (60 Hz) with high-speed relay	
Drop-off time	Approx. 30 ms	
Stage timers	0.00 s to 30.00 s; ∞ for all zones; separate time setting possibilities for single-phase and multi-phase faults for the zones Z1, Z2, and Z1B	Increments 0.01 s
Time expiry tolerances	1 % of setting value or 10 ms	
The set time is a pure delay time.		

Emergency Operation

In case of measured voltage failure, e.g. voltage transformer mcb trip see Subsection 4.11 "Time Overcurrent Protection"

4.3   Power Swing Detection (optional)

Power swing detection	Rate of the impedance vector and observation of the path curve	
Maximum power swing frequency	Approx. 7 Hz	
Power swing blocking programs	Block 1st zone only	
	Block higher zones	
	Block 1st and 2nd zone	
	Block all zones	
Power swing trip	Trip following instable power swings (out-of-step)	
Trip time delay after power swing block	0.08 to 5.00 s	Increments 0.01 s

4.4 Teleprotection for Distance Protection

Mode

For two line ends	With one channel for each direction or with three channels for each direction for phase segregated transmission
For three line ends	With one channel for each direction or connection

Underreach Transfer Trip Schemes

Method	Transfer trip with overreaching zone Z1B PUTT (Pickup) Direct transfer trip	
Send signal prolongation	0.00 s to 30.00 s	Increments 0.01 s

Underreach Schemes via Protection Data Interface (optional)

Phase-segregated for two or three line ends		
Method	Transfer trip with overreaching zone Z1B	
Send signal prolongation	0.00 s to 30.00 s	Increments 0.01 s

Overreach Schemes

Method	Permissive Overreach Transfer Trip (POTT) (with overreaching zone Z1B) Dir. Comp. Pickup Unblocking (with overreaching zone Z1B) Blocking (with overreaching zone Z1B) Pilot wire comp. Rev. Interlock	
Send signal prolongation	0.00 s to 30.00 s	Increments 0.01 s
Enable delay	0 s to 30.000 s	Increments 0.001 s
Transient blocking time	0.00 s to 30.00 s	Increments 0.01 s
Wait time for transient blocking	0.00 s to 30.00 s; ∞	Increments 0.01 s
Echo delay time	0.00 s to 30.00 s	Increments 0.01 s
Echo impulse duration	0.00 to 30.00 s	Increments 0.01 s
Time expiry tolerances	1 % of setting value or 10 ms	
The set time is a pure delay time.		

Overreach Schemes via Protection Data Interface (optional)

Phase-segregated for two or three line ends		
Method	Permissive Overreach Transfer Trip (POTT) (with overreaching zone Z1B)	
Send signal prolongation	0.00 s to 30.00 s	Increments 0.00 s
Enable delay	0.000 s to 30.000 s	Increments 0.001 s
Transient blocking time	0.00 s to 30.00 s	Increments 0.01 s
Wait time for transient blocking	0.00 s to 30.00 s; ∞	Increments 0.01 s
Echo delay time	0.00 s to 30.00 s	Increments 0.01 s
Echo impulse duration	0.00 s to 30.00 s	Increments 0.01 s
Time expiry tolerances	1 % of setting value or 10 ms	
The set time is a pure delay time.		

4.5 Earth Fault Overcurrent Protection in Earthed Systems (optional)

Definite Time Stages	$3I_0>>>$, $3I_0>>$, $3I_0>$
Inverse time stage (IDMT)	$3I_{0p}$ one of the characteristics according to Figure 4-1 to Figure 4-4 can be selected
Voltage-dependent stage (U_0-inverse)	Characteristics according to Figure 4-4
Zero-sequence power protection	Characteristics according to Figure 4-6

Definite Time Very High Set Current Stage

Pickup value $3I_0>>>$	for I_N = 1 A	0.05 A to 25.00 A	Increments 0.01 A
	for I_N = 5 A	0.25 A to 125.00 A	
Delay $T_{3I0>>>}$		0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
Dropout/pickup ratio		Approx. 0.95 for $I/I_N \geq 0.5$	
Pickup time		Approx. 35 ms	
Drop-off time		Approx. 30 ms	
Tolerances	Current	3 % of setting value or 1 % nominal current	
	Time	1 % of setting value or 10 ms	
The set times are pure delay times			

Definite Time High Set Current Stage

Pickup value $3I_0>>$	for I_N = 1 A	0.05 A to 25.00 A	Increments 0.01 A
	for I_N = 5 A	0.25 A to 125.00 A	
Delay $T_{3I0>>}$		0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
Dropout Ratio		Approx. 0.95 for $I/I_N \geq 0.5$	
Pickup time		Approx. 35 ms	
Dropout time		Approx. 30 ms	
Tolerances	Current	3 % of setting value or 1 % nominal current	
	Time	1 % of setting value or 10 ms	
The set times are pure delay times			

Definite Time Overcurrent Stage

Pickup value $3I_0>$	for $I_N = 1$ A	0.05 A to 25.00 A or 0.003 A to 25.000 A	Increments 0.01 A Increments 0.001 A
	for $I_N = 5$ A	0.25 A to 125.00 A or 0.015 A to 125.000 A	Increments 0.01 A Increments 0.001 A
Delay $T_{3I0>}$		0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
Dropout Ratio		Approx. 0.95 for $I/I_N \geq 0.5$	
Pickup time (1.5 set value) (2.5 set value)		Approx. 45 ms Approx. 35 ms	
Dropout time		Approx. 30 ms	
Tolerances	Current	3 % of setting value or 1 % nominal current	
	Time	1 % of setting value or 10 ms	
The set times are pure delay times			

Inverse Time Overcurrent Stage (IEC)

Pickup value $3I_{0P}$	for $I_N = 1$ A	0.05 A to 25.00 A or 0.003 A to 25.000 A	Increments 0.01 A Increments 0.001 A
	for $I_N = 5$ A	0.25 A to 125.00 A or 0.015 A to 125.000 A	Increments 0.01 A Increments 0.001 A
Time factor T_{3I0P}		0.05 s to 3.00 s or ∞ (ineffective)	Increments 0.01 s
Additional time delay $T_{3I0P\ verz}$		0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
Characteristics		See Figure 4-1	
Tolerances	Current	Pickup at $1.05 \leq I/3I_{0P} \leq 1.15$	
	Time	5 % ± 15 ms for $2 \leq I/3I_{0P} \leq 20$ and $T_{3I0P}/s \geq 1$	

Inverse Time Overcurrent Stage (ANSI)

Pickup value $3I_{0P}$	for $I_N = 1$ A	0.05 A to 25.00 A or 0.003 A to 25.000 A	Increments 0.01 A Increments 0.001 A
	for $I_N = 5$ A	0.25 A to 125.00 A or 0.015 A to 125.000 A	Increments 0.01 A Increments 0.001 A
Time factor D_{3I0P}		0.50 s to 15.00 s or ∞ (ineffective)	Increments 0.01 s
Additional time delay $T_{3I0P\ verz}$		0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
Characteristics		See Figure 4-2 and 4-3	
Tolerances	Current	Pickup at $1.05 \leq I/3I_{0P} \leq 1.15$	
	Time	5 % ± 15 ms for $2 \leq I/3I_{0P} \leq 20$ and $D_{3I0P}/s \geq 1$	

Inverse Time Overcurrent Stage with Logarithmic-inverse Characteristic

Pickup value $3I_{0P}$	for I_N = 1 A	0.05 A to 25.00 A or 0.003 A to 25.000 A	Increments 0.01 A Increments 0.001 A
	for I_N = 5 A	0.25 A to 125.00 A or 0.015 A to 125.000 A	Increments 0.01 A Increments 0.001 A
Pickup value $3I_{0P\ FACTOR}$		1.0 to 4.0	Increments 0.1
Time factor T_{3I0P}		0.05 s to 15.00 s; ∞	Increments 0.01 s
Maximum time $T_{3I0P\ max}$		0.00 s to 30.00 s	Increments 0.01 s
Minimum time $T_{3I0P\ min}$		0.00 s to 30.00 s	Increments 0.01 s
Additional time delay $T_{3I0P\ verz}$		0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
Characteristics		See Figure 4-4	
Tolerances Times	inv.	5 % ± 15 ms for $2 \leq I/3I_{0P} \leq 20$ and $T_{3I0P}/s \geq 1$	
	def.	1 % of setting value or 10 ms	

Zero Sequence Voltage Time Protection Stage (U0-inverse)

Pickup value $3I_{0P}$	for I_N = 1 A	0.05 A to 25.00 A or 0.003 A to 25.000 A	Increments 0.01 A Increments 0.001 A
	for I_N = 5 A	0.25 A to 125.00 A or 0.015 A to 125.000 A	Increments 0.01 A Increments 0.001 A
Pickup value $3U_0>$		1.0 V to 10.0 V	Increments 0.1 V
Voltage factor $U_{0\ inv.\ minimal}$		0.1 V to 5.0 V	Increments 0.1 V
Additional time delay	$T_{directional}$	0.00 s to 32.00 s	Increments 0.01 s
	$T_{non-directional}$	0.00 s to 32.00 s	Increments 0.01 s
Characteristics		See Figure 4-5	
Tolerances times		1 % of setting value or 10 ms	
Dropout Ratio	Current	Approx. 0.95 for $I/I_N \geq 0.5$	
	Voltage	Approx. 0.95 for $3U_0 \geq 1$ V	
The set times are pure delay times			

Zero Sequence Power Protection Stage

Pickup value $3I_{0P}$	for $I_N = 1$ A	0.05 A to 25.00 A 0.003 A to 25.000 A	Increments 0.01 A Increments 0.001 A
	for $I_N = 5$ A	0.25 A to 125.00 A 0.015 A to 125.000 A	Increments 0.01 A Increments 0.001 A
Pickup value S FORWARD		0.1 VA to 10.0 VA	Increments 0.1 VA
Additional delay $T3I_{OPverz}$		0.00 s to 30.00 s	Increments 0.01 s
Characteristics		See Figure 4-6	
Tolerances pick-up values		1 % of set value at sensitive earth current transformer	
Tolerances times		5 % of set value or 15 ms at sensitive earth current transformer 6 % of set value or 15 ms at normal earth current transformer / without earth current transformer	

Inrush Stabilization

Second harmonic content for inrush		10 % to 45 %	Increments 1 %
		Referred to fundamental wave	
Inrush blocking is cancelled above	for I_N = 1 A	0.50 A to 25.00 A	Increments 0.01 A
	for I_N = 5 A	2.50 A to 125.00 A	
Inrush stabilization may be switched effective or ineffective for each individual stage.			

Determination of Direction

Each zone can be set to operate in forward or reverse direction, non-directional or ineffective.			
Direction measurement		With I_E (= 3 I_0) and 3 U_0 and I_Y odr I_2 and U_2	
		With I_E (= 3 I_0) and 3 U_0 and I_Y	
		With I_E (= 3 I_0) and I_0 (transformer star-point current)	
		With I_2 and U_2 (negative sequence quantities)	
		With zero-sequence power	
Limit values			
Displacement voltage $3U_0$>		0.5 V to 10.0 V	Increments 0.1V
Starpoint current of a power transformer I_Y>	for I_N = 1 A	0.05 A to 1.00 A	Increments 0.01 A
	for I_N = 5 A	0.25 A to 5.00 A	
Negative sequence current $3I_2$>	for I_N = 1 A	0.05 A to 1.00 A	Increments 0.01 A
	for I_N = 5 A	0.25 A to 5.00 A	
Negative sequence voltage $3U_2$>		0.5 V to 10.0 V	Increments 0.1V
"Forward" angle			
Capacitive alpha		0° to 360°	Increments 1°
Inductive beta		0° to 360°	Increments 1°
Tolerances pick-up values		10 % of set value or 5 % of nominal current or 0.5 V	
Tolerance forward angle		5°	
Re-orientation time after direction change		Approx. 30 ms	

Normal inverse: $\quad t = \dfrac{0.14}{(I/I_p)^{0.02} - 1} \cdot T_p \quad$ [s]
(Type A)

Very inverse: $\quad t = \dfrac{13.5}{(I/I_p)^{1} - 1} \cdot T_p \quad$ [s]
(Type B)

Extremely inverse: $\quad t = \dfrac{80}{(I/I_p)^{2} - 1} \cdot T_p \quad$ [s]
(Type C)

Longtime inverse: $\quad t = \dfrac{120}{(I/I_p)^{1} - 1} \cdot T_p \quad$ [s]

t   Trip time
T_p Setting value time multiplier
I   Fault current
I_p Setting value current

Note: For earth fault read $3I_{0p}$ instead of I_p and T_{3I0p} instead of T_p
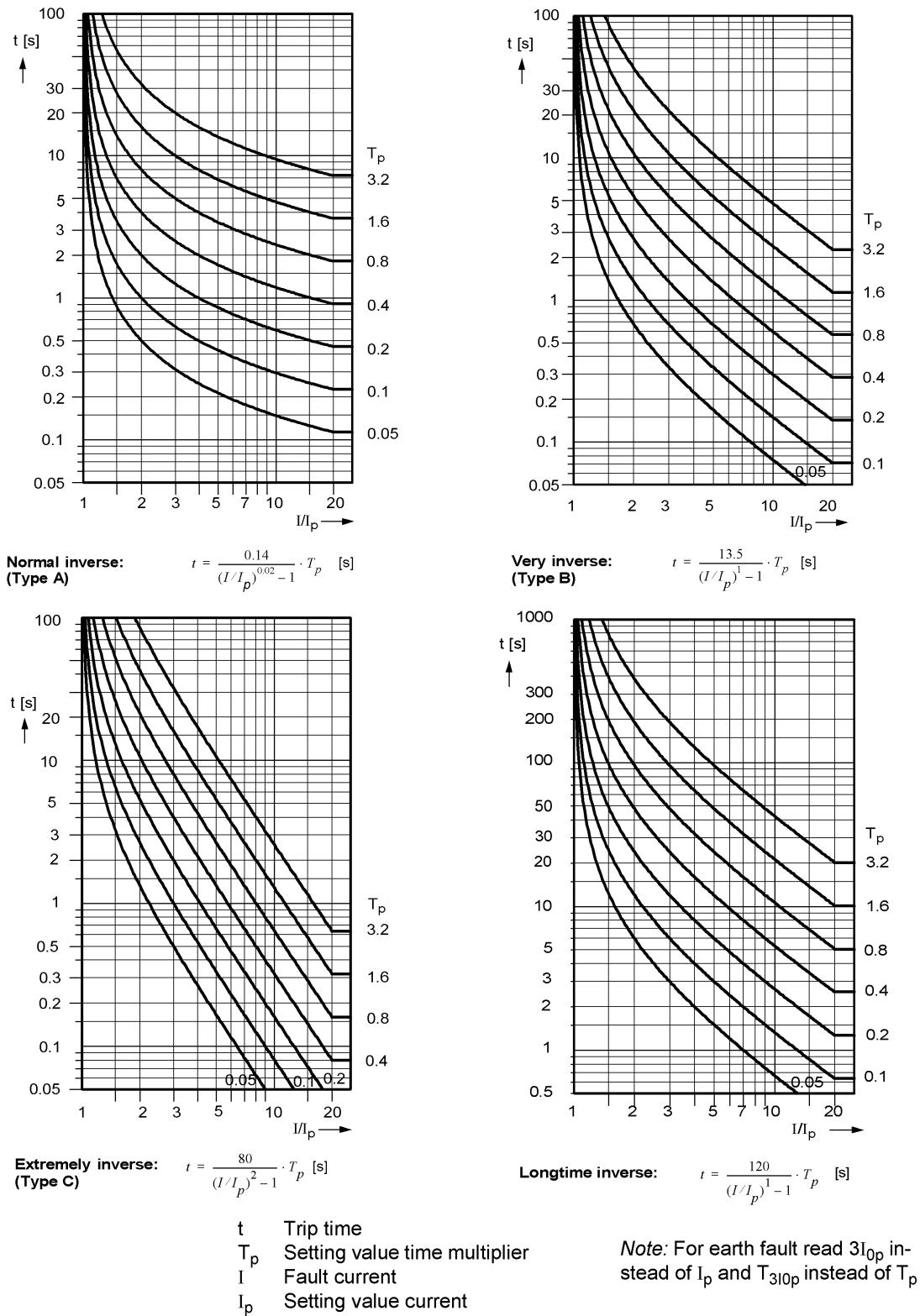
Figure 4-1   Trip time characteristics of inverse time overcurrent stage, acc. IEC (phases and earth)
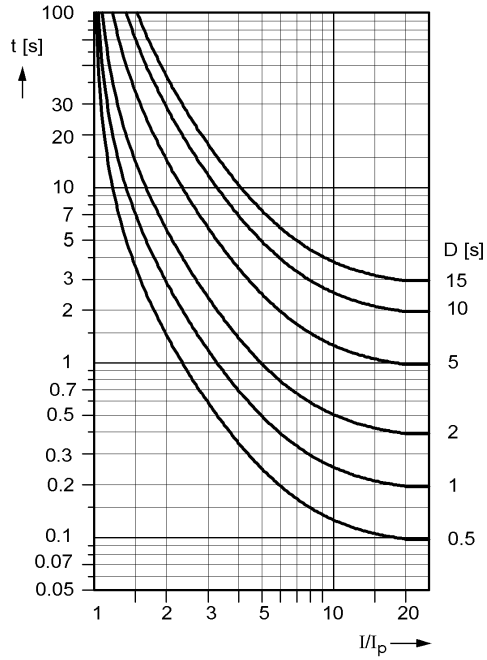
INVERSE

$$t = \left(\frac{8.9341}{(I/I_p)^{2.0938} - 1} + 0.17966 \right) \cdot D \quad [s]$$
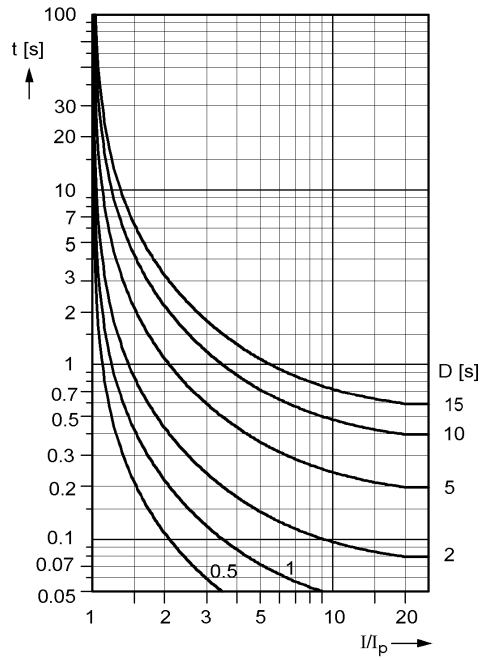
SHORT INVERSE

$$t = \left(\frac{0.2663}{(I/I_p)^{1.2969} - 1} + 0.03393 \right) \cdot D \quad [s]$$
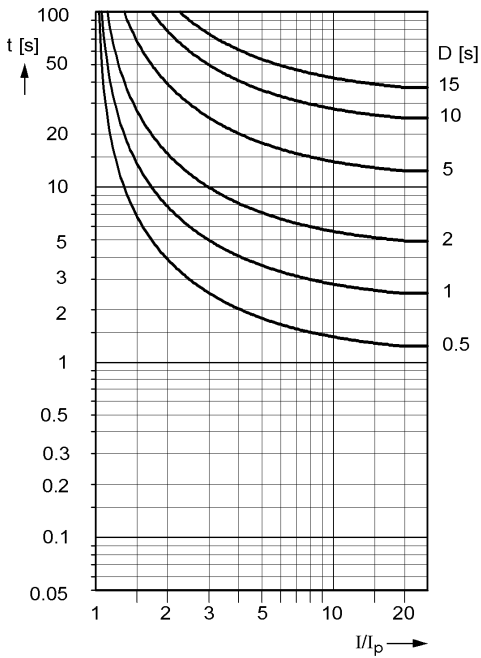
LONG INVERSE

$$t = \left(\frac{5.6143}{(I/I_p) - 1} + 2.18592 \right) \cdot D \quad [s]$$
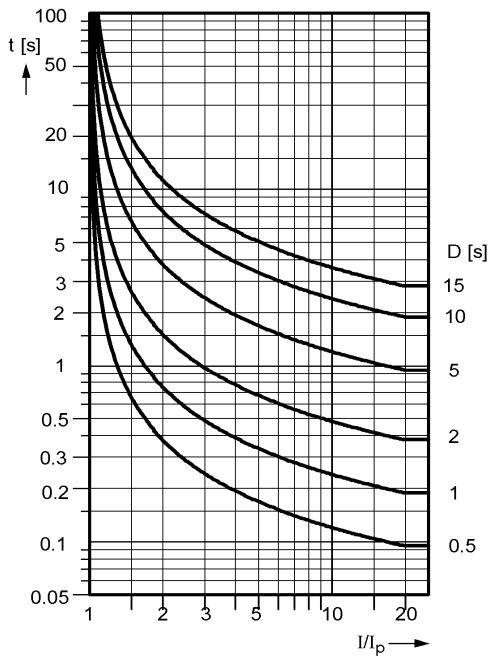
MODERATELY INVERSE

$$t = \left(\frac{0.0103}{(I/I_p)^{0.02} - 1} + 0.0228 \right) \cdot D \quad [s]$$

Figure 4-2 Trip time characteristics of inverse time overcurrent stage, acc. ANSI/IEEE (phases and earth)
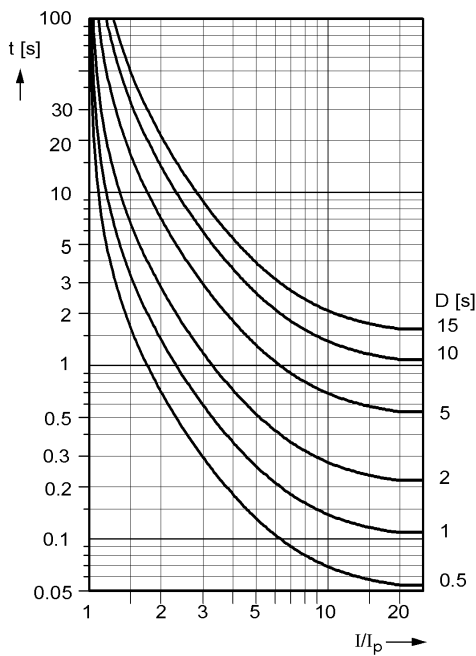
VERY INVERSE
$$t = \left(\frac{3{,}922}{(I/I_p)^2 - 1} + 0.0982 \right) \cdot D \quad [\text{s}]$$
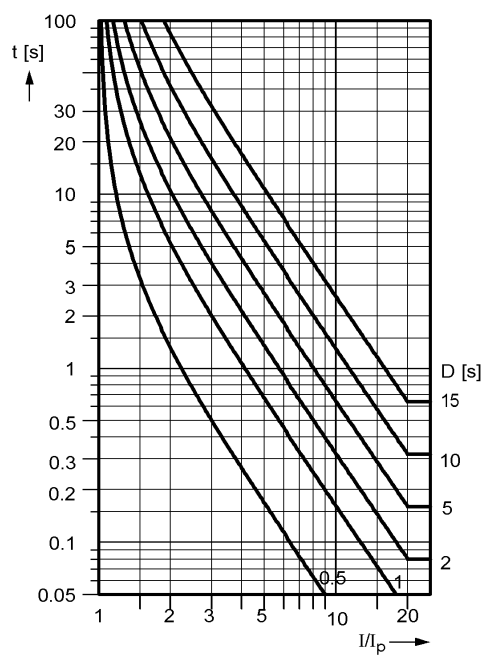
EXTREMELY INVERSE
$$t = \left(\frac{5.64}{(I/I_p)^2 - 1} + 0.02434 \right) \cdot D \quad [\text{s}]$$
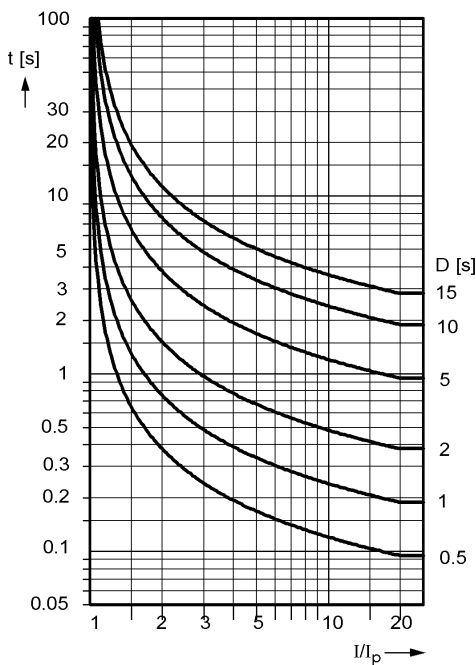
DEFINITE INVERSE
$$t = \left(\frac{0.4797}{(I/I_p)^{1.5625} - 1} + 0.21359 \right) \cdot D \quad [\text{s}]$$

t   Trip time
D   Setting value time multiplier
I   Fault current
I_p Setting value current

Note: For earth fault read $3I_{0p}$ instead of I_p and D_{3I0p} instead of D_{Ip}

Figure 4-3   Trip time characteristics of inverse time overcurrent stage, acc. ANSI/IEEE (phases and earth)
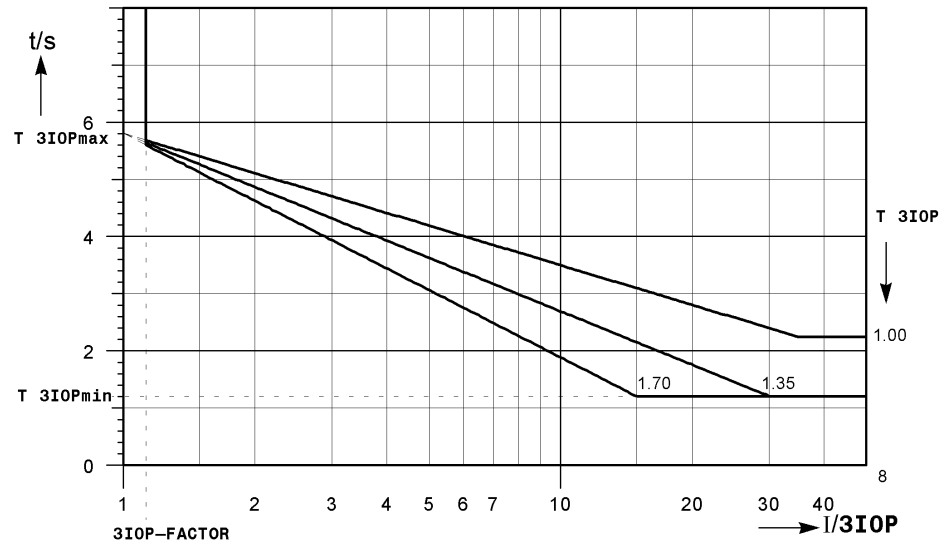
Figure 4-4   Trip time caracteristic of the inverse time overcurrent stage with logarithmic-inverse characteristic

Logarithmic inverse $t = T_{3I0p\ Max\ T\text{-}delay} - T_{3I0p\ Time\ Dial} \cdot \ln(I/\textbf{3I0p PICKUP})$

Note: For $I/\textbf{3I0p PICKUP} > 35$ the time applies for $I/\textbf{3I0p PICKUP} = 35$

U_0 **invers:** $t = \dfrac{2\ s}{0.25\ U_0/V - U_{0min}/V}$ with U_{0min} = Parameter $\textbf{U0inv. minimal}$ (Adr. 3183)
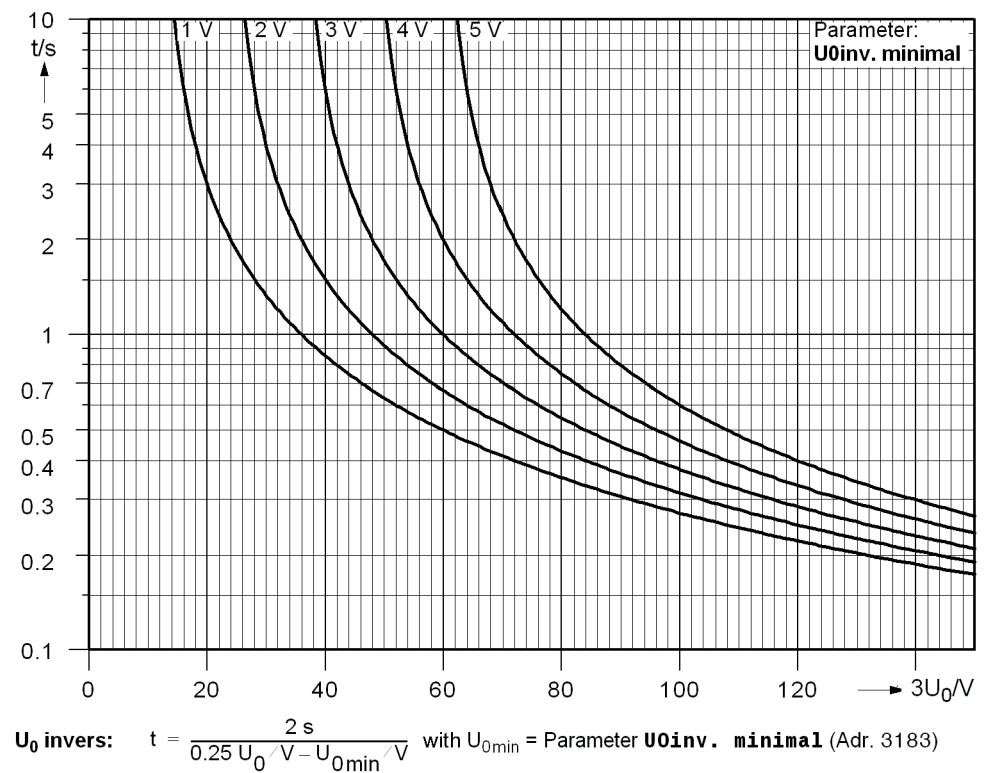
Figure 4-5   Trip time characteristics of the zero sequence voltage protection $U_{0\ inv.}$
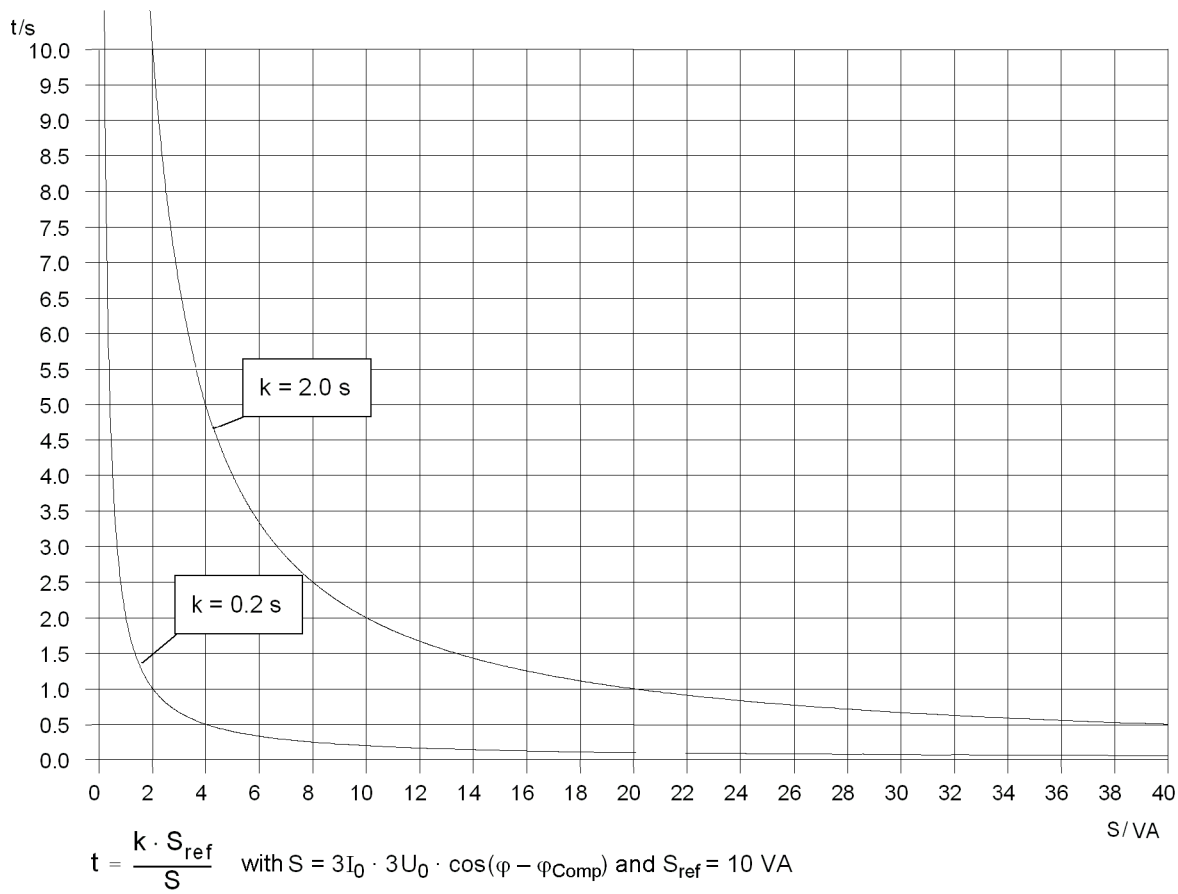
Figure 4-6   Tripping characteristics of the zero-sequence power protection

This characteristic applies for: S_{ref} = 10 VA and $T3I_{OPverz}$ = 0 s.

4.6 Teleprotection for Earth Fault Overcurrent Protection (optional)

Mode

For two line ends	One channel for each direction or three channels each direction for phase-segregated transmission
For three line ends	With one channel for each direction or connection

Comparison Schemes

Method	Dir. comp. pickup	
	Directional unblocking scheme	
	Directional blocking scheme	
Send signal prolongation	0.00 s to 30.00 s	Increments 0.01 s
Enable delay	0.000 s to 30.000 s	Increments 0.001 s
Transient blocking time	0.00 s to 30.00 s	Increments 0.01 s
Wait time for transient blocking	0.00 s to 30.00 s; ∞	Increments 0.01 s
Echo delay time	0.00 s to 30.00 s	Increments 0.01 s
Echo impulse duration	0.00 s to 30.00 s	Increments 0.01 s
Time expiry tolerances	1 % of setting value or 10 ms	
The set times are pure delay times		

Comparison Schemes via Protection Data Interface (optional)

Phase-segregated for two or three line ends		
Method	Dir. comp. pickup	
Send signal prolongation	0.00 s to 30.00 s	Increments 0.01 s
Enable delay	0 s to 30,000 s	Increments 0.001 s
Transient blocking time	0.00 s to 30.00 s	Increments 0.01 s
Wait time for transient blocking	0.00 s to 30.00 s; ∞	Increments 0.01 s
Echo delay time	0.00 s to 30.00 s	Increments 0.01 s
Echo impulse duration	0.00 s to 30.00 s	Increments 0.01 s
Time expiry tolerances	1 % of setting value or 10 ms	
The set times are pure delay times		

4.7 Weak-Infeed Tripping (classic)

Operating Mode

Phase segregated undervoltage detection after reception of a carrier signal from the remote end

Undervoltage

Set value $U_{PhE}<$	2 V to 70 V	Increments 1 V
Drop-off to pick-up ratio	Approx. 1.1	
Pick-up tolerance	≤ 5 % of setting value, or 0.5 V	

Times

Enable delay	0.00 s to 30.00 s	Increments 0.01 s
Enable delay	0.00 s to 30.00 s	Increments 0.01 s
Echo blocking duration after echo	0.00 s to 30.00 s	Increments 0.01 s
Pick-up tolerance	1 % of setting value or 10 ms	

4.8   Weak-Infeed Tripping (French specification)

Operating Mode

Phase segregated undervoltage detection after reception of a carrier signal from the remote end

Undervoltage

Set value $U_{PhE}<$ (factor)	0.10 to 1.00	Increments 0.01
Dropout/pickup ratio	Approx. 1.1	
Pick-up tolerance	≤ 5 %	

Times

Receive prolongation	0.00 s to 30.00 s	Increments 0.01 s
Enable delay	0.00 s to 30.00 s	Increments 0.01 s
Alarm time	0.00 s to 30.00 s	Increments 0.01 s
Pick-up tolerance	1 % of setting value or 10 ms	

Stage timers

Delay (single-pole)	0.00 s to 30.00 s	Increments 0.01 s
Delay (multi-pole)	0.00 s to 30.00 s	Increments 0.01 s
Pick-up tolerance	1 % of setting value or 10 ms	

4.9 Protection Data Interfaces and Communication Topology (optional)

Protection Data Interfaces

Quantity	1
- Connection optical fibre	Mounting location "D"
For flush-mounted case	On the rear side
For panel surface-mounted case	At the inclined housing on the case bottom
Connection modules for protection data interface, depending on the ordering version:	

Module in device	Connector type	Fibre type	Optical wavelength	Perm. path attenuation	Distance, maximum
FO5 [1]	ST	Multimode 62.5/125μm	820 nm	8 dB	1.5 km 0.95 miles
FO6 [2]	ST	Multimode 62.5/125μm	820 nm	16 dB	3.5 km 2.2 miles
FO7 [2]	ST	Monomode 9/125 μm	1300 nm	7 dB	10 km 6.25 miles
FO8 [2]	FC	Monomode 9/125 μm	1300 nm	18 dB	35 km 22 miles
[1] Laser class I according to EN 60825-1/ -2 using glass fibre 62.5/125 μm					
[2] Laser class 3A according to EN 60825-1/ -2					

- Character idle state	"Light Off"

Protection Data Communication

Direct connection:		
Transmission rate	512 kbit/s	
Fibre type		
Optical wavelength	Refer to table above	
Permissible link signal attenuation		
Transmission distance		
Connection via communication networks:		
Communication converter	See Appendix A.1, Subsection Accessories	
Supported network interfaces	G703.1 with 64 kbit/s;	
	X.21 with 64 or 128 or 512 kbit/s	
Connection to communication converter	See table above under module FO 5	
Transmission rate	64 kbit/s with G703.1	
	512 kbit/s or 128 kBit/s or 64 kbit/s with X.21	
Max. runtime time	0.1 ms to 30 ms	Increments 0.1 ms
Max. runtime difference	0.000 ms to 3.000 ms	Increments 0.001 ms
Transmission accuracy	CRC 32 according to CCITT or ITU	

4.10 External Direct and Remote Tripping

External Trip of the Local Breaker

Operating time, total	Approx. 11 ms	
Trip time delay	0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
Time expiry tolerances	1 % of setting value or 10 ms	
The set times are pure delay times		

4.11 Time Overcurrent Protection

Operating Modes

As Emergency Overcurrent Protection or Back-up Overcurrent Protection:	
Emergency overcurrent protection	Operates on failure of the measured voltage, • On trip of a voltage transformer mcb (via binary input) • For pickup of the "Fuse Failure Monitor"
Back-up overcurrent protection	Operates independent of any events

Characteristics

Definite dime stages (definite)	$I_{Ph}>>, 3I_0>>$, $I_{Ph}>$, $3I_0>$
Inverse time stages (IDMT)	I_P, $3I_{0p\ PICKUP}$; one of the characteristics according to Figure 4-1 to 4-3 (see Section 4.5) can be selected

Definite Time High Set Current Stage

Pickup value $I_{Ph}>>$ (phases)	For I_N = 1 A	0.10 A to 25.00 A or ∞ (ineffective)	Increments 0.01 A
	For I_N = 5 A	0.50 A to 125.00 A or ∞ (ineffective)	
Pickup value $3I_0>>$ (earth)	For I_N = 1 A	0.05 A to 25.00 A Or ∞ (ineffective)	Increments 0.01 A
	For I_N = 5 A	0.25 A to 125.00 A Or ∞ (ineffective)	
Delay $T_{Ph}>>$ (phases)		0.00 s to 30.00 s Or ∞ (ineffective)	Increments 0.01 s
Delay $T_{3I0}>>$ (earth)		0.00 s to 30.00 s Or ∞ (ineffective)	Increments 0.01 s
Dropout Ratio		Approx. 0.95 for $I/I_N \geq 0.5$	
Pickup times		Approx. 25 ms	
Drop-off times		Approx. 30 ms	
Tolerances	Currents	3 % of setting value or 1 % nominal current	
	Times	1 % of setting value or 10 ms	
The set times are pure delay times			

Definite Time Overcurrent Stage

Pickup value $I_{Ph}>$ (phases)	For I_N = 1 A	0.10 A to 25.00 A Or ∞ (ineffective)	Increments 0.01 A
	For I_N = 5 A	0.50 A to 125.00 A Or ∞ (ineffective)	
Pickup value $3I_0>$ (earth)	For I_N = 1 A	0.05 A to 25.00 A Or ∞ (ineffective)	Increments 0.01 A
	For I_N = 5 A	0.25 A to 125.00 A Or ∞ (ineffective)	
Delay $T_{Ph}>$ (phases)		0.00 s to 30.00 s Or ∞ (ineffective)	Increments 0.01 s
Delay $T_{3I0}>$ (earth)		0.00 s to 30.00 s Or ∞ (ineffective)	Increments 0.01 s
Dropout Ratio		Approx. 0.95 for $I/I_N ≥ 0.5$	
Pickup times		Approx. 25 ms	
Drop-off times		Approx. 30 ms	
Tolerances	Currents	3 % of setting value or 1 % nominal current	
	Times	1 % of setting value or 10 ms	
The set times are pure delay times			

Inverse Time Overcurrent Stage (IEC)

Pickup value I_{Ph} (phases)	for I_N = 1 A	0.10 A to 4.00 A or ∞ (ineffective)	Increments 0.01 A
	for I_N = 5 A	0.50 A to 20.00 A or ∞ (ineffective)	
Pickup value $3I_{0p\ PICKUP}$ (earth)	for I_N = 1 A	0.05 A to 4.00 A or ∞ (ineffective)	Increments 0.01 A
	for I_N = 5 A	0.25 A to 20.00 A or ∞ (ineffective)	
Time factors	T_{IP} (phases)	0.05 s to 3.00 s or ∞ (ineffective)	Increments 0.01 s
	$T_{3I0p\ Time\ Dial}$ (earth)	0.05 s to 3.00 s or ∞ (ineffective)	Increments 0.01 s
Additional time delays	$T_{IP\ add\ T\text{-}Delay}$ (phases)	0.00 s to 30.00 s	Increments 0.01 s
	$T_{3I0p\ add\ T\text{-}Delay}$ (earth)	0.00 s to 30.00 s	Increments 0.01 s
Characteristics		See Figure 4-1	
Tolerances currents		Pick-up at $1.05 ≤ I/I_P ≤ 1.15$ or $1.05 ≤ I/3I_{0P} ≤ 1.15$	
Tolerances times		5 % ± 15 ms for $2 ≤ I/3I_{OP} ≤ 20$ and $T_{3I0P}/s ≥ 1$ or $2 ≤ I/3I_{0p\ PICKUP} ≤ 20$ and $T_{3I0p\ Time\ Dial}/s ≥ 1$	
Defined times		1 % of setting value or 10 ms	

Inverse Time Overcurrent Stage (ANSI)

Pickup value I_P (phases)	for I_N = 1 A	0.10 A to 4.00 A or ∞ (ineffective)	Increments 0.01 A
	for I_N = 5 A	0.50 A to 20.00 A or ∞ (ineffective)	
Pickup value $3I_{0p\ PICKUP}$ (earth)	for I_N = 1 A	0.05 A to 4.00 A or ∞ (ineffective)	Increments 0.01 A
	for I_N = 5 A	0.25 A to 20.00 A or ∞ (ineffective)	
Time factors	D_{IP} (phases)	0.50 s to 15.00 s or ∞ (ineffective)	Increments 0.01 s
	$D_{3I0p\ Time\ Dial}$ (earth)	0.50 s to 15.00 s or ∞ (ineffective)	Increments 0.01 s
Additional time delays	$T_{IP\ delayed}$ (phases)	0.00 s to 30.00 s	Increments 0.01 s
	$T_{3I0p\ add\ T\text{-}Delay}$ (earth)	0.00 s to 30.00 s	Increments 0.01 s
Characteristics		See Figure 4-2 and 4-3	
Tolerances currents		Pick-up at $1.05 ≤ I/I_P ≤ 1.15$ or $1.05 ≤ I/3I_{0P} ≤ 1.15$	
Tolerances times		5 % ± 15 ms for $2 ≤ I/3I_{OP} ≤ 20$ and $D_{3I0P}/s ≥ 1$ or $2 ≤ I/3I_{0p\ PICKUP} ≤ 20$ and $D_{3I0p\ Time\ Dial}/s ≥ 1$	
Defined times		1 % of setting value or 10 ms	

Stub Fault Protection

Pickup value $I_{Ph}>>>$ (phases)	for I_N = 1 A	0.10 A to 25.00 A or ∞ (ineffective)	Increments 0.01 A
	for I_N = 5 A	0.50 A to 125.00 A or ∞ (ineffective)	
Pickup value $3I_0>>>$ (earth)	for I_N = 1 A	0.05 A to 25.00 A or ∞ (ineffective)	Increments 0.01 A
	for I_N = 5 A	0.25 A to 125.00 A or ∞ (ineffective)	
Delays	$T_{IPh}>>>$	0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
	$T_{3I0}>>>$	0.00 s to 30.00 s or ∞ (ineffective)	Increments 0.01 s
Drop-off to pick-up ratio		Approx. 0.95 for $I/I_N ≥ 0.5$	
Pickup times		Approx. 25 ms	
Drop-off times		Approx. 30 ms	
Tolerances currents	Currents	3 % of setting value or 1 % nominal current	
	Times	1 % of setting value or 10 ms	
The set times are pure delay times.			

4.12 Instantaneous High-Current Switch-onto-Fault Protection

Pickup

High current pick-up I>>>	for I_N = 1 A	1.00 A to 25.00 A	Increments 0.01 A
	for I_N = 5 A	5.00 A to 125.00 A	
Drop-off to pick-up ratio		Approx. 90 %	
Pick-up tolerance		3 % of set value or 1 % of I_N	

Times

Shortest trip time	Approx. 13 ms for fast relays and Approx 8 ms for high-speed relays

4.13 Earth Fault Detection in Non-Earthed Systems (optional)

Pickup / Tripping

Displacement voltage $3U_0$>	1 V to 150 V	Increments 1 V
Delay $T_{Sens.E/F}$	0.00 s to 320.00 s	Increments 0.01 s
Optional trip with additional delay time $T_{Sens.E/F\ TRIP}$	0.00 s to 320.00 s	Increments 0.01 s
Measuring tolerance	5 % of set value	
Time tolerance	1 % of setting value or 10 ms	
The set times are pure delay times.		

Phase Determination

Measuring principle	Voltage measurement phase-earth	
Earth fault phase $U_{ph\ min}$	10 V to 100 V	Increments 1 V
Healthy phases $U_{ph\ max}$	10 V to 100 V	Increments 1 V
Measuring tolerance	5 % of set value	

Determination of Direction

Measuring principle	Real/reactive power measurement	
Pick-up value I>$_{Sens.E/F}$	0.003 A to 1.000 A[2]	Increments 0.001 A
Angle correction for toroidal current transformer	0.0° to 5.0° in 2 steps	Increments 0.1°
Measuring tolerance	10 % of set value for tan $\varphi \leq 20$ (for active power)	
[2] Sensitive earth current input independent from I_N.		

4.14 Automatic Reclosure Function (optional)

Automatic Reclosures

Number of reclosures	Max. 8, first 4 with individual settings	
Type (depending on ordered version)	1-pole, 3-pole or 1-/3-pole	
Control	With pickup or trip command	
Action times Initiation possible without pick-up and action time	0.01 s to 300.00 s; ∞	Increments 0.01 s
Different dead times before reclosure can be set for all operating modes and cycles	0.01 s to 1800.00 s; ∞	Increments 0.01 s
Dead times after evolving fault recognition	0.01 s to 1800.00 s	Increments 0.01 s
Reclaim time after reclosure	0.50 s to 300.00 s	Increments 0.01 s
Blocking time after dynamic blocking	0.5 sec	
Blocking time after manual closing	0.50 s to 300.00 s; 0	Increments 0.01 s
Start signal monitoring time	0.01 s to 300.00 s	Increments 0.01 s
Circuit-breaker monitoring time	0.01 s to 300.00 s	Increments 0.01 s

Adaptive Dead Time (ADT) / Reduced Dead Time (RDT) / Dead Line Check

Adaptive dead time	With voltage measurement or with close command transmission	
Action times Initiation possible without pick-up and action time	0.01 s to 300.00 s; ∞	Increments 0.01 s
Maximum dead time	0.50 s to 3000.00 s	Increments 0.01 s
Voltage measurement dead line or bus	2 V to 70 V (Ph-E)	Increments 1 V
Voltage measurement live or bus	30 V to 90 V (Ph-E)	Increments 1 V
Voltage measuring time	0.10 s to 30.00 s	Increments 0.01 s
Time delay for close command transmission	0.00 to 300.00; ∞	Increments 0.01 s

4.15 Synchronism and Voltage Check (optional)

Operating Modes

Operating modes with automatic reclosure	Synchronism check
	Live bus - dead line
	Dead bus - live line
	Dead bus and dead line
	Bypassing
	Or combination of the above
Synchronism	Closing the circuit breaker under asynchronous power conditions possible (with circuit breaker action time)
Operating modes for manual closure	As for automatic reclosure, independently selectable

Voltages

Maximum operating voltage	20 V to 140 V (phase-to-phase)	Increments 1 V
U< for dead status	1 V to 60 V (phase-to-phase)	Increments 1 V
V> for live status	20 V to 125 V (phase-to-phase)	Increments 1 V
Tolerances	2 % of pickup value or 1 V	
Drop-off to pick-up ratio	Approx. 0.9 (V>) or 1.1 (V<)	

ΔU-Measurement

Voltage difference	1.0 V to 40.0 V (phase-to-phase)	Increments 0.1V
Tolerance	1 V	
Drop-off to pick-up ratio	Approx. 1.05	

Synchronous Power Conditions

$\Delta\varphi$-measurement	2° to 80°	Increments 1°
Tolerance	2°	
Δf-measurement	0.03 Hz to 2.00 Hz	Increments 0.01 Hz
Tolerance	15 mHz	
Enable delay	0.00 s to 30.00 s	Increments 0.01 s

Asynchronous Power Conditions

Δf-measurement	0.03 Hz to 2.00 Hz	Increments 0.01 Hz
Tolerance	15 mHz	
Max. angle error	5° for $\Delta f \leq$ 1 Hz	
	10° for $\Delta f >$ 1 Hz	
Synchronous/asynchronous limits	0.01 Hz	
Circuit breaker operating time	0.01 s to 0.60 s	Increments 0.01 s

Times

Minimum measuring time	Approx. 80 ms	
Maximum measuring time	0.01 s to 600.00 s; ∞	Increments 0.01 s
Tolerance of all timers	1 % of setting value or 10 ms	

4.16   Undervoltage and Overvoltage Protection (optional)

Overvoltage Phase-Earth

Overvoltage U_{Ph}>>		1.0 V to 170.0 V; ∞	Increments 0.1V
Delay $T_{UPh>>}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Overvoltage U_{Ph}>		1.0 V to 170.0 V; ∞	Increments 0.1V
Delay $T_{UPh>}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Drop-off to pick-up ratio		0.30 to 0.98	Increments 0.01
Pickup time		Approx. 35 ms (50 Hz) / approx. 30 ms (60 Hz)	
Drop-off time		Approx. 30 ms	
Tolerances	Voltages	3 % of setting value or 1 V	
	Times	1 % of setting value or 10 ms	

Overvoltage Phase–Phase

Overvoltage U_{PhPh}>>		2.0 V to 220.0 V; ∞	Increments 0.1V
Delay $T_{UPhPh>>}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Overvoltage U_{PhPh}>		2.0 V to 220.0 V; ∞	Increments 0.1V
Delay $T_{UPhPh>}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Drop-off to pick-up ratio		0.30 to 0.98	Increments 0.01
Pickup time		Approx. 35 ms (50 Hz) / approx. 30 ms (60 Hz)	
Drop-off time		30 ms	
Tolerances	Voltages	3 % of setting value or 1 V	
	Times	1 % of setting value or 10 ms	

Overvoltage Positive Sequence System U_1

Overvoltage U_1>>		2.0 V to 220.0 V; ∞	Increments 0.1V
Delay $T_{U1>>}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Overvoltage U_1>		2.0 V to 220.0 V; ∞	Increments 0.1V
Delay $T_{U1>}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Drop-off to pick-up ratio		0.30 to 0.98	Increments 0.01
Compounding		Can be switched on/off	
Pickup time		Approx. 35 ms (50 Hz) / approx. 30 ms (60 Hz)	
Drop-off time		Approx. 30 ms	
Tolerances	Voltages	3 % of setting value or 1 V	
	Times	1 % of setting value or 10 ms	

Overvoltage Negative Sequence System U$_2$

Overvoltage U$_2$>>	2.0 V to 220.0 V; ∞	Increments 0.1V
Delay T$_{U2>>}$	0.00 s to 100.00 s; ∞	Increments 0.01 s
Overvoltage U$_2$>	2.0 V to 220.0 V; ∞	Increments 0.1V
Delay T$_{U2>}$	0.00 s to 100.00 s; ∞	Increments 0.01 s
Drop-off to pick-up ratio	0.30 to 0.98	Increments 0.01
Pickup time	Approx. 35 ms (50 Hz) / approx. 30 ms (60 Hz)	
Drop-off time	Approx. 30 ms	
Tolerances	Voltages	3 % of setting value or 1 V
	Times	1 % of setting value or 10 ms

Overvoltage Zero Sequence System 3U$_0$ or any Single-Phase Voltage U$_X$

Overvoltage 3U$_0$>>	1.0 V to 220.0 V; ∞	Increments 0.1V
Delay T$_{3U0>>}$	0.00 s to 100.00 s; ∞	Increments 0.01 s
Overvoltage 3U$_0$>	1.0 V to 220.0 V; ∞	Increments 0.1V
Delay T$_{3U0>}$	0.00 s to 100.00 s; ∞	Increments 0.01 s
Drop-off to pick-up ratio	0.30 to 0.98	Increments 0.01
Pickup time		
With repeated measurement	Approx. 75 ms (50 Hz) / approx. 65 ms (60 Hz)	
Without repeated measurement	Approx. 35 ms (50 Hz) / approx. 30 ms (60 Hz)	
Drop-off time	30 ms	
Tolerances	Voltages	3 % of setting value or 1 V
	Times	1 % of setting value or 10 ms

Undervoltage Phase–Earth

Undervoltage U$_{Ph}$<<	1.0 V to 100.0 V	Increments 0.1V
Delay T$_{UPh<<}$	0.00 s to 100.00 s; ∞	Increments 0.01 s
Undervoltage U$_{Ph}$<	1.0 V to 100.0 V	Increments 0.1V
Delay T$_{UPh<}$	0.00 s to 100.00 s; ∞	Increments 0.01 s
Drop-off to pick-up ratio	Approx. 1.05	
Current criterion	Can be switched on/off	
Pickup time	Approx. 35 ms (50 Hz) / approx. 30 ms (60 Hz)	
Drop-off time	Approx. 30 ms	
Tolerances	Voltages	3 % of setting value or 1 V
	Times	1 % of setting value or 10 ms

Undervoltage Phase–Phase

Undervoltage $U_{PhPh}<<$		1.0 V to 175.0 V	Increments 0.1V
Delay $T_{UPhPh<<}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Undervoltage $U_{PhPh}<$		1.0 V to 175.0 V	Increments 0.1V
Delay $T_{UPhPh<}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Drop-off to pick-up ratio		Approx. 1.05	
Current criterion		Can be switched on/off	
Pickup time		Approx. 35 ms (50 Hz) / approx. 30 ms (60 Hz)	
Drop-off time		30 ms	
Tolerances	Voltages	3 % of setting value or 1 V	
	Times	1 % of setting value or 10 ms	

Undervoltage Positive Sequence System U_1

Undervoltage $U_1<<$		1.0 V to 100.0 V	Increments 0.1V
Delay $T_{U1<<}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Undervoltage $U_1<$		1.0 V to 100.0 V	Increments 0.1V
Delay $T_{U1<}$		0.00 s to 100.00 s; ∞	Increments 0.01 s
Drop-off to pick-up ratio		Approx. 1.05	
Current criterion		Can be switched on/off	
Pickup time		Approx. 35 ms (50 Hz) / approx. 30 ms (60 Hz)	
Drop-off time		30 ms	
Tolerances	Voltages	3 % of setting value or 1 V	
	Times	1 % of setting value or 10 ms	

4.17   Frequency Protection (optional)

Frequency Elements

Quantity	4, depending on setting effective on f< or f>

Pickup Values

f> or f< adjustable for each element		
For f_N = 50 Hz	45.50 Hz to 54.50 Hz	Increments 0.01 Hz
For f_N = 60 Hz	55.50 Hz to 64.50 Hz	Increments 0.01 Hz

Times

Pickup times f>, f<	Approx. 85 ms	
Dropout times f>, f<	Approx. 80 ms	
Delay times T	0.00 s to 600.00 s	Increments 0.01 s
The set times are pure delay times. Note on drop-off times: Drop-off was enforced by current = 0 A and voltage = 0 V. Enforcing the drop-off by means of a frequency change below the drop-off threshold extends the drop-off times.		

Dropout Frequency

Δf = | pickup value – dropout value |	Approx. 20 mHz

Operating Ranges

In voltage range	Approx. 6 V to 230 V (phase-earth)
In frequency range	25 Hz to 70 Hz

Tolerances

Frequencies f>, f< in specific range (f_N ± 10 %)	15 mHz in range U_{LE}: 29 to 230 V
Time delays T(f<, f>)	1 % of setting value or 10 ms

4.18   Fault Locator

General

Start		With trip command or drop-off	
Setting range reactance (secondary), miles or km	for I_N = 1 A	0.0050 Ω/km to 9.5000 Ω/km	Increments 0.001 Ω/km
	for I_N = 5 A	0.0010 Ω/km to 1.9000 Ω/km	
	for I_N = 1 A	0.0050 Ω/mile to 15.0000 Ω/mile	Increments 0.001 Ω/mile
	for I_N = 5 A	0.0010 Ω/mile to 3.0000 Ω/mile	
Parallel line compensation (selectable)		Can be switched on/off The setting values are the same as for distance protection (see Section 4.2)	
Taking into consideration the load current in case of single-phase earth faults		Correction of the X-value, can be activated and deactivated	
Output of the fault distance		In Ω primary and Ω secondary, In km or miles line [1] In % line length [1]	
Measuring tolerances with sinusoidal quantities		2.5 % of the line length at $30° ≤ \varphi_k ≤ 90°$ and $U_K/U_N ≥ 0.1$	
Further output options (depending on ordered version)		As analog value 0 mA to 22.5 mA; as BCD-code 4 Bit units + 4 Bit tens + 1 Bit hundreds + validity bit	
— Output time, settable — BCD		0.01 s to 180.00 s; ∞ 0.01 s to 180.00 s; ∞	Increments 0.01 s Increments 0.01 s
[1] Output of the fault distance in km, miles, and % requires homogeneous lines.			

4.19 Circuit Breaker Failure Protection (optional)

Circuit Breaker Monitoring

Current flow monitoring	for I_N = 1 A	0.05 A to 20.00 A	Increments 0.01 A
	for I_N = 5 A	0.25 A to 100.00 A	
Drop-off to pick-up ratio		Approx. 0.95	
Tolerance		5 % of setting value or 1 % of nominal current	
Monitoring of circuit-breaker auxiliary contact position			
- for three-pole tripping		Binary input for circuit breaker auxiliary contact	
- for single-pole tripping		1 binary input for auxiliary contact per pole or 1 binary input for series connection NO contact and NC contact	

Note:
The circuit breaker failure protection can also operate without the indicated circuit breaker auxiliary contacts, but the function range is then reduced.
Auxiliary contacts are necessary for the circuit breaker failure protection for tripping without or with a very low current flow (e.g. Buchholz protection, stub fault protection, circuit breaker pole discrepancy monitoring).

Initiation Conditions

For circuit breaker failure protection	Single-pole tripping internal Three-pole tripping internal Single-pole tripping external [1] Three-pole tripping external [1] Three-pole tripping without current [1]
[1] via binary inputs	

Times

Pickup time	Approx. 5 ms with measured quantities present Approx. 20 ms after switch-on of measured quantities
Drop-off time, internal (overshoot time)	$\leq$ 15 ms at sinusoidal measured values, $\leq$ 25 ms maximal
Delay times for all stages	0.00 s to 30.00 s; ∞ Increments 0.01 s
Tolerance	1 % of setting value or 10 ms

End Fault Protection

With signal transmission to the opposite line end	
Time delay	0.00 s to 30.00 s; ∞ Increments 0.01 s
Tolerance	1 % of setting value or 10 ms

Pole Discrepancy Supervision

Initiation criterion	Not all poles are closed or open
Monitoring time	0.00 s to 30.00 s; ∞ Increments 0.01 s
Tolerance	1 % of setting value or 10 ms

4.20   Thermal Overload Protection (optional)

Setting Ranges

Factor k according to IEC 60255-8		0.10 to 4.00	Increments 0.01
Time Constant τ_{th}		1.0 min to 999.9 min	Increments 0.1 min
Thermal Alarm $\Theta_{Alarm}/\Theta_{Trip}$		50% to 100% of the trip overtemperature	Increments 1 %
Current Overload I_{Alarm}	for I_N = 1 A	0.10 A to 4.00 A	Increments 0.01 A
	for I_N = 5 A	0.50 A to 20.00 A	

Calculation Method

Calculation method temperature rise	Maximum temperature rise of 3 phases
	Average of temperature rise of 3 phases
	Temperature rise from maximum current

Tripping Characteristic

Tripping characteristic

for $(I/\, k \cdot I_N) \leq 8$

Meaning of abbreviations:

$$t = \tau \cdot ln \frac{\left(\frac{I}{k \cdot I_N}\right)^2 - \left(\frac{I_{pre}}{k \cdot I_N}\right)^2}{\left(\frac{I}{k \cdot I_N}\right)^2 - 1}$$

t Tripping time
τ Temperature rise time factor
I Load current
I_{pre} Previous load current
k Setting factor according to IEC 60255–8
I_N Rated current of protected object

Drop-off to Pick-up Ratio

Θ/Θ_{Trip}	Drops out with Θ_{Alarm}
Θ/Θ_{Alarm}	Approx. 0.99
I/I_{Alarm}	Approx. 0.97

Tolerances

Referred to $k \cdot I_N$ Ralating to tripping time	2 % or 1 % of nominal current; Class 2 % according to IEC 60255-8
	3 % or 1 s for $I/(k \cdot I_N)$ > 1.25; class 3 % per IEC 60255-8
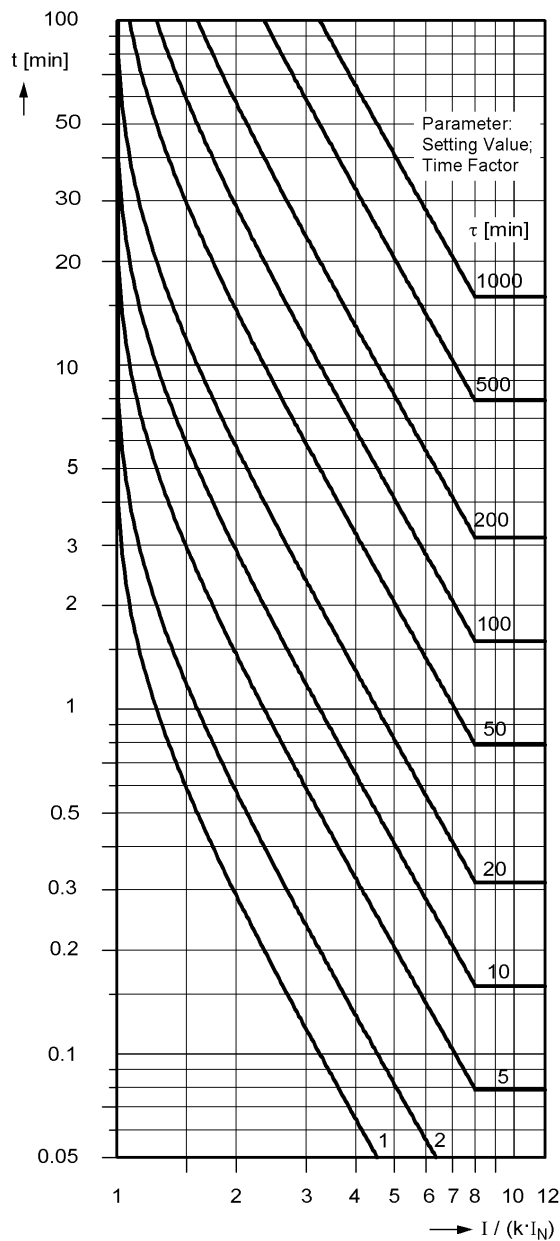
without Previous Load Current:

$$t = \tau \cdot ln \frac{\left(\frac{I}{k \cdot I_N}\right)^2}{\left(\frac{I}{k \cdot I_N}\right)^2 - 1} \quad [min]$$
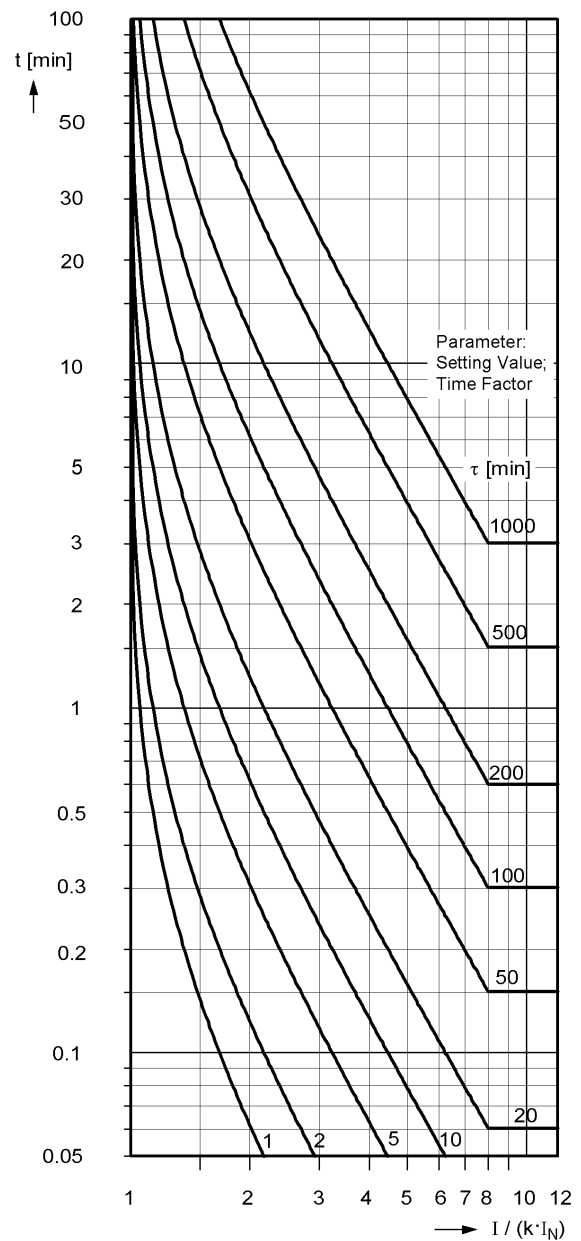
with 90 % Previous Load Current:

$$t = \tau \cdot ln \frac{\left(\frac{I}{k \cdot I_N}\right)^2 - \left(\frac{I_{pre}}{k \cdot I_N}\right)^2}{\left(\frac{I}{k \cdot I_N}\right)^2 - 1} \quad [min]$$

Figure 4-7   Trip time characteristics of the overload protection

4.21 Monitoring Function

Measured Values

Current sum		$I_F = \|\underline{I}_{L1} + \underline{I}_{L2} + \underline{I}_{L3} + k_I \cdot \underline{I}_E\| >$ SUM.I Threshold $\cdot I_N$ + SUM.I factor $\cdot \Sigma \| I \|$	
- SUM I THRESHOLD	for I_N = 1 A	0.05 A to 2.00 A	Increments 0.01 A
	for I_N = 5 A	0.25 A to 10.00 A	Increments 0.01 A
- SUM.I factor		0.00 to 0.95	Increments 0.01
Voltage sum		$U_F = \|\underline{U}_{L1} + \underline{U}_{L2} + \underline{U}_{L3} + k_U \cdot \underline{U}_{EN}\| > 25$ V	
Current Symmetry		$\| I_{min} \| / \| I_{max} \| <$ BAL.FACTOR.I as long as $I_{max} / I_N >$ BAL.I LIMIT / I_N	
- BAL.FACTOR I		0.10 to 0.95	Increments 0.01
- BAL.I LIMIT	for I_N = 1 A	0.10 A to 1.00 A	Increments 0.01 A
	for I_N = 5 A	0.50 A to 5.00 A	Increments 0.01 A
- T BAL.I LIMIT		5 s to 100 s	Increments 1 s
Broken conductor		One conductor without current, the others with current	
Voltage Symmetry		$\| U_{min} \| / \| U_{max} \| <$ BAL.FACTOR.U as long as $\| U_{max} \| >$ BAL.U LIMIT	
- BAL.FACTOR U		0.58 to 0.95	Increments 0.01
- BAL.U LIMIT		10 V to 100 V	Increments 1 V
- T BAL.U LIMIT		5 s to 100 s	Increments 1 s
Voltage phase sequence		$\underline{U}_{L1}$ before $\underline{U}_{L2}$ before $\underline{U}_{L3}$ as long as $\| \underline{U}_{L1}\|, \| \underline{U}_{L2}\|, \| \underline{U}_{L3}\| > 40$ V/$\sqrt{3}$	
Non-symmetrical voltages (Fuse failure monitoring)		$3 \cdot U_0 >$ FFM U> OR $3 \cdot U_2 >$ FFM U> AND at the same time $3 \cdot I_0 <$ FFM I< AND $3 \cdot I_2 <$ FFM I<	
- FFM U>		10 V to 100 V	Increments 1 V
- FFM I<	for I_N = 1 A	0.10 A to 1.00 A	Increments 0.01 A
	for I_N = 5 A	0.50 A to 5.00 A	Increments 0.01 A
Three-phase measuring voltage failure (fuse failure monitoring)		All $U_{Ph-E} <$ FFM UMEAS< AND at the same time All $\Delta I_{Ph} <$ FFM Idelta AND All $I_{Ph} > (I_{Ph}>$ (Dist.)) OR All $U_{Ph-E} <$ FFM UMEAS< AND at the same time All $I_{Ph} < (I_{Ph}>$ (Dist.)) AND All $I_{Ph} > 40$ mA	
- FFM U<max		2 V to 100 V	Increments 1 V
- FFM I_{delta}	for I_N = 1 A	0.05 A to 1.00 A	Increments 0.01 A
	for I_N = 5 A	0.25 A to 5.00 A	Increments 0.01 A
- T V-Supervision (wait time for additional measured voltage failure monitoring)		0.00 s to 30.00 s	Increments 0.01 s
- T VT mcb		0 ms to 30 ms	Increments 1 ms

Trip Circuit Monitoring

Number of monitored circuits	1 to 3	
Operation per circuit	With 1 binary input or with 2 binary inputs	
Pickup and Dropout Time	Approx. 1 to 2 s	
Settable delay time for operation with 1 binary input	1 s to 30 s	Increments 1 s

4.22 Transmission of Binary Information (optional)

General

> **Note:** The setting for remote signal reset delay for communication failure may be 0 s to 300 s or ∞. With setting ∞ annunciations are maintained indefinitely.

Remote Commands

Number of possible remote commands	4		
Operating times, total approx.			
Transmission speed	512 kbit/s	128 kbit/s	64 kbit/s
2 ends, minimum, typical	12 ms 14 ms	14 ms 16 ms	16 ms 18 ms
3 ends, minimum, typical	13 ms 15 ms	16 ms 19 ms	21 ms 24 ms

Drop-off times, total approx.			
Transmission speed	512 kbit/s	128 kbit/s	64 kbit/s
2 ends, minimum, typical	10 ms 12 ms	12 ms 14 ms	13 ms 16 ms
3 ends, minimum, typical	10 ms 12 ms	13 ms 16 ms	18 ms 21 ms

> The operating times refer to the entire signal path from entry via binary inputs until output of commands via fast output relays. For high-speed relays (7SA6***-*M/N/P/Q/R/S) approx. 5 ms can be subtracted from the time values.

Remote Signals

Number of possible remote signals	24		
Operating times, total approx.			
Transmission speed	512 kbit/s	128 kbit/s	64 kbit/s
2 ends, minimum, typical	12 ms 14 ms	14 ms 16 ms	16 ms 18 ms
3 ends, minimum, typical	13 ms 15 ms	16 ms 19 ms	21 ms 24 ms

Drop-off times, total approx.			
Transmission speed	512 kbit/s	128 kbit/s	64 kbit/s
2 ends, minimum, typical	10 ms 12 ms	12 ms 14 ms	13 ms 16 ms
3 ends, minimum, typical	10 ms 12 ms	13 ms 16 ms	18 ms 21 ms

The operating times refer to the entire signal path from entry via binary inputs until output of commands via fast output relays. For high-speed relays (7SA6***-*M/N/P/Q/R/S) approx. 5 ms can be subtracted from the time values.

4.23   User Defined Functions (CFC)

Function Modules and Possible Assignments to Task Levels

Function Module	Explanation	Task Level			
		MW_BEARB	PLC1_BEARB	PLC_BEARB	SFS_BEARB
ABSVALUE	Magnitude calculation	X	-	-	-
ADD	Addition	X	X	X	X
AND	AND - Gate	X	X	X	X
BOOL_TO_CO	Boolean to Control (conversion)	-	X	X	-
BOOL_TO_DL	Boolean to Double Point (conversion)	-	X	X	X
BOOL_TO_IC	Bool to internal SI, conversion	-	X	X	X
BUILD_DI	Create Double Point annunciation	-	X	X	X
CMD_CHAIN	Switching sequence	-	X	X	-
CMD_INF	Command information	-	-	-	X
CONNECT	Connection	-	X	X	X
D_FF	D- Flipflop	-	X	X	X
D_FF_MEMO	Status memory for restart	X	X	X	X
DI_TO_BOOL	Double Point to Boolean (conversion)	-	X	X	X
DIV	Division	X	X	X	X
DM_DECODE	Decode double point	X	X	X	X
DYN_OR	Dynamic OR	X	X	X	X
LIVE_ZERO	Live-zero, non linear Curve	X	-	-	-
LONG_TIMER	Timer (max.1193h)	X	X	X	X
LOOP	Feedback loop	X	X	X	X
LOWER_SETPOINT	Lower limit	X	-	-	-
MUL	Multiplication	X	X	X	X
NAND	NAND - Gate	X	X	X	X
NEG	Negator	X	X	X	X
NOR	NOR - Gate	X	X	X	X
OR	OR - Gate	X	X	X	X
RS_FF	RS- Flipflop	-	X	X	X
SQUARE_ROOT	Root extractor	X	X	X	X
SR_FF	SR- Flipflop	-	X	X	X
SUB	Substraction	X	X	X	X
TIMER	Timer	-	X	X	-
UPPER_SETPOINT	Upper limit	X	-	-	-
X_OR	XOR - Gate	X	X	X	X
ZERO_POINT	Zero supression	X	-	-	-

General Limits

Description	Limit	Comments
Maximum number of all CFC charts considering all task levels	32	When the limit is exceeded, an error message is output by the device. Consequently, the device starts monitoring. The red ERROR-LED lights up.
Maximum number of all CFC charts considering one task level	16	Only Error Message (evolving fault in processing procedure)
Maximum number of all CFC inputs considering all charts	400	When the limit is exceeded, an error message is output by the device. Consequently, the device starts monitoring. The red ERROR-LED lights up.
Maximum number of inputs of one chart for each task level (number of unequal information items of the left border per task level)	400	Only fault annunciation; here the number of elements of the left border per task level is counted. Since the same information is indicated at the border several times, only unequal information is to be counted.
Maximum number of reset-resistant flipflops D_FF_MEMO	50	When the limit is exceeded, an error message is output by the device. Consequently, the device is put into monitoring mode. The red ERROR-LED lights up.

Device-specific Limits

Description	Limit	Comments
Maximum number of synchronous changes of chart inputs per task level	50	When the limit is exceeded, an error message is output by the device. Consequently, the device is put into monitoring mode. The red ERROR-LED lights up.
Maximum number of chart outputs per task level	150	

Additional Limits

Additional Limits [1] for the following 4 CFC Blocks:				
Task Level	Maximum Number of Modules in the Task Levels			
	LONG_TIMER	TIMER	CMD_CHAIN	D_FF_MEMO
MW_BEARB	18	9	20	50
PLC1_BEARB				
PLC_BEARB				
SFS_BEARB				

[1] When the limit is exceeded, an error message is output by the device. Consequently, the device is put into monitoring mode. The red ERROR-LED lights up.

Maximum Number of TICKS in the Task Levels

Task Level	Limit in TICKS [1]
MW_BEARB (Measured Value Processing)	10 000
PLC1_BEARB (Slow PLC Processing)	1 900
PLC_BEARB (Fast PLC Processing)	200
SFS_BEARB (switchgear interlocking)	10 000

[1] When the sum of TICKS of all blocks exceeds the limits before-mentioned, an error message is output by CFC.

Processing Times in TICKS required by the Individual Elements

Individual Element		Number of TICKS
Block, basic requirement		5
Each input more than 3 inputs for generic modules		1
Connection to an input signal		6
Connection to an output signal		7
Additional for each chart		1
Operating sequence module	CMD_CHAIN	34
Flipflop	D_FF_MEMO	6
Loop module	LOOP	8
Decoder	DM_DECODE	8
Dynamic OR	DYN_OR	6
Addition	ADD	26
Subtraction	SUB	26
Multiplication	MUL	26
Division	DIV	54
Square root	SQUARE_ROOT	83

4.24 Auxiliary Functions

Measured Values

Operational measured values for currents	I_{L1}; I_{L2}; I_{L3}; $3I_0$; I_1; I_2; I_Y; I_P in A primary and secondary and in % I_N
Tolerance	0.5 % of measured value, or 0.5 % of U_N
Operational measured values for voltages	U_{L1-E}, U_{L2-E}, U_{L3-E}; U_X in kV primary, in V secondary or in % of $U_N/\sqrt{3}$
Tolerance	0.5 % of measured value, or 0.5 % of U_N
Operational measured values for voltages	$3U_0$ in kV primary, in V secondary or in % of $U_N/\sqrt{3}$
Tolerance	0.5 % of measured value, or 0.5 % of U_N
Operational measured values for voltages	$U_{L1–L2}$, $U_{L2–L3}$, U_{L3-L1}, U_X, U_1; U_2; U_{1Ko} in kV primary, in V secondary or in % of U_N
Tolerance	0.5 % of measured value, or 0.5 % of U_N
Operational measured values of impedances	R_{L1-L2}, R_{L2-L3}, R_{L3-L1}, R_{L1-E}, R_{L2-E}, R_{L3-E}, X_{L1-L2}, X_{L2-L3}, X_{L3-L1}, X_{L1-E}, X_{L2-E}, X_{L3-E} in Ω primary and secondary
Operational measured values for power	S; P; Q (apparent, active and reactive power) in MVA; MW; Mvar primary and % S_N (operational nominal power) = $\sqrt{3} \cdot U_N \cdot I_N$
Tolerance	1 % of S_N at I/I_N and U/U_N from 50 to 120%
	1 % of P_N at I/I_N and U/U_N from 50 to 120% and ABS ($\cos\varphi$) from 0.7 to 1
	1 % of Q_N at I/I_N and U/U_N from 50 to 120% and ABS ($\cos\varphi$) from 0.7 to 1
Operating measured value for power factor	$\cos \varphi$
Tolerance	0.02
Counter values for energy	Wp, Wq (real and reactive energy) in kWh (MWh or GWh) and in kVARh (MVARh or GVARh)
Tolerance [1]	5 % for $I > 0.5\ I_N$, $U > 0.5\ U_N$ and $|\cos\varphi| \geq 0.707$
Operational measured values for frequency	f in Hz and % f_N
Range	94 % to 106 % of f_N
Tolerance	10 mHz and 0.2 %
Thermal measured values	$\Theta_{L1}/\Theta_{TRIP}$, $\Theta_{L2}/\Theta_{TRIP}$, $\Theta_{L3}/\Theta_{TRIP}$, Θ/Θ_{TRIP} related to tripping temperature rise
Operational measured values of synchro check	U_{line}, U_{sync}, U_{diff} f_{line}, f_{sync}, f_{diff} in Hz; φ_{diff} in°
Measured values of earth fault	I_{Ea}; I_{Er} active and reactive component of earth fault (residual) current In A primary and mA secondary
Long-term mean value	I_{L1}dmd; I_{L2}dmd; I_{L3}dmd; I_{1d}md; Pdmd; Pdmd Forw, Pdmd Rev; Qdmd; QdmdForw; QdmdRev; Sdmd in primary values

Minimum and maximum values	I_{L1}; I_{L2}; I_{L3}; I_1; $I_{L1}d$; $I_{L2}d$; $I_{L3}d$; I_1d; U_{L1-E}; U_{L2-E}; U_{L3-E}; U_1; U_{L1-L2}; U_{L2-L3}; U_{L3-L1}; $3U_0$; P Forw; P Rev; Q Forw; Q Rev; S; Pd; Qd; Sd; cos φ Pos; cos φ Neg; f in primary values
Remote measured values for currents	I_{L1}, I_{L2}, I_{L3} of remote end $\varphi(I_{L1})$; $\varphi(I_{L2})$; $\varphi(I_{L3})$ (remote versus local) in °
Remote measured values for currents	U_{L1}; U_{L2}; U_{L3} of remote end $\varphi(U_{L1})$; $\varphi(U_{L2})$; $\varphi(U_{L3})$ (remote versus local) in °

[1] at nominal frequency

Analog Outputs (optional)

Quantity	Max. 4 (depending on variant)	
Possible measured values	I_{L2}; U_{L2-L3}; $|P|$; $|Q|$ in %	
Possible fault values	Fault distance d in % or km/miles; latest max. fault current	
Range	0 mA to 22.5 mA	
Output time for fault values	0.10 s to 180.00 s; ∞	Increments 0.01 s

Operational Event Log Buffer

Capacity	200 records

Earth Fault Detection Buffer (non-earthed systems)

Capacity	8 earth faults with a total of max. 200 messages

Fault Protocol

Capacity	8 faults with a total of max. 600 messages

Fault Recording

Number of stored fault records	Max. 8
Storage time	Max. 5s for each fault approx. 15 s in total
Sampling rate at f_N = 50 Hz	1 ms
Sampling rate at f_N = 60 Hz	0.83 ms

Statistics (serial protection data interface)

Availability of transmission for applications with protection data interface	Availability in %/min and %/h
Delay time of transmission	Resolution 0.01 ms

Statistics

Number of trip events caused by the device	Separately for each breaker pole (if single-pole tripping is possible)
Number of automatic reclosures initiated by the device	Separate for 1-pole and 3-pole AR; separate for 1st AR cycle and for all further cyles
Total of interrupted currents	Pole segregated
Maximum interrupted current	Pole segregated

Real Time Clock and Buffer Battery

Resolution for operational events	1 ms
Resolution for fault events	1 ms
Buffer battery	Type: 3 V/1 Ah, Type CR 1/2 AA self-discharging time approx. 10 years

4.25   Dimensions

4.25.1   Panel Flush and Cubicle Mounting (Housing Size $^1/_3$)

Side View (with Screw Terminals)   Side View (with Plug-in Terminals)   Rear View

Dimensions in mm
Values in Brackets in Inches
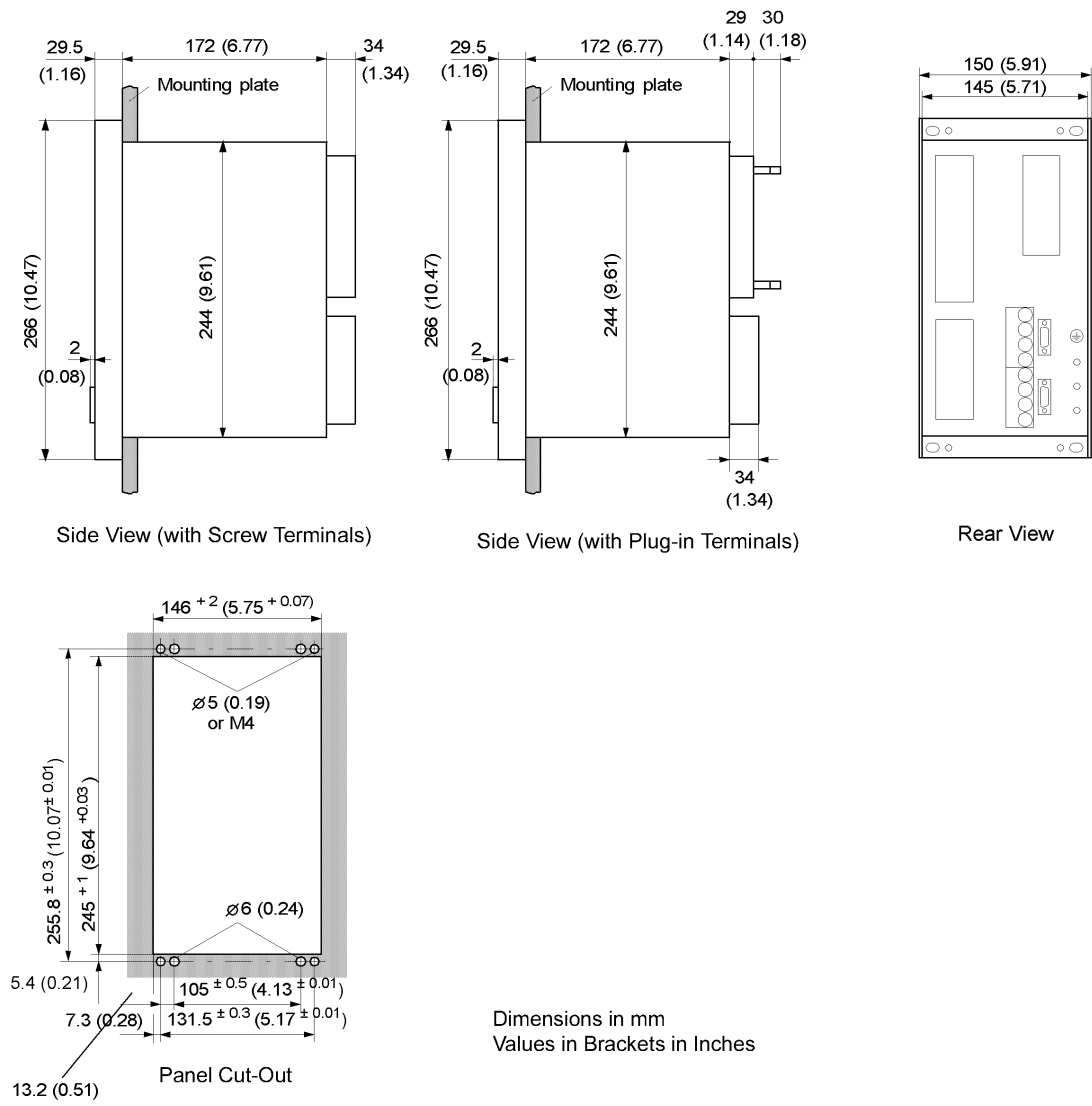
Panel Cut-Out

Figure 4-8   Dimensions of a device for panel flush mounting or cubicle installation (size $^1/_3$)

4.25.2 Panel Flush and Cubicle Mounting (Housing Size $^1/_2$)

Side View (with Screw Terminals)

Side View (with Plug-in Terminals)

Rear View

Panel Cut-Out

Dimensions in mm
Values in Brackets in Inches

Figure 4-9   Dimensions of a device for panel flush or cubicle mounting (size $^1/_2$)

4.25.3 Panel Flush and Cubicle Mounting (Housing Size $^2/_3$)
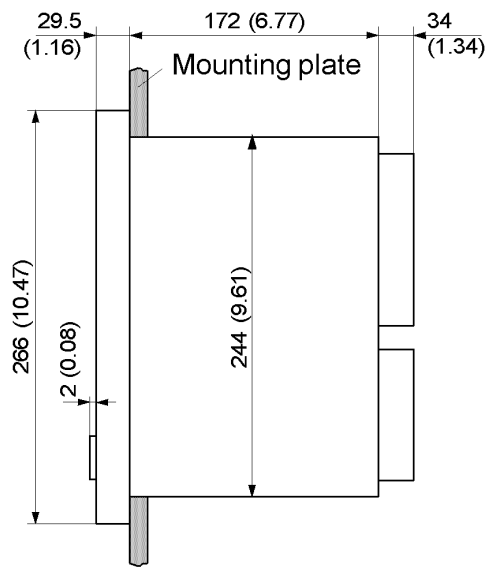
29.5 (1.16)   172 (6.77)   34 (1.34)

Mounting plate

266 (10.47)

2 (0.08)

244 (9.61)

Dimensions in mm
Values in Brackets in Inches

Side View (with Screw Terminals)

300 (11.81)
295 (11.61)

R   P   K   F

Q   N   J

Rear View

296 $^{+2}$ (11.65 $^{\pm 0.08}$)

255.8 $^{\pm 0.3}$

245 $^{+1}$ (9.64 $^{\pm 0.03}$)

5.4 (0.21)

Ø5 (0.20) or M4

Ø5 (0.20) or M4

Ø6 (0.24)

Ø5 (0.20) or M4

Ø5 (0.20) or M4

13.2 (0.52)

105 $^{\pm 0.5}$ (4.13 $^{\pm 0.12}$)   13.2 (0.52)

255 $^{\pm 0.5}$ (10.04 $^{\pm 0.12}$)

7.3 (0.29)   281.5 $^{\pm 0.3}$ (11.08 $^{\pm 0.01}$)
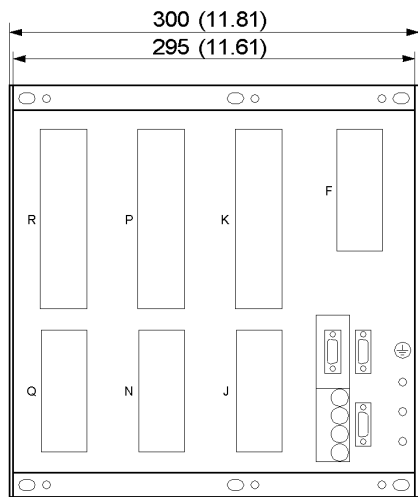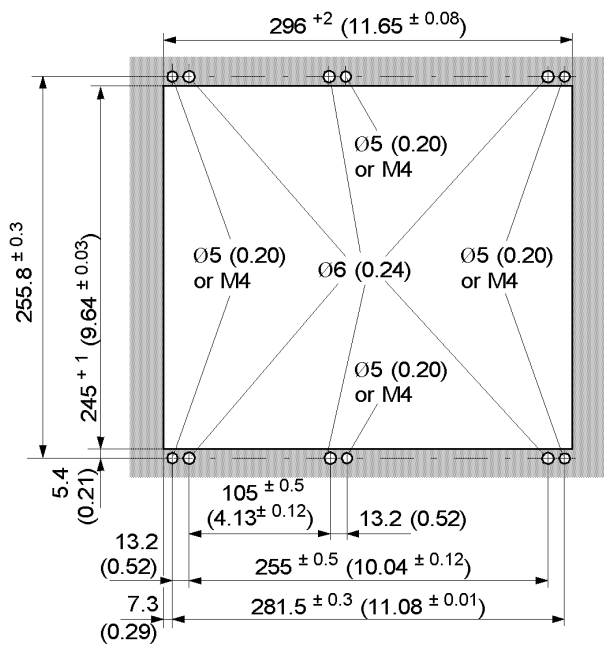
Panel Cut-Out

Figure 4-10   Dimensions of a device for panel flush mounting or cubicle installation (size $^2/_3$)

4.25.4 Panel Flush and Cubicle Mounting (Housing Size $^1/_1$)

Side View (with Screw Terminals)

Side View (with Plug-in Terminals)

Rear View

Dimensions in mm
Values in Brackets in Inches

Panel Cut-Out
(View form the Device Front)
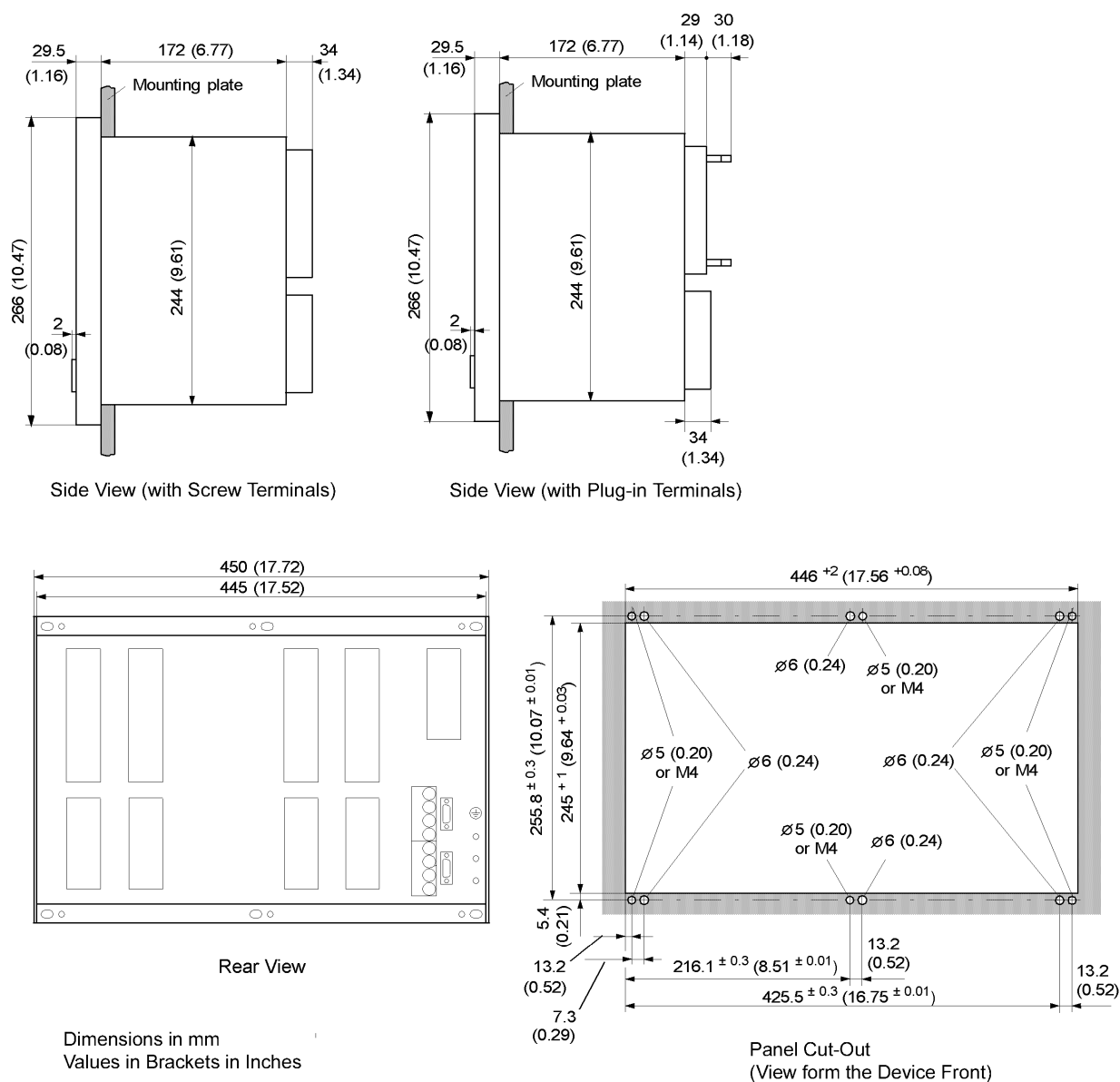
Figure 4-11   Dimensions of a device for panel flush or cubicle mounting (size $^1/_1$)

4.25.5 Panel Surface Mounting (Housing Size $^1/_3$)
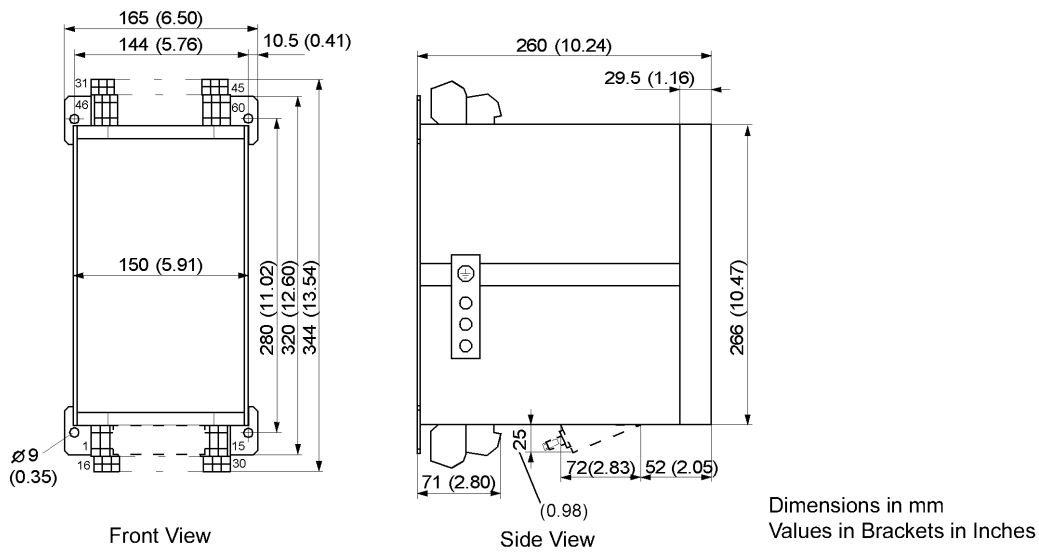
Figure 4-12   Dimensions of a device for panel surface mounting (size $^1/_3$)

4.25.6 Panel Surface Mounting (Housing Size $^1/_2$)
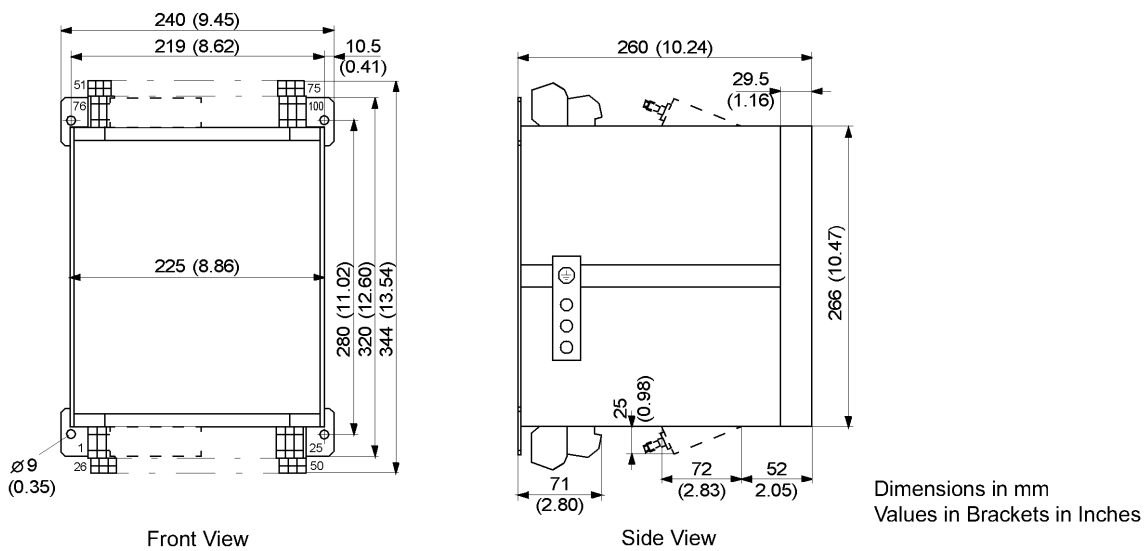
Figure 4-13   Dimensions of a device for panel surface mounting (size $^1/_2$)

4.25.7 Panel Surface Mounting (Housing Size $^1/_1$)
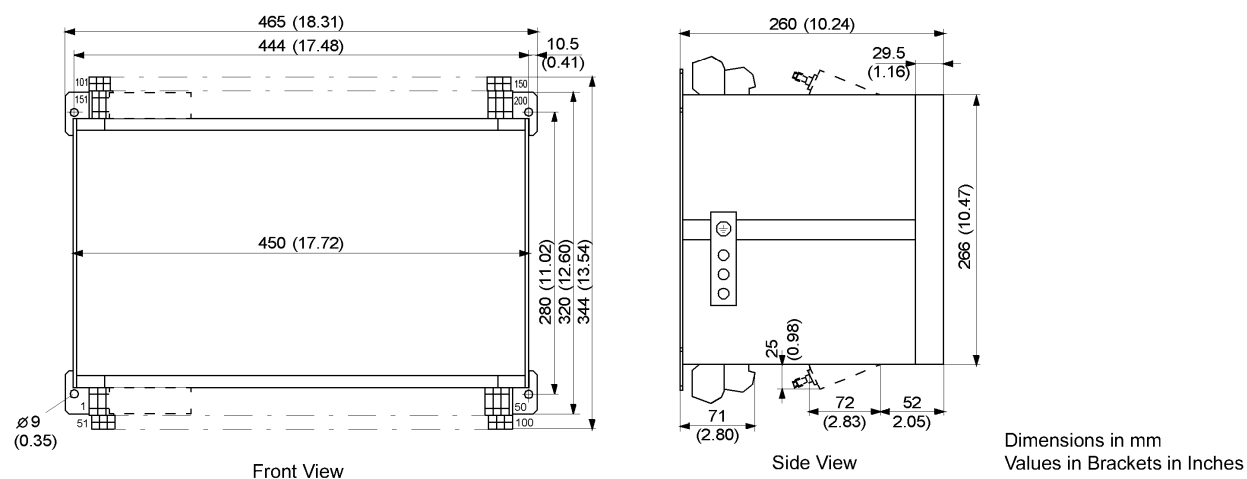
Figure 4-14   Dimensions of a device for panel surface mounting (size $^1/_1$)

4.25.8 Surface Mounting Housing with Detached Operator Panel (Housing Size $^1/_2$)

Side View (with Screw Terminals)

Side View (with Plug-in Terminals)

Rear View

Mounting Holes of Mounting Plate

Dimensions in mm
Values in Brackets in Inches
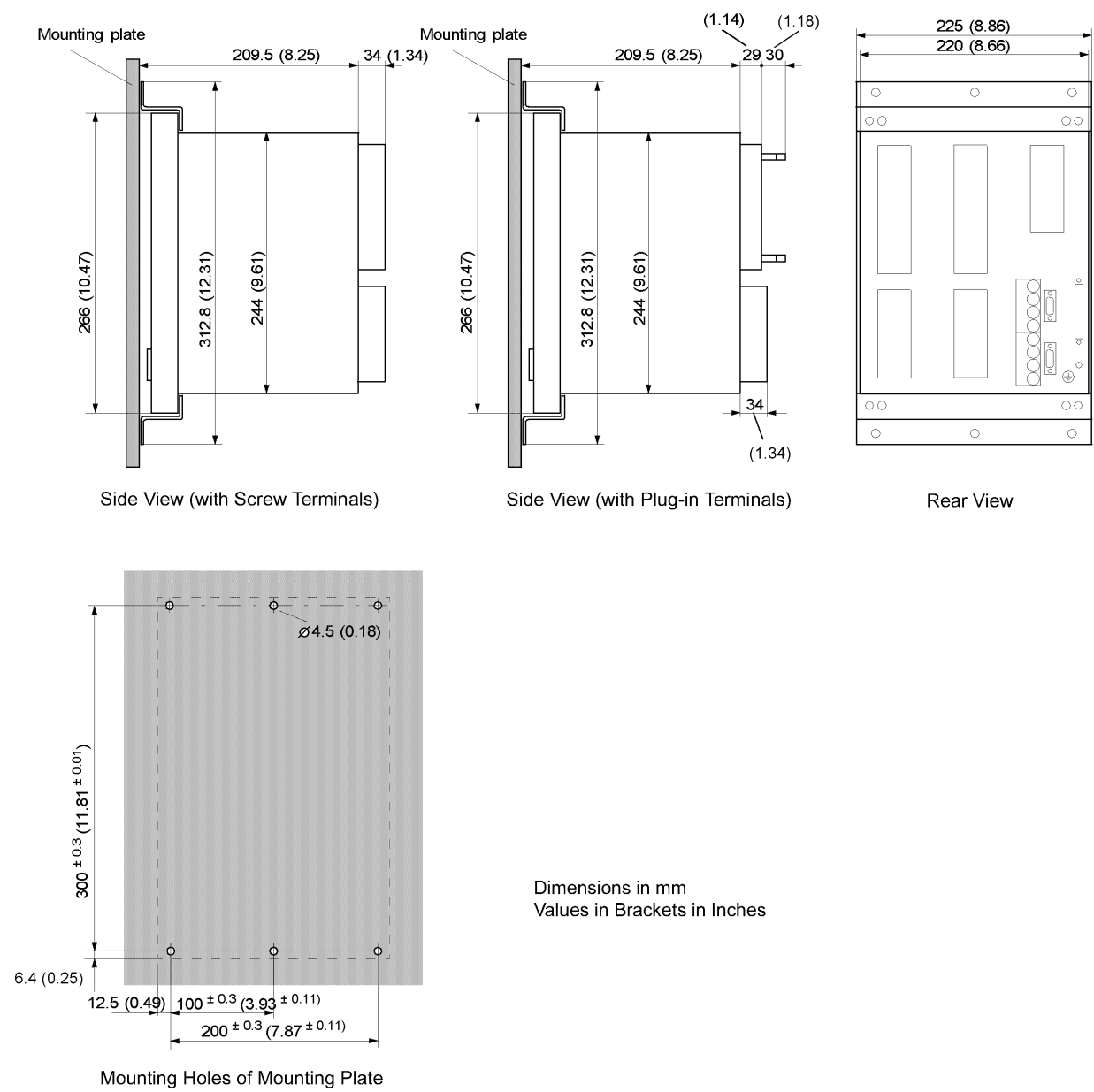
Figure 4-15   Dimensions of a device for surface mounting with detached operator panel (size $^1/_2$)

4.25.9 Surface Mounting Housing with Detached Operator Panel (Housing Size $^1/_1$)

Mounting Plate

209.5 (8.25)   34 (1.34)

266 (10.47)

312.8 (12.31)

244 (9.61)

Side View (with Screw Terminals)

(1.14)   (1.18)

Mounting Plate

209.5 (8.25)   29 30

266 (10.47)

312.8 (12.31)

244 (9.61)

34 (1.34)

Side View (with Plug-in Terminals)

450 (17.72)

445 (17.52)

Rear View

Ø4.5 (0.18)

300 ± 0.3 (11.81 $\pm$ 0.01)

6.4 (0.25)

25   100 ± 0.3 (3.94 $\pm$ 0.01)

200 ± 0.3 (7.87 $\pm$ 0.01)

300 ± 0.3 (11.81 $\pm$ 0.01)

400 ± 0.3 (15.75 $\pm$ 0.01)

Mounting Holes of Mounting Plate

Dimensions in mm
Values in Brackets in Inches

Figure 4-16   Dimensions of a device for surface mounting with detached operator panel (size $^1/_1$)

4.25.10 Detached Operator Panel
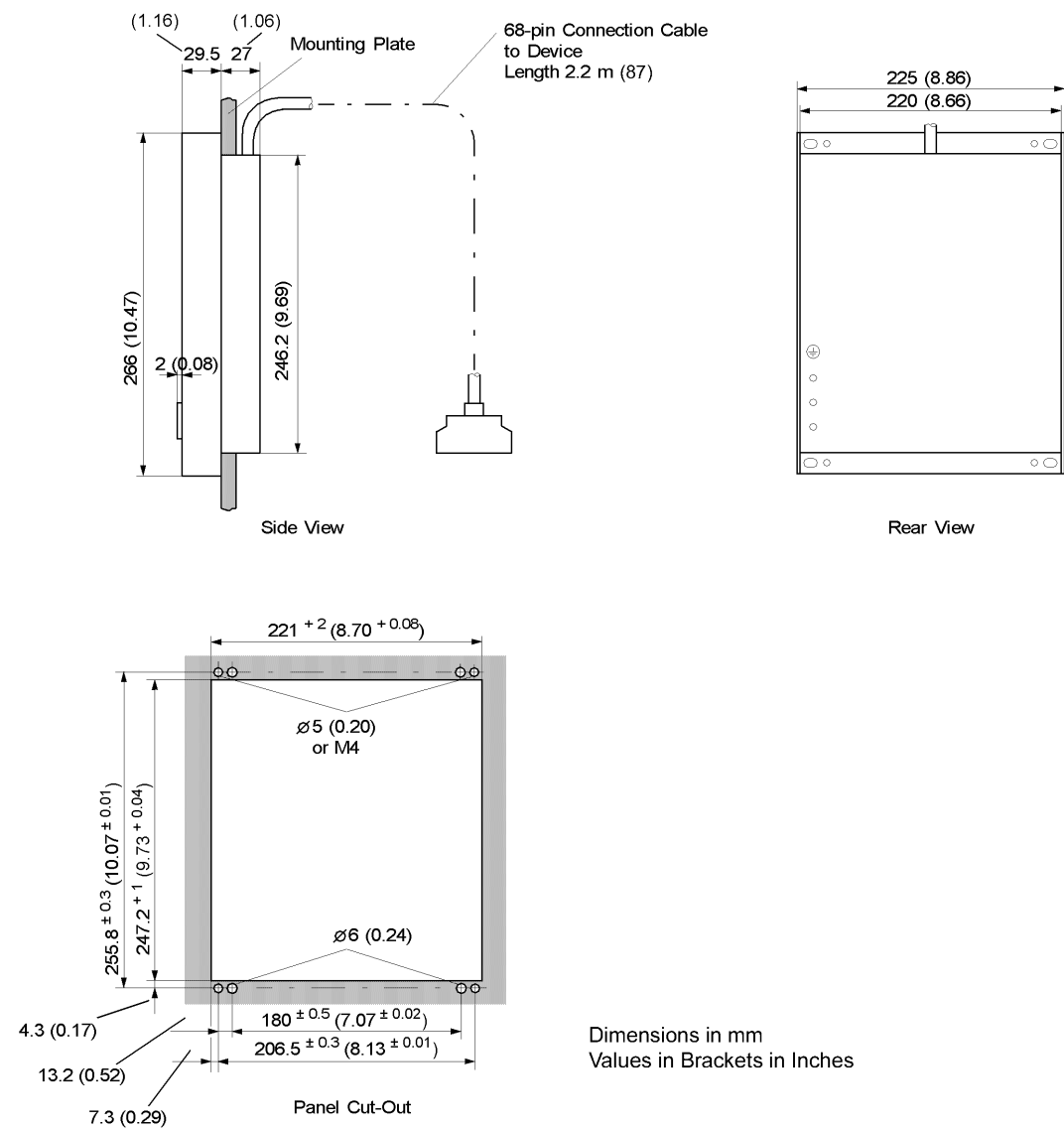
Figure 4-17   Dimensions of a Detached Operator Panel

■

Appendix A

This appendix is primarily a reference for the experienced user. This section provides ordering information for the models of this device. General diagrams indicating the terminal connections of the models of this device are included. Following the general diagrams are diagrams that show the proper connections of the devices to primary equipment in many typical power system configurations. Tables with all settings and all information available in this device equipped with all options are provided. Default settings are also given.

A.1 Ordering Information and Accessories

A.1.1 Ordering information

A.1.1.1 Ordering Code (MLFB)

Numerical Distance Protection (position 1 to 9 [3])	7	S	A	6	5	6	7	–	8	9	10	11	12	–	13	14	15	16	+	17	18	19

Function Package/Version	Pos. 5
Distance protection with 4-line display	1

Device Type	Pos. 6
Distance protection, medium voltage / high voltage. Housing size $^1/_3$ x 19"	0

Measuring Inputs (4 x U, 4 x I)	Pos. 7
I_{ph} = 1 A, I_e = 1 A (min. = 0.05 A)	1
I_{ph} = 1 A, I_e = sensitive (min. = 0.005 A)	2
I_{ph} = 5 A, I_e = 5 A (min. = 0.25 A)	5
I_{ph} = 5 A, I_e = sensitive (min. = 0.005 A)	6

Auxiliary Voltage (Power Supply, Pickup Threshold of Binary Inputs)	Pos. 8
24 to 48 VDC, binary input threshold 17 V [2]	2
60 to 125 VDC [1], Binary Input Threshold 17 V [2]	4
110 to 250 VDC [1], 115 VAC, binary input threshold 73 VDC [2]	5

Housing / Number of Binary Inputs (BI) and Outputs (BO)	Pos. 9
Flush mounting housing $^1/_3$ x 19", 5 BI, 8 BO, 1 live status contact	A
Flush mounting housing $^1/_3$ x 19", 7 BI, 5 BO, 1 live status contact	B
Surface mounting housing $^1/_3$ x 19", 5 BI, 8 BO, 1 live status contact	E
Surface mounting housing $^1/_3$ x 19", 7 BI, 5 BO, 1 live status contact	Z
Housing, $^1/_3$ x 19", with plug-in terminals, 5 BI, 8 BO, 1 live status contact	J
Housing, $^1/_3$ x 19", with plug-in terminals, 7 BI, 5 BO, 1 live status contact	K

[1] with plug-in jumper one of the 2 voltage ranges can be selected

[2] for each binary input one of 2 pick-up threshold ranges can be selected with plug-in jumper

[3] for details on positions 10 to 19 see beneath

					5	6	7		8	9	10	11	12		13	14	15	16		17	18	19
Numerical Distance Protection (position 1 to 9 [3])	7	S	A	6				–						–					+			

Function Package/Version	Pos. 5
Distance protection with 4-line display	1
Distance protection with graphic display and control keys (integrated)	3

Device Type	Pos. 6
Distance protection, medium voltage / high voltage. Housing size $^1/_2$ x 19"	1

Measuring Inputs (4 x U, 4 x I)	Pos. 7
I_{ph} = 1 A, I_e = 1 A (min. = 0.05 A)	1
I_{ph} = 1 A, I_e = sensitive (min. = 0.005 A)	2
I_{ph} = 5 A, I_e = 5 A (min. = 0.25 A)	5
I_{ph} = 5 A, I_e = sensitive (min. = 0.005 A)	6

Auxiliary Voltage (Power Supply, Pickup Threshold of Binary Inputs)	Pos. 8
24 to 48 VDC, binary input threshold 17 V [2]	2
60 to 125 VDC [1], binary input threshold 17 V [2]	4
110 to 250 VDC [1], 115 VAC, binary input threshold 73 VDC [2]	5

Housing / Number of Binary Inputs (BI) and Outputs (BO)	Pos. 9
Flush mounting housing $^1/_2$ x 19", 13 BI, 16 BO (thereof 7 fast BO), 1 live status contact	A
Flush mounting housing $^1/_2$ x 19", 20 BI, 8 BO, 4 (2) power relays [4], 1 live status contact	B
Surface mounting housing $^1/_2$ x 19", 13 BI, 16 BO (thereof 7 fast BO), 1 live status contact	E
Surface mounting housing $^1/_2$ x 19", 20 BI, 8 BO, 4 (2) power relays [4], 1 live status contact	F
Flush mounting housing, $^1/_2$ x 19", with plug-in terminals, 13 BI, 16 BO (thereof 7 fast BO), 1 live status contact	J
Flush mounting housing, $^1/_2$ x 19", with plug-in terminals, 20 BI, 8 BO, 4 (2) power relays [4], 1 live status contact	K
Flush mounting housing, $^1/_2$ x 19", 13 BI, 16 BO (thereof 5 BO with high-speed relay), 1 live status contact	M
Surface mounting housing, $^1/_2$ x 19", 13 BI, 16 BO (thereof 5 BO with high-speed relay), 1 live status contact	N
Flush mounting housing, $^1/_2$ x 19", with plug-in terminals, 13 BI, 16 BO (thereof 5 BO with high-speed relay), 1 live status contact	P

[1] with plug-in jumper one of the 2 voltage ranges can be selected

[2] for each binary input one of 2 pick-up threshold ranges can be selected with plug-in jumper

[3] for details on positions 10 to 19 see beneath

[4] 4 (2) power relays: 4 power relays (can be used in pairs)

Numerical Distance Protection (position 1 to 9 [3])	7 S A 6	5	6	7		8	9	10	11	12		13	14	15	16	+	17	18	19

Function Package/Version	Pos. 5
Distance protection with 4-line display	1
Distance protection with graphic display and control keys (integrated)	3

Device Type	Pos. 6
Distance protection, medium voltage / high voltage. Housing size $^1/_1$ x 19"	2

Measuring Inputs (4 x U, 4 x I)	Pos. 7
I_{ph} = 1 A, I_e = 1 A (min. = 0.05 A)	1
I_{ph} = 1 A, I_e = sensitive (min. = 0.005 A)	2
I_{ph} = 5 A, I_e = 5 A (min. = 0.25 A)	5
I_{ph} = 5 A, I_e = sensitive (min. = 0.005 A)	6

Auxiliary Voltage (Power Supply, Pickup Threshold of Binary Inputs)	Pos. 8
24 to 48 VDC, binary input threshold 17 V [2]	2
60 to 125 VDC [1], binary input threshold 17 V [2]	4
110 to 250 VDC [1], 115 VAC, binary input threshold 73 VDC [2]	5

Housing / Number of Binary Inputs (BI) and Outputs (BO)	Pos. 9
Flush mounting housing $^1/_1$ x 19", 21 BI, 24 BO (thereof 7 fast BO), 1 live status contact	A
Flush mounting housing $^1/_1$ x 19", 29 BI, 32 BO (thereof 7 fast BO), 1 live status contact	B
Flush mounting housing $^1/_1$ x 19", 33 BI, 11 BO, 8 (4) power relays [4], 1 live status contact	C
Surface mounting housing $^1/_1$ x 19", 21 BI, 24 BO (thereof 7 fast BO), 1 live status contact	E
Surface mounting housing $^1/_1$ x 19", 29 BI, 32 BO (thereof 7 fast BO), 1 live status contact	F
Surface mounting housing $^1/_1$ x 19", 33 BI, 11 BO, 8 (4) power relays [4], 1 live status contact	G
Flush mounting housing, $^1/_1$ x 19", with plug-in terminals, 21 BI, 24 BO (thereof 7 fast BO), 1 live status contact	J
Flush mounting housing, $^1/_1$ x 19", with plug-in terminals, 29 BI, 32 BO (thereof 7 fast BO), 1 live status contact	K
Flush mounting housing, $^1/_1$ x 19", with plug-in terminals, 33 BI, 11 BO, 8 (4) power relays [4], 1 live status contact	L
Flush mounting housing, $^1/_1$ x 19", 21 BI, 24 BO (thereof 5 BO with high-speed relay), 1 live status contact	M
Flush mounting housing, $^1/_1$ x 19", 29 BI, 32 BO (thereof 5 BO with high-speed relay), 1 live status contact	N
Surface mounting housing, $^1/_1$ x 19", 21 BI, 24 BO (thereof 5 BO with high-speed relay), 1 live status contact	P
Surface mounting housing, $^1/_1$ x 19", 29 BI, 32 BO (thereof 5 BO with high-speed relay), 1 live status contact	Q

Housing / Number of Binary Inputs (BI) and Outputs (BO)	Pos. 9
Flush mounting housing, $^1/_1$ x 19", with plug-in terminals, 21 BI, 24 BO (thereof 5 BO with high-speed relay), 1 live status contact	R
Flush mounting housing, $^1/_1$ x 19", with plug-in terminals, 29 BI, 32 BO (thereof 5 BO with high-speed relay), 1 live status contact	S

[1] with plug-in jumper one of the 2 voltage ranges can be selected

[2] for each binary input one of 2 pick-up threshold ranges can be selected with plug-in jumper

[3] for details on positions 10 to 19 see beneath

[4] 8 (4) Power Relay: 8 Power Relay (can be used in pairs)

				5	6	7		8	9	10	11	12		13	14	15	16		17	18	19
Numerical Distance Protection (position 1 to 9 [3])	7	S	A	6			−						−				+			

Function Package/Version	Pos. 5
Distance protection with 4-line display	1

Device Type	Pos. 6
Distance protection, medium voltage / high voltage. Housing size $^2/_3$ x 19"	3

Measuring Inputs (4 x U, 4 x I)	Pos. 7
I_{ph} = 1 A, I_e = 1 A (min. = 0.05 A)	1
I_{ph} = 1 A, I_e = sensitive (min. = 0.005 A)	2
I_{ph} = 5 A, I_e = 5 A (min. = 0.25 A)	5
I_{ph} = 5 A, I_e = sensitive (min. = 0.005 A)	6

Auxiliary Voltage (Power Supply, Pickup Threshold of Binary Inputs)	Pos. 8
24 to 48 VDC, binary input threshold 17 V [2]	2
60 to 125 VDC [1], binary input threshold 17 V [2]	4
110 to 250 VDC [1], 115 VAC, binary input Threshold 73 VDC [2]	5

Housing / Number of Binary Inputs (BI) and Outputs (BO)	Pos. 9
Flush mounting housing $^2/_3$ x 19'', 21 BI, 24 BO (thereof 7 fast BO), 1 live status contact	A
Flush mounting housing, $^2/_3$ x 19", 21 BI, 24 BO (thereof 5 BO with high-speed relay), 1 live status contact	M

[1] with plug-in jumper one of the 2 voltage ranges can be selected

[2] for each binary input one of 2 pick-up threshold ranges can be selected with plug-in jumper

[3] for details on positions 10 to 19 see beneath

				5	6	7		8	9	10	11	12		13	14	15	16		17	18	19
Numerical Distance Protection (position 1 to 9 [3])	7	S	A	6			−						−					+			

Function Package / Version	Pos. 5
Distance protection with graphic display and detached operator panel	4

Device Type	Pos. 6
Distance protection, medium voltage / high voltage. Housing size $^1/_2$ x 19"	1

Measuring Inputs (4 x U, 4 x I)	Pos. 7
I_{ph} = 1 A, I_e = 1 A (min. = 0.05 A)	1
I_{ph} = 1 A, I_e = sensitive (min. = 0.005 A)	2
I_{ph} = 5 A, I_e = 5 A (min. = 0.25 A)	5
I_{ph} = 5 A, I_e = sensitive (min. = 0.005 A)	6

Auxiliary Voltage (Power Supply, Pickup Threshold of Binary Inputs)	Pos. 8
24 to 48 VDC, binary input threshold 17°V [2]	2
60 to 125 VDC [1], binary input threshold 17°V [2]	4
110 to 250 VDC [1], 115 VAC, binary input threshold 73 V DC [2]	5

Housing / Number of Binary Inputs (BI) and Outputs (BO)	Pos. 9
Housing $^1/_2$ x 19", with screwed terminals, 13 BI, 16 BO (thereof 7 fast BO), 1 live status contact	A
Housing $^1/_2$ x 19", with screwed terminals, 20 BI, 8 BO, 4 (2) power relay [4], 1 live status contact	B
Housing $^1/_2$ x 19", with plug-in terminals, 13 BI, 16 BO (thereof 7 fast BO), 1 live status contact	J
Housing $^1/_2$ x 19", with plug-in terminals, 20 BI, 8 BO, 4 (2) power relay [4], 1 live status contact	K
Housing, $^1/_2$ x 19", with screwed terminals, 13 BI, 16 BO (thereof 5 BO with high-speed relay), 1 live status contact	M
Housing, $^1/_2$ x 19", with screwed terminals, 13 BI, 16 BO (thereof 5 BO with high-speed relay), 1 live status contact	P

[1] with plug-in jumper one of the 2 voltage ranges can be selected

[2] for each binary input one of 2 pick-up threshold ranges can be selected with plug-in jumper

[3] for details on positions 10 to 19 see beneath

[4] 4 (2) power relays: 4 power relays (can be used in pairs)

					5	6	7		8	9	10	11	12		13	14	15	16		17	18	19
Numerical Distance Protection (position 1 to 9 [3])	7	S	A	6				–						–					+			

Function Package/Version	Pos. 5
Distance protection with graphic display and detached operator panel	4

Device Type	Pos. 6
Distance protection, medium voltage / high voltage. Housing size $^1/_1$ x 19"	2

Measuring Inputs (4 x U, 4 x I)	Pos. 7
I_{ph} = 1 A, I_e = 1 A (min. = 0.05 A)	1
I_{ph} = 1 A, I_e = sensitive (min. = 0.005 A)	2
I_{ph} = 5 A, I_e = 5 A (min. = 0.25 A)	5
I_{ph} = 5 A, I_e = sensitive (min. = 0.005 A)	6

Auxiliary Voltage (Power Supply, Pickup Threshold of Binary Inputs)	Pos. 8
24 to 48 VDC, binary input threshold 17 V [2]	2
60 to 125 VDC [1], binary input threshold 17 V [2]	4
110 to 250 VDC [1], 115 VAC, binary input threshold 73 VDC [2]	5

Housing / Number of Binary Inputs (BI) and Outputs (BO)	Pos. 9
Housing $^1/_1$ x 19", with screwed terminals, 21 BI, 24 BO (thereof 7 fast BO), 1 live status contact	A
Housing $^1/_1$ x 19", with screwed terminals, 29 BI, 32 BO (thereof 7 fast BO), 1 live status contact	B
Housing $^1/_1$ x 19", with screwed terminals, 33 BI, 11 BO, 8 (4) power relay [4], 1 Live status contact	C
Housing $^1/_1$ x 19", with plug-in terminals, 21 BI, 24 BO (thereof 7 fast BO), 1 live status contact	J
Housing $^1/_1$ x 19", with plug-in terminals, 29 BI, 32 BO (thereof 7 fast BO), 1 live status contact	K
Housing $^1/_1$ x 19", with plug-in terminals, 33 BI, 11 BO, 8 (4) power relay [4], 1 Live status contact	L
Housing, $^1/_1$ x 19", with screwed terminals, 21 BI, 24 BO (thereof 5 BO with high-speed relay), 1 live status contact	M
Housing, $^1/_1$ x 19", with screwed terminals, 29 BI, 32 BO (thereof 5 BO with high-speed relay), 1 live status contact	N
Housing, $^1/_1$ x 19", with plug-in terminals, 21 BI, 24 BO (thereof 5 BO with high-speed relay), 1 live status contact	R
Housing, $^1/_1$ x 19", with plug-in terminals, 29 BI, 32 BO (thereof 5 BO with high-speed relay), 1 live status contact	S

[1] with plug-in jumper one of the 2 voltage ranges can be selected

[2] for each binary input one of 2 pick-up threshold ranges can be selected with plug-in jumper

[3] for details on positions 10 to 19 see beneath

[4] 8 (4) power relays: 8 power relays (can be used in pairs)

					5	6	7		8	9	10	11	12		13	14	15	16		17	18	19
Numerical Distance Protection (position 10 to 16)	7	S	A	6				−						−					+			

Region-specific Default/Language Settings and Function Versions [1]	Pos. 10
Region DE, German language (can be changed)	A
Region World, English language (GB) (language can be changed)	B
Region US, English language (US)(can be changed)	C
Region FR, French language (on request)	D
Region World, Spanish language (on request)	E
Region World, Italian language (on request)	F

[1] <u>Regulations</u> for Region-specific Default and Function Settings:
<u>Region World:</u> Default setting f = 50 Hz and line length in km, earth fault direction detection: no direction decision with zero sequence power protection, no logarithmic inverse characteristic available.
<u>Region US:</u> Default setting f = 60 Hz and line length in miles, only ANSI-inverse characteristic available, earth fault direction detection: no direction decision with zero sequence power protection, no logarithmic inverse characteristic available.
<u>Region FR:</u> Default setting f = 50 Hz and line length in km, earth fault direction detection: no logarithmic inverse characteristic available, with zero sequence power protection and weak infeed logic according to the French Specification.
<u>Region GE:</u> Default setting f = 50 Hz and line length in km, only IEC-inverse characteristic available, no STUB-Bus stage available, no logarithmic inverse characteristic for earth fault protection, no direction decision with zero sequence power protection.

Port B	Pos. 11
None	0
System port, IEC protocol 60870-5-103, electrical RS232	1
System port, IEC protocol 60870-5-103, electrical RS485	2
System port, IEC protocol 60870-5-103, optical 820 nm, ST connector	3
System port, Profibus FMS slave, electrical RS485	4
System port, Profibus FMS slave, optical, double ring, ST-connector [3]	6
Analog output 2 x 0 to 20 mA	7
For further protocols see additional information L (position 17 to 19)	9

Port C and D	Pos. 12
DIGSI/Modem, electrical RS232, port C	1
DIGSI/Modem, electrical RS485, port C	2
With port C <u>and</u> D see additional information M (position 17 to 19)	9

Functions 1	Pos. 13
Only three-pole tripping, without overload protection, without BCD-output fault location	0
Only three-pole tripping, without overload protection, with BCD-output fault location	1
Only three-pole tripping, with overload protection, without BCD-output fault location	2
Only three-pole tripping, with overload protection, with BCD-output fault location	3
Single-/three-pole tripping, without overload protection, without BCD-output fault location	4
Single-/three-pole tripping, without overload protection, with BCD-output fault location	5

Functions 1	Pos. 13
Single-/three-pole tripping, with overload protection, without BCD-output fault location	6
Single-/three-pole tripping, with overload protection, with BCD-output fault location	7

Functions 2	Pos. 14
Pickup I>, without power swing option, without parallel line compensation	A
Pickup U, I, without power swing option, without parallel line compensation	B
Pickup Z<, polygon, without power swing option, without parallel line compensation	C
Pickup Z<, polygon, U, I, φ, without power swing option, without parallel line compensation	D
Pickup Z<, polygon, with power swing option, without parallel line compensation	F
Pickup Z<, polygon, U, I, φ, with power swing option, without parallel line compensation	G
Pickup U, I, without power swing option, with parallel line compensation [2]	J
Pickup Z<, polygon, without power swing option, with parallel line compensation [2]	K
Pickup Z<, polygon, U, I, φ, without power swing option, with parallel line compensation [2]	L
Pickup Z<, polygon, with power swing option, with parallel line compensation [2]	N
Pickup Z<, polygon, U, I, φ, with power swing option, with parallel line compensation [2]	P

Functions 3				Pos. 15
Automatic Reclosure	Synchro-nism Check	Breaker Failure Protection	Voltage Protection, Frequency Protection	
without	without	without	without	A
without	without	without	with	B
without	without	with	without	C
without	without	with	with	D
without	with	without	without	E
without	with	without	with	F
without	with	with	without	G
without	with	with	with	H
with	without	without	without	J
with	without	without	with	K
with	without	with	without	L
with	without	with	with	M
with	with	without	without	N
with	with	without	with	P
with	with	with	without	Q
with	with	with	with	R

Functions 4			Pos. 16
Earth Fault Protection / Directional for Earthed Systems	Earth Fault Detection for Resonant-Earthed / Isolated Systems	Measured Values, Extended, Min / Max Values	
without	without	without	0
without	without	with	1
without	with [1]	without	2
without	with [1]	with	3
with	without	without	4
with	without	with	5
with	with [1]	without	6
with	with [1]	with	7

[1] available only with "2" or "6" on position 7

[2] available only with "1" or "5" on position 7

[3] not available with surface mounting housing

				5	6	7		8	9	10	11	12		13	14	15	16		17	18	19
Numerical Distance Protection (position 17 to 19)	7	S	A	6			–						–					+	L		

Additional Information L, Further Protocols Port B	Position 18, 19
System port, Profibus DP slave, electrical RS485	0, A
System port, Profibus DP slave, optical 820 nm, double ring, ST-connector [1]	0, B
System port, DNP3.0, electrical RS485	0, G
System port, DNP3.0, optical 820 nm, ST-connector [1]	0, H

				5	6	7		8	9	10	11	12		13	14	15	16		17	18	19
Numerical Distance Protection (position 17 to 19)	7	S	A	6			–						–					+	M		

Additional Information M, Port C	Pos. 18
DIGSI/Modem, electrical RS232	1
DIGSI/Modem, electrical RS485	2

Additional Information M, Port D for [A] Direct Connection, [B] Communication Networks	Pos. 19
Optical 820 nm, 2-ST connector, length of optical fibre up to 3.5 km for multimode-fibre (FO5), [A] or [B]	A
Optical 820 nm, 2-ST connector, length of optical fibre up to 3.5 km for multimode-fibre (FO6) [A]	B
Optical 1300 nm, 2-ST connector, length of optical fibre up to 3.5 km for monomode-fibre (FO7) [A]	C

Additional Information M, Port D for ^A) Direct Connection, ^B) Communication Networks	Pos. 19
Optical 1300 nm, 2-FC connector, length of optical fibre up to 35 km for monomode-fibre (FO8) ^A)	D
For analog output 2 x 0 to 20 mA	K

¹⁾ not available with surface mounting housing

A.1.2 Accessories

Voltage Transformer Miniature Circuit Breaker	Nominal Values	Order No.
	Thermal 1.6 A; magnetic 6 A	3RV1611-1AG14

Communication Converter	Converter for the serial connection of the distance protection system 7SA6 to the synchronous communication interfaces X.21 or G703, or for pilot wire pairs.	Order No.
	Optical–electrical communication converter X/G	7XV5662-0AA00
	Optical–electrical communication converter CC-CC	7XV5662-0AC00

Interface Modules	Exchange modules for interfaces	Order No.
	RS232	C53207-A351-D641-1
	RS485	C53207-A351-D642-1
	FO 820 nm	C53207-A351-D643-1
	Profibus FMS RS485	C53207-A351-D603-1
	Profibus FMS double ring	C53207-A351-D606-1
	Profibus DP RS485	C53207-A351-D611-1
	Profibus DP double ring	C53207-A351-D613-1
	DNP 3.0 RS 485	C53207-A351-D631-1
	DNP 3.0 820 nm	C53207-A351-D633-1
	AN20	C53207-A351-D661-1
	FO5 with ST–connector; 820nm; multi-mode optical fibre -maximum length: 1.5km 1)	C53207-A351-D651-1
	FO6 with ST–connector; 820nm; multi-mode optical fibre -maximum length: 3 km	C53207-A351-D652-1
	FO7 with ST-connector; 1300 nm; mono-mode optical fibre - maximum length: 10 km	C53207-A351-D653-1
	FO8 with FC-connector; 1300 nm; mono-mode optical fibre - maximum length: 35 km	C53207-A351-D654-1
	1) also used for connection to optical-electrical communication converter	

Terminal Block Covering Caps	Terminal Block Covering Cap for Block Type	Order No.
	18 terminal voltage, 12 terminal current block	C73334-A1-C31-1
	12 terminal voltage, 8 terminal current block	C73334-A1-C32-1

Short-Circuit Links	Short Circuit Links for Purpose / Terminal Type	Order No.
	Voltage connections (18 terminal or 12 terminal)	C73334-A1-C34-1
	Current connections (12 terminal or 8 terminal)	C73334-A1-C33-1

Plug-in Connector	Plug-in Connector	Order No.
	2-pin	C73334-A1-C35-1
	3-pin	C73334-A1-C36-1

Mounting Rail for 19"- Racks	Name	Order No.
	Angle Strip (Mounting Rail)	C73165-A63-C200-3

Battery	Lithium battery 3 V/1 Ah, type CR 1/2 AA	Order No.
	VARTA	6127 101 501

Interface Cable	An interface cable and the DIGSI® software is necessary for communication between the SIPROTEC® 4 device and a PC or Laptop: Requirements for the computer are Windows 95 or Windows NT4.	Order No.
	Interface cable between PC and SIPROTEC, Cable with 9-pin male/female connectors	7XV5100-4

DIGSI® Operating Software	Software for Configuration and Operation of SIPROTEC® 4 devices	Order No. DIGSI® software for configuration and operation
	DIGSI®, basic version with licenses for 10 computers	7XS5400-0AA00
	DIGSI®, complete version with all option packages	7XS5402-0AA0

Graphical Analysis Program SIGRA	Software for graphical visualization, analysis, and evaluation of fault data. Option package of the complete version of DIGSI®	Order No.
	Graphical Analysis Program SIGRA®, Full version with license for 10 computers	7XS5410-0AA0

Display Editor	Software for creating basic and power system control pictures (option package of the complete version of DIGSI®)	Order No.
	Display Editor 4; Full version with license for 10 PCs	7XS5420-0AA0

Graphic Tools	Graphical Software to aid in the setting of characteristic curves and provide zone diagrams for overcurrent and distance protective devices. Option package of the complete version of DIGSI® .	Order No.
	Graphic Tools 4; Full version with license for 10 PCs	7XS5430-0AA0

DIGSI REMOTE 4	Software for remotely operating protective devices via a modem (and possibly a star connector) using DIGSI (option package of the complete version of DIGSI® 4)	Order No.
	DIGSI REMOTE 4; Full version with license for 10 PCs; Language: German	7XS5440-1AA0

SIMATIC CFC 4	Graphical software for setting interlocking (latching) control conditions and creating additional functions (option package of the complete version of DIGSI®)	Order No.
	SIMATIC CFC 4; Full version with license for 10 PCs	7XS5450-0AA0

A.2 Terminal Assignments

A.2.1 Housing for Panel Flush or Cubicle Mounting

7SA610*-*A/J
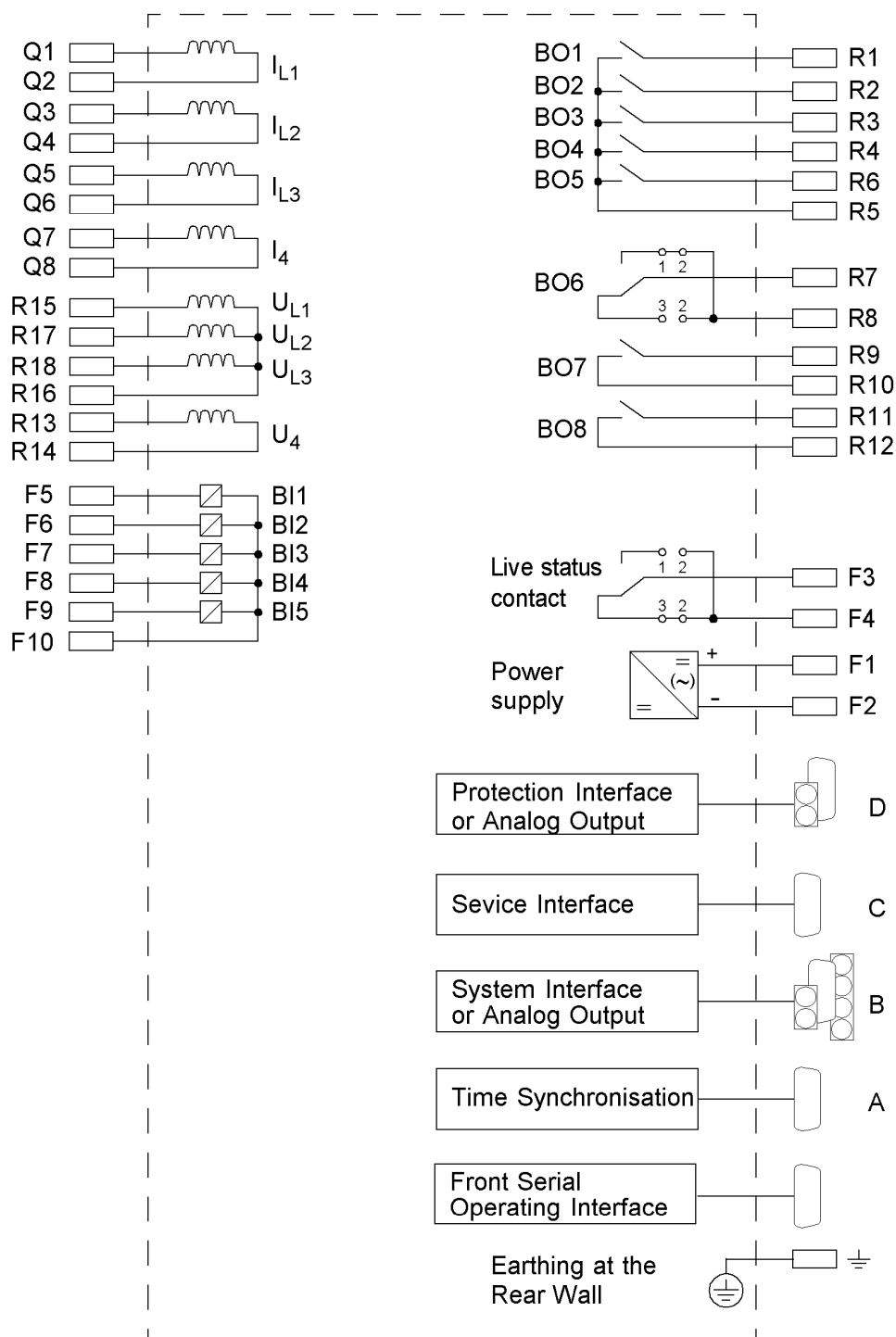
Figure A-1   General diagram for 7SA610*-*A/J (panel flush mounting or cubicle mounting)

7SA610*-*B/K
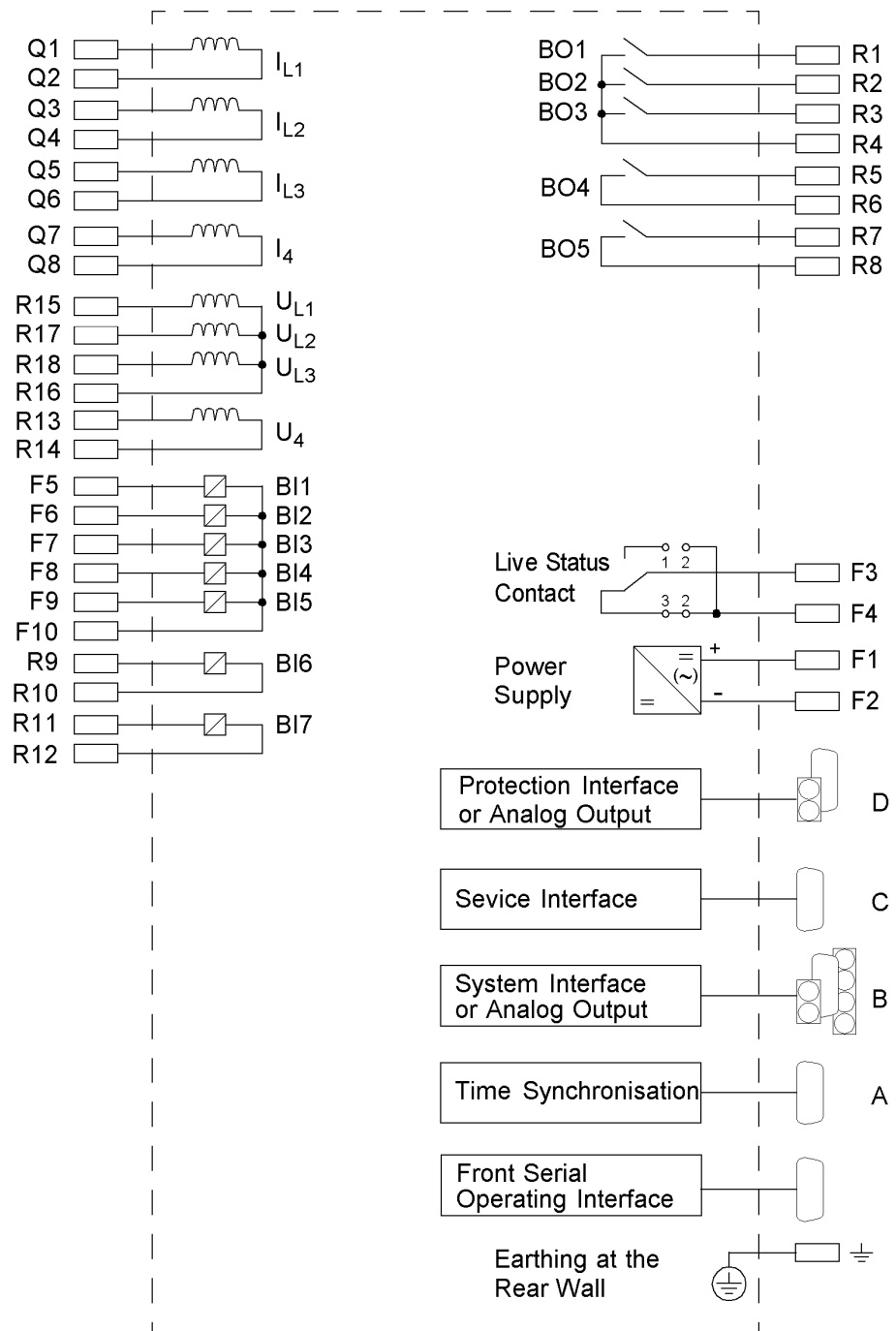
Figure A-2   General diagram for 7SA610*-*B/K (panel flush mounting or cubicle mounting)

7SA6*1*-*A/J
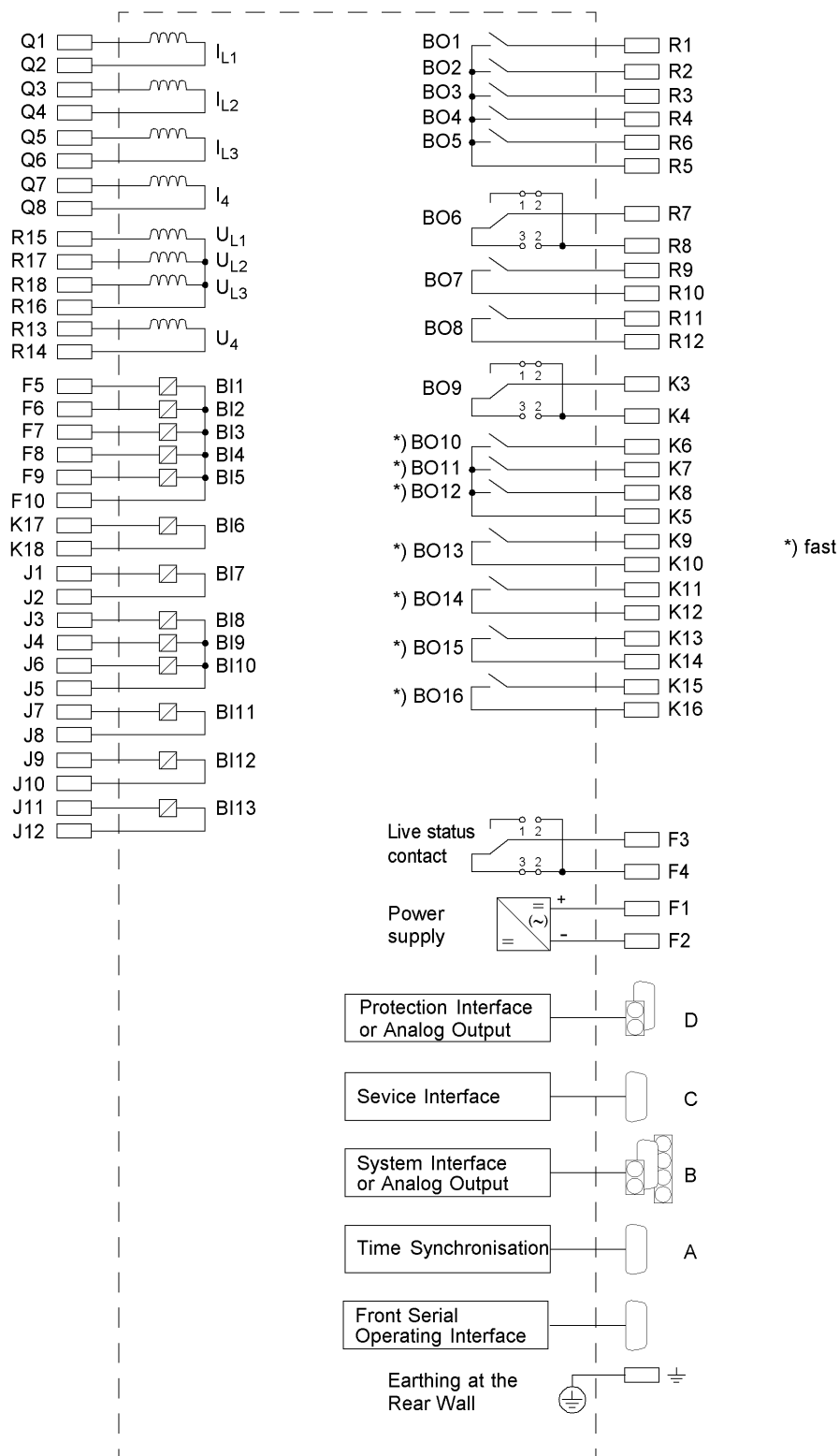
Figure A-3   General diagram for 7SA6*1*-*A/J (panel flush mounting or cubicle mounting)

7SA6*1*-*B/K
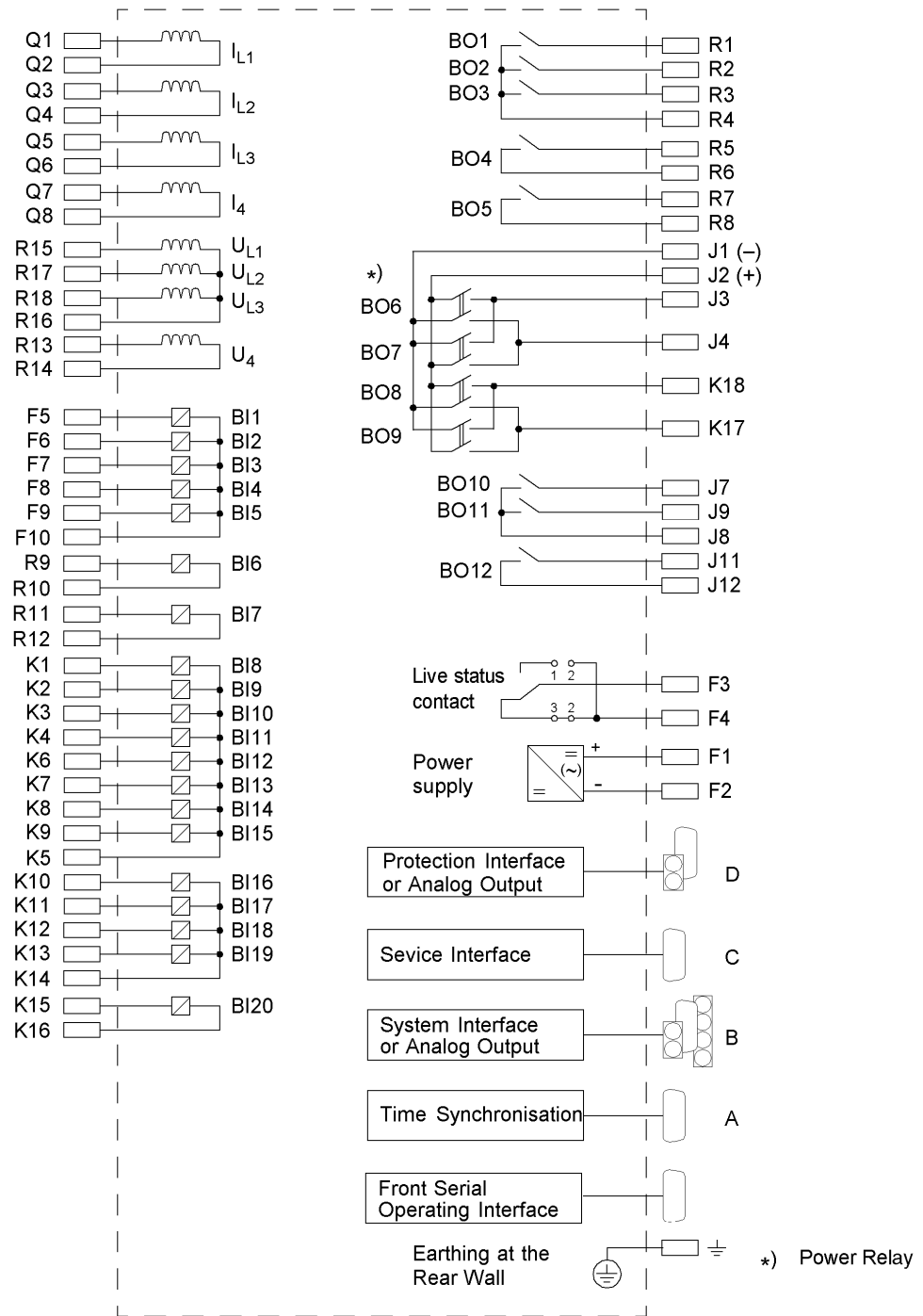
Figure A-4   General diagram for 7SA6*1*-*B/K (panel flush mounting or cubicle mounting)

7SA6*1*-*M/P
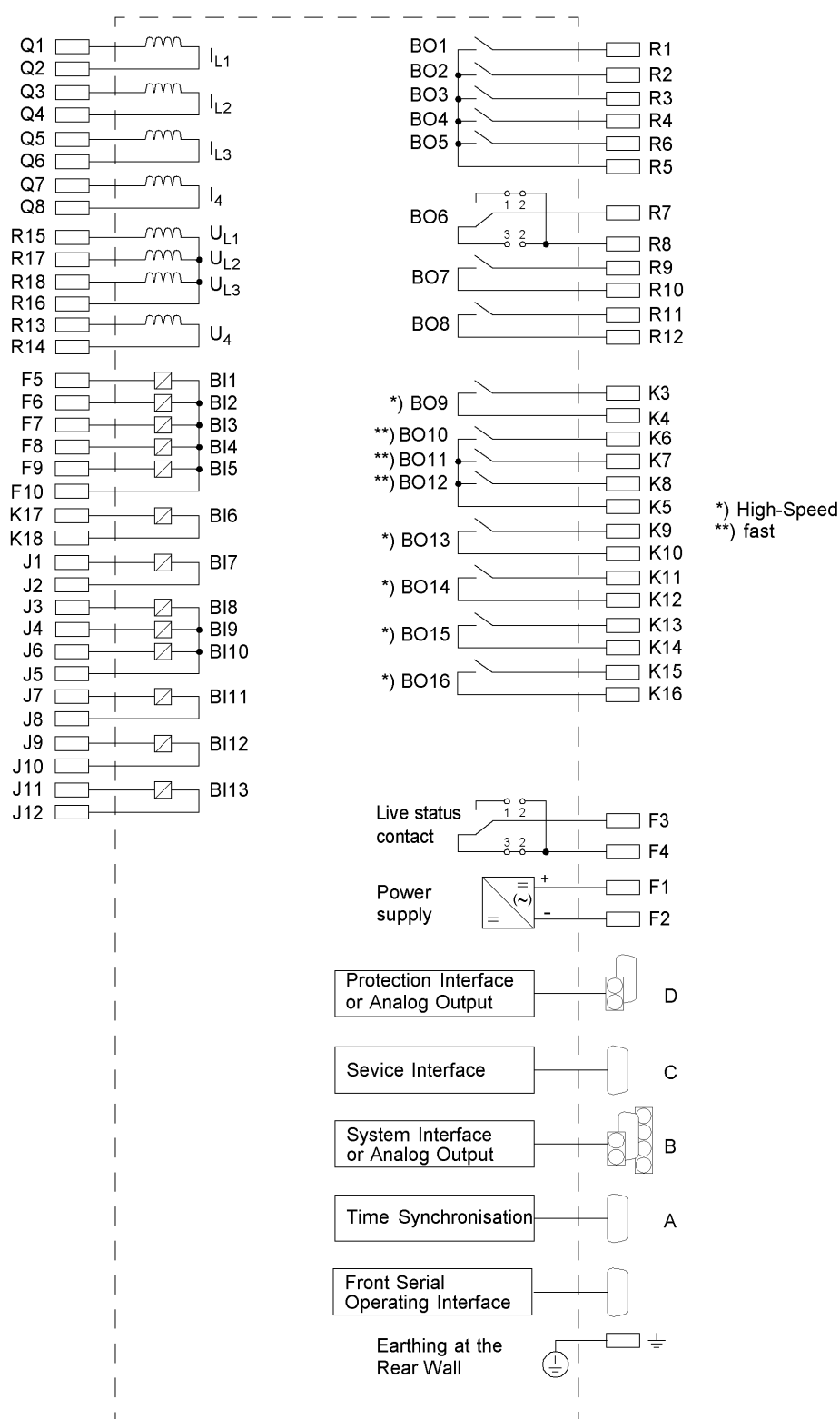
Figure A-5   General diagram for 7SA6*1*-*M/R (panel flush mounting or cubicle mounting)

7SA6*2*-*A/J
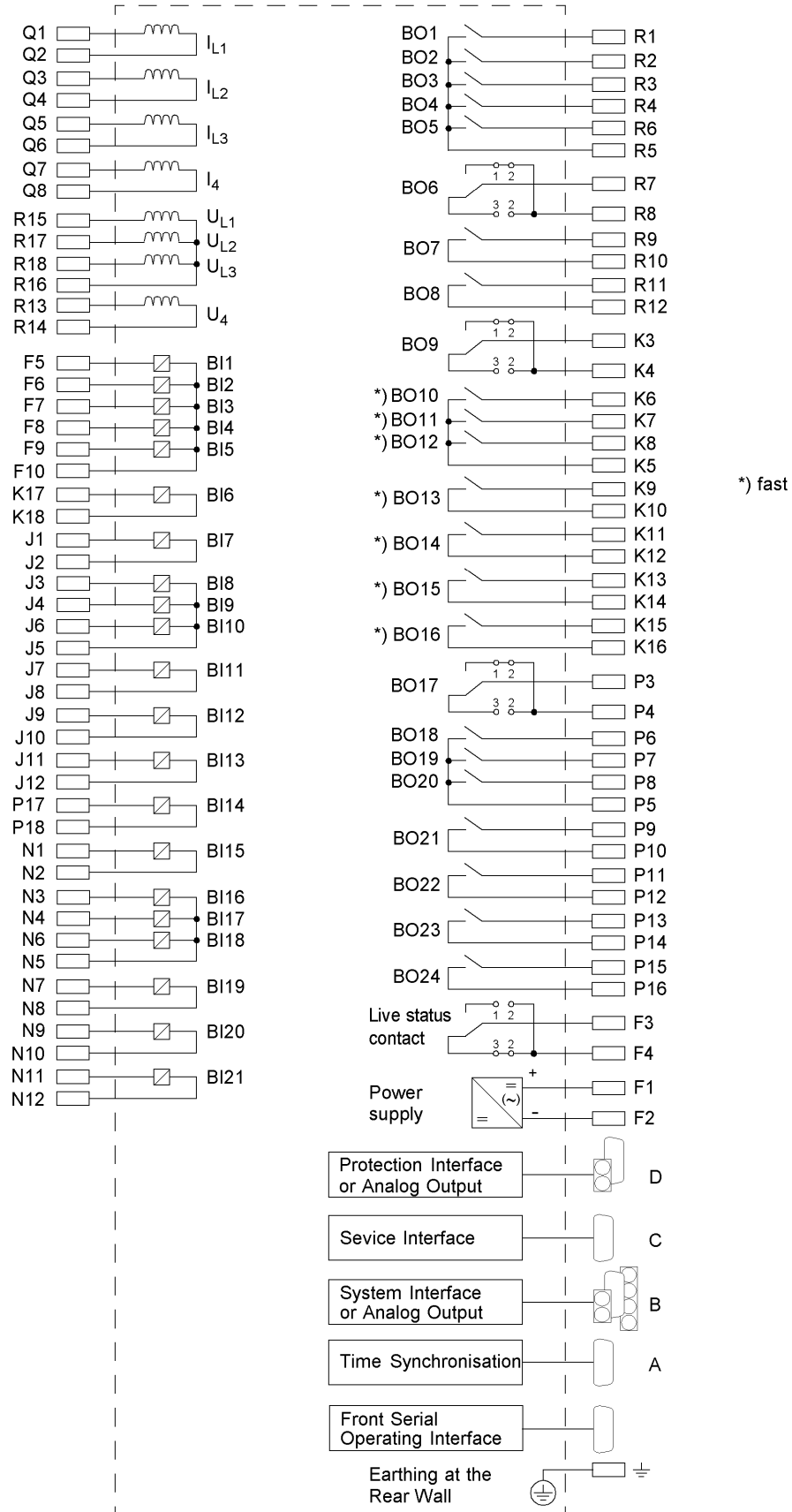
Figure A-6   General diagram for 7SA6*2*-*A/J (panel flush mounting or cubicle mounting)

7SA6*2*-*B/K

Left side (analog inputs):

Q1, Q2		I_{L1}
Q3, Q4		I_{L2}
Q5, Q6		I_{L3}
Q7, Q8		I_4
R15		U_{L1}
R17		U_{L2}
R18		U_{L3}
R16		
R13, R14		U_4

Binary inputs:

F5 — BI1
F6 — BI2
F7 — BI3
F8 — BI4
F9 — BI5
F10
K17 — BI6
K18
J1 — BI7
J2
J3 — BI8
J4 — BI9
J6 — BI10
J5
J7 — BI11
J8
J9 — BI12
J10
J11 — BI13
J12
P17 — BI14
P18
N1 — BI15
N2
N3 — BI16
N4 — BI17
N6 — BI18
N5
N7 — BI19
N8
N9 — BI20
N10
N11 — BI21
N12
H17 — BI22
H18
G1 — BI23
G2
G3 — BI24
G4 — BI25
G6 — BI26
G5
G7 — BI27
G8
G9 — BI28
G10
G11 — BI29
G12

continued next page

Right side (binary outputs):

BO1 — R1
BO2 — R2
BO3 — R3
BO4 — R4
BO5 — R6
— R5
BO6 — R7 / R8
BO7 — R9 / R10
BO8 — R11 / R12
BO9 — K3 / K4
*) BO10 — K6
*) BO11 — K7
*) BO12 — K8
— K5
*) BO13 — K9 / K10
*) BO14 — K11 / K12
*) BO15 — K13 / K14
*) BO16 — K15 / K16
BO17 — P3 / P4
BO18 — P6
BO19 — P7
BO20 — P8
— P5
BO21 — P9 / P10
BO22 — P11 / P12
BO23 — P13 / P14
BO24 — P15 / P16
BO25 — H3 / H4
BO26 — H6
BO27 — H7
BO28 — H8
— H5
BO29 — H9 / H10
BO30 — H11 / H12
BO31 — H13 / H14
BO32 — H15 / H16

Live status contact — F3 / F4

Power supply — F1 / F2

*) fast

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Figure A-7   General diagram for 7SA6*2*-*B/K (panel flush mounting or cubicle mounting)

7SA6*2*-*M/R
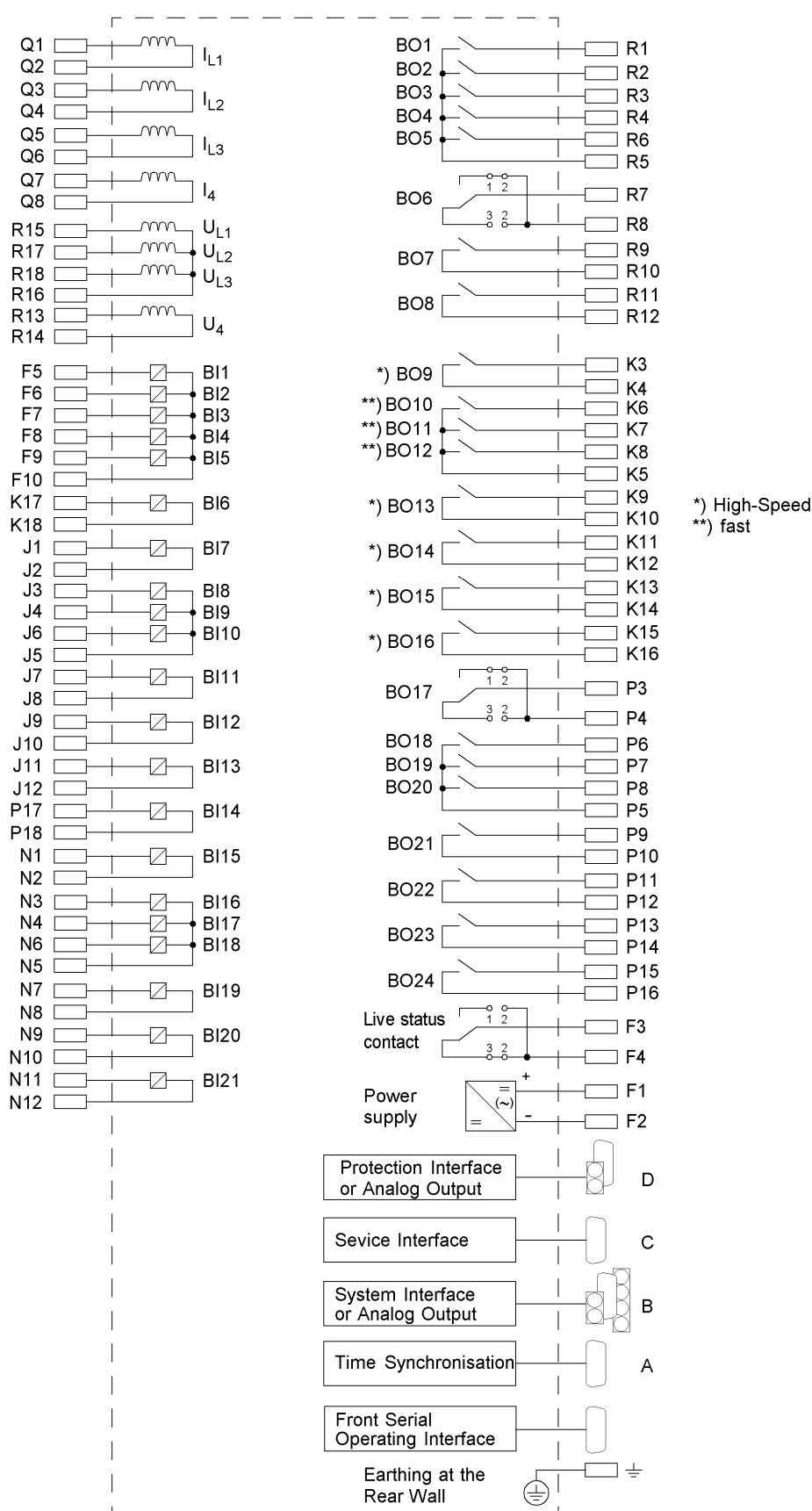
Figure A-8   General diagram for 7SA6*2*-*M/R (panel flush mounting or cubicle mounting)

7SA6*2*-*N/S

Q1 Q2	I_{L1}
Q3 Q4	I_{L2}
Q5 Q6	I_{L3}
Q7 Q8	I_4
R15 R17	U_{L1} U_{L2}
R18 R16	U_{L3}
R13 R14	U_4

F5	BI1
F6	BI2
F7	BI3
F8	BI4
F9	BI5
F10	
K17 K18	BI6
J1 J2	BI7
J3	BI8
J4	BI9
J6	BI10
J5	
J7 J8	BI11
J9 J10	BI12
J11 J12	BI13
P17 P18	BI14
N1 N2	BI15
N3	BI16
N4	BI17
N6	BI18
N5	
N7 N8	BI19
N9 N10	BI20
N11 N12	BI21
H17 H18	BI22
G1 G2	BI23
G3	BI24
G4	BI25
G6	BI26
G5	
G7 G8	BI27
G9 G10	BI28
G11 G12	BI29

BO1	R1
BO2	R2
BO3	R3
BO4	R4
BO5	R6
	R5
BO6	R7
	R8
BO7	R9
	R10
BO8	R11
	R12
*) BO9	K3 K4
**) BO10	K6
**) BO11	K7
**) BO12	K8
	K5
*) BO13	K9 K10
*) BO14	K11 K12
*) BO15	K13 K14
*) BO16	K15 K16
BO17	P3
	P4
BO18	P6
BO19	P7
BO20	P8
	P5
BO21	P9 P10
BO22	P11 P12
BO23	P13 P14
BO24	P15 P16
BO25	H3
	H4
BO26	H6
BO27	H7
BO28	H8
	H5
BO29	H9 H10
BO30	H11 H12
BO31	H13 H14
BO32	H15 H16
Live status contact	F3
	F4
Power supply	F1
	F2

*) High-Speed
**) fast

Figure A-9   General diagram for 7SA6*2*-*N/S (panel flush mounting or cubicle mounting)

7SA6*2*-*C/L
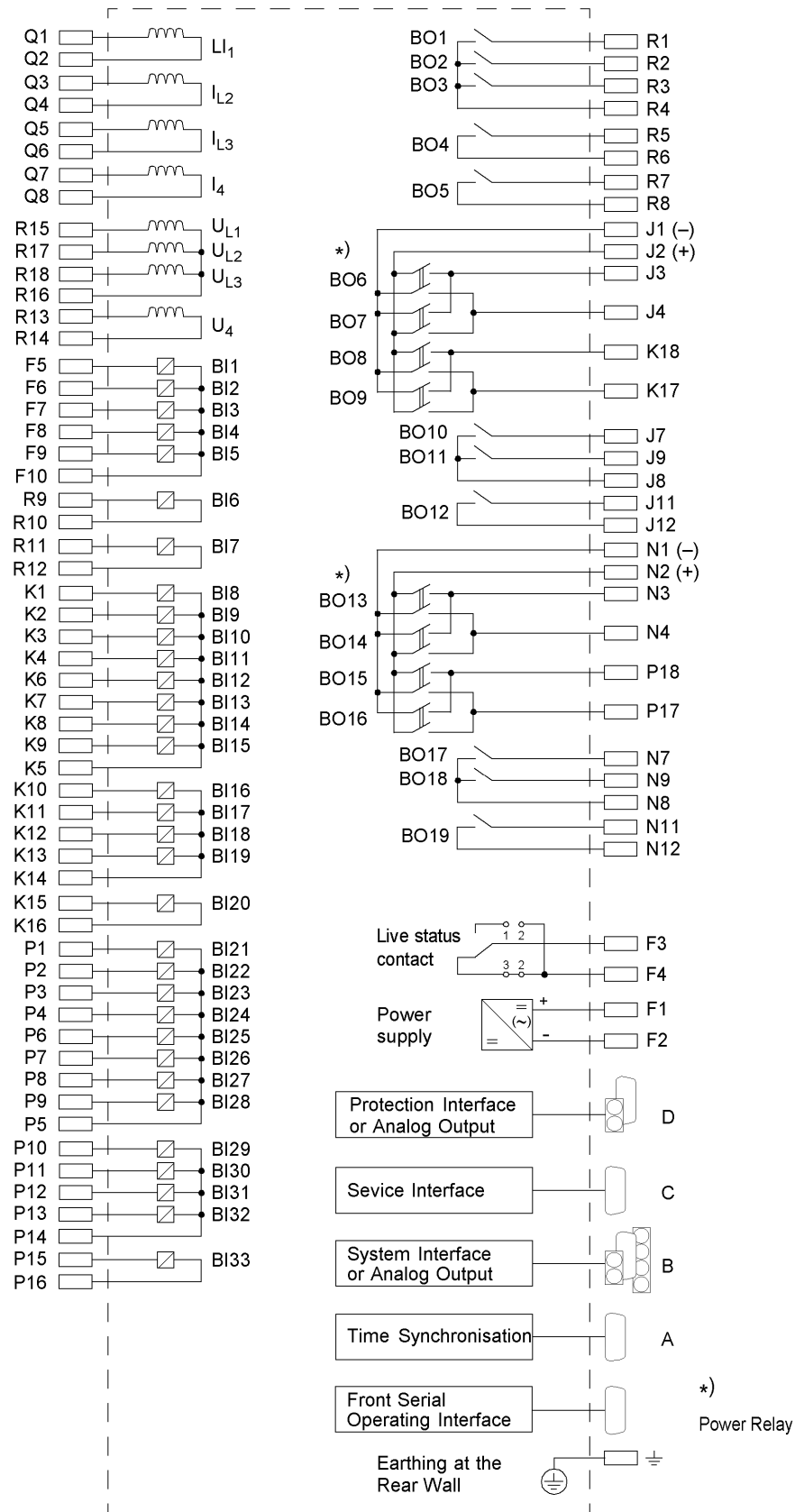
Figure A-10　　General diagram for 7SA6*2*-*C/L (panel flush mounting or cubicle mounting)

7SA613*-*A
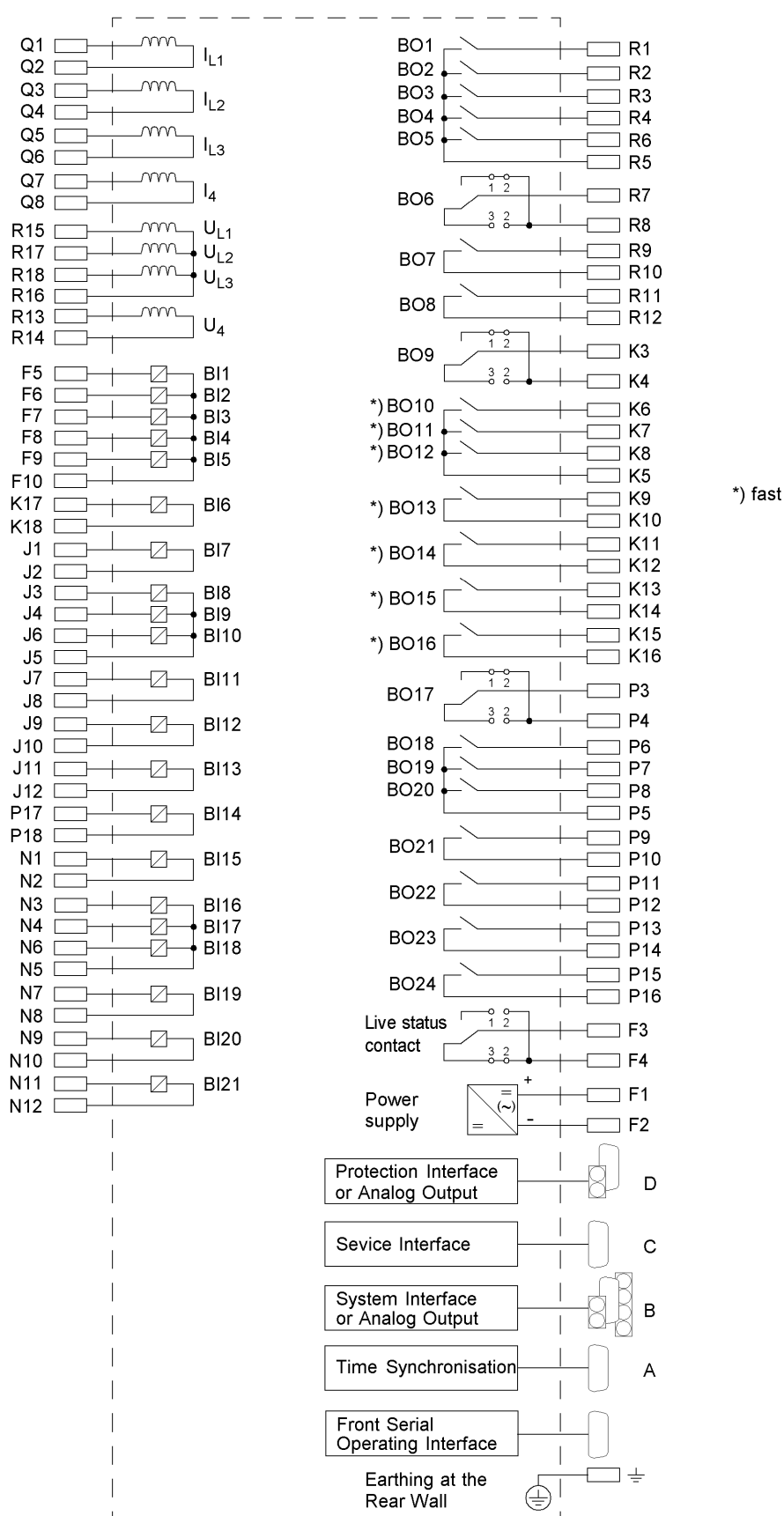
Figure A-11   General diagram for 7SA613*-*A (panel flush mounting or cubicle mounting)

7SA613*-*M
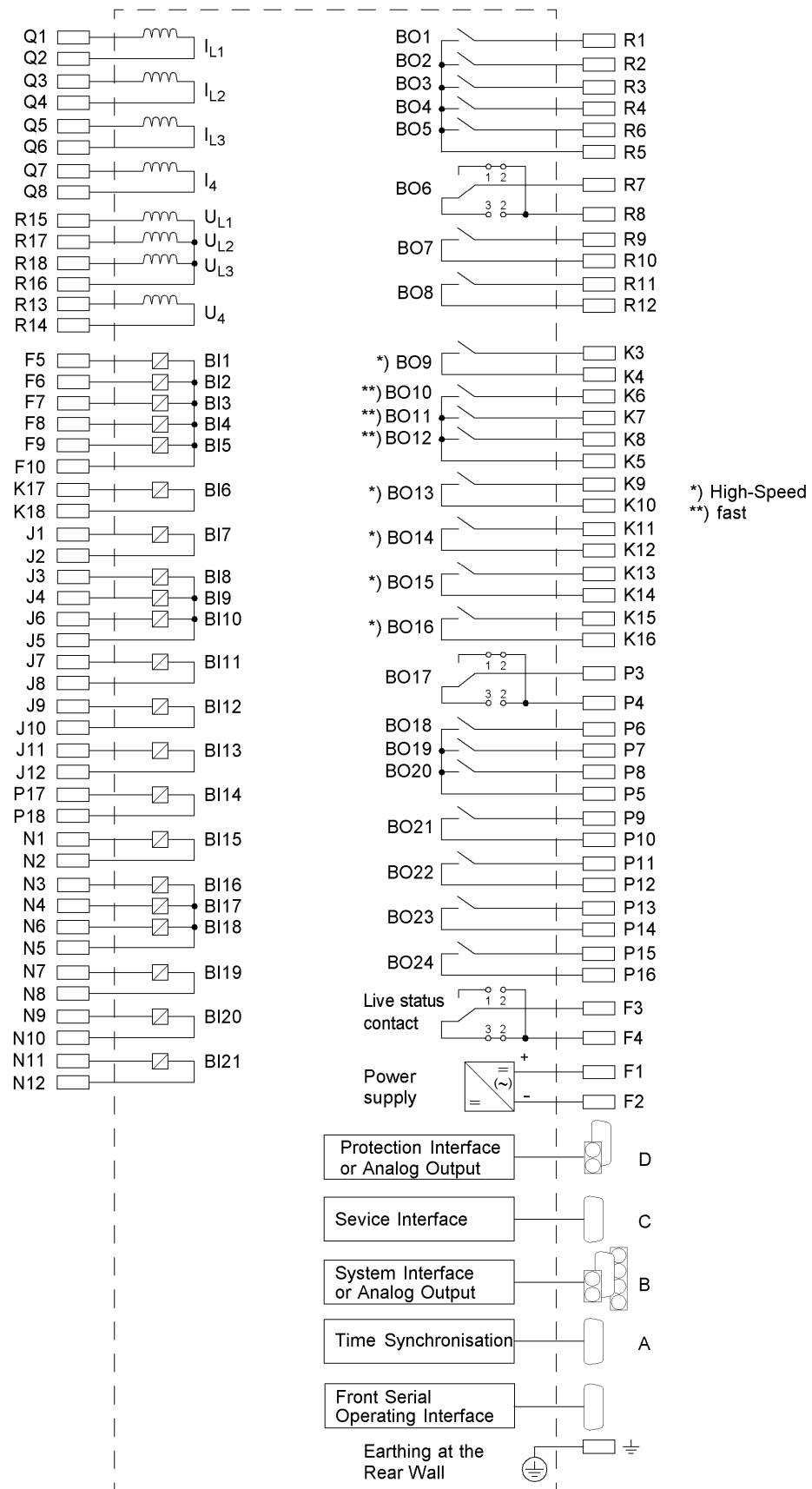
Figure A-12   General diagram for 7SA613*-*M (panel flush mounting or cubicle mounting)

A.2.2 Housing for Panel Surface Mounting

7SA610*-*E
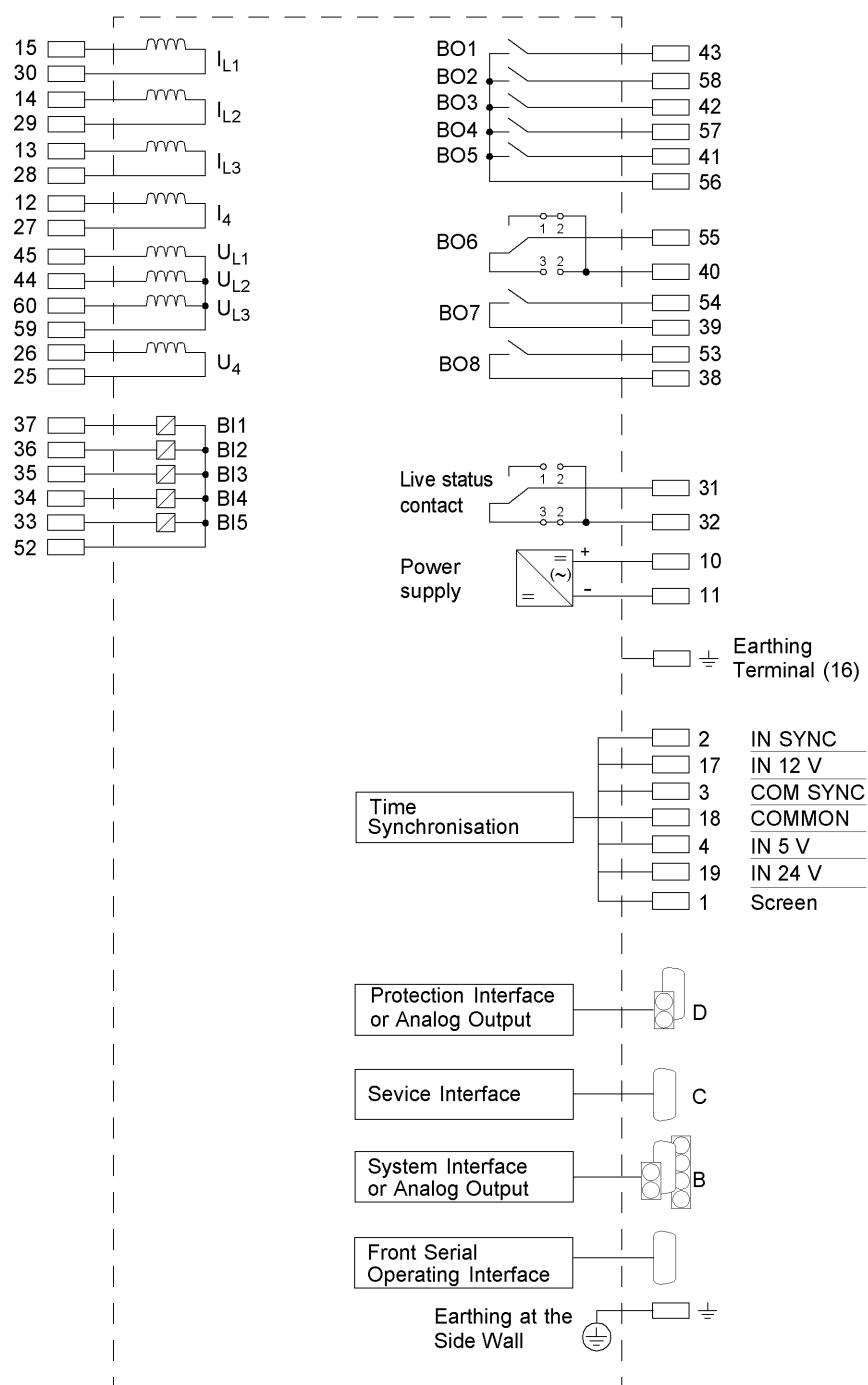
Figure A-13   General diagram for 7SA610*-*E (panel surface mounting)

7SA610*-*F
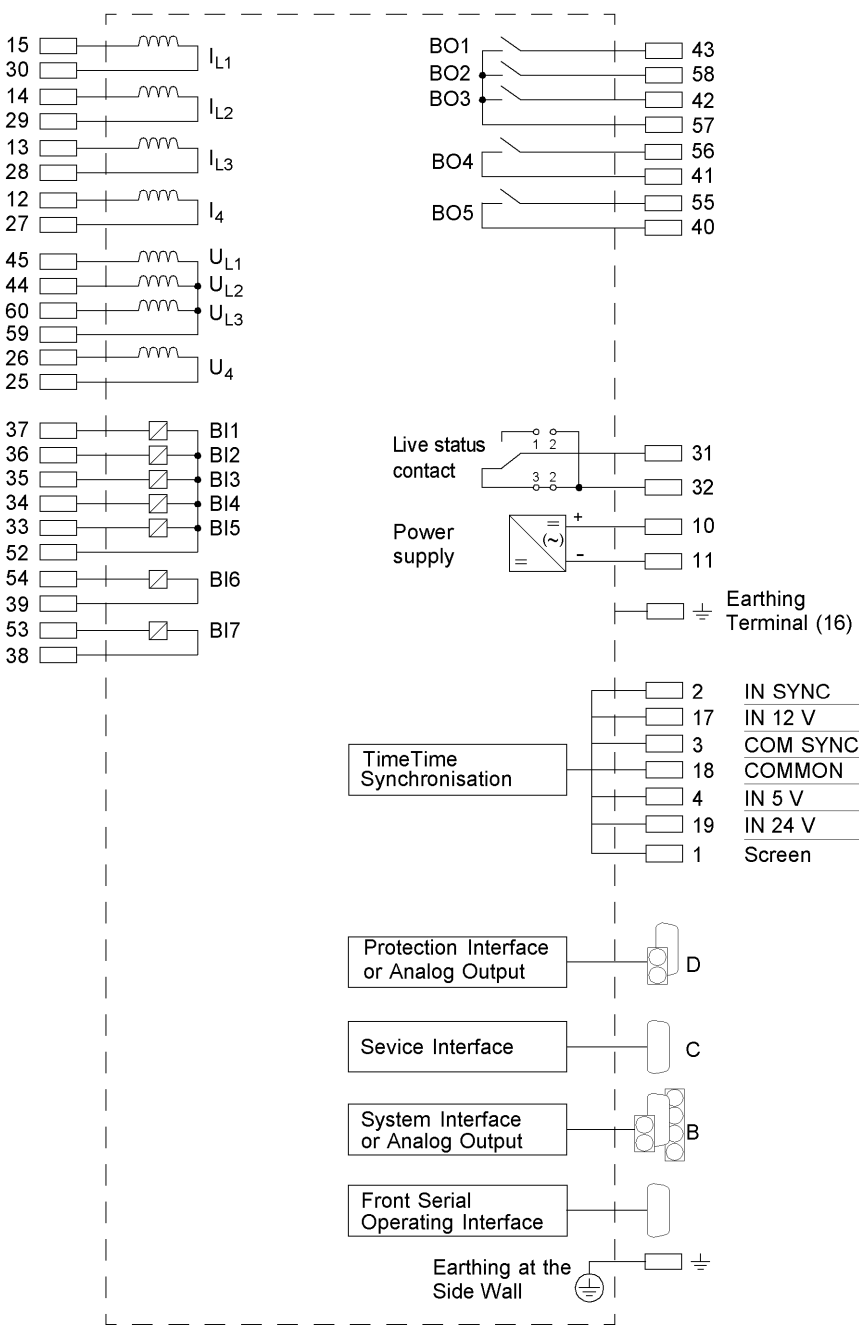
Figure A-14   General diagram for 7SA610*-*F (panel surface mounting)

7SA6*1*-*E

25	I_{L1}	BO1 74
50		BO2 99
24	I_{L2}	BO3 73
49		BO4 98
23	I_{L3}	BO5 72
48		97
22	I_4	
47		BO6 96
20	U_{L1}	71
19	U_{L2}	BO7 95
44	U_{L3}	70
45		BO8 94
21	U_4	69
46		
		BO9 90
58	BI1	65
57	BI2	*) BO10 64
56	BI3	*) BO11 88
55	BI4	*) BO12 63
54	BI5	89
83		*) BO13 87 *) fast
43	BI6	62
18		*) BO14 86
42	BI7	61
17		*) BO15 85
41	BI8	60
40	BI9	*) BO16 84
14	BI10	59
39		
38	BI11	Live status contact 51
13		52
37	BI12	
12		Power supply 15
36	BI13	16
11		

Earthing Terminal (26)

Time Synchronisation	2	IN SYNC
	27	IN 12 V
	3	COM SYNC
	28	COMMON
	4	IN 5 V
	29	IN 24 V
	1	Screen

Protection Interface or Analog Output — D

Sevice Interface — C

System Interface or Analog Output — B

Front Serial Operating Interface

Earthing at the Side Wall

Figure A-15   General diagram for 7SA6*1*-*E (panel surface mounting)

7SA6*1*-*F
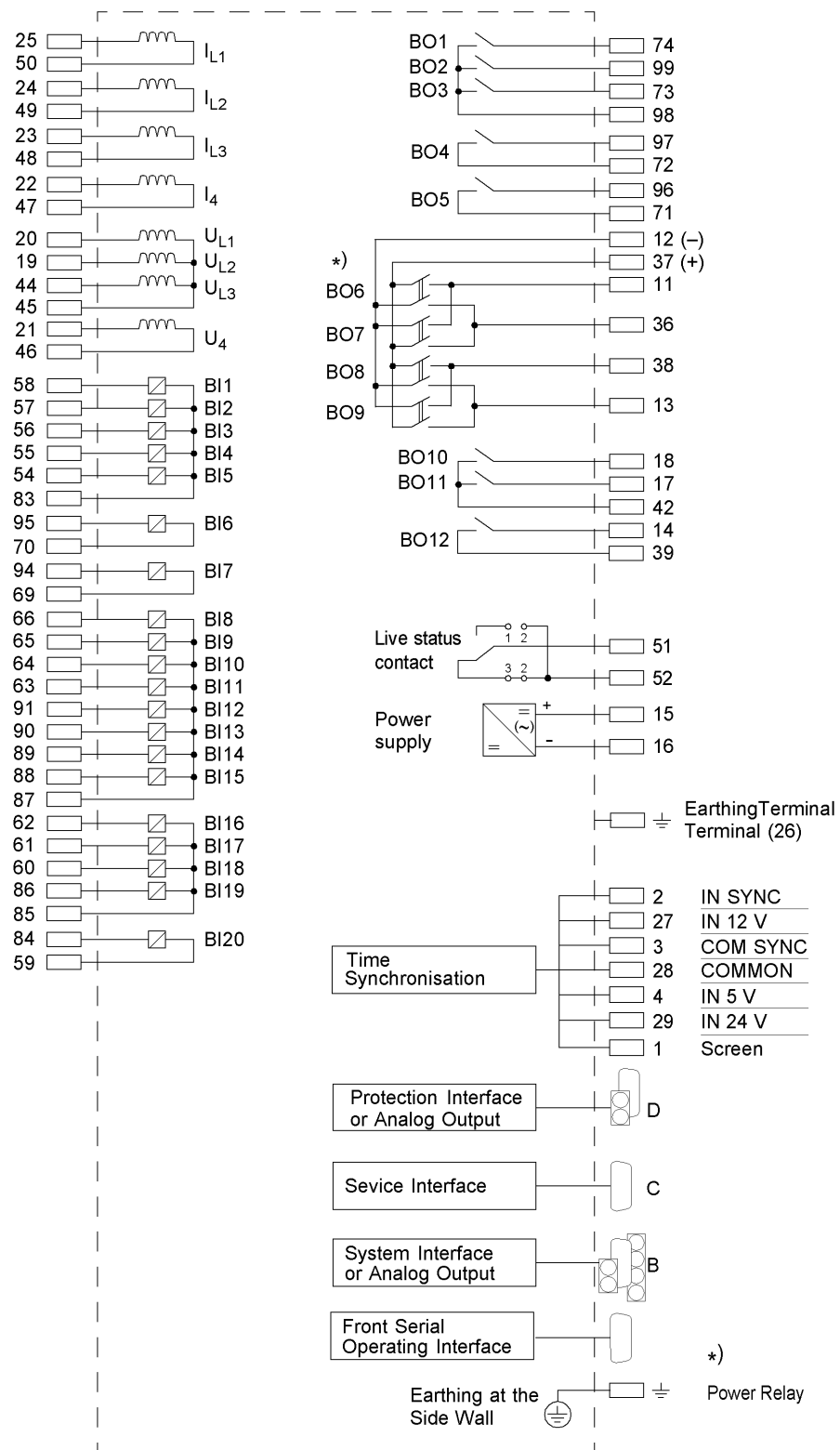
Figure A-16   General diagram for 7SA6*1*-*F (panel surface mounting)

7SA6*1*-*N
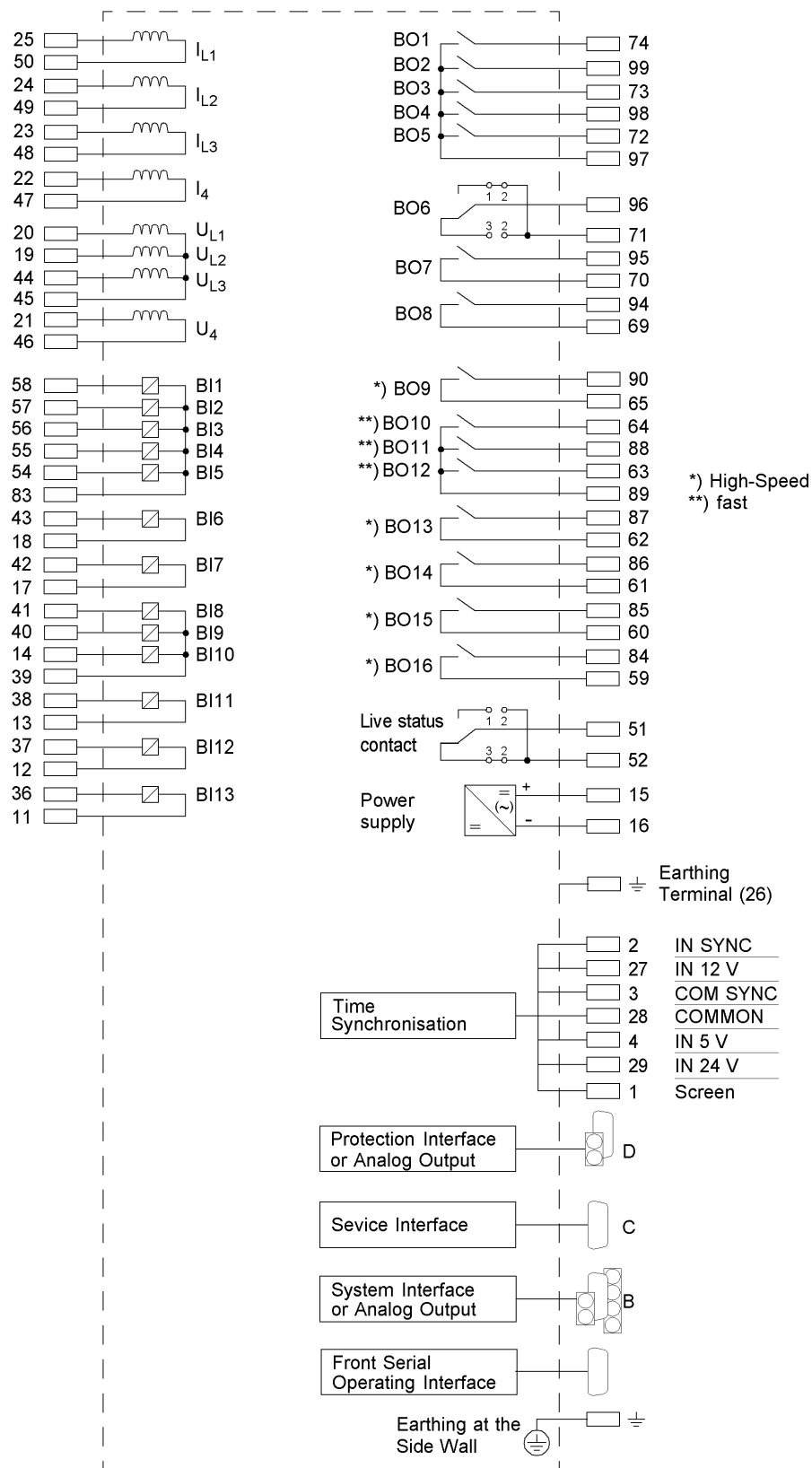
Figure A-17   General diagram for 7SA6*1*-*N (panel surface mounting)

7SA6*2*-*E

50 / 100	I_{L1}
49 / 99	I_{L2}
48 / 98	I_{L3}
47 / 97	I_4
45	U_{L1}
44	U_{L2}
94	U_{L3}
95	
46 / 96	U_4
108	BI1
107	BI2
106	BI3
105	BI4
104	BI5
158	
75 / 25	BI6
74 / 24	BI7
73	BI8
23	BI9
22	BI10
72	
71 / 21	BI11
70 / 20	BI12
69 / 19	BI13
90 / 40	BI14
89 / 39	BI15
86	BI16
36	BI17
35	BI18
85	
84 / 34	BI19
83 / 33	BI20
82 / 32	BI21

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BO1	149
BO2	199
BO3	148
BO4	198
BO5	147
	197
BO6 1 2 / 3 2	196 / 146
BO7	195 / 145
BO8	194 / 144
BO9 1 2 / 3 2	174 / 124
*) BO10	123
*) BO11	172
*) BO12	122
	173
*) BO13	171 / 121
*) BO14	170 / 120
*) BO15	169 / 119
*) BO16	168 / 118
BO17 1 2 / 3 2	190 / 140
BO18	139
BO19	188
BO20	138
	189
BO21	187 / 137
BO22	186 / 136
BO23	185 / 135
BO24	184 / 134
Live status contact 1 2 / 3 2	101 / 102
Power supply + / –	37 / 38

*) fast

continued next page

Figure A-18   General diagram for 7SA6*2*-*E (panel surface mounting)

7SA6*2*-*F

Left terminals		Right terminals	
50 / 100	I_{L1}	BO1	149
49 / 99	I_{L2}	BO2	199
48 / 98	I_{L3}	BO3	148
47 / 97	I_4	BO4	198
45	U_{L1}	BO5	147
44	U_{L2}		197
94	U_{L3}	BO6	196
95			146
46 / 96	U_4	BO7	195
108	BI1		145
107	BI2	BO8	194
106	BI3		144
105	BI4	BO9	174
104	BI5		124
158		*) BO10	123
75 / 25	BI6	*) BO11	172
74 / 24	BI7	*) BO12	122
73	BI8		173
23	BI9	*) BO13	171
22	BI10		121
72		*) BO14	170
71 / 21	BI11		120
70 / 20	BI12	*) BO15	169
69 / 19	BI13		119
90 / 40	BI14	*) BO16	168
89 / 39	BI15		118
86	BI16	BO17	190
36	BI17		140
35	BI18	BO18	139
85		BO19	188
84 / 34	BI19	BO20	138
83 / 33	BI20		189
82 / 32	BI21	BO21	187
68 / 18	BI22		137
67 / 17	BI23	BO22	186
66	BI24		136
16	BI25	BO23	185
15	BI26		135
65		BO24	184
64 / 14	BI27		134
63 / 13	BI28	BO25	166
62 / 12	BI29		116
		BO26	115
		BO27	164
		BO28	114
			165
		BO29	163
			113
		BO30	162
			112
		BO31	161
			111
		BO32	160
			110
		Live status contact	101 / 102
		Power supply	37 / 38

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Figure A-19   General diagram for 7SA6*2*-*F (panel surface mounting)

7SA6*2*-*G
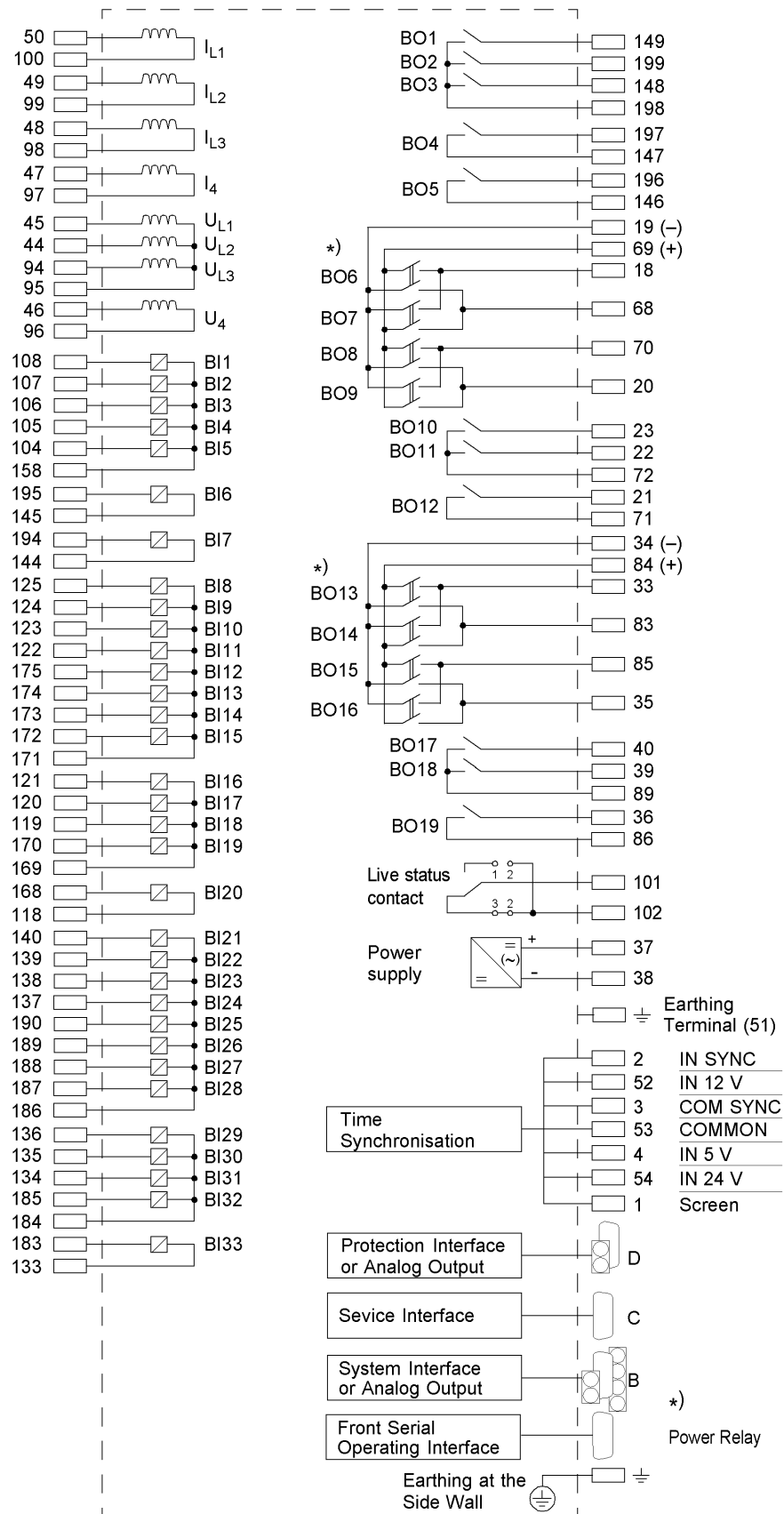
Figure A-20   General diagram for 7SA6*2*-*G (panel surface mounting)

7SA6*2*-*P

Left side (current/voltage inputs and binary inputs):

Terminal	Signal
50 / 100	I_{L1}
49 / 99	I_{L2}
48 / 98	I_{L3}
47 / 97	I_4
45	U_{L1}
44	U_{L2}
94 / 95	U_{L3}
46 / 96	U_4
108	BI1
107	BI2
106	BI3
105	BI4
104 / 158	BI5
75 / 25	BI6
74 / 24	BI7
73	BI8
23	BI9
22 / 72	BI10
71 / 21	BI11
70 / 20	BI12
69 / 19	BI13
90 / 40	BI14
89 / 39	BI15
86	BI16
36	BI17
35 / 85	BI18
84 / 34	BI19
83 / 33	BI20
82 / 32	BI21

Right side (binary outputs):

Terminal	Signal
BO1	149
BO2	199
BO3	148
BO4	198
BO5	147 / 197
BO6	196 / 146
BO7	195 / 145
BO8	194 / 144
*) BO9	174 / 124
**) BO10	123
**) BO11	172
**) BO12	122 / 173
*) BO13	171 / 121
*) BO14	170 / 120
*) BO15	169 / 119
*) BO16	168 / 118
BO17	190 / 140
BO18	139
BO19	188
BO20	138 / 189
BO21	187 / 137
BO22	186 / 136
BO23	185 / 135
BO24	184 / 134
Live status contact	101 / 102
Power supply	37 (+) / 38 (-)

*) High-Speed
**) fast

Figure A-21   General diagram for 7SA6*2*-*P (panel surface mounting)

7SA6*2*-*Q

50 — I_{L1} — 100	BO1 — 149
49 — I_{L2} — 99	BO2 — 199
48 — I_{L3} — 98	BO3 — 148
47 — I_4 — 97	BO4 — 198
45 — U_{L1}	BO5 — 147
44 — U_{L2}	— 197
94 — U_{L3}	BO6 — 196
95	— 146
46 — U_4 — 96	BO7 — 195
108 — BI1	— 145
107 — BI2	BO8 — 194
106 — BI3	— 144
105 — BI4	*) BO9 — 174
104 — BI5	— 124
158	**) BO10 — 123
75 — BI6	**) BO11 — 172
25	**) BO12 — 122
74 — BI7	— 173
24	*) BO13 — 171
73 — BI8	— 121
23 — BI9	*) BO14 — 170
22 — BI10	— 120
72	*) BO15 — 169
71 — BI11	— 119
21	*) BO16 — 168
70 — BI12	— 118
20	BO17 — 190
69 — BI13	— 140
19	BO18 — 139
90 — BI14	BO19 — 188
40	BO20 — 138
89 — BI15	— 189
39	BO21 — 187
86 — BI16	— 137
36 — BI17	BO22 — 186
35 — BI18	— 136
85	BO23 — 185
84 — BI19	— 135
34	BO24 — 184
83 — BI20	— 134
33	BO25 — 166
82 — BI21	— 116
32	BO26 — 115
68 — BI22	BO27 — 164
18	BO28 — 114
67 — BI23	— 165
17	BO29 — 163
66 — BI24	— 113
16 — BI25	BO30 — 162
15 — BI26	— 112
65	BO31 — 161
64 — BI27	— 111
14	BO32 — 160
63 — BI28	— 110
13	Live status contact — 101
62 — BI29	— 102
12	Power supply — 37 / 38

*) High-Speed
**) fast

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Figure A-22   General diagram for 7SA6*2*-*Q (panel surface mounting)

A.2.3 Housing for Mounting with Detached Operator Panel

7SA641*-*A/J
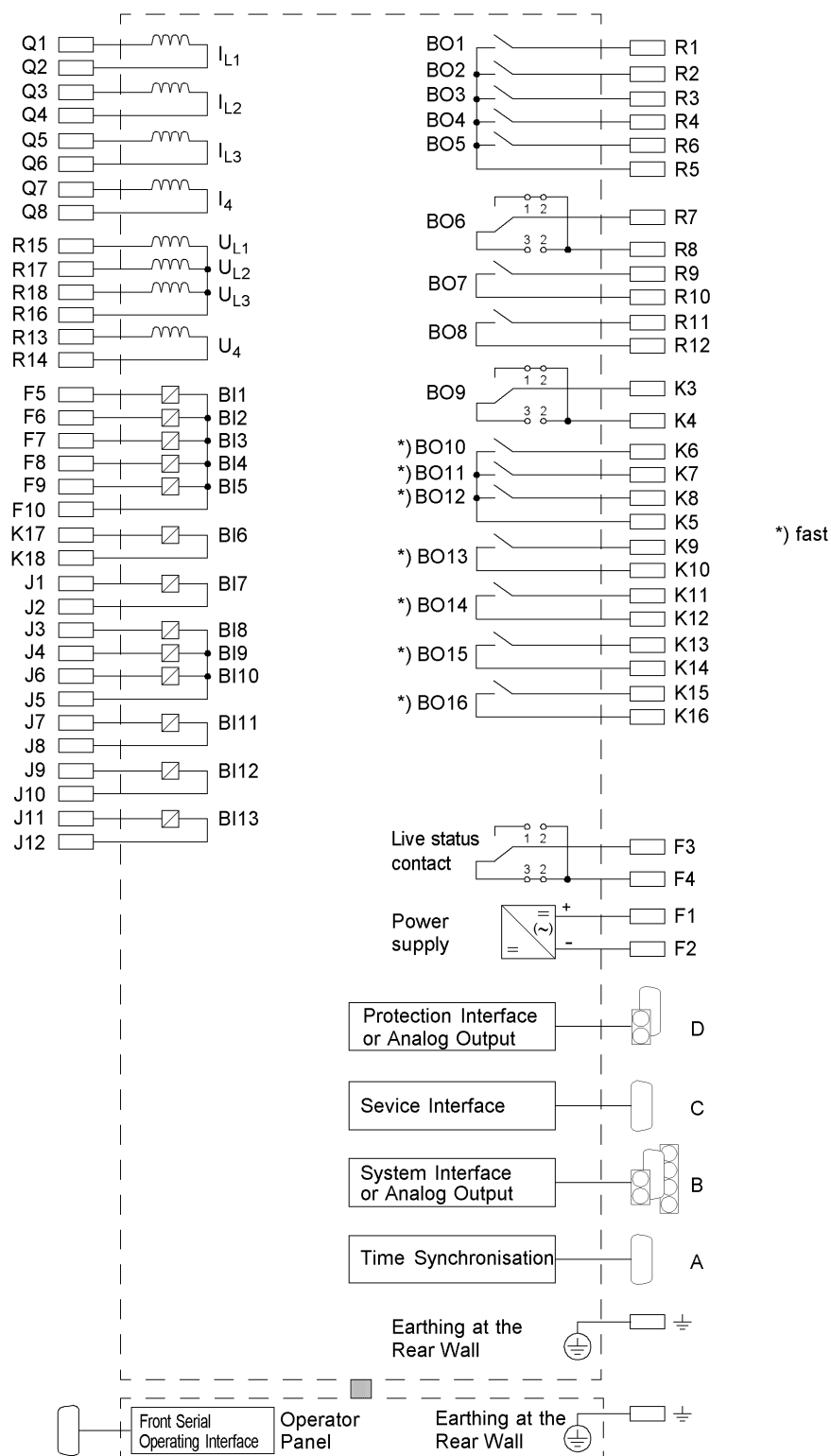
Figure A-23   General diagram 7SA641*-*A/J (panel surface mounting with detached operator panel)

7SA641*-*B/K
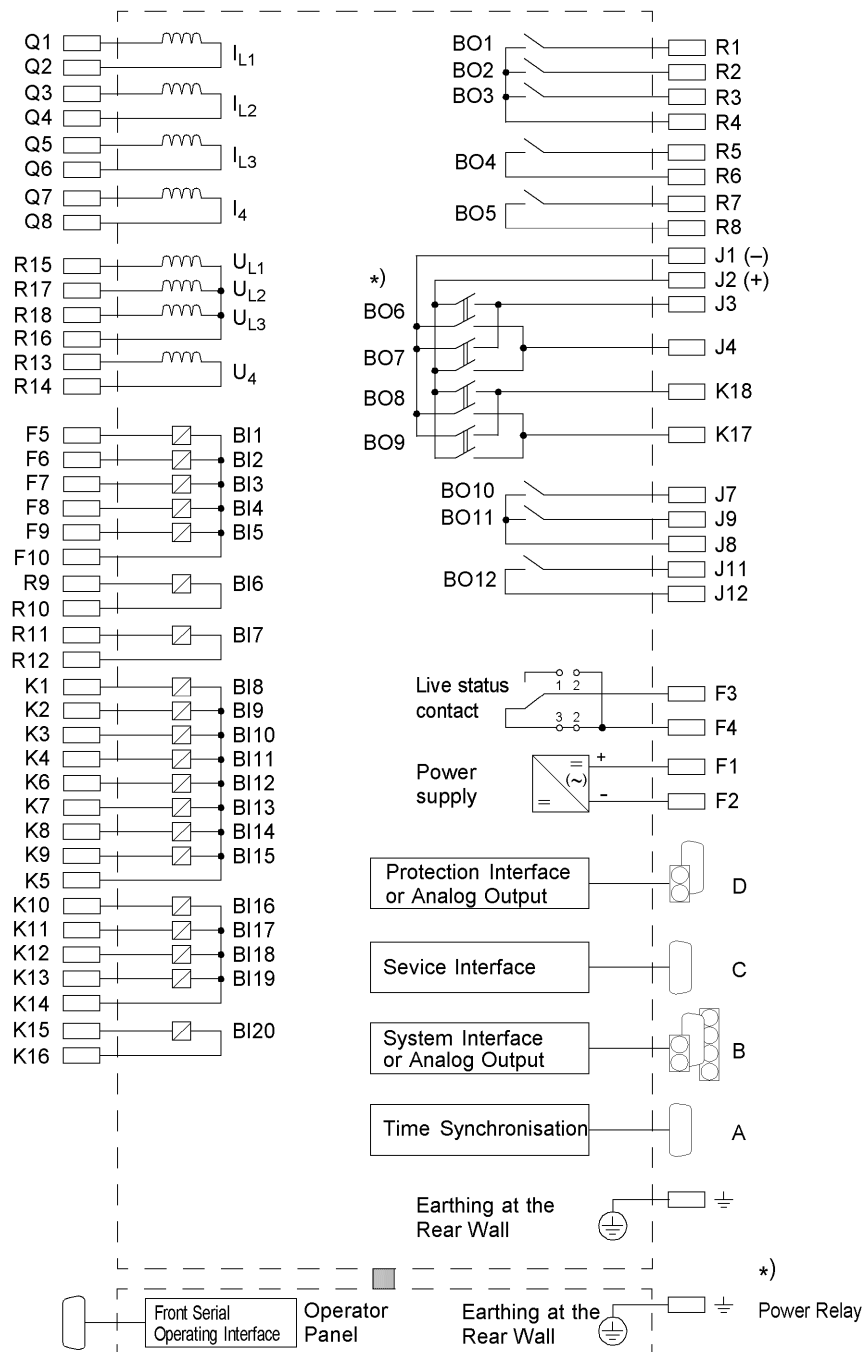
Figure A-24   General diagram 7SA641*-*B/K (panel surface mounting with detached operator panel)

7SA641*-*M/P
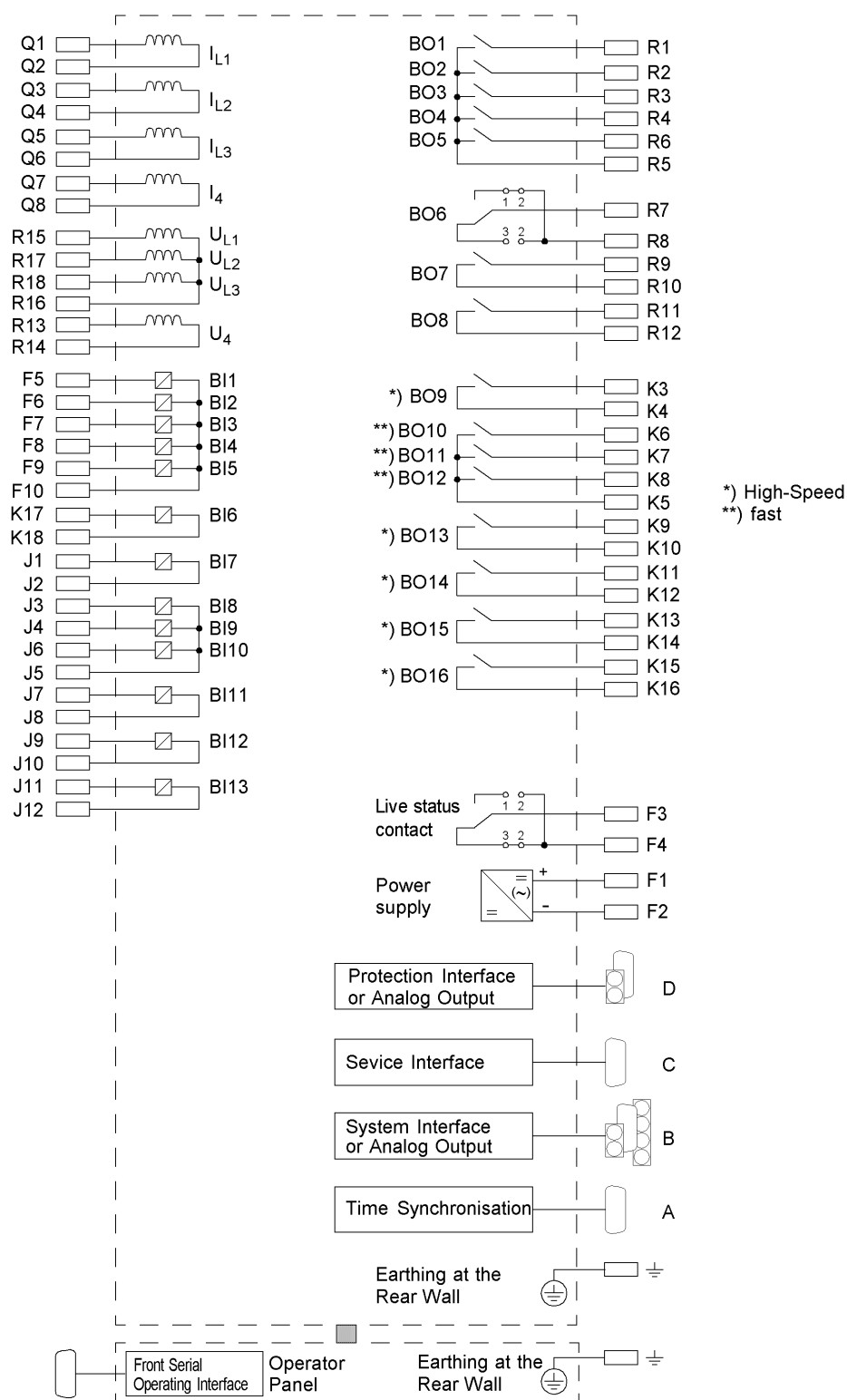
Figure A-25   General diagram 7SA641*-*M/P (panel surface mounting with detached opera-
tor panel)

7SA642*-*A/J

Figure A-26   General diagram 7SA642*-*A/J (panel surface mounting with detached operator panel)

7SA642*-*B/K

Q1, Q2	I_{L1}
Q3, Q4	I_{L2}
Q5, Q6	I_{L3}
Q7, Q8	I_4
R15, R17	U_{L1}
R17, R18	U_{L2}
R18, R16	U_{L3}
R13, R14	U_4

BO1 — R1
BO2 — R2
BO3 — R3
BO4 — R4
BO5 — R6, R5
BO6 — R7, R8
BO7 — R9, R10
BO8 — R11, R12
BO9 — K3, K4
*) BO10 — K6
*) BO11 — K7
*) BO12 — K8, K5
*) BO13 — K9, K10
*) BO14 — K11, K12
*) BO15 — K13, K14
*) BO16 — K15, K16
BO17 — P3, P4
BO18 — P6
BO19 — P7
BO20 — P8, P5
BO21 — P9, P10
BO22 — P11, P12
BO23 — P13, P14
BO24 — P15, P16
BO25 — H3, H4
BO26 — H6
BO27 — H7
BO28 — H8, H5
BO29 — H9, H10
BO30 — H11, H12
BO31 — H13, H14
BO32 — H15, H16
Live status contact — F3, F4
Power supply — F1 (+), F2 (−)

*) fast

BI1 — F5, F6, F7, F8, F9, F10
BI6 — K17, K18
BI7 — J1, J2
BI8 — J3, J4, J6, J5
BI11 — J7, J8
BI12 — J9, J10
BI13 — J11, J12
BI14 — P17, P18
BI15 — N1, N2
BI16 — N3, N4, N6, N5
BI19 — N7, N8
BI20 — N9, N10
BI21 — N11, N12
BI22 — H17, H18
BI23 — G1, G2
BI24 — G3, G4, G6, G5
BI27 — G7, G8
BI28 — G9, G10
BI29 — G11, G12

continued next page   continued next page

Figure A-27   General diagram 7SA642*-*B/K (panel surface mounting with detached operator panel)

7SA642*-*C/L
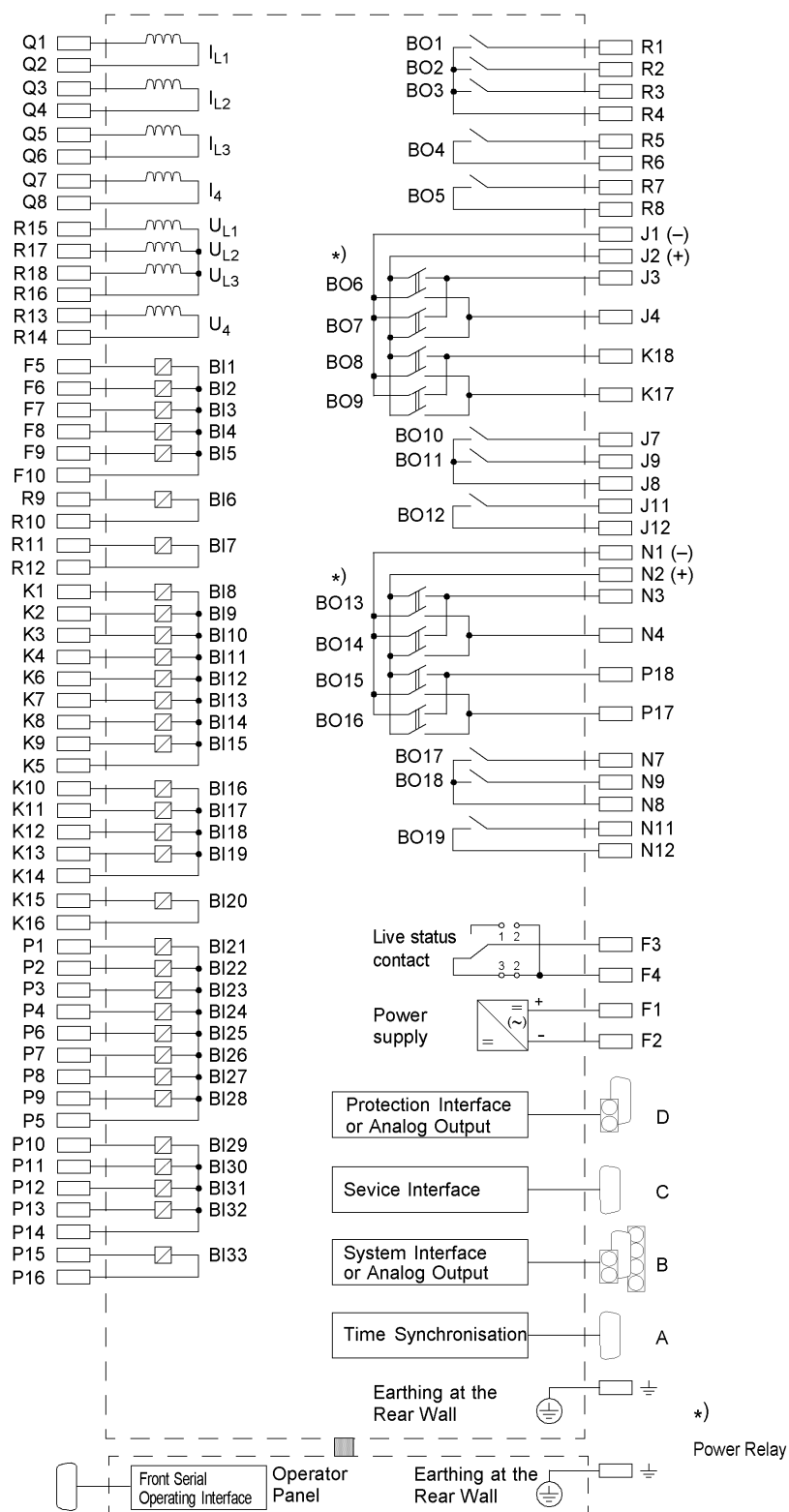
Figure A-28   General diagram 7SA642*-*C/L (panel surface mounting with detached opera-
tor panel)

7SA642*-*M/R

Q1		I_{L1}
Q2		
Q3		I_{L2}
Q4		
Q5		I_{L3}
Q6		
Q7		I_4
Q8		

R15 — U_{L1}
R17 — U_{L2}
R18 — U_{L3}
R16
R13 — U_4
R14

F5 — BI1
F6 — BI2
F7 — BI3
F8 — BI4
F9 — BI5
F10
K17 — BI6
K18
J1 — BI7
J2
J3 — BI8
J4 — BI9
J6 — BI10
J5
J7 — BI11
J8
J9 — BI12
J10
J11 — BI13
J12
P17 — BI14
P18
N1 — BI15
N2
N3 — BI16
N4 — BI17
N6 — BI18
N5
N7 — BI19
N8
N9 — BI20
N10
N11 — BI21
N12

BO1 — R1
BO2 — R2
BO3 — R3
BO4 — R4
BO5 — R6
— R5
BO6 — R7
— R8
BO7 — R9
— R10
BO8 — R11
— R12

*) BO9 — K3
— K4
**) BO10 — K6
**) BO11 — K7
**) BO12 — K8
— K5
*) BO13 — K9
— K10
*) BO14 — K11
— K12
*) BO15 — K13
— K14
*) BO16 — K15
— K16

*) High-Speed
**) fast

BO17 — P3
— P4
BO18 — P6
BO19 — P7
BO20 — P8
— P5
BO21 — P9
— P10
BO22 — P11
— P12
BO23 — P13
— P14
BO24 — P15
— P16

Live status contact — F3
— F4

Power supply — F1
— F2

Protection Interface or Analog Output — D

Sevice Interface — C

System Interface or Analog Output — B

Time Synchronisation — A

Earthing at the Rear Wall

Front Serial Operating Interface | Operator Panel | Earthing at the Rear Wall

Figure A-29 General diagram 7SA642*-*M/R (panel surface mounting with detached operator panel)

7SA642*-*N/S

Left terminals	Right terminals
Q1, Q2 — I_{L1}	BO1 — R1
Q3, Q4 — I_{L2}	BO2 — R2
Q5, Q6 — I_{L3}	BO3 — R3
Q7, Q8 — I_4	BO4 — R4
R15 — U_{L1}	BO5 — R6, R5
R17 — U_{L2}	BO6 — R7, R8
R18 — U_{L3}	BO7 — R9, R10
R16, R13, R14 — U_4	BO8 — R11, R12

*) High-Speed
**) fast

continued next page

Protection Interface
or Analog Output — D

Sevice Interface — C

System Interface
or Analog Output — B

Time Synchronisation — A

Earthing at the
Rear Wall

Front Serial
Operating Interface | Operator
Panel

Earthing at the
Rear Wall

Figure A-30   General diagram 7SA642*-*N/S (panel surface mounting with detached opera-
tor panel)

A.3 Connection Examples

A.3.1 Current Transformer Connection Examples
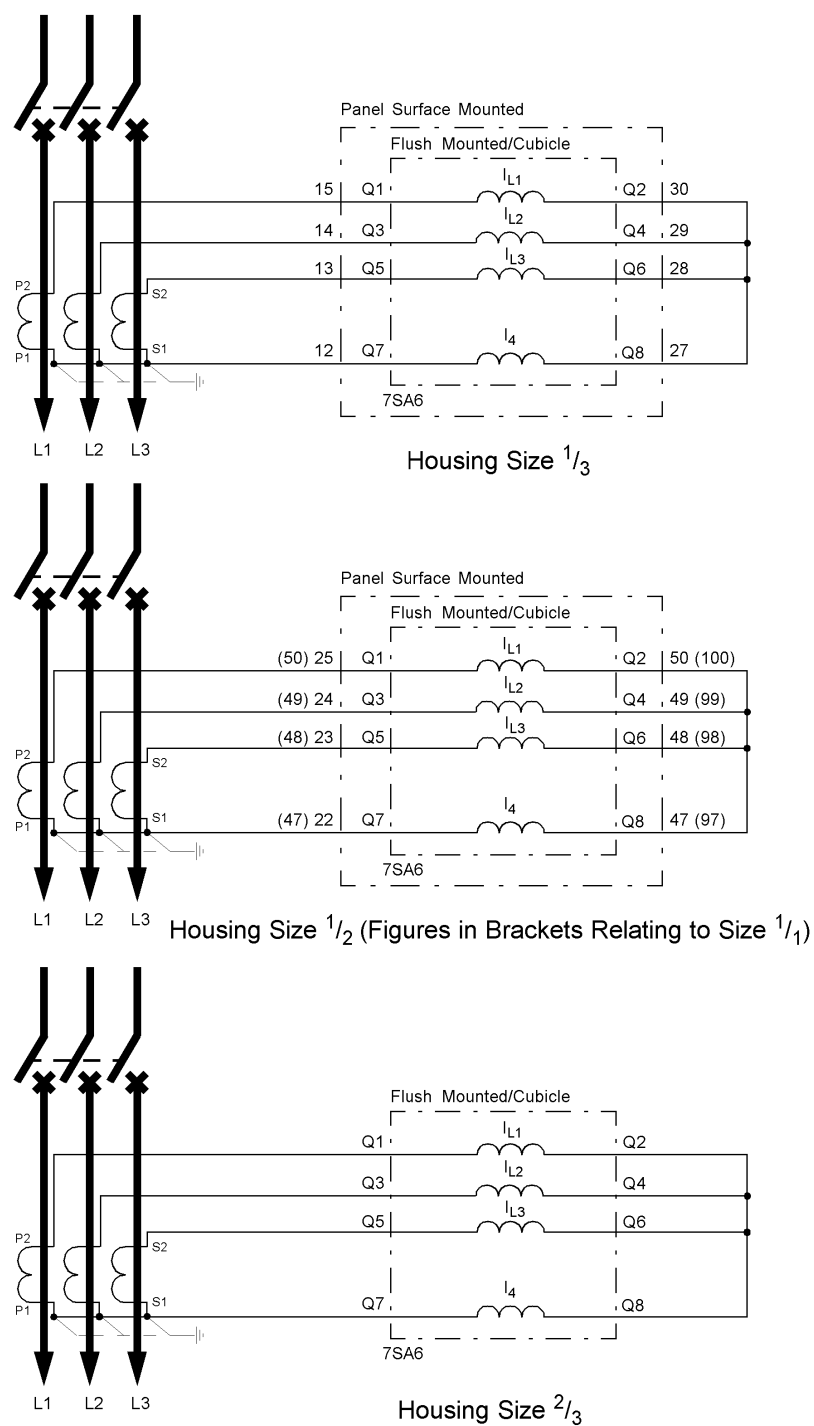
Figure A-31   Current connections to three current transformers with a starpoint connection for earth current (residual 3I0 neutral current), normal circuit layout

Important! Cable shield grounding must be done on the cable side!

Note: Change of Address 0201 setting changes polarity of $3I_0$ Current Input, i.e. terminal Q7 must be connected to that CT terminal pointing in the same direction as the starpoint of the phase current CTs (towards "Line side" in this diagram)

Housing Size $^1/_3$

Important! Cable shield grounding must be done on the cable side!

Note: Change of Address 0201 setting changes polarity of $3I_0$ Current Input, i.e. terminal Q7 must be connected to that CT terminal pointing in the same direction as the starpoint of the phase current CTs (towards "Line side" in this diagram)

Housing Size $^1/_2$ (Figures in Brackets Relating to Size $^1/_1$)

Figure A-32   Current connections to three current transformers with separate earth current transformer (summation current transformer or toroidal current transformer)

Figure A-33   Current connections to three current transformers with separate earth current transformer (summation current transformer or toroidal current transformer)

Panel Surface Mounted
Flush Mounted/Cubicle

I_{L1}
15 | Q1 — Q2 | 30
I_{L2}
14 | Q3 — Q4 | 29
I_{L3}
13 | Q5 — Q6 | 28

I_4
27 | Q8 — Q7 | 12

7SA6

Important! Cable shield grounding must be done on the cable side!

Note: Change of Address 0201 setting changes polarity of $3I_0$ Current Input, i.e. terminal Q7 must be connected to that CT terminal pointing in the same direction as the starpoint of the phase current CTs (towards "Line side" in this diagram)

Housing Size $^1/_3$

Panel Surface Mounted
Flush Mounted/Cubicle

I_{L1}
(50) 25 | Q1 — Q2 | 50 (100)
I_{L2}
(49) 24 | Q3 — Q4 | 49 (99)
I_{L3}
(48) 23 | Q5 — Q6 | 48 (98)

I_4
(97) 47 | Q8 — Q7 | 22 (47)

7SA6

Important! Cable shield grounding must be done on the cable side!

Note: Change of Address 0201 setting changes polarity of $3I_0$ Current Input, i.e. terminal Q7 must be connected to that CT terminal pointing in the same direction as the starpoint of the phase current CTs (towards "Line side" in this diagram)

Housing Size $^1/_2$ (Figures in Brackets Relating to Size $^1/_1$)

Figure A-34   Current connections to 2 current transformers with separate earth current transformer (summation current transformer or toroidal transformer) **not permitted for earthed systems**

Important! Cable shield grounding must be done on the cable side!

Note: Change of Address 0201 setting changes polarity of $3I_0$ Current Input, i.e. terminal Q7 must be connected to that CT terminal pointing in the same direction as the starpoint of the phase current CTs (towards "Line side" in this diagram)
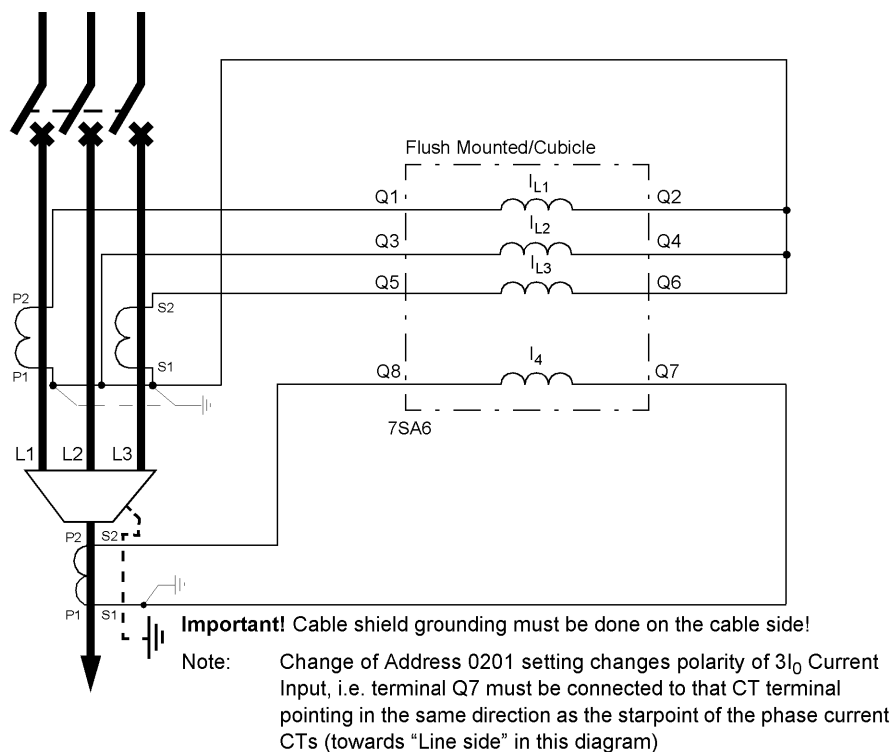
Housing Size $^2/_3$

Figure A-35   Current connections to 2 current transformers with separate earth current transformer (summation current transformer or toroidal transformer) **not permitted for earthed systems**

Housing Size $^1/_3$
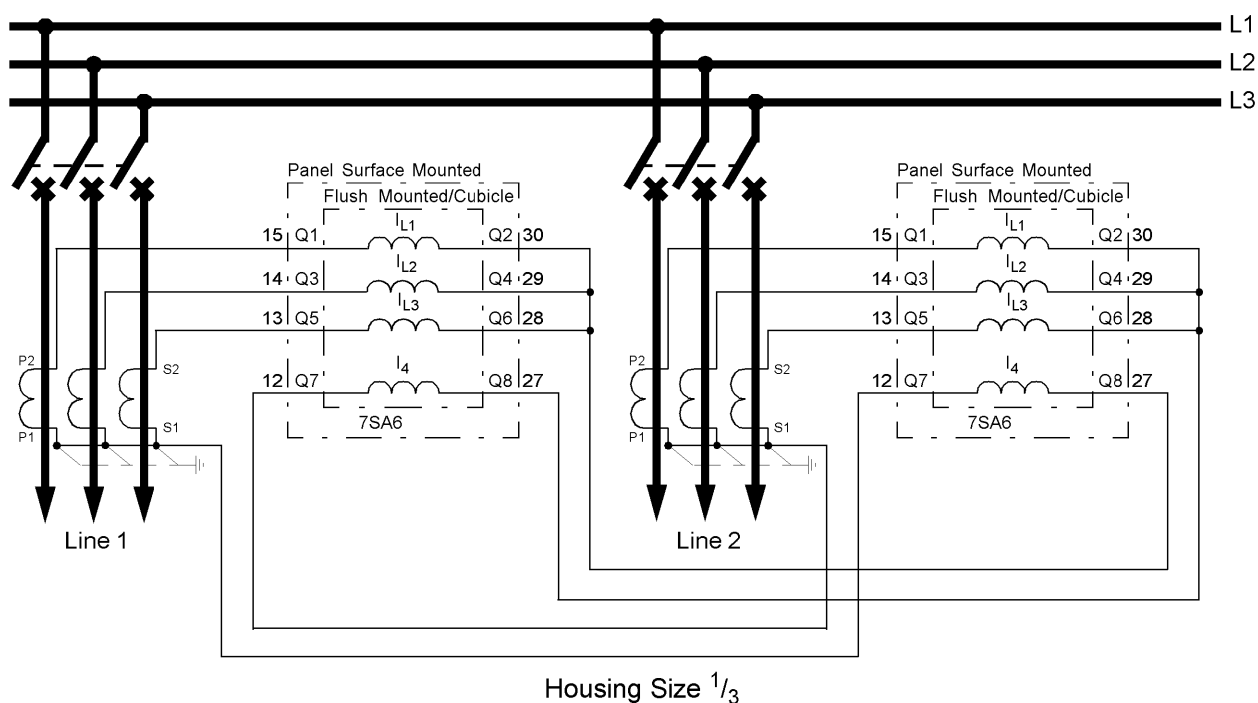
Figure A-36   Current connections to three current transformers and earth current from the star-point connection of a parallel line (for parallel line compensation)
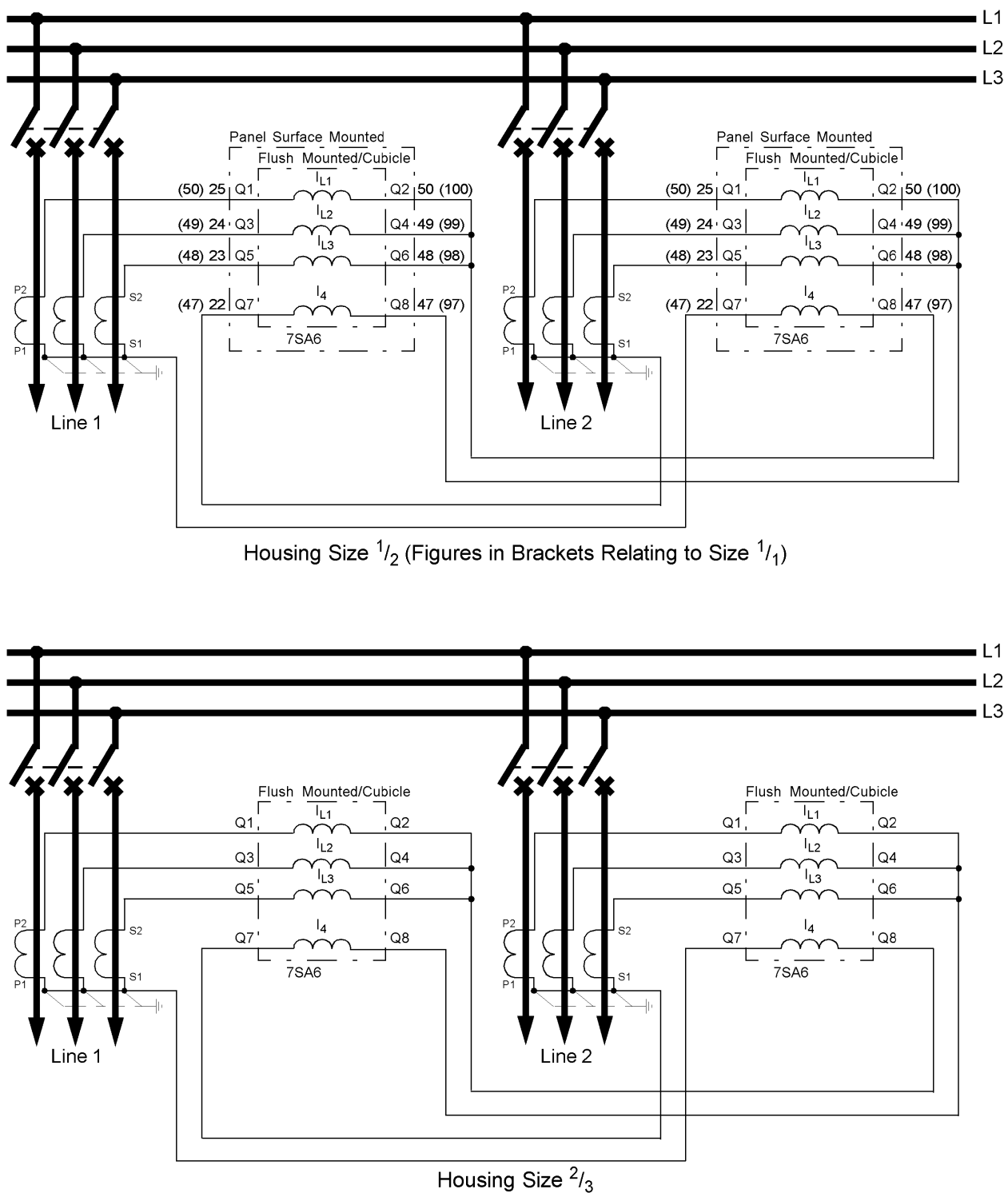
Figure A-37   Current connections to three current transformers and earth current from the star-point connection of a parallel line (for parallel line compensation)

Housing Size $^1/_3$

Housing Size $^1/_2$ (Figures in Brackets Relating to Size $^1/_1$)
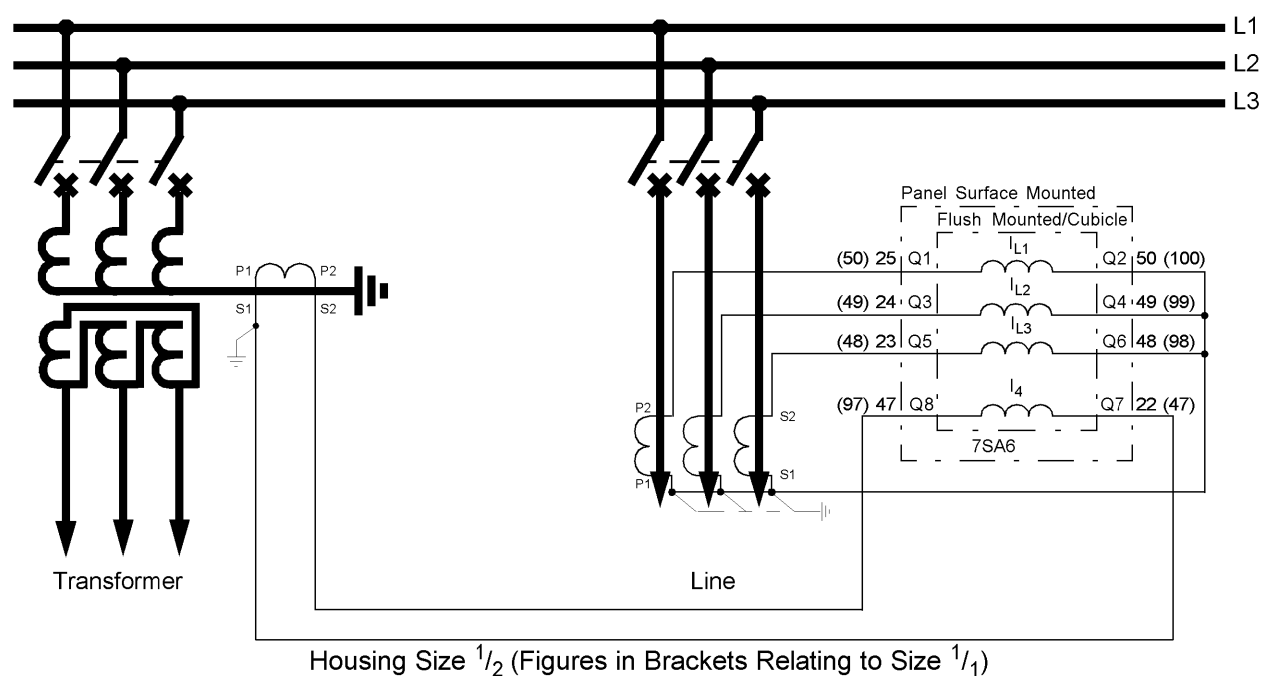
Figure A-38   Current connections to three current transformers and earth current from the star-point current of an earthed power transformer (for directional earth fault protection)
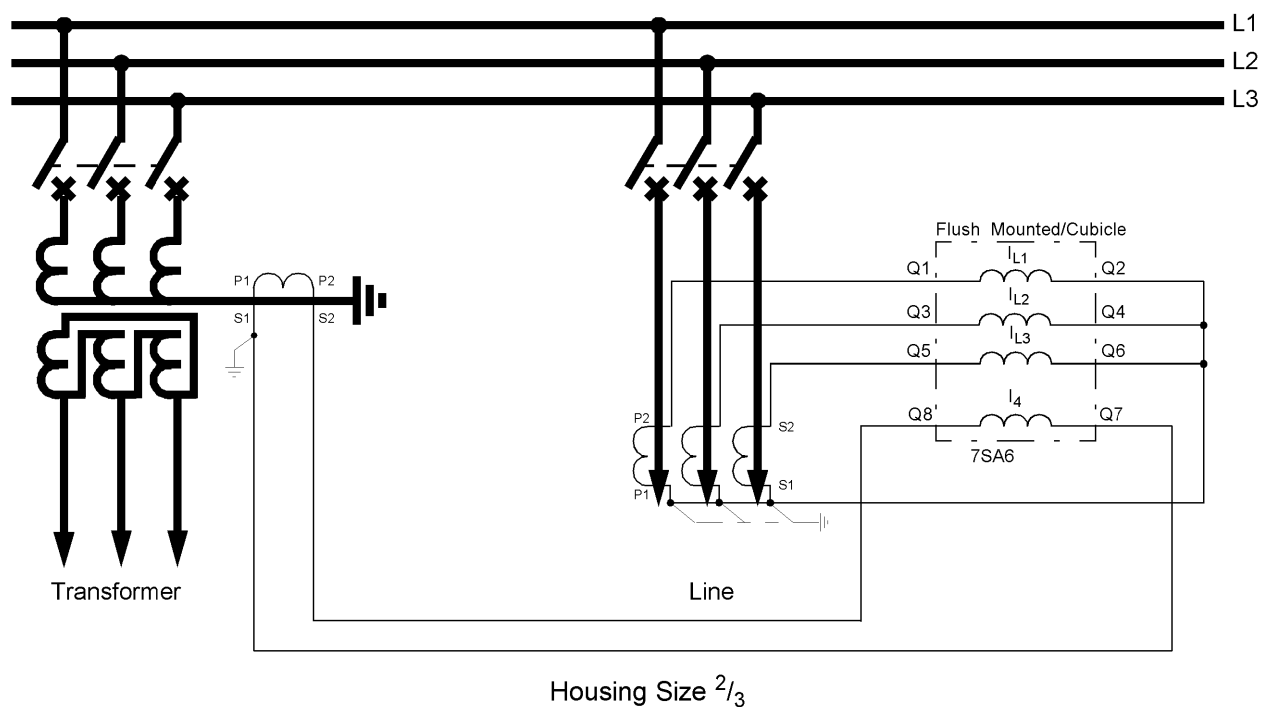
Figure A-39   Current connections to three current transformers and earth current from the star-point current of an earthed power transformer (for directional earth fault protection)

A.3.2   Voltage Transformer

Housing Size $^1/_3$

Housing Size $^1/_2$ (Figures in Brackets Relating to Size $^1/_1$)

Housing Size $^2/_3$
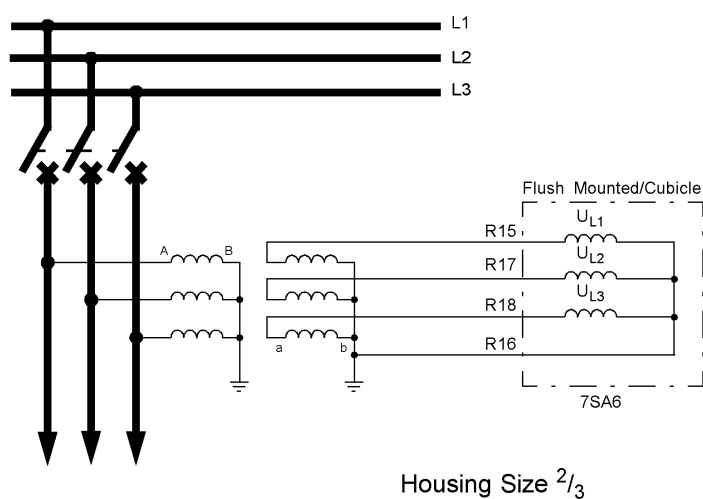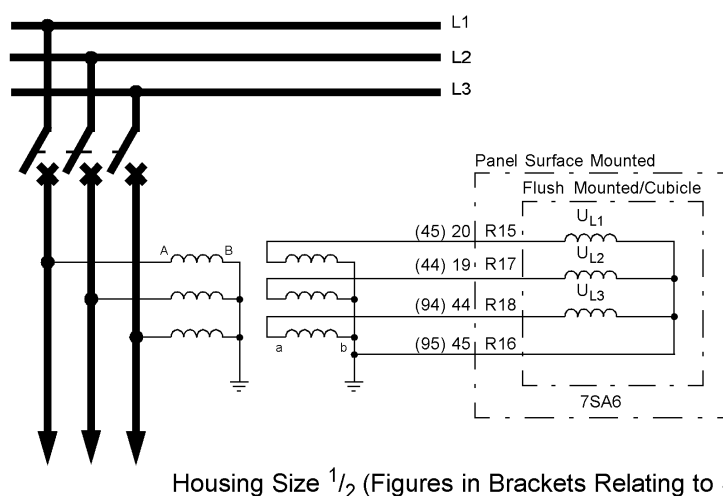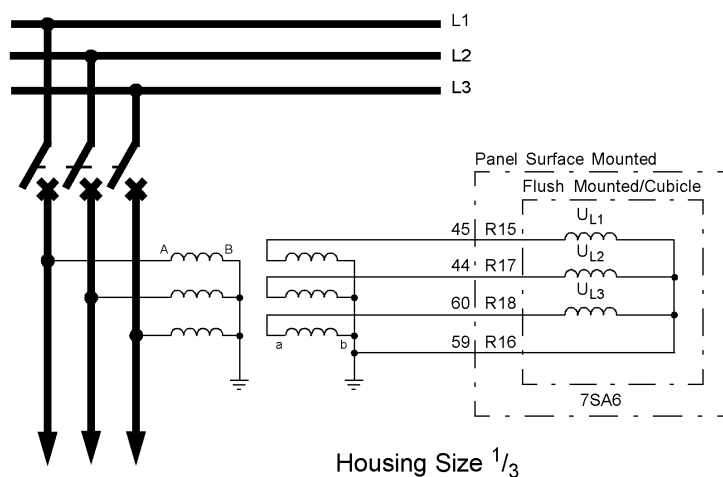
Figure A-40   Voltage connections to three wye-connected voltage transformers (normal circuit layout)
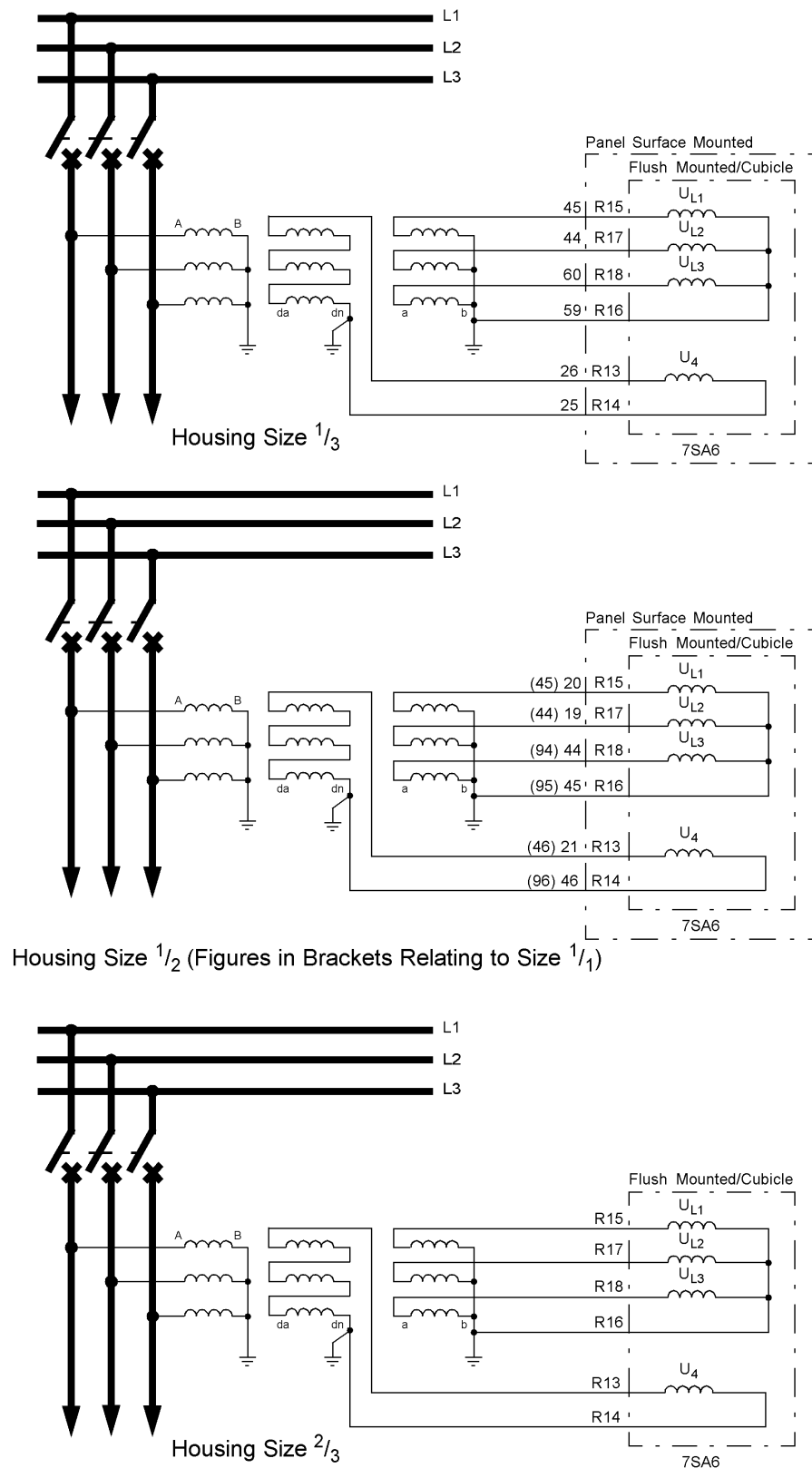
Figure A-41   Voltage connections to three wye-connected voltage transformers with additional open-delta windings (da–dn–winding)

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Housing Size $^1/_3$

Housing Size $^1/_2$ (Figures in Brackets Relating to Size $^1/_1$)
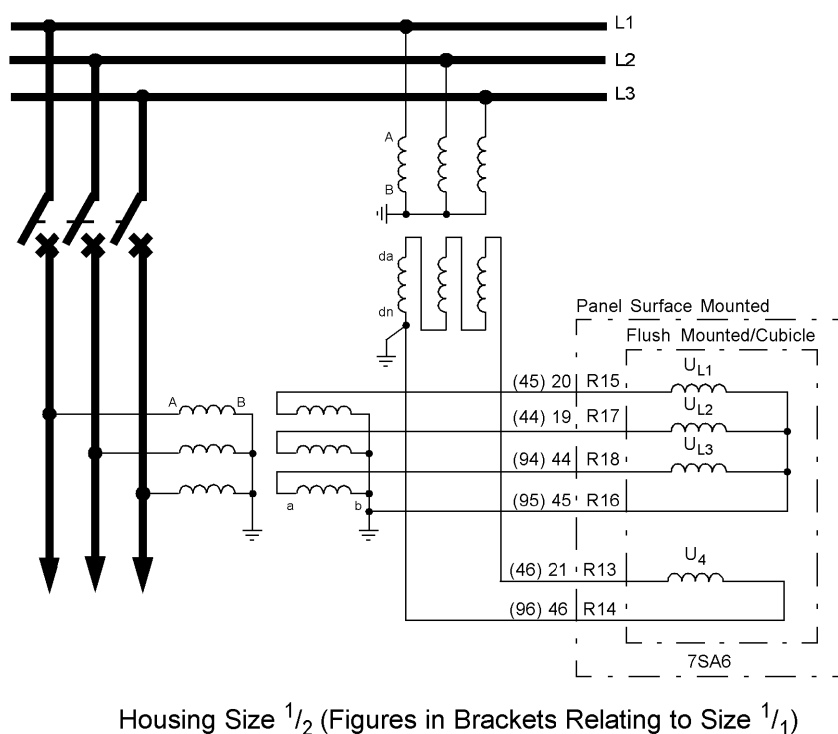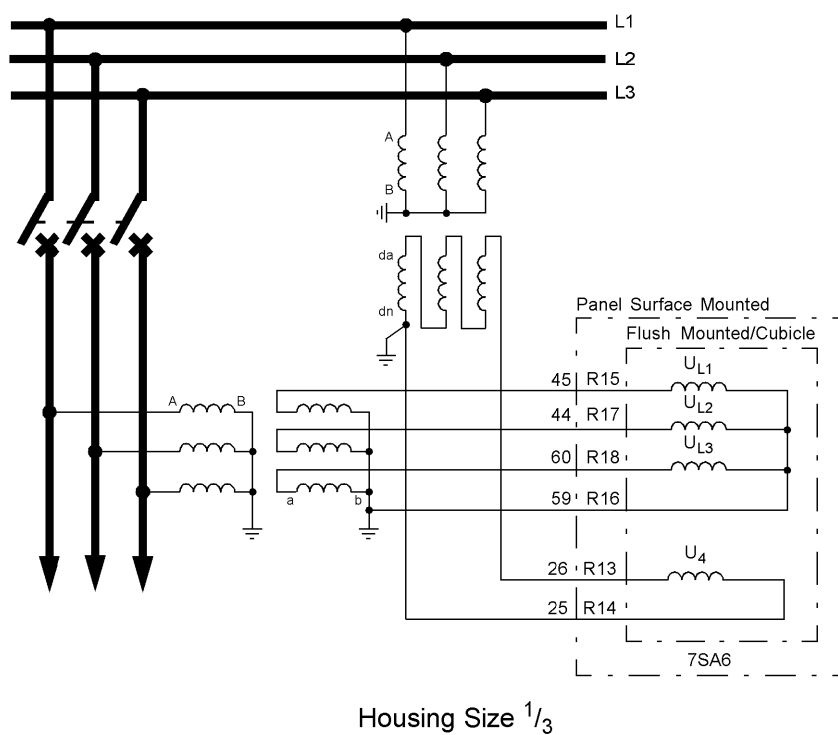
Figure A-42   Voltage connections to three Wye-connected voltage transformers with additional open-delta windings (da–dn–winding) from the busbar
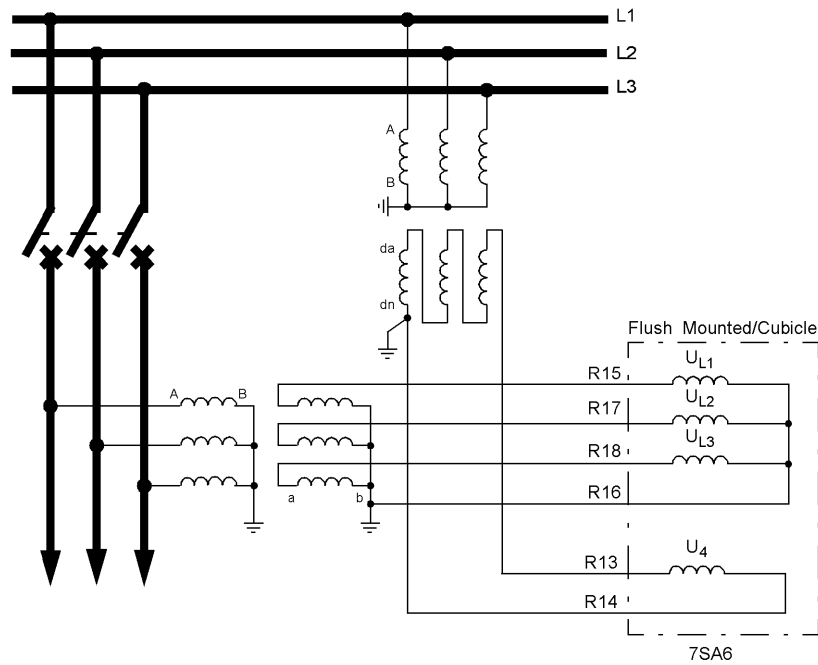
Housing Size $^2/_3$

Figure A-43   Voltage connections to three Wye-connected voltage transformers with additional open-delta windings (da–dn–winding) from the busbar
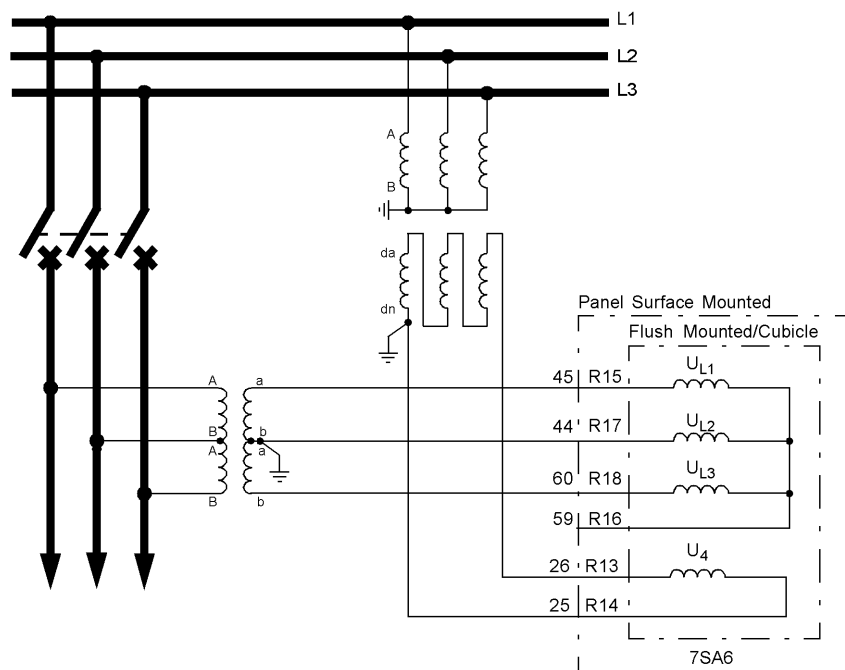
Housing Size $^1/_3$

Figure A-44   Voltage connections to two V-connected voltage transformers with additional open-delta windings (da–dn–winding) from the busbar — **not permitted for earthed networks**
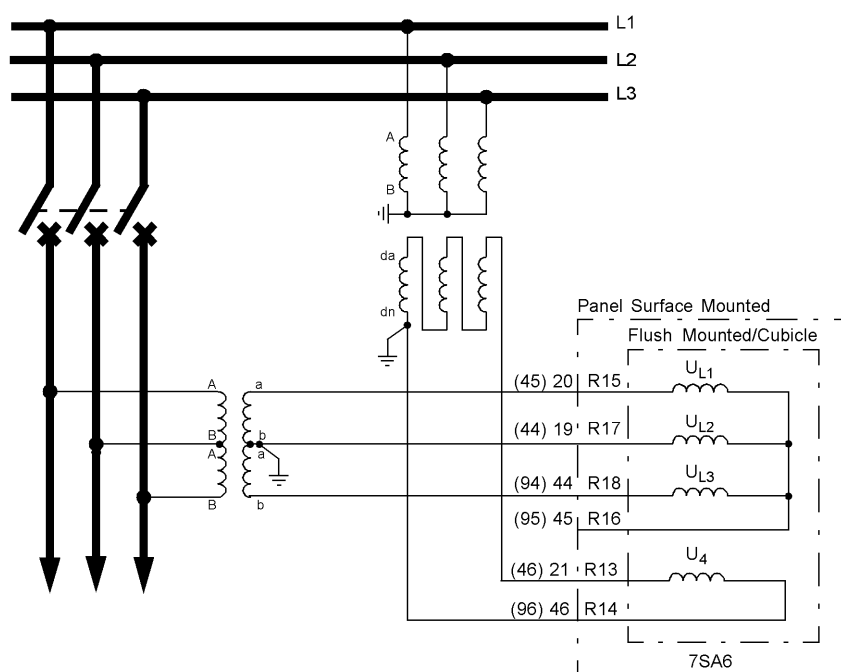
Housing Size $^1/_2$ (Figures in Brackets Relating to Size $^1/_1$)
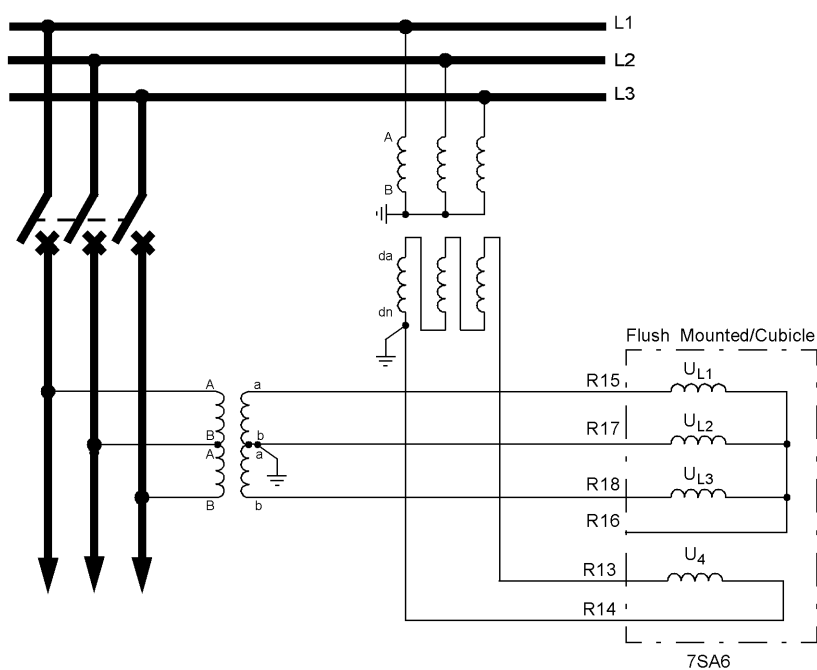
Housing Size $^2/_3$

Figure A-45   Voltage connections to two V-connected voltage transformers with additional open-delta windings (da–dn–winding) from the busbar — **not permitted for earthed networks**
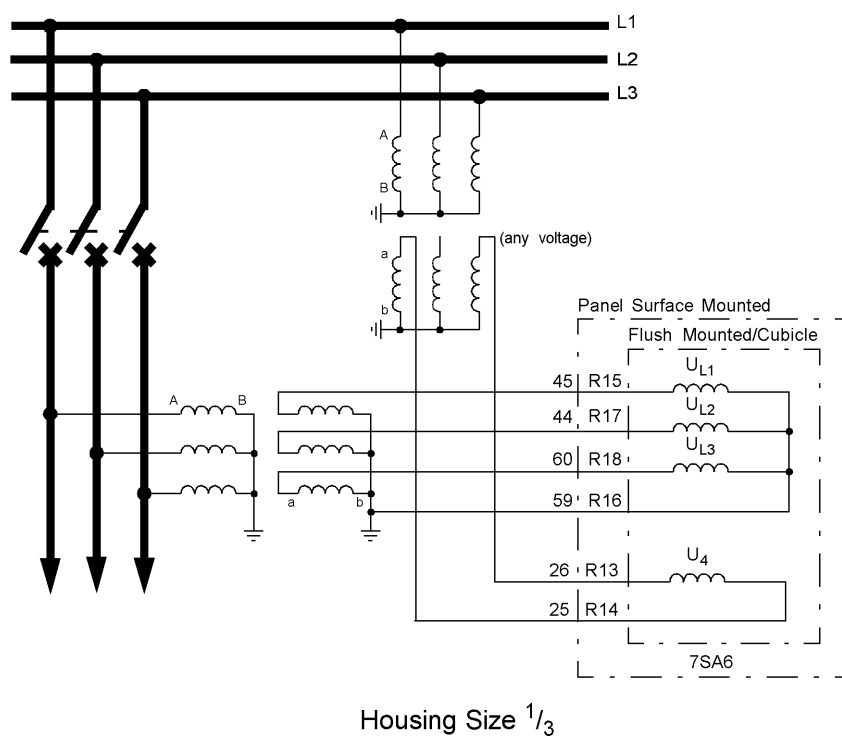
Housing Size $^1/_3$

Figure A-46   Voltage connections to three wye-connected voltage transformers and addition-ally to any busbar voltage (for overvoltage protection and/or synchronism check)
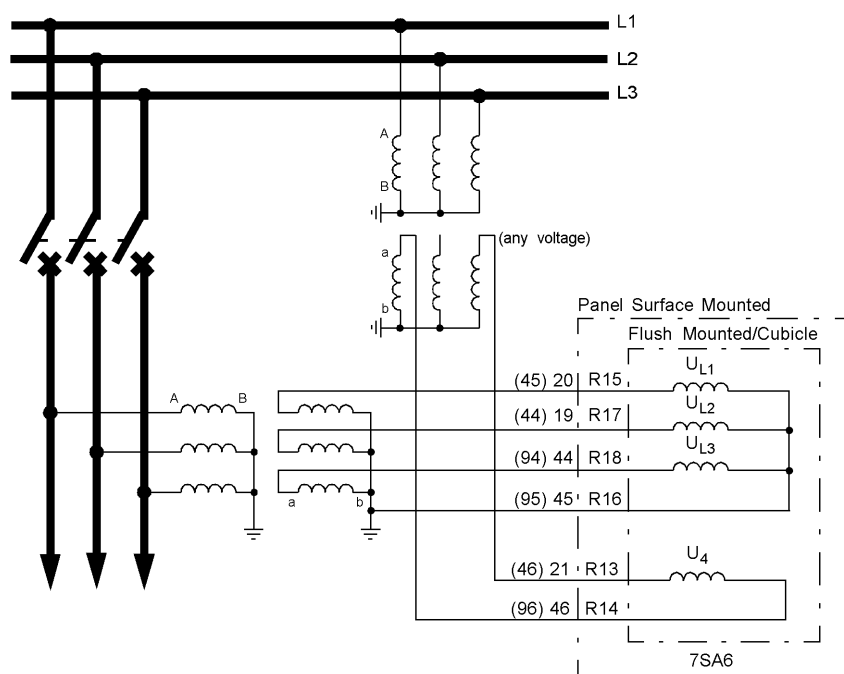
Housing Size $^1/_2$ (Figures in Brackets Relating to Size $^1/_1$)
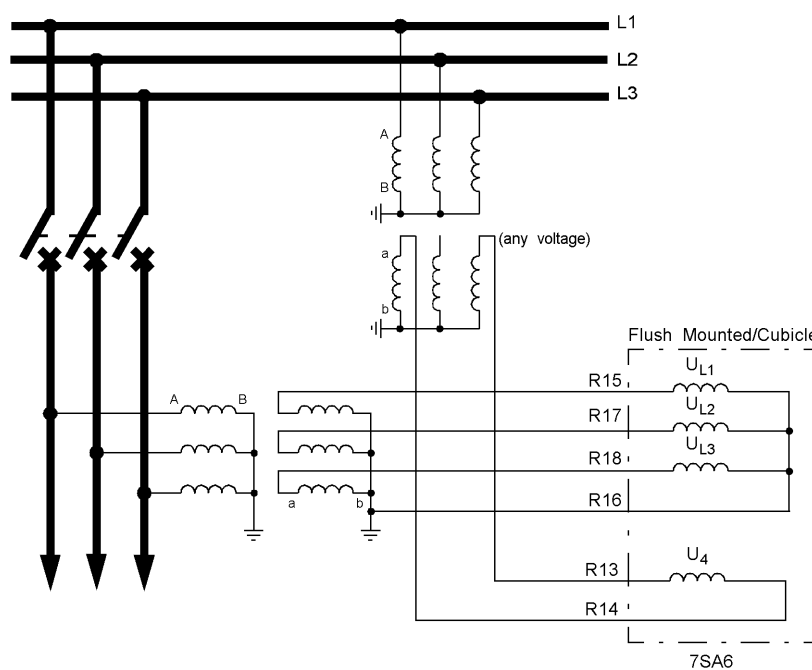
Housing Size $^2/_3$

Figure A-47   Voltage connections to three wye-connected voltage transformers and additionally to any busbar voltage (for overvoltage protection and/or synchronism check)

A.4 Default Settings

When the device leaves the factory, a large number of LED indications, binary inputs and outputs as well as function keys are already preset. They are summarised in the following table.

A.4.1 LEDs

Table A-1   LED Indication Presettings

LEDs	Short Text	Function No.	Description
LED1	Relay TRIP	511	Relay GENERAL TRIP command
LED2	Relay PICKUP L1	503	Relay PICKUP Phase L1
LED3	Relay PICKUP L2	504	Relay PICKUP Phase L2
LED4	Relay PICKUP L3	505	Relay PICKUP Phase L3
LED5	Relay PICKUP E	506	Relay PICKUP Earth
LED6	EF reverse	1359	E/F picked up REVERSE
	Dis. reverse	3720	Distance Pickup REVERSE
LED7	Relay TRIP 1pL1	512	Relay TRIP command - Only Phase L1
	Relay TRIP 1pL2	513	Relay TRIP command - Only Phase L2
	Relay TRIP 1pL3	514	Relay TRIP command - Only Phase L3
LED8	Dis.TripZ1/1p	3811	Distance TRIP single-phase Z1
	DisTRIP3p. Z1sf	3823	DisTRIP 3phase in Z1 with single-ph Flt.
	DisTRIP3p. Z1mf	3824	DisTRIP 3phase in Z1 with multi-ph Flt.
LED9	Dis.TripZ1B1p	3813	Distance TRIP single-phase Z1B
	DisTRIP3p.Z1Bsf	3825	DisTRIP 3phase in Z1B with single-ph Flt
	DisTRIP3p Z1Bmf	3826	DisTRIP 3phase in Z1B with multi-ph Flt.
LED10	Dis.TripZ2/1p	3816	Distance TRIP single-phase Z2
	Dis.TripZ2/3p	3817	Distance TRIP 3phase in Z2
LED11	Dis.TripZ3/T3	3818	Distance TRIP 3phase in Z3
	Dis.TRIP 3p. Z4	3821	Distance TRIP 3phase in Z4
	Dis.TRIP 3p. Z5	3822	Distance TRIP 3phase in Z5
LED12	AR not ready	2784	AR: Auto-reclose is not ready
LED13	Emer. mode	2054	Emergency mode
LED14	Alarm Sum Event	160	Alarm Summary Event

A.4.2 Binary Inputs

Table A-2   Binary input presettings for all devices and ordering variants

Binary Inputs	Short Text	Function No.	Description
BI1	>Reset LED	5	>Reset LED
BI2	>Manual Close	356	>Manual close signal
BI3	>FAIL:Feeder VT	361	>Failure: Feeder VT (MCB tripped)
BI4	>DisTel Rec.Ch1	4006	>Dis.Tele. Carrier RECEPTION Channel 1
BI5	>1p Trip Perm	381	>Single-phase trip permitted from ext.AR

Table A-3   Further binary input presettings for 7SA610*-B/F/K

Binary Inputs	Short Text	Function No.	Description
BI6	>CB 3p Open	380	>CB aux. contact 3pole Open
	>CB1 3p Open	411	>CB1 aux. 3p Open (for AR, CB-Test)
BI7	>CB 3p Closed	379	>CB aux. contact 3pole Closed
	>CB1 3p Closed	410	>CB1 aux. 3p Closed (for AR, CB-Test)

Table A-4   Further binary input presettings for 7SA6*1, 7SA6*2 7SA613

Binary Inputs	Short Text	Function No.	Description
BI6	>TripC1 TripRel	6854	>Trip circuit superv. 1: Trip Relay
BI8	>CB 3p Open	380	>CB aux. contact 3pole Open
	>CB1 3p Open	411	>CB1 aux. 3p Open (for AR, CB-Test)
	Breaker		Breaker
BI9	>CB 3p Closed	379	>CB aux. contact 3pole Closed
	>CB1 3p Closed	410	>CB1 aux. 3p Closed (for AR, CB-Test)
	Breaker		Breaker
BI10	Disc.Swit.		Disconnect Switch
BI11	Disc.Swit.		Disconnect Switch
BI12	EarthSwit		Earth Switch
BI13	EarthSwit		Earth Switch
BI16	>Door open		>Cabinet door open

A.4.3 Binary Output

Table A-5   Output Relay Presettings for All Devices and Ordering Variants

Binary Output	Short Text	Function No.	Description
BO1	Relay PICKUP	501	Relay PICKUP
BO5	Alarm Sum Event	160	Alarm Summary Event

Table A-6   Further Output Relay Presettings for 7SA610*-*A/E/J

Binary Output	Short Text	Function No.	Description
BO3	AR CLOSE Cmd.	2851	AR: Close command
BO7	Dis.T.SEND	4056	Dis. Telep. Carrier SEND signal

Table A-7   Further Output Relay Presettings for 7SA610*-*B/F/K

Binary Output	Short Text	Function No.	Description
BO3	AR CLOSE Cmd.	2851	AR: Close command

Table A-8   Further Output Relay Presettings for 7SA6*1*-*A/E/J, 7SA6*2*-*A/E/J/B/F/K and 7SA613*-*A

Binary Output	Short Text	Function No.	Description
BO2	Relay TRIP	511	Relay GENERAL TRIP command
BO10	Dis.T.SEND	4056	Dis. Telep. Carrier SEND signal
BO12	AR CLOSE Cmd.	2851	AR: Close command
BO14	Relay TRIP	511	Relay GENERAL TRIP command
	Relay TRIP 1pL1	512	Relay TRIP command - Only Phase L1
	Relay TRIP 3ph.	515	Relay TRIP command Phases L123
BO15	Not configured	1	No Function configured
	Relay TRIP 1pL2	513	Relay TRIP command - Only Phase L2
	Relay TRIP 3ph.	515	Relay TRIP command Phases L123
BO16	Not configured	1	No Function configured
	Relay TRIP 1pL3	514	Relay TRIP command - Only Phase L3
	Relay TRIP 3ph.	515	Relay TRIP command Phases L123

Table A-9   Further Output Relay Presettings for 7SA6*1*-*B/F/K and 7SA6*2*-*C/G/L

Binary Output	Short Text	Function No.	Description
BO2	Breaker		Breaker
	Relay TRIP	511	Relay GENERAL TRIP command
BO3	Breaker		Breaker
	AR CLOSE Cmd.	2851	AR: Close command
BO4	Breaker		Breaker
	AR CLOSE Cmd.	2851	AR: Close command
BO6	Disc.Swit.		Disconnect Switch
BO7	Disc.Swit.		Disconnect Switch
BO8	EarthSwit		Earth Switch

Binary Output	Short Text	Function No.	Description
BO9	EarthSwit		Earth Switch
BO10	Relay TRIP 1pL1	512	Relay TRIP command - Only Phase L1
	Relay TRIP 3ph.	515	Relay TRIP command Phases L123
BO11	Relay TRIP 1pL2	513	Relay TRIP command - Only Phase L2
	Relay TRIP 3ph.	515	Relay TRIP command Phases L123
BO12	Relay TRIP 1pL3	514	Relay TRIP command - Only Phase L3
	Relay TRIP 3ph.	515	Relay TRIP command Phases L123

A.4.4 Function Keys

Table A-10   Applies to All Devices and Ordered Variants

Function Keys	Short Text	Function No.	Description
F1	Display of Operational Annunciations	-	-
F2	Operating Measured Values, Primary	-	-
F3	An Overview of the Last Eight Network Faults	-	-
F4	not allocated	-	-

A.4.5 Default Display

4-line Display   Table A-11   This selection is available as start page which may be configured.

| Page 1 | ``` 1▊ 0.50kA   12▊ 6.31kV
2▊ 0.50kA   23▊ 6.30kV
3▊ 0.50kA   31▊ 6.29kV
E▊ 0.0A   E ▊   2V ``` |
|---|---|
| Page 2 | ``` [%] I   ULE   ULL
L1▊78.4 99.6   99.5
L2▊78.1 99.4   99.3
L3▊78.9 99.8   99.7 ``` |
| Page 3 | ``` S: 0.0MVA U12: 0kV
P: 0.0MW   IL2: 0A
Q: 0.0MVAR
f: ---   cosφ: --- ``` |

| Page 4 | <pre>L1 ▌78.4A   MAX 81.2A
L2 ▌78.1A   MAX 81.0A
L3 ▌78.9A   MAX 81.9A
E ▌0.0A</pre> |
| --- | --- |
| Page 5 | <pre>L1 ▌78.4A
L2 ▌78.1A
L3 ▌78.9A
E ▌0.0A</pre> |

Graphic Display
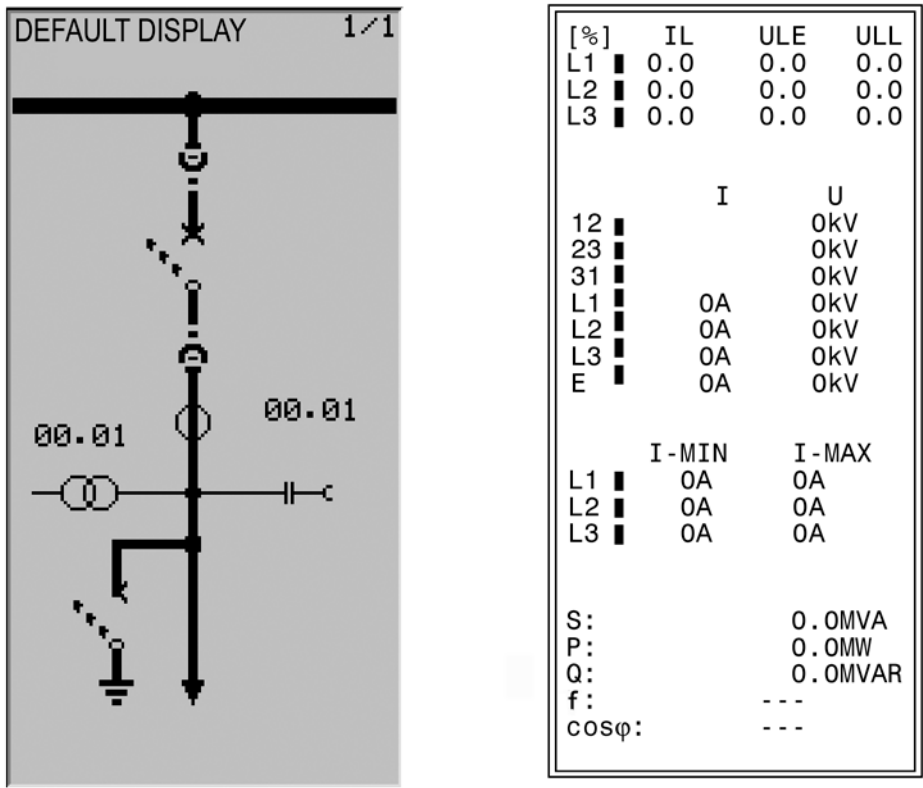
Figure A-48   Default displays of a graphical display

Spontaneous Fault Indication of the 4-Line Display

The spontaneous annunciations on devices with 4-line display serve to display the most important data about a fault. They appear automatically in the display after general interrogation of the device, in the sequence shown in the following Figure.

<pre>50-1 picked up
50-1 TRIP
T — Pickup
T — TRIP</pre>

Protective Function that picked up first;
Protective Function that tripped last;
Running time from general pickup to dropout;
Running time from general pickup to the first trip command
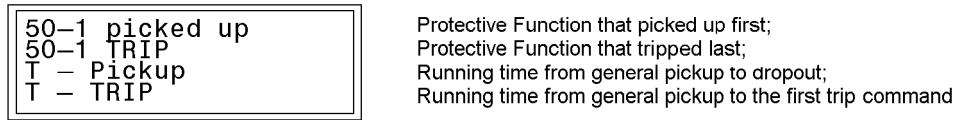
Figure A-49   Spontaneous Fault Annunciation Display

Spontaneous Fault Indication of the Graphic Display

All devices featuring a graphic display allow you to select whether or not to view automatically the most important fault data on the display after a general interrogation. The information corresponds to those of figure shown before.

Default Display in the Graphic Editor
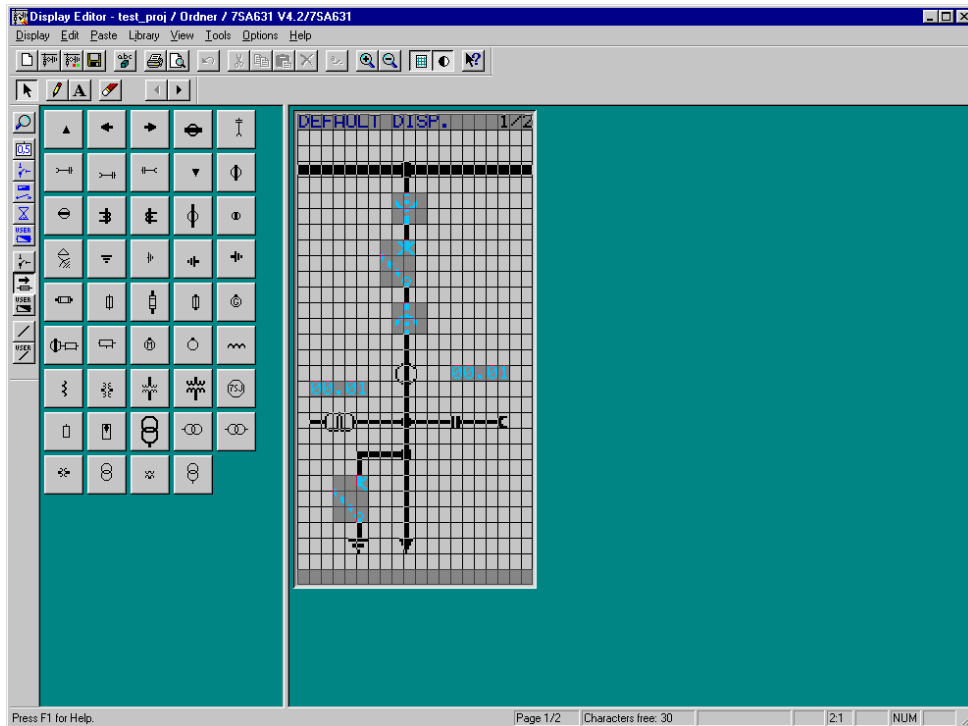
Figure A-50   Standard default display after starting the Display Editor - example

A.4.6   Pre-defined CFC Charts

Some CFC charts are already supplied with the SIPROTEC® device. Depending on the variant the following charts may be implemented:

Device and System Logic

Some of the event-controlled logical allocations are created with blocks of the slow logic (**PLC1_BEARB** = slow PLC processing). This way, the binary input "Data Stop" is modified from a single point indication (SP) into an internal single point indication (IntSP) by means of a negator block.

With the double point indication "EarthSwit." = CLOSE an indication saying "fdrEARTHED" ON, and with "EarthSwit." = OPEN or F the indication "fdrEARTHED" OFF is generated.

From the output indication "definite TRIP" the internal indication "Brk OPENED"is generated. As indication "definite TRIP" only queued for 500ms, also indication "Device Brk OPENED" is reset after this time period.

"IN: Device >Data Stop SP"	
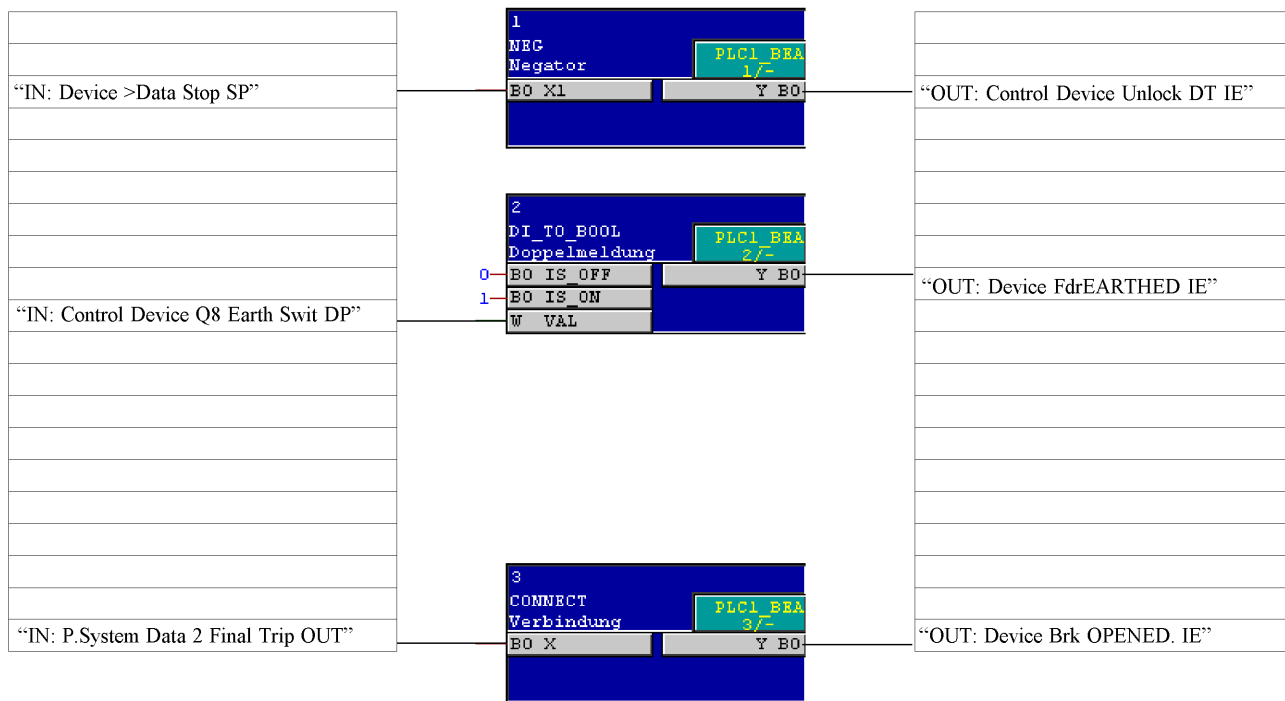
Figure A-51   Allocation of input and output with blocks of priority class System Logic

Interlocking   With blocks of level Interlocking (SFS_BEARB = interlocking), standard interlocking for three switchgears (circuit breaker, disconnector and earth switch) is pre-defined. Due to the large functional scope of the logic you will find this level on two worksheets.

The circuit breaker can be only be opened, if
- the circuit breaker is set to OPEN or CLOSE and
- the disconnector is set to OPEN or CLOSE and
- the earth switch is set to OPEN or CLOSE and
- the disconnector and the earth switch are not set to CLOSE at the same time and
- the input indication "CB wait" is OFF and
- the input indication "Door open" is OFF.

The disconnector can only be closed, if:
- the circuit breaker is set to OPEN and
- the earth switch is set to OPEN and
- the disconnector is set to OPEN or CLOSE and
- the input indication "Door open" is OFF.

The disconnector can only be closed, if:
- the circuit breaker is set to OPEN and
- the disconnector is set to OPEN or CLOSE and
- the earth switch is set to OPEN or CLOSE and
- the input indication "Door open" is OFF.

The earth switch can only be closed, if:
- the circuit breaker is set to OPEN and
- the disconnector is set to OPEN and

- the earth switch is set to OPEN or CLOSE and
- the input indication "Door open" is OFF.

If the above requirements are not fulfilled, the actions of the switch commands will be blocked with error messages by DIGSI®.

Worksheet 1
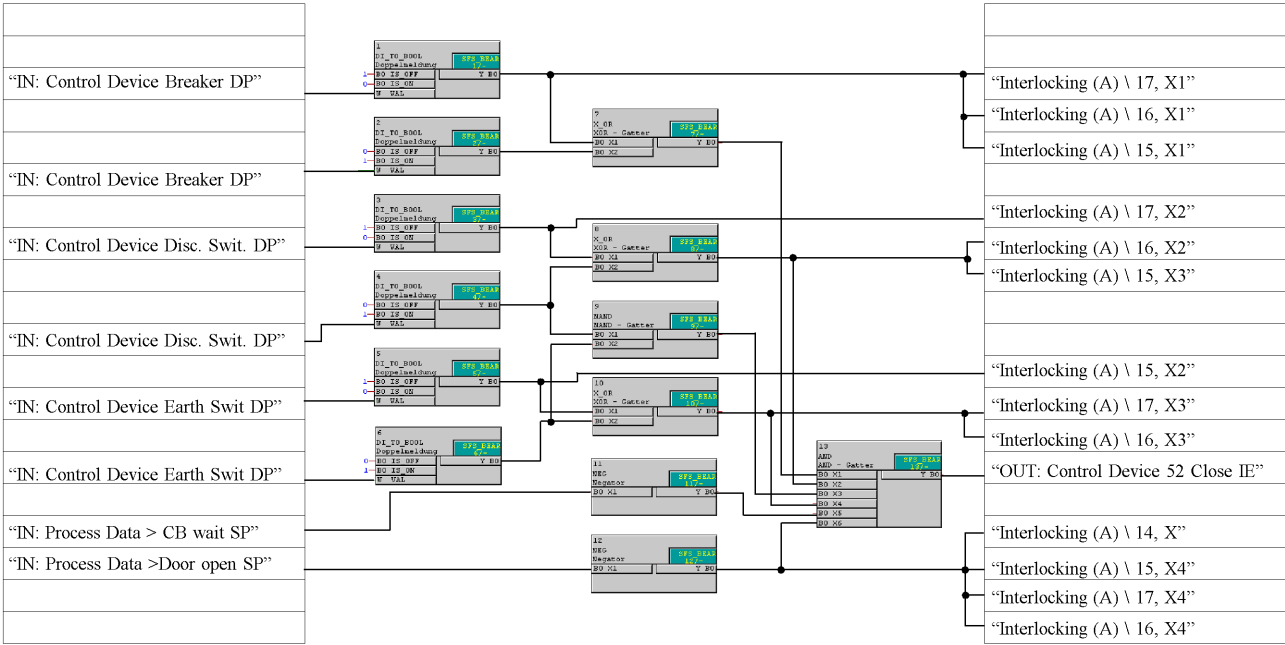
Worksheet 2 (continuation of Worksheet 1)
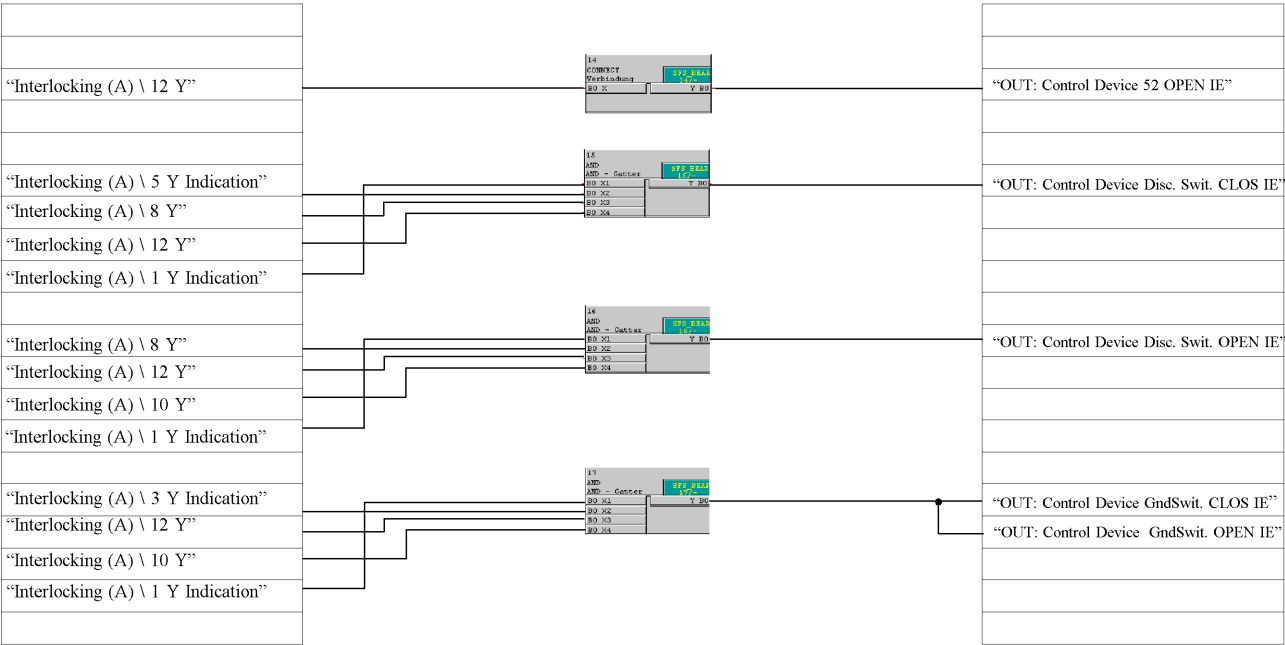
Figure A-52   Standard interlocking for circuit breaker, disconnector and earth switch

Limit Value Handling (Set Points)

On two worksheets a set point supervision of the sum of power factor |cosφ| < and in the maximum functional scope additional set point supervisions of currents (demand meter of phase currents and positive-sequence component) and supervisions of power (apparent power, active power and reactive power) are created with blocks of level "Processing of Measured Values".

A drop-out ratio of 0.95, or at least 0.5% applies for each drop.

Worksheet1
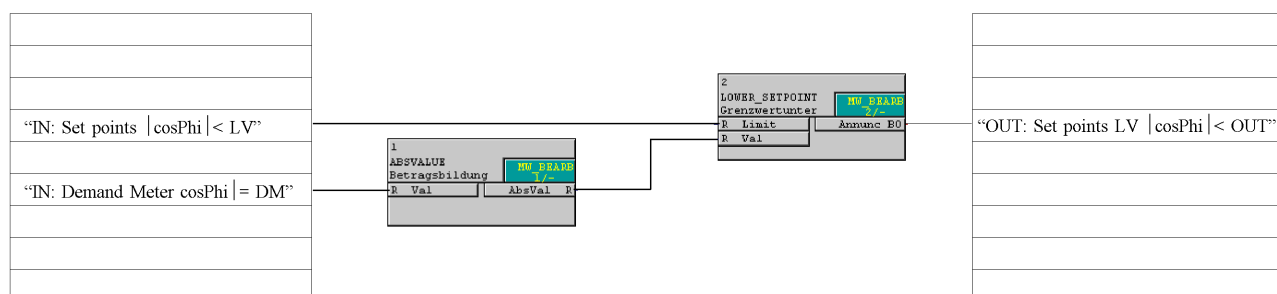
Worksheet 2
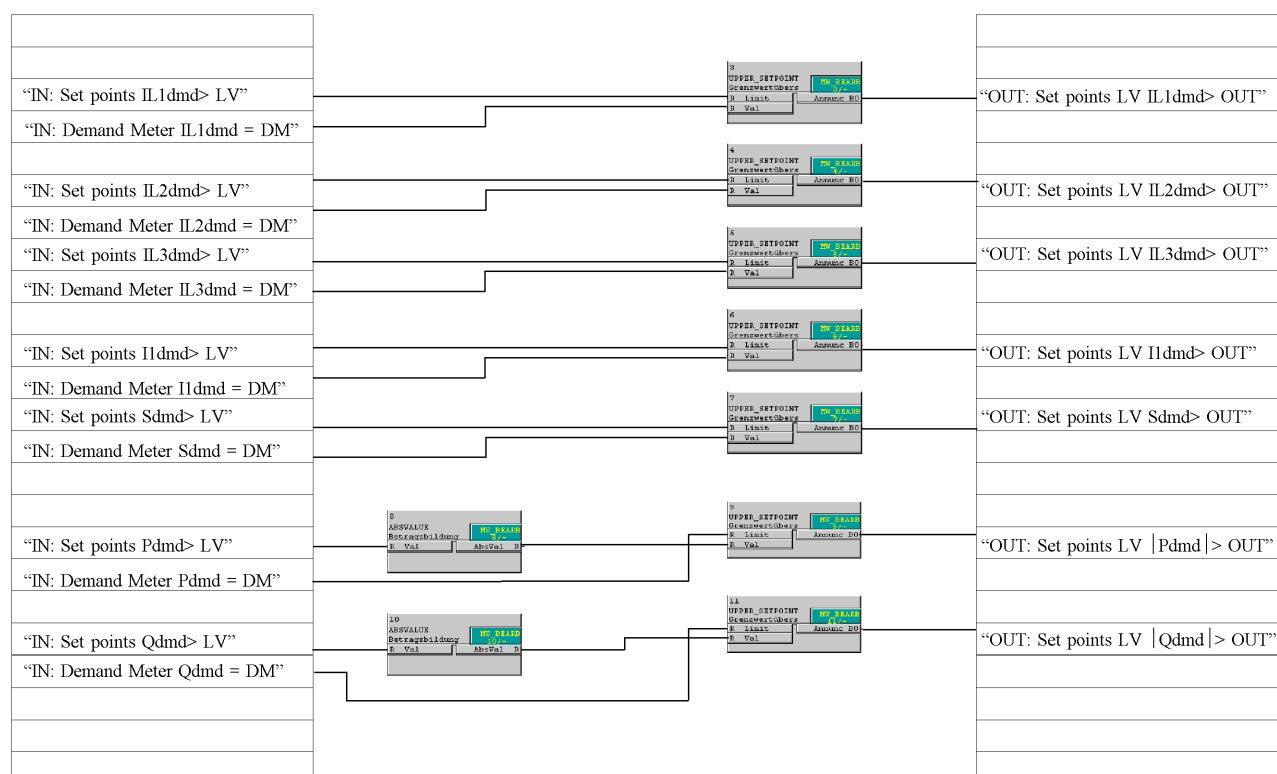
Figure A-53   Set point configuration with blocks of priority class Processing of Measured Values (**MW_BEARB**)

A.5 Protocol-dependent Functions

Protocol → Function ↓	IEC 60870-5-103	PROFIBUS FMS	PROFIBUS DP	DNP3.0	Additional Interface (optional)
Operational Measured Values	Yes	Yes	Yes	Yes	Yes
Metered Values	Yes	Yes	Yes	Yes	Yes
Fault Recording	Yes	Yes	No. Only via additional service interface	No. Only via additional service interface	Yes
Remote Relay Setting	No. Only via additional service interface	Yes	No. Only via additional service interface	No. Only via additional service interface	Yes
User-defined Alarms and Switching Objects	Yes	Yes	Pre-defined "user-defined messages" in CFC	Pre-defined "User-defined messages" in CFC	Yes
Time Synchronisation	Via protocol; DCF77/IRIG B; Interface; Binary input	Via protocol; DCF77/IRIG B; Interface; Binary input	Via DCF77/IRIG B; Interface; Binary input	Via protocol; DCF77/IRIG B; Interface; Binary input	-
Messages with Time Stamp	Yes	Yes	No	Yes	Yes
Commissioning Tools					
Alarm and Measured Value Transmission Blocking	Yes	Yes	No	No	Yes
Generate Test Alarms	Yes	Yes	No	No	Yes
Physical Mode	Asynchronous	Asynchronous	Asynchronous	Asynchronous	-
Transmission Mode	Cyclic/Event	Cyclic/Event	Cyclic	Cyclic/Event	-
Baud Rate	4800 to 38400	Up to 1.5 MBaud	Up to 1.5 MBaud	2400 to 19200	2400 to 115200
Type	RS 232 RS 485 Optical fibre	RS 485 Optical fibre Double ring	RS 485 Optical fibre Double ring	RS 485 Optical fibre	RS232/RS485

A.6   Functional Scope

Addr.	Parameter	Setting Options	Default Setting	Comments
103	Grp Chge OPTION	Disabled Enabled	Disabled	Setting Group Change Option
110	Trip mode	3pole only 1-/3pole	3pole only	Trip mode
114	Dis. PICKUP	Z< (quadrilat.) I> (overcurr.) U/I U/I/φ Disabled	Z< (quadrilat.)	Distance protection pickup program
120	Power Swing	Disabled Enabled	Disabled	Power Swing detection
121	Teleprot. Dist.	PUTT (Z1B) PUTT (Pickup) POTT Dir.Comp.Pickup UNBLOCKING BLOCKING Rev. Interlock Pilot wire comp SIGNALv.ProtInt Disabled	Disabled	Teleprotection for Distance prot.
122	DTT Direct Trip	Disabled Enabled	Disabled	DTT Direct Transfer Trip
124	SOTF Overcurr.	Disabled Enabled	Disabled	Instantaneous HighSpeed SOTF Overcurrent
125	Weak Infeed	Disabled Enabled Logic no. 2	Disabled	Weak Infeed (Trip and/or Echo)
126	Back-Up O/C	Disabled TOC IEC TOC ANSI	TOC IEC	Backup overcurrent
130	Sens. Earth Flt	Disabled Enabled	Disabled	Sensitive Earth Flt.(comp/ isol. starp.)
131	Earth Fault O/C	Disabled TOC IEC TOC ANSI TOC Logarithm. Definite Time U0 inverse Sr inverse	Disabled	Earth fault overcurrent
132	Teleprot. E/F	Dir.Comp.Pickup SIGNALv.ProtInt UNBLOCKING BLOCKING Disabled	Disabled	Teleprotection for Earth fault overcurr.

Addr.	Parameter	Setting Options	Default Setting	Comments
133	Auto Reclose	1 AR-cycle 2 AR-cycles 3 AR-cycles 4 AR-cycles 5 AR-cycles 6 AR-cycles 7 AR-cycles 8 AR-cycles ADT Disabled	Disabled	Auto-Reclose Function
134	AR control mode	Pickup w/ Tact Pickup w/o Tact Trip w/ Tact Trip w/o Tact	Trip w/ Tact	Auto-Reclose control mode
135	Synchro-Check	Disabled Enabled	Disabled	Synchronism and Voltage Check
136	FREQUENCY Prot.	Disabled Enabled	Disabled	Over / Underfrequency Protection
137	U/O VOLTAGE	Disabled Enabled Enabl. w. comp.	Disabled	Under / Overvoltage Protection
138	Fault Locator	Enabled Disabled with BCD-output	Enabled	Fault Locator
139	BREAKER FAILURE	Disabled Enabled	Disabled	Breaker Failure Protection
140	Trip Cir. Sup.	Disabled 1 trip circuit 2 trip circuits 3 trip circuits	Disabled	Trip Circuit Supervision
142	Ther. OVERLOAD	Disabled Enabled	Disabled	Thermal overload protection
145	P. INTERFACE 1	Enabled Disabled	Enabled	Protection Interface 1 (Port D)
147	NUMBER OF RELAY	2 relays 3 relays	2 relays	Number of relays
150	AnalogOutput B1	Disabled IL2 [%] UL23 [%] |P| [%] |Q| [%] d [%] d [km] d [miles] Imax TRIP [pri]	Disabled	Analog Output B1 (Port B)
151	AnalogOutput B2	Disabled IL2 [%] UL23 [%] |P| [%] |Q| [%] d [%] d [km] d [miles] Imax TRIP [pri]	Disabled	Analog Output B2 (Port B)

Addr.	Parameter	Setting Options	Default Setting	Comments
152	AnalogOutput D1	Disabled IL2 [%] UL23 [%] |P| [%] |Q| [%] d [%] d [km] d [miles] Imax TRIP [pri]	Disabled	Analog Output D1 (Port D)
153	AnalogOutput D2	Disabled IL2 [%] UL23 [%] |P| [%] |Q| [%] d [%] d [km] d [miles] Imax TRIP [pri]	Disabled	Analog Output D2 (Port D)

A.7 Settings

Addresses which have an appended "A" can only be changed with DIGSI, under Additional Settings.

The table indicates region-specific presettings. Column C (configuration) indicates the corresponding secondary nominal current of the current transformer.

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
201	CT Starpoint	P.System Data 1		towards Line towards Busbar	towards Line	CT Starpoint
203	Unom PRIMARY	P.System Data 1		1.0 .. 1200.0 kV	400.0 kV	Rated Primary Voltage
204	Unom SECONDARY	P.System Data 1		80 .. 125 V	100 V	Rated Secondary Voltage (L-L)
205	CT PRIMARY	P.System Data 1		10 .. 5000 A	1000 A	CT Rated Primary Current
206	CT SECONDARY	P.System Data 1		1A 5A	1A	CT Rated Secondary Current
207	SystemStarpoint	P.System Data 1		Solid Earthed Peterson-Coil Isolated	Solid Earthed	System Starpoint is
210	U4 transformer	P.System Data 1		Not connected Udelta transf. Usync transf. Ux transformer	Not connected	U4 voltage transformer is
211	Uph / Udelta	P.System Data 1		0.10 .. 9.99	1.73	Matching ratio Phase-VT To Open-Delta-VT
212	Usync connect.	P.System Data 1		L1-E L2-E L3-E L1-L2 L2-L3 L3-L1	L1-L2	VT connection for sync. voltage
214A	φ Usync-Uline	P.System Data 1		0 .. 360 °	0 °	Angle adjustment Usync-Uline
215	U-line / Usync	P.System Data 1		0.50 .. 2.00	1.00	Matching ratio U-line / Usync
220	I4 transformer	P.System Data 1		Not connected In prot. line In paral. line IY starpoint	In prot. line	I4 current transformer is
221	I4/Iph CT	P.System Data 1		0.010 .. 5.000	1.000	Matching ratio I4/Iph for CT's
230	Rated Frequency	P.System Data 1		50 Hz 60 Hz	50 Hz	Rated Frequency
235	PHASE SEQ.	P.System Data 1		L1 L2 L3 L1 L3 L2	L1 L2 L3	Phase Sequence
236	Distance Unit	P.System Data 1		km Miles	km	Distance measurement unit
237	Format Z0/Z1	P.System Data 1		RE/RL, XE/XL K0	RE/RL, XE/XL	Setting format for zero seq.comp. format
239	T-CB close	P.System Data 1		0.01 .. 0.60 sec	0.06 sec	Closing (operating) time of CB
240A	TMin TRIP CMD	P.System Data 1		0.02 .. 30.00 sec	0.10 sec	Minimum TRIP Command Duration
241A	TMax CLOSE CMD	P.System Data 1		0.01 .. 30.00 sec	0.10 sec	Maximum Close Command Duration
242	T-CBtest-dead	P.System Data 1		0.00 .. 30.00 sec	0.10 sec	Dead Time for CB test-autoreclosure
302	CHANGE	Change Group		Group A Group B Group C Group D Binary Input Protocol	Group A	Change to Another Setting Group
402A	WAVEFORMTRIGGER	Osc. Fault Rec.		Save w. Pickup Save w. TRIP Start w. TRIP	Save w. Pickup	Waveform Capture
403A	WAVEFORM DATA	Osc. Fault Rec.		Fault event Pow.Sys.Flt.	Fault event	Scope of Waveform Data
410	MAX. LENGTH	Osc. Fault Rec.		0.30 .. 5.00 sec	2.00 sec	Max. length of a Waveform Capture Record

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
411	PRE. TRIG. TIME	Osc. Fault Rec.		0.05 .. 0.50 sec	0.25 sec	Captured Waveform Prior to Trigger
412	POST REC. TIME	Osc. Fault Rec.		0.05 .. 0.50 sec	0.10 sec	Captured Waveform after Event
415	BinIn CAPT.TIME	Osc. Fault Rec.		0.10 .. 5.00 sec; ∞	0.50 sec	Capture Time via Binary Input
610	FltDisp.LED/LCD	Device		Target on PU Target on TRIP	Target on PU	Fault Display on LED / LCD
615	Spont. FltDisp.	Device		NO YES	NO	Spontaneous display of flt.annunciations
640	Start image DD	Device		image 1 image 2 image 3 image 4 image 5	image 1	Start image Default Display
1103	FullScaleVolt.	P.System Data 2		1.0 .. 1200.0 kV	400.0 kV	Measurement: Full Scale Voltage (100%)
1104	FullScaleCurr.	P.System Data 2		10 .. 5000 A	1000 A	Measurement: Full Scale Current (100%)
1105	Line Angle	P.System Data 2		30 .. 89 °	85 °	Line Angle
1107	P,Q sign	P.System Data 2		not reversed reversed	not reversed	P,Q operational measured values sign
1110	x'	P.System Data 2	1A	0.0050 .. 9.5000 Ω/km	0.1500 Ω/km	x' - Line Reactance per length unit
			5A	0.0010 .. 1.9000 Ω/km	0.0300 Ω/km	
1111	Line Length	P.System Data 2		0.1 .. 1000.0 km	100.0 km	Line Length
1112	x'	P.System Data 2	1A	0.0050 .. 15.0000 Ω/mi	0.2420 Ω/mi	x' - Line Reactance per length unit
			5A	0.0010 .. 3.0000 Ω/mi	0.0484 Ω/mi	
1113	Line Length	P.System Data 2		0.1 .. 650.0 Miles	62.1 Miles	Line Length
1114	c'	P.System Data 2	1A	0.000 .. 100.000 μF/km	0.010 μF/km	c' - capacit. per unit line len. μF/km
			5A	0.000 .. 500.000 μF/km	0.050 μF/km	
1115	c'	P.System Data 2	1A	0.000 .. 160.000 μF/mi	0.016 μF/mi	c' - capacit. per unit line len. μF/mile
			5A	0.000 .. 800.000 μF/mi	0.080 μF/mi	
1116	RE/RL(Z1)	P.System Data 2		-0.33 .. 7.00	1.00	Zero seq. comp. factor RE/RL for Z1
1117	XE/XL(Z1)	P.System Data 2		-0.33 .. 7.00	1.00	Zero seq. comp. factor XE/XL for Z1
1118	RE/RL(Z1B...Z5)	P.System Data 2		-0.33 .. 7.00	1.00	Zero seq. comp.factor RE/RL for Z1B...Z5
1119	XE/XL(Z1B...Z5)	P.System Data 2		-0.33 .. 7.00	1.00	Zero seq. comp.factor XE/XL for Z1B...Z5
1120	K0 (Z1)	P.System Data 2		0.000 .. 4.000	1.000	Zero seq. comp. factor K0 for zone Z1
1121	Angle K0(Z1)	P.System Data 2		-135.00 .. 135.00 °	0.00 °	Zero seq. comp. angle for zone Z1
1122	K0 (> Z1)	P.System Data 2		0.000 .. 4.000	1.000	Zero seq.comp.factor K0,higher zones >Z1
1123	AngleI K0(> Z1)	P.System Data 2		-135.00 .. 135.00 °	0.00 °	Zero seq. comp. angle, higher zones >Z1
1126	RM/RL ParalLine	P.System Data 2		0.00 .. 8.00	0.00	Mutual Parallel Line comp. ratio RM/RL
1127	XM/XL ParalLine	P.System Data 2		0.00 .. 8.00	0.00	Mutual Parallel Line comp. ratio XM/XL
1128	RATIO Par. Comp	P.System Data 2		50 .. 95 %	85 %	Neutral current RATIO Parallel Line Comp
1130A	PoleOpenCurrent	P.System Data 2	1A	0.05 .. 1.00 A	0.10 A	Pole Open Current Threshold
			5A	0.25 .. 5.00 A	0.50 A	
1131A	PoleOpenVoltage	P.System Data 2		2 .. 70 V	30 V	Pole Open Voltage Threshold
1132A	SI Time all Cl.	P.System Data 2		0.01 .. 30.00 sec	0.05 sec	Seal-in Time after ALL closures
1134	Line Closure	P.System Data 2		only with ManCl I OR U or ManCl CB OR I or M/C I or Man.Close	only with ManCl	Recognition of Line Closures with
1135	Reset Trip CMD	P.System Data 2		CurrentOpenPole Current AND CB	CurrentOpenPole	RESET of Trip Command

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
1140A	I-CTsat. Thres.	P.System Data 2	1A	0.2 .. 50.0 A; ∞	20.0 A	CT Saturation Threshold
			5A	1.0 .. 250.0 A; ∞	100.0 A	
1150A	SI Time Man.Cl	P.System Data 2		0.01 .. 30.00 sec	0.30 sec	Seal-in Time after MANUAL closures
1151	MAN. CLOSE	P.System Data 2		with Sync-check w/o Sync-check NO	NO	Manual CLOSE COMMAND generation
1152	Man.Clos. Imp.	P.System Data 2		None Breaker Disc.Swit. EarthSwit Q2 Op/Cl Q9 Op/Cl Fan ON/OFF	None	MANUAL Closure Impulse after CONTROL
1155	3pole coupling	P.System Data 2		with PICKUP with TRIP	with TRIP	3 pole coupling
1156A	Trip2phFlt	P.System Data 2		3pole 1pole leading Ø 1pole lagging Ø	3pole	Trip type with 2phase faults
1201	FCT Distance	Dis. General		ON OFF	ON	Distance protection is
1202	Minimum Iph>	Dis. General	1A	0.05 .. 4.00 A	0.10 A	Phase Current threshold for dist. meas.
			5A	0.25 .. 20.00 A	0.50 A	
1203	3I0> Threshold	Dis. General	1A	0.05 .. 4.00 A	0.10 A	3I0 threshold for neutral current pickup
			5A	0.25 .. 20.00 A	0.50 A	
1204	3U0> Threshold	Dis. General		1 .. 100 V; ∞	5 V	3U0 threshold zero seq. voltage pickup
1205	3U0> COMP/ISOL.	Dis. General		10 .. 200 V	40 V	3U0> pickup (comp/ isol. starpoint)
1206	T3I0 1PHAS	Dis. General		0.00 .. 0.50 sec; ∞	0.04 sec	Delay 1ph-faults (comp/isol. starpoint)
1207A	3I0>/ Iphmax	Dis. General		0.05 .. 0.30	0.10	3I0>-pickup-stabilisation (3I0> /Iphmax)
1208	SER-COMP.	Dis. General		NO YES	NO	Series compensated line
1209A	E/F recognition	Dis. General		3I0> OR 3U0> 3I0> AND 3U0>	3I0> OR 3U0>	criterion of earth fault recognition
1210	Start Timers	Dis. General		on Dis. Pickup on Zone Pickup	on Dis. Pickup	Condition for zone timer start
1211	Distance Angle	P.System Data 2 Dis. General		30 .. 90 °	85 °	Angle of inclination, distance charact.
1215	Paral.Line Comp	Dis. General		NO YES	YES	Mutual coupling parall.line compensation
1220	PHASE PREF.2phe	Dis. General		L3 (L1) ACYCLIC L1 (L3) ACYCLIC L2 (L1) ACYCLIC L1 (L2) ACYCLIC L3 (L2) ACYCLIC L2 (L3) ACYCLIC L3 (L1) CYCLIC L1 (L3) CYCLIC All loops	L3 (L1) ACYCLIC	Phase preference for 2ph-e faults
1221A	2Ph-E faults	Dis. General		Block leading Ø Block lagging Ø All loops Ø-Ø loops only Ø-E loops only	Block leading Ø	Loop selection with 2Ph-E faults
1232	SOTF zone	Dis. General		PICKUP Zone Z1B Inactive Z1B undirect.	Inactive	Instantaneous trip after Switch-OnToFault
1241	R load (Ø-E)	Dis. General	1A	0.100 .. 600.000 Ω; ∞	∞ Ω	R load, minimum Load Impedance (ph-e)
			5A	0.020 .. 120.000 Ω; ∞	∞ Ω	
1242	φ load (Ø-E)	Dis. General		20 .. 60 °	45 °	PHI load, maximum Load Angle (ph-e)
1243	R load (Ø-Ø)	Dis. General	1A	0.100 .. 600.000 Ω; ∞	∞ Ω	R load, minimum Load Impedance (ph-ph)
			5A	0.020 .. 120.000 Ω; ∞	∞ Ω	

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
1244	φ load (Ø-Ø)	Dis. General		20 .. 60 °	45 °	PHI load, maximum Load Angle (ph-ph)
1301	Op. mode Z1	Dis. Quadril.		Forward Reverse Non-Directional Inactive	Forward	Operating mode Z1
1302	R(Z1) Ø-Ø	Dis. Quadril.	1A	0.050 .. 600.000 Ω	1.250 Ω	R(Z1), Resistance for ph-ph-faults
			5A	0.010 .. 120.000 Ω	0.250 Ω	
1303	X(Z1)	Dis. Quadril.	1A	0.050 .. 600.000 Ω	2.500 Ω	X(Z1), Reactance
			5A	0.010 .. 120.000 Ω	0.500 Ω	
1304	RE(Z1) Ø-E	Dis. Quadril.	1A	0.050 .. 600.000 Ω	2.500 Ω	RE(Z1), Resistance for ph-e faults
			5A	0.010 .. 120.000 Ω	0.500 Ω	
1305	T1-1phase	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.00 sec	T1-1phase, delay for single phase faults
1306	T1-multi-phase	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.00 sec	T1multi-ph, delay for multi phase faults
1307	Zone Reduction	Dis. Quadril.		0 .. 45 °	0 °	Zone Reduction Angle (load compensation)
1311	Op. mode Z2	Dis. Quadril.		Forward Reverse Non-Directional Inactive	Forward	Operating mode Z2
1312	R(Z2) Ø-Ø	Dis. Quadril.	1A	0.050 .. 600.000 Ω	2.500 Ω	R(Z2), Resistance for ph-ph-faults
			5A	0.010 .. 120.000 Ω	0.500 Ω	
1313	X(Z2)	Dis. Quadril.	1A	0.050 .. 600.000 Ω	5.000 Ω	X(Z2), Reactance
			5A	0.010 .. 120.000 Ω	1.000 Ω	
1314	RE(Z2) Ø-E	Dis. Quadril.	1A	0.050 .. 600.000 Ω	5.000 Ω	RE(Z2), Resistance for ph-e faults
			5A	0.010 .. 120.000 Ω	1.000 Ω	
1315	T2-1phase	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.30 sec	T2-1phase, delay for single phase faults
1316	T2-multi-phase	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.30 sec	T2multi-ph, delay for multi phase faults
1317A	Trip 1pole Z2	Dis. General Dis. Quadril.		NO YES	NO	Single pole trip for faults in Z2
1321	Op. mode Z3	Dis. Quadril.		Forward Reverse Non-Directional Inactive	Reverse	Operating mode Z3
1322	R(Z3) Ø-Ø	Dis. Quadril.	1A	0.050 .. 600.000 Ω	5.000 Ω	R(Z3), Resistance for ph-ph-faults
			5A	0.010 .. 120.000 Ω	1.000 Ω	
1323	X(Z3)	Dis. Quadril.	1A	0.050 .. 600.000 Ω	10.000 Ω	X(Z3), Reactance
			5A	0.010 .. 120.000 Ω	2.000 Ω	
1324	RE(Z3) Ø-E	Dis. Quadril.	1A	0.050 .. 600.000 Ω	10.000 Ω	RE(Z3), Resistance for ph-e faults
			5A	0.010 .. 120.000 Ω	2.000 Ω	
1325	T3 DELAY	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.60 sec	T3 delay
1331	Op. mode Z4	Dis. Quadril.		Forward Reverse Non-Directional Inactive	Non-Directional	Operating mode Z4
1332	R(Z4) Ø-Ø	Dis. Quadril.	1A	0.050 .. 600.000 Ω	12.000 Ω	R(Z4), Resistance for ph-ph-faults
			5A	0.010 .. 120.000 Ω	2.400 Ω	
1333	X(Z4)	Dis. Quadril.	1A	0.050 .. 600.000 Ω	12.000 Ω	X(Z4), Reactance
			5A	0.010 .. 120.000 Ω	2.400 Ω	
1334	RE(Z4) Ø-E	Dis. Quadril.	1A	0.050 .. 600.000 Ω	12.000 Ω	RE(Z4), Resistance for ph-e faults
			5A	0.010 .. 120.000 Ω	2.400 Ω	
1335	T4 DELAY	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.90 sec	T4 delay
1341	Op. mode Z5	Dis. Quadril.		Forward Reverse Non-Directional Inactive	Inactive	Operating mode Z5

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
1342	R(Z5) Ø-Ø	Dis. Quadril.	1A	0.050 .. 600.000 Ω	12.000 Ω	R(Z5), Resistance for ph-ph-faults
			5A	0.010 .. 120.000 Ω	2.400 Ω	
1343	X(Z5)+	Dis. Quadril.	1A	0.050 .. 600.000 Ω	12.000 Ω	X(Z5)+, Reactance for Forward direction
			5A	0.010 .. 120.000 Ω	2.400 Ω	
1344	RE(Z5) Ø-E	Dis. Quadril.	1A	0.050 .. 600.000 Ω	12.000 Ω	RE(Z5), Resistance for ph-e faults
			5A	0.010 .. 120.000 Ω	2.400 Ω	
1345	T5 DELAY	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.90 sec	T5 delay
1346	X(Z5)-	Dis. Quadril.	1A	0.050 .. 600.000 Ω	4.000 Ω	X(Z5)-, Reactance for Reverse direction
			5A	0.010 .. 120.000 Ω	0.800 Ω	
1351	Op. mode Z1B	Dis. Quadril.		Forward Reverse Non-Directional Inactive	Forward	Operating mode Z1B (overreach zone)
1352	R(Z1B) Ø-Ø	Dis. Quadril.	1A	0.050 .. 600.000 Ω	1.500 Ω	R(Z1B), Resistance for ph-ph-faults
			5A	0.010 .. 120.000 Ω	0.300 Ω	
1353	X(Z1B)	Dis. Quadril.	1A	0.050 .. 600.000 Ω	3.000 Ω	X(Z1B), Reactance
			5A	0.010 .. 120.000 Ω	0.600 Ω	
1354	RE(Z1B) Ø-E	Dis. Quadril.	1A	0.050 .. 600.000 Ω	3.000 Ω	RE(Z1B), Resistance for ph-e faults
			5A	0.010 .. 120.000 Ω	0.600 Ω	
1355	T1B-1phase	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.00 sec	T1B-1phase, delay for single ph. faults
1356	T1B-multi-phase	Dis. General Dis. Quadril.		0.00 .. 30.00 sec; ∞	0.00 sec	T1B-multi-ph, delay for multi ph. faults
1357	1st AR -> Z1B	Dis. General Dis. Quadril.		NO YES	YES	Z1B enabled before 1st AR (int. or ext.)
1601	PROGAM U/I	Dis. General		LE:Uphe/LL:Uphp LE:Uphp/LL:Uphp LE:Uphe/LL:Uphe LE:Uphe/LL:I>>	LE:Uphe/LL:Uphp	Pickup program U/I
1602	DELAY FORW. PU	Dis. General Dis. General		0.00 .. 30.00 sec; ∞	1.20 sec	Trip delay for Forward-PICKUP
1603	DEL. NON-DIR PU	Dis. General Dis. General		0.00 .. 30.00 sec; ∞	1.20 sec	Trip delay for non-directional PICKUP
1610	Iph>>	Dis. General	1A	0.25 .. 10.00 A	1.80 A	Iph>> Pickup (overcurrent)
			5A	1.25 .. 50.00 A	9.00 A	
1611	Iph>	Dis. General	1A	0.10 .. 4.00 A	0.20 A	Iph> Pickup (minimum current)
			5A	0.50 .. 20.00 A	1.00 A	
1612	Uph-e (I>>)	Dis. General		20 .. 70 V	48 V	Undervoltage (ph-e) at Iph>>
1613	Uph-e (I>)	Dis. General		20 .. 70 V	48 V	Undervoltage (ph-e) at Iph>
1614	Uph-ph (I>>)	Dis. General		40 .. 130 V	80 V	Undervoltage (ph-ph) at Iph>>
1615	Uph-ph (I>)	Dis. General		40 .. 130 V	80 V	Undervoltage (ph-ph) at Iph>
1616	Iphi>	Dis. General	1A	0.10 .. 8.00 A	0.50 A	Iphi> Pickup (minimum current at phi>)
			5A	0.50 .. 40.00 A	2.50 A	
1617	Uph-e (Iphi>)	Dis. General		20 .. 70 V	48 V	Undervoltage (ph-e) at Iphi>
1618	Uph-ph (Iphi>)	Dis. General		40 .. 130 V	80 V	Undervoltage (ph-ph) at Iphi>
1619A	EFFECT φ	Dis. General		forward&reverse Forward	forward&reverse	Effective direction of phi-pickup
1620	φ>	Dis. General		30 .. 60 °	50 °	PHI> pickup (lower setpoint)
1621	φ<	Dis. General		90 .. 120 °	110 °	PHI< pickup (upper setpoint)
1630A	1ph FAULTS	Dis. General		PHASE-EARTH PHASE-PHASEONLY	PHASE-EARTH	1ph-pickup loop selection (PU w/o earth)
2002	P/S Op. mode	Power Swing		All zones block Z1/Z1B block Z2 to Z5 block Z1,Z1B,Z2 block	All zones block	Power Swing Operating mode
2006	PowerSwing trip	Power Swing		NO YES	NO	Power swing trip
2007	Trip DELAY P/S	Power Swing		0.08 .. 5.00 sec; 0	0.08 sec	Trip delay after Power Swing Blocking

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
2101	FCT Telep. Dis.	Teleprot. Dist.		ON PUTT (Z1B) POTT OFF	ON	Teleprotection for Distance prot. is
2102	Type of Line	Teleprot. Dist.		Two Terminals Three terminals	Two Terminals	Type of Line
2103A	Send Prolong.	Teleprot. Dist.		0.00 .. 30.00 sec	0.05 sec	Time for send signal prolongation
2107A	Delay for alarm	Teleprot. Dist.		0.00 .. 30.00 sec	10.00 sec	Time Delay for Alarm
2108	Release Delay	Teleprot. Dist.		0.000 .. 30.000 sec	0.000 sec	Time Delay for release after pickup
2109A	TrBlk Wait Time	Teleprot. Dist.		0.00 .. 30.00 sec; ∞	0.04 sec	Transient Block.: Duration external flt.
2110A	TrBlk BlockTime	Teleprot. Dist.		0.00 .. 30.00 sec	0.05 sec	Transient Block.: Blk.T. after ext. flt.
2201	FCT Direct Trip	DTT Direct Trip		ON OFF	OFF	Direct Transfer Trip (DTT)
2202	Trip Time DELAY	DTT Direct Trip		0.00 .. 30.00 sec; ∞	0.01 sec	Trip Time Delay
2401	FCT SOTF-O/C	SOTF Overcurr.		ON OFF	ON	Inst. High Speed SOTF-O/C is
2404	I>>>	SOTF Overcurr.	1A	1.00 .. 25.00 A	2.50 A	I>>> Pickup
			5A	5.00 .. 125.00 A	12.50 A	
2501	FCT Weak Infeed	Weak Infeed		OFF ECHO only ECHO and TRIP	ECHO only	Weak Infeed function is
2502A	Trip/Echo DELAY	Weak Infeed		0.00 .. 30.00 sec	0.04 sec	Trip / Echo Delay after carrier receipt
2503A	Trip EXTENSION	Weak Infeed		0.00 .. 30.00 sec	0.05 sec	Trip Extension / Echo Impulse time
2504A	Echo BLOCK Time	Weak Infeed		0.00 .. 30.00 sec	0.05 sec	Echo Block Time
2505	UNDERVOLTAGE	Weak Infeed		2 .. 70 V	25 V	Undervoltage (ph-e)
2509	Echo:1channel	Weak Infeed		NO YES	NO	Echo logic: Dis and EF on common channel
2510	Uphe< Factor	Weak Infeed		0.10 .. 1.00	0.70	Factor for undervoltage Uphe<
2511	Time const. τ	Weak Infeed		1 .. 60 sec	5 sec	Time constant Tau
2512A	Rec. Ext.	Weak Infeed		0.00 .. 30.00 sec	0.65 sec	Reception extension
2513A	T 3I0> Ext.	Weak Infeed		0.00 .. 30.00 sec	0.60 sec	3I0> exceeded extension
2514	3I0> Threshold	Weak Infeed	1A	0.05 .. 1.00 A	0.50 A	3I0 threshold for neutral current pickup
			5A	0.25 .. 5.00 A	2.50 A	
2515	TM	Weak Infeed		0.00 .. 30.00 sec	0.40 sec	WI delay single pole
2516	TT	Weak Infeed		0.00 .. 30.00 sec	1.00 sec	WI delay multi pole
2517	1pol. Trip	Weak Infeed		ON OFF	ON	Single pole WI trip allowed
2518	1pol. with 3I0	Weak Infeed		ON OFF	ON	Single pole WI trip with 3I0
2519	3pol. Trip	Weak Infeed		ON OFF	ON	Three pole WI trip allowed
2520	T 3I0> alarm	Weak Infeed		0.00 .. 30.00 sec	10.00 sec	3I0> exceeded delay for alarm
2530	WI non delayed	Weak Infeed		ON OFF	ON	WI non delayed
2531	WI delayed	Weak Infeed		ON OFF by receive fail	OFF	WI delayed
2601	Operating Mode	Back-Up O/C		ON:with VT loss ON:always activ OFF	ON:with VT loss	Operating mode
2610	Iph>>	Back-Up O/C	1A	0.10 .. 25.00 A; ∞	2.00 A	Iph>> Pickup
			5A	0.50 .. 125.00 A; ∞	10.00 A	
2611	T Iph>>	Back-Up O/C		0.00 .. 30.00 sec; ∞	0.30 sec	T Iph>> Time delay
2612	3I0>> PICKUP	Back-Up O/C	1A	0.05 .. 25.00 A; ∞	0.50 A	3I0>> Pickup
			5A	0.25 .. 125.00 A; ∞	2.50 A	
2613	T 3I0>>	Back-Up O/C		0.00 .. 30.00 sec; ∞	2.00 sec	T 3I0>> Time delay
2614	I>> Telep/BI	Back-Up O/C		NO YES	YES	Instantaneous trip via Teleprot./BI

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
2615	I>> SOTF	Back-Up O/C		NO YES	NO	Instantaneous trip after Switch-OnToFault
2620	Iph>	Back-Up O/C	1A	0.10 .. 25.00 A; ∞	1.50 A	Iph> Pickup
			5A	0.50 .. 125.00 A; ∞	7.50 A	
2621	T Iph>	Back-Up O/C		0.00 .. 30.00 sec; ∞	0.50 sec	T Iph> Time delay
2622	3I0>	Back-Up O/C	1A	0.05 .. 25.00 A; ∞	0.20 A	3I0> Pickup
			5A	0.25 .. 125.00 A; ∞	1.00 A	
2623	T 3I0>	Back-Up O/C		0.00 .. 30.00 sec; ∞	2.00 sec	T 3I0> Time delay
2624	I> Telep/BI	Back-Up O/C		NO YES	NO	Instantaneous trip via Teleprot./BI
2625	I> SOTF	Back-Up O/C		NO YES	NO	Instantaneous trip after Switch-OnToFault
2630	Iph> STUB	Back-Up O/C	1A	0.10 .. 25.00 A; ∞	1.50 A	Iph> STUB Pickup
			5A	0.50 .. 125.00 A; ∞	7.50 A	
2631	T Iph STUB	Back-Up O/C		0.00 .. 30.00 sec; ∞	0.30 sec	T Iph STUB Time delay
2632	3I0> STUB	Back-Up O/C	1A	0.05 .. 25.00 A; ∞	0.20 A	3I0> STUB Pickup
			5A	0.25 .. 125.00 A; ∞	1.00 A	
2633	T 3I0 STUB	Back-Up O/C		0.00 .. 30.00 sec; ∞	2.00 sec	T 3I0 STUB Time delay
2634	I-STUB Telep/BI	Back-Up O/C		NO YES	NO	Instantaneous trip via Teleprot./BI
2635	I-STUB SOTF	Back-Up O/C		NO YES	NO	Instantaneous trip after Switch-OnToFault
2640	Ip>	Back-Up O/C	1A	0.10 .. 4.00 A; ∞	∞ A	Ip> Pickup
			5A	0.50 .. 20.00 A; ∞	∞ A	
2642	T Ip Time Dial	Back-Up O/C		0.05 .. 3.00 sec; ∞	0.50 sec	T Ip Time Dial
2643	Time Dial TD Ip	Back-Up O/C		0.50 .. 15.00 ; ∞	5.00	Time Dial TD Ip
2646	T Ip Add	Back-Up O/C		0.00 .. 30.00 sec	0.00 sec	T Ip Additional Time Delay
2650	3I0p PICKUP	Back-Up O/C	1A	0.05 .. 4.00 A; ∞	∞ A	3I0p Pickup
			5A	0.25 .. 20.00 A; ∞	∞ A	
2652	T 3I0p TimeDial	Back-Up O/C		0.05 .. 3.00 sec; ∞	0.50 sec	T 3I0p Time Dial
2653	TimeDial TD3I0p	Back-Up O/C		0.50 .. 15.00 ; ∞	5.00	Time Dial TD 3I0p
2656	T 3I0p Add	Back-Up O/C		0.00 .. 30.00 sec	0.00 sec	T 3I0p Additional Time Delay
2660	IEC Curve	Back-Up O/C		Normal Inverse Very Inverse Extremely Inv. LongTimeInverse	Normal Inverse	IEC Curve
2661	ANSI Curve	Back-Up O/C		Inverse Short Inverse Long Inverse Moderately Inv. Very Inverse Extremely Inv. Definite Inv.	Inverse	ANSI Curve
2670	I(3I0)p Tele/BI	Back-Up O/C		NO YES	NO	Instantaneous trip via Teleprot./BI
2671	I(3I0)p SOTF	Back-Up O/C		NO YES	NO	Instantaneous trip after Switch-OnToFault
2680	SOTF Time DELAY	Back-Up O/C		0.00 .. 30.00 sec	0.00 sec	Trip time delay after SOTF
2801	DMD Interval	Demand meter		15 Min., 1 Sub 15 Min., 3 Subs 15 Min.,15 Subs 30 Min., 1 Sub 60 Min., 1 Sub	60 Min., 1 Sub	Demand Calculation Intervals
2802	DMD Sync.Time	Demand meter		On The Hour 15 After Hour 30 After Hour 45 After Hour	On The Hour	Demand Synchronization Time
2811	MinMax cycRESET	Min/Max meter		NO YES	YES	Automatic Cyclic Reset Function
2812	MiMa RESET TIME	Min/Max meter		0 .. 1439 min	0 min	MinMax Reset Timer
2813	MiMa RESETCYCLE	Min/Max meter		1 .. 365 Days	7 Days	MinMax Reset Cycle Period
2814	MinMaxRES.START	Min/Max meter		1 .. 365 Days	1 Days	MinMax Start Reset Cycle in

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
2901	MEASURE. SUPERV	Measurem.Superv		ON OFF	ON	Measurement Supervision
2902A	BALANCE U-LIMIT	Measurem.Superv		10 .. 100 V	50 V	Voltage Threshold for Balance Monitoring
2903A	BAL. FACTOR U	Measurem.Superv		0.58 .. 0.95	0.75	Balance Factor for Voltage Monitor
2904A	BALANCE I LIMIT	Measurem.Superv	1A	0.10 .. 1.00 A	0.50 A	Current Balance Monitor
			5A	0.50 .. 5.00 A	2.50 A	
2905A	BAL. FACTOR I	Measurem.Superv		0.10 .. 0.95	0.50	Balance Factor for Current Monitor
2906A	ΣI THRESHOLD	Measurem.Superv	1A	0.05 .. 2.00 A	0.10 A	Summated Current Monitoring Threshold
			5A	0.25 .. 10.00 A	0.50 A	
2907A	ΣI FACTOR	Measurem.Superv		0.00 .. 0.95	0.10	Summated Current Monitoring Factor
2908A	T BAL. U LIMIT	Measurem.Superv		5 .. 100 sec	5 sec	T Balance Factor for Voltage Monitor
2909A	T BAL. I LIMIT	Measurem.Superv		5 .. 100 sec	5 sec	T Current Balance Monitor
2910	FUSE FAIL MON.	Measurem.Superv		ON OFF	ON	Fuse Failure Monitor
2911A	FFM U>(min)	Measurem.Superv		10 .. 100 V	30 V	Minimum Voltage Threshold U>
2912A	FFM I< (max)	Measurem.Superv	1A	0.10 .. 1.00 A	0.10 A	Maximum Current Threshold I<
			5A	0.50 .. 5.00 A	0.50 A	
2913A	FFM U<max (3ph)	Measurem.Superv		2 .. 100 V	5 V	Maximum Voltage Threshold U< (3phase)
2914A	FFM Idelta (3p)	Measurem.Superv	1A	0.05 .. 1.00 A	0.10 A	Delta Current Threshold (3phase)
			5A	0.25 .. 5.00 A	0.50 A	
2915	V-Supervision	Measurem.Superv		w/ CURR.SUP w/ I> & CBaux OFF	w/ CURR.SUP	Voltage Failure Supervision
2916A	T V-Supervision	Measurem.Superv		0.00 .. 30.00 sec	3.00 sec	Delay Voltage Failure Supervision
2921	T mcb	Measurem.Superv		0 .. 30 ms	0 ms	VT mcb operating time
3001	Sens. Earth Flt	Sens. Earth Flt		Alarm Only ON: with Trip OFF	Alarm Only	Sensitive Earth Flt.(comp/ isol. starp.)
3002	3U0>	Sens. Earth Flt		1 .. 150 V	50 V	3U0> pickup
3003	Uph-e min	Sens. Earth Flt		10 .. 100 V	40 V	Uph-e min of faulted phase
3004	Uph-e max	Sens. Earth Flt		10 .. 100 V	75 V	Uph-e max of healthy phases
3005	3I0>	Sens. Earth Flt		0.003 .. 1.000 A	0.050 A	3I0> Release directional element
3006	T Sens.E/F	Sens. Earth Flt		0.00 .. 320.00 sec	1.00 sec	Time delay for sens. E/F detection
3007	T 3U0>	Sens. Earth Flt		0.00 .. 320.00 sec	0.00 sec	Time delay for sens. E/F trip
3008A	TRIP Direction	Sens. Earth Flt		Forward Reverse Non-Directional	Forward	Direction for sens. E/F trip
3010	CT Err. I1	Sens. Earth Flt		0.003 .. 1.600 A	0.050 A	Current I1 for CT Angle Error
3011	CT Err. F1	Sens. Earth Flt		0.0 .. 5.0 °	0.0 °	CT Angle Error at I1
3012	CT Err. I2	Sens. Earth Flt		0.003 .. 1.600 A	1.000 A	Current I2 for CT Angle Error
3013	CT Err. F2	Sens. Earth Flt		0.0 .. 5.0 °	0.0 °	CT Angle Error at I2
3101	FCT EarthFltO/C	Earth Fault O/C		ON OFF	ON	Earth Fault overcurrent function is
3102	BLOCK for Dist.	Earth Fault O/C		every PICKUP 1phase PICKUP multiph. PICKUP NO	every PICKUP	Block E/F for Distance protection
3103	BLOCK 1pDeadTim	Earth Fault O/C		YES NO	YES	Block E/F for 1pole Dead time
3104A	Iph-STAB. Slope	Earth Fault O/C		0 .. 30 %	10 %	Stabilisation Slope with Iphase
3105	3IoMin Teleprot	Earth Fault O/C	1A	0.01 .. 1.00 A	0.50 A	3Io-Min threshold for Teleprot. schemes
			5A	0.05 .. 5.00 A	2.50 A	
3105	3IoMin Teleprot	Earth Fault O/C	1A	0.003 .. 1.000 A	0.500 A	3Io-Min threshold for Teleprot. schemes
			5A	0.015 .. 5.000 A	2.500 A	
3109	Trip 1pole E/F	Earth Fault O/C		YES NO	YES	Single pole trip with earth flt.prot.

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
3110	Op. mode 3I0>>>	Earth Fault O/C		Forward Reverse Non-Directional Inactive	Inactive	Operating mode
3111	3I0>>>	Earth Fault O/C	1A	0.05 .. 25.00 A	4.00 A	3I0>>> Pickup
			5A	0.25 .. 125.00 A	20.00 A	
3112	T 3I0>>>	Earth Fault O/C		0.00 .. 30.00 sec; ∞	0.30 sec	T 3I0>>> Time delay
3113	3I0>>> Telep/BI	Earth Fault O/C		NO YES	NO	Instantaneous trip via Teleprot./BI
3114	3I0>>>SOTF-Trip	Earth Fault O/C		NO YES	NO	Instantaneous trip after Switch-OnToFault
3115	3I0>>>InrushBlk	Earth Fault O/C		NO YES	NO	Inrush Blocking
3120	Op. mode 3I0>>	Earth Fault O/C		Forward Reverse Non-Directional Inactive	Inactive	Operating mode
3121	3I0>>	Earth Fault O/C	1A	0.05 .. 25.00 A	2.00 A	3I0>> Pickup
			5A	0.25 .. 125.00 A	10.00 A	
3122	T 3I0>>	Earth Fault O/C		0.00 .. 30.00 sec; ∞	0.60 sec	T 3I0>> Time Delay
3123	3I0>> Telep/BI	Earth Fault O/C		NO YES	NO	Instantaneous trip via Teleprot./BI
3124	3I0>> SOTF-Trip	Earth Fault O/C		NO YES	NO	Instantaneous trip after Switch-OnToFault
3125	3I0>> InrushBlk	Earth Fault O/C		NO YES	NO	Inrush Blocking
3130	Op. mode 3I0>	Earth Fault O/C		Forward Reverse Non-Directional Inactive	Inactive	Operating mode
3131	3I0>	Earth Fault O/C	1A	0.05 .. 25.00 A	1.00 A	3I0> Pickup
			5A	0.25 .. 125.00 A	5.00 A	
3131	3I0>	Earth Fault O/C	1A	0.003 .. 25.000 A	1.000 A	3I0> Pickup
			5A	0.015 .. 125.000 A	5.000 A	
3132	T 3I0>	Earth Fault O/C		0.00 .. 30.00 sec; ∞	0.90 sec	T 3I0> Time Delay
3133	3I0> Telep/BI	Earth Fault O/C		NO YES	NO	Instantaneous trip via Teleprot./BI
3134	3I0> SOTF-Trip	Earth Fault O/C		NO YES	NO	Instantaneous trip after Switch-OnToFault
3135	3I0> InrushBlk	Earth Fault O/C		NO YES	NO	Inrush Blocking
3140	Op. mode 3I0p	Earth Fault O/C Earth Fault O/C Earth Fault O/C Earth Fault O/C		Forward Reverse Non-Directional Inactive	Inactive	Operating mode
3141	3I0p PICKUP	Earth Fault O/C Earth Fault O/C Earth Fault O/C Earth Fault O/C	1A	0.05 .. 25.00 A	1.00 A	3I0p Pickup
			5A	0.25 .. 125.00 A	5.00 A	
3141	3I0p PICKUP	Earth Fault O/C Earth Fault O/C Earth Fault O/C Earth Fault O/C	1A	0.003 .. 25.000 A	1.000 A	3I0p Pickup
			5A	0.015 .. 125.000 A	5.000 A	
3142	3I0p MinT-DELAY	Earth Fault O/C		0.00 .. 30.00 sec	1.20 sec	3I0p Minimum Time Delay
3143	3I0p Time Dial	Earth Fault O/C		0.05 .. 3.00 sec; ∞	0.50 sec	3I0p Time Dial
3144	3I0p Time Dial	Earth Fault O/C		0.50 .. 15.00 ; ∞	5.00	3I0p Time Dial
3145	3I0p Time Dial	Earth Fault O/C		0.05 .. 15.00 sec; ∞	1.35 sec	3I0p Time Dial
3146	3I0p MaxT-DELAY	Earth Fault O/C		0.00 .. 30.00 sec	5.80 sec	3I0p Maximum Time Delay
3147	Add.T-DELAY	Earth Fault O/C Earth Fault O/C Earth Fault O/C Earth Fault O/C		0.00 .. 30.00 sec; ∞	1.20 sec	Additional Time Delay

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
3148	3I0p Telep/BI	Earth Fault O/C Earth Fault O/C Earth Fault O/C Earth Fault O/C		NO YES	NO	Instantaneous trip via Teleprot./BI
3149	3I0p SOTF-Trip	Earth Fault O/C Earth Fault O/C Earth Fault O/C Earth Fault O/C		NO YES	NO	Instantaneous trip after Switch-OnToFault
3150	3I0p InrushBlk	Earth Fault O/C Earth Fault O/C Earth Fault O/C Earth Fault O/C		NO YES	NO	Inrush Blocking
3151	IEC Curve	Earth Fault O/C		Normal Inverse Very Inverse Extremely Inv. LongTimeInverse	Normal Inverse	IEC Curve
3152	ANSI Curve	Earth Fault O/C		Inverse Short Inverse Long Inverse Moderately Inv. Very Inverse Extremely Inv. Definite Inv.	Inverse	ANSI Curve
3153	LOG Curve	Earth Fault O/C		Log. inverse	Log. inverse	LOGARITHMIC Curve
3154	3I0p Startpoint	Earth Fault O/C		1.0 .. 4.0	1.1	Start point of inverse characteristic
3155	k	Earth Fault O/C		0.00 .. 3.00 sec	0.50 sec	k-factor for Sr-characteristic
3156	S ref	Earth Fault O/C		1 .. 100 VA	10 VA	S ref for Sr-characteristic
3160	POLARIZATION	Earth Fault O/C		U0 + IY or U2 U0 + IY with IY only with U2 and I2 zero seq. power	U0 + IY or U2	Polarization
3162A	Dir. ALPHA	Earth Fault O/C		0 .. 360 °	338 °	ALPHA, lower angle for forward direction
3163A	Dir. BETA	Earth Fault O/C		0 .. 360 °	122 °	BETA, upper angle for forward direction
3164	3U0>	Earth Fault O/C		0.5 .. 10.0 V	0.5 V	Min. zero seq.voltage 3U0 for polarizing
3165	IY>	Earth Fault O/C	1A	0.05 .. 1.00 A	0.05 A	Min. earth current IY for polarizing
			5A	0.25 .. 5.00 A	0.25 A	
3166	3U2>	Earth Fault O/C		0.5 .. 10.0 V	0.5 V	Min. neg. seq. polarizing voltage 3U2
3167	3I2>	Earth Fault O/C	1A	0.05 .. 1.00 A	0.05 A	Min. neg. seq. polarizing current 3I2
			5A	0.25 .. 5.00 A	0.25 A	
3168	PHI comp	Earth Fault O/C		0 .. 360 °	255 °	Compensation angle PHI comp. for Sr
3169	S forward	Earth Fault O/C		0.1 .. 10.0 VA	0.3 VA	Forward direction power treshold
3170	2nd InrushRest	Earth Fault O/C		10 .. 45 %	15 %	2nd harmonic ratio for inrush restraint
3171	Imax InrushRest	Earth Fault O/C	1A	0.50 .. 25.00 A	7.50 A	Max.Current, overriding inrush restraint
			5A	2.50 .. 125.00 A	37.50 A	
3172	SOTF Op. Mode	Earth Fault O/C		PICKUP PICKUP+DIRECT.	PICKUP+DIRECT.	Instantaneous mode after Switch-OnToFault
3173	SOTF Time DELAY	Earth Fault O/C		0.00 .. 30.00 sec	0.00 sec	Trip time delay after SOTF
3174	BLK for DisZone	Earth Fault O/C		in zone Z1 in zone Z1/Z1B in each zone	in each zone	Block E/F for Distance Protection Pickup
3182	3U0>(U0 inv)	Earth Fault O/C		1.0 .. 10.0 V	5.0 V	3U0> setpoint
3183	U0inv. minimum	Earth Fault O/C		0.1 .. 5.0 V	0.2 V	Minimum voltage U0min for T->oo
3184	T forw. (U0inv)	Earth Fault O/C		0.00 .. 32.00 sec	0.90 sec	T-forward Time delay (U0inv)
3185	T rev. (U0inv)	Earth Fault O/C		0.00 .. 32.00 sec	1.20 sec	T-reverse Time delay (U0inv)
3201	FCT Telep. E/F	Teleprot. E/F		ON OFF	ON	Teleprotection for Earth Fault O/C
3202	Line Config.	Teleprot. E/F		Two Terminals Three terminals	Two Terminals	Line Configuration

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
3203A	Send Prolong.	Teleprot. E/F		0.00 .. 30.00 sec	0.05 sec	Time for send signal prolongation
3207A	Delay for alarm	Teleprot. E/F		0.00 .. 30.00 sec	10.00 sec	Unblocking: Time Delay for Alarm
3208	Release Delay	Teleprot. E/F		0.000 .. 30.000 sec	0.000 sec	Time Delay for release after pickup
3209A	TrBlk Wait Time	Teleprot. E/F		0.00 .. 30.00 sec; ∞	0.04 sec	Transient Block.: Duration external flt.
3210A	TrBlk BlockTime	Teleprot. E/F		0.00 .. 30.00 sec	0.05 sec	Transient Block.: Blk.T. after ext. flt.
3401	AUTO RECLOSE	Autoreclosure		OFF ON	ON	Auto-Reclose function
3402	CB? 1.TRIP	Autoreclosure		YES NO	NO	CB ready interrogation at 1st trip
3403	T-RECLAIM	Autoreclosure		0.50 .. 300.00 sec	3.00 sec	Reclaim time after successful AR cycle
3404	T-BLOCK MC	Autoreclosure		0.50 .. 300.00 sec; 0	1.00 sec	AR blocking duration after manual close
3406	EV. FLT. RECOG.	Autoreclosure		with PICKUP with TRIP	with TRIP	Evolving fault recognition
3407	EV. FLT. MODE	Autoreclosure		blocks AR starts 3p AR	starts 3p AR	Evolving fault (during the dead time)
3408	T-Start MONITOR	Autoreclosure		0.01 .. 300.00 sec	0.20 sec	AR start-signal monitoring time
3409	CB TIME OUT	Autoreclosure		0.01 .. 300.00 sec	3.00 sec	Circuit Breaker (CB) Supervision Time
3410	T RemoteClose	Autoreclosure		0.00 .. 300.00 sec; ∞	∞ sec	Send delay for remote close command
3411A	T-DEAD EXT.	Autoreclosure		0.50 .. 300.00 sec; ∞	∞ sec	Maximum dead time extension
3420	AR w/ DIST.	Autoreclosure		YES NO	YES	AR with distance protection
3421	AR w/ SOTF-O/C	Autoreclosure		YES NO	YES	AR with switch-onto-fault overcurrent
3422	AR w/ W/I	Autoreclosure		YES NO	YES	AR with weak infeed tripping
3423	AR w/ EF-O/C	Autoreclosure		YES NO	YES	AR with earth fault overcurrent prot.
3424	AR w/ DTT	Autoreclosure		YES NO	YES	AR with direct transfer trip
3425	AR w/ BackUpO/C	Autoreclosure		YES NO	YES	AR with back-up overcurrent
3430	AR TRIP 3pole	Autoreclosure Autoreclosure		YES NO	YES	3pole TRIP by AR
3431	DLC or RDT	Autoreclosure		WITHOUT RDT DLC	WITHOUT	Dead Line Check or Reduced Dead Time
3433	T-ACTION ADT	Autoreclosure		0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3434	T-MAX ADT	Autoreclosure		0.50 .. 3000.00 sec	5.00 sec	Maximum dead time
3435	ADT 1p allowed	Autoreclosure		YES NO	NO	1pole TRIP allowed
3436	ADT CB? CLOSE	Autoreclosure		YES NO	NO	CB ready interrogation before re-closing
3437	ADT SynRequest	Autoreclosure		YES NO	NO	Request for synchro-check after 3pole AR
3438	T U-stable	Autoreclosure Autoreclosure		0.10 .. 30.00 sec	0.10 sec	Supervision time for dead/ live voltage
3440	U-live>	Autoreclosure Autoreclosure		30 .. 90 V	48 V	Voltage threshold for live line or bus
3441	U-dead<	Autoreclosure Autoreclosure		2 .. 70 V	30 V	Voltage threshold for dead line or bus
3450	1.AR: START	Autoreclosure		YES NO	YES	Start of AR allowed in this cycle
3451	1.AR: T-ACTION	Autoreclosure		0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3453	1.AR Tdead 1Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1phase faults
3454	1.AR Tdead 2Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 2phase faults
3455	1.AR Tdead 3Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3phase faults
3456	1.AR Tdead1Trip	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1pole trip
3457	1.AR Tdead3Trip	Autoreclosure		0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3pole trip

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
3458	1.AR: Tdead EV.	Autoreclosure		0.01 .. 1800.00 sec	1.20 sec	Dead time after evolving fault
3459	1.AR: CB? CLOSE	Autoreclosure		YES NO	NO	CB ready interrogation before re-closing
3460	1.AR SynRequest	Autoreclosure		YES NO	NO	Request for synchro-check after 3pole AR
3461	2.AR: START	Autoreclosure		YES NO	NO	AR start allowed in this cycle
3462	2.AR: T-ACTION	Autoreclosure		0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3464	2.AR Tdead 1Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1phase faults
3465	2.AR Tdead 2Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 2phase faults
3466	2.AR Tdead 3Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3phase faults
3467	2.AR Tdead1Trip	Autoreclosure		0.01 .. 1800.00 sec; ∞	∞ sec	Dead time after 1pole trip
3468	2.AR Tdead3Trip	Autoreclosure		0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3pole trip
3469	2.AR: Tdead EV.	Autoreclosure		0.01 .. 1800.00 sec	1.20 sec	Dead time after evolving fault
3470	2.AR: CB? CLOSE	Autoreclosure		YES NO	NO	CB ready interrogation before re-closing
3471	2.AR SynRequest	Autoreclosure		YES NO	NO	Request for synchro-check after 3pole AR
3472	3.AR: START	Autoreclosure		YES NO	NO	AR start allowed in this cycle
3473	3.AR: T-ACTION	Autoreclosure		0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3475	3.AR Tdead 1Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1phase faults
3476	3.AR Tdead 2Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 2phase faults
3477	3.AR Tdead 3Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3phase faults
3478	3.AR Tdead1Trip	Autoreclosure		0.01 .. 1800.00 sec; ∞	∞ sec	Dead time after 1pole trip
3479	3.AR Tdead3Trip	Autoreclosure		0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3pole trip
3480	3.AR: Tdead EV.	Autoreclosure		0.01 .. 1800.00 sec	1.20 sec	Dead time after evolving fault
3481	3.AR: CB? CLOSE	Autoreclosure		YES NO	NO	CB ready interrogation before re-closing
3482	3.AR SynRequest	Autoreclosure		YES NO	NO	Request for synchro-check after 3pole AR
3483	4.AR: START	Autoreclosure		YES NO	NO	AR start allowed in this cycle
3484	4.AR: T-ACTION	Autoreclosure		0.01 .. 300.00 sec; ∞	0.20 sec	Action time
3486	4.AR Tdead 1Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 1phase faults
3487	4.AR Tdead 2Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	1.20 sec	Dead time after 2phase faults
3488	4.AR Tdead 3Flt	Autoreclosure		0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3phase faults
3489	4.AR Tdead1Trip	Autoreclosure		0.01 .. 1800.00 sec; ∞	∞ sec	Dead time after 1pole trip
3490	4.AR Tdead3Trip	Autoreclosure		0.01 .. 1800.00 sec; ∞	0.50 sec	Dead time after 3pole trip
3491	4.AR: Tdead EV.	Autoreclosure		0.01 .. 1800.00 sec	1.20 sec	Dead time after evolving fault
3492	4.AR: CB? CLOSE	Autoreclosure		YES NO	NO	CB ready interrogation before re-closing
3493	4.AR SynRequest	Autoreclosure		YES NO	NO	Request for synchro-check after 3pole AR
3501	FCT Synchronism	Sync. Check		ON OFF ON:w/o CloseCmd	ON	Synchronism and Voltage Check function
3502	Dead Volt. Thr.	Sync. Check		1 .. 60 V	5 V	Voltage threshold dead line / bus
3503	Live Volt. Thr.	Sync. Check		20 .. 125 V	90 V	Voltage threshold live line / bus
3504	Umax	Sync. Check		20 .. 140 V	110 V	Maximum permissible voltage
3507	T-SYN. DURATION	Sync. Check		0.01 .. 600.00 sec; ∞	1.00 sec	Maximum duration of synchronism-check
3508	T SYNC-STAB	Sync. Check		0.00 .. 30.00 sec	0.00 sec	Synchronous condition stability timer
3509	SyncCB	Sync. Check		None Breaker Disc.Swit. EarthSwit Q2 Op/Cl Q9 Op/Cl Fan ON/OFF	None	Synchronizable circuit breaker

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
3510	Op.mode with AR	Sync. Check		with T-CB close w/o T-CB close	w/o T-CB close	Operating mode with AR
3511	Max. Volt. Diff	Sync. Check		1.0 .. 40.0 V	2.0 V	Maximum voltage difference
3512	Max. Freq. Diff	Sync. Check		0.03 .. 2.00 Hz	0.10 Hz	Maximum frequency difference
3513	Max. Angle Diff	Sync. Check		2 .. 80 °	10 °	Maximum angle difference
3515A	SYNC-CHECK	Sync. Check		YES NO	YES	Live bus / live line and Sync before AR
3516	Usync> U-line<	Sync. Check		YES NO	NO	Live bus / dead line check before AR
3517	Usync< U-line>	Sync. Check		YES NO	NO	Dead bus / live line check before AR
3518	Usync< U-line<	Sync. Check		YES NO	NO	Dead bus / dead line check before AR
3519	OVERRIDE	Sync. Check		YES NO	NO	Override of any check before AR
3530	Op.mode with MC	Sync. Check		with T-CB close w/o T-CB close	w/o T-CB close	Operating mode with Man.Cl
3531	MC maxVolt.Diff	Sync. Check		1.0 .. 40.0 V	2.0 V	Maximum voltage difference
3532	MC maxFreq.Diff	Sync. Check		0.03 .. 2.00 Hz	0.10 Hz	Maximum frequency difference
3533	MC maxAngleDiff	Sync. Check		2 .. 80 °	10 °	Maximum angle difference
3535A	MC SYNCHR	Sync. Check		YES NO	YES	Live bus / live line and Sync before MC
3536	MC Usyn> Uline<	Sync. Check		YES NO	NO	Live bus / dead line check before Man.Cl
3537	MC Usyn< Uline>	Sync. Check		YES NO	NO	Dead bus / live line check before Man.Cl
3538	MC Usyn< Uline<	Sync. Check		YES NO	NO	Dead bus / dead line check before Man.Cl
3539	MC O/RIDE	Sync. Check		YES NO	NO	Override of any check before Man.Cl
3601	O/U FREQ. f1	Frequency Prot.		ON: Alarm only ON: with Trip OFF	ON: Alarm only	Over/Under Frequency Protection stage f1
3602	f1 PICKUP	Frequency Prot.		45.50 .. 54.50 Hz	49.50 Hz	f1 Pickup
3603	f1 PICKUP	Frequency Prot.		55.50 .. 64.50 Hz	59.50 Hz	f1 Pickup
3604	T f1	Frequency Prot.		0.00 .. 600.00 sec	60.00 sec	T f1 Time Delay
3611	O/U FREQ. f2	Frequency Prot.		ON: Alarm only ON: with Trip OFF	ON: Alarm only	Over/Under Frequency Protection stage f2
3612	f2 PICKUP	Frequency Prot.		45.50 .. 54.50 Hz	49.00 Hz	f2 Pickup
3613	f2 PICKUP	Frequency Prot.		55.50 .. 64.50 Hz	57.00 Hz	f2 Pickup
3614	T f2	Frequency Prot.		0.00 .. 600.00 sec	30.00 sec	T f2 Time Delay
3621	O/U FREQ. f3	Frequency Prot.		ON: Alarm only ON: with Trip OFF	ON: Alarm only	Over/Under Frequency Protection stage f3
3622	f3 PICKUP	Frequency Prot.		45.50 .. 54.50 Hz	47.50 Hz	f3 Pickup
3623	f3 PICKUP	Frequency Prot.		55.50 .. 64.50 Hz	59.50 Hz	f3 Pickup
3624	T f3	Frequency Prot.		0.00 .. 600.00 sec	3.00 sec	T f3 Time Delay
3631	O/U FREQ. f4	Frequency Prot.		ON: Alarm only ON: with Trip OFF	ON: Alarm only	Over/Under Frequency Protection stage f4
3632	f4 PICKUP	Frequency Prot.		45.50 .. 54.50 Hz	51.00 Hz	f4 Pickup
3633	f4 PICKUP	Frequency Prot.		55.50 .. 64.50 Hz	62.00 Hz	f4 Pickup
3634	T f4	Frequency Prot.		0.00 .. 600.00 sec	30.00 sec	T f4 Time Delay
3701	Uph-e>(>)	Voltage Prot.		OFF Alarm Only ON	OFF	Operating mode Uph-e overvoltage prot.
3702	Uph-e>	Voltage Prot.		1.0 .. 170.0 V; ∞	85.0 V	Uph-e> Pickup
3703	T Uph-e>	Voltage Prot.		0.00 .. 100.00 sec; ∞	2.00 sec	T Uph-e> Time Delay
3704	Uph-e>>	Voltage Prot.		1.0 .. 170.0 V; ∞	100.0 V	Uph-e>> Pickup
3705	T Uph-e>>	Voltage Prot.		0.00 .. 100.00 sec; ∞	1.00 sec	T Uph-e>> Time Delay
3709A	Uph-e>(>) RESET	Voltage Prot.		0.30 .. 0.98	0.98	Uph-e>(>) Reset ratio

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
3711	Uph-ph>(>)	Voltage Prot.		OFF Alarm Only ON	OFF	Operating mode Uph-ph overvoltage prot.
3712	Uph-ph>	Voltage Prot.		2.0 .. 220.0 V; ∞	150.0 V	Uph-ph> Pickup
3713	T Uph-ph>	Voltage Prot.		0.00 .. 100.00 sec; ∞	2.00 sec	T Uph-ph> Time Delay
3714	Uph-ph>>	Voltage Prot.		2.0 .. 220.0 V; ∞	175.0 V	Uph-ph>> Pickup
3715	T Uph-ph>>	Voltage Prot.		0.00 .. 100.00 sec; ∞	1.00 sec	T Uph-ph>> Time Delay
3719A	Uphph>(>) RESET	Voltage Prot.		0.30 .. 0.98	0.98	Uph-ph>(>) Reset ratio
3721	3U0>(>) (or Ux)	Voltage Prot.		OFF Alarm Only ON	OFF	Operating mode 3U0 (or Ux) overvoltage
3722	3U0>	Voltage Prot.		1.0 .. 220.0 V; ∞	30.0 V	3U0> Pickup (or Ux>)
3723	T 3U0>	Voltage Prot.		0.00 .. 100.00 sec; ∞	2.00 sec	T 3U0> Time Delay (or T Ux>)
3724	3U0>>	Voltage Prot.		1.0 .. 220.0 V; ∞	50.0 V	3U0>> Pickup (or Ux>>)
3725	T 3U0>>	Voltage Prot.		0.00 .. 100.00 sec; ∞	1.00 sec	T 3U0>> Time Delay (or T Ux>>)
3728A	3U0>(>) Stabil.	Voltage Prot.		ON OFF	ON	3U0>(>): Stabilization 3U0-Measurement
3729A	3U0>(>) RESET	Voltage Prot.		0.30 .. 0.98	0.95	3U0>(>) Reset ratio (or Ux)
3731	U1>(>)	Voltage Prot.		OFF Alarm Only ON	OFF	Operating mode U1 overvoltage prot.
3732	U1>	Voltage Prot.		2.0 .. 220.0 V; ∞	150.0 V	U1> Pickup
3733	T U1>	Voltage Prot.		0.00 .. 100.00 sec; ∞	2.00 sec	T U1> Time Delay
3734	U1>>	Voltage Prot.		2.0 .. 220.0 V; ∞	175.0 V	U1>> Pickup
3735	T U1>>	Voltage Prot.		0.00 .. 100.00 sec; ∞	1.00 sec	T U1>> Time Delay
3736	U1> Compound	Voltage Prot.		OFF ON	OFF	U1> with Compounding
3737	U1>> Compound	Voltage Prot.		OFF ON	OFF	U1>> with Compounding
3739A	U1>(>) RESET	Voltage Prot.		0.30 .. 0.98	0.98	U1>(>) Reset ratio
3741	U2>(>)	Voltage Prot.		OFF Alarm Only ON	OFF	Operating mode U2 overvoltage prot.
3742	U2>	Voltage Prot.		2.0 .. 220.0 V; ∞	30.0 V	U2> Pickup
3743	T U2>	Voltage Prot.		0.00 .. 100.00 sec; ∞	2.00 sec	T U2> Time Delay
3744	U2>>	Voltage Prot.		2.0 .. 220.0 V; ∞	50.0 V	U2>> Pickup
3745	T U2>>	Voltage Prot.		0.00 .. 100.00 sec; ∞	1.00 sec	T U2>> Time Delay
3749A	U2>(>) RESET	Voltage Prot.		0.30 .. 0.98	0.98	U2>(>) Reset ratio
3751	Uph-e<(<)	Voltage Prot.		OFF Alarm Only ON	OFF	Operating mode Uph-e undervoltage prot.
3752	Uph-e<	Voltage Prot.		1.0 .. 100.0 V; 0	30.0 V	Uph-e< Pickup
3753	T Uph-e<	Voltage Prot.		0.00 .. 100.00 sec; ∞	2.00 sec	T Uph-e< Time Delay
3754	Uph-e<<	Voltage Prot.		1.0 .. 100.0 V; 0	10.0 V	Uph-e<< Pickup
3755	T Uph-e<<	Voltage Prot.		0.00 .. 100.00 sec; ∞	1.00 sec	T Uph-e<< Time Delay
3758	CURR.SUP. Uphe<	Voltage Prot.		ON OFF	ON	Current supervision (Uph-e)
3761	Uph-ph<(<)	Voltage Prot.		OFF Alarm Only ON	OFF	Operating mode Uph-ph undervoltage prot.
3762	Uph-ph<	Voltage Prot.		1.0 .. 175.0 V; 0	50.0 V	Uph-ph< Pickup
3763	T Uph-ph<	Voltage Prot.		0.00 .. 100.00 sec; ∞	2.00 sec	T Uph-ph< Time Delay
3764	Uph-ph<<	Voltage Prot.		1.0 .. 175.0 V; 0	17.0 V	Uph-ph<< Pickup
3765	T Uphph<<	Voltage Prot.		0.00 .. 100.00 sec; ∞	1.00 sec	T Uph-ph<< Time Delay
3768	CURR.SUP.Uphph<	Voltage Prot.		ON OFF	ON	Current supervision (Uph-ph)
3771	U1<(<)	Voltage Prot.		OFF Alarm Only ON	OFF	Operating mode U1 undervoltage prot.
3772	U1<	Voltage Prot.		1.0 .. 100.0 V; 0	30.0 V	U1< Pickup
3773	T U1<	Voltage Prot.		0.00 .. 100.00 sec; ∞	2.00 sec	T U1< Time Delay

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
3774	U1<<	Voltage Prot.		1.0 .. 100.0 V; 0	10.0 V	U1<< Pickup
3775	T U1<<	Voltage Prot.		0.00 .. 100.00 sec; ∞	1.00 sec	T U1<< Time Delay
3778	CURR.SUP.U1<	Voltage Prot.		ON OFF	ON	Current supervision (U1)
3802	START	Fault Locator		Pickup TRIP	Pickup	Start fault locator with
3805	Paral.Line Comp	Fault Locator		NO YES	YES	Mutual coupling parall.line compensation
3806	Load Compensat.	Fault Locator		NO YES	NO	Load Compensation
3811	Tmax OUTPUT BCD	Fault Locator		0.10 .. 180.00 sec	0.30 sec	Maximum output time via BCD
3901	FCT BreakerFail	Breaker Failure		ON OFF	ON	Breaker Failure Protection is
3902	I> BF	Breaker Failure	1A	0.05 .. 20.00 A	0.10 A	Pick-up threshold I>
			5A	0.25 .. 100.00 A	0.50 A	
3903	1p-RETRIP (T1)	Breaker Failure		NO YES	YES	1pole retrip with stage T1 (local trip)
3904	T1-1pole	Breaker Failure		0.00 .. 30.00 sec; ∞	0.00 sec	T1, Delay after 1pole start (local trip)
3905	T1-3pole	Breaker Failure		0.00 .. 30.00 sec; ∞	0.00 sec	T1, Delay after 3pole start (local trip)
3906	T2	Breaker Failure		0.00 .. 30.00 sec; ∞	0.15 sec	T2, Delay of 2nd stage (busbar trip)
3907	T3-BkrDefective	Breaker Failure		0.00 .. 30.00 sec; ∞	0.00 sec	T3, Delay for start with defective bkr.
3908	Trip BkrDefect.	Breaker Failure		NO with T1-trip with T2-trip w/ T1/T2-trip	NO	Trip output selection with defective bkr
3909	Chk BRK CONTACT	Breaker Failure		NO YES	YES	Check Breaker contacts
3921	End Flt. stage	Breaker Failure		ON OFF	OFF	End fault stage is
3922	T-EndFault	Breaker Failure		0.00 .. 30.00 sec; ∞	2.00 sec	Trip delay of end fault stage
3931	PoleDiscrepancy	Breaker Failure		ON OFF	OFF	Pole Discrepancy supervision
3932	T-PoleDiscrep.	Breaker Failure		0.00 .. 30.00 sec; ∞	2.00 sec	Trip delay with pole discrepancy
4001	FCT TripSuperv.	TripCirc.Superv		ON OFF	OFF	TRIP Circuit Supervision is
4002	No. of BI	TripCirc.Superv		1 .. 2	2	Number of Binary Inputs per trip circuit
4003	Alarm Delay	TripCirc.Superv		1 .. 30 sec	2 sec	Delay Time for alarm
4201	Ther. OVERLOAD	Therm. Overload		OFF ON Alarm Only	OFF	Thermal overload protection
4202	K-FACTOR	Therm. Overload		0.10 .. 4.00	1.10	K-Factor
4203	TIME CONSTANT	Therm. Overload		1.0 .. 999.9 min	100.0 min	Time constant
4204	Θ ALARM	Therm. Overload		50 .. 100 %	90 %	Thermal Alarm Stage
4205	I ALARM	Therm. Overload	1A	0.10 .. 4.00 A	1.00 A	Current Overload Alarm setpoint
			5A	0.50 .. 20.00 A	5.00 A	
4206	CALC. METHOD	Therm. Overload		Θ max Average Θ Θ from Imax	Θ max	Method of Acquiring Temperature
4501	STATE PROT I 1	Prot. Interface		ON OFF	ON	State of protection interface 1
4502	CONNEC. 1 OVER	Prot. Interface		F.optic direct Com conv 64 kB Com conv 128 kB Com conv 512 kB	F.optic direct	Connection 1 over
4505A	PROT 1 T-DELAY	Prot. Interface		0.1 .. 30.0 ms	30.0 ms	Prot 1: Maximal permissible delay time
4509	T-DATA DISTURB	Prot. Interface		0.05 .. 2.00 sec	0.10 sec	Time delay for data disturbance alarm
4510	T-DATAFAIL	Prot. Interface		0.0 .. 60.0 sec	6.0 sec	Time del for transmission failure alarm

Addr.	Parameter	Function	C	Setting Options	Default Setting	Comments
4511	Td ResetRemote	Prot. Interface		0.00 .. 300.00 sec; ∞	0.00 sec	Remote signal RESET DELAY for comm.fail
4701	ID OF RELAY 1	Prot. Interface		1 .. 65534	1	Identification number of relay 1
4702	ID OF RELAY 2	Prot. Interface		1 .. 65534	2	Identification number of relay 2
4703	ID OF RELAY 3	Prot. Interface		1 .. 65534	3	Identification number of relay 3
4710	LOCAL RELAY	Prot. Interface		relay 1 relay 2 relay 3	relay 1	Local relay is
5001	20 mA (B1) =	AnalogOutputs		10.0 .. 1000.0 %	200.0 %	20 mA (B1) correspond to
5002	20 mA (B1) =	AnalogOutputs		10 .. 100000 A	20000 A	20 mA (B1) correspond to
5003	20 mA (B1) =	AnalogOutputs		1.0 .. 1000.0 km	50.0 km	20 mA (B1) correspond to
5004	20 mA (B1) =	AnalogOutputs		1.0 .. 1000.0 Miles	50.0 Miles	20 mA (B1) correspond to
5006	MIN VALUE (B1)	AnalogOutputs		0.0 .. 5.0 mA	4.0 mA	Output value (B1) valid from
5007	NEG VALUE (B1)	AnalogOutputs		1.00 .. 22.50 mA	19.84 mA	Output value (B1) for negative values
5008	OVERFLOW (B1)	AnalogOutputs		1.00 .. 22.50 mA	22.50 mA	Output value (B1) for overflow
5009	Tmax OUTPUT(B1)	AnalogOutputs		0.10 .. 180.00 sec; ∞	5.00 sec	Maximum output time (B1)
5011	20 mA (B2) =	AnalogOutputs		10.0 .. 1000.0 %	200.0 %	20 mA (B2) correspond to
5012	20 mA (B2) =	AnalogOutputs		10 .. 100000 A	20000 A	20 mA (B2) correspond to
5013	20 mA (B2) =	AnalogOutputs		1.0 .. 1000.0 km	50.0 km	20 mA (B2) correspond to
5014	20 mA (B2) =	AnalogOutputs		1.0 .. 1000.0 Miles	50.0 Miles	20 mA (B2) correspond to
5016	MIN VALUE (B2)	AnalogOutputs		0.0 .. 5.0 mA	4.0 mA	Output value (B2) valid from
5017	NEG VALUE (B2)	AnalogOutputs		1.00 .. 22.50 mA	19.84 mA	Output value (B2) for negative values
5018	OVERFLOW (B2)	AnalogOutputs		1.00 .. 22.50 mA	22.50 mA	Output value (B2) for overflow
5019	Tmax OUTPUT(B2)	AnalogOutputs		0.10 .. 180.00 sec; ∞	5.00 sec	Maximum output time (B2)
5021	20 mA (D1) =	AnalogOutputs		10.0 .. 1000.0 %	200.0 %	20 mA (D1) correspond to
5022	20 mA (D1) =	AnalogOutputs		10 .. 100000 A	20000 A	20 mA (D1) correspond to
5023	20 mA (D1) =	AnalogOutputs		1.0 .. 1000.0 km	50.0 km	20 mA (D1) correspond to
5024	20 mA (D1) =	AnalogOutputs		1.0 .. 1000.0 Miles	50.0 Miles	20 mA (D1) correspond to
5026	MIN VALUE (D1)	AnalogOutputs		0.0 .. 5.0 mA	4.0 mA	Output value (D1) valid from
5027	NEG VALUE (D1)	AnalogOutputs		1.00 .. 22.50 mA	19.84 mA	Output value (D1) for negative values
5028	OVERFLOW (D1)	AnalogOutputs		1.00 .. 22.50 mA	22.50 mA	Output value (D1) for overflow
5029	Tmax OUTPUT(D1)	AnalogOutputs		0.10 .. 180.00 sec; ∞	5.00 sec	Maximum output time (D1)
5031	20 mA (D2) =	AnalogOutputs		10.0 .. 1000.0 %	200.0 %	20 mA (D2) correspond to
5032	20 mA (D2) =	AnalogOutputs		10 .. 100000 A	20000 A	20 mA (D2) correspond to
5033	20 mA (D2) =	AnalogOutputs		1.0 .. 1000.0 km	50.0 km	20 mA (D2) correspond to
5034	20 mA (D2) =	AnalogOutputs		1.0 .. 1000.0 Miles	50.0 Miles	20 mA (D2) correspond to
5036	MIN VALUE (D2)	AnalogOutputs		0.0 .. 5.0 mA	4.0 mA	Output value (D2) valid from
5037	NEG VALUE (D2)	AnalogOutputs		1.00 .. 22.50 mA	19.84 mA	Output value (D2) for negative values
5038	OVERFLOW (D2)	AnalogOutputs		1.00 .. 22.50 mA	22.50 mA	Output value (D2) for overflow
5039	Tmax OUTPUT(D2)	AnalogOutputs		0.10 .. 180.00 sec; ∞	5.00 sec	Maximum output time (D2)

A.8   Information List

Indications for IEC 60 870-5-103 are always reported ON / OFF if they are subject to general interrogation for IEC 60 870-5-103. If not, they are reported only as ON.

New user-defined indications or such newly allocated to IEC 60 870-5-103 are set to ON / OFF and subjected to general interrogation if the information type is not a spontaneous event (".._Ev"). Further information on messages can be found in detail in the SIPROTEC® 4 System Description, Order No. E50417-H1176-C151.

In columns "Event Log", "Trip Log" and "Ground Fault Log" the following applies:

UPPER CASE NOTATION "ON/OFF":   definitely set, not allocatable

lower case notation "on/off":   preset, allocatable

*:   not preset, allocatable

<blank>:   neither preset nor allocatable

In column "Marked in Oscill.Record" the following applies:

UPPER CASE NOTATION "M":   definitely set, not allocatable

lower case notation "m":   preset, allocatable

*:   not preset, allocatable

<blank>:   neither preset nor allocatable

No.	Description	Function	Type of Information	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
-	Test mode (Test mode)	Device	IntSP	ON OFF	*		*	LED			BO		128	21	1	Yes
-	Stop data transmission (DataStop)	Device	IntSP	ON OFF	*		*	LED			BO		128	20	1	Yes
-	Clock Synchronization (SynchClock)	Device	IntSP _Ev	*	*		*	LED			BO					
-	>Back Light on (>Light on)	Device	SP	ON OFF	*		*		BI							
-	Hardware Test Mode (HWTestMod)	Device	IntSP	ON OFF	*		*	LED			BO					
-	Error FMS FO 1 (Error FMS1)	Device	OUT	ON OFF	*	*	*	LED			BO					
-	Error FMS FO 2 (Error FMS2)	Device	OUT	ON OFF	*	*	*	LED			BO					
-	Breaker OPENED (Brk OPENED)	Device	IntSP	*	*		*	LED			BO					
-	Feeder EARTHED (FdrEARTHED)	Device	IntSP	*	*		*	LED			BO					
-	Group A (Group A)	Change Group	IntSP	ON OFF	*		*	LED			BO		128	23	1	Yes

No.	Description	Function	Type of Information	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
-	Group B (Group B)	Change Group	IntSP	ON OFF	*		*	LED			BO		128	24	1	Yes
-	Group C (Group C)	Change Group	IntSP	ON OFF	*		*	LED			BO		128	25	1	Yes
-	Group D (Group D)	Change Group	IntSP	ON OFF	*		*	LED			BO		128	26	1	Yes
-	Fault Recording Start (FltRecSta)	Osc. Fault Rec.	IntSP	ON OFF	*		*	LED			BO					
-	Reset Minimum and Maximum counter (ResMinMax)	Min/Max meter	IntSP _Ev	ON	*											
-	CB1-TEST trip/close - Only L1 (CB1tst L1)	Testing	-		*	*										
-	CB1-TEST trip/close - Only L2 (CB1tst L2)	Testing	-		*	*										
-	CB1-TEST trip/close - Only L3 (CB1tst L3)	Testing	-		*	*										
-	CB1-TEST trip/close Phases L123 (CB1tst 123)	Testing	-		*	*										
-	Control Authority (Cntrl Auth)	Cntrl Authority	DP	ON OFF	*			LED								
-	Controlmode LOCAL (ModeLO-CAL)	Cntrl Authority	DP	ON OFF	*			LED								
-	Controlmode REMOTE (ModeR-EMOTE)	Cntrl Authority	IntSP	ON OFF	*			LED								
-	Control Authority (Cntrl Auth)	Cntrl Authority	IntSP	ON OFF	*			LED					101	85	1	Yes
-	Controlmode LOCAL (ModeLO-CAL)	Cntrl Authority	IntSP	ON OFF	*			LED					101	86	1	Yes
-	Breaker (Breaker)	Control Device	CF_D 12	on off	*						BO		240	160	20	
-	Breaker (Breaker)	Control Device	DP	on off	*				BI			CB	240	160	1	Yes
-	Disconnect Switch (Disc.Swit.)	Control Device	CF_D 2	on off	*						BO		240	161	20	
-	Disconnect Switch (Disc.Swit.)	Control Device	DP	on off	*				BI			CB	240	161	1	Yes
-	Earth Switch (EarthSwit)	Control Device	CF_D 2	on off	*						BO		240	164	20	
-	Earth Switch (EarthSwit)	Control Device	DP	on off	*				BI			CB	240	164	1	Yes
-	Interlocking: 52 Open (52 Open)	Control Device	IntSP	*	*		*									
-	Interlocking: 52 Close (52 Close)	Control Device	IntSP	*	*		*									
-	Interlocking: Disconnect switch Open (Disc.Open)	Control Device	IntSP	*	*		*									
-	Interlocking: Disconnect switch Close (Disc.Close)	Control Device	IntSP	*	*		*									

No.	Description	Function	Type of Infor-mation	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
-	Interlocking: Earth switch Open (E Sw Open)	Control Device	IntSP	*	*		*									
-	Interlocking: Earth switch Close (E Sw Cl.)	Control Device	IntSP	*	*		*									
-	Q2 Open/Close (Q2 Op/Cl)	Control Device	CF_D2	on off	*						BO		240	162	20	
-	Q2 Open/Close (Q2 Op/Cl)	Control Device	DP	on off	*				BI			CB	240	162	1	Yes
-	Q9 Open/Close (Q9 Op/Cl)	Control Device	CF_D2	on off	*						BO		240	163	20	
-	Q9 Open/Close (Q9 Op/Cl)	Control Device	DP	on off	*				BI			CB	240	163	1	Yes
-	Fan ON/OFF (Fan ON/OFF)	Control Device	CF_D2	on off	*						BO		240	175	20	
-	Fan ON/OFF (Fan ON/OFF)	Control Device	DP	on off	*				BI			CB	240	175	1	Yes
-	Unlock data transmission via BI (UnlockDT)	Control Device	IntSP	*	*		*									
-	>Cabinet door open (>Door open)	Process Data	SP	on off	*		*	LED	BI		BO	CB	101	1	1	Yes
-	>CB waiting for Spring charged (>CB wait)	Process Data	SP	on off	*		*	LED	BI		BO	CB	101	2	1	Yes
-	>Error Motor Voltage (>Err Mot U)	Process Data	SP	on off	*		*	LED	BI		BO	CB	240	181	1	Yes
-	>Error Control Voltage (>ErrCntr-lU)	Process Data	SP	on off	*		*	LED	BI		BO	CB	240	182	1	Yes
-	>SF6-Loss (>SF6-Loss)	Process Data	SP	on off	*		*	LED	BI		BO	CB	240	183	1	Yes
-	>Error Meter (>Err Meter)	Process Data	SP	on off	*		*	LED	BI		BO	CB	240	184	1	Yes
-	>Transformer Temperature (>Tx Temp.)	Process Data	SP	on off	*		*	LED	BI		BO	CB	240	185	1	Yes
-	>Transformer Danger (>Tx Danger)	Process Data	SP	on off	*		*	LED	BI		BO	CB	240	186	1	Yes
-	Reset meter (Meter res)	Energy	IntSP _Ev	ON	*											
-	Error Systeminterface (SysIn-tErr.)	Protocol	IntSP	on off				LED			BO					
-	Threshold Value 1 (ThreshVal1)	Thresh.-Switch	IntSP	ON OFF	*		*	LED	BI	FC TN	BO	CB				
1	No Function configured (Not con-figured)	Device	SP													
2	Function Not Available (Non Ex-istent)	Device	SP													
3	>Synchronize Internal Real Time Clock (>Time Synch)	Device	SP	*	*		*	LED	BI		BO					

No.	Description	Function	Type of Information	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
				Log Buffers				Configurable in Matrix					IEC 60870-5-103			
4	>Trigger Waveform Capture (>Trig.Wave.Cap.)	Osc. Fault Rec.	SP	ON	*		m	LED	BI		BO					
5	>Reset LED (>Reset LED)	Device	SP	*	*		*	LED	BI		BO					
7	>Setting Group Select Bit 0 (>Set Group Bit0)	Change Group	SP	*	*		*	LED	BI		BO					
8	>Setting Group Select Bit 1 (>Set Group Bit1)	Change Group	SP	*	*		*	LED	BI		BO					
11	>User defined annunciation 1 (>Annunc. 1)	Device	SP	*	*	*	*	LED	BI		BO		128	27	1	Yes
12	>User defined annunciation 2 (>Annunc. 2)	Device	SP	*	*	*	*	LED	BI		BO		128	28	1	Yes
13	>User defined annunciation 3 (>Annunc. 3)	Device	SP	*	*	*	*	LED	BI		BO		128	29	1	Yes
14	>User defined annunciation 4 (>Annunc. 4)	Device	SP	*	*	*	*	LED	BI		BO		128	30	1	Yes
15	>Test mode (>Test mode)	Device	SP	ON OFF	*		*	LED	BI		BO		135	53	1	Yes
16	>Stop data transmission (>DataStop)	Device	SP	*	*		*	LED	BI		BO		135	54	1	Yes
51	Device is Operational and Protecting (Device OK)	Device	OUT	ON OFF	*		*	LED			BO		135	81	1	Yes
52	At Least 1 Protection Funct. is Active (ProtActive)	Device	IntSP	ON OFF	*		*	LED			BO		128	18	1	Yes
55	Reset Device (Reset Device)	Device	OUT	*	*		*	LED			BO		128	4	1	No
56	Initial Start of Device (Initial Start)	Device	OUT	ON	*		*	LED			BO		128	5	1	No
60	Reset LED (Reset LED)	Device	OUT_Ev	ON	*		*	LED			BO		128	19	1	No
67	Resume (Resume)	Device	OUT	ON	*		*	LED			BO		135	97	1	No
68	Clock Synchronization Error (Clock SyncError)	Device	OUT	ON OFF	*		*	LED			BO					
69	Daylight Saving Time (DayLightSavTime)	Device	OUT	ON OFF	*		*	LED			BO					
70	Setting calculation is running (Settings Calc.)	Device	OUT	ON OFF	*		*	LED			BO		128	22	1	Yes
71	Settings Check (Settings Check)	Device	OUT	*	*		*	LED			BO					
72	Level-2 change (Level-2 change)	Device	OUT	ON OFF	*		*	LED			BO					
73	Local setting change (Local change)	Device	OUT	*	*		*									
110	Event lost (Event Lost)	Device	OUT_Ev	ON	*		*	LED			BO		135	130	1	No
113	Flag Lost (Flag Lost)	Device	OUT	ON	*		m	LED			BO		135	136	1	Yes
125	Chatter ON (Chatter ON)	Device	OUT	ON OFF	*		*	LED			BO		135	145	1	Yes

No.	Description	Function	Type of Informatio n	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
126	Protection ON/OFF (via system port) (ProtON/OFF)	Device	IntSP	ON OFF	*		*	LED			BO					
127	Auto Reclose ON/OFF (via system port) (AR ON/OFF)	Device	IntSP	ON OFF	*		*	LED			BO					
128	Teleprot. ON/OFF (via system port) (TelepONoff)	Device	IntSP	ON OFF	*		*	LED			BO					
140	Error with a summary alarm (Error Sum Alarm)	Device	OUT	ON OFF	*		*	LED			BO		128	47	1	Yes
144	Error 5V (Error 5V)	Device	OUT	ON OFF	*		*	LED			BO		135	164	1	Yes
160	Alarm Summary Event (Alarm Sum Event)	Device	OUT	*	*		*	LED			BO		128	46	1	Yes
161	Failure: General Current Supervision (Fail I Superv.)	Measurem.Superv	OUT	*	*		*	LED			BO		128	32	1	Yes
162	Failure: Current Summation (Failure Σ I)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	182	1	Yes
163	Failure: Current Balance (Fail I balance)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	183	1	Yes
164	Failure: general Voltage Supervision (Fail U Superv.)	Measurem.Superv	OUT	*	*		*	LED			BO		128	33	1	Yes
165	Failure: Voltage summation Phase-Earth (Fail Σ U Ph-E)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	184	1	Yes
167	Failure: Voltage Balance (Fail U balance)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	186	1	Yes
168	Failure: Voltage absent (Fail U absent)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	187	1	Yes
169	VT Fuse Failure (alarm >10s) (VT FuseFail>10s)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	188	1	Yes
170	VT Fuse Failure (alarm instantaneous) (VT FuseFail)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO					
171	Failure: Phase Sequence (Fail Ph. Seq.)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		128	35	1	Yes
177	Failure: Battery empty (Fail Battery)	Device	OUT	ON OFF	*		*	LED			BO		135	193	1	Yes
181	Error: A/D converter (Error A/D-conv.)	Device	OUT	ON OFF	*		*	LED			BO		135	178	1	Yes
182	Alarm: Real Time Clock (Alarm Clock)	Device	OUT	ON OFF	*		*	LED			BO		135	194	1	Yes
183	Error Board 1 (Error Board 1)	Device	OUT	ON OFF	*		*	LED			BO		135	171	1	Yes
184	Error Board 2 (Error Board 2)	Device	OUT	ON OFF	*		*	LED			BO		135	172	1	Yes
185	Error Board 3 (Error Board 3)	Device	OUT	ON OFF	*		*	LED			BO		135	173	1	Yes
186	Error Board 4 (Error Board 4)	Device	OUT	ON OFF	*		*	LED			BO		135	174	1	Yes

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
187	Error Board 5 (Error Board 5)	Device	OUT	ON OFF	*		*	LED			BO		135	175	1	Yes
188	Error Board 6 (Error Board 6)	Device	OUT	ON OFF	*		*	LED			BO		135	176	1	Yes
189	Error Board 7 (Error Board 7)	Device	OUT	ON OFF	*		*	LED			BO		135	177	1	Yes
190	Error Board 0 (Error Board 0)	Device	OUT	ON OFF	*		*	LED			BO		135	210	1	Yes
191	Error: Offset (Error Offset)	Device	OUT	ON OFF	*		*	LED			BO					
192	Error:1A/5Ajumper different from setting (Error1A/5Awrong)	Device	OUT	ON OFF	*		*	LED			BO		135	169	1	Yes
193	Alarm: NO calibration data available (Alarm NO calibr)	Device	OUT	ON OFF	*		*	LED			BO		135	181	1	Yes
194	Error: Neutral CT different from MLFB (Error neutralCT)	Device	OUT	ON OFF	*		*	LED			BO		135	180	1	Yes
195	Failure: Broken Conductor (Fail Conductor)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	195	1	Yes
196	Fuse Fail Monitor is switched OFF (Fuse Fail M.OFF)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	196	1	Yes
197	Measurement Supervision is switched OFF (MeasSup OFF)	Measurem.Superv	OUT	ON OFF	*		*	LED			BO		135	197	1	Yes
203	Waveform data deleted (Wave. deleted)	Osc. Fault Rec.	OUT_Ev	ON	*		*	LED			BO		135	203	1	No
273	Set Point Phase L1 dmd> (SP. IL1 dmd>)	Set Points(MV)	OUT	on off	*		*	LED			BO		135	230	1	Yes
274	Set Point Phase L2 dmd> (SP. IL2 dmd>)	Set Points(MV)	OUT	on off	*		*	LED			BO		135	234	1	Yes
275	Set Point Phase L3 dmd> (SP. IL3 dmd>)	Set Points(MV)	OUT	on off	*		*	LED			BO		135	235	1	Yes
276	Set Point positive sequence I1dmd> (SP. I1dmd>)	Set Points(MV)	OUT	on off	*		*	LED			BO		135	236	1	Yes
277	Set Point |Pdmd|> (SP. |Pdmd|>)	Set Points(MV)	OUT	on off	*		*	LED			BO		135	237	1	Yes
278	Set Point |Qdmd|> (SP. |Qdmd|>)	Set Points(MV)	OUT	on off	*		*	LED			BO		135	238	1	Yes
279	Set Point |Sdmd|> (SP. |Sdmd|>)	Set Points(MV)	OUT	on off	*		*	LED			BO		135	239	1	Yes
285	Power factor alarm (cosφ alarm)	Set Points(MV)	OUT	on off	*		*	LED			BO		135	245	1	Yes
301	Power System fault (Pow.Sys.Flt.)	P.System Data 2	OUT	ON OFF	ON		*						135	231	2	Yes
302	Fault Event (Fault Event)	P.System Data 2	OUT	*	ON		*						135	232	2	No
303	E/Flt.det. in isol/comp.netw. (E/F Det.)	P.System Data 2	OUT	ON OFF	*	ON	*						135	233	2	No

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
351	>Circuit breaker aux. contact: Pole L1 (>CB Aux. L1)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	1	1	Yes
352	>Circuit breaker aux. contact: Pole L2 (>CB Aux. L2)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	2	1	Yes
353	>Circuit breaker aux. contact: Pole L3 (>CB Aux. L3)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	3	1	Yes
356	>Manual close signal (>Manual Close)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	6	1	Yes
357	>Block all Close commands from external (>Close Cmd. Blk)	P.System Data 2	SP	ON OFF	*		*	LED	BI		BO		150	7	1	Yes
361	>Failure: Feeder VT (MCB tripped) (>FAIL:Feeder VT)	P.System Data 2	SP	ON OFF	*		*	LED	BI		BO		128	38	1	Yes
362	>Failure: Busbar VT (MCB tripped) (>FAIL:Bus VT)	P.System Data 2	SP	ON OFF	*		*	LED	BI		BO		150	12	1	Yes
366	>CB1 Pole L1 (for AR,CB-Test) (>CB1 Pole L1)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	66	1	Yes
367	>CB1 Pole L2 (for AR,CB-Test) (>CB1 Pole L2)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	67	1	Yes
368	>CB1 Pole L3 (for AR,CB-Test) (>CB1 Pole L3)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	68	1	Yes
371	>CB1 READY (for AR,CB-Test) (>CB1 Ready)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	71	1	Yes
378	>CB faulty (>CB faulty)	P.System Data 2	SP	*	*		*	LED	BI		BO					
379	>CB aux. contact 3pole Closed (>CB 3p Closed)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	78	1	Yes
380	>CB aux. contact 3pole Open (>CB 3p Open)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	79	1	Yes
381	>Single-phase trip permitted from ext.AR (>1p Trip Perm)	P.System Data 2	SP	ON OFF	*		*	LED	BI		BO					
382	>External AR programmed for 1phase only (>Only 1ph AR)	P.System Data 2	SP	ON OFF	*		*	LED	BI		BO					
383	>Enable all AR Zones / Stages (>Enable ARzones)	P.System Data 2	SP	ON OFF	ON OFF		*	LED	BI		BO					
385	>Lockout SET (>Lockout SET)	P.System Data 2	SP	ON OFF	*		*	LED	BI		BO		150	35	1	Yes
386	>Lockout RESET (>Lockout RESET)	P.System Data 2	SP	ON OFF	*		*	LED	BI		BO		150	36	1	Yes
395	>I MIN/MAX Buffer Reset (>I MinMax Reset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
396	>I1 MIN/MAX Buffer Reset (>I1 MiMaReset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
397	>U MIN/MAX Buffer Reset (>U MiMaReset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
398	>Uphph MIN/MAX Buffer Reset (>UphphMiMaRes)	Min/Max meter	SP	ON	*		*	LED	BI		BO					

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
399	>U1 MIN/MAX Buffer Reset (>U1 MiMa Reset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
400	>P MIN/MAX Buffer Reset (>P MiMa Reset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
401	>S MIN/MAX Buffer Reset (>S MiMa Reset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
402	>Q MIN/MAX Buffer Reset (>Q MiMa Reset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
403	>Idmd MIN/MAX Buffer Reset (>Idmd MiMaReset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
404	>Pdmd MIN/MAX Buffer Reset (>Pdmd MiMaReset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
405	>Qdmd MIN/MAX Buffer Reset (>Qdmd MiMaReset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
406	>Sdmd MIN/MAX Buffer Reset (>Sdmd MiMaReset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
407	>Frq. MIN/MAX Buffer Reset (>Frq MiMa Reset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
408	>Power Factor MIN/MAX Buffer Reset (>PF MiMaReset)	Min/Max meter	SP	ON	*		*	LED	BI		BO					
410	>CB1 aux. 3p Closed (for AR, CB-Test) (>CB1 3p Closed)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	80	1	Yes
411	>CB1 aux. 3p Open (for AR, CB-Test) (>CB1 3p Open)	P.System Data 2	SP	*	*		*	LED	BI		BO		150	81	1	Yes
501	Relay PICKUP (Relay PICKUP)	P.System Data 2	OUT	*	*		m	LED			BO		128	84	2	Yes
503	Relay PICKUP Phase L1 (Relay PICKUP L1)	P.System Data 2	OUT	*	*		m	LED			BO		128	64	2	Yes
504	Relay PICKUP Phase L2 (Relay PICKUP L2)	P.System Data 2	OUT	*	*		m	LED			BO		128	65	2	Yes
505	Relay PICKUP Phase L3 (Relay PICKUP L3)	P.System Data 2	OUT	*	*		m	LED			BO		128	66	2	Yes
506	Relay PICKUP Earth (Relay PICKUP E)	P.System Data 2	OUT	*	*		m	LED			BO		128	67	2	Yes
507	Relay TRIP command Phase L1 (Relay TRIP L1)	P.System Data 2	OUT	*	*		m	LED			BO		128	69	2	No
508	Relay TRIP command Phase L2 (Relay TRIP L2)	P.System Data 2	OUT	*	*		m	LED			BO		128	70	2	No
509	Relay TRIP command Phase L3 (Relay TRIP L3)	P.System Data 2	OUT	*	*		m	LED			BO		128	71	2	No
510	Relay GENERAL CLOSE command (Relay CLOSE)	P.System Data 2	OUT	*	*	*	*	LED			BO					
511	Relay GENERAL TRIP command (Relay TRIP)	P.System Data 2	OUT	*	OFF		m	LED			BO		128	68	2	No
512	Relay TRIP command - Only Phase L1 (Relay TRIP 1pL1)	P.System Data 2	OUT	*	*		*	LED			BO					

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
513	Relay TRIP command - Only Phase L2 (Relay TRIP 1pL2)	P.System Data 2	OUT	*	*		*	LED			BO					
514	Relay TRIP command - Only Phase L3 (Relay TRIP 1pL3)	P.System Data 2	OUT	*	*		*	LED			BO					
515	Relay TRIP command Phases L123 (Relay TRIP 3ph.)	P.System Data 2	OUT	*	*		*	LED			BO					
530	LOCKOUT is active (LOCKOUT)	P.System Data 2	IntSP	ON OFF	ON OFF		*	LED			BO		150	170	1	Yes
533	Primary fault current IL1 (IL1 =)	P.System Data 2	OUT	*	ON OFF								150	177	4	No
534	Primary fault current IL2 (IL2 =)	P.System Data 2	OUT	*	ON OFF								150	178	4	No
535	Primary fault current IL3 (IL3 =)	P.System Data 2	OUT	*	ON OFF								150	179	4	No
536	Relay Definitive TRIP (Definitive TRIP)	P.System Data 2	OUT	ON	ON	*	*	LED			BO		150	180	2	No
545	Time from Pickup to drop out (PU Time)	P.System Data 2	OUT													
546	Time from Pickup to TRIP (TRIP Time)	P.System Data 2	OUT													
560	Single-phase trip was coupled 3phase (Trip Coupled 3p)	P.System Data 2	OUT	*	ON		*	LED			BO		150	210	2	No
561	Manual close signal detected (Man.Clos.Detect)	P.System Data 2	OUT	ON	*		*	LED			BO		150	211	1	No
562	CB CLOSE command for manual closing (Man.Close Cmd)	P.System Data 2	OUT	*	*		*	LED			BO		150	212	1	No
563	CB alarm suppressed (CB Alarm Supp)	P.System Data 2	OUT	*	*	*		LED			BO					
590	Line closure detected (Line closure)	P.System Data 2	OUT	ON OFF	ON OFF		m	LED			BO					
591	Single pole open detected in L1 (1pole open L1)	P.System Data 2	OUT	ON OFF	ON OFF		m	LED			BO					
592	Single pole open detected in L2 (1pole open L2)	P.System Data 2	OUT	ON OFF	ON OFF		m	LED			BO					
593	Single pole open detected in L3 (1pole open L3)	P.System Data 2	OUT	ON OFF	ON OFF		m	LED			BO					
916	Increment of active energy (WpΔ=)	Energy	-													
917	Increment of reactive energy (WqΔ=)	Energy	-													
1000	Number of breaker TRIP commands (# TRIPs=)	Statistics	OUT													
1001	Number of breaker TRIP commands L1 (TripNo L1=)	Statistics	OUT													
1002	Number of breaker TRIP commands L2 (TripNo L2=)	Statistics	OUT													

No.	Description	Function	Type of In- for- matio n	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
1003	Number of breaker TRIP com- mands L3 (TripNo L3=)	Statistics	OUT													
1027	Accumulation of interrupted current L1 (Σ IL1 =)	Statistics	OUT													
1028	Accumulation of interrupted current L2 (Σ IL2 =)	Statistics	OUT													
1029	Accumulation of interrupted current L3 (Σ IL3 =)	Statistics	OUT													
1030	Max. fault current Phase L1 (Max IL1 =)	Statistics	OUT													
1031	Max. fault current Phase L2 (Max IL2 =)	Statistics	OUT													
1032	Max. fault current Phase L3 (Max IL3 =)	Statistics	OUT													
1114	Flt Locator: primary RESIS- TANCE (Rpri =)	Fault Locator	OUT		ON OFF								151	14	4	No
1115	Flt Locator: primary REAC- TANCE (Xpri =)	Fault Locator	OUT		ON OFF								128	73	4	No
1117	Flt Locator: secondary RESIS- TANCE (Rsec =)	Fault Locator	OUT		ON OFF								151	17	4	No
1118	Flt Locator: secondary REAC- TANCE (Xsec =)	Fault Locator	OUT		ON OFF								151	18	4	No
1119	Flt Locator: Distance to fault (dist =)	Fault Locator	OUT		ON OFF								151	19	4	No
1120	Flt Locator: Distance [%] to fault (d[%] =)	Fault Locator	OUT		ON OFF								151	20	4	No
1122	Flt Locator: Distance to fault (dist =)	Fault Locator	OUT		ON OFF								151	22	4	No
1123	Fault Locator Loop L1E (FL Loop L1E)	Fault Locator	OUT_ Ev		ON											
1124	Fault Locator Loop L2E (FL Loop L2E)	Fault Locator	OUT_ Ev		ON											
1125	Fault Locator Loop L3E (FL Loop L3E)	Fault Locator	OUT_ Ev		ON											
1126	Fault Locator Loop L1L2 (FL Loop L1L2)	Fault Locator	OUT_ Ev		ON											
1127	Fault Locator Loop L2L3 (FL Loop L2L3)	Fault Locator	OUT_ Ev		ON											
1128	Fault Locator Loop L3L1 (FL Loop L3L1)	Fault Locator	OUT_ Ev		ON											
1132	Fault location invalid (Flt.Loc.in- valid)	Fault Locator	OUT	*	ON		*	LED			BO					
1133	Fault locator setting error K0,an- gle(K0) (Flt.Loc.ErrorK0)	Fault Locator	OUT	*	ON		*	LED			BO					
1143	BCD Fault location [1%] (BCD d[1%])	Fault Locator	OUT	*	*		*	LED			BO					

No.	Description	Function	Type of Infor- matio n	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
					Log Buffers				Configurable in Matrix				IEC 60870-5-103			
1144	BCD Fault location [2%] (BCD d[2%])	Fault Locator	OUT	*	*		*	LED			BO					
1145	BCD Fault location [4%] (BCD d[4%])	Fault Locator	OUT	*	*		*	LED			BO					
1146	BCD Fault location [8%] (BCD d[8%])	Fault Locator	OUT	*	*		*	LED			BO					
1147	BCD Fault location [10%] (BCD d[10%])	Fault Locator	OUT	*	*		*	LED			BO					
1148	BCD Fault location [20%] (BCD d[20%])	Fault Locator	OUT	*	*		*	LED			BO					
1149	BCD Fault location [40%] (BCD d[40%])	Fault Locator	OUT	*	*		*	LED			BO					
1150	BCD Fault location [80%] (BCD d[80%])	Fault Locator	OUT	*	*		*	LED			BO					
1151	BCD Fault location [100%] (BCD d[100%])	Fault Locator	OUT	*	*		*	LED			BO					
1152	BCD Fault location valid (BCD dist. VALID)	Fault Locator	OUT	*	*		*	LED			BO					
1219	Active 3I0sen (sensitive Ie) = (3I0senA=)	Sens. Earth Flt	OUT	*	*	ON OFF										
1220	Reactive 3I0sen (sensitive Ie) = (3I0senR=)	Sens. Earth Flt	OUT	*	*	ON OFF										
1251	>Switch on sensitive E/F detec- tion (>SensEF on)	Sens. Earth Flt	SP	*	*		*	LED	BI		BO					
1252	>Switch off sensitive E/F detec- tion (>SensEF off)	Sens. Earth Flt	SP	*	*		*	LED	BI		BO					
1253	>Block sensitive E/F detection (>SensEF block)	Sens. Earth Flt	SP	*	*		*	LED	BI		BO					
1260	Sensitve E/F detection ON/OFF via BI (SensEF on/offBI)	Sens. Earth Flt	IntSP	ON OFF	*		*	LED			BO					
1261	Sensitve E/F detection is switched OFF (SensEF OFF)	Sens. Earth Flt	OUT	ON OFF	*		*	LED			BO		151	161	1	Yes
1262	Sensitve E/F detection is BLOCKED (SensEF BLOCK)	Sens. Earth Flt	OUT	ON OFF	ON OFF		*	LED			BO		151	162	1	Yes
1263	Sensitve E/F detection is ACTIVE (SensEF ACTIVE)	Sens. Earth Flt	OUT	ON OFF	*		*	LED			BO		151	163	1	Yes
1271	Sensitve E/F detection picked up (SensEF Pickup)	Sens. Earth Flt	OUT	*	ON OFF	*	m	LED			BO					
1272	Sensitve E/F detection Phase L1 (SensEF Phase L1)	Sens. Earth Flt	OUT	*	*	ON	*	LED			BO		128	48	1	Yes
1273	Sensitve E/F detection Phase L2 (SensEF Phase L2)	Sens. Earth Flt	OUT	*	*	ON	*	LED			BO		128	49	1	Yes
1274	Sensitve E/F detection Phase L3 (SensEF Phase L3)	Sens. Earth Flt	OUT	*	*	ON	*	LED			BO		128	50	1	Yes
1276	Sensitve E/F detection Forward (SensEF Forward)	Sens. Earth Flt	OUT	*	*	ON	*	LED			BO		128	51	1	Yes

No.	Description	Function	Type of Information	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
1277	Sensitve E/F detection Reverse (SensEF Reverse)	Sens. Earth Flt	OUT	*	*	ON	*	LED			BO		128	52	1	Yes
1278	Sensitve E/F detection Undef. Direction (SensEF undefDir)	Sens. Earth Flt	OUT	*	*	ON	*	LED			BO		151	178	1	Yes
1281	Sensitve E/F detection TRIP command (SensEF TRIP)	Sens. Earth Flt	OUT	*	ON	ON	*	LED			BO		151	181	2	Yes
1291	Sensitve E/F detection 3U0> pickup (SensEF 3U0>)	Sens. Earth Flt	OUT	*	*		*	LED			BO					
1305	>Earth Fault O/C Block 3I0>>> (>EF BLK 3I0>>>)	Earth Fault O/C	SP	ON OFF	*		*	LED	BI		BO		166	5	1	Yes
1307	>Earth Fault O/C Block 3I0>> (>EF BLOCK 3I0>>)	Earth Fault O/C	SP	ON OFF	*		*	LED	BI		BO		166	7	1	Yes
1308	>Earth Fault O/C Block 3I0> (>EF BLOCK 3I0>)	Earth Fault O/C	SP	ON OFF	*		*	LED	BI		BO		166	8	1	Yes
1309	>Earth Fault O/C Block 3I0p (>EF BLOCK 3I0p)	Earth Fault O/C	SP	ON OFF	*		*	LED	BI		BO		166	9	1	Yes
1310	>Earth Fault O/C Instantaneous trip (>EF InstTRIP)	Earth Fault O/C	SP	ON OFF	ON OFF		*	LED	BI		BO		166	10	1	Yes
1311	>E/F Teleprotection ON (>EF Teleprot.ON)	Teleprot. E/F	SP	*	*		*	LED	BI		BO					
1312	>E/F Teleprotection OFF (>EF TeleprotOFF)	Teleprot. E/F	SP	*	*		*	LED	BI		BO					
1313	>E/F Teleprotection BLOCK (>EF TeleprotBLK)	Teleprot. E/F	SP	ON OFF	*		*	LED	BI		BO		166	13	1	Yes
1318	>E/F Carrier RECEPTION, Channel 1 (>EF Rec.Ch1)	Teleprot. E/F	SP	on off	on		*	LED	BI		BO		166	18	1	Yes
1319	>E/F Carrier RECEPTION, Channel 2 (>EF Rec.Ch2)	Teleprot. E/F	SP	on off	on		*	LED	BI		BO		166	19	1	Yes
1320	>E/F Unblocking: UNBLOCK, Channel 1 (>EF UB ub 1)	Teleprot. E/F	SP	ON OFF	ON		*	LED	BI		BO		166	20	1	Yes
1321	>E/F Unblocking: BLOCK, Channel 1 (>EF UB bl 1)	Teleprot. E/F	SP	ON OFF	ON		*	LED	BI		BO		166	21	1	Yes
1322	>E/F Unblocking: UNBLOCK, Channel 2 (>EF UB ub 2)	Teleprot. E/F	SP	ON OFF	ON		*	LED	BI		BO		166	22	1	Yes
1323	>E/F Unblocking: BLOCK, Channel 2 (>EF UB bl 2)	Teleprot. E/F	SP	ON OFF	ON		*	LED	BI		BO		166	23	1	Yes
1324	>E/F BLOCK Echo Signal (>EF BlkEcho)	Teleprot. E/F	SP	ON OFF	ON		*	LED	BI		BO		166	24	1	Yes
1325	>E/F Carrier RECEPTION, Channel 1, Ph.L1 (>EF Rec.Ch1 L1)	Teleprot. E/F	SP	on off	on		*	LED	BI		BO		166	25	1	Yes
1326	>E/F Carrier RECEPTION, Channel 1, Ph.L2 (>EF Rec.Ch1 L2)	Teleprot. E/F	SP	on off	on		*	LED	BI		BO		166	26	1	Yes
1327	>E/F Carrier RECEPTION, Channel 1, Ph.L3 (>EF Rec.Ch1 L3)	Teleprot. E/F	SP	on off	on		*	LED	BI		BO		166	27	1	Yes

| No. | Description | Function | Type of Informatio n | Log Buffers | | | | Configurable in Matrix | | | | | IEC 60870-5-103 | | | |
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
1328	>E/F Unblocking: UNBLOCK Chan. 1, Ph.L1 (>EF UB ub 1-L1)	Teleprot. E/F	SP	ON OFF	ON		*	LED	BI		BO		166	28	1	Yes
1329	>E/F Unblocking: UNBLOCK Chan. 1, Ph.L2 (>EF UB ub 1-L2)	Teleprot. E/F	SP	ON OFF	ON		*	LED	BI		BO		166	29	1	Yes
1330	>E/F Unblocking: UNBLOCK Chan. 1, Ph.L3 (>EF UB ub 1-L3)	Teleprot. E/F	SP	ON OFF	ON		*	LED	BI		BO		166	30	1	Yes
1331	Earth fault protection is switched OFF (E/F Prot. OFF)	Earth Fault O/C	OUT	ON OFF	*		*	LED			BO		166	31	1	Yes
1332	Earth fault protection is BLOCKED (E/F BLOCK)	Earth Fault O/C	OUT	ON OFF	ON OFF		*	LED			BO		166	32	1	Yes
1333	Earth fault protection is ACTIVE (E/F ACTIVE)	Earth Fault O/C	OUT	*	*		*	LED			BO		166	33	1	Yes
1335	Earth fault protection Trip is blocked (EF TRIP BLOCK)	Earth Fault O/C	OUT	ON OFF	ON OFF		*	LED			BO					
1336	E/F phase selector L1 selected (E/F L1 selec.)	Earth Fault O/C	OUT	*	ON OFF		*	LED			BO					
1337	E/F phase selector L2 selected (E/F L2 selec.)	Earth Fault O/C	OUT	*	ON OFF		*	LED			BO					
1338	E/F phase selector L3 selected (E/F L3 selec.)	Earth Fault O/C	OUT	*	ON OFF		*	LED			BO					
1345	Earth fault protection PICKED UP (EF Pickup)	Earth Fault O/C	OUT	*	off		m	LED			BO		166	45	2	Yes
1354	E/F 3I0>>> PICKED UP (EF 3I0>>>Pickup)	Earth Fault O/C	OUT	*	ON		*	LED			BO					
1355	E/F 3I0>> PICKED UP (EF 3I0>> Pickup)	Earth Fault O/C	OUT	*	ON		*	LED			BO					
1356	E/F 3I0> PICKED UP (EF 3I0> Pickup)	Earth Fault O/C	OUT	*	ON		*	LED			BO					
1357	E/F 3I0p PICKED UP (EF 3I0p Pickup)	Earth Fault O/C	OUT	*	ON		*	LED			BO					
1358	E/F picked up FORWARD (EF forward)	Earth Fault O/C	OUT	*	ON		*	LED			BO		166	58	2	No
1359	E/F picked up REVERSE (EF reverse)	Earth Fault O/C	OUT	*	ON		*	LED			BO		166	59	2	No
1361	E/F General TRIP command (EF Trip)	Earth Fault O/C	OUT	*	*		*	LED			BO		166	61	2	No
1362	Earth fault protection: Trip 1pole L1 (E/F Trip L1)	Earth Fault O/C	OUT	*	ON		m	LED			BO		166	62	2	Yes
1363	Earth fault protection: Trip 1pole L2 (E/F Trip L2)	Earth Fault O/C	OUT	*	ON		m	LED			BO		166	63	2	Yes
1364	Earth fault protection: Trip 1pole L3 (E/F Trip L3)	Earth Fault O/C	OUT	*	ON		m	LED			BO		166	64	2	Yes
1365	Earth fault protection: Trip 3pole (E/F Trip 3p)	Earth Fault O/C	OUT	*	ON		m	LED			BO		166	65	2	Yes
1366	E/F 3I0>>> TRIP (EF 3I0>>> TRIP)	Earth Fault O/C	OUT	*	ON		*	LED			BO		166	66	2	No

No.	Description	Function	Type of Information	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
1367	E/F 3I0>> TRIP (EF 3I0>> TRIP)	Earth Fault O/C	OUT	*	ON		*	LED			BO		166	67	2	No
1368	E/F 3I0> TRIP (EF 3I0> TRIP)	Earth Fault O/C	OUT	*	ON		*	LED			BO		166	68	2	No
1369	E/F 3I0p TRIP (EF 3I0p TRIP)	Earth Fault O/C	OUT	*	ON		*	LED			BO		166	69	2	No
1370	E/F Inrush picked up (EF Inrush-PU)	Earth Fault O/C	OUT	*	ON OFF		*	LED			BO		166	70	2	No
1371	E/F Telep. Carrier SEND signal, Phase L1 (EF Tele SEND L1)	Teleprot. E/F	OUT	on	on		*	LED			BO		166	71	1	No
1372	E/F Telep. Carrier SEND signal, Phase L2 (EF Tele SEND L2)	Teleprot. E/F	OUT	on	on		*	LED			BO		166	72	1	No
1373	E/F Telep. Carrier SEND signal, Phase L3 (EF Tele SEND L3)	Teleprot. E/F	OUT	on	on		*	LED			BO		166	73	1	No
1374	E/F Telep. Block: carrier STOP signal L1 (EF Tele STOP L1)	Teleprot. E/F	OUT	*	on		*	LED			BO		166	74	1	No
1375	E/F Telep. Block: carrier STOP signal L2 (EF Tele STOP L2)	Teleprot. E/F	OUT	*	on		*	LED			BO		166	75	1	No
1376	E/F Telep. Block: carrier STOP signal L3 (EF Tele STOP L3)	Teleprot. E/F	OUT	*	on		*	LED			BO		166	76	1	No
1380	E/F Teleprot. ON/OFF via BI (EF TeleON/offBI)	Teleprot. E/F	IntSP	ON OFF	*		*	LED			BO					
1381	E/F Teleprotection is switched OFF (EF Telep. OFF)	Teleprot. E/F	OUT	ON OFF	*		*	LED			BO		166	81	1	Yes
1384	E/F Telep. Carrier SEND signal (EF Tele SEND)	Teleprot. E/F	OUT	on	on		*	LED			BO		166	84	2	No
1386	E/F Telep. Transient Blocking (EF TeleTransBlk)	Teleprot. E/F	OUT	*	ON		*	LED			BO		166	86	2	No
1387	E/F Telep. Unblocking: FAILURE Channel 1 (EF TeleUB Fail1)	Teleprot. E/F	OUT	ON OFF	*		*	LED			BO		166	87	1	Yes
1388	E/F Telep. Unblocking: FAILURE Channel 2 (EF TeleUB Fail2)	Teleprot. E/F	OUT	ON OFF	*		*	LED			BO		166	88	1	Yes
1389	E/F Telep. Blocking: carrier STOP signal (EF Tele BL STOP)	Teleprot. E/F	OUT	*	on		*	LED			BO		166	89	2	No
1390	E/F Tele.Blocking: Send signal with jump (EF Tele BL Jump)	Teleprot. E/F	OUT	*	*		*	LED			BO		166	90	2	No
1391	EF Tele.Carrier RECEPTION, L1, Device1 (EF Rec.L1 Dev1)	Teleprot. E/F	OUT	on off	on		*	LED			BO					
1392	EF Tele.Carrier RECEPTION, L2, Device1 (EF Rec.L2 Dev1)	Teleprot. E/F	OUT	on off	on		*	LED			BO					
1393	EF Tele.Carrier RECEPTION, L3, Device1 (EF Rec.L3 Dev1)	Teleprot. E/F	OUT	on off	on		*	LED			BO					
1394	EF Tele.Carrier RECEPTION, L1, Device2 (EF Rec.L1 Dev2)	Teleprot. E/F	OUT	on off	on		*	LED			BO					
1395	EF Tele.Carrier RECEPTION, L2, Device2 (EF Rec.L2 Dev2)	Teleprot. E/F	OUT	on off	on		*	LED			BO					
1396	EF Tele.Carrier RECEPTION, L3, Device2 (EF Rec.L3 Dev2)	Teleprot. E/F	OUT	on off	on		*	LED			BO					

No.	Description	Function	Type of Infor-mation	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
				Log Buffers				Configurable in Matrix					IEC 60870-5-103			
1397	EF Tele.Carrier RECEPTION, L1, Device3 (EF Rec.L1 Dev3)	Teleprot. E/F	OUT	on off	on		*	LED			BO					
1398	EF Tele.Carrier RECEPTION, L2, Device3 (EF Rec.L2 Dev3)	Teleprot. E/F	OUT	on off	on		*	LED			BO					
1399	EF Tele.Carrier RECEPTION, L3, Device3 (EF Rec.L3 Dev3)	Teleprot. E/F	OUT	on off	on		*	LED			BO					
1401	>BF: Switch on breaker fail protection (>BF on)	Breaker Failure	SP	*	*		*	LED	BI		BO					
1402	>BF: Switch off breaker fail protection (>BF off)	Breaker Failure	SP	*	*		*	LED	BI		BO					
1403	>BLOCK Breaker failure (>BLOCK BkrFail)	Breaker Failure	SP	ON OFF	*		*	LED	BI		BO		166	103	1	Yes
1415	>BF: External start 3pole (>BF Start 3pole)	Breaker Failure	SP	ON OFF	*		*	LED	BI		BO					
1432	>BF: External release (>BF release)	Breaker Failure	SP	ON OFF	*		*	LED	BI		BO					
1435	>BF: External start L1 (>BF Start L1)	Breaker Failure	SP	ON OFF	*		*	LED	BI		BO					
1436	>BF: External start L2 (>BF Start L2)	Breaker Failure	SP	ON OFF	*		*	LED	BI		BO					
1437	>BF: External start L3 (>BF Start L3)	Breaker Failure	SP	ON OFF	*		*	LED	BI		BO					
1439	>BF: External start 3pole (w/o current) (>BF Start w/o I)	Breaker Failure	SP	ON OFF	*		*	LED	BI		BO					
1440	Breaker failure prot. ON/OFF via BI (BkrFailON/offBI)	Breaker Failure	IntSP	ON OFF	*		*	LED			BO					
1451	Breaker failure is switched OFF (BkrFail OFF)	Breaker Failure	OUT	ON OFF	*		*	LED			BO		166	151	1	Yes
1452	Breaker failure is BLOCKED (BkrFail BLOCK)	Breaker Failure	OUT	ON OFF	ON OFF		*	LED			BO		166	152	1	Yes
1453	Breaker failure is ACTIVE (BkrFail ACTIVE)	Breaker Failure	OUT	*	*		*	LED			BO		166	153	1	Yes
1461	Breaker failure protection started (BF Start)	Breaker Failure	OUT	*	ON OFF		*	LED			BO		166	161	1	Yes
1472	BF Trip T1 (local trip) - only phase L1 (BF T1-TRIP 1pL1)	Breaker Failure	OUT	*	ON		*	LED			BO					
1473	BF Trip T1 (local trip) - only phase L2 (BF T1-TRIP 1pL2)	Breaker Failure	OUT	*	ON		*	LED			BO					
1474	BF Trip T1 (local trip) - only phase L3 (BF T1-TRIP 1pL3)	Breaker Failure	OUT	*	ON		*	LED			BO					
1476	BF Trip T1 (local trip) - 3pole (BF T1-TRIP L123)	Breaker Failure	OUT	*	ON		*	LED			BO					
1493	BF Trip in case of defective CB (BF TRIP CBdefec)	Breaker Failure	OUT	*	ON		*	LED			BO					
1494	BF Trip T2 (busbar trip) (BF T2-TRIP(bus))	Breaker Failure	OUT	*	ON		*	LED			BO		128	85	2	No

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
1495	BF Trip End fault stage (BF EndFlt TRIP)	Breaker Failure	OUT	*	ON		*	LED			BO					
1496	BF Pole discrepancy pickup (BF CBdiscrSTART)	Breaker Failure	OUT	*	ON OFF		*	LED			BO					
1497	BF Pole discrepancy pickup L1 (BF CBdiscr L1)	Breaker Failure	OUT	*	ON OFF		*	LED			BO					
1498	BF Pole discrepancy pickup L2 (BF CBdiscr L2)	Breaker Failure	OUT	*	ON OFF		*	LED			BO					
1499	BF Pole discrepancy pickup L3 (BF CBdiscr L3)	Breaker Failure	OUT	*	ON OFF		*	LED			BO					
1500	BF Pole discrepancy Trip (BF CBdiscr TRIP)	Breaker Failure	OUT	*	ON		*	LED			BO					
1503	>BLOCK Thermal Overload Protection (>BLK ThOverload)	Therm. Overload	SP	ON OFF	*		*	LED	BI		BO		167	3	1	Yes
1511	Thermal Overload Protection OFF (Th.Overload OFF)	Therm. Overload	OUT	ON OFF	*		*	LED			BO		167	11	1	Yes
1512	Thermal Overload Protection BLOCKED (Th.Overload BLK)	Therm. Overload	OUT	ON OFF	ON OFF		*	LED			BO		167	12	1	Yes
1513	Thermal Overload Protection ACTIVE (Th.O/L ACTIVE)	Therm. Overload	OUT	ON OFF	*		*	LED			BO		167	13	1	Yes
1515	Th. Overload: Current Alarm (I alarm) (Th.O/L I Alarm)	Therm. Overload	OUT	ON OFF	*		*	LED			BO		167	15	1	Yes
1516	Th. Overload Alarm: Near Thermal Trip (Th.O/L Θ Alarm)	Therm. Overload	OUT	ON OFF	*		*	LED			BO		167	16	1	Yes
1517	Th. Overload Pickup before trip (Th.O/L Pickup)	Therm. Overload	OUT	ON OFF	*		*	LED			BO		167	17	1	Yes
1521	Th. Overload TRIP command (Th.O/L TRIP)	Therm. Overload	OUT	*	ON		m	LED			BO		167	21	1	No
2054	Emergency mode (Emer. mode)	Back-Up O/C	OUT	ON OFF	ON OFF		*	LED			BO		128	37	1	Yes
2701	>AR: Switch on auto-reclose function (>AR on)	Autoreclosure	SP	*	*		*	LED	BI		BO		40	1	1	No
2702	>AR: Switch off auto-reclose function (>AR off)	Autoreclosure	SP	*	*		*	LED	BI		BO		40	2	1	No
2703	>AR: Block auto-reclose function (>AR block)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	3	1	Yes
2711	>External start of internal Auto reclose (>AR Start)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	11	2	Yes
2712	>AR: External trip L1 for AR start (>Trip L1 AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	12	2	Yes
2713	>AR: External trip L2 for AR start (>Trip L2 AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	13	2	Yes
2714	>AR: External trip L3 for AR start (>Trip L3 AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	14	2	Yes
2715	>AR: External 1pole trip for AR start (>Trip 1pole AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	15	2	Yes

| No. | Description | Function | Type of In-for-mation | Log Buffers | | | | Configurable in Matrix | | | | | IEC 60870-5-103 | | | |
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
2716	>AR: External 3pole trip for AR start (>Trip 3pole AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	16	2	Yes
2727	>AR: Remote Close signal (>AR RemoteClose)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	22	2	Yes
2731	>AR: Sync. release from ext. sync.-check (>Sync.release)	Autoreclosure	SP	*	*		*	LED	BI		BO		40	31	2	Yes
2737	>AR: Block 1pole AR-cycle (>BLOCK 1pole AR)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	32	1	Yes
2738	>AR: Block 3pole AR-cycle (>BLOCK 3pole AR)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	33	1	Yes
2739	>AR: Block 1phase-fault AR-cycle (>BLK 1phase AR)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	34	1	Yes
2740	>AR: Block 2phase-fault AR-cycle (>BLK 2phase AR)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	35	1	Yes
2741	>AR: Block 3phase-fault AR-cycle (>BLK 3phase AR)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	36	1	Yes
2742	>AR: Block 1st AR-cycle (>BLK 1.AR-cycle)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	37	1	Yes
2743	>AR: Block 2nd AR-cycle (>BLK 2.AR-cycle)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	38	1	Yes
2744	>AR: Block 3rd AR-cycle (>BLK 3.AR-cycle)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	39	1	Yes
2745	>AR: Block 4th and higher AR-cycles (>BLK 4.-n. AR)	Autoreclosure	SP	ON OFF	*		*	LED	BI		BO		40	40	1	Yes
2746	>AR: External Trip for AR start (>Trip for AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	41	2	Yes
2747	>AR: External pickup L1 for AR start (>Pickup L1 AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	42	2	Yes
2748	>AR: External pickup L2 for AR start (>Pickup L2 AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	43	2	Yes
2749	>AR: External pickup L3 for AR start (>Pickup L3 AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	44	2	Yes
2750	>AR: External pickup 1phase for AR start (>Pickup 1ph AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	45	2	Yes
2751	>AR: External pickup 2phase for AR start (>Pickup 2ph AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	46	2	Yes
2752	>AR: External pickup 3phase for AR start (>Pickup 3ph AR)	Autoreclosure	SP	*	ON		*	LED	BI		BO		40	47	2	Yes
2781	AR: Auto-reclose is switched off (AR off)	Autoreclosure	OUT	ON OFF	*		*	LED			BO		40	81	1	Yes
2782	AR: Auto-reclose is switched on (AR on)	Autoreclosure	IntSP	*	*		*	LED			BO		128	16	1	Yes
2783	AR: Auto-reclose is blocked (AR is blocked)	Autoreclosure	OUT	ON OFF	*		*	LED			BO		40	83	1	Yes
2784	AR: Auto-reclose is not ready (AR not ready)	Autoreclosure	OUT	*	ON		*	LED			BO		128	130	1	Yes

No.	Description	Function	Type of Infor- matio n	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
2787	AR: Circuit breaker not ready (CB not ready)	Autoreclosure	OUT	*	*		*	LED			BO		40	87	1	No
2788	AR: CB ready monitoring window expired (AR T-CBreadyExp)	Autoreclosure	OUT	*	ON		*	LED			BO		40	88	2	No
2796	AR: Auto-reclose ON/OFF via BI (AR on/off BI)	Autoreclosure	IntSP	*	*		*	LED			BO					
2801	AR in progress (AR in progress)	Autoreclosure	OUT	*	ON		*	LED			BO		40	101	2	Yes
2809	AR: Start-signal monitoring time expired (AR T-Start Exp)	Autoreclosure	OUT	*	ON		*	LED			BO		40	174	1	No
2810	AR: Maximum dead time expired (AR TdeadMax Exp)	Autoreclosure	OUT	*	ON		*	LED			BO		40	175	1	No
2818	AR: Evolving fault recognition (AR evolving Flt)	Autoreclosure	OUT	*	ON		*	LED			BO		40	118	2	Yes
2820	AR is set to operate after 1p trip only (AR Program1pole)	Autoreclosure	OUT	*	*		*	LED			BO		40	143	1	No
2821	AR dead time after evolving fault (AR Td. evol.Flt)	Autoreclosure	OUT	*	ON		*	LED			BO		40	197	2	No
2839	AR dead time after 1pole trip running (AR Tdead 1pTrip)	Autoreclosure	OUT	*	ON		*	LED			BO		40	148	2	Yes
2840	AR dead time after 3pole trip running (AR Tdead 3pTrip)	Autoreclosure	OUT	*	ON		*	LED			BO		40	149	2	Yes
2841	AR dead time after 1phase fault running (AR Tdead 1pFlt)	Autoreclosure	OUT	*	ON		*	LED			BO		40	150	2	Yes
2842	AR dead time after 2phase fault running (AR Tdead 2pFlt)	Autoreclosure	OUT	*	ON		*	LED			BO		40	151	2	Yes
2843	AR dead time after 3phase fault running (AR Tdead 3pFlt)	Autoreclosure	OUT	*	ON		*	LED			BO		40	154	2	Yes
2844	AR 1st cycle running (AR 1stCyc. run.)	Autoreclosure	OUT	*	ON		*	LED			BO		40	155	2	Yes
2845	AR 2nd cycle running (AR 2ndCyc. run.)	Autoreclosure	OUT	*	ON		*	LED			BO		40	157	2	Yes
2846	AR 3rd cycle running (AR 3rdCyc. run.)	Autoreclosure	OUT	*	ON		*	LED			BO		40	158	2	Yes
2847	AR 4th or higher cycle running (AR 4thCyc. run.)	Autoreclosure	OUT	*	ON		*	LED			BO		40	159	2	Yes
2848	AR cycle is running in ADT mode (AR ADT run.)	Autoreclosure	OUT	*	ON		*	LED			BO		40	130	2	Yes
2851	AR: Close command (AR CLOSE Cmd.)	Autoreclosure	OUT	*	ON		m	LED			BO		128	128	1	No
2852	AR: Close command after 1pole, 1st cycle (AR Close1.Cyc1p)	Autoreclosure	OUT	*	*		*	LED			BO		40	152	1	No
2853	AR: Close command after 3pole, 1st cycle (AR Close1.Cyc3p)	Autoreclosure	OUT	*	*		*	LED			BO		40	153	1	No
2854	AR: Close command 2nd cycle (and higher) (AR Close 2.Cyc)	Autoreclosure	OUT	*	*		*	LED			BO		128	129	1	No

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				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
2861	AR: Reclaim time is running (AR T-Recl. run.)	Autoreclosure	OUT	*	*		*	LED			BO		40	161	1	No
2862	AR successful (AR successful)	Autoreclosure	OUT	*	*		*	LED			BO		40	162	1	No
2864	AR: 1pole trip permitted by inter- nal AR (AR 1p Trip Perm)	Autoreclosure	OUT	*	*		*	LED			BO		40	164	1	Yes
2865	AR: Synchro-check request (AR Sync.Request)	Autoreclosure	OUT	*	*		*	LED			BO		40	165	2	Yes
2871	AR: TRIP command 3pole (AR TRIP 3pole)	Autoreclosure	OUT	*	ON		*	LED			BO		40	171	2	Yes
2889	AR 1st cycle zone extension release (AR 1.CycZoneRel)	Autoreclosure	OUT	*	*		*	LED			BO		40	160	1	No
2890	AR 2nd cycle zone extension release (AR 2.CycZoneRel)	Autoreclosure	OUT	*	*		*	LED			BO		40	169	1	No
2891	AR 3rd cycle zone extension release (AR 3.CycZoneRel)	Autoreclosure	OUT	*	*		*	LED			BO		40	170	1	No
2892	AR 4th cycle zone extension release (AR 4.CycZoneRel)	Autoreclosure	OUT	*	*		*	LED			BO		40	172	1	No
2893	AR zone extension (general) (AR Zone Release)	Autoreclosure	OUT	*	*		*	LED			BO		40	173	1	Yes
2894	AR Remote close signal send (AR Remote Close)	Autoreclosure	OUT	*	ON		*	LED			BO		40	129	1	No
2895	No. of 1st AR-cycle CLOSE com- mands,1pole (AR #Close1./1p=)	Statistics	OUT													
2896	No. of 1st AR-cycle CLOSE com- mands,3pole (AR #Close1./3p=)	Statistics	OUT													
2897	No. of higher AR-cycle CLOSE commands,1p (AR #Close2./1p=)	Statistics	OUT													
2898	No. of higher AR-cycle CLOSE commands,3p (AR #Close2./3p=)	Statistics	OUT													
2901	>Switch on synchro-check func- tion (>Sync. on)	Sync. Check	SP	*	*		*	LED	BI		BO					
2902	>Switch off synchro-check func- tion (>Sync. off)	Sync. Check	SP	*	*		*	LED	BI		BO					
2903	>BLOCK synchro-check function (>BLOCK Sync.)	Sync. Check	SP	*	*		*	LED	BI		BO					
2905	>Start synchro-check for Manual Close (>Sync. Start MC)	Sync. Check	SP	on off	*		*	LED	BI		BO					
2906	>Start synchro-check for AR (>Sync. Start AR)	Sync. Check	SP	on off	*		*	LED	BI		BO					
2907	>Sync-Prog. Live bus / live line / Sync (>Sync. synch)	Sync. Check	SP	*	*		*	LED	BI		BO					
2908	>Sync-Prog. Dead bus / live line (> Usyn< U-line>)	Sync. Check	SP	*	*		*	LED	BI		BO					
2909	>Sync-Prog. Live bus / dead line (> Usyn> U-line<)	Sync. Check	SP	*	*		*	LED	BI		BO					

No.	Description	Function	Type of In-for-matio n	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
2910	>Sync-Prog. Dead bus / dead line (> Usyn< U-line<)	Sync. Check	SP	*	*		*	LED	BI		BO					
2911	>Sync-Prog. Override (bypass) (>Sync. o/ride)	Sync. Check	SP	*	*		*	LED	BI		BO					
2930	Synchro-check ON/OFF via BI (Sync. on/off BI)	Sync. Check	IntSP	ON OFF	*		*	LED			BO					
2931	Synchro-check is switched OFF (Sync. OFF)	Sync. Check	OUT	ON OFF	*		*	LED			BO		41	31	1	Yes
2932	Synchro-check is BLOCKED (Sync. BLOCK)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO		41	32	1	Yes
2934	Synchro-check function faulty (Sync. faulty)	Sync. Check	OUT	ON OFF	*		*	LED			BO		41	34	1	Yes
2935	Synchro-check supervision time expired (Sync.Tsup.Exp)	Sync. Check	OUT	ON	ON		*	LED			BO		41	35	1	No
2936	Synchro-check request by control (Sync. req.CNTRL)	Sync. Check	OUT	ON	ON		*	LED			BO		41	36	1	No
2941	Synchronization is running (Sync. running)	Sync. Check	OUT	ON OFF	ON		*	LED			BO		41	41	1	Yes
2942	Synchro-check override/bypass (Sync.Override)	Sync. Check	OUT	ON OFF	ON		*	LED			BO		41	42	1	Yes
2943	Synchronism detected (Synchro-nism)	Sync. Check	OUT	ON OFF	*		*	LED			BO		41	43	1	Yes
2944	Sync. dead bus / live line detect-ed (Usyn< U-line>)	Sync. Check	OUT	ON OFF	*		*	LED			BO		41	44	1	Yes
2945	Sync. live bus / dead line detect-ed (Usyn> U-line<)	Sync. Check	OUT	ON OFF	*		*	LED			BO		41	45	1	Yes
2946	Sync. dead bus / dead line de-tected (Usyn< U-line<)	Sync. Check	OUT	ON OFF	*		*	LED			BO		41	46	1	Yes
2947	Sync. Voltage diff. greater than limit (Sync. Udiff>)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO		41	47	1	Yes
2948	Sync. Freq. diff. greater than limit (Sync. fdiff>)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO		41	48	1	Yes
2949	Sync. Angle diff. greater than limit (Sync. φ-diff>)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO		41	49	1	Yes
2951	Synchronism release (to ext. AR) (Sync. release)	Sync. Check	OUT	*	*		*	LED			BO		41	51	1	Yes
2961	Close command from synchro-check (Sync.CloseCmd)	Sync. Check	OUT	*	*		*	LED			BO		41	61	1	Yes
2970	Sync. Bus frequency > (fn + 3Hz) (Sync. f-bus>>)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO					
2971	Sync. Bus frequency < (fn - 3Hz) (Sync. f-bus<<)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO					
2972	Sync. Line frequency > (fn + 3Hz) (Sync. f-line>>)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO					
2973	Sync. Line frequency < (fn - 3Hz) (Sync. f-line<<)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO					

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				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
2974	Sync. Bus voltage > Umax (P.3504) (Sync. U-syn>>)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO					
2975	Sync. Bus voltage < U> (P.3503) (Sync. U-syn<<)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO					
2976	Sync. Line voltage > Umax (P.3504) (Sync. U-line>>)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO					
2977	Sync. Line voltage < U> (P.3503) (Sync. U-line<<)	Sync. Check	OUT	ON OFF	ON OFF		*	LED			BO					
3196	Local relay in Teststate (local Teststate)	Prot. Interface	IntSP	ON OFF	ON		*	LED		FC TN	BO					
3215	Incompatible Firmware Versions (Wrong Firmware)	Prot. Interface	OUT	ON	*		*	LED			BO					
3217	Prot Int 1: Own Datas received (PI1 Data reflec)	Prot. Interface	OUT	ON OFF	*		*	LED			BO					
3227	>Prot Int 1: Transmitter is switched off (>PI1 light off)	Prot. Interface	SP	ON OFF	*		*	LED	BI		BO					
3229	Prot Int 1: Reception of faulty data (PI1 Data fault)	Prot. Interface	OUT	ON OFF	*		*	LED			BO		93	135	1	Yes
3230	Prot Int 1: Total reception failure (PI1 Datafailure)	Prot. Interface	OUT	ON OFF	*		*	LED			BO		93	136	1	Yes
3233	Device table has inconsistent numbers (DT inconsistent)	Prot. Interface	OUT	ON OFF	*		*	LED			BO					
3234	Device tables are unequal (DT unequal)	Prot. Interface	OUT	ON OFF	*		*	LED			BO					
3235	Differences between common parameters (Par. different)	Prot. Interface	OUT	ON OFF	*		*	LED			BO					
3236	Different PI for transmit and receive (PI1<->PI2 error)	Prot. Interface	OUT	ON OFF	*		*	LED			BO					
3239	Prot Int 1: Transmission delay too high (PI1 TD alarm)	Prot. Interface	OUT	ON OFF	*		*	LED			BO		93	139	1	Yes
3243	Prot Int 1: Connected with relay ID (PI1 with)	Prot. Interface	OUT	ON OFF	*		*									
3457	System operates in a closed Ringtopology (Ringtopology)	Prot. Interface	OUT	ON OFF	*		*	LED			BO		93	141	1	Yes
3458	System operates in a open Chaintopology (Chaintopology)	Prot. Interface	OUT	ON OFF	*		*	LED			BO		93	142	1	Yes
3464	Communication topology is complete (Topol complete)	Prot. Interface	OUT	ON OFF	*		*	LED			BO					
3475	Relay 1 in Logout state (Rel1Logout)	Prot. Interface	IntSP	ON OFF	*		*	LED		FC TN	BO		93	143	1	Yes
3476	Relay 2 in Logout state (Rel2Logout)	Prot. Interface	IntSP	ON OFF	*		*	LED		FC TN	BO		93	144	1	Yes
3477	Relay 3 in Logout state (Rel3Logout)	Prot. Interface	IntSP	ON OFF	*		*	LED		FC TN	BO		93	145	1	Yes
3484	Local activation of Logout state (Logout)	Prot. Interface	IntSP	ON OFF	*		*	LED		FC TN	BO		93	149	1	Yes

No.	Description	Function	Type of Informatio n	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
3487	Equal IDs in constellation (Equal IDs)	Prot. Interface	OUT	ON OFF	*		*	LED			BO					
3491	Relay 1 in Login state (Rel1 Login)	Prot. Interface	OUT	ON OFF	*		*	LED			BO		93	191	1	Yes
3492	Relay 2 in Login state (Rel2 Login)	Prot. Interface	OUT	ON OFF	*		*	LED			BO		93	192	1	Yes
3493	Relay 3 in Login state (Rel3 Login)	Prot. Interface	OUT	ON OFF	*		*	LED			BO		93	193	1	Yes
3541	>Remote Trip 1 signal input (>Remote Trip1)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3542	>Remote Trip 2 signal input (>Remote Trip2)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3543	>Remote Trip 3 signal input (>Remote Trip3)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3544	>Remote Trip 4 signal input (>Remote Trip4)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3545	Remote Trip 1 received (RemoteTrip1 rec)	Remote Signals	OUT	on off	*		*	LED			BO		93	154	1	Yes
3546	Remote Trip 2 received (RemoteTrip2 rec)	Remote Signals	OUT	on off	*		*	LED			BO		93	155	1	Yes
3547	Remote Trip 3 received (RemoteTrip3 rec)	Remote Signals	OUT	on off	*		*	LED			BO		93	156	1	Yes
3548	Remote Trip 4 received (RemoteTrip4 rec)	Remote Signals	OUT	on off	*		*	LED			BO		93	157	1	Yes
3549	>Remote Signal 1 input (>Rem. Signal 1)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3550	>Remote Signal 2 input (>Rem.Signal 2)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3551	>Remote Signal 3 input (>Rem.Signal 3)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3552	>Remote Signal 4 input (>Rem.Signal 4)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3553	>Remote Signal 5 input (>Rem.Signal 5)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3554	>Remote Signal 6 input (>Rem.Signal 6)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3555	>Remote Signal 7 input (>Rem.Signal 7)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3556	>Remote Signal 8 input (>Rem.Signal 8)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3557	>Remote Signal 9 input (>Rem.Signal 9)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3558	>Remote Signal 10 input (>Rem.Signal10)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3559	>Remote Signal 11 input (>Rem.Signal11)	Remote Signals	SP	on off	*		*	LED	BI		BO					

No.	Description	Function	Type of Information	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
					Log Buffers				**Configurable in Matrix**				**IEC 60870-5-103**			
3560	>Remote Signal 12 input (>Rem.Signal12)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3561	>Remote Signal 13 input (>Rem.Signal13)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3562	>Remote Signal 14 input (>Rem.Signal14)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3563	>Remote Signal 15 input (>Rem.Signal15)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3564	>Remote Signal 16 input (>Rem.Signal16)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3565	>Remote Signal 17 input (>Rem.Signal17)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3566	>Remote Signal 18 input (>Rem.Signal18)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3567	>Remote Signal 19 input (>Rem.Signal19)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3568	>Remote Signal 20 input (>Rem.Signal20)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3569	>Remote Signal 21 input (>Rem.Signal21)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3570	>Remote Signal 22 input (>Rem.Signal22)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3571	>Remote Signal 23 input (>Rem.Signal23)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3572	>Remote Signal 24 input (>Rem.Signal24)	Remote Signals	SP	on off	*		*	LED	BI		BO					
3573	Remote signal 1 received (Rem.Sig 1recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	158	1	Yes
3574	Remote signal 2 received (Rem.Sig 2recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	159	1	Yes
3575	Remote signal 3 received (Rem.Sig 3recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	160	1	Yes
3576	Remote signal 4 received (Rem.Sig 4recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	161	1	Yes
3577	Remote signal 5 received (Rem.Sig 5recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	162	1	Yes
3578	Remote signal 6 received (Rem.Sig 6recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	163	1	Yes
3579	Remote signal 7 received (Rem.Sig 7recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	164	1	Yes
3580	Remote signal 8 received (Rem.Sig 8recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	165	1	Yes
3581	Remote signal 9 received (Rem.Sig 9recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	166	1	Yes
3582	Remote signal 10 received (Rem.Sig10recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	167	1	Yes

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
3583	Remote signal 11 received (Rem.Sig11recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	168	1	Yes
3584	Remote signal 12 received (Rem.Sig12recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	169	1	Yes
3585	Remote signal 13 received (Rem.Sig13recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	170	1	Yes
3586	Remote signal 14 received (Rem.Sig14recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	171	1	Yes
3587	Remote signal 15 received (Rem.Sig15recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	172	1	Yes
3588	Remote signal 16 received (Rem.Sig16recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	173	1	Yes
3589	Remote signal 17 received (Rem.Sig17recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	174	1	Yes
3590	Remote signal 18 received (Rem.Sig18recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	175	1	Yes
3591	Remote signal 19 received (Rem.Sig19recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	176	1	Yes
3592	Remote signal 20 received (Rem.Sig20recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	177	1	Yes
3593	Remote signal 21 received (Rem.Sig21recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	178	1	Yes
3594	Remote signal 22 received (Rem.Sig22recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	179	1	Yes
3595	Remote signal 23 received (Rem.Sig23recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	180	1	Yes
3596	Remote signal 24 received (Rem.Sig24recv)	Remote Signals	OUT	on off	*		*	LED			BO		93	181	1	Yes
3603	>BLOCK 21 Distance (>BLOCK 21 Dist.)	Dis. General	SP	*	*		*	LED	BI		BO					
3611	>ENABLE Z1B (with setted Time Delay) (>ENABLE Z1B)	Dis. General	SP	ON OFF	*		*	LED	BI		BO		28	11	1	Yes
3613	>ENABLE Z1B instantanous (w/o T-Delay) (>ENABLE Z1Binst)	Dis. General	SP	ON OFF	*		*	LED	BI		BO		28	13	1	Yes
3617	>BLOCK Z4-Trip (>BLOCK Z4-Trip)	Dis. General	SP	ON OFF	*		*	LED	BI		BO		28	17	1	Yes
3618	>BLOCK Z5-Trip (>BLOCK Z5-Trip)	Dis. General	SP	ON OFF	*		*	LED	BI		BO		28	18	1	Yes
3619	>BLOCK Z4 for ph-e loops (>BLOCK Z4 Ph-E)	Dis. General	SP	ON OFF	*		*	LED	BI		BO		28	19	1	Yes
3620	>BLOCK Z5 for ph-e loops (>BLOCK Z5 Ph-E)	Dis. General	SP	ON OFF	*		*	LED	BI		BO		28	20	1	Yes
3651	Distance is switched off (Dist. OFF)	Dis. General	OUT	ON OFF	*		*	LED			BO		28	51	1	Yes
3652	Distance is BLOCKED (Dist. BLOCK)	Dis. General	OUT	ON OFF	ON OFF		*	LED			BO		28	52	1	Yes

No.	Description	Function	Type of In-for-mation	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
3653	Distance is ACTIVE (Dist. ACTIVE)	Dis. General	OUT	*	*		*	LED			BO		28	53	1	Yes
3654	Setting error K0(Z1) or Angle K0(Z1) (Dis.ErrorK0(Z1))	Dis. General	OUT	ON OFF	*		*	LED			BO					
3655	Setting error K0(>Z1) or Angle K0(>Z1) (DisErrorK0(>Z1))	Dis. General	OUT	ON OFF	*		*	LED			BO					
3671	Distance PICKED UP (Dis. PICKUP)	Dis. General	OUT	*	OFF		*	LED			BO		28	71	2	Yes
3672	Distance PICKUP L1 (Dis.Pick-up L1)	Dis. General	OUT	*	*		m	LED			BO		28	72	2	Yes
3673	Distance PICKUP L2 (Dis.Pick-up L2)	Dis. General	OUT	*	*		m	LED			BO		28	73	2	Yes
3674	Distance PICKUP L3 (Dis.Pick-up L3)	Dis. General	OUT	*	*		m	LED			BO		28	74	2	Yes
3675	Distance PICKUP Earth (Dis.Pickup E)	Dis. General	OUT	*	*		m	LED			BO		28	75	2	Yes
3681	Distance Pickup Phase L1 (only) (Dis.Pickup 1pL1)	Dis. General	OUT	*	ON		*	LED			BO		28	81	2	No
3682	Distance Pickup L1E (Dis.Pick-up L1E)	Dis. General	OUT	*	ON		*	LED			BO		28	82	2	No
3683	Distance Pickup Phase L2 (only) (Dis.Pickup 1pL2)	Dis. General	OUT	*	ON		*	LED			BO		28	83	2	No
3684	Distance Pickup L2E (Dis.Pick-up L2E)	Dis. General	OUT	*	ON		*	LED			BO		28	84	2	No
3685	Distance Pickup L12 (Dis.Pickup L12)	Dis. General	OUT	*	ON		*	LED			BO		28	85	2	No
3686	Distance Pickup L12E (Dis.Pick-up L12E)	Dis. General	OUT	*	ON		*	LED			BO		28	86	2	No
3687	Distance Pickup Phase L3 (only) (Dis.Pickup 1pL3)	Dis. General	OUT	*	ON		*	LED			BO		28	87	2	No
3688	Distance Pickup L3E (Dis.Pick-up L3E)	Dis. General	OUT	*	ON		*	LED			BO		28	88	2	No
3689	Distance Pickup L31 (Dis.Pickup L31)	Dis. General	OUT	*	ON		*	LED			BO		28	89	2	No
3690	Distance Pickup L31E (Dis.Pick-up L31E)	Dis. General	OUT	*	ON		*	LED			BO		28	90	2	No
3691	Distance Pickup L23 (Dis.Pickup L23)	Dis. General	OUT	*	ON		*	LED			BO		28	91	2	No
3692	Distance Pickup L23E (Dis.Pick-up L23E)	Dis. General	OUT	*	ON		*	LED			BO		28	92	2	No
3693	Distance Pickup L123 (Dis.Pick-up L123)	Dis. General	OUT	*	ON		*	LED			BO		28	93	2	No
3694	Distance Pickup123E (Dis.Pickup123E)	Dis. General	OUT	*	ON		*	LED			BO		28	94	2	No
3695	Dist.: Phi phase L1 Pickup (Dis Pickup φ L1)	Dis. General	OUT	*	*		m	LED			BO					

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
3696	Dist.: Phi phase L2 Pickup (Dis Pickup φ L2)	Dis. General	OUT	*	*		m	LED			BO					
3697	Dist.: Phi phase L3 Pickup (Dis Pickup φ L3)	Dis. General	OUT	*	*		m	LED			BO					
3701	Distance Loop L1E selected forward (Dis.Loop L1-E f)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3702	Distance Loop L2E selected forward (Dis.Loop L2-E f)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3703	Distance Loop L3E selected forward (Dis.Loop L3-E f)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3704	Distance Loop L12 selected forward (Dis.Loop L1-2 f)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3705	Distance Loop L23 selected forward (Dis.Loop L2-3 f)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3706	Distance Loop L31 selected forward (Dis.Loop L3-1 f)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3707	Distance Loop L1E selected reverse (Dis.Loop L1-E r)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3708	Distance Loop L2E selected reverse (Dis.Loop L2-E r)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3709	Distance Loop L3E selected reverse (Dis.Loop L3-E r)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3710	Distance Loop L12 selected reverse (Dis.Loop L1-2 r)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3711	Distance Loop L23 selected reverse (Dis.Loop L2-3 r)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3712	Distance Loop L31 selected reverse (Dis.Loop L3-1 r)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3713	Distance Loop L1E selected non-direct. (Dis.Loop L1E<->)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3714	Distance Loop L2E selected non-direct. (Dis.Loop L2E<->)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3715	Distance Loop L3E selected non-direct. (Dis.Loop L3E<->)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3716	Distance Loop L12 selected non-direct. (Dis.Loop L12<->)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3717	Distance Loop L23 selected non-direct. (Dis.Loop L23<->)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3718	Distance Loop L31 selected non-direct. (Dis.Loop L31<->)	Dis. General	OUT	*	ON OFF		*	LED			BO					
3719	Distance Pickup FORWARD (Dis. forward)	Dis. General	OUT	*	*		m	LED			BO		128	74	2	No
3720	Distance Pickup REVERSE (Dis. reverse)	Dis. General	OUT	*	*		m	LED			BO		128	75	2	No
3741	Distance Pickup Z1, Loop L1E (Dis. Z1 L1E)	Dis. General	OUT	*	*		*	LED			BO					

No.	Description	Function	Type of Infor-mation	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
						Log Buffers				Configurable in Matrix				IEC 60870-5-103		
3742	Distance Pickup Z1, Loop L2E (Dis. Z1 L2E)	Dis. General	OUT	*	*		*	LED			BO					
3743	Distance Pickup Z1, Loop L3E (Dis. Z1 L3E)	Dis. General	OUT	*	*		*	LED			BO					
3744	Distance Pickup Z1, Loop L12 (Dis. Z1 L12)	Dis. General	OUT	*	*		*	LED			BO					
3745	Distance Pickup Z1, Loop L23 (Dis. Z1 L23)	Dis. General	OUT	*	*		*	LED			BO					
3746	Distance Pickup Z1, Loop L31 (Dis. Z1 L31)	Dis. General	OUT	*	*		*	LED			BO					
3747	Distance Pickup Z1B, Loop L1E (Dis. Z1B L1E)	Dis. General	OUT	*	*		*	LED			BO					
3748	Distance Pickup Z1B, Loop L2E (Dis. Z1B L2E)	Dis. General	OUT	*	*		*	LED			BO					
3749	Distance Pickup Z1B, Loop L3E (Dis. Z1B L3E)	Dis. General	OUT	*	*		*	LED			BO					
3750	Distance Pickup Z1B, Loop L12 (Dis. Z1B L12)	Dis. General	OUT	*	*		*	LED			BO					
3751	Distance Pickup Z1B, Loop L23 (Dis. Z1B L23)	Dis. General	OUT	*	*		*	LED			BO					
3752	Distance Pickup Z1B, Loop L31 (Dis. Z1B L31)	Dis. General	OUT	*	*		*	LED			BO					
3755	Distance Pickup Z2 (Dis. Pickup Z2)	Dis. General	OUT	*	*		*	LED			BO					
3758	Distance Pickup Z3 (Dis. Pickup Z3)	Dis. General	OUT	*	*		*	LED			BO					
3759	Distance Pickup Z4 (Dis. Pickup Z4)	Dis. General	OUT	*	*		*	LED			BO					
3760	Distance Pickup Z5 (Dis. Pickup Z5)	Dis. General	OUT	*	*		*	LED			BO					
3771	DistanceTime Out T1 (Dis.Time Out T1)	Dis. General	OUT	*	*		*	LED			BO		128	78	2	No
3774	DistanceTime Out T2 (Dis.Time Out T2)	Dis. General	OUT	*	*		*	LED			BO		128	79	2	No
3777	DistanceTime Out T3 (Dis.Time Out T3)	Dis. General	OUT	*	*		*	LED			BO		128	80	2	No
3778	DistanceTime Out T4 (Dis.Time Out T4)	Dis. General	OUT	*	*		*	LED			BO		128	81	2	No
3779	DistanceTime Out T5 (Dis.Time Out T5)	Dis. General	OUT	*	*		*	LED			BO		128	82	2	No
3780	DistanceTime Out T1B (Dis.Tim-eOut T1B)	Dis. General	OUT	*	*		*	LED			BO		28	180	2	No
3781	DistanceTime Out Forward PICKUP (Dis.TimeOut Tfw)	Dis. General	OUT	*	*		*	LED			BO		28	160	2	No
3782	DistanceTime Out Non-direction-al PICKUP (Dis.TimeOut Tnd)	Dis. General	OUT	*	*		*	LED			BO		28	161	2	No

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103		
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
3801	Distance protection: General trip (Dis.Gen. Trip)	Dis. General	OUT	*	*		*	LED			BO		28	201	2	No
3802	Distance TRIP command - Only Phase L1 (Dis.Trip 1pL1)	Dis. General	OUT	*	ON		*	LED			BO		28	202	2	No
3803	Distance TRIP command - Only Phase L2 (Dis.Trip 1pL2)	Dis. General	OUT	*	ON		*	LED			BO		28	203	2	No
3804	Distance TRIP command - Only Phase L3 (Dis.Trip 1pL3)	Dis. General	OUT	*	ON		*	LED			BO		28	204	2	No
3805	Distance TRIP command Phases L123 (Dis.Trip 3p)	Dis. General	OUT	*	ON		*	LED			BO		28	205	2	No
3811	Distance TRIP single-phase Z1 (Dis.TripZ1/1p)	Dis. General	OUT	*	*		*	LED			BO		28	211	2	No
3813	Distance TRIP single-phase Z1B (Dis.TripZ1B1p)	Dis. General	OUT	*	*		*	LED			BO		28	213	2	No
3816	Distance TRIP single-phase Z2 (Dis.TripZ2/1p)	Dis. General	OUT	*	*		*	LED			BO		28	216	2	No
3817	Distance TRIP 3phase in Z2 (Dis.TripZ2/3p)	Dis. General	OUT	*	*		*	LED			BO		28	217	2	No
3818	Distance TRIP 3phase in Z3 (Dis.TripZ3/T3)	Dis. General	OUT	*	*		*	LED			BO		28	218	2	No
3819	Dist.: Trip by fault detection, forward (Dis.Trip FD->)	Dis. General	OUT	*	*		*	LED			BO		28	219	2	No
3820	Dist.: Trip by fault detec, rev/non-dir. (Dis.Trip <->)	Dis. General	OUT	*	*		*	LED			BO		28	220	2	No
3821	Distance TRIP 3phase in Z4 (Dis.TRIP 3p. Z4)	Dis. General	OUT	*	*		*	LED			BO		28	209	2	No
3822	Distance TRIP 3phase in Z5 (Dis.TRIP 3p. Z5)	Dis. General	OUT	*	*		*	LED			BO		28	210	2	No
3823	DisTRIP 3phase in Z1 with single-ph Flt. (DisTRIP3p. Z1sf)	Dis. General	OUT	*	*		*	LED			BO		28	224	2	No
3824	DisTRIP 3phase in Z1 with multi-ph Flt. (DisTRIP3p. Z1mf)	Dis. General	OUT	*	*		*	LED			BO		28	225	2	No
3825	DisTRIP 3phase in Z1B with single-ph Flt (DisTRIP3p.Z1Bsf)	Dis. General	OUT	*	*		*	LED			BO		28	244	2	No
3826	DisTRIP 3phase in Z1B with multi-ph Flt. (DisTRIP3p Z1Bmf)	Dis. General	OUT	*	*		*	LED			BO		28	245	2	No
3850	DisTRIP Z1B with Teleprotection scheme (DisTRIP Z1B Tel)	Dis. General	OUT	*	*		*	LED			BO		28	251	2	No
4001	>Distance Teleprotection ON (>Dis.Telep. ON)	Teleprot. Dist.	SP	*	*		*	LED	BI		BO					
4002	>Distance Teleprotection OFF (>Dis.Telep.OFF)	Teleprot. Dist.	SP	*	*		*	LED	BI		BO					
4003	>Distance Teleprotection BLOCK (>Dis.Telep. Blk)	Teleprot. Dist.	SP	ON OFF	ON OFF		*	LED	BI		BO		29	3	1	Yes
4005	>Dist. teleprotection: Carrier faulty (>Dis.RecFail)	Teleprot. Dist.	SP	on off	*		*	LED	BI		BO					

| No. | Description | Function | Type of Infor- mation | Log Buffers | | | | Configurable in Matrix | | | | | IEC 60870-5-103 | | | |
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
4006	>Dis.Tele. Carrier RECEPTION Channel 1 (>DisTel Rec.Ch1)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	6	1	Yes
4007	>Dis.Tele.Carrier RECEPTION Channel 1,L1 (>Dis.T.RecCh1L1)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	7	1	Yes
4008	>Dis.Tele.Carrier RECEPTION Channel 1,L2 (>Dis.T.RecCh1L2)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	8	1	Yes
4009	>Dis.Tele.Carrier RECEPTION Channel 1,L3 (>Dis.T.RecCh1L3)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	9	1	Yes
4010	>Dis.Tele. Carrier RECEPTION Channel 2 (>Dis.T.Rec.Ch2)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	10	1	Yes
4030	>Dis.Tele. Unblocking: UNBLOCK Channel 1 (>Dis.T.UB ub 1)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	30	1	Yes
4031	>Dis.Tele. Unblocking: BLOCK Channel 1 (>Dis.T.UB bl 1)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	31	1	Yes
4032	>Dis.Tele. Unblocking: UNBLOCK Ch. 1, L1 (>Dis.T.UB ub1L1)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	32	1	Yes
4033	>Dis.Tele. Unblocking: UNBLOCK Ch. 1, L2 (>Dis.T.UB ub1L2)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	33	1	Yes
4034	>Dis.Tele. Unblocking: UNBLOCK Ch. 1, L3 (>Dis.T.UB ub1L3)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	34	1	Yes
4035	>Dis.Tele. Unblocking: UNBLOCK Channel 2 (>Dis.T.UB ub 2)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	35	1	Yes
4036	>Dis.Tele. Unblocking: BLOCK Channel 2 (>Dis.T.UB bl 2)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	36	1	Yes
4040	>Dis.Tele. BLOCK Echo Signal (>Dis.T.BlkEcho)	Teleprot. Dist.	SP	on off	on		*	LED	BI		BO		29	40	1	Yes
4050	Dis. Teleprotection ON/OFF via BI (Dis.T.on/off BI)	Teleprot. Dist.	IntSP	ON OFF	*		*	LED			BO					
4051	Teleprotection is switched ON (Telep. ON)	Device	IntSP	*	*		*	LED			BO		128	17	1	Yes
4052	Dis. Teleprotection is switched OFF (Dis.Telep. OFF)	Teleprot. Dist.	OUT	ON OFF	*		*	LED			BO					
4054	Dis. Telep. Carrier signal re- ceived (Dis.T.Carr.rec.)	Teleprot. Dist.	OUT	*	*		*	LED			BO		128	77	2	No
4055	Dis. Telep. Carrier CHANNEL FAILURE (Dis.T.Carr.Fail)	Teleprot. Dist.	OUT	*	*		*	LED			BO		128	39	1	Yes
4056	Dis. Telep. Carrier SEND signal (Dis.T.SEND)	Teleprot. Dist.	OUT	on	on		*	LED			BO		128	76	2	No
4057	Dis. Telep. Carrier SEND signal, L1 (Dis.T.SEND L1)	Teleprot. Dist.	OUT	*	*		*	LED			BO					
4058	Dis. Telep. Carrier SEND signal, L2 (Dis.T.SEND L2)	Teleprot. Dist.	OUT	*	*		*	LED			BO					

| No. | Description | Function | Type of Informatio n | Log Buffers | | | | Configurable in Matrix | | | | | IEC 60870-5-103 | | | |
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
4059	Dis. Telep. Carrier SEND signal, L3 (Dis.T.SEND L3)	Teleprot. Dist.	OUT	*	*		*	LED			BO					
4060	Dis.Tele.Blocking: Send signal with jump (DisJumpBlocking)	Teleprot. Dist.	OUT	*	*		*	LED			BO		29	60	2	No
4068	Dis. Telep. Transient Blocking (Dis.T.Trans.Blk)	Teleprot. Dist.	OUT	*	ON		*	LED			BO		29	68	2	No
4070	Dis. Tele.Blocking: carrier STOP signal (Dis.T.BL STOP)	Teleprot. Dist.	OUT	*	ON		*	LED			BO		29	70	2	No
4080	Dis. Tele.Unblocking: FAILURE Channel 1 (Dis.T.UB Fail1)	Teleprot. Dist.	OUT	on off	*		*	LED			BO		29	80	1	Yes
4081	Dis. Tele.Unblocking: FAILURE Channel 2 (Dis.T.UB Fail2)	Teleprot. Dist.	OUT	on off	*		*	LED			BO		29	81	1	Yes
4082	DisTel Blocking: carrier STOP signal, L1 (Dis.T.BL STOPL1)	Teleprot. Dist.	OUT	*	*		*	LED			BO					
4083	DisTel Blocking: carrier STOP signal, L2 (Dis.T.BL STOPL2)	Teleprot. Dist.	OUT	*	*		*	LED			BO					
4084	DisTel Blocking: carrier STOP signal, L3 (Dis.T.BL STOPL3)	Teleprot. Dist.	OUT	*	*		*	LED			BO					
4085	Dis.Tele.Carrier RECEPTION, L1, Device1 (Dis.T.RecL1Dev1)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4086	Dis.Tele.Carrier RECEPTION, L2, Device1 (Dis.T.RecL2Dev1)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4087	Dis.Tele.Carrier RECEPTION, L3, Device1 (Dis.T.RecL3Dev1)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4088	Dis.Tele.Carrier RECEPTION, L1, Device2 (Dis.T.RecL1Dev2)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4089	Dis.Tele.Carrier RECEPTION, L2, Device2 (Dis.T.RecL2Dev2)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4090	Dis.Tele.Carrier RECEPTION, L3, Device2 (Dis.T.RecL3Dev2)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4091	Dis.Tele.Carrier RECEPTION, L1, Device3 (Dis.T.RecL1Dev3)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4092	Dis.Tele.Carrier RECEPTION, L2, Device3 (Dis.T.RecL2Dev3)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4093	Dis.Tele.Carrier RECEPTION, L3, Device3 (Dis.T.RecL3Dev3)	Teleprot. Dist.	OUT	on off	on		*	LED			BO					
4160	>BLOCK Power Swing detection (>Pow. Swing BLK)	Power Swing	SP	ON OFF	ON OFF		*	LED	BI		BO					
4163	Power Swing unstable (P.Swing unstab.)	Power Swing	OUT	ON	ON		*	LED			BO					
4164	Power Swing detected (Power Swing)	Power Swing	OUT	ON OFF	ON OFF		*	LED			BO		29	164	1	Yes
4166	Power Swing TRIP command (Pow. Swing TRIP)	Power Swing	OUT	ON	ON		*	LED			BO		29	166	1	No
4167	Power Swing detected in L1 (Pow. Swing L1)	Power Swing	OUT	ON OFF	ON OFF		*	LED			BO					

No.	Description	Function	Type of Information	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
4168	Power Swing detected in L2 (Pow. Swing L2)	Power Swing	OUT	ON OFF	ON OFF		*	LED			BO					
4169	Power Swing detected in L3 (Pow. Swing L3)	Power Swing	OUT	ON OFF	ON OFF		*	LED			BO					
4203	>BLOCK Weak Infeed (>BLOCK Weak Inf)	Weak Infeed	SP	*	*		*	LED	BI		BO					
4204	>BLOCK delayed Weak Infeed stage (>BLOCK del. WI)	Weak Infeed	SP	ON OFF	ON OFF		*	LED	BI		BO					
4205	>Reception (channel) for Weak Infeed OK (>WI rec. OK)	Weak Infeed	SP	ON OFF	ON OFF		*	LED	BI		BO					
4206	>Receive signal for Weak Infeed (>WI reception)	Weak Infeed	SP	ON OFF	ON OFF		*	LED	BI		BO					
4221	Weak Infeed is switched OFF (WeakInf. OFF)	Weak Infeed	OUT	ON OFF	*		*	LED			BO		25	21	1	Yes
4222	Weak Infeed is BLOCKED (Weak Inf. BLOCK)	Weak Infeed	OUT	ON OFF	ON OFF		*	LED			BO		25	22	1	Yes
4223	Weak Infeed is ACTIVE (Weak Inf ACTIVE)	Weak Infeed	OUT	*	*		*	LED			BO		25	23	1	Yes
4225	Weak Infeed Zero seq. current detected (3I0 detected)	Weak Infeed	OUT	ON OFF	ON OFF		*	LED			BO					
4226	Weak Infeed Undervoltg. L1 (WI U L1<)	Weak Infeed	OUT	ON OFF	ON OFF		*	LED			BO					
4227	Weak Infeed Undervoltg. L2 (WI U L2<)	Weak Infeed	OUT	ON OFF	ON OFF		*	LED			BO					
4228	Weak Infeed Undervoltg. L3 (WI U L3<)	Weak Infeed	OUT	ON OFF	ON OFF		*	LED			BO					
4229	WI TRIP with zero sequence current (WI AUS 3I0)	Weak Infeed	OUT	*	*		*	LED			BO					
4231	Weak Infeed PICKED UP (Weak-Inf. PICKUP)	Weak Infeed	OUT	*	OFF		*	LED			BO		25	31	2	Yes
4232	Weak Infeed PICKUP L1 (W/I Pickup L1)	Weak Infeed	OUT	*	ON		*	LED			BO					
4233	Weak Infeed PICKUP L2 (W/I Pickup L2)	Weak Infeed	OUT	*	ON		*	LED			BO					
4234	Weak Infeed PICKUP L3 (W/I Pickup L3)	Weak Infeed	OUT	*	ON		*	LED			BO					
4241	Weak Infeed General TRIP command (WeakInfeed TRIP)	Weak Infeed	OUT	*	*		*	LED			BO		25	41	2	No
4242	Weak Infeed TRIP command - Only L1 (Weak TRIP 1p.L1)	Weak Infeed	OUT	*	ON		*	LED			BO		25	42	2	No
4243	Weak Infeed TRIP command - Only L2 (Weak TRIP 1p.L2)	Weak Infeed	OUT	*	ON		*	LED			BO		25	43	2	No
4244	Weak Infeed TRIP command - Only L3 (Weak TRIP 1p.L3)	Weak Infeed	OUT	*	ON		*	LED			BO		25	44	2	No
4245	Weak Infeed TRIP command L123 (Weak TRIP L123)	Weak Infeed	OUT	*	ON		*	LED			BO		25	45	2	No

No.	Description	Function	Type of In- for- matio n	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
4246	ECHO Send SIGNAL (ECHO SIGNAL)	Weak Infeed	OUT	ON	ON		*	LED			BO		25	46	2	Yes
4247	ECHO Tele.Carrier RECEPTION, Device1 (ECHO Rec. Dev1)	Echo Rec. ov.PI	OUT	ON OFF	ON		*	LED			BO					
4248	ECHO Tele.Carrier RECEPTION, Device2 (ECHO Rec. Dev2)	Echo Rec. ov.PI	OUT	ON OFF	ON		*	LED			BO					
4249	ECHO Tele.Carrier RECEPTION, Device3 (ECHO Rec. Dev3)	Echo Rec. ov.PI	OUT	ON OFF	ON		*	LED			BO					
4253	>BLOCK Instantaneous SOTF Overcurrent (>BLOCK SOTF-O/C)	SOTF Overcurr.	SP	*	*		*	LED	BI		BO					
4271	SOTF-O/C is switched OFF (SOTF-O/C OFF)	SOTF Overcurr.	OUT	ON OFF	*		*	LED			BO		25	71	1	Yes
4272	SOTF-O/C is BLOCKED (SOTF-O/C BLOCK)	SOTF Overcurr.	OUT	ON OFF	ON OFF		*	LED			BO		25	72	1	Yes
4273	SOTF-O/C is ACTIVE (SOTF-O/C ACTIVE)	SOTF Overcurr.	OUT	*	*		*	LED			BO		25	73	1	Yes
4281	SOTF-O/C PICKED UP (SOTF-O/C PICKUP)	SOTF Overcurr.	OUT	*	OFF		*	LED			BO		25	81	2	Yes
4282	SOTF-O/C Pickup L1 (SOF O/CpickupL1)	SOTF Overcurr.	OUT	*	ON		*	LED			BO		25	82	2	Yes
4283	SOTF-O/C Pickup L2 (SOF O/CpickupL2)	SOTF Overcurr.	OUT	*	ON		*	LED			BO		25	83	2	Yes
4284	SOTF-O/C Pickup L3 (SOF O/CpickupL3)	SOTF Overcurr.	OUT	*	ON		*	LED			BO		25	84	2	Yes
4295	SOTF-O/C TRIP command L123 (SOF O/CtripL123)	SOTF Overcurr.	OUT	*	ON		*	LED			BO		25	95	2	No
4403	>BLOCK Direct Transfer Trip function (>BLOCK DTT)	DTT Direct Trip	SP	*	*		*	LED	BI		BO					
4412	>Direct Transfer Trip INPUT Phase L1 (>DTT Trip L1)	DTT Direct Trip	SP	ON OFF	*		*	LED	BI		BO					
4413	>Direct Transfer Trip INPUT Phase L2 (>DTT Trip L2)	DTT Direct Trip	SP	ON OFF	*		*	LED	BI		BO					
4414	>Direct Transfer Trip INPUT Phase L3 (>DTT Trip L3)	DTT Direct Trip	SP	ON OFF	*		*	LED	BI		BO					
4417	>Direct Transfer Trip INPUT 3ph L123 (>DTT Trip L123)	DTT Direct Trip	SP	ON OFF	*		*	LED	BI		BO					
4421	Direct Transfer Trip is switched OFF (DTT OFF)	DTT Direct Trip	OUT	ON OFF	*		*	LED			BO		51	21	1	Yes
4422	Direct Transfer Trip is BLOCKED (DTT BLOCK)	DTT Direct Trip	OUT	ON OFF	ON OFF		*	LED			BO		51	22	1	Yes
4432	DTT TRIP command - Only L1 (DTT TRIP 1p. L1)	DTT Direct Trip	OUT	*	ON		*	LED			BO		51	32	2	No
4433	DTT TRIP command - Only L2 (DTT TRIP 1p. L2)	DTT Direct Trip	OUT	*	ON		*	LED			BO		51	33	2	No
4434	DTT TRIP command - Only L3 (DTT TRIP 1p. L3)	DTT Direct Trip	OUT	*	ON		*	LED			BO		51	34	2	No

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
4435	DTT TRIP command L123 (DTT TRIP L123)	DTT Direct Trip	OUT	*	ON		*	LED			BO		51	35	2	No
5203	>BLOCK frequency protection (>BLOCK Freq.)	Frequency Prot.	SP	ON OFF	*		*	LED	BI		BO		70	176	1	Yes
5206	>BLOCK frequency protection stage f1 (>BLOCK f1)	Frequency Prot.	SP	ON OFF	*		*	LED	BI		BO		70	177	1	Yes
5207	>BLOCK frequency protection stage f2 (>BLOCK f2)	Frequency Prot.	SP	ON OFF	*		*	LED	BI		BO		70	178	1	Yes
5208	>BLOCK frequency protection stage f3 (>BLOCK f3)	Frequency Prot.	SP	ON OFF	*		*	LED	BI		BO		70	179	1	Yes
5209	>BLOCK frequency protection stage f4 (>BLOCK f4)	Frequency Prot.	SP	ON OFF	*		*	LED	BI		BO		70	180	1	Yes
5211	Frequency protection is switched OFF (Freq. OFF)	Frequency Prot.	OUT	ON OFF	*		*	LED			BO		70	181	1	Yes
5212	Frequency protection is BLOCKED (Freq. BLOCKED)	Frequency Prot.	OUT	ON OFF	ON OFF		*	LED			BO		70	182	1	Yes
5213	Frequency protection is ACTIVE (Freq. ACTIVE)	Frequency Prot.	OUT	ON OFF	*		*	LED			BO		70	183	1	Yes
5232	Frequency protection: f1 picked up (f1 picked up)	Frequency Prot.	OUT	*	ON OFF		*	LED			BO		70	230	2	Yes
5233	Frequency protection: f2 picked up (f2 picked up)	Frequency Prot.	OUT	*	ON OFF		*	LED			BO		70	231	2	Yes
5234	Frequency protection: f3 picked up (f3 picked up)	Frequency Prot.	OUT	*	ON OFF		*	LED			BO		70	232	2	Yes
5235	Frequency protection: f4 picked up (f4 picked up)	Frequency Prot.	OUT	*	ON OFF		*	LED			BO		70	233	2	Yes
5236	Frequency protection: f1 TRIP (f1 TRIP)	Frequency Prot.	OUT	*	ON		*	LED			BO		70	234	2	Yes
5237	Frequency protection: f2 TRIP (f2 TRIP)	Frequency Prot.	OUT	*	ON		*	LED			BO		70	235	2	Yes
5238	Frequency protection: f3 TRIP (f3 TRIP)	Frequency Prot.	OUT	*	ON		*	LED			BO		70	236	2	Yes
5239	Frequency protection: f4 TRIP (f4 TRIP)	Frequency Prot.	OUT	*	ON		*	LED			BO		70	237	2	Yes
5240	Frequency protection: TimeOut Stage f1 (Time Out f1)	Frequency Prot.	OUT	*	*		*	LED			BO					
5241	Frequency protection: TimeOut Stage f2 (Time Out f2)	Frequency Prot.	OUT	*	*		*	LED			BO					
5242	Frequency protection: TimeOut Stage f3 (Time Out f3)	Frequency Prot.	OUT	*	*		*	LED			BO					
5243	Frequency protection: TimeOut Stage f4 (Time Out f4)	Frequency Prot.	OUT	*	*		*	LED			BO					
6854	>Trip circuit superv. 1: Trip Relay (>TripC1 TripRel)	TripCirc.Superv	SP	ON OFF	*		*	LED	BI		BO					
6855	>Trip circuit superv. 1: Breaker Relay (>TripC1 Bkr.Rel)	TripCirc.Superv	SP	ON OFF	*		*	LED	BI		BO					

| No. | Description | Function | Type of Information | Log Buffers | | | | Configurable in Matrix | | | | | IEC 60870-5-103 | | | |
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
6856	>Trip circuit superv. 2: Trip Relay (>TripC2 TripRel)	TripCirc.Superv	SP	ON OFF	*		*	LED	BI		BO					
6857	>Trip circuit superv. 2: Breaker Relay (>TripC2 Bkr.Rel)	TripCirc.Superv	SP	ON OFF	*		*	LED	BI		BO					
6858	>Trip circuit superv. 3: Trip Relay (>TripC3 TripRel)	TripCirc.Superv	SP	ON OFF	*		*	LED	BI		BO					
6859	>Trip circuit superv. 3: Breaker Relay (>TripC3 Bkr.Rel)	TripCirc.Superv	SP	ON OFF	*		*	LED	BI		BO					
6861	Trip circuit supervision OFF (TripC OFF)	TripCirc.Superv	OUT	ON OFF	*		*	LED			BO					
6865	Failure Trip Circuit (FAIL: Trip cir.)	TripCirc.Superv	OUT	ON OFF	*		*	LED			BO		128	36	1	Yes
6866	TripC1 blocked: Binary input is not set (TripC1 ProgFAIL)	TripCirc.Superv	OUT	ON OFF	*		*	LED			BO					
6867	TripC2 blocked: Binary input is not set (TripC2 ProgFAIL)	TripCirc.Superv	OUT	ON OFF	*		*	LED			BO					
6868	TripC3 blocked: Binary input is not set (TripC3 ProgFAIL)	TripCirc.Superv	OUT	ON OFF	*		*	LED			BO					
7104	>BLOCK Backup OverCurrent I>> (>BLOCK O/C I>>)	Back-Up O/C	SP	ON OFF	*		*	LED	BI		BO		64	4	1	Yes
7105	>BLOCK Backup OverCurrent I> (>BLOCK O/C I>)	Back-Up O/C	SP	ON OFF	*		*	LED	BI		BO		64	5	1	Yes
7106	>BLOCK Backup OverCurrent Ip (>BLOCK O/C Ip)	Back-Up O/C	SP	ON OFF	*		*	LED	BI		BO		64	6	1	Yes
7110	>Backup OverCurrent Instanta-neousTrip (>O/C InstTRIP)	Back-Up O/C	SP	ON OFF	ON OFF		*	LED	BI		BO		64	10	1	Yes
7130	>BLOCK I-STUB (>BLOCK I-STUB)	Back-Up O/C	SP	ON OFF	*		*	LED	BI		BO		64	30	1	Yes
7131	>Enable I-STUB-Bus function (>I-STUB ENABLE)	Back-Up O/C	SP	ON OFF	ON OFF		*	LED	BI		BO		64	31	1	Yes
7151	Backup O/C is switched OFF (O/C OFF)	Back-Up O/C	OUT	ON OFF	*		*	LED			BO		64	51	1	Yes
7152	Backup O/C is BLOCKED (O/C BLOCK)	Back-Up O/C	OUT	ON OFF	ON OFF		*	LED			BO		64	52	1	Yes
7153	Backup O/C is ACTIVE (O/C ACTIVE)	Back-Up O/C	OUT	*	*		*	LED			BO		64	53	1	Yes
7161	Backup O/C PICKED UP (O/C PICKUP)	Back-Up O/C	OUT	*	OFF		m	LED			BO		64	61	2	Yes
7162	Backup O/C PICKUP L1 (O/C Pickup L1)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	62	2	Yes
7163	Backup O/C PICKUP L2 (O/C Pickup L2)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	63	2	Yes
7164	Backup O/C PICKUP L3 (O/C Pickup L3)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	64	2	Yes
7165	Backup O/C PICKUP EARTH (O/C Pickup E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	65	2	Yes

No.	Description	Function	Type of Infor-mation	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
7171	Backup O/C Pickup - Only EARTH (O/C PU only E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	71	2	No
7172	Backup O/C Pickup - Only L1 (O/C PU 1p. L1)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	72	2	No
7173	Backup O/C Pickup L1E (O/C Pickup L1E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	73	2	No
7174	Backup O/C Pickup - Only L2 (O/C PU 1p. L2)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	74	2	No
7175	Backup O/C Pickup L2E (O/C Pickup L2E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	75	2	No
7176	Backup O/C Pickup L12 (O/C Pickup L12)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	76	2	No
7177	Backup O/C Pickup L12E (O/C Pickup L12E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	77	2	No
7178	Backup O/C Pickup - Only L3 (O/C PU 1p. L3)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	78	2	No
7179	Backup O/C Pickup L3E (O/C Pickup L3E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	79	2	No
7180	Backup O/C Pickup L31 (O/C Pickup L31)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	80	2	No
7181	Backup O/C Pickup L31E (O/C Pickup L31E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	81	2	No
7182	Backup O/C Pickup L23 (O/C Pickup L23)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	82	2	No
7183	Backup O/C Pickup L23E (O/C Pickup L23E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	83	2	No
7184	Backup O/C Pickup L123 (O/C Pickup L123)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	84	2	No
7185	Backup O/C Pickup L123E (O/C PickupL123E)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	85	2	No
7191	Backup O/C Pickup I>> (O/C PICKUP I>>)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	91	2	Yes
7192	Backup O/C Pickup I> (O/C PICKUP I>)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	92	2	Yes
7193	Backup O/C Pickup Ip (O/C PICKUP Ip)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	93	2	Yes
7201	O/C I-STUB Pickup (I-STUB PICKUP)	Back-Up O/C	OUT	*	ON OFF		*	LED			BO		64	101	2	Yes
7211	Backup O/C General TRIP command (O/C TRIP)	Back-Up O/C	OUT	*	*		*	LED			BO		128	72	2	No
7212	Backup O/C TRIP - Only L1 (O/C TRIP 1p.L1)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	112	2	No
7213	Backup O/C TRIP - Only L2 (O/C TRIP 1p.L2)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	113	2	No
7214	Backup O/C TRIP - Only L3 (O/C TRIP 1p.L3)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	114	2	No

| No. | Description | Function | Type of Infor- matio n | Log Buffers | | | | Configurable in Matrix | | | | | IEC 60870-5-103 | | | |
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
7215	Backup O/C TRIP Phases L123 (O/C TRIP L123)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	115	2	No
7221	Backup O/C TRIP I>> (O/C TRIP I>>)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	121	2	No
7222	Backup O/C TRIP I> (O/C TRIP I>)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	122	2	No
7223	Backup O/C TRIP Ip (O/C TRIP Ip)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	123	2	No
7235	O/C I-STUB TRIP (I-STUB TRIP)	Back-Up O/C	OUT	*	ON		*	LED			BO		64	135	2	No
7325	CB1-TEST TRIP command - Only L1 (CB1-TESTtrip L1)	Testing	OUT	ON OFF	*		*	LED			BO		153	25	2	Yes
7326	CB1-TEST TRIP command - Only L2 (CB1-TESTtrip L2)	Testing	OUT	ON OFF	*		*	LED			BO		153	26	2	Yes
7327	CB1-TEST TRIP command - Only L3 (CB1-TESTtrip L3)	Testing	OUT	ON OFF	*		*	LED			BO		153	27	2	Yes
7328	CB1-TEST TRIP command L123 (CB1-TESTtrip123)	Testing	OUT	ON OFF	*		*	LED			BO		153	28	2	Yes
7329	CB1-TEST CLOSE command (CB1-TEST close)	Testing	OUT	ON OFF	*		*	LED			BO		153	29	2	Yes
7345	CB-TEST is in progress (CB-TEST running)	Testing	OUT	ON OFF	*		*	LED			BO		153	45	2	Yes
7346	CB-TEST canceled due to Power Sys. Fault (CB-TSTstop FLT.)	Testing	OUT_ Ev	ON	*											
7347	CB-TEST canceled due to CB already OPEN (CB-TSTstop OPEN)	Testing	OUT_ Ev	ON	*											
7348	CB-TEST canceled due to CB was NOT READY (CB-TSTstop NOTr)	Testing	OUT_ Ev	ON	*											
7349	CB-TEST canceled due to CB stayed CLOSED (CB-TSTstop CLOS)	Testing	OUT_ Ev	ON	*											
7350	CB-TEST was succesful (CB-TST .OK.)	Testing	OUT_ Ev	ON	*											
10201	>BLOCK Uph-e>(>) Overvolt. (phase-earth) (>Uph-e>(>) BLK)	Voltage Prot.	SP	*	*		*	LED	BI		BO					
10202	>BLOCK Uph-ph>(>) Overvolt (phase-phase) (>Uph-ph>(>) BLK)	Voltage Prot.	SP	*	*		*	LED	BI		BO					
10203	>BLOCK 3U0>(>) Overvolt. (zero sequence) (>3U0>(>) BLK)	Voltage Prot.	SP	*	*		*	LED	BI		BO					
10204	>BLOCK U1>(>) Overvolt. (posi- tive seq.) (>U1>(>) BLK)	Voltage Prot.	SP	*	*		*	LED	BI		BO					
10205	>BLOCK U2>(>) Overvolt. (neg- ative seq.) (>U2>(>) BLK)	Voltage Prot.	SP	*	*		*	LED	BI		BO					
10206	>BLOCK Uph-e<(<) Undervolt (phase-earth) (>Uph-e<(<) BLK)	Voltage Prot.	SP	*	*		*	LED	BI		BO					

No.	Description	Function	Type of Informatio n	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
10207	>BLOCK Uphph<(<) Undervolt (phase-phase) (>Uphph<(<) BLK)	Voltage Prot.	SP	*	*		*	LED	BI		BO					
10208	>BLOCK U1<(<) Undervolt (posi­tive seq.) (>U1<(<) BLK)	Voltage Prot.	SP	*	*		*	LED	BI		BO					
10215	Uph-e>(>) Overvolt. is switched OFF (Uph-e>(>) OFF)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	15	1	Yes
10216	Uph-e>(>) Overvolt. is BLOCKED (Uph-e>(>) BLK)	Voltage Prot.	OUT	ON OFF	ON OFF		*	LED			BO		73	16	1	Yes
10217	Uph-ph>(>) Overvolt. is switched OFF (Uph-ph>(>) OFF)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	17	1	Yes
10218	Uph-ph>(>) Overvolt. is BLOCKED (Uph-ph>(>) BLK)	Voltage Prot.	OUT	ON OFF	ON OFF		*	LED			BO		73	18	1	Yes
10219	3U0>(>) Overvolt. is switched OFF (3U0>(>) OFF)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	19	1	Yes
10220	3U0>(>) Overvolt. is BLOCKED (3U0>(>) BLK)	Voltage Prot.	OUT	ON OFF	ON OFF		*	LED			BO		73	20	1	Yes
10221	U1>(>) Overvolt. is switched OFF (U1>(>) OFF)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	21	1	Yes
10222	U1>(>) Overvolt. is BLOCKED (U1>(>) BLK)	Voltage Prot.	OUT	ON OFF	ON OFF		*	LED			BO		73	22	1	Yes
10223	U2>(>) Overvolt. is switched OFF (U2>(>) OFF)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	23	1	Yes
10224	U2>(>) Overvolt. is BLOCKED (U2>(>) BLK)	Voltage Prot.	OUT	ON OFF	ON OFF		*	LED			BO		73	24	1	Yes
10225	Uph-e<(<) Undervolt. is switched OFF (Uph-e<(<) OFF)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	25	1	Yes
10226	Uph-e<(<) Undervolt. is BLOCKED (Uph-e<(<) BLK)	Voltage Prot.	OUT	ON OFF	ON OFF		*	LED			BO		73	26	1	Yes
10227	Uph-ph<(<) Undervolt. is switched OFF (Uph-ph<(<) OFF)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	27	1	Yes
10228	Uphph<(<) Undervolt. is BLOCKED (Uph-ph<(<) BLK)	Voltage Prot.	OUT	ON OFF	ON OFF		*	LED			BO		73	28	1	Yes
10229	U1<(<) Undervolt. is switched OFF (U1<(<) OFF)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	29	1	Yes
10230	U1<(<) Undervolt. is BLOCKED (U1<(<) BLK)	Voltage Prot.	OUT	ON OFF	ON OFF		*	LED			BO		73	30	1	Yes
10231	Over-/Under-Voltage protection is ACTIVE (U</> ACTIVE)	Voltage Prot.	OUT	ON OFF	*		*	LED			BO		73	31	1	Yes
10240	Uph-e> Pickup (Uph-e> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	40	2	Yes
10241	Uph-e>> Pickup (Uph-e>> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	41	2	Yes
10242	Uph-e>(>) Pickup L1 (Uph-e>(>) PU L1)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	42	2	Yes
10243	Uph-e>(>) Pickup L2 (Uph-e>(>) PU L2)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	43	2	Yes

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
10244	Uph-e>(>) Pickup L3 (Uph-e>(>) PU L3)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	44	2	Yes
10245	Uph-e> TimeOut (Uph-e> Time-Out)	Voltage Prot.	OUT	*	*		*	LED			BO					
10246	Uph-e>> TimeOut (Uph-e>> TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10247	Uph-e>(>) TRIP command (Uph-e>(>) TRIP)	Voltage Prot.	OUT	*	ON		*	LED			BO		73	47	2	Yes
10255	Uph-ph> Pickup (Uphph> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	55	2	Yes
10256	Uph-ph>> Pickup (Uphph>> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	56	2	Yes
10257	Uph-ph>(>) Pickup L1-L2 (Uph-ph>(>)PU L12)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	57	2	Yes
10258	Uph-ph>(>) Pickup L2-L3 (Uph-ph>(>)PU L23)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	58	2	Yes
10259	Uph-ph>(>) Pickup L3-L1 (Uph-ph>(>)PU L31)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	59	2	Yes
10260	Uph-ph> TimeOut (Uphph> TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10261	Uph-ph>> TimeOut (Uphph>> TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10262	Uph-ph>(>) TRIP command (Uphph>(>) TRIP)	Voltage Prot.	OUT	*	ON		*	LED			BO		73	62	2	Yes
10270	3U0> Pickup (3U0> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	70	2	Yes
10271	3U0>> Pickup (3U0>> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	71	2	Yes
10272	3U0> TimeOut (3U0> TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10273	3U0>> TimeOut (3U0>> Time-Out)	Voltage Prot.	OUT	*	*		*	LED			BO					
10274	3U0>(>) TRIP command (3U0>(>) TRIP)	Voltage Prot.	OUT	*	ON		*	LED			BO		73	74	2	Yes
10280	U1> Pickup (U1> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	80	2	Yes
10281	U1>> Pickup (U1>> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	81	2	Yes
10282	U1> TimeOut (U1> TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10283	U1>> TimeOut (U1>> TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10284	U1>(>) TRIP command (U1>(>) TRIP)	Voltage Prot.	OUT	*	ON		*	LED			BO		73	84	2	Yes
10290	U2> Pickup (U2> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	90	2	Yes
10291	U2>> Pickup (U2>> Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	91	2	Yes

No.	Description	Function	Type of Information	Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
				Log Buffers				Configurable in Matrix					IEC 60870-5-103			
10292	U2> TimeOut (U2> TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10293	U2>> TimeOut (U2>> TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10294	U2>(>) TRIP command (U2>(>) TRIP)	Voltage Prot.	OUT	*	ON		*	LED			BO		73	94	2	Yes
10300	U1< Pickup (U1< Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	100	2	Yes
10301	U1<< Pickup (U1<< Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	101	2	Yes
10302	U1< TimeOut (U1< TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10303	U1<< TimeOut (U1<< TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10304	U1<(<) TRIP command (U1<(<) TRIP)	Voltage Prot.	OUT	*	ON		*	LED			BO		73	104	2	Yes
10310	Uph-e< Pickup (Uph-e< Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	110	2	Yes
10311	Uph-e<< Pickup (Uph-e<< Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	111	2	Yes
10312	Uph-e<(<) Pickup L1 (Uph-e<(<) PU L1)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	112	2	Yes
10313	Uph-e<(<) Pickup L2 (Uph-e<(<) PU L2)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	113	2	Yes
10314	Uph-e<(<) Pickup L3 (Uph-e<(<) PU L3)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	114	2	Yes
10315	Uph-e< TimeOut (Uph-e< TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10316	Uph-e<< TimeOut (Uph-e<< TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10317	Uph-e<(<) TRIP command (Uph-e<(<) TRIP)	Voltage Prot.	OUT	*	ON		*	LED			BO		73	117	2	Yes
10325	Uph-ph< Pickup (Uph-ph< Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	125	2	Yes
10326	Uph-ph<< Pickup (Uph-ph<< Pickup)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	126	2	Yes
10327	Uphph<(<) Pickup L1-L2 (Uph-ph<(<)PU L12)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	127	2	Yes
10328	Uphph<(<) Pickup L2-L3 (Uph-ph<(<)PU L23)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	128	2	Yes
10329	Uphph<(<) Pickup L3-L1 (Uph-ph<(<)PU L31)	Voltage Prot.	OUT	*	ON OFF		*	LED			BO		73	129	2	Yes
10330	Uphph< TimeOut (Uphph< TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					
10331	Uphph<< TimeOut (Uphph<< TimeOut)	Voltage Prot.	OUT	*	*		*	LED			BO					

No.	Description	Function	Type of Information	Log Buffers				Configurable in Matrix					IEC 60870-5-103			
				Event Log ON/OFF	Trip (Fault) Log ON/OFF	Ground Fault Log ON/OFF	Marked in Oscill. Record	LED	Binary Inputs	Function Key	Relay	Chatter suppression	Type	Information Number	Data Unit	General Interrogation
10332	Uphph<(<) TRIP command (Uphph<(<) TRIP)	Voltage Prot.	OUT	*	ON		*	LED			BO		73	132	2	Yes
11000	>RESET Analog Outputs (>RES Analog Out)	AnalogOutputs	SP	*			*	LED	BI		BO					

A.9　Group Alarms

No.	Description	No.	Description
140	Error Sum Alarm	144 181 192 194	Error 5V Error A/D-conv. Error1A/5Awrong Error neutralCT
160	Alarm Sum Event	162 163 165 167 168 169 170 171 177 183 184 185 186 187 188 189 190 193 361	Failure Σ I Fail I balance Fail Σ U Ph-E Fail U balance Fail U absent VT FuseFail>10s VT FuseFail Fail Ph. Seq. Fail Battery Error Board 1 Error Board 2 Error Board 3 Error Board 4 Error Board 5 Error Board 6 Error Board 7 Error Board 0 Alarm NO calibr >FAIL:Feeder VT
161	Fail I Superv.	162 163	Failure Σ I Fail I balance
164	Fail U Superv.	165 167 168	Fail Σ U Ph-E Fail U balance Fail U absent

A.10 Measured Values

No.	Description	Function	IEC 60870-5-103					Configurable in Matrix		
			Type	Information Number	Compatibility	Data Unit	Position	CFC	Control Display	Default Display
-	Control DIGSI (CntrlDIGSI)	Cntrl Authority	-	-	-	-	-	CFC	CD	DD
-	Upper setting limit for IL1dmd (IL1dmd>)	Set Points(MV)	-	-	-	-	-	CFC	CD	DD
-	Upper setting limit for IL2dmd (IL2dmd>)	Set Points(MV)	-	-	-	-	-	CFC	CD	DD
-	Upper setting limit for IL3dmd (IL3dmd>)	Set Points(MV)	-	-	-	-	-	CFC	CD	DD
-	Upper setting limit for I1dmd (I1dmd>)	Set Points(MV)	-	-	-	-	-	CFC	CD	DD
-	Upper setting limit for Pdmd (|Pdmd|>)	Set Points(MV)	-	-	-	-	-	CFC	CD	DD
-	Upper setting limit for Qdmd (|Qdmd|>)	Set Points(MV)	-	-	-	-	-	CFC	CD	DD
-	Upper setting limit for Sdmd (Sdmd>)	Set Points(MV)	-	-	-	-	-	CFC	CD	DD
-	Lower setting limit for Power Factor (PF<)	Set Points(MV)	-	-	-	-	-	CFC	CD	DD
601	I L1 (IL1 =)	Measurement	128	148	Yes	9	1	CFC	CD	DD
			134	124	No	9	1			
602	I L2 (IL2 =)	Measurement	128	148	Yes	9	2	CFC	CD	DD
			134	124	No	9	2			
603	I L3 (IL3 =)	Measurement	128	148	Yes	9	3	CFC	CD	DD
			134	124	No	9	3			
610	3I0 (zero sequence) (3I0 =)	Measurement	134	124	No	9	14	CFC	CD	DD
611	3I0sen (sensitive zero sequence) (3I0sen=)	Measurement	-	-	-	-	-	CFC	CD	DD
612	IY (star point of transformer) (IY =)	Measurement	-	-	-	-	-	CFC	CD	DD
613	3I0par (parallel line neutral) (3I0par=)	Measurement	-	-	-	-	-	CFC	CD	DD
619	I1 (positive sequence) (I1 =)	Measurement	-	-	-	-	-	CFC	CD	DD
620	I2 (negative sequence) (I2 =)	Measurement	-	-	-	-	-	CFC	CD	DD
621	U L1-E (UL1E=)	Measurement	128	148	Yes	9	4	CFC	CD	DD
			134	124	No	9	4			
622	U L2-E (UL2E=)	Measurement	128	148	Yes	9	5	CFC	CD	DD
			134	124	No	9	5			
623	U L3-E (UL3E=)	Measurement	128	148	Yes	9	6	CFC	CD	DD
			134	124	No	9	6			
624	U L12 (UL12=)	Measurement	134	124	No	9	10	CFC	CD	DD
625	U L23 (UL23=)	Measurement	134	124	No	9	11	CFC	CD	DD
626	U L31 (UL31=)	Measurement	134	124	No	9	12	CFC	CD	DD
627	Uen (Uen =)	Measurement	-	-	-	-	-	CFC	CD	DD
631	3U0 (zero sequence) (3U0 =)	Measurement	-	-	-	-	-	CFC	CD	DD
632	Usync (synchronism) (Usync =)	Measurement	-	-	-	-	-	CFC	CD	DD
633	Ux (separate VT) (Ux =)	Measurement	-	-	-	-	-	CFC	CD	DD
634	U1 (positive sequence) (U1 =)	Measurement	-	-	-	-	-	CFC	CD	DD
635	U2 (negative sequence) (U2 =)	Measurement	-	-	-	-	-	CFC	CD	DD
636	U-diff (line-bus) (Udiff =)	Measurement	130	1	No	9	2	CFC	CD	DD
637	U-line (Uline =)	Measurement	130	1	No	9	3	CFC	CD	DD
638	U-bus (Ubus =)	Measurement	130	1	No	9	1	CFC	CD	DD
641	P (active power) (P =)	Measurement	128	148	Yes	9	7	CFC	CD	DD
			134	124	No	9	7			
642	Q (reactive power) (Q =)	Measurement	128	148	Yes	9	8	CFC	CD	DD
			134	124	No	9	8			

No.	Description	Function	IEC 60870-5-103					Configurable in Matrix		
			Type	Information Number	Compatibility	Data Unit	Position	CFC	Control Display	Default Display
643	Power Factor (PF =)	Measurement	134	124	No	9	13	CFC	CD	DD
644	Frequency (Freq=)	Measurement	128	148	Yes	9	9	CFC	CD	DD
			134	124	No	9	9			
645	S (apparent power) (S =)	Measurement	-	-	-	-	-	CFC	CD	DD
646	Frequency (busbar) (F-bus =)	Measurement	130	1	No	9	4	CFC	CD	DD
647	Frequency (difference line-bus) (F-diff=)	Measurement	130	1	No	9	5	CFC	CD	DD
648	Angle (difference line-bus) (φ-diff=)	Measurement	130	1	No	9	6	CFC	CD	DD
649	Frequency (line) (F-line=)	Measurement	130	1	No	9	7	CFC	CD	DD
679	U1co (positive sequence, compounding) (U1co=)	Measurement	-	-	-	-	-	CFC	CD	DD
684	U0 (zero sequence) (U0 =)	Measurement	-	-	-	-	-	CFC	CD	DD
701	Active 3I0sen (sensitive Ie) (3I0senA)	Measurement	134	124	No	9	15	CFC	CD	DD
702	Reactive 3I0sen (sensitive Ie) (3I0senR)	Measurement	134	124	No	9	16	CFC	CD	DD
801	Temperat. rise for warning and trip (Θ/Θtrip =)	Measurement	-	-	-	-	-	CFC	CD	DD
802	Temperature rise for phase L1 (Θ/ΘtripL1=)	Measurement	-	-	-	-	-	CFC	CD	DD
803	Temperature rise for phase L2 (Θ/ΘtripL2=)	Measurement	-	-	-	-	-	CFC	CD	DD
804	Temperature rise for phase L3 (Θ/ΘtripL3=)	Measurement	-	-	-	-	-	CFC	CD	DD
833	I1 (positive sequence) Demand (I1dmd =)	Demand meter	-	-	-	-	-	CFC	CD	DD
834	Active Power Demand (Pdmd =)	Demand meter	-	-	-	-	-	CFC	CD	DD
835	Reactive Power Demand (Qdmd =)	Demand meter	-	-	-	-	-	CFC	CD	DD
836	Apparent Power Demand (Sdmd =)	Demand meter	-	-	-	-	-	CFC	CD	DD
837	I L1 Demand Minimum (IL1d Min)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
838	I L1 Demand Maximum (IL1d Max)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
839	I L2 Demand Minimum (IL2d Min)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
840	I L2 Demand Maximum (IL2d Max)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
841	I L3 Demand Minimum (IL3d Min)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
842	I L3 Demand Maximum (IL3d Max)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
843	I1 (positive sequence) Demand Minimum (I1dmdMin)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
844	I1 (positive sequence) Demand Maximum (I1dmdMax)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
845	Active Power Demand Minimum (PdMin=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
846	Active Power Demand Maximum (PdMax=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
847	Reactive Power Demand Minimum (QdMin=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
848	Reactive Power Demand Maximum (Qd-Max=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
849	Apparent Power Demand Minimum (SdMin=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
850	Apparent Power Demand Maximum (Sd-Max=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
851	I L1 Minimum (IL1Min=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
852	I L1 Maximum (IL1Max=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
853	I L2 Mimimum (IL2Min=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
854	I L2 Maximum (IL2Max=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
855	I L3 Minimum (IL3Min=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
856	I L3 Maximum (IL3Max=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
857	Positive Sequence Minimum (I1 Min=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
858	Positive Sequence Maximum (I1 Max=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
859	U L1E Minimum (UL1EMin=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
860	U L1E Maximum (UL1EMax=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
861	U L2E Minimum (UL2EMin=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD

No.	Description	Function	IEC 60870-5-103					Configurable in Matrix		
			Type	Information Number	Compatibility	Data Unit	Position	CFC	Control Display	Default Display
862	U L2E Maximum (UL2EMax=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
863	U L3E Minimum (UL3EMin=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
864	U L3E Maximum (UL3EMax=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
865	U L12 Minimum (UL12Min=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
867	U L12 Maximum (UL12Max=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
868	U L23 Minimum (UL23Min=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
869	U L23 Maximum (UL23Max=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
870	U L31 Minimum (UL31Min=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
871	U L31 Maximum (UL31Min=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
874	U1 (positive sequence) Voltage Minimum (U1 Min =)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
875	U1 (positive sequence) Voltage Maximum (U1 Max =)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
880	Apparent Power Minimum (SMin=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
881	Apparent Power Maximum (SMax=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
882	Frequency Minimum (fMin=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
883	Frequency Maximum (fMax=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
888	Pulsed Energy Wp (active) (Wp(puls))	Energy	133	55	No	205	-		CD	DD
888	Pulsed Energy Wp (active) (Wp(puls))	Energy	-	-	-	-	-		CD	DD
889	Pulsed Energy Wq (reactive) (Wq(puls))	Energy	133	56	No	205	-		CD	DD
889	Pulsed Energy Wq (reactive) (Wq(puls))	Energy	-	-	-	-	-		CD	DD
924	Wp Forward (Wp+=)	Energy	133	51	No	205	-		CD	DD
924	Wp Forward (Wp+=)	Energy	-	-	-	-	-		CD	DD
925	Wq Forward (Wq+=)	Energy	133	52	No	205	-		CD	DD
925	Wq Forward (Wq+=)	Energy	-	-	-	-	-		CD	DD
928	Wp Reverse (Wp-=)	Energy	133	53	No	205	-		CD	DD
928	Wp Reverse (Wp-=)	Energy	-	-	-	-	-		CD	DD
929	Wq Reverse (Wq-=)	Energy	133	54	No	205	-		CD	DD
929	Wq Reverse (Wq-=)	Energy	-	-	-	-	-		CD	DD
963	I L1 demand (IL1dmd=)	Demand meter	-	-	-	-	-	CFC	CD	DD
964	I L2 demand (IL2dmd=)	Demand meter	-	-	-	-	-	CFC	CD	DD
965	I L3 demand (IL3dmd=)	Demand meter	-	-	-	-	-	CFC	CD	DD
966	R L1E (R L1E=)	Measurement	-	-	-	-	-	CFC	CD	DD
967	R L2E (R L2E=)	Measurement	-	-	-	-	-	CFC	CD	DD
970	R L3E (R L3E=)	Measurement	-	-	-	-	-	CFC	CD	DD
971	R L12 (R L12=)	Measurement	-	-	-	-	-	CFC	CD	DD
972	R L23 (R L23=)	Measurement	-	-	-	-	-	CFC	CD	DD
973	R L31 (R L31=)	Measurement	-	-	-	-	-	CFC	CD	DD
974	X L1E (X L1E=)	Measurement	-	-	-	-	-	CFC	CD	DD
975	X L2E (X L2E=)	Measurement	-	-	-	-	-	CFC	CD	DD
976	X L3E (X L3E=)	Measurement	-	-	-	-	-	CFC	CD	DD
977	X L12 (X L12=)	Measurement	-	-	-	-	-	CFC	CD	DD
978	X L23 (X L23=)	Measurement	-	-	-	-	-	CFC	CD	DD
979	X L31 (X L31=)	Measurement	-	-	-	-	-	CFC	CD	DD
1040	Active Power Minimum Forward (Pmin Forw=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1041	Active Power Maximum Forward (Pmax Forw=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1042	Active Power Minimum Reverse (Pmin Rev =)	Min/Max meter	-	-	-	-	-	CFC	CD	DD

No.	Description	Function	IEC 60870-5-103					Configurable in Matrix		
			Type	Information Number	Compatibility	Data Unit	Position	CFC	Control Display	Default Display
1043	Active Power Maximum Reverse (Pmax Rev =)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1044	Reactive Power Minimum Forward (Qmin Forw=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1045	Reactive Power Maximum Forward (Qmax Forw=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1046	Reactive Power Minimum Reverse (Qmin Rev =)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1047	Reactive Power Maximum Reverse (Qmax Rev =)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1048	Power Factor Minimum Forward (PFmin-Forw=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1049	Power Factor Maximum Forward (PFmax-Forw=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1050	Power Factor Minimum Reverse (PFmin Rev=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1051	Power Factor Maximum Reverse (PFmax Rev=)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
1052	Active Power Demand Forward (Pdmd Forw=)	Demand meter	-	-	-	-	-	CFC	CD	DD
1053	Active Power Demand Reverse (Pdmd Rev =)	Demand meter	-	-	-	-	-	CFC	CD	DD
1054	Reactive Power Demand Forward (Qdmd Forw=)	Demand meter	-	-	-	-	-	CFC	CD	DD
1055	Reactive Power Demand Reverse (Qdmd Rev =)	Demand meter	-	-	-	-	-	CFC	CD	DD
7751	Prot Int 1:Transmission delay (PI1 TD)	Statistics	-	-	-	-	-	CFC	CD	DD
7753	Prot Int 1: Availability per min. (PI1A/m)	Statistics	-	-	-	-	-	CFC	CD	DD
7754	Prot Int 1: Availability per hour (PI1A/h)	Statistics	-	-	-	-	-	CFC	CD	DD
7757	Prot Int 1: DTOG (Device Time Offset) (PI1 DTOG)	Statistics	-	-	-	-	-	CFC	CD	DD
7761	Relay ID of 1. relay (Relay ID)	Measure relay1	-	-	-	-	-	CFC	CD	DD
7781	Relay ID of 2. relay (Relay ID)	Measure relay2	-	-	-	-	-	CFC	CD	DD
7801	Relay ID of 3. relay (Relay ID)	Measure relay3	-	-	-	-	-	CFC	CD	DD
10102	Min. Zero Sequence Voltage 3U0 (3U0min =)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
10103	Max. Zero Sequence Voltage 3U0 (3U0max =)	Min/Max meter	-	-	-	-	-	CFC	CD	DD
14000	IL1 (primary) (IL1 =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14001	Angle IL1 (φIL1 =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14002	IL2 (primary) (IL2 =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14003	Angle IL2 (φIL2 =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14004	IL3 (primary) (IL3 =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14005	Angle IL3 (φIL3 =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14010	UL1E (primary) (UL1E =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14011	Angle UL1E (φUL1E =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14012	UL2E (primary) (UL2E =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14013	Angle UL2E (φUL2E =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14014	UL3E (primary) (UL3E =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14015	Angle UL3E (φUL3E =)	Measure relay1	-	-	-	-	-	CFC	CD	DD
14020	IL1 (primary) (IL1 =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14021	Angle IL1 (φIL1 =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14022	IL2 (primary) (IL2 =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14023	Angle IL2 (φIL2 =)	Measure relay2	-	-	-	-	-	CFC	CD	DD

No.	Description	Function	IEC 60870-5-103					Configurable in Matrix		
			Type	Information Number	Compatibility	Data Unit	Position	CFC	Control Display	Default Display
14024	IL3 (primary) (IL3 =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14025	Angle IL3 (φIL3 =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14030	UL1E (primary) (UL1E =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14031	Angle UL1E (φUL1E =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14032	UL2E (primary) (UL2E =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14033	Angle UL2E (φUL2E =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14034	UL3E (primary) (UL3E =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14035	Angle UL3E (φUL3E =)	Measure relay2	-	-	-	-	-	CFC	CD	DD
14040	IL1 (primary) (IL1 =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14041	Angle IL1 (φIL1 =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14042	IL2 (primary) (IL2 =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14043	Angle IL2 (φIL2 =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14044	IL3 (primary) (IL3 =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14045	Angle IL3 (φIL3 =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14050	UL1E (primary) (UL1E =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14051	Angle UL1E (φUL1E =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14052	UL2E (primary) (UL2E =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14053	Angle UL2E (φUL2E =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14054	UL3E (primary) (UL3E =)	Measure relay3	-	-	-	-	-	CFC	CD	DD
14055	Angle UL3E (φUL3E =)	Measure relay3	-	-	-	-	-	CFC	CD	DD

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Literature

/1/   SIPROTEC 4 System Description; E50417-H1176-C151-A2

/2/   SIPROTEC DIGSI, Start UP; E50417-G1176-C152-A2

/3/   DIGSI CFC, Manual; E50417-H1176-C098-A4

/4/   SIPROTEC SIGRA 4, Manual; E50417-H1176-C070-A2

Glossary

Battery The buffer battery ensures that specified data areas, flags, timers and counters are retained retentively.

Bay controllers Bay controllers are devices with control and monitoring functions without protective functions.

Bit pattern indication Bit pattern indication is a processing function by means of which items of digital process information applying across several inputs can be detected together in parallel and processed further. The bit pattern length can be specified as 1, 2, 3 or 4 bytes.

BP_xx → Bit pattern indication (Bitstring Of x Bit), x designates the length in bits (8, 16, 24 or 32 bits).

C_xx Command without feedback

CF_xx Command with feedback

CFC Continuous Function Chart. CFC is a graphics editor with which a program can be created and configured by using ready-made blocks.

CFC blocks Blocks are parts of the user program delimited by their function, their structure or their purpose.

Chatter blocking A rapidly intermittent input (for example, due to a relay contact fault) is switched off after a configurable monitoring time and can thus not generate any further signal changes. The function prevents overloading of the system when a fault arises.

Combination devices Combination devices are bay devices with protection functions and a control display.

Combination matrix Up to 16 compatible SIPROTEC 4 devices can communicate with one another in an Inter Relay Communication combination (IRC combination). Which device exchanges which information is defined with the help of the combination matrix.

Communication branch A communications branch corresponds to the configuration of 1 to n users which communicate by means of a common bus.

Communication reference CR The communication reference describes the type and version of a station in communication by PROFIBUS.

Component view	In addition to a topological view, SIMATIC Manager offers you a component view. The component view does not offer any overview of the hierarchy of a project. It does, however, provide an overview of all the SIPROTEC 4 devices within a project.
COMTRADE	Common Format for Transient Data Exchange, format for fault records.
Container	If an object can contain other objects, it is called a container. The object Folder is an example of such a container.
Control display	The display which is displayed on devices with a large (graphic) display after you have pressed the control key is called the control display. It contains the switchgear that can be controlled in the feeder with status display. It is used to perform switching operations. Defining this diagram is part of the configuration.
Data pane	→ The right-hand area of the project window displays the contents of the area selected in the → navigation window, for example indications, measured values, etc. of the information lists or the function selection for the device configuration.
DCF77	The extremely precise official time is determined in Germany by the "Physikalisch-Technischen-Bundesanstalt PTB" in Braunschweig. The atomic clock unit of the PTB transmits this time via the long-wave time-signal transmitter in Mainflingen near Frankfurt/Main. The emitted time signal can be received within a radius of approx. 1,500 km from Frankfurt/Main.
Device container	In the Component View, all SIPROTEC 4 devices are assigned to an object of type Device container. This object is a special object of DIGSI Manager. However, since there is no component view in DIGSI Manager, this object only becomes visible in conjunction with STEP 7.
Double command	Double commands are process outputs which indicate 4 process states at 2 outputs: 2 defined (for example ON/OFF) and 2 undefined states (for example intermediate positions)
Double-point indication	Double-point indications are items of process information which indicate 4 process states at 2 inputs: 2 defined (for example ON/OFF) and 2 undefined states (for example intermediate positions).
DP	→ Double-point indication
DP_I	→ Double point indication, intermediate position 00
Drag-and-drop	Copying, moving and linking function, used at graphics user interfaces. Objects are selected with the mouse, held and moved from one data area to another.
Earth	The conductive earth whose electric potential can be set equal to zero at every point. In the area of ground electrodes the earth can have a potential deviating from zero. The term "Ground reference plane" is often used for this state.

Earthing	Earthing means that a conductive part is to connect via an earthing system to the → earth.
Earthing	Earthing is the total of all means and measured used for earthing.
Electromagnetic compatibility	Electromagnetic compatibility (EMC) is the ability of an electrical apparatus to function fault-free in a specified environment without influencing the environment unduly.
EMC	→ Electromagnetic compatibility
ESD protection	ESD protection is the total of all the means and measures used to protect electrostatic sensitive devices.
ExBPxx	External bit pattern indication via an ETHERNET connection, device-specific → Bit pattern indication
ExC	External command without feedback via an ETHERNET connection, device-specific
ExCF	External command with feedback via an ETHERNET connection, device-specific
ExDP	External double point indication via an ETHERNET connection, device-specific → Double-point indication
ExDP_I	External double point indication via an ETHERNET connection, intermediate position 00, device-specific → Double-point indication
ExMV	External metered value via an ETHERNET connection, device-specific
ExSI	External single point indication via an ETHERNET connection, device-specific → Single point indication
ExSI_F	External single point indication via an ETHERNET connection, device-specific → Transient information, → Single point indication
Field devices	Generic term for all devices assigned to the field level: Protection devices, combination devices, bay controllers.
Floating	→ Without electrical connection to the → Earth.
FMS communication branch	Within an FMS communication branch the users communicate on the basis of the PROFIBUS FMS protocol via a PROFIBUS FMS network.
Folder	This object type is used to create the hierarchical structure of a project.
General interrogation (GI)	During the system start-up the state of all the process inputs, of the status and of the fault image is sampled. This information is used to update the system-end process

image. The current process state can also be sampled after a data loss by means of a GI.

GPS   Global Positioning System. Satellites with atomic clocks on board orbit the earth twice a day in different parts in approx. 20,000 km. They transmit signals which also contain the GPS universal time. The GPS receiver determines its own position from the signals received. From its position it can derive the running time of a satellite and thus correct the transmitted GPS universal time.

Hierarchy level   Within a structure with higher-level and lower-level objects a hierarchy level is a container of equivalent objects.

HV field description   The HV project description file contains details of fields which exist in a ModPara-project. The actual field information of each field is memorized in a HV field description file. Within the HV project description file, each field is allocated such a HV field description file by a reference to the file name.

HV project description   All the data is exported once the configuration and parameterisation of PCUs and sub-modules using ModPara has been completed. This data is split up into several files. One file contains details about the fundamental project structure. This also includes, for example, information detailing which fields exist in this project. This file is called a HV project description file.

ID   Internal double point indication → Double-point indication

ID_S   Internal double point indication intermediate position 00, → Double-point indication

IEC   International Electrotechnical Commission

IEC address   Within an IEC bus a unique IEC address has to be assigned to each SIPROTEC 4 device. A total of 254 IEC addresses are available for each IEC bus.

IEC communication branch   Within an IEC communication branch the users communicate on the basis of the IEC60-870-5-103 protocol via an IEC bus.

Initialization string   An initialization string comprises a range of modem-specific commands. These are transmitted to the modem within the framework of modem initialization. The commands can, for example, force specific settings for the modem.

Inter relay communication   → IRC combination

IRC combination   Inter Relay Communication, IRC, is used for directly exchanging process information between SIPROTEC 4 devices. You require an object of type IRC combination to configure an Inter Relay Communication. Each user of the combination and all the necessary communication parameters are defined in this object. The type and scope of the information exchanged among the users is also stored in this object.

IRIG-B   Time signal code of the Inter-Range Instrumentation Group

IS	Internal single point indication → Single point indication
IS_F	Single-point indication fleeting → Transient information, → Single point indication
ISO 9001	The ISO 9000 ff range of standards defines measures used to ensure the quality of a product from the development stage to the manufacturing stage.
Link address	The link address gives the address of a V3/V2 device.
List view	The right pane of the project window displays the names and icons of objects which represent the contents of a container selected in the tree view. Because they are displayed in the form of a list, this area is called the list view.
LV	Limit value
LVU	Limit value, user-defined
Master	Masters may send data to other users and request data from other users. DIGSI operates as a master.
Metered value	Metered values are a processing function with which the total number of discrete similar events (counting pulses) is determined for a period, usually as an integrated value. In power supply companies the electrical work is usually recorded as a metered value (energy purchase/supply, energy transportation).
MLFB Number	MLFB is the abbreviation for "MaschinenLesbare FabrikateBezeichnung" (machine-readable product designation). This is the equivalent of an order number. The type and version of a SIPROTEC 4 device are coded in the order number.
Modem connection	This object type contains information on both partners of a modem connection, the local modem and the remote modem.
Modem profile	A modem profile consists of the name of the profile, a modem driver and may also comprise several initialization commands and a user address. You can create several modem profiles for one physical modem. To do so you need to link various initialization commands or user addresses to a modem driver and its properties and save them under different names.
Modems	Modem profiles for a modem connection are saved in this object type.
MV	Measured value
MVMV	Metered value which is formed from the measured value
MVT	Measured value with time
MVU	Measured value, user-defined

Navigation pane   The left pane of the project window displays the names and symbols of all containers of a project in the form of a folder tree.

Object   Each element of a project structure is called an object in DIGSI.

Object properties   Each object has properties. These might be general properties that are common to several objects. An object can also have specific properties.

Off-line   In Off-line mode a link with the SIPROTEC 4 device is not necessary. You work with data which are stored in files.

OI_F   Output indication fleeting → Transient information

On-line   When working in On-line mode, there is a physical link to a SIPROTEC 4 device which can be implemented in various ways. This link can be implemented as a direct connection, as a modem connection or as a PROFIBUS FMS connection.

OUT   Output indication

Parameter set   The parameter set is the set of all parameters that can be set for a SIPROTEC 4 device.

Phone book   User addresses for a modem connection are saved in this object type.

PMV   Pulse metered value

Process bus   Devices with a process bus interface allow direct communication with SICAM HV modules. The process bus interface is equipped with an Ethernet module.

PROFIBUS   PROcess FIeld BUS, the German process and field bus standard, as specified in the standard EN 50170, Volume 2, PROFIBUS. It defines the functional, electrical, and mechanical properties for a bit-serial field bus.

PROFIBUS address   Within a PROFIBUS network a unique PROFIBUS address has to be assigned to each SIPROTEC 4 device. A total of 254 PROFIBUS addresses are available for each PROFIBUS network.

Project   Content-wise, a project is the image of a real power supply system. Graphically, a project is represented by a number of objects which are integrated in a hierarchical structure. Physically, a project consists of a series of folders and files containing project data.

Protection devices   All devices with a protective function and no control display.

Reorganizing   Frequent addition and deletion of objects gives rise to memory areas that can no longer be used. By cleaning up projects, you can release these memory areas again. However, a clean up also reassigns the VD addresses. The consequence of that is that all SIPROTEC 4 devices have to be reinitialised.

RIO file	Relay data Interchange format by Omicron.
RSxxx-interface	Serial interfaces RS232, RS422/485
SCADA Interface	Rear serial interface on the devices for connecting to a control system via IEC or PROFIBUS.
Service port	Rear serial interface on the devices for connecting DIGSI (for example, via modem).
Setting parameters	General term for all adjustments made to the device. Parameterization jobs are executed by means of DIGSI or, in some cases, directly on the device.
SI	→ Single point indication
SI_F	→ Single-point indication fleeting → Transient information, → Single point indication
SICAM SAS	Modularly structured station control system, based on the substation controller → SICAM SC and the SICAM WinCC operator control and monitoring system.
SICAM SC	Substation Controller. Modularly structured substation control system, based on the SIMATIC M7 automation system.
SICAM WinCC	The SICAM WinCC operator control and monitoring system displays the state of your network graphically, visualizes alarms, interrupts and indications, archives the network data, offers the possibility of intervening manually in the process and manages the system rights of the individual employee.
Single command	Single commands are process outputs which indicate 2 process states (for example, ON/OFF) at one output.
Single point indication	Single indications are items of process information which indicate 2 process states (for example, ON/OFF) at one output.
SIPROTEC	The registered trademark SIPROTEC is used for devices implemented on system base V4.
SIPROTEC 4 device	This object type represents a real SIPROTEC 4 device with all the setting values and process data it contains.
SIPROTEC 4 variant	This object type represents a variant of an object of type SIPROTEC 4 device. The device data of this variant may well differ from the device data of the source object. However, all variants derived from the source object have the same VD address as the source object. For this reason they always correspond to the same real SIPROTEC 4 device as the source object. Objects of type SIPROTEC 4 variant have a variety of uses, such as documenting different operating states when entering parameter settings of a SIPROTEC 4 device.

Slave	A slave may only exchange data with a master after being prompted to do so by the master. SIPROTEC 4 devices operate as slaves.
Time stamp	Time stamp is the assignment of the real time to a process event.
Topological view	DIGSI Manager always displays a project in the topological view. This shows the hierarchical structure of a project with all available objects.
Transformer Tap Indication	Transformer tap indication is a processing function on the DI by means of which the tap of the transformer tap changer can be detected together in parallel and processed further.
Transient information	A transient information is a brief transient → single-point indication at which only the coming of the process signal is detected and processed immediately.
Tree view	The left pane of the project window displays the names and symbols of all containers of a project in the form of a folder tree. This area is called the tree view.
TxTap	→ Transformer Tap Indication
User address	A user address comprises the name of the station, the national code, the area code and the user-specific phone number.
Users	Up to 16 compatible SIPROTEC 4 devices can communicate with one another in an Inter Relay Communication combination. The individual participating devices are called users.
VD	A VD (Virtual Device) includes all communication objects and their properties and states that are used by a communication user through services. A VD can be a physical device, a module of a device or a software module.
VD address	The VD address is assigned automatically by DIGSI Manager. It exists only once in the entire project and thus serves to identify unambiguously a real SIPROTEC 4 device. The VD address assigned by DIGSI Manager must be transferred to the SIPROTEC 4 device in order to allow communication with DIGSI Device Editor.
VFD	A VFD (Virtual Field Device) includes all communication objects and their properties and states that are used by a communication user through services.

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