REL 512
Line Distance Protection Terminal

Instruction Book

1MRW512029-MEN (IB 40.512)

ABB Automation Inc.

Instruction Booklet
REL512

March 2000 (IB 40-512)

This Instruction Book is applicable to the REL512 Versions 2.0 and 1.58 and all previous versions.

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Introduction

Congratulations! You are about to embark upon a new adventure; testing and evaluating the many new operating characteristics and features of the REL 512 and the supporting software. The relay was developed based on customer focused input into the original marketing requirements specification. We have captured your needs and have implemented most of them into the REL 512. Technology has evolved and we have evolved with it building a state-of-the-art platform designed for technical longevity. The REL 512 will provide you the base platform to meet new protection and automated control requirements for years to come.

Highlights

The highlights of the REL 512 are:

Less than one cycle trip time.

Extremely reliable operating elements that allow zone-1 settings to 95% of the line.

Comprehensive DFR capabilities and fault analysis program.

Programmable logic.

Easy to learn and use communication interface.

Modbus Plus, DNP 3.0 network communications for Substation Automation.

Comprehensive support software and documentation.

This Manual

This manual addresses the product application, specifications, platform overview and catalog information. It also provides basic instructions for installation, operation. It is expected that you have experience operating computer operated test sets and testing microprocessor based relays.

Section 1 provides a product overview to familiarize the reader with the basic product application, relay features, and functional specifications. Information to select the proper relay catalog (style) number is also provided.

Section 2 provides information to accept, install and maintain the REL512. This includes dimensional drawings, I/O terminations and typical scheme drawings to assist in system design.

Section 3 covers the REL512 operations. This includes communicating with the relay through its front panel UI and computer (ASCII/RS232) interface to setup the relay for operation. The appropriate communication cables are also defined.

Section 4 provides complete settings and application information.

Section 5 discusses the measrung units and operational logic. The operational characteristics of each measuring unit...impedance, overcurrent, undervoltage, etc., are discussed. Complete relay logic is also provided.

Section 6 provides procedures and information for testing the relay.

Section 7 provides instructions for using REL512's support software.

Section 8 provides complete instructions for the optional reclosing function of the relay.

Section 9 provides instruction on upgrading the relay's firmware.

Section 10 provides additional product support information that includes Application Notes relevant to the REL 512.

REL 512 Revision History

There are four boards (hardware modules) that are independently programmed and are periodically provided with new firmware version releases. These boards are:

- Main Board that provides the protection functions,
- Reclosing Board that provides reclosing and voltage supervision for reclosing,
- DNP 3.0 Network Interface Board that provides an interface to SCADA or substation automation utilizing the DNP 3.0 protocol, and
- Modbus Plus Network Interface Board that provides an interface to SCADA or substation automation utilizing the Modbus Plus protocol.

RELTools support software is also periodically upgraded to meet the requirements of new firmware releases. Correct coordination of the different firmware and support software is essential to assure proper operation of the REL 512 and RELTools. The following table defines the firmware and software version requirements for different Main Board firmware version releases.

Compatible Firmware and Software Releases

Main Board CPU	Version 1 Reclosing Board 1618C07G01	Version 2 Reclosing Board 1919C38G01	DNP 3.0 Board	Modbus Plus Board	RELTOOLS (2)	Settings Database
2.09 (1)	---	2.0	2.2	1.0	2.1	1.27
1.58	1.25	2.0	2.2	1.0	2.1	1.27
1.57	1.25	2.0	2.2	1.0	1.26/1.27	1.26
1.55	- - -	2.0	- - -	- - -	1.25A	1.25
1.25	1.25	- - -	- - -	- - -	1.25A	1.25
1.54	- - -	2.0	- - -	- - -	1.24	1.24
1.24	1.24	- - -	- - -	- - -	1.24	1.24
1.0 to 1.23	Upgrade to the latest firmware versions is recommended.				- - -	- - -
Notes: 1. New Main Board hardware. 2. Use the listed or more recent version of RELTools.						

Following is a history of REL 512 firmware and RELTools support software version releases.

Main Board

Version 2.09 (03/24/00)

This version is provided for the new Version 2.x main board currently being manufactured and shipped. It cannot be used to upgrade installed units with a Version 1.x main board. Version 1.58 should be used for this.

1. Provided the capability to accept modulated and demodulated IRIG-B signals as input to the REL 512. A processor was added to analog board to process IRIG-B signal and interface with main board.
2. Jumper selectable binary voltage input ratings of 24V, 48V, 120V and 250Vdc was provided. The inputs on previous versions are the same as the power rating.
3. Upgrade MC68360 Microprocessor from 25 MHz to 33 MHz. Upgrade hardware and software to accommodate a 33 MHz 68360 instead of the present 25 MHz.

4. Provided battery back up of the present RAM so that the data remains intact in spite of cycling power or power failure.
5. Removed the unused PCMCIA card slot from main board.
6. Firmware modifications included in Version 1.58

Version 1.58 (03/24/00)

This version is provided to support existing product installations. It will be discontinued on new products manufactured with the Version 2.x main board.

1. A two cycle dropout (off-delay) time was added to Zone-2, Zone-3, forward pilot and reverse pilot trip timers to prevent dropout during evolving fault transients.
2. A 12-cycle dropout timer was added to the HSRI and TDRI reclose initiate signals to insure that external reclosers can sense the reclose initiate output.
3. Implemented trip blocking such that fixed TRIP units and all except 3 physical outputs (OUT2, OUT3 and OUT4) are blocked when TRIP BLOCK programmable input is asserted.

Version 1.57 (11/03/99)

1. A DNP 3.0 Level 2 implementation was added for SCADA and substation automation network communications.
2. The main board software was modified so that only one software version is required to interface with any reclosing board.

Version 1.25 (9/27/99)

1. Improved accuracy of fault location and faulted phase selection reported on the LED's, LCD user interface and DFR record for time delayed tripping longer than 14 cycles.
2. Modified the loss of potential logic (page XX –below) to include the signal HS LOP BLOCK SET. HS LOP BLOCK SET appears in programmable (mapped) output signals, RELWISE and RELLOGIC software instead of LOSS OF POT BLOCK DIST. Previous settings and programmable logic files opened with the 1.25 software versions will convert from LOSS OF POT BLOCK DIST to HS LOP BLOCK SET.
3. Added logic that indicates open breaker with the 52a contact. Refer to logic drawing module 002-00-000. The BREAKER OPEN logic is asserted by either BREAKER 1(or 2) OPEN 52b or NOT BREAKER 1(or 2) CLOSED 52a. If BREAKER 1(or 2) CLOSED 52a is not mapped to an a binary input it will be set to a logic 1 value.
4. Added 52a-closed breaker logic to the breaker failure logic. Refer to logic drawing module 030-00-000.
5. The high speed and time delay reclose selectivity was improved. The settings Z1 TD FAULTS, PS TD FAULTS and HS 50 TD FAULTS were added. These settings enable time delayed reclosing for fault types not selected for high speed reclosing with the Z1 (PS or HS 50) RI FAULT TYPE setting.

Version 1.55 (9/27/99)

Includes all V1.25 modifications and new software to accommodate new recloser board with analog outputs and 50 Hz operation.

Version 1.24 (7/24/99)

1. Improved DFR to record power swings.
2. Added the capability to record a DFR record via binary (voltage) input. (XDFR)
3. Added the ability to clear the programmable logic output contact control via the ASCII/RS232 interface.
4. Added the ability to provide 6 trip output contacts for three pole tripping via setting control.
5. Extended the K0 ANGLE setting range for all impedance zones from –40° to 40° to –120° to 40°.
6. Fixed the relay to automatically reboot after editing configuration settings.
7. Fixed an error in the ASCII display for metering of primary quantities. The display should read the transformer (CT or VT) ratio times the applied current or voltage when the setting UNITS PRI/SEC is selected as PRIMARY.
8. Improved the LN R PU and LN X PU resolution from 2 to 4 places … 0.0101.
9. Improved transient block logic timing resolution from 1.25 cycle to 0.25 cycle to speed up dropout time to improve coordination.
10. Improved 2PHG FAULT logic by adding Zone-3 phase-to-ground elements and a dropout timer.

Version 1.54 (7/24/99)

Includes all V1.24 modifications and new software to accommodate new recloser board with analog outputs and 50 Hz operation.

Version 1.23 (3/11/99)

1. Additional LOP logic added to latch LOP and block operation for all conditions.
2. Xmodem header files corrected to facilitate new settings.
3. Expanded firmware to 4 variations to include 60/50 Hz and 5/1 amp ct inputs.
4. Corrected UI display of low value currents to match ASCII/RS232 metered values.
5. Modified TDRI to operate for all faults only.
6. Increased BF control timer maximum settting form 0.5 sec to 2.0 sec.

Note: This release does not support reclosing for 50 Hz.

Version 1.21 (10/26/98)

1. Fixed an error that recorded an extra record of fault data.
2. Fixed Breaker Failure Initiate (contact 10), Time Delay Reclose Initiate (contact 11) and High Speed Reclose Initiate (contact 12) to not operate if SPT BKR2 OUT is set to ENABLE.
3. Fix the mis-spelling of ‘success’ in file transfer completions.
4. Remove from TTY PUTT Weakfeed menu not required.
5. Reduce watchdog time for CPU lock-up reboot from 7 minutes to 1 minute.

Version 1.20 (8/26/98)

1. Quadrilateral units for Zone-1 ground were added.
2. Modbus+ Phase 1, 6X and Global registers were added.
3. DNP 3.0 Phase 1 was added.
4. Relay Settings upload checks for Version Control with RELTools were added.
5. Logic Settings upload checks for Version Control with RELTools were added.
6. Factory Default Settings Warning message appears when unit is reprogram was added.
7. Main Board firmware supporting Reclosing firmware Version 1.1 was added.
8. Manual Breaker Open/Close and Supervision though TTY were added.
9. Fixes to be 100% Compatible with HyperTerminal™ were added.
10. Maximium value setting for Z1_PH_REACH, Z1_GND_REACH, Z2_PH_REACH, Z2_GND_REACH, Z3_PH_REACH, Z3_GND_REACH, FWP_PH_REACH, FWP_GND_REACH, RVP_PH_REACH, RVP_GND_REACH were changed from 50 to 36 Ohms.
11. Product information display screen updated to support new hardware options.

Version 1.10 (4/24/98)

1. Main Board firmware supporting Reclosing firmware Version 1.0 was added.
2. Single Pole additional trips were added using relay outputs 10, 11, and 12.
3. Unit style number and serial number was added to product information display.

Version 1.01 (3/27/98)

1. Single pole trip logic implemented
2. Unblocking logic was updated.
3. Inverse-time overcurrent (51N) unit logic was modified.
4. LED and UI Fault Data Display was updated.

Version 1.00 (11/13/97)

Initial release.

Reclosing Board Version 1

This is the original reclosing board design and does not include analog outputs for SCADA.

Reclosing Board Version 2

Version 2.0 (09/27/99)

1. New reclosing board design that includes analog outputs for SCADA.
   (Version 1 reclosing board is discontinued.)

DNP 3.0 Network Interface Board

Version 2.2 (11/03/99)

1. A DNP 3.0 Level 2 implementation.

Version 1.01 (3/11/99)

1. Initial DNP 3.0 sub-Level 2 beta implementation.

Modbus Plus Network Interface Board

Version 1.0 (3/11/99)

1. Initial Modbus Plus implementation.

REL 512 Revision History

There are four boards (hardware modules) that are independently programmed and are periodically provided with new firmware version releases. These boards are:

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- Modbus Plus Network Interface Board that provides an interface to SCADA or substation automation utilizing the Modbus Plus protocol.

RELTOOLS support software and the REL 512 setting database are also periodically upgraded to meet the requirements of new firmware releases. Correct coordination of the different firmware and support software is essential to assure proper operation of the REL 512 and RELTOOLS. The following table defines the firmware, software and setting database version requirements for different Main Board (CPU) firmware version releases.

Compatible Firmware and Software Releases

Main Board CPU	Version 1 Reclosing Board 1618C07G01	Version 2 Reclosing Board 1919C38G01	DNP 3.0 Board	Modbus Plus Board	RELTOOLS (2)	Settings Data base
2.09 (1)	---	2.0	2.2	1.0	2.1	1.27
1.58	1.25	2.0	2.2	1.0	2.1	1.27
1.57	1.25	2.0	2.2	1.0	1.26/1.27	1.26
1.55	- - -	2.0	- - -	- - -	1.25A	1.25
1.25	1.25	- - -	- - -	- - -	1.25A	1.25
1.54	- - -	2.0	- - -	- - -	1.24	1.24
1.24	1.24	- - -	- - -	- - -	1.24	1.24
1.0 to 1.23	Upgrade to the latest firmware versions is recommended				- - -	- - -
Notes:	1. New Main Board hardware 2. Use the listed or more recent version of RELTOOLS.					

Following is a history of REL 512 firmware and RELTOOLS support software version releases.

Main Board

Version 2.09 (03/17/00)

This version is provided for the new version 2.x main board currently being manufactured and shipped. It cannot be used to upgrade installed units with a version 1.x main board. Version 1.58 should be used for this.

1. Provided the capability to accept modulated and demodulated IRIG-B signals as input to the REL 512. A processor was added to analog board to process IRIG-B signal and interface with main board.

2. Jumper selectable binary voltage input ratings of 24V, 48V, 120V and 240V was provided. The inputs on previous versions are the same as the power rating.

3. Upgrade MC68360 Microprocessor from 25MHz to 33 MHz. Upgrade hardware and software to accommodate a 33 MHz 68360 instead of the present 25MHz.

4. Provided battery back up of the present RAM so that the data remains intact in spite of cycling power or power failure.

5. Removed the unused PCMCIA card slot from main board.

6. Firmware modifications included in version 1.58

Version 1.58 (03/17/00)

This version is provided to support existing product installations. I will be discontinued on new products manufactured with the version 2.x main board.

1. A two cycle dropout (off-delay) time was added to zone-2, zone-3, forward pilot and reverse pilot trip timers to prevent dropout during evolving fault transients.

2. A 12-cycle dropout timer was added to the HSRI and TDRI reclose initiate signals to insure that external reclosers can sense the reclose initiate output.

3. Implemented trip blocking such that fixed TRIP units and all except 3 physical outputs (OUT2, OUT3 and OUT4) are blocked when TRIP BLOCK programmable input is asserted.

Version 1.57 (11/03/99)

4. A DNP 3.0 Level 2 implementation was added for SCADA and substation automation network communications.

5. The main board software was modified so that only one software version is required to interface with any reclosing board.

Version 1.25 (9/27/99)

1. Improved accuracy of fault location and faulted phase selection reported on the LED's, LCD user interface and DFR record for time delayed tripping longer than 14 cycles.

2. Modified the loss of potential logic to include the signal HS LOP BLOCK SET. HS LOP BLOCK SET appears in programmable (mapped) output signals, RELWISE and RELLOGIC software instead of LOSS OF POT BLOCK DIST. Previous settings and programmable logic files opened with the 1.25 software versions will convert from LOSS OF POT BLOCK DIST to HS LOP BLOCK SET.

3. Added logic that indicates open breaker with the 52a contact. Refer to logic drawing module 002-00-000. The BREAKER OPEN logic is asserted by either BREAKER 1(or 2) OPEN 52b or NOT BREAKER 1(or 2) CLOSED 52a. If BREAKER 1(or 2) CLOSED 52a is not mapped to an a binary input it will be set to a logic 1 value.

4. Added 52a-closed breaker logic to the breaker failure logic. Refer to logic drawing module 030-00-000.

5. The high speed and time delay reclose selectivity was improved. The settings Z1 TD FAULTS, PS TD FAULTS and HS 50 TD FAULTS were added. These settings enable time delayed reclosing for fault types not selected for high speed reclosing with the Z1(PS or HS 50) RI FAULT TYPE setting.

Version 1.55 (9/27/99)

Includes all v1.25 modifications and new software to accommodate new recloser board with analog outputs and 50Hz operation.

Version 1.24 (7/24/99)

1. Improved DFR to record power swings.
2. Added the capability to record a DFR record via binary (voltage) input. (XDFR)
3. Added the ability to clear the programmable logic output contact control via the ASCII/RS232 interface
4. Added the ability to provide 6 trip output contacts for three pole tripping via setting control.
5. Extended the K0 ANGLE setting range for all impedance zones from -40^0 to 40^0 to -120^0 to 40^0.
6. Fixed the relay to automatically reboot after editing configuration settings.
7. Fixed an error in the ASCII display for metering of primary quantities. The display should read the transformer (CT or VT) ratio times the applied current or voltage when the setting UNITS PRI/SEC is selected as PRIMARY.
8. Improved the LN R PU and LN X PU resolution from 2 to 4 places … 0.0101.
9. Improved transient block logic timing resolution from 1.25 cycle to 0.25 cycle to speed up dropout time to improve coordination.
10. Improved 2PHG FAULT logic by adding Zone-3 phase-to-ground elements and a dropout timer.(IL 40-512.3, Figure 31 2PHG Logic)

Version 1.54 (7/24/99)

Includes all v1.24 modifications and new software to accommodate new recloser board with analog outputs and 50Hz operation.

Version 1.23 (3/11/99)

1. Additional LOP logic added to latch LOP and block operation for all conditions.
2. Xmodem header files corrected to facilitate new settings.
3. Expanded firmware to 4 variations to include 60/50 Hz and 5/1 amp ct inputs.
4. Corrected UI display of low value currents to match ASCII/RS232 metered values.
5. Modified TDRI to operate for all faults only.
6. Increased BF control timer maximum setting form 0.5 sec to 2.0 sec.

Note: This release does not support reclosing for 50 Hz.

Version 1.21 (10/26/98)

1. Fixed an error that recorded an extra record of fault data.
2. Fixed Breaker Failure Initiate (contact 10), Time Delay Reclose Initiate (contact 11) and High Speed Reclose Initiate (contact 12) to not operate if SPT BKR2 OUT is set to ENABLE.
3. Fix the mis-spelling of 'success' in file transfer completions.
4. Remove from TTY PUTT Weakfeed menu not required.
5. Reduce watchdog time for CPU lock-up reboot from 7 minutes to 1 minute.

Version 1.20 (8/26/98)

1. Quadrilateral units for zone-1 ground were added.
2. Modbus Plus, Phase 1, 6X and Global registers were added.
3. DNP 3.0 Phase 1 was added.
4. Relay Setting upload checks for Version Control with RelTools were added.
5. Logic setting upload checks for Version Control with RelTools were added.
6. Factory Default Settings warning message appears when unit is reprogram was added.
7. Main Board firmware supporting Reclosing firmware version 1.1 was added.
8. Manual Breaker Open/Close and Supervision though TTY were added.
9. Fixes to be 100% Compatible with HyperTerminal were added.
10. Maximum value setting for Z1_PH_REACH, Z1_GND_REACH, Z2_PH_REACH, Z2_GND_REACH, Z3_PH_REACH, Z3_GND_REACH, FWP_PH_REACH, FWP_GND_REACH, RVP_PH_REACH, RVP_GND_REACH were changed from 50 to 36 Ohms.
11. Product information display screen updated to support new hardware options.

Version 1.10 (4/24/98)

1. Main Board firmware supporting Reclosing firmware version 1.0 was added.
2. Single Pole additional trips were added using relay outputs 10, 11, and 12.
3. Unit style number and serial number was added to product information display.

Version 1.01 (3/27/98)

1. Single pole trip logic implemented
2. Unblocking logic was updated.
3. Inverse-time overcurrent (51N) unit logic was modified.
4. LED and UI Fault Data Display was updated.

Version 1.00 (11/13/97)

Initial release.

Reclosing Board Version 1

This is the original reclosing board design and does not include analog outputs for SCADA.

Version 1.25 (09/27/99)

1. Changes to previous version

Version 1.24 (9/27/99)

1. Changes to previous version.

Version 1.23 (03/11/99)

1. Changes to previous version

Version 1.21 (10/28/99)

1. Changes to previous version.

Reclosing Board Version 2

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Version 2.0 (09/27/99)

1. New reclosing board design that includes analog outputs for SCADA. (Version 1 reclosing board is discontinued)

DNP 3.0 Network Interface Board

Version 2.2 (11/03/99)

1. A DNP 3.0 Level 2 implementation.

Version 1.01 (3/11/99)

1. Initial DNP 3.0 sub-Level 2 beta implementation

Modbus Plus Network Interface Board

Version 1.0 (3/11/99)

1. Initial Modbus Plus implementation

Future Releases

The REL 512 will be provided with a new main board design that will include:

1. Non-volatile memory for DFR records.
2. Jumper selectable binary voltage input ratings of all binary inputs. The selections are 24 V/ ?? mA, 48, 125 and 250 V dc.

Product Overview

Application

The REL 512 relay system is an integrated numerical transmission line impedance protection system and circuit breaker control terminal. It offers new protection concepts delivering true one cycle tripping, the most advanced functions, and flexibility available to meet transmission line distance protection application requirements for both pilot and non-pilot. The REL 512 also includes options for automatic reclosing and breaker failure protection. The protection system is further enhanced with programmable I/O and logic, which can be set for local user functions, or monitored and controlled by your SCADA or automation system. Also, advanced patented self-testing techniques eliminate routine maintenance requirements. Concepts introduced by the REL 512 opens the door to more creative approaches for addressing protection and control needs.

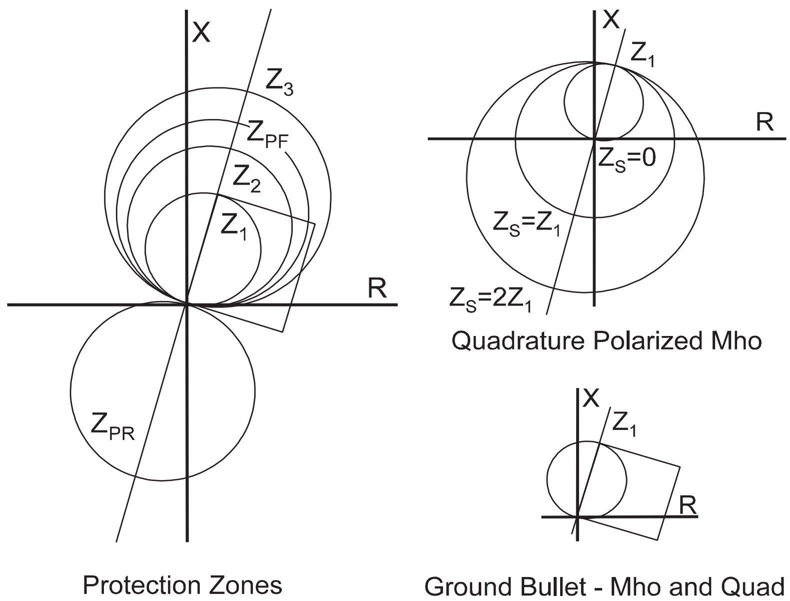


Figure 1-1. Zone Phase and Ground Impedance Units

New Protection Concepts

The REL 512 utilizes a combination of time and frequency domain algorithms, and multiple microprocessors. This provides comprehensive high-performance protection and control with one cycle operating speed and high reach accuracy. Overreach errors due to CCVT subsidence and asymmetrical fault current are eliminated. The pilot zones and Zone 1 elements, and all the elements which supervise them, are time-domain based algorithms. These follow closely the dynamic operation of the power system, responding rapidly to maintain stability during system disturbances. Some backup and support functions are handled in the frequency domain using conventional Fourier notch filter methods.

One Cycle Operation

High-energy faults cause fast tripping while the response is slower for low-energy or zone-boundary faults. The unit provides reliable one cycle operation for Zone 1, and pilot faults within 80% of the zone reach setting. Transient overreach of the distance elements due to asymmetrical fault current and CCVT voltage do not exist due to the adaptive nature of the inverse characteristics.

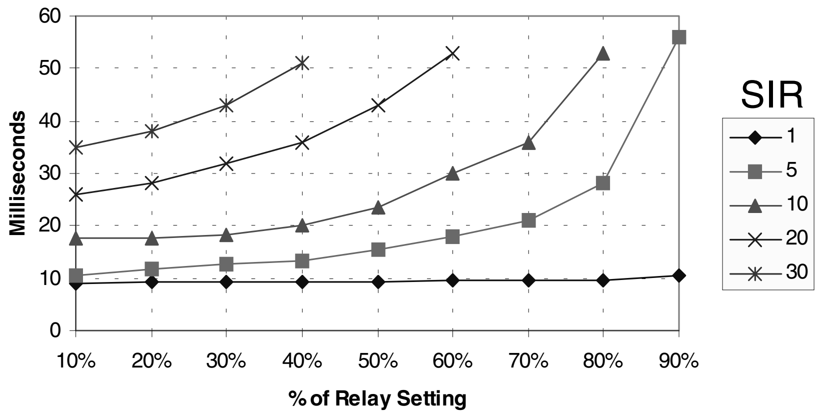


Figure 1-2. Zone Impedance Unit Operating Time

The operating times determined in the above curves are based on the ratio of the system equivalent source impedance to the relay setting. This is refered to as SIR and curves are shown for values of SIR from 1 to 30. These tests were made using the high speed outputs.

Distance Protection

The non-pilot protection function of the REL 512 is a full distance scheme with three phase and ground quadrature polarized impedance measuring zones having variable mho characteristics. Additional forward and reverse phase and ground measuring zones are provided for pilot or other user applications, giving a total of 5 zones.

Pilot Logic

The REL 512 uses a comprehensive, modularized, finely tuned pilot logic scheme based on years of application experience with microprocessor based distance protection. Separate forward and reverse phase and ground pilot zones are provided. Pilot options include Blocking, Unblocking, POTT and PUTT. The logic includes two- or three-terminal line protection, transient blocking, weak feed and echo keying. High-speed carrier starting and a blocking coordination timer are provided for the blocking system to insure coordination with existing remote terminals.

Overcurrent Protection & Supervision

Overcurrent protection includes phase, ground and negative-sequence inverse-time functions which can be controlled with directional or Zone-2 elements. All inverse time overcurrent functions offer choice of instantaneous or time-delayed reset. Overcurrent supervision of distance units provides secure operation for loss of potential conditions, during 3 phase faults, and bus-transfer operations. A negative-sequence fault detector is provided for greater sensitivity to multiphase faults.

Fault Locator

The REL 512 utilizes a highly accurate fault location algorithm with fault resistance and load flow compensation.

I/O Mapping Logic

More than 50 binary signals can be mapped to any of 8 output contacts. This allows the user to use REL 512 operating elements or logic signals to control output contacts for alarms, trips, triggering or control of external devices.

Programmable Logic

More than 100 binary signals can be combined using AND and OR gated, negation, on/off delay timers and flip-flops mapped to any of 8 output contacts. This allows the user to use REL 512 operating elements or logic signals to control output contacts for alarms, trips, triggering, or control of external devices.

Communication to the Relay

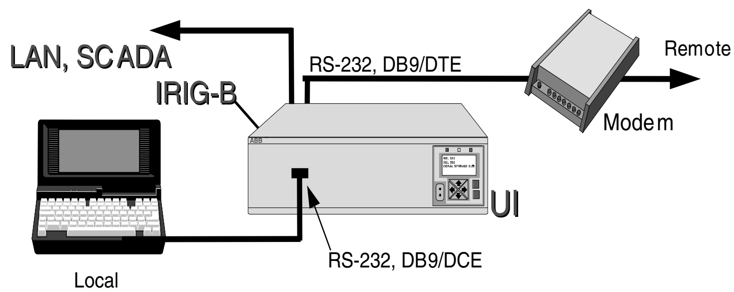


Figure 1-3. Communications to the Relay

The front panel User Interface communications includes a 4 x 16 character backlit LCD with multi-function keypad, plus 12 LED's for status and target indication, and a reset push-button. Front and rear communications ports are available for local and remote computer access. Interactive access or file transfers can be provided with industry communications software such as Procomm®, Crosstalk®, or Windows® Terminal.

Digital Fault Recorder

Data on the most recent 15 faults are time-tagged and stored in digital fault records. Each fault record provides detailed data for operation analysis. This includes voltage and current analog quantities, DSP operating unit and logic digital signals. Each record is 16 cycles long with a sampling frequency of 1200 Hz (20 samples per cycle based on 60 Hz basis). This includes 2 cycles of prefault data and 14 cycles of post fault data. System events lasting longer than 14 cycles will produce multiple records to capture the entire event. The records are coordinated to within 1 ms resolution. Reference Section 7 RELTools Support Software for more detailed information.

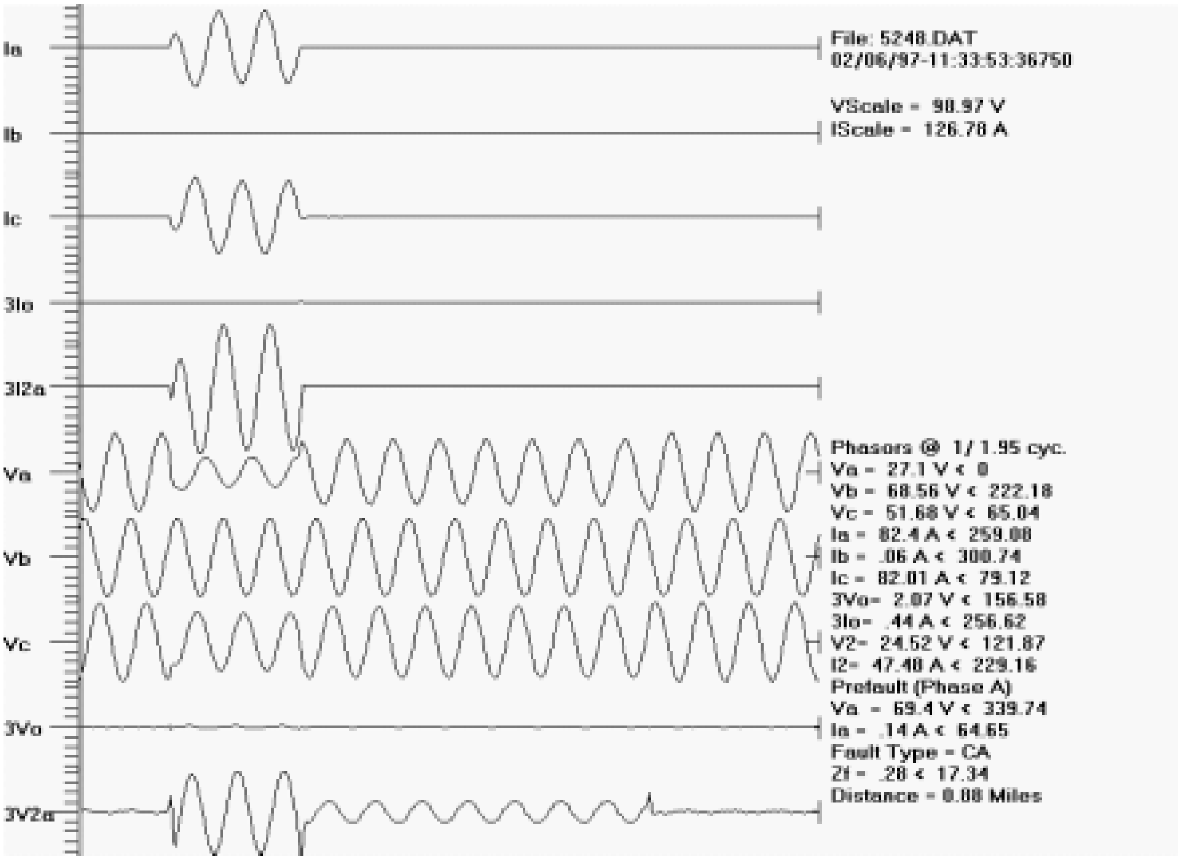


Figure 1-4. Fault Oscillographic Record

Platform Overview

Platform Components

The relay platform is suitable for mounting horizontally in a 3 RU high space on a standard 19-inch wide rack, or vertically in an FT-42 panel cutout.

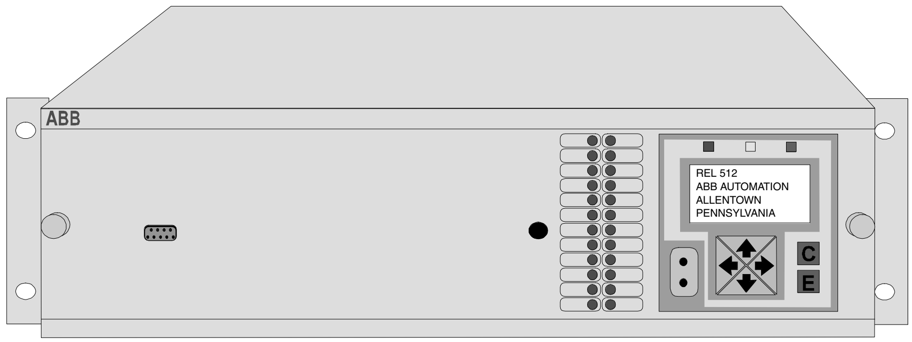


Figure 1-5. REL 512 Platform Front Panel (Horizontal Mounting)

The platform outer chassis consists of:

rear mounted terminal blocks for analog (instrument transformer) inputs, binary (dc voltage) inputs, and binary (contact) outputs;

rear mounted communication interfaces and a time synchronization IRIG-B input;

a front panel with a DB9/RS232 communication interface, a local user interface (UI) for metering, access to fault information and settings editing, LED's for instant visual relay operational status, and a recessed LED reset button.

The front panel is released with two thumb screws and removeable to allow access to the internal components. The main board, and optional expansion and communication boards are easily removed and re-installed.

Hardware/Firmware Structure

Relay Operation

The following describes the basic relay operation. The basic hardware consists of:

Analog input transformers for analog input signals

A front end filter, multiplexer and A/D converter of those input signals

One digital signal processors (DSP) for high speed measuring unit and logic operation

One CPU processor for DSP signal buffering, logic analysis and control, and communications

Status Inputs for logic operations

Output contacts for control of external devices

NOVRAM (non-volatile memory) for storage of relay settings and fault records (V2.x)

Communication interfaces

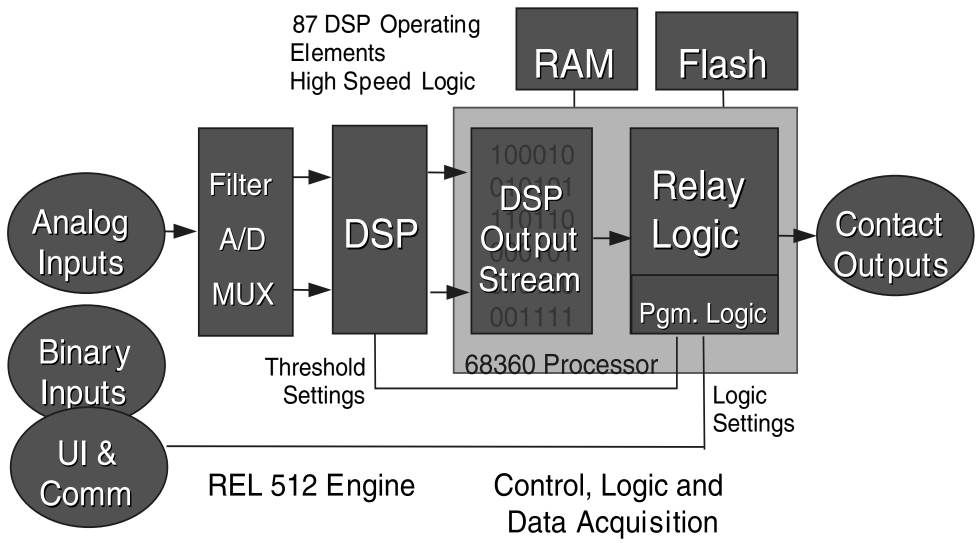


Figure 1-6. Basic Relay Operation

REL 512 Engine

The REL 512 engine consists primarily of the analog inputs, front end filtering, multiplexing and A/D processing, and digital signal processing (DSP) based on relay operating element comparator equations with outputs going into a logic buffer for protection and programmable logic analysis. The DSP elements are the heart of the relay operation, and it is their energy dependent equation performance that provides both operating speed and accuracy.

A relay element operation is based on the phase comparison of a restraining phasor and an operating phasor. These are derived from the analog inputs. When the operating phasor, S1 (see Figure 1-7) leads the restraining phasor, S2, the relay element will operate providing a logical 1 output. When S1 lags S2 the relay element will not operate and has a logical 0 output. When S1 leads or lags S2 by 90°, maximum operating energy, and speed, is delivered in either the operating or restraining direction. Relay analog input quantities and threshold settings control the operation.

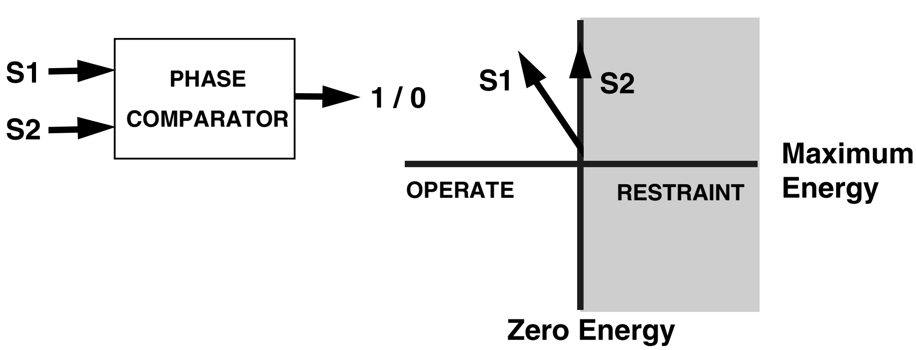


Figure 1-7. Phase Comparator

Control, Logic and Data Acquisition

Logic functions are the selectable and settable relay protection logic, and provide user programmable logic. With each sample, the output status of each relay-operating element in the DSP is input to the logic buffer to await logic processing. Every logic function cannot be processed at every sample. Therefore, logic functions are performed on a defined priority schedule, and will read the continuously updated buffer as required.

User programmable logic has access to selected relay operating element and logic signals, and input and output relays. Using the programmable logic, the user can perform a large number of auxiliary functions.

The CPU processor also provides integration and control of the UI, communication interfaces, binary I/O, data storage, flash memory, communication to the DSP, and advanced diagnostics.

Advanced Relay Diagnostics

Advanced relay diagnostics eliminates the need for extensive installation evaluation testing and scheduled periodic maintenance. The relay is provided with a comprehensive set of diagnostic tools capable of testing the relay hardware operation including input status points, output relays, and LED’s.

Platform Rating and Tolerances

Table 1-1. Analog Input Circuits

Input	Rating
5 A Rating	16 A continuous and 450 A for 1 second
1 A Rating	3 A continuous and 100 A for 1 second
Input Burden	Less than 0.1 VA @ 5 A
Voltage Rating (69/120 V Wye)	160 V continuous and 480 V for 10 seconds
Frequency	50 or 60 Hz

Table 1-2. Binary (Voltage) Input Circuits

Input	Burden
24 V dc	< 0.16 VA
48 V dc	< 0.16 VA
125 V dc	< 0.44 VA
250 V dc	< 0.44 VA

NOTE: *The optically isolated binary input dc voltage rating is the same as the control power (power supply) voltage on the Version 1.X platform. The binary input dc voltage rating is jumper selectable on Version 2.X platforms.*

Table 1-3. Binary (Contact) Output Circuits

Circuit Voltage	Trip Rating	Continuous Rating	Circuit Break Rating	
			Resistive	Inductive
48 - 250 Vdc	30 A	8 A	50 W	15 VA
120 Vac	30 A	8 A	50 W	15 VA

Table 1-4. Control Power Requirements

Control Voltage	Amps (Burden)	Operating Voltage Range
48 Vdc	0.35	33 to 58 Vdc
125 / 250 Vdc	0.17 to 0.085	85 to 300

Table 1-5. Operating Environment

Parameter	Value	Applicable Standard
Operating Temperature	-25° C to + 70° C	ANSI C37.90, IEC 255-6
Storage Temperature	-40° C to + 80° C	ANSI C37.90, IEC 255-6
Humidity	Up to 95% without internal condensation	ANSI C37.90, IEC 68-2-30
Insulation Voltage	2.8 kV dc, 1.0 min	ANSI C37.90, IEC 255-5
Impulse Voltage	5 kV peak, 1.2 x 50 us	ANSI C37.90, IEC 225-5
Oscillatory Surge Withstand	2.5 kV, 1 MHz	ANSI C37.90.1, IEC 255-22-1
Fast Transient	4 kV peak, 10 x 100 ns	ANSI C37.90.1, IEC 255-22-4
EMI Volts/Meter	35 V/m, 25 MHz to 1 GHz	ANSI C37.90.2, IEC 1000-4-3
ESD	Electro-static discharge	IEC 255-22-2

Table 1-6. Metering Accuracy

Quantity	% Error, Average*	% Error, Maximum
Voltage (40 – 120 V)	1.0	2.0
Current (1 – 5 A)	1.0	2.0
Watts (PF = 1.0)	1.5	3.0
VARs (PF = 0.0)	1.5	3.0
Watts (PF = 0.866)	2.0	3.0
VARs (PF = 0.866)	1.5	3.0

* The error is less than the values shown. The average error is the error averaged over a long period of time (1 minute). The maximum error is a momentary maximum as read from the metering screen.

Functional Specifications

Operating Units

Impedance Measuring Units

Refer to Settings Table for complete settings data.
Three forward phase and ground zones with independent reach and timer settings for step distance protection.

Additional forward and reverse phase and ground zones for pilot protection or other user function.

Each zone has six impedance mho units. They are:

2 - Three phase impedance units
1 - Phase-to-phase impedance unit, and
3 - Phase-to-ground impedance units

The impedance units are quadrature polarized having variable mho characteristics settable 0.03 – 36 (5A) or 0.15 – 180 (1A) ohms.

Zone-2, Zone-3, forward pilot and reverse pilot zones have a time delayed trip setting of 0.0 to 10.0 seconds.

Zone-1 has three additional ground unit with quadrilateral characteristics.

Blinder Units

Two sets of impedance blinders provide for out-of-step block and trip functions, and load encroachment logic.

Overcurrent Units

Instantaneous (Type 50) Units

High set 2-100 A. (5A) or 0.4 – 20 A. (1A) phase unit for high-speed detection of multi-phase faults.

High set 2-100 A. (5A) or 0.4 – 20 A. (1A) ground unit for high-speed detection of phase-to-ground faults.

High set 2-100 A. (5A) or 0.4 – 20 A. (1A) negative sequence unit for greater sensitivity and high speed detection of phase-to-phase faults.

All high set units can be set to trip with or without directional supervision.

Medium set 0.5-12 A. (5A) or 0.1 – 2.4 A. (1A) phase unit for overcurrent detection of multi-phase faults and supervision of phase impedance units and OS functions.

Medium set 0.5-12 A. (5A) or 0.1 – 2.4 A. (1A) forward directional ground unit for detection of phase-to-ground faults, SPT logic, pilot logic, and supervision of ground impedance units.

Medium set 0.5-12 A. (5A) or 0.1 – 2.4 A. (1A) forward directional negative sequence unit for greater sensitivity and detection of phase-to-phase faults.

Medium set ground units can be set to trip with a time delay (0.0 to 10.0 sec) to provide greater sensitivity to high resistance ground faults.

Medium set negative sequence units can be set to trip with a time delay (0.0 to 10.0 sec) to provide greater sensitivity to phase-to-phase faults.

Low set 0.5-10 A. (5A) or 0.1 – 2.0 A. (1A) phase unit for overcurrent detection of multi-phase faults, close-into-fault, and accelerated trip logic.

Low set 0.5-10 A. (5A) or 0.1 – 2.0 A. (1A) ground unit for detection of phase-to-ground faults, close-into-fault, out-of-step-block, loss-of-potential, and pilot logic.

Low set 0.5-10 A. (5A) or 0.1 – 2.0 A. (1A) negative sequence unit for greater sensitivity and detection of phase-to-phase faults, and out-of-step-block logic.

Time Overcurrent (Type 51) Units

3 – Phase, inverse time, overcurrent phase units 0.5-10 A. (5A) or 0.1 – 2.0 A. (1A) with directional or Zone-2 torque control.

1 – Ground, inverse time, overcurrent phase units 0.5-10 A. (5A) or 0.1 – 2.0 A. (1A) with directional or Zone-2 torque control.

1 – Negative sequence, inverse time, overcurrent units 0.5-10 A. (5A) or 0.1 – 2.0 A. (1A) with directional or phase, and/or ground Zone-2 torque control.

Settings constants are based on the proposed IEEE Standard C37.112, and emulate any curve including CO and IEC time curve characteristics.

Selectable reset time curve.

Voltage Units

Three independent phase undervoltage elements with (the same) threshold setting (40-60 V) for low voltage alarms with loss-of potential logic and user applications.

Zero sequence voltage element ($3V_0$) with an overvoltage threshold setting (0-120 V) for loss-of potential logic and user applications.

Operating Unit Accuracy

Impedance Units

Impedance reach accuracy is less than 3% underreach and 0% overreach.

All impedance unit operating times are based on the system equivalent source (to relay setting) impedance ratio (SIR), and are determined below in Figure 1-8 for a SIR range of 1 to 30.

The maximum time delay trip setting error is unit operating time plus 40 ms.

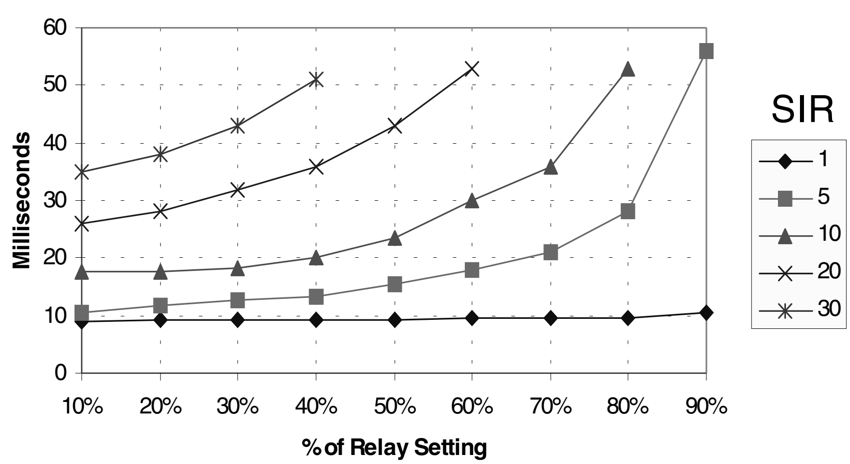


Figure 1-8. Impedance Unit Operating Time

Instantaneous Overcurrent Units

The operating accuracy of the overcurrent units is less than 2%, and the dropout to pickup ratio is greater than 0.95.

The operating time of the instantaneous overcurrent units are defined in Figure 1-9.

The maximum time delay trip setting error is unit operating time plus 40 ms.

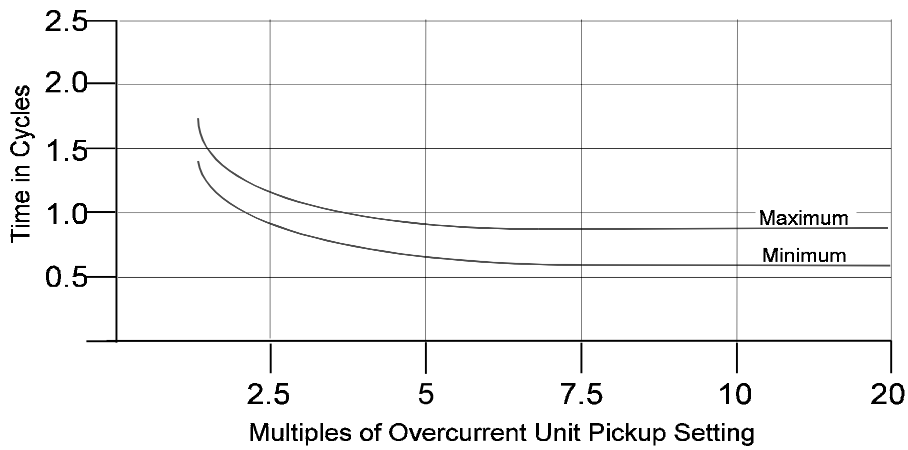


Figure 1-9. Instantaneous Overcurrent Unit Operating Time

Inverse Time Overcurrent Units

Maximum operating time error for the applied current is the computed time based on settings plus 40 ms.

Voltage Units

The operating accuracy of the phase undervoltage units is less than 2% of the setting, and the dropout to pickup ratio is less than 1.05.

The operating accuracy of the ground overvoltage unit is less than 2%, and the dropout to pickup ratio is greater than 0.95.

Time Delay Timers

The time delay trip timers operate with a 1.25 cycle resolution. Considering typical measuring unit operating times of 0.75 to 1.5 cycle, output relay time of 4 to 6 ms and this resolution, total operating times are consistently 30 to 50 ms greater than setting for 60 Hz operation and 40 to 60 ms for 50 Hz operation. Operating times are never less than the setting. This allows a reduced operating time and greater accuracy. For example at 60 Hz, if the desired setting is 0.5 seconds then set the relay to 0.46. Twenty Zone-2 trip operations with a 0.46 setting will statistically produce the following:

Average operating time = 0.4988 seconds	(0.24% error)
Maximum operating time = 0.5058 seconds	(1.16% error)
Minimum operating time = 0.4915 seconds	(1.7% error)

> **NOTE**: *Time delay operating times include the set time delay, plus the measuring unit operating time, plus 40 ms. Testing near the boundary or threshold of an impedance measuring unit may result in longer operating times than expected. Operating time testing should always be done with faults applies under 80% of the reach setting.*

Protection Functions

Basic Distance Functions

Three zone step distance protection.

Selectable Zone-1 extension logic for high speed clearing of remote end zone faults.

Selectable loss of load accelerated trip for high speed clearing of remote end zone faults.

One cycle operation for Zone 1, forward pilot and reverse pilot zone operations within 80% of the respective zone reach setting.

Inherent immunity to CCVT and offset dc current transient prevents Zone 1 overreaching.

Selectable power swing block for each tripping zone and/or out-of-step trip using double blinder logic.

Load restriction logic.

Overcurrent Functions

Directional high set overcurrent phase and ground protection.

Time delay overcurrent phase and ground protection.

Zone 2 or directional torque-controlled phase, ground and negative sequence overcurrent protection.

Close into fault detection and tripping.

Stub bus protection.

Unequal pole closing load pickup logic.

Loss of current monitoring.

Voltage Functions

Loss of potential blocking.

Single and three phase undervoltage supervision and output.

Ground overvoltage supervision and output.

Pilot Functions

Options for blocking, unblocking, Permissive Overreaching Transfer Trip (POTT) and Permissive Underreaching Transfer Trip (PUTT) schemes.

Transient block logic.

Three-terminal line protection logic.

Weakfeed logic.

Blocking coordination timer.

Pilot receive pulse stretcher.

High speed carrier start for blocking system.

Breaker Failure Functions (Optional)

Single breaker failure scheme.

Breaker retrip.

Short time timer for multi-phase faults.

Long time timer for all faults.

Settings

Eight relay settings groups with local or remote control of setting selections.

Change settings groups with binary input, ASCII interface or network control.

Automation Functions

Open and close breaker.

Operate I/O metering.

Reclose

High speed tripping recloser initiate.

Time delayed tripping reclose initial.

Reclose block functions.

Optional 4 shot reclosing with voltage and synchronism checks.

Inputs and Outputs

Inputs

12 independently programmable isolated dc voltage inputs.

Outputs

8 programmable trip rated contacts rated 30 A make and carry for 1 sec, and 6 A continuous for trip, control and alarms.

10 trip rated contacts rated 30 A make and carry for 1 sec, and 6 A continuous for trip, control and alarms.

I/O Mapping and Programmable Logic

Mapping logic control of output contacts using Relay Logic Signals and status input.

Fault Information

LED's

24 LED's that include:

Fault type LED's: A phase, B phase, C phase, Ground.

Six trip type LED's: Zone 1, Zone 2, Zone 3, Pilot, Overcurrent,Trip and Fault

Monitoring LED's: In service, Pilot Enabled, Self-Testing, LOP/LOI, 50M (current level), Breaker 1 and Breaker 2 status, and Reclosing.

Fault Location

Accurate fault location method accounting for prefault load, fault resistance, and source impedance.

Accurate faulted phase selection.

Digital Fault Recording

15 most recent fault records include:

2 prefault cycles

14 post fault cycles

Sampling rate 20/cycle

Voltage and current analog channels

165 digital channels for operating unit, DSP logic, and I/O status at 0.833 ms resolution

Fault Distance

Trip (LED) Summary

Programmable Logic

Combines key relay operating unit and logic signals.

AND and OR gates with negation.

On and off delay timers.

Flip-flop latches.

Catalog Information

Options		Cat.# R512	H	6	B	1	N	4	N	N	1	N
Mounting	Horizontal	H	H	.	.	.	.	.	.	.	.	.
	Vertical	V		.	.	.	.	.	.	.	.	.
Frequency	50 Hz	5		.	.	.	.	.	.	.	.	.
	60 Hz	6		6	.	.	.	.	.	.	.	.
Current Rating	1 A	A			.	.	.	.	.	.	.	.
	5 A	B	.		B	.	.	.	.	.	.	.
Battery Voltage	24 V dc	5				.	.	.	.	.	.	.
	48/60 V dc	4	.		.	.	.	.	.	.	.	.
	110/125 V dc	1				1	.	.	.	.	.	.
	220/250 V dc	2					.	.	.	.	.	.
Breaker Failure (BF)	Breaker BF	B					.	.	.	.	.	.
Protection	None	N	.	.	.	.	N	.	.	.	.	.
Multi-shot Reclosing	with volt/sync check	3						.	.	.	.	.
	No Reclosing	4	.	.	.	.	.	4	.	.	.	.
Network Port #1	MODBUS Plus	M								.	.	.
	DNP 3.0	D	.	.	.	.	.	.	N	.	.	.
	None	N							.	.	.	.
Network Port #2	None	N	.		.	.	.	.	.	N	.	.
Trip Outputs	Standard (4-6 ms)	1	.		.	.	.	.	.	.	1	.
	High Speed (1 ms)	2										.
Reserved	Reserved	N	.	.	.	.	.	.	.	.	.	N

Acceptance, Installation, and Maintenance

Acceptance

The relay should be tested in accordance with the acceptance test procedure provided in Section 6, to insure the relay is received without damage and is functioning properly.

Installation

Dimensions

- inches (mm)

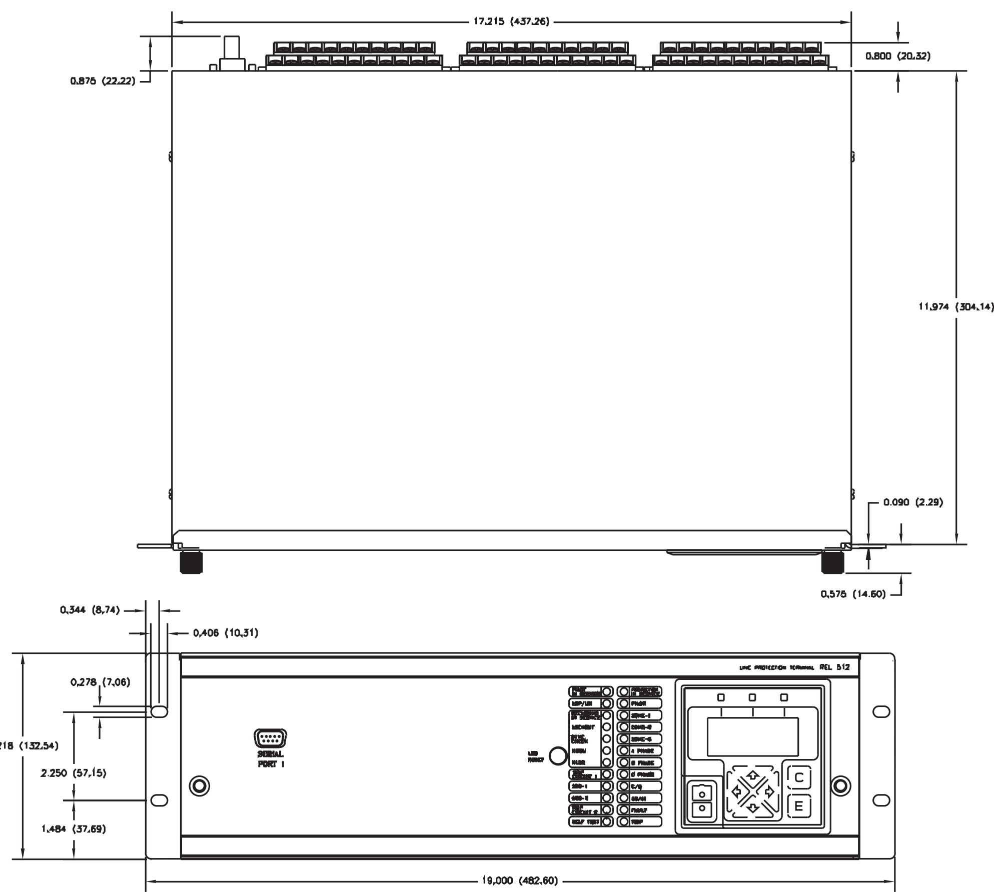


Figure 2-1. Top and Front View

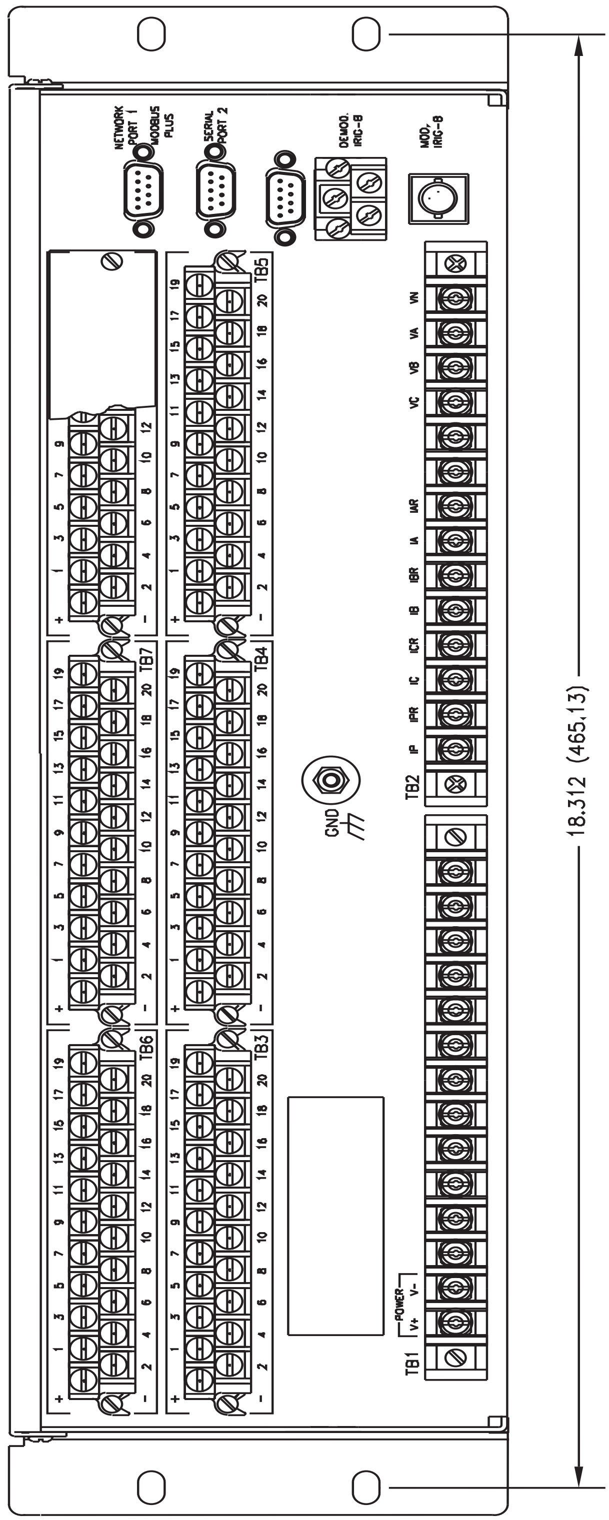


Figure 2-2. Rear View

External Connections

AC and DC Connections

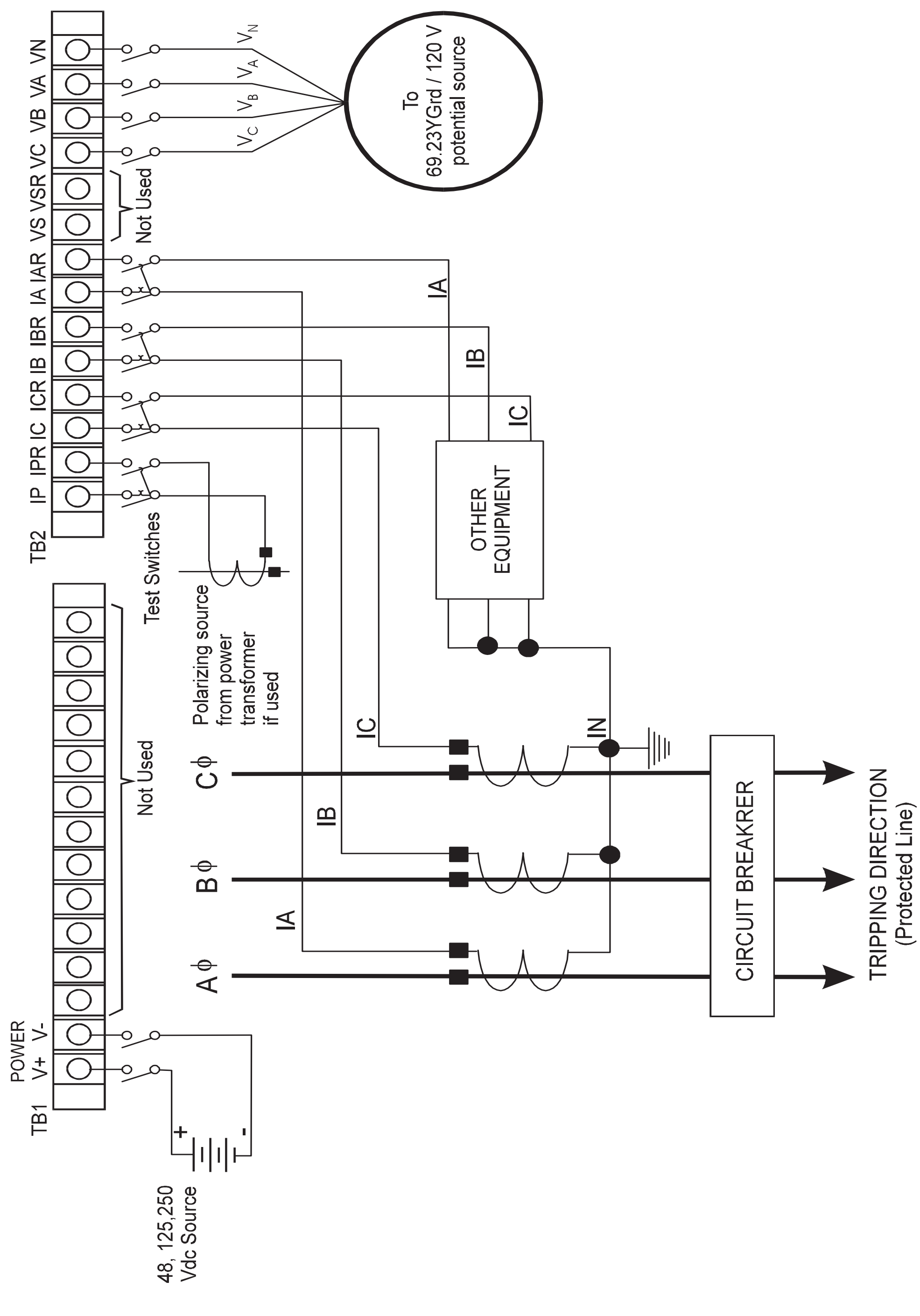


Figure 2-3. Terminal Blocks TB1 and TB2 (see Rear View)

I/O Connections

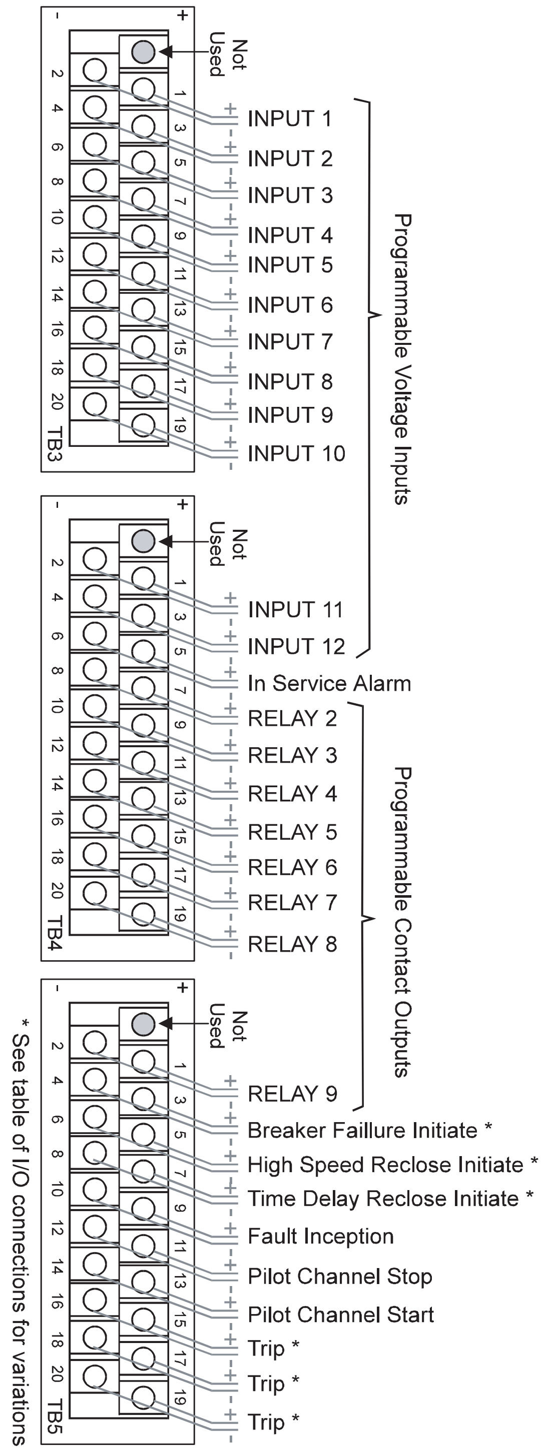


Figure 2-4. Terminal Blocks TB3, TB4 and TB5

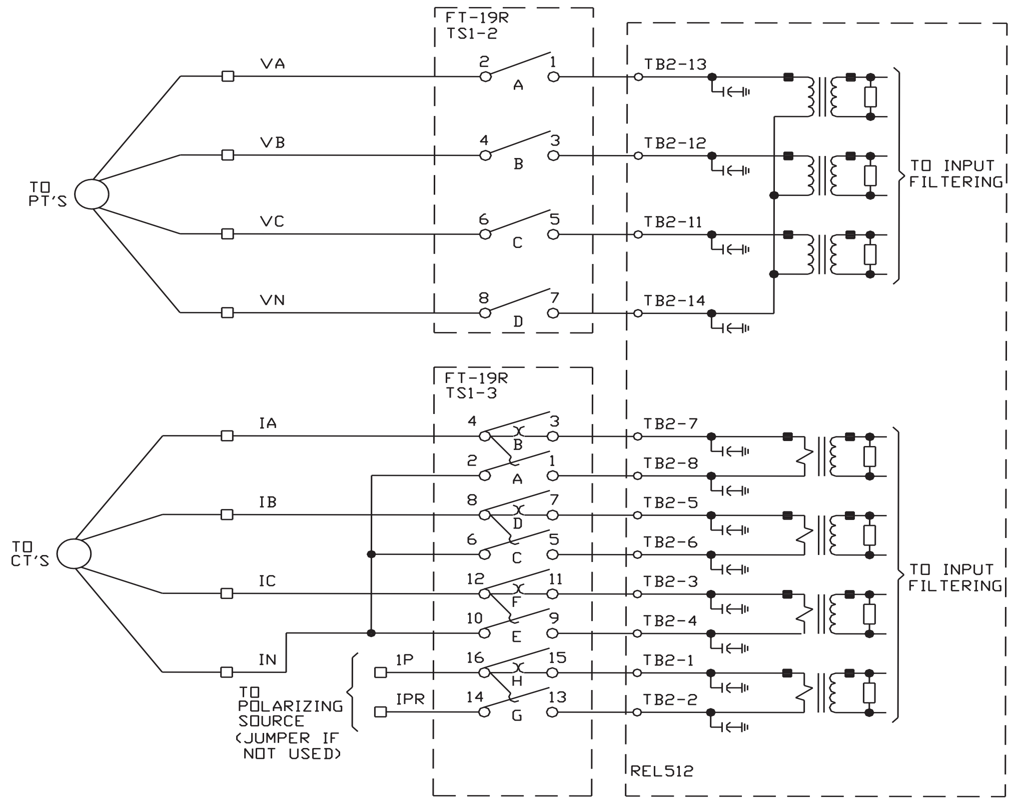
*Refer to Section 8, for Optional Reclosing I/O Connections to TB6, TB7, and TB8.

Table 2-1. I/O Connection Table

Function	Terminal Block	+ DC	- DC	NO/NC Jumper
Input 1 (Programmable)	TB3	1	2	N/A
Input 2 (Programmable)	TB3	3	4	N/A
Input 3 (Programmable)	TB3	5	6	N/A
Input 4 (Programmable)	TB3	7	8	N/A
Input 5 (Programmable)	TB3	9	10	N/A
Input 6 (Programmable)	TB3	11	12	N/A
Input 7 (Programmable)	TB3	13	14	N/A
Input 8 (Programmable)	TB3	15	16	N/A
Input 9 (Programmable)	TB3	17	18	N/A
Input 10 (Programmable)	TB3	19	20	N/A
Input 11 (Programmable)	TB4	1	2	N/A
Input 12 (Programmable)	TB4	3	4	N/A
Relay 1 (In Service/Alarm)	TB4	5	6	JP18
Relay 2 (Programmable)	TB4	7	8	JP17
Relay 3 (Programmable)	TB4	9	10	JP16
Relay 4 (Programmable)	TB4	11	12	JP15
Relay 5 (Programmable)	TB4	13	14	JP14
Relay 6 (Programmable)	TB4	15	16	JP13
Relay 7 (Programmable)	TB4	17	18	JP12
Relay 8 (Programmable)	TB4	19	20	JP11
Relay 9 (Programmable)	TB5	1	2	JP10
Relay 10 (Breaker Failure Initiate or SPT Phase A #2)	TB5	3	4	JP9
Relay 11 (Time Delay Reclose Initiate or SPT Phase B #2)	TB5	5	6	JP8
Relay 12 (High Speed Reclose Initiate or SPT Phase C #2)	TB5	7	8	JP7
Relay 13 (Fault Inception)	TB5	9	10	JP6
Relay 14 (Pilot Channel Stop)	TB5	11	12	JP5
Relay 15 (Pilot Channel Start)	TB5	13	14	JP4
Relay 16 (Trip 3 pole or SPT phase A)	TB5	15	16	JP3
Relay 17 (Trip 3 pole or SPT phase B)	TB5	17	18	JP2
Relay 18 (Trip 3 pole or SPT phase C)	TB5	19	20	JP1

NOTES:

1. *DC polarity must be followed to insure correct operation and prevent damage to relay.*
2. *Relay 1, 2, ..., 18, as identified above, are labeled in reverse order on the main printed circuit board. That is Relay 1 is labeled K18 and Relay 18 is labeled K1, etc.*
3. *Relay configuration, Normally Open (NO) or Normally Closed (NC), is accomplished by placing the associated jumper (shown above) in the desired position.*
4. *Relays 10, 11 and 12 are used for single pole trip output #2 which are enabled by the setting SPT BKR2 OUT. These can also be used for additional three pole tripping if additional trip outputs are required.*



DEVICE CHART

DEVICE	TYPE	FUNCTION	INTERNAL DIAGRAM
	REL512	MICROPROCESSOR RELAY SYSTEM	I.L. 40-512 R512H6B4N4MN1N
	TC-10B	ON/OFF POWER LINE CARRIER	PULSAR
TS1	FT-19R	FLEXITEST SWITCH ASSEMBLY	FR3G001001083 I.L. 41-075D

NOTE: INPUTS 1 - 12 AND OUTPUTS 2 - 9 ARE PROGRAMMABLE.
FOR MORE AVAILABLE OPTIONS, SEE I.L. 40-512 SEC. 2.

TABLE 1 BINARY INPUT MAPPING

CONTACTS:	1	2	3	4	5	6	7	8	9	10	11	12
85CO	x											
CHANNEL BLOCK 1		x										
CHANNEL BLOCK 2			x									
CHANNEL RECEIVE 1				x								
CHANNEL RECEIVE 2					x							
86B CLOSED						x						
BREAKER 1 CLOSED 52A							x					
BREAKER 1 OPEN 52B								x				
TRIP CIRCUIT 1									x			
BREAKER 2 CLOSED 52A										x		
BREAKER 2 OPEN 52B											x	
TRIP CIRCUIT 2												x

REL 512

OUTPUT CONTACT MAPPING

THE FOLLOWING CHART SHOWS THE LOGIC SIGNALS WHICH OPERATE THE OUTPUT CONTACTS.

TABLE 2

CONTACTS: DSP (E) & 360 LOGIC SIGNALS, PHASE SELECTOR FAULT TYPE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
IN Service (Failure)	x																	
3 POLE TRIP, TRIP SEAL (#13=TRIP ALARM)																x	x	x
PILOT CHANNEL START															x			
PILOT CHANNEL STOP														x				
FAULT INCEPTION DETECTOR [E]													x					
HSRI												x						
TDRI											x							
BREAKER FAILURE INITIATE										x								
PROGRAMMABLE DSP																		
DSP																		
HS TRIP																		
Z1 TRIP																		
DSP TRIP																		
PFT																		
PRT																		
50M SUPV PHASE																		
50M SUPV 3PH																		
UNDERVOLTAGE																		
3PH UNDERVOLTAGE																		
FORWARD GF																		
REVERSE GF																		
FORWARD 3PH																		
REVERSE 3PH																		
OSB																		
PROGRAMMABLE CPU																		
BLINDR IN SUPV																		
BLINDR OUT SUPV																		
LOSS OF CURRENT ALARM																		
LOSS OF POTENTIAL BLK DIST.																		
PILOT CHANNEL START																		
PILOT CHANNEL STOP																		
ZONE 2 TRIP																		
ZONE 3 TRIP																		
RECL BLOCK																		
HSRI																		
TDRI																		
BREAKER FAILURE INITIATE																		
BREAKER 1 CLOSED 52A																		
BREAKER 1 OPEN 52B																		
TCM/52 ALARM 1																		
TRIP COIL 1 MONITOR																		
BREAKER 2 CLOSED 52A																		
BREAKER 2 OPEN 52B																		
TCM/52 ALARM 2																		
TRIP COIL 2 MONITOR																		
OUT OF STEP BLOCK FOR HS																		

Figure 2-5. Typical REL 512 DCB Pilot Scheme Connection to TC-10B, Part 1

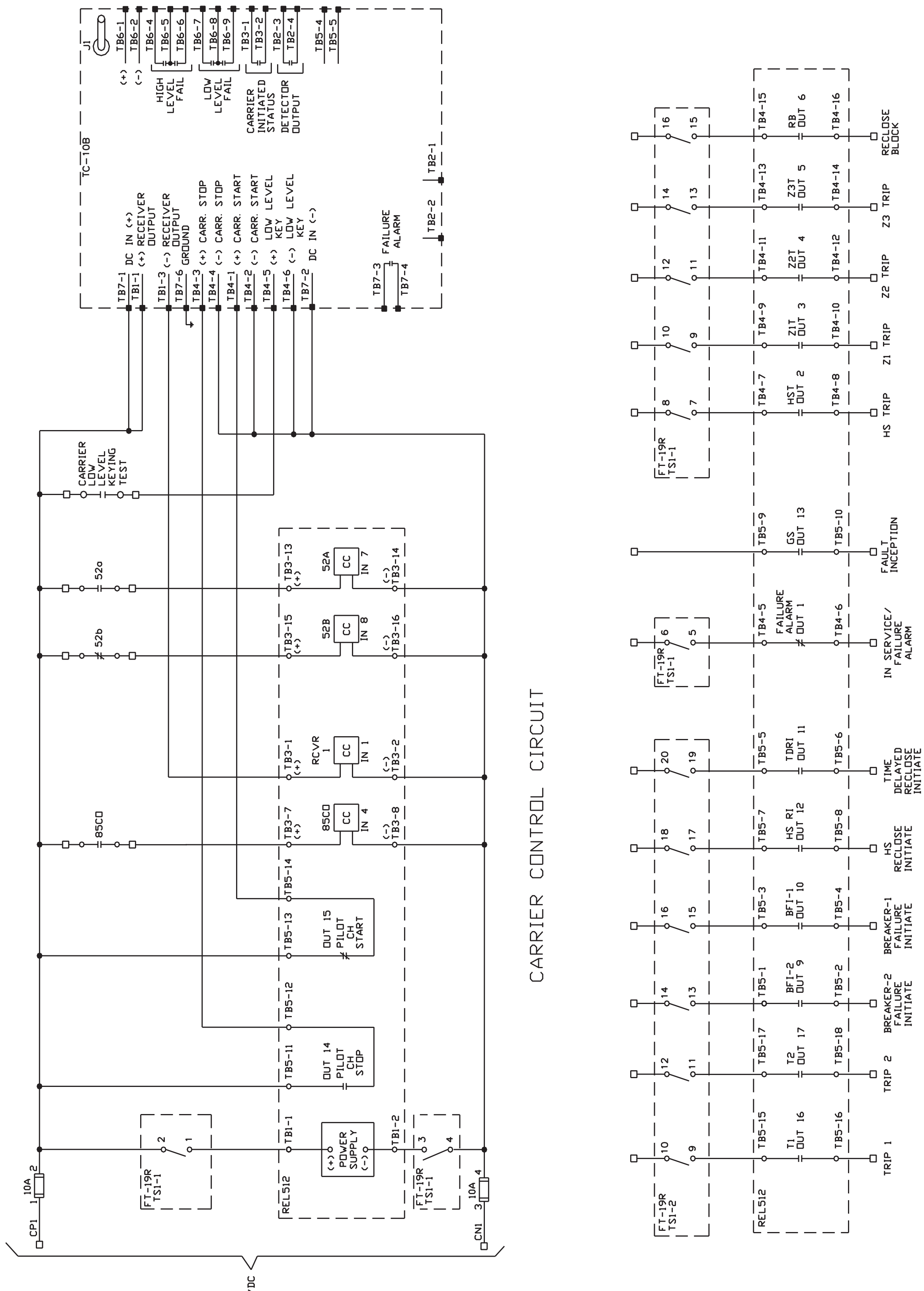


Figure 2-6. Typical REL 512 DCB Pilot Scheme Connection to TC-10B, Part 2

Communication Connectors

Serial Port 1 (Front View):

DB9, (female) DCE, RS232 for direct cable connection to PC serial port.

Serial Port 2 (Rear View):

DB9, (male) DTE, RS232 or RS485 for direct cable connection to Modem or RS232 switch serial port.

Network Port 1 (Rear View):

DB9 (female) connector for Network 1 protocol.

Network Port 2A (Rear View):

DB9 (female) connector for Network 2 protocol.

Network Port 2B (Rear View):

Alternate Network 2 protocol physical layer of twisted wire pair and shield termination.

IRIG-B:

Standard chassis BNC connector for connection to modulated, IRIG-B signal source.

> **NOTE:** *Connecting the incorrect serial cable from you computer or modem for ASCII communications to the network port may result in damage to the network card.*

Maintenance

The protection terminal is self-supervised. No special maintenance tests are required.

However, company directives for maintenance of the power system should be followed and in this respect, the REL512 can be regarded as a standard relay device in your system.

Operation

Communicating With the Relay

There are several ways to communicate and exchange information with the relay. These include the front panel mounted UI for a manual interface, LED's for a quick visual status of the relay and operation information, IRIG-B for updating the relay's time, and front and rear communication ports for remote computer access.

Front Panel User Interface

The front panel UI is a 4 line X 16 character/line Liquid Crystal Display (LCD) with 4 directional scrolling keys and 2 push-buttons. In addition there are 24 LED's and a push-button reset. All active group settings, 15 most recent sets of targets and metering display quantities, can be viewed or edited from the front panel UI.

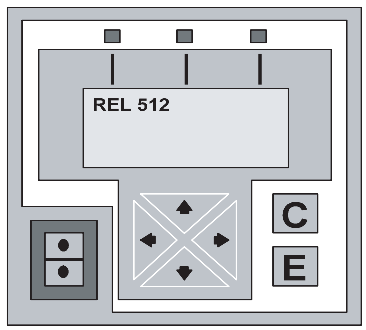


Figure 3-1. Front LCD User Inferface

The UI provides a metering and target display, and allows a user to view or edit the active group settings. The view mode is suitable to access relay information for review such as settings, product information and metering, and target information. The editing mode is more appropriate for changing relay settings. Below is a brief description explaining how to use the UI for viewing, or editing relay settings.

View Mode

After powering up the relay, the UI will be in metering mode. To view or edit settings, press any of the 4 directional scrolling keys or either of the 2 push-button keys. After a brief delay, there will be a menu to select view or edit settings, or to view product information. The user may traverse through the settings menus in view mode at will. The menus are set up in a hierarchical fashion. The 'E' key pushes into the next menu level. The 'C' key pops to the previous menu level. Arrow keys in the left column of the display show the present level menu items and indicate how to scroll through them. If the user selects edit mode, they will be required to enter a password to continue. The default factory password is "ABB". When leaving the menus in the edit mode, the user will be warned that the unit must reset to allow their changes to take effect.

Editing Mode

While editing settings, the setting being changed is located on line 3 of the LCD display. The cursor and auto-repeat are both active when editing settings. The right and left arrow keys are used to parse back and forth between digits or characters. If the setting is a selection, the left arrow scrolls through the different selection items. When editing digits or characters, the up and down arrows are used to increment or decrement the digit or character above the cursor. When editing digits, all leading and trailing zeros are erased during parsing. If the user parses to the right of the least significant digit, a zero will be added to the right side of the value. This new digit may then be edited. If the user parses to the left of the most significant digit, a zero will be added to the left side of the value. This new digit may now be edited. The leading digit may be any digit or a '+' or '-'. All other digits may only be digits. If a value has a decimal point, the decimal point may not be removed. There will always be a leading zero for decimal values. Once a value has been edited, pressing 'E' saves it. Pressing 'C' may terminate the edit session. Digital values may be set to any value that will fit on one line of the display. When a value is entered, it is checked against an upper and lower limit. If the new value is outside these limits, it will be set to the appropriate upper or lower limit. If a value is modified, the change does not take effect until exiting the UI menus and selecting reset when prompted resets the unit.

LED's

The following table shows the relay logic signals that operate the LED's.

Table 3-1. LED Functions

LED	Function (LOGIC SIGNALS which activate LED)
PROTECTION IN SERVICE	Relay energized and functioning properly
PILOT	Shows the operation of the direct tripping of the Forward or Reverse pilot zones if tripping is enabled. Shows Pilot Tripping if PILOT SYSTEM is enabled. FWP PILOT TRIP, RVP PILOT TRIP, PILOT TRIP COMBINED, PILOT WEAKFEED TRIP
ZONE-1	Zone-1 tripped. ZONE 1 TRIP, LLT
ZONE-2	Zone-2 tripped. ZONE 2 TRIP
ZONE-3	Zone-3 tripped. ZONE 3 TRIP
A PHASE	Fault involves A phase (Phase selector)
B PHASE	Fault involves B phase (Phase selector)
C PHASE	Fault involves C phase (Phase selector)
G/Q	Fault involves Ground (Phase selector) or was a zero or negative sequence overcurrent trip. MEDIUMSET GROUND TRIP, MEDIUMSET NEGATIVE SEQUENCE TRIP, HS N TRIP, HS Q TRIP, 51N BACKUP TRIP, 51Q BACKUP TRIP
50/51	An instantaneous or inverse time overcurrent unit operated, or a close into fault trip. HS TRIP, MEDIUMSET GROUND TRIP, MEDIUMSET NEGATIVE SEQUENCE TRIP, 51P BACKUP TRIP, 51N BACKUP TRIP, 51Q BACKUP TRIP, CLOSE INTO FAULT TRIP
FAULT	A fault has occurred and a digital fault record was saved.
TRIP	A trip has occurred and a digital fault record was saved. TRIP SEAL, DSP TRIP SEAL, PILOT WEAKFEED TRIP
PILOT IN SERVICE	The relay is set for pilot operation and the pilot enable switch (85CO) is programmed, properly wired and closed. PILOT ENABLE
LOP/LOI	A loss of potential or loss of current. UNDERVOLTAGE OR LOSS OF CURRENT ALARM if BREAKER OPEN is FALSE
RECLOSE IN SERVICE*	Reclosing module is present and reclosing is in service.
LOCKOUT*	Reclosing logic is in the lockout state as the result of a reclosing failure or driving to lockout via external input.
SYNC-CHECK*	The power system voltages on each side of the breaker are within set limits that define synchronism.
HBDL*	Indicates hot bus and dead line.
HLDB*	Indicates hot line and dead bus.
TRIP CIRCUIT 1	There is a problem with the trip circuit on Breaker # 1 or a breaker failure trip occurred. TCM/52 ALARM 1, BREAKER FAILURE TRIP
52B-1	Breaker #1 is open when 52B-1 is programmed, properly wired and closed.
52B-2	Breaker #2 is open when 52B-2 is programmed, properly wired and closed.
TRIP CIRCUIT 2	There is a problem with the trip circuit on Breaker # 2. TCM/52 ALARM 2
SELF TEST	The relay is self-testing. A flashing LED indicates normal relay operation.

*Reclosing functions - only operational if reclosing option installed.

Reset Button

The reset button clear the LED's. It can also be used to reset default settings. Press the reset button while energizing the relay. Keep the reset button depressed allowing the LED's to cycle twice. The relay will boot with factory default settings.

Computer Communication Interfaces

RS232 Ports

There is one front accessible RS232 optically isolated, buffered port for local access from a portable computer for relay data interrogation, settings editing, operating and testing. The front port is a DB9/ DCE connector (female) for direct computer connection.

There is one rear accessible RS232 optically isolated, buffered port for local or remote access from a PC or modem for relay data interrogation, settings editing, operating and testing. The rear port is a DB9/DTE connector (male) for direct modem or smart switch connection.

Simultaneous communications through both RS232 ports is not possible. In the unattended or default mode communications is done through the rear port. If local access is desired using the front port, then communications is transferred to the front port with the correct cable interface and keystroke. Communications is switched back to the rear port 15 minutes after the last keystroke.

RS232 communication can run simultaneously with network communications, DNP 3.0 or Modbus Plus.

Cable Connections

A standard 9 pin DTE to DCE RS232 (PC to modem) cable is required for the interface between a computer and the front port, and a modem and the rear port. To interface a computer with the rear port a null modem adapter (or separate null modem cable) is required.

> **NOTE:** *Connecting the incorrect serial cable from you computer or modem for ASCII communications to the network port may result in damage to the network card.*

ASCII/English Protocol

Off-the-shelf industry accepted communication programs such as Cross Talk™ or PROCOMM PLUS™ might be used to communicate with the relay in a (dumb) terminal emulation mode via either port. Also, up or down loading of settings and fault records is done using the program's Xmodem (Checksum or CRC) binary file transfer protocol.

The relay is delivered with the following communication settings for both the front and rear interfaces:

Bit rate 9600 - change to 115200 if supported by your computer's software, serial port or modem.

Word Length	8
Parity	None
Stop Bits	2

Optional network interfaces in addition to above may be provided depending on the substation network requirements.

Typical Communication Program Settings

The following settings are typical for communication programs. They may vary depending on your communications program and computer.

Terminal Emulation	DEC VT-100 or VT-102 (ANSI)
Binary Transfers	Xmodem (Checksum or CRC)
Terminal Preferences	Function, Arrow, and Ctrl Keys should be set to OFF
Baud Rate	115200 (based on modem and relay setting)
Data Bits	8 (relay setting)
Stop Bits	2 (relay setting)
Parity	None (relay setting)
Flow Control	None
Comm Port	Computer's communication port

Interfacing with the Relay

Power up the relay and start your communications program. Open the REL 512 communications file or make the appropriate communications program settings. When the communication settings are correct, the relay will display 'Root Menu'. If operating a Windows based program maximize your window for better overview. You advance through the menu by pressing the selected number or letter key. You backup to the previous ment by pressing < / >.

Save your communication program settings for REL 512 communications.

> **NOTE:** *If communication can not be established, please check the communication port settings by using the front UI. Also, remember that if you change the port settings for the active port when you are communicating with the relay, communications may be stopped. You will then need to change the settings of the communications program accordingly to re-establish communications.*

The REL 512 Interface Menu

> **NOTE:** *The < / > key is used to return to the previous menu level. This is done to avoid conflicts with communication prograns that use the < Esc > or arrow keys.*

The REL 512 has been designed with a menu system that allows viewing the state of selected logic elements, as well as changing relay settings and system parameters. The menus are self explanatory. A lower level menu or function is accessed by pressing the appropriate selection key number or letter. To return to an upper level, press < / >.

On the lower part of the screen, a status message showing the Active Group is continuously shown.

Root Menu

The Root Menu is the first menu seen upon establishing correct communications. The following Root Menu items are available:

[1] View Product Information

Relay product ID, serial #, software version(s), hardware status, etc.

[2] View Configuration Settings

View “only” of relay configuration settings. The following functions are available with this selection:

[1] Station ID

[2] System Parameters

[3] Comm Ports

[4] Data Display & Recording

[5] Set Date & Time

[3] View Protection Settings

View “only” any of 8 groups of relay protection settings. The following functions are available with this selection:

[1] Distance

[2] Out of Step

[3] Overcurrent

[4] Voltage O/U

[5] System Type

[6] Trip Type

[7] Breaker Failure

[8] Breaker Reclosing

[4] View I/O Mapping

View “only” the programmed I/O maps. The following functions are available with this selection:

[1] View DSP Relay Output Map

[2] View CPU Relay Output Map

[3] View Binary Input Map

[4] View PLC Output Map

[5] Monitoring Functions

Enables you to view the metering of line quantities, status of I/O, and status of operating elements and key logic signals. The following functions are available with this selection:

[1] Metering

[2] Binary Input Status

[3] Relay Output Status

[4] DSP Elements and Logic

[5] CPU Logic Scope A

[6] CPU Ligic Scope B

[6] Password Functions

The relay is shipped with "ABB" as a factory password setting. Changes can be made using this menu choice. The following functions are available with this selection:

[1] Edit Configuration Settings

[2] Edit Protection & I/O Map Group Settings

[3] Copy Protection & I/O Map Group Settings

[4] Set Active Group

[5] Send Settings to Relay

[6] Send Programmable Logic to Relay

[7] Reset LED Panel

[8] I/O Diagnostics

[9] Change Password

[A] Breaker Control

[7] Retrieve Data

The following functions are available with this selection:

[1] Receive Fault Records from Relay

[2] Receive Settings from Relay

The above selections are self explanatory and relatively easy to follow. Root Menu items [5] Monitoring Functions, [6] Password Functions and [7] Retrieve Data, however, will be discussed in more detail.

Monitoring Functions

[1] Metering

View the metered line quantities including phase, positive sequence, negative sequence, and zero sequence voltages and currents. Power flow quantities are also displayed.

[2] Binary Input Status

View the status (ON/off) of the binary inputs. ON means a voltage is applied.

[3] Relay Output Status

View the status (ON/off) of the contact outputs. ON means they are reverse of their normal open or closed state as set by the internal jumpers. Contacts 1 to 4 are normally set closed. Contacts 5 to 18 are normally set open.

[4] DSP Elements and Logic

View the operational status (Logical 1 or 0) of all the operating elements and key DSP logic signals.

[5] & [6] CPU Logic Scope A & B

Allows for monitoring of the logic state of selected CPU logic signals.

Password Functions

[1] Edit Configuration Settings

Refer to the Settings Tables for more information.

[1] Station ID

[2] System Parameters

[3] Comm Ports

[4] Data Display & Recording

[5] Set Date & Time

[2] Edit Protection & I/O Map Settings

A unique feature of the relay is that it maintains one active (operational) group of settings and parameters. In order to maintain operating security from undesired tripping the active group settings cannot be edited. To edit the active group, the active group values must first be copied to another group, 8 for example, edited and then be copied back to the active group. The settings copied to the active group become the “new” active group settings. An alternate method is to edit the settings of a nonactive group and then make the edited group the active group. Following either process the relay will reset momentarily going out of service load the new active settings. Settings and parameters are changed by toggling the space bar to toggle between choices or entering numerical values and pressing the enter key.

[1] Distance

[2] Out of Step

[3] Overcurrent

[4] Voltage O/U

[5] System Type

[6] Trip Type

[7] Breaker Failure

[8] Configure Output Maps

Selected operating units and logic signals can be mapped to operate any of 8 programmable output contacts. See I/O Mapping.

[9] Configure Input Maps

Any of 12 relay binary (voltage) inputs can be mapped to any of a number of selected logic signals, ... *Channel Receive #1, Channel Block #1, Open Breaker 52b, etc.* See I/O Mapping.

[A] Breaker Reclosing

Single breaker reclosing logic settings. Requires reclosing option module to be present.

[3] Copy Protection & I/O Map Settings

Copy the complete protection and I/O map group settings from one group to another. If the destination group is the active group, the relay will reset momentarily going out of service while loading new settings.

[4] Set Active Group

The active group is the group of settings that the relay is using for processing. This function allows setting another group to be active. The relay will reset when setting a new group to be the active group.

[5] Send Settings to Relay

Sends an off-line edited binary settings file to the relay via a communications program using Xmodem binary file transfer protocol.

> **NOTE:** Be sure to select the correct menu item numbers [5] or [6] when sending settings or programmable logic is the relay. For example, if sending a programmable logic file (*.pl) and you incorrectly select menu item [5] the transfer is attempted but the file is not accepted. A note indicating failure is displayed.

[6] Send Programmable Logic to Relay

Sends an off-line developed binary programmable logic file to the relay via the communications program using Xmodem binary file transfer protocol.

> **NOTE:** The prgroammable logic file (*.pl) used, must be sent (or resent) to the realy after the settings file (*.bin) has been sent tot he relay to assure proper implementation of the programmable logic.

[7] Reset LED Panel

Clears the front panel LEDs.

[8] I/O Diagnostics

This function tests the operation of the LEDs and relay outputs

[1] Cycle LEDs.

[2] Cycle Relay Outputs

[3] Single Relay Output

[9] Edit Relay Password

This allows editing of the relay password. You must know the existing password to change it. The default password is ABB or abb you have 15 minutes after energizing the relay to use this password to change to a new one.

[A] Breaker Control

This function allows the operation of the Trip contacts and a programmable output contact, Close, for operation of the connected power circuit breaker.

[1] Open Breaker

[2] Close Breaker

[3] Close Breaker with Supervision

Both Open Breaker and Close Breaker are unsupervised operations, which cause operation of the output contacts regardless of system conditions. Close Breaker with Supervision requires the optional reclosing module and operated through the Manual Close supervision functions.

Retrieve Data

[1] Fault Record

View the fault data summary currently stored in the relay and download a selected fault record. Select from a list of the latest 16 available records. The REL 512 is set to download using XModem protocol. Follow the instructions of your communication program for downloading files. Refer to AN-54L-00 in Section 10 for specific instructions using Windows™ Hyperterminal.

[2] Settings

Download the relay settings.

I/O Mapping

The Logic State of operating units or selected logic signals can be configured (mapped) to operate any of 8 programmable relay outputs. There are also 12 binary inputs that can be mapped to selected input signals for logic which requires external (to the relay) status information ...52B, 85CO, etc.

Mapping an operating element or logic signal with a binary input or contact output is done by placing an X at the corresponding intersection in the appropriate mapping matrix. This is done by moving the cursor to the desired intersection and toggling the space bar. The mapped signal can be removed by locating the cursor under the X and toggling the space bar.

It is also recommended to "Clear All Maps" before beginning map editing.

DSP Signals	Relay Output							
	2	3	4	5	6	7	8	9
PRT:	.	.	.	X	.	.	.	.
PFT:	.	.	.	.	.	.	.	.
DSP Trip:	.	.	.	.	X	.	.	.
Z1 Trip:	.	.	.	.	.	.	.	.
HS Trip:	.	.	.	.	.	.	.	.
59N Overvoltage:	.	.	.	.	.	.	.	.
Reverse 3PH:	.	.	.	.	.	.	.	.
Forward 3PH:	X	.	.	.	.	.	.	.
Reverse GF:	.	.	.	.	.	.	.	.
Forward GF:	.	.	.	.	.	.	.	.
OSB:	.	.	.	.	.	.	.	.
3PH Undervoltage:	.	.	.	.	.	.	.	.
Undervoltage:	.	.	.	.	.	.	.	.
50 M Supv 3PH:	.	X	.	.	.	.	.	.
50 M Supv PHASE:	.	.	.	.	.	.	.	.

Relay Inputs and Outputs

Output Contacts

Fixed (Non-Programmable) Outputs

The following logic signals are permanently mapped to the indicated contacts.

Table 3-2. Fixed Outputs

Signal or Function		Relay Output
Three Pole Trip	**Single Pole Trip**	
In Service Failure	In Service Failure	1
Breaker Failure Initiate	Breaker Failure Initiate	10
Time Delay Reclose Initiate	Time Delay Reclose Initiate	11
High Speed Reclose Initiate	High Speed Reclose Initiate	12
Fault Inception	Fault Inception	13
Pilot Channel Stop	Pilot Channel Stop	14
Pilot Channel Start	Pilot Channel Start	15
Trip	Trip Phase A-1	16
Trip	Trip Phase B-1	17
Trip	Trip Phase C-1	18

Programmable Outputs

There are two methods of programming outputs 2 through 9. One method is to use the off-line programmable logic editor, RELLOGIC, and program the outputs using a AND and OR gates, inverters, on and off-delay timers and latches. Information and available logic signals for programming with RELLOGIC is found in Section 7.

A second method of programming the outputs is to use the direct mapping function that ties a relay logic signal to an output contact. There are no associated logic gates, timers and etc. This mapping can be done as described in the previous discussion of I/O Mapping. This method is referred to as mapping.

The following DSP and CPU measuring unit and logic signals are mappable to contacts 2 through 9.

DSP Signals

HS TRIP	Z1 TRIP
DSP TRIP	PFT
PRT	50M SUPV PHASE
50M SUPV 3PH	UNDERVOLTAGE
3PH UNDERVOLTAGE	FORWARD GF
REVERSE GF	FORWARD 3PH
REVERSE 3PH	59N Overvoltage
OSB	

Programmable CPU Logic Signals

BREAKER FAILURE TRIP	BREAKER FAILURE RETRIP
INNER BLINDER	OUTER BLINDER
LOSS OF CURRENT ALARM	LOSS OF POTENTIAL BLOCK DIST
PILOT CHANNEL START	PILOT CHANNEL STOP
ZONE 2 TRIP	ZONE 3 TRIP
RECLOSE BLOCK	BKR FAIL RB
HSRI	TDRI
BREAKER FAILURE INITIATE	TCM/52 ALARM 1
TRIP COIL 1 MONITOR	TCM/52 ALARM 2
TRIP COIL 2 MONITOR	

The I/O logic signal functions are defined in Section 4.

Programmable Binary Inputs

The following inputs are programmable to the indicated logic signal.

85CO[1]	CHANNEL BLOCK 1[2]
CHANNEL BLOCK 2	CHANNEL RECEIVE 1[2]
CHANNEL RECEIVE 2	89B CLOSED
BREAKER 1 CLOSED 52A[4]	BREAKER 1 OPEN 52B[3]
TRIP CIRCUIT 1 (Trip Coil 1 Mon)	BREAKER 2 CLOSED 52A[4]
BREAKER 2 OPEN 52B[3]	TRIP CIRCUIT 2 (Trip Coil 2 Mon)
XBFI	86T
XLED RESET	XDFR
TRIP BLOCK	

[1] 85CO Pilot carrier on/off (or cutout) is a required input for pilot logic operation.

[2] CHANNEL RECEIVE 1 and CHANNEL BLOCK 1 (Channel Block required for Directional Comparison Unblocking logic) must be programmed for use in two terminal applications. That is, inputs labeled Channel Block 1 and Channel Receive 1 are required for both two and three terminal applications. Inputs labeled Channel Block 2 and Channel Receive 2 are also required for three terminal applications.

[3] If used, BREAKER 1 OPEN 52B and BREAKER 2 OPEN 52B must be mapped to the same input for single breaker applications. Separate inputs are required for two breaker applications . . . ring and 1-1/2 breaker.

[4] If used, BREAKER 1 CLOSED 52A and BREAKER 2 CLOSED 52A must be mapped to the same input for single breaker applications. Separate inputs are required for two breaker applications . . . ring and 1-1/2 breaker.

Miscellaneous Functions

Trip Coil Monitoring

Trip coil monitoring looks for no voltage across the open trip contacts while the breaker is closed (52a closed) or a voltage when the breaker is open (52a open) to indicate a trip coil or circuit problem.

To implement trip coil monitoring an external jumper needs to be made from the monitored trip output contact terminals to the binary input terminals that have been programmed for trip coil monitoring. For example, breakers #1 is to be tripped by relay 16 and monitored by input 5, and breakers #2 is to be tripped by relay 17 and monitored by input 6, the following connection chart would apply. The logic signals TRIP COIL 1 MONITOR and TRIP COIL 2 MONITOR must be mapped to input 5 and 6, respectively, for this example.

Table 3-3. Trip Coil Monitoring Connections

Breaker	From Trip Relay	Terminals	To Binary Input	Terminals
1	16	TB5 -15 (+)	5	TB3 - 9 (+)
		TB5 -16 (-)		TB3 -10 (-)
2	17	TB5 -17 (+)	6	TB3 -11 (+)
		TB5 -18 (-)		TB3 -12 (-)

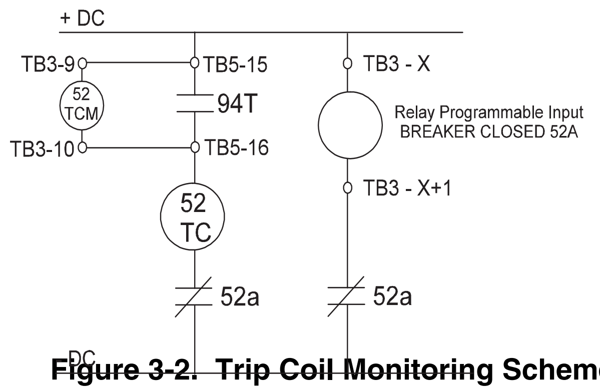


Figure 3-2. Trip Coil Monitoring Scheme

Changing the Settings from an External Switch

A binary switch can be used to change relay settings to any of setting groups 1 - 7. Three binary inputs are required, 10, 11 and 12. The inputs are combined in the relay to determine the correct group. To implement this operation the External Settings Change setting must be set to ENABLE. If enabled, the programmable inputs are used for this function. If disabled, the programmable inputs are available for other functions. This setting is found in the System Configuration Settings/System Parameters. A binary switch is used to apply dc voltage at the desired input terminals for at least 10 seconds. After 10 seconds the relay will reboot. Upon initializing the binary inputs will be read and the appropriate settings loaded. The new active group can be confirmed by viewing the UI display during the initializing process.

Table 3-4. External Switch Operation

Binary Input	**10**		**11**		**12**	
Terminal	TB3-19	TB3-20	TB4-1	TB4-2	TB4-3	TB4-4
dc Voltage Polarity	+	-	+	-	+	-
To Set group:						
No Change	0		0		0	
1	0		0		1	
2	0		1		0	
3	0		1		1	
4	1		0		0	
5	1		0		1	
6	1		1		0	
7	1		1		1	
	1 indicates an applied dc voltage for more than 10 seconds.					

Programmable Logic

Programmable logic can be used to provide auxiliary protection. control and testing functions unique to the application. The programmable logic files are created off line using RELLOGIC software (discussed in Section 7) and uploaded to the relay via your communications program. Viewing the PLC Mapping from the relay's View I/O Mapping in the main menu will allow you to see which contacts are being controlled by the programmable logic. There should be no mapped contacts on a new unit. If up loading new logic, a test procedure defined by the person /department responsible for developing the logic should be followed.

Settings and Application

This section provides detailed application and product setting information for engineers evaluating the suitability or characteristics of the relay; or by those who are determining the settings for applications, or providing instructions or documentation for use within their organizations. The application of each setting and all I/O logic signals are discussed.

Settings Notation

There are three basic types of settings. The first defining the relay setup parameters, the second defining the threshold operating value of the relay measuring elements (units), and the third defining logic operations. The following nomenclature defines the relationship between the settings and their application.

Relay Configuration Parameter Settings

SETTING (Configuration Parameter)

The setting is the value (or choice) of the relay configuration parameter ... CT ratio, communication bit rate, substation name, etc. The setting is shown in bold capital letters. The configuration parameter is shown in bold type and within parenthesis.

Operating Element Settings

SETTING (Operating Element Name) *Logic Variable Name*

The setting is the threshold value for which the relay operating element's output, the logic variable, changes state from logical 0 (False or not-operated) to logical 1 (True or operated). The setting is shown in bold capital letters. The operating element name which the setting controls is shown in bold type and within parenthesis. The logic variable name, which is the output of the relay operating element and used with the relay logic is shown in normal italics. The logic variable name is also used as the reference name for the operating element parameter ...current, voltage, ohms, etc. For example: for blocking pilot applications, the low set ground current, *50NL*, must be coordinated with the remote terminal's medium set ground current, *50NM.*

Logic Operation Settings

SETTING (Logic Operation)

The setting is used to enable or control relay logic operations ...close into fault, out of step, loss of potential, etc. The setting is shown in bold capital letters. The relay logic operation is shown in bold type and within parenthesis.

Protection I/O Mapping

LOGIC SIGNAL NAME

Also included in this manual are the definitions of logic signals that can be mapped (programmed) to either binary voltage inputs or a binary contact outputs.

Relay Configuration

Settings that pertain to the relay's location and general application are reviewed here.

Relay Location and Identification

STATION NAME (Substation Identification Name)

The name of the substation where the relay is applied. This insures a positive identification of the relay on disturbance records or when accessing the relay through remote communications.

BAY NAME (Bay Identification Name)

The identification of the breaker bay (or breaker number) in the substation where the relay is applied. This insures a positive identification of the relay on disturbance records or when accessing the relay through remote communications.

LINE NAME (Line Identification Name)

The name of the protected line (or remote terminal/substation name) where the relay is applied. This insures a positive identification of the relay on disturbance records or when accessing the relay through remote communications.

> **NOTE:** *Disturbance records are the digital fault records of system disturbances recorded and saved by the relay.*

Instrument Transformer Connections

VT RATIO (Voltage Transformer Ratio)

The turns ratio of the device that reduces system voltage to the appropriate level for the relay, for example 69000:69 volts for use on a 115000 volt system, to give a ratio of 1000:1. In this example the setting would be 1000.

CT RATIO (Current Transformer Turns Ratio)

The turns ratio of the device that reduces primary circuit current to the appropriate level for the relay, for example 1200:5 multi-ratio used on the 400:5 tap corresponds to an 80:1 ratio. The setting would be 80.

Power System Parameters

GND DIR POL (Ground Directional Polarization)

Several choices exist for polarizing of the ground directional units. Zero sequence voltage polarizing ($3V_0$) negative sequence voltage polarizing ($3V_2$) or dual polarizing $3V_0 / I_P$ may be selected. The zero sequence voltage polarizing is developed internally using the phase-to-ground voltages supplied to the relay. No external wye-ground-broken-delta auxiliary transformer is required.

Negative sequence voltage polarizing is generated internally by the directional algorithm and is compared to the negative sequence current to establish the direction to a fault.

Dual polarizing utilizes two directional measurements, one using zero sequence voltage polarizing ($3V_0$) and the other using zero sequence current polarizing(I_P), each then being compared with zero sequence current ($3I_0$) to establish the direction to a fault. The two measurements function in an "OR" mode. Either measurement may provide a common output to supervise other relaying elements. Zero sequence current polarizing (I_P) requires the availability of a separate current input from a power transformer neutral or delta winding.

For short line applications in which no zero sequence mutual problems exist, zero sequence voltage supervision is preferred. For long line applications in which no zero sequence mutual problems exist, dual polarizing is useful. The level of the two polarizing quantities are complementary for variations in source impedance and ground fault location, and also no detrimental effects occur when the polarizing current is not available.

Negative sequence voltage polarizing is most useful in long line applications where zero sequence mutual problems exist. Negative sequence mutual is insignificant and zero sequence mutual does not influence a negative sequence directional measurement.

In general, zero sequence voltage is higher than negative sequence voltage at the fault, but decreases more rapidly the farther away from the fault it is measured. This makes the use of zero sequence voltage polarizing preferable in short line applications where no mutual problems exist.

EXT SET SELECT (External Settings Selector)

If this setting is set to ENABLE then three binary inputs, 10, 11, 12 are used to change the active settings group. The binary combination of the three bits define the new group. The combinations for inputs 10, 11,12 are:

000 - Reset and no action	001 - Set group #1 active	010 - Set group #2 active
011 - Set group #3 active	100 - Set group #4 active	101 - Set group #5 active
110 - Set group #6 active	111 - Set group #7 active	

Data Display and Fault Recording

DATA CAPTURE (Data Capture Recording)

A fault record is recorded with every fault inception and trip the relay sees. The selected setting, however, determines if the fault record is to be saved. There are three settings, **DVDI**, **PILOT** and **TRIP**.

> **NOTE:** *When bench testing both the voltage and current must change to operate the Fault Inception mechanism for any records to be captured. (Voltage change at least 7 volts and current change at least 0.5 amperes.)*

DVDI is the fault inception and will save any record collected. This will include very remote faults as well. This could result in the saving of a large number of undesired records depending on the number of system disturbances. DVDI setting is recommended only when troubleshooting.

PILOT requires that the forward or reverse pilot impedance units operate. The coverage is determined by the forward and reverse pilot unit reach settings. If a pilot unit operation occurs within 14 cycles of the fault inception one record is saved. If a trip occurs more than 14 cycles after fault inception that is the result of a fault within the pilot zones, a second record will be saved. **PILOT** is the recommended setting.

TRIP records the same as the PILOT setting except it illuminates the LEDs only when the relay trips.

UNITS PRI/SEC (Analog Data Display in Primary or Secondary Units)

This choice allows voltage and current values, displayed on the UI or recorded in the disturbance target record, to be expressed in secondary terms or in primary terms. The secondary values are those actually applied to the relay while the primary values would be secondary values multiplied by the CT or VT ratio to give the actual power system values. This is a matter of personal choice.

Communication

There are three communication ports used for the customer to edit settings and access data generated or recorded by the relay. An RS232 (DB-9, female) serial interface is provided on the front of the relay to provide convenient local access to the relay with a portable PC computer. A second RS232 (DB-9, male) serial interface is provided on the rear and is intended for remote communication access through a modem. A third port is available for interfacing the relay to a substation automation system or SCADA. The physical connection will vary with the communication protocol requirements. The following defines the setting requirements for communications through these ports.

> **NOTE:** *Protocol is a structured communication language and physical media that permit communications between terminal applications.*

Front RS232 Communication Port Settings

The following settings define the data format and protocol for communicating through the front and rear RS232 ports. The settings for each port are independent and may be set differently because of different interface requirements.

FRNT BIT RATE (Front Port Bit Rate)

This is communication speed which the relay and the computer exchange data. It is often referred to as baud. The bit rate is limited by the terminal computer's modem and communication software. The relay allows communications at a bit rate between 2400 and 115,200 bps.

FRNT DATA LGTH (Front Port Data Word Length)

Word length is the number of bits used in a word. The word length or number of data bits for most modems and communications software is 7 or 8 bits. These are the choices provided by the relay. Refer to your modem and/or communications software for the appropriate word length setting.

FRNT PARITY (Front Port Parity)

Parity is a binary check value used in serial communications data formats to perform basic data communications error checks. The parity settings available with basic serial communications are no parity, odd parity or even parity. These are the choices provided by the relay. Refer to your modem and/or communications software for the appropriate parity setting.

FRNT STOP BITS (Front Port Stop Bits)

Stop bits are used to define the end of a word. The number of stop bits for most modems and communications software is 1 or 2 bits. These are the choices provided by the relay. Refer to your modem and/or communications software for the appropriate parity setting.

Rear RS232 Communication Port Settings

REAR BIT RATE (Rear Port Bit Rate)

This is communication speed which the relay and the computer exchange data. It is often referred to as baud. The bit rate is limited by the terminal computer's modem and communication software. The relay allows communications at a bit rate between 2400 and 115,200 bps.

REAR DATA LGTH (Rear Port Data Word Length)

Word length is the number of bits used in a word. The word length or number of data bits for most modems and communications software is 7 or 8 bits. These are the choices provided by the relay. Refer to your modem and/or communications software for the appropriate word length setting.

REAR PARITY (Rear Port Parity)

Parity is a binary check value used in serial communications data formats to perform basic data communications error checks. The parity settings available with basic serial communications are no parity, odd parity or even parity. These are the choices provided by the relay. Refer to your modem and/or communications software for the appropriate parity setting.

REAR STOP BITS (Rear Port Stop Bits)

Stop bits are used to define the end of a word. The number of stop bits for most modems and communications software is 1 or 2 bits. These are the choices provided by the relay. Refer to your modem and/or communications software for the appropriate parity setting.

Networks/SCADA Protocols

MODBUS +

This protocol is selected for network applications requiring the Modbus+ protocol. See the Modbus+ documentation for additional settings information.

DNP

This protocol is selected for network applications requiring the DNP 3.0 protocol. See the DNP documentation for additional settings information.

Impedance Elements

The REL 512 relay has 5 zones of phase and ground protection. Zones 1, 2, and 3 are for non-pilot step distance applications. The fourth and fifth zones, called Pilot Forward (Zpf) and Pilot Reverse (Zpr), are available for pilot protection or other user programmable function. Each zone has six impedance mho units and three quadrilateral units. They are:

3 phase and phase-to-phase protection:

2 - Three phase impedance units
1 - Phase-to-phase impedance unit

Phase-to-ground protection:

3 - Phase-to-ground impedance units

Zone-1 has an additional set of ground quadrilateral units.

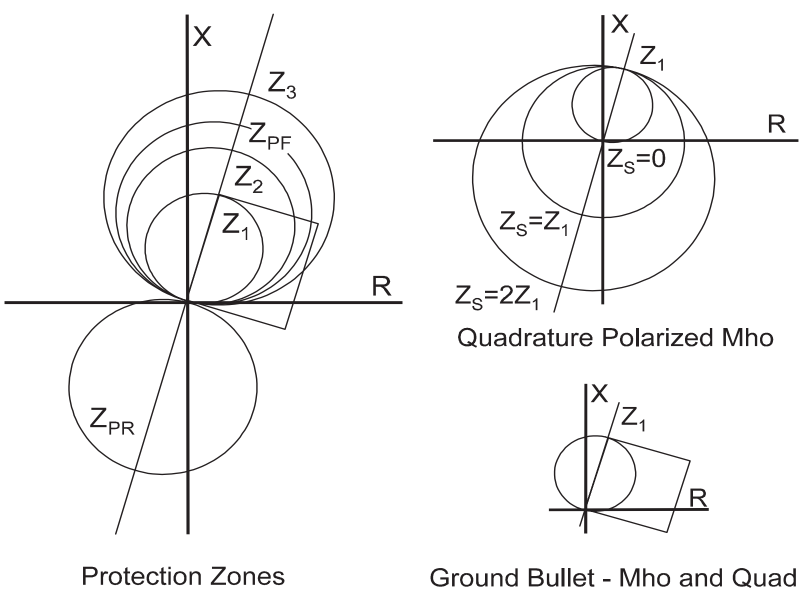


Figure 4-1. Impedance Measuring Units

Zone-1

Careful consideration should be given to using (or depending on) short line applications where Zone-1 for SIR is greater that 20. For these applications the operationg times may be excessive for faults beond 40% to 50% of the line. Zone-1 represents a portion of the protected transmission line near the relaying terminal. Faults in this region may be identified easily without requiring any information over a communications channel from the far terminal. This is a direct tripping function.

Z1 K0 MAG (Zone-1 Zero Sequence Compensation Magnitude)

The voltage appearing at the relay location for a ground fault on the protected line is influenced by the zero sequence current flowing to the fault. This influence is weighted by a factor K0 which contains both magnitude and angle. K0 is (Z0L-Z1L)/Z1L, where Z1L is positive sequence zone impedance and Z0L is zero sequence zone impedance. These are phasor values, and the total angle must be preserved for use as a setting. REL 512 allows an independent choice to be made of this factor for each of the zone settings. For the Zone 1 K0, the line impedance are used. The magnitude of the total quantity (Z0L-Z1L)/Z1L is K0 magnitude and may be entered into the relay. The range of settings available is 0 to 10 in increments of 0.01.

Z1 K0 ANG (Zone-1 Zero Sequence Compensation Angle)

The angle of (Z0L -Z1L)/Z1L is entered. The range of settings is -120 to +40 degrees in 1 degree increments.

Z1 LINE ANG (Zone-1 Line Angle)

This is the angle of the positive sequence impedance of the protected circuit. The range of settings is 10 to 90 degrees in 1 degree increments.

Z1 PH TRIP (Zone-1 Phase Trip)

The phase distance measuring units operate and execute appropriate protection or programmable logic, however, tripping can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

Z1 PH REACH (Zone-1 Phase Impedance Reach)

This is the setting for the phase distance function, which determines the maximum distance from the relay location that phase faults may occur and produce operation of that element. It is set in positive sequence secondary ohms. For a Zone 1 function, the reach is typically set for 90% of the line length. For example, a line having a total impedance of 14 ohms, a CT ratio of 1200:5 and a VT ratio of 1000:1 would have a secondary ohmic value of ZS = ZP RC/RV = 14(240/1000) = 3.36. A setting of 0.9 (3.36) = 3.02 ohms may be used. For the phase element, the accuracy of the positive sequence impedance data and the instrument transformers may allow a Zone 1 reach as high as 95%. The range of settings is 0.03 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 in 0.05 ohm increments for 1 A CT inputs. Note that the very low impedance settings, while available, may not be usable. Extremely large current is required for a fault at the balance point (depending on the source/line impedance ratio) when very low settings are used.

Z1 GND TRIP (Zone-1 Ground Trip)

The ground distance measuring units operate and execute appropriate protection or programmable logic, however, tripping can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

Z1 GND REACH (Zone-1 Ground Reach Impedance)

This is the setting for the ground distance function which determines the maximum distance from the relay location on the protected line that ground faults may occur and produce operation of that element. It is set in positive sequence secondary ohms. This reach setting may be the same as the phase reach previously described. The K0 magnitude and angle takes into consideration the influence of the line zero sequence impedance on the apparent distance to the fault. The range of settings for Z1 is 0.03 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 ohms in 0.05 ohm increments for 1 A CT inputs. Note that the very low impedance settings, while available, may not be usable. Extremely large current is required for a fault at the balance point (depending on the source to line impedance ratio) when very low settings are used. Also the maximum setting is limited by K0. The maximum accurate reach is 36/(1+K0/3) for 5 A or 180/(1+K0/3) fo 1 A. Beyond this value the unit will begin to underreach by more than 5%.

Z1 GND BULLET (Zone-1 Ground Bullet)

This setting enables the Zone-1 quadrilateral impedance unit. The quadrilateral unit's reach in the reactance direction is the Z1 GND REACH setting times the sine of the Z1 LINE ANG setting. The reach in the resistance direction is defined by the Z1 RESISTANCE setting below.

Z1 RESISTANCE (Zone-1 Quadrilateral Unit Resistance Reach)

This setting sets the resistive reach of the ground quadrilateral unit. It should be set to a maximum of 80% of the minimum phase load impedence.

Z1 RESISTANCE = $\mathrm{Real}\{V_{LN}/I_{LM}\}$
V_{LN} = Normal system maximum line to ground voltage
I_{LM} = Maximum phase load current

The resistance reach is not zero zequence compensated and therefore operation of the non-faulted phase units may result due to the resistance setting being larger than the load impedance.

Z1 OS BLOCK (Zone-1 Out-of-Step Block)

Choosing the ENABLE setting will activate this function. This allows the out-of-step block logic to inhibit operation of the Zone 1 phase element during system swings or out-of-step conditions. If out-of-step tripping (by other logic) is to be used, the blocking of Zone 1 may be enabled. If not, blocking of tripping may be DISABLE. This would allow Zone 1 phase to trip for out-of-step conditions. If this latter option is selected, the ability of the controlled circuit breakers to interrupt for out-of-phase conditions should be investigated.

Z1 RECL INIT (Zone-1 Reclose Initiate)

High speed reclosing, to be successful, must occur following high speed simultaneous tripping of the breakers at each end of the transmission line. Zone 1 tripping may be allowed to initiate high speed reclosing by selecting **HIGH SPEED**. Time delayed reclosing is usually applied with time delayed tripping, but may be desired for the application. Choosing **HIGH SPEED** or **TIME DELAY** allows further choices regarding the types of faults for which high speed or time delayed reclosing is desired.

By selecting **DISABLE**, all high speed and time delayed reclosing is prohibited, except as governed by other elements.

Z1 RI FLT TYPE (Zone-1 Reclose Initiate Fault Type)

To limit reclosing to only those cases involving phase-to-ground faults (for which the impact on nearby generators is limited), select PH-GND. To allow reclosing for both phase-to-ground and phase-to-phase faults, select PH-GND/PH-PH. To allow high-speed reclosing for all faults for which Zone 1 operates, select ALL FAULTS. If time delayed reclosing is selected ALL FAULTS is usually appropriate.

Z1 TD FAULTS (Zone-1 Time Delayed Faults)

This setting applies to applications where Z1 RECL INIT is selected as HIGH SPEED and Z1 RI FAULT TYPE is other than ALL FAULTS. If it is desired to time delay reclose for fault types not selected for high speed reclosing, then this setting should be ENABLE.

Zone-2

Zone-2 describes setting of a distance relay which allows it to detect all faults on the entire protected transmission line plus a pre-selected area beyond the next bus in the forward direction.

Z2 K0 MAG (Zone-2 Zero Sequence Compensation Magnitude)

Similar to the K0 setting for Zone 1, this factor is chosen to compensate for the influence of zero sequence current on the apparent impedance seen by the ground distance unit for faults on the line. The same magnitude K0 that was chosen for Zone 1 may be used for Zone 2, unless the protected circuit is not homogeneous and a different (Z0L-Z1L)/Z1L for the total line is calculated to be different from the Zone 1 value. The magnitude of K0 may be selected in the range of 0 to 10 in increments of 0.01.

Z2 K0 ANG (Zone-2 Zero Sequence Compensation Angle)

The angle of the total quantity (Z0L-Z1L)/Z1L may be selected in the range of -120 to +40 degrees in 1 degree increments.

Z2 LINE ANG (Zone-2 Line Angle)

This is the angle of the positive sequence impedance of the total protected circuit. The range of settings is 10 to 90 degrees in 1 degree increments.

Z2 PH TRIP (Zone-2 Phase Trip)

The phase distance measuring units operate and execute appropriate protection or programmable logic, however, tripping can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

Z2 PH REACH (Zone-2 Phase Impedance Reach)

This is the setting for the Zone 2 phase distance function which must reach the most remote multiple phase fault on the protected line plus providing remote backup for devices at the next station. While very large settings are desired in the interest of providing as much coverage as possible, even with the reach shortening effect of remote-end infeed, the Zone 2 phase unit cannot be allowed to over-reach any Zone 1 relay protecting other circuits connected to the remote bus. To deviate from this rule is to face the formidable task of coordinating phase and ground time delays on adjacent transmission lines. Zone 2 phase reach should be set to Z1 + Z1A where Z, is the total positive sequence impedance of the line and Z1A is the apparent impedance, with minimum infeed, of the line having the shortest Zone 1 setting for a fault at the end of that Zone 1. The range of Zone 2 phase magnitude settings is 0.03 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 ohms in 0.05 ohm increments for 1 A CT inputs.

Z2 PH DLY (Zone-2 Phase Time Delay)

A time delay to permit clearing of faults on or beyond the next bus. Zone-1 relays at that next bus must be allowed to operate and to initiate tripping of the breakers required to clear the fault. If the relays or breakers fail to perform that function, dependence for clearing such faults may fall to the Zone 2 relay. The time delay required for Zone 2 tripping is dependent on the relative operating times of Zone 2 and the remote relaying units such as Zone 1 (including any intentional Zone 1 delay) breaker clearing time and Zone 2 reset time. Selection of the phase and ground timer settings should also consider remote bus faults and remote breaker failure relay timing. Remote Zone 2 should not be allowed to trip until bus differential relays or breaker failure relays have had time to energize their lockout relays and clear the fault. With no Zone 1 delay and a 5 cycle breaker, the commonly used 15 cycle (0.25 sec) delay for Zone 2 tripping is more than adequate. Shorter times are possible with settings available from 0 to 10 seconds in 0.01 second increments. Longer times may be necessary to override remote breaker failure clearing times.

Z2 GND TRIP (Zone-2 Ground Trip)

The ground distance measuring units operate and execute appropriate protection or programmable logic, however, tripping can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

Z2 GND REACH (Zone-2 Ground Reach Impedance)

This is the setting for the Zone 2 ground distance function which determines the maximum distance from the relay location that ground faults may be recognized. It is set in positive sequence ohms. It must reach the most remote ground fault on the protected line plus providing remote backup for devices at the next station. The same restrictions in reach that apply to Zone 2 phase distance settings also apply to Zone 2 ground. The Zone 2 ground unit cannot be allowed to overreach any Zone 1 unit protecting other circuits connected to the remote bus. Zone 2 ground reach should be set to Z1 + Z1A where Z1 is the total positive sequence impedance of the line and Z1A is the apparent impedance with minimum infeed, of the line having the shortest Zone 1 setting, for a fault at the end of that Zone 1. Note that the effect of zero sequence as well as positive sequence infeed current must be considered.

In general a Zone 2 ground reach setting may be conservatively chosen to be the line impedance plus 50% of the impedance of the shortest line off of the next bus. Settings are available between 0.3 and 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 ohms in 0.05 ohm increments for 1 A CT inputs. Also, the maximum Zone-2 setting is limited by K0. The maximum accurate reach is 36/(1+K0/3) for 5A or 180/(1+K0/3) for 1 A. Beyond this value the unit will begin to underreach by more than 5%.

Z2 GND DLY (Zone-2 Ground Time Delay)

A ground delay is required for the same reasons that were outlined for the phase delay setting. Coordination is required with several remote devices: delayed Zone 1, bus relays and breaker failure clearing time. In general the commonly used 15 cycle (0.25 sec) time setting may be used, but the range of settings of 0 to 10 seconds with 0.01 increments allows higher settings if required.

Z2 OS BLOCK (Zone-2 Out-of-Step Block)

Choosing the ENABLE setting will activate this function. This allows the out-of-step block logic to inhibit operation of the Zone 1 phase element during system swings or out-of-step conditions. If out-of-step tripping (by other logic) is to be used, the blocking of Zone 1 may be enabled. If not, blocking of tripping may be DISABLE. This would allow Zone 1 phase to trip for out-of-step conditions. If this latter option is selected, the ability of the controlled circuit breakers to interrupt for out-of-phase conditions should be investigated.

Z2 RECL INIT (Zone-2 Time Delayed Reclose Initiate)

There are two outputs for reclose initiate functions. One for high speed reclose initiate and the other for a time delayed reclose initiate. Usually high speed tripping functions ...high set overcurrent, Zone-1 and pilot, provide a high speed reclose initiates where synchro-checking is normally not required for reclosing. Time delayed tripping functions ...Zone-2, Zone-3 and time delayed overcurrent issue a time delayed reclose initiate where synchro-checking is required.

Choosing **ENABLE** to permit time delayed reclosing on all faults.

By selecting **DISABLE**, all time delayed reclosing is prohibited, except as governed by other elements.

Zone-3

Zone-3 describes the setting of a distance relay which allows a reach setting to be greater than the Zone 2 setting. Zone-3 ground units are also used to detect two phase-to-ground faults and block Zone-1 and forward pilot single phase-to-ground tripping. The Zone-3 phase and ground reach settings should be 150% of the forward pilot zone reach setting.

Z3 K0 MAG (Zone-3 Zero Sequence Compensation Magnitude)

Similar to the K0 setting for Zone 2, this factor is chosen to compensate for the influence of zero sequence current on the apparent impedance seen by the ground distance for faults in the selected direction. Normally, the same K0 used for Zone 2 is used, if the lines off of the next forward bus are quite dissimilar from the protected line, K0 may be modified to reflect that difference.

The magnitude of K0 may be selected in the range of 0 to 10 in increments of 0.01.

Z3 K0 ANG (Zone-3 Zero Sequence Compensation Angle)

The angle of the total quantity (Z0L - Z1L)/Z1L may be selected in the range of -120 to +40 degrees in 1 degree increments.

Z3 LINE ANG (Zone-3 Line Angle)

This is the angle of the positive sequence impedance of the total circuit protected by the Zone 3 element. It is not a critical setting and a reasonable compromise is to use the protected line angle. For faults external to the protected line, infeed effect from out of phase generation will generally prevent possible refinement of this angle. The range of setting is 10 to 90 degrees in 1 degree increments.

Z3 PH TRIP (Zone-3 Phase Trip)

The phase distance measuring units operate and execute appropriate protection or programmable logic, however, tripping can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

Z3 PH REACH (Zone-3 Phase Impedance Reach)

This is the setting for the Zone 3 forward phase distance function. The Zone 3 relay is generally set farther than the Zone 2 phase distance function. Blinder supervision eliminates the restriction imposed on reach by load. The actual reach is obscured by the infeed effect of other circuits connected to the bus at the end of the protected line. The range of the Zone 3 phase reach settings is 0.03 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 ohms in 0.05 ohm increments for 1 A CT inputs.

Z3 PH DLY (Zone-3 Phase Time Delay)

A time delay to permit other phase elements to operate, if possible, thus producing a minimum outage area for faults. Zone 3 setting must be time-coordinated with the Zone 2 phase delay. With 0.25 second Zone 2 phase delay, 0.5 second Zone 3 phase delay is generally adequate to allow Zone 2 to trip through its phase delay and to have the circuit breaker clear the fault before Zone 3 phase delay can time out.

Z3 GND TRIP (Zone-3 Ground Trip)

The ground distance measuring units operate and execute appropriate protection or programmable logic, however, tripping can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

Z3 GND REACH (Zone-3 Ground Reach Impedance)

This is the setting for the Zone 3 distance function which determines the maximum distance from the relay location that ground faults may be recognized. It is set in positive sequence ohms. The Zone 3 ground distance element should be set farther than the Zone 2 and forward pilot ground distance zones, preferably to reach the end of the longest line off of the next forward bus. The actual reach is obscured by the infeed effect of other circuits connected to the bus at the end of the protected line. The range of the Zone 3 ground reach settings is 0.03 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 ohms in 0.05 ohm increments for 1 A CT inputs. The maximum Zone-3 setting is limited by K0. The maximum accurate reach is 36/(1+K0/3) for 5 A or 180/(1+K0/3) for 1A. Beyond this value the unit will begin to underreach by more than 5%.

Z3 GND DLY (Zone-3 Ground Time Delay)

The same principles described for Zone 3 phase delay apply as well to Zone 3 ground delay. 0.5 second phase delay is generally suitable to coordinate with Zone 2 ground.

Z3 OS BLOCK (Zone-3 Out-of-Step Block)

Each zone may be independently blocked, as selected, when an out-of-step or power system swing condition is detected. The function may be activated for Zone 3 by choosing the ENABLE setting. This allows the out-of-step block logic to inhibit operation of the Zone 3 phase element. Large reach setting suggests OS block should be enabled. However the long time setting provides considerable security, and Zone 3 time tripping is a last backup function and some prefer not to block it.

Z3 RECL INIT (Zone-3 Time Delayed Reclose Initiate)

The initiation of reclosing by the time delayed Zone 3 tripping for all fault types may be selected by choosing ENABLE for this setting.

Due to the multiple contingency nature of any Zone 3 operation, reclosing is not generally recommended and the setting should be DISABLE.

Forward Pilot Zone

Pilot is a designation applied to relaying systems which utilize a communication system between the two or more transmission line terminals. This gives the local terminal, information regarding the status of elements at each remote terminal. The REL 500 Series provides independent phase and ground pilot zones for pilot applications. For non-pilot applications these zones elements are available for other user defined applications using programmable logic. The reach of the pilot zones also controls the reach of the fault recording function.

FWP K0 MAG (Forward Pilot Zero Sequence Compensation Magnitude)

Similar to the K0 setting for Zone 1, this factor is chosen to compensate for the influence of zero sequence current on the apparent impedance seen by the ground distance unit for faults on the line. The same magnitude K0 that was chosen for Zone 1 may be used for forward pilot ground, unless the protected circuit is not homogeneous and a different (Z0L-Z1L)/Z1L for the total line is calculated to be different from the Zone 1 value. The magnitude of K0 may be selected in the range of 0 to 10 in increments of 0.01.

FWP K0 ANG (Forward Pilot Zero Sequence Compensation Angle)

The angle of the total quality (Z0L-Z1L)/Z1L may be selected in the range of -120 to +40 degrees in 1 degree increments.

FWP LINE ANG (Forward Pilot Line Angle)

This is the angle of the positive sequence impedance of the total protected circuit. The range of settings is 10 to 90 degrees in 1 degree increments.

FWP PH TRIP (Forward Pilot Phase Trip)

The phase distance measuring units operate and execute appropriate protection, pilot or programmable logic, however, tripping by the unit (without pilot) can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

FWP PH REACH (Forward Pilot Phase Impedance Reach)

This is the setting for the pilot phase distance function which must reach the most remote multiple phase fault on the protected line.

For pilot applications the forward pilot phase reach may be set without concern for coordinating with other devices. Contrary to the limitations of the Zone 2 forward reach, no such limits exists for the pilot phase element. In general the reach is set at 150% of the line positive sequence impedance. This may be done without concern of overreaching adjacent line Zone 1 phase elements. Also it need not consider maximum load conditions because of the inclusion of a selectable blinder load restriction function. It is set in positive sequence ohms. The range of pilot phase magnitude settings is 0.03 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 ohms in 0.05 ohm increments for 1 A CT inputs.

Using this zone for non-pilot tripping may require coordination with the other zone impedance reach elements. One such application would be to use the forward pilot zone to enhance Zone-2 coverage for some three terminal line applications where Zone-2 setting, limited by an adjacent short line connected to a remote bus, cannot overreach the other remote bus. Both the reach and time delay must be carefully coordinated with Zones 2 and 3.

FWP PH DLY (Forward Pilot Phase Time Delay)

This function complements the Z2 PH DLY function as discussed above. Unless there is a special need this unit would normally be set to DISABLE. DISABLE prevents direct time delayed tripping with the forward pilot zone, but still allows it to work with all pilot functions.

FWP GND TRIP (Forward Pilot Ground Trip)

The ground distance measuring units operate and execute appropriate protection, pilot or programmable logic, however, tripping by the unit (without pilot) can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

FWP GND REACH (Forward Pilot Ground Impedance Reach)

This is the setting for the pilot ground distance function which determines the maximum distance from the relay location that ground faults may be recognized. It is set in positive sequence ohms. It must reach the most remote ground fault on the protected line.

Parallel lines, having zero sequence contributions to remote ground faults have a reach-shortening effect on ground distance relays. The pilot ground element must cover the entire protected line even though a parallel line has a substantial zero sequence mutual effect and is contributing in the same direction to the fault. To assure total line coverage, in spite of this detrimental effect, it may be necessary to use a setting of as much as 160% of the total line impedance. Settings are available between 0.03 and 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 ohms in 0.05 ohm increments for 1 A CT inputs. The maximum forward pilot zone setting is limited by K0. The maximum accurate reach is 36/(1+K0/3) for 5A or 180/(1+K0/3) for 1 A. Beyond this value the unit will begin to underreach by more than 5%.

This element with its timer may also be used for time delayed tripping.

FWP GND DLY (Forward Pilot Ground Time Delay)

The same principles described for the forward pilot phase delay apply as well to forward pilot ground delay.

FWP OS BLK (Forward Pilot Out-of-Step Block)

Each zone may be independently blocked, as selected, when an out-of-step or swing condition is detected. This function may be activated for **FORWARD PILOT** by choosing the ENABLE setting. This allows the out-of-step block logic to inhibit operation of the pilot 3-phase elements during system swings or out-of-step conditions. Because of the large setting of the forward pilot phase element, it is advisable to ENABLE this function. Blinder (inner) supervision may be enabled (under the OUT-OF-STEP group of settings) for the pilot 3-phase element, even though **OUT-OF-STEP** blocking is disabled.

Reverse Pilot Zone

This is a function that serves as a supplement to the forward pilot relaying. Its logic is very much dependent on the chosen pilot system type. When used with a **BLOCKING** scheme, it serves as a carrier start function to complement the overcurrent carrier start. Coordination is required between the local reverse pilot settings and the remote forward pilot settings to assure that all external faults within the reach of the forward pilot element will be recognized by the reverse pilot element to cause channel keying to prevent tripping.

In **POTT** (permissive overreaching transfer trip) or unblocking applications, the reverse pilot element serves the purpose of controlling the transient blocking function to avoid undesired tripping for faults on adjacent lines for which sequential clearing occurs. Reverse pilot prevents echo keying for reverse faults, and also prevents weakfeed tripping for external faults.

This zone is also available for backup tripping functions or other user programmed applications for both pilot and non-pilot applications. Also, the reach of the pilot zones also controls the reach of the fault recording function.

<u>RVP K0 MAG (Revere Pilot Zero Sequence Compensation Factor Magnitude)</u>

The same setting used for **FWP K0 MAG** should be used for reverse pilot. For “through” faults it is imperative that the two systems respond in the same way.

<u>RVP K0 ANG (Reverse Pilot Zero Sequence Compensation Angle)</u>

The same setting used for **FWP K0 ANG** angle should be used for reverse pilot.

<u>RVP LINE ANG (Reverse Pilot Line Angle)</u>

The same setting used for **FWP LINE ANG** should be used for reverse pilot.

<u>RVP PH TRIP (Reverse Pilot Phase Trip)</u>

The phase distance measuring units operate and execute appropriate protection, pilot or programmable logic, however, tripping by the unit can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

<u>RVP PH REACH (Reverse Pilot Phase Impedance Reach)</u>

When using the **BLOCKING** system type, this setting must be chosen carefully to assure that all external faults which can be recognized by the remote **forward pilot** element will be recognized by this local **REVERSE PILOT** element. In general, a reach setting of 50-70% of the setting of the remote **FWP PH REACH** will be adequate. The range of settings available is 0.03 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 0.15 to 180 ohms in 0.05 ohm increments for 1 A CT inputs.

In the POTT and UNBLOCK systems, weak-feed trip is based upon undervoltage and no reverse element operation. For tripping to occur, the remote FORWARD PILOT elements must operate. To assure compatibility between the undervoltage and the REVERSE PILOT action, the REVERSE PILOT relay must recognize all external faults that can be detected by the remote FORWARD PILOT elements. By using the same setting strategy for POTT and UNBLOCK, REVERSE PILOT as is recommended for the BLOCKING scheme, security will be assured.

If the PUTT (permissive underreaching transfer-trip) pilot system type is chosen the REVERSE PILOT function serves no useful purpose, and the distance functions may be set for zero reach.

RVP PH DLY (Reverse Pilot Phase Time Delay)

The reverse pilot zone may be used to provide backup protection for bus faults. The phase delay should exceed the 87B plus 86B plus breaker time plus margin. A setting as low as 0.17 seconds may be possible, thus preventing remote Zone 2 relays from operating for backup bus tripping by the reverse pilot element.

RVP GND TRIP (Reverse Pilot Ground Trip)

The ground distance measuring units operate and execute appropriate protection, pilot or programmable logic, however, tripping by the unit can be enabled or disabled. This allows the use of the units for other functions. The setting choices are ENABLE or DISABLE.

RVP GND REACH (Reverse Pilot Ground Impedance Reach)

A setting identical to that used for PHASE REACH may be selected. The maximum reverse ground setting is limited by K0. The maximum accurate reach is 36/(1+K0/3) or 180/(1+K0/3). Beyond this value the unit will begin to underreach by more than 5%.

RVP GND DLY (Reverse Pilot Ground Time Delay)

The same principles described for the forward pilot phase delay apply as well to reverse pilot ground delay.

Line Characteristics

LN LGTH UNITS (Line Length Units)

This setting defines the units of length, as miles or kilometers, that will be displayed for the distance to fault on the UI and in the target record.

LN R PU (Resistance Per Line Length Unit)

This is the resistive impedance per unit of the protected line. It is expressed in secondary ohms/mile or ohms/kilometer. This value is used in fault location calculations.

LN X PU (Reactance Per Line Length Unit)

This is the reactive impedance per unit of the protected line. It is expressed in secondary ohms/mile or ohms/kilometer. This value is used in fault location calculations.

Out-of-Step and Load Restriction

Out-of-step conditions involve the loss of synchronism of a machine or collection of machines with respect to another part of the power system. Another related phenomenon is a stable swing condition which has a similar character, but for which no instability occurs. Out-of-step conditions require that the two system segments be separated and that, possibly after load shedding, they be re-synchronized. Swing conditions produce voltages and currents within the system which may cause undesired operation of distance relaying functions. Out-of-step conditions must be corrected by tripping either through this relaying system or through another which will produce a more equitable generation load match following the separation. Stable swing conditions are self-restoring and require no tripping, but may require blocking of certain distance relaying elements.

Out-of-step (unstable) and stable swing conditions are both sensed by the relative time of operation of an outer blinder sensing function and an inner blinder sensing function. Faults may cause them to operate essentially simultaneously whereas swing conditions produce sequential operation of first the outer blinder and then the inner blinder. For the REL 512 50 milliseconds is the time limit for which the outer blinder must operate and the inner blinder not operate (time between points 1 and 2) to establish that the condition being observed is a swing and not a fault. Swings take a longer time than this value while faults take less.

Out-of-step conditions involve a trajectory (as time passes) of ohms on the R-X (resistance-reactance) diagram (see figure below) such that the moving ohmic value enters from one side crossing the outer blinder first (point 1) and then the inner blinder (point 2), crosses the circular impedance characteristics, and departs from the other side (points 3 and 4). Once point 2 is crossed the swing is considered unstable. Stable swing conditions cause the ohmic trajectory to emerge from inside the outer blinder moving toward the direction from which it entered (from point 1 back to 5). The inner blinder is never crossed. This difference allows a distinction to be made between stable swings (recoverable) and unstable swings (unrecoverable).

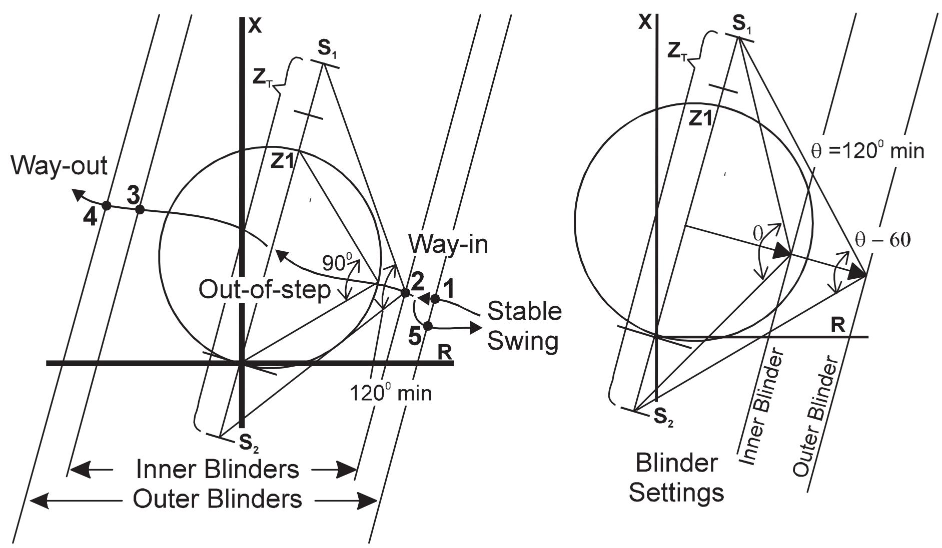


Figure 4-2. Out-of-Step

Blinder Settings

<u>BLNDR INNER R (Inner Blinder Resistive Reach)</u>

This is the resistance setting for the inner blinder. If it is to be used for load restriction it must have a setting sufficiently low (in ohms) to avoid operation on the minimum stable swing ohms expected. Similarly it must have a setting sufficiently high to accommodate the maximum fault resistance that is likely to be encountered for 3-phase faults on the protected line. Operation of the 3-phase distance function for all zones can be avoided for swing angles (between the two equivalent sources) as great as 120^0 if the inner blinder is given a resistance setting of 0.288 Z_T (derived from basic trig) or less, where Z_T is the protected line positive sequence impedance plus the sum of the lowest positive sequence source impedances at each end of the line. The minimum setting should accommodate a 3-phase fault resistance value of at least 0.1 Z_T ohms based on an arc voltage of 400 volts per foot (primary) and typical phase separation.

Using the average of these two conservative figures a reasonable value to use for the inner blinder resistance setting is 0.2 Z_T. The range of settings available is 1 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 5.0 to 180 ohms in 0.05 ohm increments for 1 A CT inputs.

This blinder is unrelated to the similar characteristic element which is part of the quadrilateral ground function, and therefore requires an independent setting.

BLNDR OUTER R (Outer Blinder Resistive Reach)

The outer blinder resistance setting must be chosen to assure proper distinction between faults and swing conditions. Based upon a severe swing rate (20^0 per cycle), the outer blinder may be set at 2.5 times the inner blinder setting, and the swing ohms will remain between blinders for at least 50 ms. This time represents approximately a 60^0 swing between blinders at 60 Hz. For faults, essentially simultaneous operation of the two blinders (four blinder lines) identifies the fact that it is a fault. For faster swings, a wider separation of the outer blinder from the inner settings is required. A 2 ohm (secondary) separation has been used historically with success. Sustained load must not be allowed to operate the outer blinder because it will block 3-phase fault tripping. The range of resistance settings available is 1.0 to 36 ohms in 0.01 ohm increments for 5 A CT inputs or 5.0 to 180 ohms in 0.05 ohm increments for 1 A CT inputs.

BLNDR ANG (Blinder Angle)

The blinder angle is chosen to be the same as the line angle unless some special consideration dictates otherwise. The range of settings is 0 to 90^0 in 1.0 degree increments.

Out-of-Step System Type

OS TYPE (Out-of-Step System Type)

The options which may be selected for **OS** system type are **OS BLK, OS TRIP** and **DISABLE. OS BLK** allows the blocking of tripping of selectable zone, 3-phase elements following the detection of a swing (stable or unstable) condition, **OS TRIP** selection provides the **OS BLK** function and produces a trip following satisfaction of the out-of-step trip logic. **DISABLE** blocks the operation of the out-of-step logic.

Load Restriction

LD RESTRICTION (Load Restriction)

The Load Restriction function allows the use of the inner blinder to restrict the trip area on the R-X diagram for all of the 3-phase elements. This prevents undesired tripping due to very large loads.

Load restriction should also be enabled if out-of-step blocking or tripping is enabled. This insures correct out-of-step functioning where the blinders intersect the impedance characteristics.

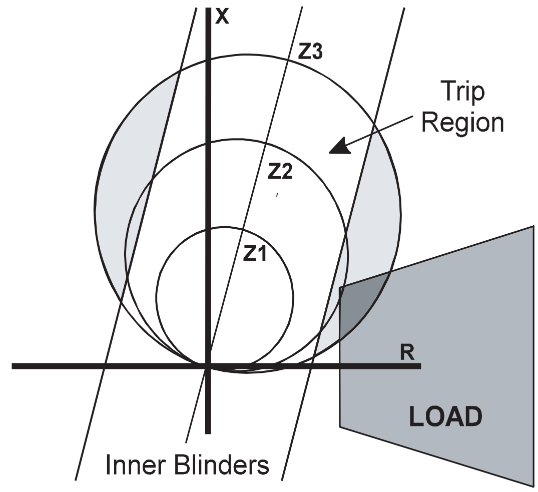


Figure 4-3. Load Restriction

Out-of-Step Block

OS OVRD TM (Out-of-Step Override Time)

The out-of-step override timer releases the out-of-step blocking or out-of-step tripping logic, depending on which is enabled, in the event an apparently slow moving impedance swing is actually an internal three phase fault. If a 3-phase fault does occur, tripping is desired immediately. On the other hand, a slow transition of swing ohms through the inner blinder area should not produce tripping through this logic, unless the protected line is jeopardized thermally. In general, a 0.4 second time setting is suitable. The range of settings available is 0.4 to 4.0 seconds in 0.01 second increments.

Out-of-Step Trip

OST TIME 1 (Out-of-Step Trip Time 1)

The outer blinder has operated and a swing condition is established. This timer is to insure that more than a momentary operation of the inner blinder has occurred before committing to an out-of-step trip. The timer should be set for 0.02 seconds. The range of settings is 0.0 to 0.12 seconds in 0.01 second increments.

OST TIME 2 (Out-of-Step Trip Time 2)

This timer insures that for 'tripping' on the 'way-out' that adequate time has elapsed between blinders (inner blinders reset, point 3 and outer blinders reset, point 4). The recommended time is 0.02 seconds. The range of settings is 0.0 to 0.12 seconds. When the outer blinder resets, the dropout time of OS TRP TM 2 prevails for a short period. When BOS, the supervised outer blinder resets, a trip period is established after 20 ms for 500 ms of out-of-step tripping.

OST RESET TIME (Out-of-Step Trip Reset Time)

This is the reset time associated with OS TRP TM1 and OS TRP TM2. It must persist for a period of time sufficiently long to commit the 20/500 ms timer to operation for 'way-out' tripping. The recommended setting is 0.05 seconds. The range of times available is 0.0 to 0.16 seconds in 0.01 second increments.

OST, WAY IN/OUT (Out-of-Step Tripping on the Way In or Way Out)

Tripping for out-of-step conditions may be selected to occur on the way in as the swing ohms progress into the trip area of the inner blinder (point 2) or on the way out as it departs from the trip area of the outer blinder (point 4). The choice is dictated by the swing rate expected.

Tripping on the "way-out" produces a much softer impact on the circuit breaker involved because of the more favorable transient recovery voltage that results from tripping at a smaller angle between the two system segments that must be separated because of loss of synchronism. Tripping on the "way-in" is reserved for the massive systems whose angular movement with respect to one another is very slow during separation. There is a real danger that transmission line thermal damage may occur if tripping is delayed until a more favorable angle is reached.

In general, choose tripping on the "**WAY-OUT**" where the swing rate is expected to be sufficiently fast, such that no transmission line thermal problems will result in the process. Otherwise choose "**WAY-IN**".

OS OVRD TM (Out-of-Step Override Time)

The out-of-step override timer is the same timer discussed in the Out-of-Step Block Section above.

Instantaneous Overcurrent Elements (Type 50)

High Set Overcurrent Elements and Functions

HS 50P PU (High Set Phase Overcurrent Pickup) *50H*

This setting sets the pickup current value for the high set phase overcurrent unit. The unit can be set to pickup from 2 to 100 amps in 0.1 amp increments for 5 A CT inputs or from 0.4 to 20 amps in 0.02 amp increments.

HS 50P TRP (High Set Phase Overcurrent Trip) *50H*

This setting enables tripping with the high set phase overcurrent unit. High speed tripping with the high set phase overcurrent unit is permitted for close proximity faults well within the Zone-1 reach. The optimum use of highset trip is to coordinate tripping for remote faults. In a networked system it is desirable not to trip for faults at the remote bus and trip for line end faults at the remote when the remote breaker is open. This ability depends on the system configuration , fault current levels and the margin between them. The *50H* units are set by coordinating three phase fault currents. The settings are ENABLE or DISABLE. Additional settings associated with the high set phase overcurrent unit are:

HS 50P DIR

This setting enables forward directional supervision of the high set phase overcurrent unit. To confine tripping to line faults only, it is normally recommended to set the high set unit to be directionally supervised. Directionality may be inherent with strong reverse sources and therefore it may be preferred that the directional setting not be used in order to have improved tripping dependability. The settings are ENABLE or DISABLE.

HS 50N PU (High Set Ground Overcurrent Pickup) *50NH*

This setting sets the pickup current value for the high set ground overcurrent unit. This unit measures the residual ground current $3I_0$. The unit can be set to pickup from 2 to 100 amps in 0.1 amp increments for 5A CT inputs or from 0.4 to 20 amps for 1A CT inputs.

HS 50N TRP (High Set Ground Overcurrent Trip) *50NH*

This setting enables tripping with the high set ground overcurrent unit. High speed tripping with the high set ground overcurrent unit is desirable for close proximity faults well within the Zone-1 reach. The optimum use of high set trip is to coordinate tripping for remote faults. In a networked system it is desirable not to trip for faults at the remote bus and trip for line end faults at the remote when the remote breaker is open. This ability depends on the system configuration , fault current levels and the margin between them. The *50NH* units are set by coordinating single phase-to-ground fault currents. The settings are ENABLE or DISABLE. Additional settings associated with the high set ground overcurrent unit are:

HS 50N DIR

This setting enables directional supervision of the high ground overcurrent unit. To confine tripping to line faults only, it is normally recommended to set the high set unit to be directionally supervised. Directionality may be inherent with strong reverse sources and therefore it may be preferred that the directional setting not be used in order to have improved tripping dependability. The settings are ENABLE or DISABLE.

HS 50Q PU (High Set Negative Sequence Overcurrent Pickup) *50QH*

This setting sets the pickup current value for the high set negative sequence overcurrent unit. This unit measures $3I_2$. The unit can be set to pickup from 2 to 100 amps in 0.1 amp increments for 5 A CT inputs or from 0.4 to 20 amps in 0.02 amp increments for 1 A CT inputs.

HS 50Q TRP (High Set Negative Sequence Overcurrent Trip) *50QH*

This setting enables tripping with the high set negative sequence overcurrent unit. Large negative sequence currents are produced as a result of phase-to-phase faults. High speed tripping for these faults is desirable for close proximity faults well within the Zone-1 reach. The optimum use of highset trip is to coordinate tripping for remote faults. In a networked system it is desirable not to trip for faults at the remote bus and trip for line end faults at the remote when the remote breaker is open. This ability depends on the system configuration , fault current levels and the margin between them. The *50QH* units are set by coordinating phase-to-phase fault currents. The settings are ENABLE or DISABLE. Additional settings associated with the high set ground overcurrent unit are:

HS 50Q DIR

This setting enables directional supervision of the high I2 overcurrent unit. To confine tripping to line faults only, it is normally recommended to set the high set unit to be directionally supervised. Directionality may be inherent with strong reverse sources and therefore it may be preferred that the directional setting not be used in order to have improved tripping dependability. The settings are ENABLE or DISABLE.

HS 50 RI (High Set Overcurrent Reclose Initiate)

High speed reclosing, to be successful, must occur following high speed simultaneous tripping of the breakers at each end of the transmission line. High set overcurrent tripping may be allowed to initiate high speed reclosing by selecting **HIGH SPEED**. Time delayed reclosing is usually applied with time delayed tripping, but may be desired depending on the application. Choosing **HIGH SPEED** or **TIME DELAY** allows further choices regarding the types of faults for which high speed or time delayed reclosing is desired.

By selecting DISABLE, all high speed and time delayed reclosing is prohibited, except as governed by other elements.

HS RI FAULT TYPE (Reclose Initiate Fault Type)

To limit reclosing to only those cases involving phase-to-ground faults (for which the impact on nearby generators is limited), select PH-GND. To allow reclosing for both phase-to-ground and phase-to-phase faults, select PH-GND/PH-PH. To allow reclosing for all faults for which the high set overcurrent element operates, select ALL FAULTS. If time delayed reclosing is selected ALL FAULTS is usually appropriate.

HS TD FAULTS (High Set Overcurrent Time Delayed Faults)

This setting applies to where HS 50RI is selected as HIGH SPEED and HS RI FAULT TYPE is other than ALL FAULTS. If it is desired to time delay reclose fro fault types not selected for high speed reclosing then this setting should be ENABLE.

Medium Set Overcurrent Elements and Functions

MS 50P PU (Medium Set Phase Overcurrent Pickup) *50M*

The medium set phase overcurrent supervises the inner and outer blinder units for the out of step logic, and the phase distance units enabling them to operate if the setting value is reached. The setting range is 0.5 to 12 amps with 0.1 amp increments for 5 A CT inputs or 0.1 to 2.4 with 0.02 amp increments for 1 A CT inputs. The setting should be set as low as possible, influenced only by the maximum load current and minimum phase-to-phase fault current. Phase-to-phase fault current must be above the setting value and within the protecting zone before tripping is allowed. This unit is also used in the single pole tripping logic if applied.

MS 50N PU (Medium Set Ground Overcurrent Pickup) *50NM*

The medium set ground pickup current, *50NM*, is always forward directional and used in the single pole trip, loss of current and pilot logic and time delayed directional overcurrent tripping. This unit measures $3I_0$. The setting range is 0.5 to 12 amps with 0.1 amp increments for 5 A CT inputs or 0.1 to 2.4 with 0.02 amp increments for 1 A CT inputs. The setting should be as low as possible and is influenced by the maximum ground current ($3I_0$) which may exist with unbalanced loads or during transient switching operations which influence line current for periods long enough for relay tripping to occur (usually load break switches or breakers with pole spans greater than 8 ms).

Ground current coordination with the remote terminal for blocking pilot schemes is also required. Single phase to ground fault current must be above the setting before tripping of the ground distance units is permitted. For blocking pilot schemes, *50NM* must coordinate with and not overreach the reverse directional supervised low set ground pickup current, *50NL*, at the remote terminal. Maximum sensitivity is desired for detection of high resistance ground faults and a setting ratio (med set local/ low set remote) of 2 is normally recommended.

MS 50N TRP (Medium Set Ground Overcurrent Trip) *50NM*

For step distance applications, definite time overcurrent backup protection is achieved by enabling the forward directional medium set overcurrent ground trip. The trip time must be set with the medium set ground time delay, **MS 50N DLY**, and be coordinated with remote terminals.

For Pilot applications, enabling the medium set overcurrent also requires that a setting be chosen for the medium set ground delay timer. This time setting delays the directional overcurrent element long enough to allow the ground distance unit to control the channel and overreaching pilot tripping if it is able to operate. If the fault resistance is too high for the ground distance element and above the setting of *50NM* (and within the sensitivity limit for ground directional sensing) normal pilot tripping will result for internal faults. A delay of 0.05 seconds is suggested for normal applications.

Where zero sequence mutual problems exist and an overreaching pilot system is selected choose **DISABLE** to avoid a possible false trip, or use negative sequence for the ground directional element.

MS 50N DLY

Sets the trip time for the medium set ground trip function if selected. The range of settings for the timer is 0 to 10.0 in 0.01 seconds increments.

MS 50Q PU (Medium Set Negative Sequence Overcurrent Pickup) *50QM*

The medium set negative sequence pickup current, *50QM*, is always forward directional. This unit measures $3I_2$. The setting range is 0.5 to 12 amps with 0.1 amp increments for 5 A CT inputs or 0.1 to 2.4 with 0.02 amp increments for 1 A CT inputs. The setting should be set as low as possible and is influenced by the maximum negative sequence current which may exist under normal operating conditions... non-transposed lines, unbalanced loads, transient switching operations which influence line current for periods long enough for relay tripping to occur (usually load break switches or breakers with pole spans greater than 8 ms).

MS 50Q TRP (Medium Set Negative Sequence Overcurrent Trip) *50QM*

Definite time I_2 overcurrent backup protection is achieved by enabling the forward directional medium set I_2 overcurrent trip. The trip time must be set with the medium set I_2 time delay, MS 50Q DLY, and be coordinated with remote terminals.

MS 50Q DLY

Sets the trip time for the medium set I_2 trip function if selected. The range of settings for the timer is 0 to 10.0 in 0.01 seconds increments.

Low Set Overcurrent Elements and Functions

LS 50P PU (Low Set Phase Overcurrent Pickup) *50L*

The low set phase pickup current is used in the close into fault trip and load loss accelerated trip logic. The setting range is 0.5 to 12 amps with 0.1 amp increments for 5 A CT inputs or 0.1 to 2.4 with 0.02 amp increments for 1 A CT inputs. The relay looks for current above the line charging current and no voltage to detect a close into fault condition. Therefore, the setting should always be above protected line’s charging current. The charging current increases with the line length and a setting of 0.5 A is usually sufficient except for very long lines. For load loss accelerated trip, the relay looks for the loss of balanced load current due to the remote line breaker clearing of an end zone (Zone-2 region of the local breaker) fault. When this condition is detected the Zone-2 timer is bypassed for accelerated Zone-2 tripping. The low set phase pickup for this application must be greater than the maximum tapped load on the protected line. If there are no tapped loads, a setting of 0.5 A is generally adequate.

LS 50N PU (Low Set Ground Overcurrent Pickup) *50NL*

The low set ground current, *50NL*, is used in the close into fault trip, out of step, loss of potential and pilot logic. The setting range is 0.5 to 12 amps with 0.1 amp increments for 5 A CT inputs or 0.1 to 2.4 with 0.02 amp increments for 1 A CT inputs. The loss of potential logic (blown fuse, open phase, etc.) will be blocked to allow tripping if *50NL* is true. The relay also looks for *50NL* and no voltage to detect a close into fault condition. For blocking pilot applications, *50NL* is directionally supervised in the reverse direction and must be coordinated with and overreach the forward looking medium set ground pickup current, *50NM*, at the remote terminal.

LS 50Q PU (Low Set Negative Sequence Overcurrent) *50QL*

There is no setting as the *50QL* is provided with a fixed threshold of 0.5 A. This unit measures 3I2. The low set negative sequence *50QL* current and low set ground *50NL* current indicate the presence of a fault and therefore block out-of-step operation.

Inverse Time Overcurrent Elements (Type 51)

Time Overcurrent Characteristics

ANSI/IEEE

The characteristic equation for the time overcurrent operate and reset characteristics based on the proposed IEEE Standard PC37.112 are:

$t(I) = [A/(M^p - 1) + B]td/5$ $\quad M > 1$ (operate)

$t = [t_r/(M^2 - 1)]td/5$ $\quad 0 < M < 1$ (reset)

where: t(I) = time to operation for the input current I

A = A constant (ie. 51P BU A VALUE)

I = input current

$M = I/I_{pu}$ (ie. for I = 5 x 51N BU PICKUP, M = 5)

p = p constant (ie. 51N Z2 p VALUE)

B = B constant (ie. 51P BU B VALUE)

td = time dial (ie. 51N BU TIME DIAL)

tr = reset time for I= 0 as determined by test on the CO family

The expression, td/5, is a modification to the IEEE equations to account for different time dial settings. This follows the desired intent of time dials and that is that the time dial setting of *2n* will result in an operating time two times that of a time dial setting of *n* for a given current. The constants A, B, p, and tr are determined for a curve near the middle of the time dial range. In the case of the CO family, time dial 5, is very near the middle setting for the range 0.5 to 11.0. For other curve families the constants should be determined for the time dial nearest the center of the family range, td_m. then the td setting (ie. 51P BU TIME DIAL) would be:

$td = (\text{desired family time dial}/td_m)5$

For example: The MCO curves have a time dial range of time dial curves from 3 to 63. Time dial 30 would be selected as the median and p, A, and B would be computed from it and entered as settings. If you wanted to use the MCO time dial 15 characteristic you would compute td = (15/30)5 and enter 2.5 as the time dial setting.

If you determine the constants directly from a specifically desired curve then the td setting should be 5.

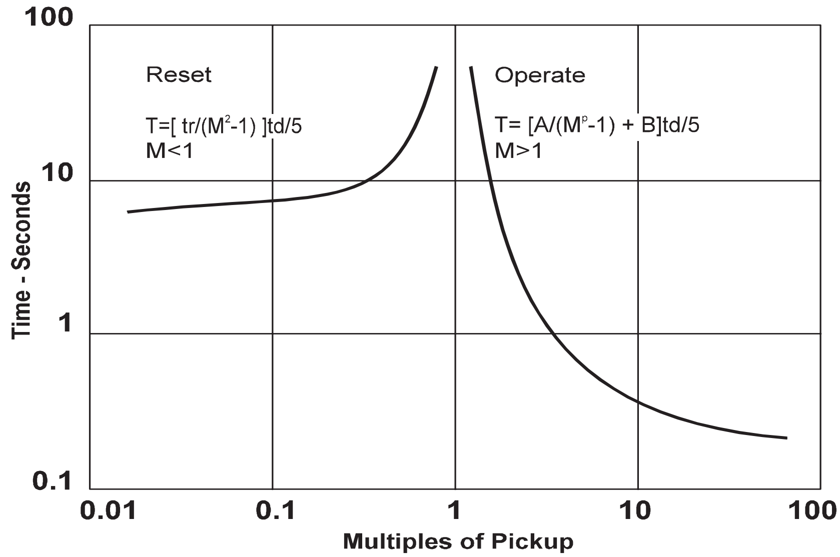


Figure 4-4. Inverse Time Overcurrent Characteristics

Following are the appropriate constants which provide a close emulation of the CO family characteristics.

Table 4-1. Type CO Induction Relay Family Models

Curve Type	CO	A	B	p	tr (sec.)
Short Time	CO-2	0.526	0.131	0.8	1.9
Long Time	CO-5	24.21	9.833	1.1	39.0
Definite Time	CO-6	1.582	0.967	1.4	3.1
Moderately Inverse	CO-7	0.047	0.183	0.02	5.4
Inverse	CO-8	29.239	0.827	2.0	30.0
Very Inverse	CO-9	20.602	0.479	2.0	21.0
Extremely Inverse	CO-11	27.85	0.14	2.0	26.5

IEC

A very similar equation is used in IEC markets.

$t(I) = K/(M^p - 1)\ tm$ $M > 1$ (operate)

where: K = A constant (ie. 51P BU A VALUE) as defined above, and

tm = time multiple.

The time dial setting (ie. 51N BU TIME DIAL) is the time multiple times 5 (td = tm*5). Also, the b constant (ie. 51P BU B VALUE) is set to zero.

Time Overcurrent Elements

TD 51P (51 Phase Time Overcurrent Backup) *51P*

This setting enables backup tripping with the phase time overcurrent element providing additional protection to remote terminals. The element can be (torque) controlled by directional or Zone-2 elements to provide greater application flexibility. Additional settings associated with the time overcurrent phase element are:

TD 51P PU

This setting sets the pickup current value for the phase overcurrent element. The setting range is 0.5 to 10 amps in 0.1 amp increments for 5 A CT inputs or 0.1 to 2.0 with 0.02 amp increments for 1 A CT inputs.

TD 51P A VALUE, TD 51P B VALUE, TD 51P P VALUE, TD 51P TM DIAL

These settings define the inverse time vs. current characteristics of the time overcurrent curve defined by the equation $t(I) = [A/(M^p - 1) + B]td/5$.

TD 51P TR VALUE

This setting defines the reset time characteristics of the 51P element with the equation $t = [t_r/(M^2 - 1)]td/5$.

TD 51P CONTROL

A (torque) control function differs from a supervision function initiate the controlling element must operate to enable the controlled element to begin operation. This insures secure operation. This setting defines the controlling element of the 51P element as either none, forward directional phase, reverse directional phase, or Zone-2 phase.

TD 51N (51 Ground Overcurrent Backup) *51N*

This setting enables backup tripping with the ground time overcurrent element providing additional protection to remote terminals. The element can be (torque) controlled by directional or Zone-2 elements to provide greater application flexibility. Additional settings associated with the time overcurrent ground element are:

TD 51N PU

This setting sets the pickup current value for the ground time overcurrent element. The setting range is 0.5 to 10 amps in 0.1 amp increments for 5 A CT inputs or 0.1 to 2.0 with 0.02 amp increments for 1 A CT inputs.

TD 51N A VALUE, TD 51N B VALUE, TD 51N P VALUE, TD 51N TM DIAL

These settings define the inverse time vs. current characteristics of the time overcurrent curve defined by the equation $t(I) = [A/(M^p - 1) + B]td/5$.

TD 51N TR VALUE

This setting defines the reset time characteristics of the 51N element with the equation $t = [t_r/(M^2 - 1)]td/5$.

TD 51N CONTROL

A (torque) control function differs from a supervision function initiate the controlling element must operate to enable the controlled element to begin operation. This insures secure operation. This setting defines the controlling element of the 51N element as either none, forward directional ground, reverse directional ground, or Zone-2 ground.

TD 51Q (51 Negative Sequence Overcurrent Backup) *51Q*

This setting enables backup tripping with the negative sequence time overcurrent element providing additional protection to remote terminals. The unit measures $3I_2$. The element can be (torque) controlled by directional or Zone-2 elements to provide greater application flexibility. Additional settings associated with the 51Q unit are:

TD 51Q PU

This setting sets the pickup current value for the negative sequence overcurrent element. The setting range is 0.5 to 10 amps in 0.1 amp increments for 5 A CT inputs or 0.1 to 2.0 with 0.02 amp increments for 1 A CT inputs.

TD 51Q A VALUE, TD 51Q B VALUE, TD 51Q P VALUE, TD 51Q TM DIAL

These settings define the inverse time vs. current characteristics of the time overcurrent curve defined by the equation $t(I) = [A/(M^p - 1) + B]td/5$.

TD 51Q TR VALUE

This setting defines reset time characteristics of the negative sequence element with the equation $t = [t_r/(M^2 - 1)]td/5$.

TD 51Q CONTROL

A (torque) control function differs from a supervision function initiate the controlling element must operate to enable the controlled element to begin operation. This insures secure operation. This setting defines the controlling element of the 51Q element as either none; forward directional negative sequence, reverse directional negative sequence, or Zone-2 phase to phase.

Other Overcurrent Elements and Logic Functions

CIFT (Close into Fault Trip)

This setting enables the close into fault trip logic which detects fault current and a low voltage conditions upon breaker closing. Close into fault logic supplements the distance units where potential transformers on the line side of the breaker are used (current transformers are on the bus side). It is intended to detect permanent faults that may have developed on the 'de-energized' line while the breaker was opened for an extended period ...ground chains. Close into fault logic should be disabled where both current and voltage transformers are applied on the bus side.

CIFT TM DLY (Close into Fault Trip Time Delay)

This is intended for single breaker applications (two relays protect different lines, control the same breaker and use the same voltage transformer). The relay with voltage and current transformers on opposite sides of the breaker will be set with the close into fault logic, the other without. The close into fault logic will be blocked for the specified time delay after the 'common' breaker closes to prevent close into fault tripping for fault conditions on the 'other' relay's protected line.

STUB BUS TRIP (Stub Bus Trip)

Stub bus protection employs the 89b contact from an open disconnect switch in conjunction with medium set overcurrent to high speed trip on overcurrent only, for faults on the stub between the current transformers and the open disconnect switch. This is to compensate for the lack of a potential source connected to the line side of the open disconnect switch. The operation is independent of breaker position(s) and the line voltage condition.

TD 51 RI (Time Delayed Reclose Initiate on Overcurrent Trip)

There are two outputs for reclose initiate functions. One for high speed reclose initiate and the other for a time delayed reclose initiate. Usually high speed tripping functions ...high set overcurrent, Zone-1 and pilot, provide a high speed reclose initiates where synchro-checking is normally not required for reclosing. Time delayed tripping functions ...Zone-2, Zone-3 and time delayed overcurrent issue a time delayed reclose initiate where synchro-checking is required.

Choosing ENABLE allows time delayed reclosing for all faults.

By selecting DISABLE, all reclosing is prohibited, except as governed by other elements.

Voltage Elements and Logic Functions

UV PH PU (Phase Undervoltage Pickup)

This unit monitors the phase rms voltages and provides a low voltage alarm output when a phase voltage drops below the set value. The output is also used in the Loss of Potential Block logic. The setting range is 40 to 60 volts in 0.1 volt increments.

OV GND PU (Ground Overvoltage Pickup)

This unit monitors the phase rms voltages and to provide input to the Loss of Potential Block logic. The setting range is 1 to 120 volts in 0.1 volt increments.

LOP BLOCK (Loss of Potential Block)

This function identifies a loss of phase potential that is the result of a long term (steady state) condition such as a blown phase fuse or an open voltage transformer winding or connection. The setting BLK ALL TRIPS will block all tripping while the relay is in this condition. The setting BLK DIST TRIP will block all tripping by the impedance units. DISABLE will permit tripping for this condition. A LOP alarm is also provided.

System Type Logic

The following settings define the type of distance protection used.

System Type (Pilot/Non-pilot)

SYSTEM TYPE (System Type Selection)

The relaying logic varies with the selected system type. PILOT SYSTEMS utilize a communications channel in a variety of ways and the proper logic is automatically assigned when the pilot system type is chosen. The communications channel allows information from the remote terminal to be compared with local information. If both terminals agree that there is an internal fault, simultaneous tripping occurs at both transmission line terminals.

Step distance allows each terminal to operate completely independently. Faults occurring in Zone 1 cause immediate tripping. For Zone 2 faults, tripping is delayed. Tripping is even further delayed for forward Zone 3 faults. Thus a stair-case plot may be used to describe the tripping speed versus fault location. This leads to the term STEP DISTANCE. Simultaneous occurs at the two transmission line terminals for all faults producing operation of both Zone 1 elements. Sequential tripping occurs for faults near one terminal for which the remote Zone 1 element does not operate. LOAD LOSS TRIP permits tripping to occur for faults producing Zone 2 operation, providing pre-fault load current existed and one or two phase currents drop to zero, indicating loss of load current in the unfaulted phases by the tripping of the remote breaker by remote Zone 1 operation. This concept is unworkable where large tapped loads are fed off of the protected line or when 3-phase faults occur.

Zone 1 extension (ZONE 1 EXTEND) logic may be selected to produce high speed tripping for all faults. Using this concept, reliance must be placed on reclosing to restore the line should overtripping occur.

Step Distance (Non-pilot) Scheme Selection

STEP DISTANCE (Non-pilot Step Distance Scheme)

Choosing this option allows access to three non-pilot systems. It is chosen when no reliable communications medium is available for use with relaying.

3 ZONE - This choice provides three zones of distance protection, each of which consists of 3 ground units, a phase-to-phase element and 2 single phase units for 3-phase fault detection. Zones 1 and 2 are for “forward” protection only, but Zone 3 may be used in a “forward” or “reverse” function.

The following selections complement the 3 zone protection described above:

LOAD LOSS TRIP - The load loss trip scheme is very effective in achieving some of the benefits of pilot relaying without requiring a communications channel. It should be selected where tapped load is non-existent or small, Zone 2 trip time is unacceptably long and a communications channel is not available. The low set phase pickup, *50L*, for this application must be greater than the maximum tapped load on the protected line.

ZONE 1 EXTEND - Zone 1 extension would more appropriately be called Zone 1 contraction. At rest (using a Zone 2 setting) the relay is set to overreach the next bus. It will then detect all faults on the protected line (except those with inordinately high ground resistance) and some into the remote line sections. Following trip, the reach of the Zone 1 element is automatically contracted to the normal Zone 1 reach. Any overtripping which results from this action will be corrected by reclosing, restoring sound lines to service and isolating the faulted line if the fault has not cleared. This scheme should be selected where high speed clearing of remote end zone faults is preferable to the momentary breaker operations (trip and reclose) at the remote bus.

Pilot Scheme Selection

PILOT SYSTEM (Pilot System Scheme)

The best choice of a pilot system is, in large measure, dictated by the nature of the communications channel. If the transmission line itself is part of the communications path, as for power line carrier, loss of the channel is one of the probable results of an internal fault. On the other hand, channels which do not include the protected transmission line as part of the signal path, may be used in a command mode to request or demand tripping upon being received. This would include pilot wires, fiber optics, and microwave. Four systems are offered:

POTT — Permissive Overreach Transfer Trip

PUTT — Permissive Underreach Transfer Trip

UNBLOCKING — Directional Comparison Unblocking

BLOCKING — Directional Comparison Blocking

Any one of the pilot system types may be selected. This assigns the appropriate logic and opens up other refinements of the chosen system for display and selection.

Permissive Overreach Transfer Trip (POTT)

The permissive overreaching transfer-trip system uses a frequency-shift tone channel on pilot wires or on microwave that is keyed by the pilot phase or ground element. A signal must be transmitted and received from each location to all other for all internal faults. Only one overreaching zone is required at each terminal. “Permissive” means that a local distance unit must operate, in addition to receiving the remote signal requesting trip, in order for tripping to occur. “Overreaching” means that the channel is keyed by an element that is set to reach beyond the next bus.

POTT 3 TERM LN (POTT Three Terminal Line Logic)

For a three terminal line, the logic is selected to require that the channel trip signal be received from two remote terminals. Choosing ENABLE imposes this requirement. Choosing DISABLE commits the logic to two terminal operation and only one channel trip is required.

POTT WEAKFEED (POTT Weakfeed Terminal Selection)

A weakfeed terminal is one from which inadequate current is supplied to an internal fault to operate any distance or overcurrent element. Faults external to the weak terminal can be identified by the fact that the reverse looking pilot relay operates. This breaks up (prevents) echo keying. For an internal fault, undervoltage (on any phase) without operation of a reverse pilot element identifies the fault location as internal. This logic is activated by selecting ENABLE.

Permissive Underreach Transfer Trip (PUTT)

The permissive underreaching transfer trip system uses a frequency shift tone channel on pilot wires or on microwave. A signal must be transmitted from any location to all others for all internal faults. The system is called underreaching, because the underreaching phase and ground distance element (Zone 1) keys the channel to cause it to shift from the guard frequency to the trip frequency. Recognition, at the receiving terminal, of this shift plus operation of an overreaching distance element (pilot phase and ground) produces tripping. Zone 1 tripping at the terminal near the fault takes place without regard to the channel. The majority of faults will be detected, using this scheme, by the operation of the Zone 1 relays at both terminals.

PUTT 3 TERM LN (PUTT Three Terminal Line Logic)

Using the permissive underreaching transfer trip scheme in a 3 terminal application requires considerable care. All faults must be seen by a Zone 1 relay at one of the terminals. All forward pilot zone relays must see all internal faults (phase or ground) with worst-case in-feed effects considered.

To choose the 3 terminal logic select ENABLE. For two terminal applications select DISABLE.

Directional Comparison Unblocking

The unblocking system differs from the POTT system in the manner in which loss of channel is treated. In the POTT scheme, the channel trip signal must be received for the tripping logic to be satisfied. In the UNBLOCKING scheme, two modes of tripping are accommodated. If the channel trip signal is received, the system behaves exactly like the POTT scheme. If the fault causes channel failure, a period of 150 ms is allowed in which pilot phase or ground distance element operation causes tripping. Channel failure without pilot distance operation produces the same trip block action as for the POTT scheme.

UNBLK 3TERM LN (Unblocking Three Terminal Line Logic)

For a three-terminal line, the logic is selected to provide a channel trip when receiving both trip (unblock) signals from the other two locations, when one is received for 150 ms and the other is not, or for a period of 150 ms following loss of signal from both of the remote stations. The forward pilot phase or ground element operating during the 150 ms interval will produce tripping.

UNBLK WEAKFEED (Unblocking Weakfeed Terminal Selection)

A weakfeed terminal is one from which inadequate current is supplied to an internal fault to operate any distance or overcurrent element. Faults external to the weak terminal can be identified by the fact that the reverse looking pilot relay operates. This breaks up (prevents) echo keying. For an internal fault, undervoltage (on any phase) without operation of a reverse pilot element identifies the fault location as internal. This logic is activated by selecting ENABLE.

Directional Comparison Blocking

The blocking scheme uses on-off power line carrier to identify to a remote terminal that the local terminal has detected on external fault. Internal faults require no signal transmission or reception. External faults require that some element (DV/DI, Reverse pilot, or low set zero sequence overcurrent) operate the start carrier.

CHAN COORD TM (Channel Coordination Timer)

The channel coordination timer permits coordination of the REL 500 Series relay with other generation or manufacturer's relays. It delays pilot tripping for a set period of time to insure an opportunity to receive a blocking signal from the remote terminal for faults beyond that terminal. The remote terminal operating time to send a blocking signal (usually to detect and operate for reverse faults) and channel time with 20% margin is recommended.

RCV PULSE STR (Receive Pulse Stretch Time)

This setting enhances the security of the blocking system operation. Some power line carrier receiver products are subject to momentary signal losses and do not sustain a continuous receive (blocking) signal to the relay. The tripping logic, once armed, permits tripping instantaneously upon the momentary loss of the blocking signal. The pulse stretching logic allows the relay to ride through the momentary signal losses which are usually not more than 2 to 4 ms.

Pilot System Reclosing

PS RECL INIT (Pilot System Reclose Initiate)

High speed reclosing, to be successful, must occur following high speed simultaneous tripping of the breakers at each end of the transmission line. Pilot tripping may be allowed to initiate high speed reclosing by selecting **HIGH SPEED**. Time delayed reclosing is usually applied with time delayed tripping, but may be desired depending on the application. Choosing **HIGH SPEED** or **TIME DELAY** allows further choices regarding the types of faults for which high speed or time delayed reclosing is desired.

By selecting **DISABLE**, all high speed and time delayed reclosing is prohibited, except as governed by other elements.

PS RI FLT TYPE (Pilot System Reclose Initiate Fault Type)

To limit reclosing to only those cases involving phase-to-ground faults (for which the impact on nearby generators is limited), select PH-GND. To allow reclosing for both phase-to-ground and phase-to-phase faults, select PH-GND/PH-PH. To allow reclosing for all faults for which the pilot system operates, select ALL FAULTS. If time delayed reclosing is selected ALL FAULTS is usually appropriate.

PS TD FAULTS (Pilot System Time Delayed Faults)

This setting applies to applications where PS RECL INIT is selected as HIGH SPEED and PS RI FAULT TYPE is other than ALL FAULTS. If it is desired to time delay reclose for fault types not selected for high speed relcosing, then this setting should be ENABLE.

PS SLOW CLR RB (Pilot System Slow Clearing Reclose Block)

Slow clearing is when a permissive signal is received or a blocking signal is stopped 132 ms. after the detection of a forward fault. This condition implies that the remote terminal breaker has not operated and the remote relay is in the breaker failure mode. In the breaker failure mode the remote terminal will send a permissive or stop the blocking signal and block reclosing. To block reclosing at the local terminal for this condition select **ENABLE**. The **DISABLE** setting will permit reclosing as defined above.

Trip Type

TRIP TYPE (System Trip Type)

The REL512 may be applied for three pole or single pole tripping. The settings are 3 POLE TRIP and SP TRIP. For 3 POLE TRIP all 3 breaker poles are tripped simultaneously for all faults. For SP TRIP only the faulted phase breaker pole trips for single phase-to-ground faults.

SP 62TRP TMR (Single Pole Trip 62T Timer)

The Single Pole Trip Timer will start when a single pole trip command has been issued and the 50N low set overcurrent function is picked up. The function will issue a three pole trip after the time has elapsed if the 50N low set overcurrent unit it still asserted. The 62T timer should be set longer than the maximum single pole dead time for the recloser but shorter than the Single Pole Open Pole Timer.

SP TRIP TMR (Single Pole Open Pole Timer)

The Single Pole Open Pole Timer is used to provide a three pole trip for evolving faults occurring after the measuring element has reset following a single pole trip. The timer should be set longer than the maximum single pole dead time for the recloser.

SPT RECLOSE INITIATE (Single Pole Trip Reclose Initiate)

The settings are **SINGLE POLE** and **3 POLE**. Note that the single pole trip reclose initiate will also follow the settings for **PILOT SYSTEM RECLOSE INITIATE.**

SPT BKR 2 OUT (Single Pole Trip Breaker #2 Trip Outputs)

Three trip outputs for phases A, B and C are provided on relay outputs 16, 17 and 18 as standard for single pole tripping of phases A, B, and C, respectively. For Breaker-and-a-half or ring bus configurations a second set of three trip outputs may be required. Select **ENABLE** to provide the second set of trip outputs on relay outputs 10, 11 and 12.

If three pole tripping is applied, this setting may be used to provide three additional trip outputs.

Breaker Failure Protection

Breaker failure coordination requires the consideration of many timing factors. These include breaker interrupting time, 50 overcurrent dropout time, local backup clearing time and transfer trip and remote backup clearing times. A typical coordination is illustrated in the figure below.

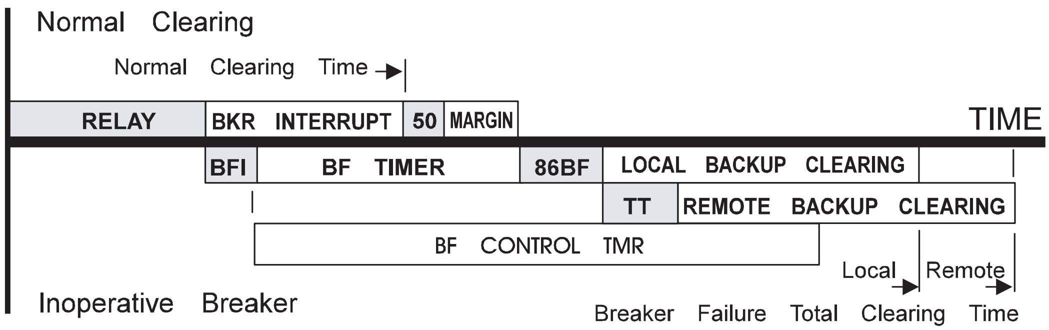


Figure 4-5. Breaker Failure Coordination

BF SHORT TIMER (Breaker Failure Short Timer)

The Breaker Failure Short Timer applies to the clearing of only multi-phase faults. The setting range is 50 to 400 ms in 1 ms increments. It should allow ample margin to allow the breaker to interrupt current and clear. If at the end of the short timer setting the 50 low set overcurrent unit is still asserted, the breaker failure trip output will assert to operate the 86BF lockout function. The 86BF lockout is normally an external function, but may be implemented via the relay's programmable logic.

BF LONG TIMER (Breaker Failure Long Timer)

The Breaker Failure Long Timer applies to the clearing of all faults and should allow ample margin to allow the breaker to interrupt current and clear. The setting range is 50 to 400 ms in 1 ms increments. If at the end of the long timer setting the 50 low set overcurrent unit is still asserted, The breaker failure trip output will assert to operate the 86BF lockout function. The 86BF lockout is normally an external function, but may be implemented via the relay's programmable logic.

BF CONTROL TMR (Breaker Failure Control Timer)

The breaker failure control timer is an on-delay timer that resets the breaker failure operation. The setting range is 10 to 500 ms in 1 ms increments. It must be set to a time greater than the BF LONG TIMER plus local 86BF lockout initiation time and transfer trip time to start remote clearing.

Protection I/O Mapping

Input Map Signals

85CO

Pilot is enabled or disabled. This signal is mapped to a voltage input when the relay is applied with a pilot schemeand high speed reclosing. A voltage input enables the selected pilot scheme. No voltage disables the pilot scheme and high speed reclosing and the relay operates as a step-distance scheme without high speed reclosing.

89B CLOSED

Line Disconnect Switch 89b contact is closed. This signal is mapped to a voltage input when the relay is applied with stub bus protection. A voltage input indicates that the line disconnect switch is open and enables the stub bus trip logic.

BREAKER 1 CLOSED 52A

Breaker #1 is closed as indicated by auxiliary contact 52a being closed. This signal is mapped to a voltage input when the closed breaker status is used. It is used for trip coil monitoring logic or other programmable logic.

BREAKER 1 OPEN 52B

Breaker #1 is open as indicated by auxiliary contact 52b being closed. This signal is mapped to a voltage input when the open breaker status is used. It is used for close into fault and pilot logic or other programmable logic.

BREAKER 2 CLOSED 52A

Breaker #2 is closed as indicated by auxiliary contact 52a being closed. This signal is mapped to a voltage input when the closed breaker status is useded. It is used for trip coil monitoring logic or other programmable logic.

BREAKER 2 OPEN 52B

Breaker #2 is open as indicated by auxiliary contact 52b being closed. This signal is mapped to a voltage input when the open breaker status is used. It is used for close into fault and pilot logic or other programmable logic.

CHANNEL BLOCK 1

The channel block or guard signal used in two terminal or three terminal unblocking pilot schemes. This signal is mapped to a voltage input that interfaces with the pilot channel equipment. Voltage at the input blocks pilot operation. This signal is required for both two and three terminal applications.

CHANNEL BLOCK 2

The second channel block or guard signal used in three terminal unblocking pilot schemes. This signal is mapped to a voltage input that interfaces with the pilot channel equipment. Voltage at the input blocks pilot operation. This signal is required only for three terminal applications

CHANNEL RECEIVE 1

The channel receive or trip permissive signal used in two terminal or three terminal POTT, Unblocking or PUTT pilot schemes. It is also the block trip signal for DCB pilot schemes. This signal is mapped to a voltage input that interfaces with the pilot channel equipment. This signal is required for both two and three terminal applications.

CHANNEL RECEIVE 2

The second channel receive or trip permissive signal used in three terminal POTT, Unblocking or PUTT pilot schemes. This signal is mapped to a voltage input that interfaces with the pilot channel equipment. This signal is required for three terminal applications.

TRIP COIL 1 MONITOR

This signal is mapped to a voltage input that monitors the voltage drop across the trip contacts.

86T

This signal is mapped to a voltage input when initiating breaker failure logic from an external source, such as a transformer differential operation, is desired.

XLED RESET

This signal is mapped to a voltage input when it is desired to reset the front panel LED's from an external source.

XDFR

This signal is mapped to a voltage input when it is desired to trigger a digital fault record from an external source.

TRIP BLOCK

This signal is mapped to a voltage input when it is desired to block all tripping during specific operating conditions, such as bus potential transfer. When this signal is asserted it will block all tripping untis and output contacts except for programmable relay outputs 2, 3 and 4.

Output Map Signals

HS TRIP

Highset overcurrent trip (DSP).

Z1 TRIP

Zone-1 trip (DSP).

PFT

Forward pilot zone and logic operated (DSP). This signal will operate even if forward pilot tripping id disabled. It also drives the FORWARD PILOT TRIP and time delay logic.

PRT

Reverse pilot zone and logic operated (DSP). This signal will operate even if reverse pilot tripping id disabled. It also drives the REVERSE PILOT TRIP and time delay logic.

50M SUPV PHASE

Any phase current exceeds the 50M SUPV PHASE setting.

50M SUPV 3PH

All phase currents exceed the 50M SUPV PHASE setting.

UNDERVOLTAGE

Any phase voltage is below the phase undervoltage setting UV PH PU.

3PH UNDERVOLTAGE

All phase voltages are below the phase undervoltage setting UV PH PU.

FORWARD GF

Forward ground fault directional unit operated based on the set polarization method.

REVERSE GF

Reverse ground fault directional unit operated based on the set polarization method.

FORWARD 3PH

Forward three-phase fault directional unit operated.

REVERSE 3PH

Reverse three-phase fault directional unit operated.

59N OVERVOLTAGE

Zero sequence (ground) overvoltage exceeds the OV GND PU setting.

OSB

Starting or in a power swing condition.

BREAKER FAILURE TRIP

Operates after the set breaker failure time delay.

BREAKER FAILURE RETRIP

Sends another trip signal to the breaker.

INNER BLINDER

The impedance measured by the relay is within the inner blinder characteristics.

OUTER BLINDER

The impedance measured by the relay is within the outer blinder characteristics.

LOSS OF CURRENT ALARM

Indicates an abnormal loss of current condition.

LOSS OF POTENTIAL BLOCK DIST

Indicates an abnormal loss of potential condition. It is generally the result of a blown potential transformer fuse.

PILOT CHANNEL START

Used with pilot scheme applications. Interfaces to external channel equipment to send a permissive (for POTT, PUTT or Unblock) or block (for DCB) signal to remote terminals.

PILOT CHANNEL STOP

Stops the channel start indicating a forward fault for DCB pilot schemes.

ZONE 2 TRIP

Indicates when the Zone-2 unit operated and the Zone-2 timer has expired resulting in a trip.

ZONE 3 TRIP

Indicates when the Zone-3 unit operated and the Zone-3 timer has expired resulting in a trip.

RECLOSE BLOCK

Reclose block signal to interface with external reclosing devices.

BKR FAIL RB

Reclose block signal indicated as a result of a slow operating breaker to interface with an external reclosing device.

HSRI

A reclose initiate signal produced by high-speed tripping.

TDRI

A reclose initiate signal produced by time-delay tripping.

BREAKER FAILURE INITIATE

Breaker failure initiate signal to interface with external breaker failure devices.

TCM/52 ALARM 1

Trip coil failure alarm #1.

TRIP COIL1 MONITOR

Indicates a voltage is present at the input to which this signal is mapped.

TCM/52 ALARM2

Trip coil failure alarm #2.

TRIP COIL2 MONITOR

Indicates a voltage is present at the input to which this signal is mapped.

Settings Tables

Guide to Settings Tables

The settings tables are provided as a quick reference to the relay setting information. Shown in the tables are the setting name, the relay operating element or logic name the setting controls, the default setting, setting range and increment, and the setting units. The settings may either be a range of values with incremental steps (Min — Max [INCR]) or a list of choices (Choice #1, #2, etc.). The tables are divided into groups based on application. The hierarchical paths to the settings via the relay's UI and communication program are shown in the heading within [ ] and in the group title block preceding the setting.

Relay Configuration

System

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Relay Location and Identification			**CONFIGURATION - SUBSTATION ID**	
STATION NAME	Substation Name	Station Name	14 Characters	
BAY NAME	Bay Name	Bay Name	14 Characters	
LINE NAME	Line Name	Line Name	14 Characters	
Power System Parameters			**CONFIGURATION - SYS PARAMETERS**	
GND DIR POL	Ground Directional Polarization	3V0	3V0, 3V2, 3V0/IP	----
EXT SET SELECT	External Setting Selector	DISABLE	ENABLE, DISABLE	

Communication

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Front RS-232 Communication Port Settings		**CONFIGURATION - COM PORTS - FRNT COM PORT**		
FRNT BIT RATE	Front Commmunication Port Bit Rate	9600	2400, 9600, 19200, 115200	BPS
FRNT DATA LGTH	Front Commmunication Port Word Length	8	7, 8	
FRNT PARITY	Front Commmunication Port Parity	NONE	NONE, ODD, EVEN	
FRNT STOP BITS	Front Communication Port Stop Bits	2	1, 2	
REAR RS-232 Communication Port Settings		**CONFIGURATION - COM PORTS - REAR COM PORT**		
REAR BIT RATE	Rear Commmunication Port Bit Rate	9600	2400, 9600, 19200, 115200	BPS
REAR DATA LGTH	Rear Commmunication Port Word Length	8	7, 8	
REAR PARITY	Rear Commmunication Port Parity	NONE	NONE, ODD, EVEN	
REAR STOP BITS	Rear Communication Port – Stop Bits	2	1, 2	
Modbus + Network Port Settings			See Modbus+ Support Document	
DNP 3.0 Network Port Settings			See DNP 3.0 Support Document	

Data Display and Fault Recording

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Data Display and Recording			**CONFIGURATION - DATA RECORD**	
VT RATIO	Voltage Transformer Turns Ratio	1920	100 -- 10,000 [1]	
CT RATIO	Current Transformer Turns Ratio	400	20 -- 5000 [1]	
UNITS PRI/SEC	Data Display and Target Metering Base	SECONDARY	PRIMARY, SECONDARY	----
DATA CAPTURE	Data Capture Triggering Operations	PILOT	PILOT, TRIP, DVDI	----

Set Date/Time

Sets the Date and Time

Active Group

Sets the Active Group when the Settings are Uploaded to the Relay via the Communications Port (front or rear).

Protection Settings

Impedance Elements and Logic

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Zone-1			**PROTECTION - DISTANCE - ZONE 1**	
Z1 K0 MAG	Zone-1 Zero Sequence Compensation Magnitude	2.0	0.00 -- 10.00 [0.01]	----
Z1 K0 ANG	Zone-1 Zero Sequence Compensation Angle	0	-120 -- 40 [1]	DEG
Z1 LINE ANG	Zone-1 Line Angle	75	10 -- 90 [1]	DEG
Z1 PH REACH	Zone-1 Phase Reach	4.0 20.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
Z1 PH TRIP	Zone-1 Phase Trip	ENABLE	ENABLE, DISABLE	
Z1 GND REACH	Zone-1 Ground Reach	4.0 20.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
Z1 GND TRIP	Zone-1 Ground Trip	ENABLE	ENABLE, DISABLE	
Z1 GND BULLET	Zone-1 Ground Bullet	DISABLE	ENABLE, DISABLE	----
Z1 RESISTANCE	Zone-1 Ground Resistance	8.00 40.0*	0.0 -- 36.00 [0.01] 0.0 – 180.00 [0.05]*	OHMS
Z1 OS BLOCK	Zone-1 Out-of-Step Block	DISABLE	ENABLE, DISABLE	----
Z1 RECL INIT	Zone-1 Reclose Initiate	HIGH SPEED	HIGH SPEED, TIME DELAY, DISABLE	----
Z1 RI FLT TYPE	Zone-1 Reclose Initiate Fault Type	ALL FAULTS	PH-GND, PH-GND/ PH-PH, ALL FAULTS	----
Z1 TD FAULTS	Zone-1 Time Delayed Faults	DISABLE	ENABLE, DISABLE	----

*1 A. CT input

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Zone-2			PROTECTION - DISTANCE - ZONE 2	
Z2 K0 MAG	Zone-2 Zero Sequence Compensation Magnitude	2.0	0.00 -- 10.00 [0.01]	----
Z2 K0 ANG	Zone-2 Zero Sequence Compensation Angle	0	-120 -- 40 [1]	DEG
Z2 LINE ANG	Zone-2 Line Angle	75	10 -- 90 [1]	DEG
Z2 PH REACH	Zone-2 Phase Reach	6.0 30.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
Z2 PH DLY	Zone-2 Phase Time Delay	0.5	0.0 -- 10.0 [0.01]	SEC
Z2 PH TRIP	Zone-2 Phase Trip	ENABLE	ENABLE, DISABLE	
Z2 GND REACH	Zone-2 Ground Reach	6.0 30.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
Z2 GND DLY	Zone-2 Ground Time Delay	0.5	0.00 -- 10.00 [0.01]	SEC
Z2 GND TRIP	Zone-2 Ground Trip	ENABLE	ENABLE, DISABLE	
Z2 OS BLOCK	Zone-2 Out-of-Step Block	DISABLE	ENABLE, DISABLE	----
Z2 RECL INIT	Zone-2 Time Delayed Reclose Initiate on All Faults	DISABLE	ENABLE, DISABLE	----

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Zone-3			PROTECTION - DISTANCE - ZONE 3	
Z3 K0 MAG	Zone-3 Zero Sequence Compensation Magnitude	2.0	0.00 -- 10.00 [0.01]	----
Z3 K0 ANG	Zone-3 Zero Sequence Compensation Angle	0	-120 -- 40 [1]	DEG
Z3 LINE ANG	Zone-3 Line Angle	75	10 -- 90 [1]	DEG
Z3 PH REACH	Zone-3 Phase Reach	9.0 45.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
Z3 PH DLY	Zone-3 Phase Time Delay	1.0	0.0 -- 10.0 [0.01]	SEC
Z3 PH TRIP	Zone-3 Phase Trip	ENABLE	ENABLE, DISABLE	
Z3 GND REACH	Zone-3 Ground Reach	9.0 45.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
Z3 GND DLY	Zone-3 Ground Time Delay	1.0	0.00 -- 10.00 [0.01]	SEC
Z3 GND TRIP	Zone-3 Ground Trip	ENABLE	ENABLE, DISABLE	
Z3 OS BLOCK	Zone-3 Out-of-Step Block	DISABLE	ENABLE, DISABLE	----
Z3 RECL INIT	Zone-3 Time Delayed Reclose Initiate on All Faults	DISABLE	ENABLE, DISABLE	----

*1 A. CT input

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Forward Pilot			**PROTECTION - DISTANCE - FORWARD PILOT**	
FWP K0 MAG	Forward Pilot Zero Sequence Compensation Magnitude	2.0	0.00 -- 10.00 [0.01]	----
FWP K0 ANG	Forward Pilot Zero Sequence Compensation Angle	0	-120 -- 40 [1]	DEG
FWP LINE ANG	Forward Pilot Line Angle	75	10 -- 90 [1]	DEG
FWP PH REACH	Forward Pilot Phase Reach	6.0 30.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
FWP PH DLY	Forward Pilot Phase Time Delay	0.7	0.0 -- 10.0 [0.01]	SEC
FWP PH TRIP	Forward Pilot Phase Trip	DISABLE	ENABLE, DISABLE	
FWP GND REACH	Forward Pilot Ground Reach	6.0 30.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
FWP GND DLY	Forward Pilot Ground Time Delay	0.7	0.00 -- 10.00 [0.01]	SEC
FWP GND TRIP	Forward Pilot Ground Trip	DISABLE	ENABLE, DISABLE	
FWP OS BLOCK	Forward Pilot Out-of-Step Block	DISABLE	ENABLE, DISABLE	----

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Reverse Pilot			**PROTECTION - DISTANCE - REVERSE PILOT**	
RVP K0 MAG	Reverse Pilot Zero Sequence Compensation Magnitude	2.0	0.00 -- 10.00 [0.01]	----
RVP K0 ANG	Reverse Pilot Zero Sequence Compensation Angle	0	-120 -- 40 [1]	DEG
RVP LINE ANG	Reverse Pilot Line Angle	75	10 -- 90 [1]	DEG
RVP PH REACH	Reverse Pilot Phase Reach	4.0 20.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
RVP PH DLY	Reverse Pilot Phase Time Delay	0.5	0.0 -- 10.0 [0.01]	SEC
RVP PH TRIP	Reverse Pilot Phase Trip	DISABLE	ENABLE, DISABLE	
RVP GND REACH	Reverse Pilot Ground Reach	4.0 20.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
RVP GND DLY	Reverse Pilot Ground Time Delay	0.5	0.00 -- 10.00 [0.01]	SEC
RVP GND TRIP	Reverse Pilot Ground Trip	DISABLE	ENABLE, DISABLE	

*1 A. CT input

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Line Characteristics			**PROTECTION - DISTANCE - LINE CHARACTERISTICS**	
LN LGTH UNITS	Line Length Units for Data Display	MILES KILOMETERS*	MILES, KILOMETERS	----
LN R PU	Resistance of Line per Unit Length (ohms/unit secondary)	.2588	0.0001 - 15.0 [0.0001]	OHMS
LN X PU	Reactance of Line per Unit Length (ohms/unit secondary)	.9659	0.0001 - 15.0 [0.0001	OHMS

Out-of-Step and Load Restriction Logic

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Out-of-Step and Load Restriction			**PROTECTION - OUT OF STEP**	
LD RESTRICTION	Load Restriction Enable or Disable	DISABLE	ENABLE, DISABLE	----
OS TYPE	Out-of-Step Logic for Block Tripping or Tripping	DISABLE	OS BLOCK, OS TRIP, DISABLE	----
Out-of-Step Trip			**PROTECTION - OUT OF STEP - OST**	
OST TIME 1	Out Of Step Trip Time 1	0.1	0.00 -- 0.12 [0.01]	SEC
OST TIME 2	Out Of Step Trip OST Time 2	0.1	0.0 -- 0.12 [0.01]	SEC
OST RESET TIME	Out Of Step Dropout Time	0.12	0.00 --0.16 [0.01]	SEC
OST WAY IN OUT	Out Of Step Trip OST Way In Out	WAY OUT	WAY IN, WAY OUT	----
Out-of-Step Block/Trip			**PROTECTION - OUT OF STEP**	
OS OVRD TM	Out Of Step Block Override Time	4.0	0.40 -- 4.00 [0.01]	SEC
Blinders			**PROTECTION - OUT OF STEP**	
BLINDER ANG	Blinder Angle	75	0 -- 90 [1]	DEG
BLNDR INNER R	Inner Blinder Resistive Reach	6.0 30.0*	0.03 -- 36.00 [0.01] 0.15 – 180.00 [0.05]*	OHMS
BLNDR OUTER R	Outer Blinder Resistive Reach	7.0 35.0*	0.03 -- 36.00 [0.01] 0.15– 180.00 [0.05]*	OHMS

*1 A. CT input

Instantaneous Overcurrent Elements and Logic

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
High Set Overcurrent Elements and Functions			**PROTECTION - OVERCURRENT - HIGH SET OC**	
HS 50P PU	High Set Phase Pickup	30 6*	2.0 -- 100.0 [0.1] 0.4 -- 20.0 [0.02]*	AMP
HS 50N PU	High Set Ground Pickup	30 6*	2.0 -- 100.0 [0.1] 0.4 -- 20.0 [0.02]*	AMP
HS 50Q PU	High Set Negative Sequence Pickup	10 2*	2.0 -- 100.0 [0.1] 0.4 -- 20.0 [0.02]*	AMP
HS 50P TRP	High Set Phase Trip	DISABLE	ENABLE, DISABLE	----
HS 50P DIR	High Set Phase Directional	DISABLE	ENABLE, DISABLE	----
HS 50N TRP	High Set Ground Trip	DISABLE	ENABLE, DISABLE	----
HS 50N DIR	High Set Ground Directional	DISABLE	ENABLE, DISABLE	----
HS 50Q TRP	High Set Negative Sequence Trip	DISABLE	ENABLE, DISABLE	----
HS 50Q DIR	High Set Negative Sequence Directional	DISABLE	ENABLE, DISABLE	----
HS 50 RI	High Set Reclose Initiate	DISABLE	HIGH SPEED, TIME DELAY, DISABLE	----
HS RI FLT TYPE	High Set Reclose Initiate Fault Type	ALL FAULTS	PH-GND, PH-GND PH-PH, ALL FAULTS	----
HS TD FAULTS	High Set Time Delayed Faults	DISABLE	ENABLE, DISABLE	----

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Medium Set Overcurrent Elements and Functions			**PROTECTION - OVERCURRENT - MEDIUM SET OC**	
MS 50P PU	Medium Set Phase Pickup	4.0 0.8*	0.5 -- 12.0 [0.1] 0.1 – 2.4 [0.02]*	AMP
MS 50N PU	Medium Set Ground Pickup	1.0 0.2*	0.5 -- 12.0 [0.1] 0.1 – 2.4 [0.02]*	AMP
MS 50Q PU	Medium Set Negative Sequence Pickup	1.0 0.2*	0.5 -- 12.0 [0.1] 0.1 – 2.4 [0.02]*	AMP
MS 50N TRP	Medium Set Ground Trip	DISABLE	ENABLE, DISABLE	----
MS 50N DLY	Medium Set Ground Time Delay	0.5	0.0 -- 10.0 [0.01]	SEC
MS 50Q TRP	Medium Set Negative Sequence Trip	DISABLE	ENABLE, DISABLE	----
MS 50Q DLY	Medium Set Negative Sequence OC Time Delay	0.5	0.0 -- 10.0 [0.01]	SEC
Low Set Overcurrent Elements and Functions			**PROTECTION - OVERCURRENT - LOW SET OC**	
LS 50P PU	Low Set Phase Pickup	1.0 0.2*	0.5 -- 12.0 [0.1] 0.1 – 2.4 [0.02]*	AMP
LS 50N PU	Low Set Ground Pickup	0.5 0.1*	0.5 -- 12.0 [0.1] 0.1 – 2.4 [0.02]*	AMP

*1 A. CT input

Time-Overcurrent Elements and Logic

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Phase Time Overcurrent Elements			**PROTECTION - OVERCURRENT - TD 51P**	
TD 51P	51 Phase Time Overcurrent Backup	DISABLE	ENABLE, DISABLE	----
TD 51P PU	51 Phase Time Overcurrent Backup Pickup	6.0 1.2*	0.5 -- 10.0 [0.1] 0.1 – 2.0 [0.02]*	AMP
TD 51P A VALUE	51 Phase Time Overcurrent Backup ‘A’ Value	30.0	0.001 -- 150.0 [0.001]	SEC
TD 51P B VALUE	51 Phase Time Overcurrent Backup ‘B’ Value	0.792	0.0 -- 50.0 [0.001]	SEC
TD 51P P VALUE	51 Phase Time Overcurrent Backup ‘P’ Value	2.0	0.01 -- 3.0 [0.01]	----
TD 51P TR VAL	51 Phase Time Overcurrent Backup ‘Tr’ VALUE	30.0	0.0 -- 50.0 [0.01]	SEC
TD 51P TM DIAL	51 Phase Time Overcurrent Backup Time Dial	5	0.5 -- 12.0 [0.1]	----
TD 51P CONTROL	51 Phase Time Overcurrent Backup Torque Control	DIR FORWARD	DIR FORWARD, DIR REVERSE, Z2 CONTROL, NONE	

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Negative Sequence Time Overcurrent Elements			**PROTECTION - OVERCURRENT - TD 51Q**	
TD 51Q	51 Negative Sequence Time Overcurrent Backup	DISABLE	ENABLE, DISABLE	----
TD 51Q PU	51 Negative Sequence Time Overcurrent Backup Pickup	1.0 0.2*	0.5 -- 10.0 [0.1] 0.1 – 2.4 [0.02]*	AMP
TD 51Q A VALUE	51 Negative Sequence Time Overcurrent Backup ‘A’ Value	30.0	0.001 -- 150.0 [0.001]	SEC
TD 51Q B VALUE	51 Negative Sequence Time Overcurrent Backup ‘B’ Value	0.792	0.0 -- 50.0 [0.001]	SEC
TD 51Q P VALUE	51 Negative Sequence Time Overcurrent Backup ‘P’ Value	2.0	0.01 -- 3.0 [0.01]	----
TD 51Q TR VAL	51 Negative Sequence Time Overcurrent Backup ‘Tr’ Value	30.0	0.0 -- 50.0 [0.01]	SEC
TD 51Q TM DIAL	51 Negative Sequence Time Overcurrent Backup Time Dial	5	0.5 -- 12.0 [0.1]	----
TD 51Q CONTROL	51 Negative Sequence Time Overcurrent Torque Control	DIR FORWARD	DIR FORWARD, DIR REVERSE, Z2 CONTROL, NONE	

*1 A. CT input

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Ground Time Overcurrent Elements			**PROTECTION - OVERCURRENT - TD 51N**	
TD 51N	51 Ground Time Overcurrent Backup	DISABLE	ENABLE, DISABLE	
TD 51N PU	51 Ground Time Overcurrent Backup Pickup	1.0 0.2*	0.5 -- 10.0 [0.1] 0.1 – 2.4 [0.02]*	AMP
TD 51N A VALUE	51 Ground Time Overcurrent Backup 'A' Value	30.0	0.001 -- 150.0 [0.001]	SEC
TD 51N B VALUE	51 Ground Time Overcurrent Backup 'B' Value	0.792	0.0 -- 50.0 [0.001]	SEC
TD 51N P VALUE	51 Ground Time Overcurrent Backup 'P' Value	2.0	0.01 -- 3.0 [0.01]	
TD 51N TR VAL	51 Ground Time Overcurrent Backup 'Tr' Value	30.0	0.0 -- 50.0 [0.01]	SEC
TD 51N TM DIAL	51 Ground Time Overcurrent Backup Time Dial	5	0.5 -- 12.0 [0.1]	
TD 51N CONTROL	51 Ground Time Overcurrent Backup Torque Control	DIR FORWARD	DIR FORWARD, DIR REVERSE, Z2 CONTROL, NONE	

Other Overcurrent Elements and Logic

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Other Overcurrent Elements and Logic Functions			**PROTECTION - OVERCURRENT**	
CIFT	Close Into Fault Trip	DISABLE	ENABLE, DISABLE	----
CIFT TM DLY	Close Into Fault Trip Time Delay	DISABLE	ENABLE, DISABLE	----
STUB BUS TRIP	Stub Bus Trip	DISABLE	ENABLE, DISABLE	----
TD 51 RI	Overcurrent Trip Time Delay Reclose Init on All Faults	DISABLE	ENABLE, DISABLE	----

Voltage Elements and Logic Functions

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Voltage Elements and Logic Functions			**PROTECTION - VOLTAGE O/U**	
UV PH PU	Phase Under Voltage Pickup	60.0	40 -- 60 [0.1]	VOLT
OV GND PU	Ground Over-Voltage Pickup	5.0	1.0 -- 120.0 [0.1]	VOLT
LOP BLOCK	Loss Of Potential Blocking	DISABLE	BLK DIST TRIP, BLK ALL TRIPS,DISABLE	----

*1 A. CT input

System Type Logic (Pilot/Non-pilot)

SETTING NAME	ELEMENT, PARAMETER, OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
System Type Selection			**PROTECTION - SYSTEM TYPE**	
SYSTEM TYPE	System Type Selection	STEP DISTANCE	STEP DISTANCE, PILOT SYSTEM	----
Step Distance Scheme Selection		**PROTECTION - SYSTEM TYPE - STEP DISTANCE**		
STEP DISTANCE	Step Distance Scheme Selection	3 ZONE	3 ZONE, LOAD LOSS TRIP ZONE 1 EXTEND	----
Pilot Scheme Selection		**PROTECTION - SYSTEM TYPE - PILOT SYSTEM**		
PILOT SCHEME	Pilot System Scheme Selection	POTT	POTT, PUTT, BLOCKING, UNBLOCKING	----
Permissive Overreaching Transfer Trip	**PROTECTION - SYS TYPE - PILOT SYSTEM - PILOT SCHEME - POTT**			
POTT 3 TERM LN	POTT 3 Terminal Line Protection	DISABLE	ENABLE, DISABLE	----
POTT WEAKFEED	POTT Weakfeed Terminal Protection	DISABLE	ENABLE, DISABLE	----
Permissive Underreaching Transfer Trip	**PROTECTION - SYS TYPE - PILOT SYSTEM - PILOT SCHEME - PUTT**			
PUTT 3 TERM LN	PUTT 3 Terminal Line Protection	DISABLE	ENABLE, DISABLE	----
Directional Comparison Unblocking	**PROTECTION - SYS TYPE - PILOT SYSTEM - PILOT SCHEME - UNBLOCKING**			
UNBLK 3TERM LN	Unblocking 3 Terminal Line Protection	DISABLE	ENABLE, DISABLE	----
UNBLK WEAKFEED	Unblocking Weakfeed Terminal Protection	DISABLE	ENABLE, DISABLE	----
Directional Comparison Blocking	**PROTECTION - SYSTEM TYPE - PILOT SYSTEM - PILOT SCHEME - BLOCKING**			
CHAN COORD TM	Channel Coordination Timer	0.0	0.00 -- 0.3 [0.001]	SEC
RCV PULSE STR	Receive Pulse Stretch Timer	0.0	0.00 -- 0.010 [0.001]	SEC
Pilot Reclosing Functions		**PROTECTION - SYSTEM TYPE - PILOT SYSTEM - PS RECLOSE**		
PS RECL INIT	Pilot System Reclose Initiate	DISABLE	HIGH SPEED , TIME DELAY, DISABLE	----
PS RI FLT TYPE	Pilot System Reclose Initiate Fault Type	ALL FAULTS	PH-GND, PH-GND PH-PH, ALL FAULTS	----
PS TD FAULTS	Pilot System Time Delayed Faults	DISABLE	ENABLE, DISABLE	----
PS SLOW CLR RB	Slow Pilot Clearing Reclose Block	DISABLE	ENABLE, DISABLE	----

*1 A. CT input

Trip Type

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Trip Type			PROTECTION - TRIP TYPE	
TRIP TYPE	System Trip Type	3 POLE TRIP	3 POLE TRIP SP TRIP	----
Single Pole Trip			PROTECTION - TRIP TYPE - SINGLE POLE TRIP	
SP 62T TRIP TMR	Single Pole Trip 62T Timer	1.0	0.1 - 5.0 [0.01]	SEC
SP TRP TMR	Single Pole Trip Open Pole Timer	1.0	0.0 - 6.0 [0.1]	SEC
SP RECL INIT	Single Pole Trip Reclose Initiate	SINGLE POLE	SINGLE POLE, 3 POLE	----
Extra Trip Outputs			PROTECTION - TRIP TYPE - SINGLE POLE TRIP	
SPT BKR2 OUT	Three Extra Trip Outputs	DISABLE	ENABLE, DISABLE	----

Breaker Failure Protection (Optional)

SETTING NAME	ELEMENT, PARAMETER OR LOGIC NAME	DEFAULT SETTING	MIN -- MAX [INCR] CHOICE #1, #2, etc.	UNITS
Trip Type			PROTECTION - BREAKER FAILURE	
BF PROTECTION	Breaker Failure Protection	DISABLE	ENABLE, DISABLE	----
BF SHORT TIMER	Breaker Failure Short Timer	0.050	0.050 – 0.400 [0.001]	SEC
BF LONG TIMER	Breaker Failure Long Timer	0.100	0.050 – 0.400 [0.001]	SEC
BF CONTROL TMR	Breaker Failure Control Timer	0.200	0.010 – 2.000 [0.001]	SEC

Measuring Elements and Operational Logic

Variable Mho Impedance Characteristics

There are a total of 30 mho type impedance measuring units, 6 per zone and 5 zones of protection.

The Mho Circle

The impedance unit operating characteristic is a mho circle. This is shown in Figure 5-1. This is a plot of test results of the three phase unit set to 4 ohms at 75°. Given the nature of the inverse characteristic, operation at the boundary cannot be theoretically achieved as the operating time approaches infinity.

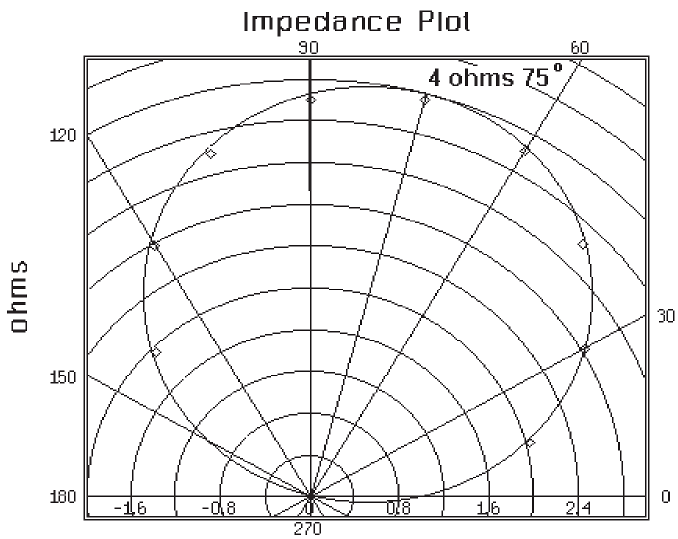


Figure 5-1. Mho Characteristic Test

The test points shown in Figure 5-1 are based on an applied balanced three phase voltage of 40 V and increasing a balanced three phase current for different angles in small increments until operation. This is to provide operation as close to the boundary as possible. The current magnitude is increased in steps from a value that puts the impedance outside the unit's reach. The impedance will decrease with each step until the unit operates. The test points are compared to the theoretical circle shown as a solid line.

All impedance units, three phase, phase-to-phase and phase-to-ground for all zones were individually tested over their range of settings to confirm their operating characteristics. Additional testing was performed on the Model Power System to evaluate each units performance to a large number of internal and external (forward and reverse) faults. The test proved quite convincingly the mho characteristic's inherent security to external faults.

Operating Times

Operating times based on the source to relay impedance ratio (SIR) are shown in Figure 5-2a for the AG unit. SIR is the ratio of the equivalent system source impedance to the relay setting expressed on the same voltage base. The operating times include the mechanical output relay operating time and were determined using a conventional computer controlled test. Model Power System results are approximately 2 ms. faster. All impedance units have very similar operating characteristics, however phase-to-phase and three phase units are slightly faster. Optional solid state outputs (Relay Output Accelerator Module) improve the operating time approximately 6 ms. Test results using the ROAM are shown in Figure 5-2b.

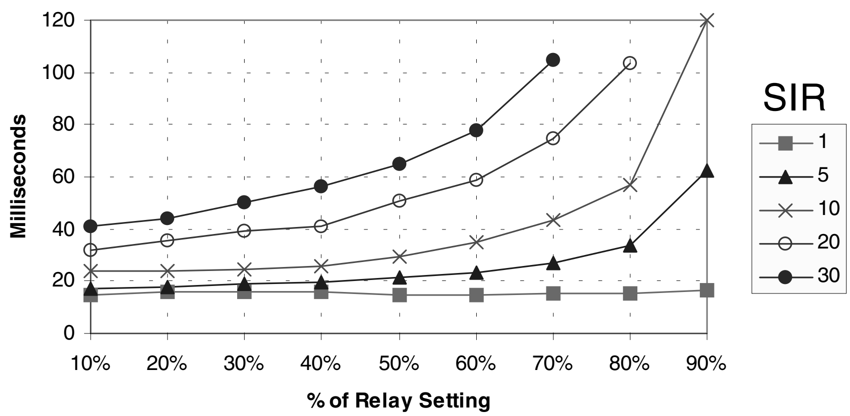


Figure 5-2a. Operating Time for SIR of 1 to 30

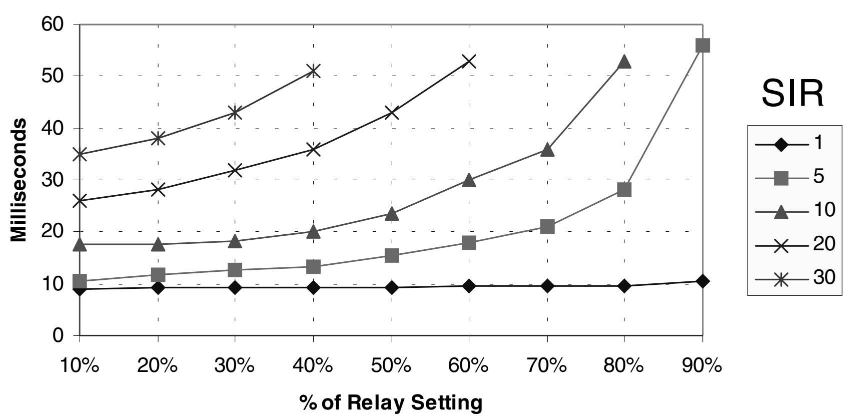


Figure 5-2b. Operating Time for SIR of 1 to 30 Using the ROAM

Ground-Quadrilateral Characteristics

Zone-1 is provided with a complementary set of ground-quadrilateral characteristics and, if enabled, will provide additional coverage for Zone-1 high resistance ground faults. The characteristics are defined by the Zone-1 Reach (Z1 GND REACH), line impedance angle (Z1 LINE ANGLE) and ground fault resistance reach (Z1 RESISTANCE) settings. The quadrilateral reach is defined as follows:

Xq = (Z1 GND REACH) * sin(Z1 LINE ANGLE)

Rq = (Z1 GND REACH) * cos(Z1 LINE ANGLE) + Z1 RESISTANCE @ X = Xq

Rq = Z1 RESISTANCE @ X = 0

Following is a plot of test results showing the composite mho-quadrilateral characteristic. The Zone-1 ground impedance reach is set to 0.5 ohms at 75° and the resistance reach is set to 4 ohms. The mho circle and the quad reactive reach (top line of the quad) are zero sequence compensated while the resistance reach (the right line of the quad) is not. This is done to make the quad more secure during load conditions where zero sequence current during a fault may affect the healthy phases. Therefore, the apparent impedance calculated (by test set and other macros) with the compensation factor will be the setting divided by (1 + K0/3) where K0 is the zero sequence compensation factor. In this case the resistance setting is 10 and the K0 setting is 2. Thus, the apparent resistance is 4/(1 + 2/3) or 2.4 ohms.

The quadrilateral logic is in the CPU and the typical operating time is 60 ms.

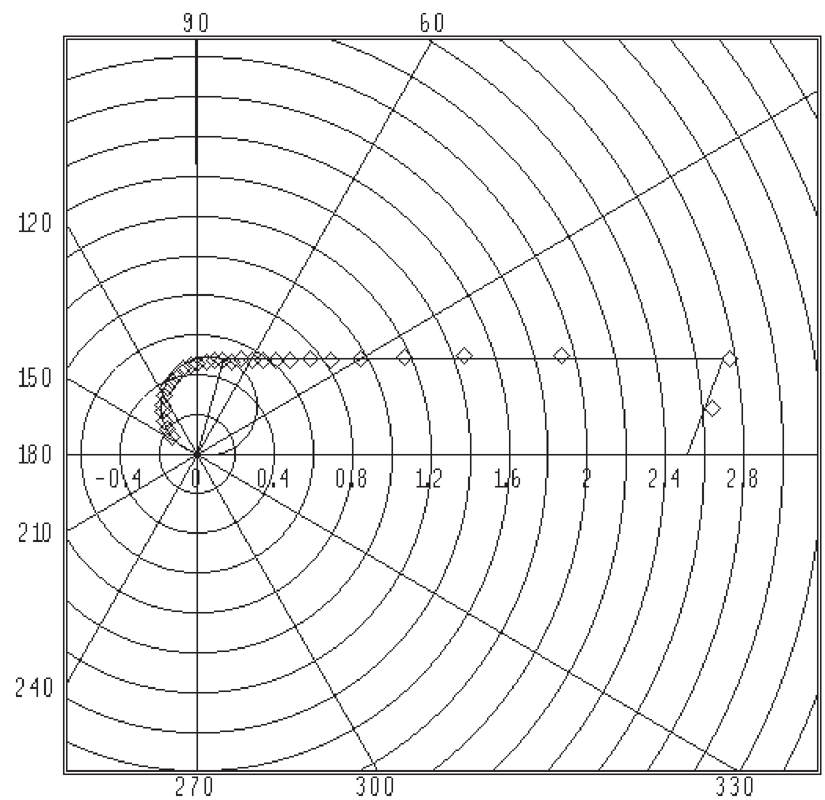


Figure 5-3. Mho-Quadrilateral Composite Characteristic

Blinders

Inner Blinders

The Inner Blinders are used for out-of-step logic as well as protection against tripping for load conditions. The Blinder characteristics are stated to be parallel lines at a set angle and are used to supervise the three phase mho elements on phases A and B. The blinder characteristic, however, is really lenticular in nature providing essentially the parallel effect within the mho characteristic, but eventually intersecting outside the mho characteristic. Figure 5-4 illustrates the lenticular characteristic. The data points were generated with a computer controlled test set for an 8 ohm inner blinder setting. In this case the intersection of the left and right blinder occurs at 70 ohms along the set blinder angle of 75°.

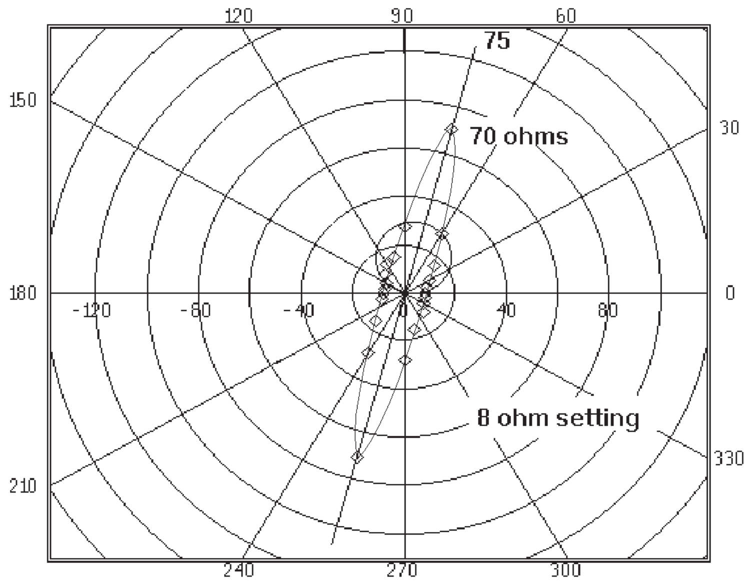


Figure 5-4. Blinder Lenticular Characteristic

For all practical purposes, however, the blinders are parallel within the range of the mho characteristic. This is illustrated in Figure 5-5 where a 30 mho characteristic is supervised by an 8 ohm blinder characteristic.

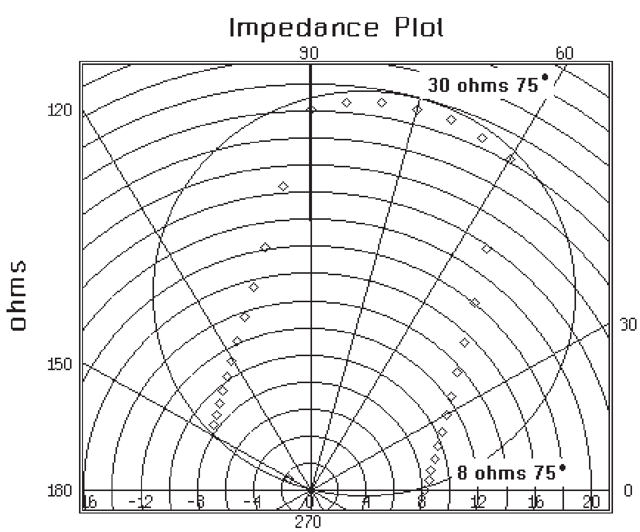


Figure 5-5. A Mho Characteristic Supervised by the Blinder Characteristic

Outer Blinders

The outer blinders are used with out-of-step logic. Outer blinders exhibit the same characteristics as the inner blinders.

Directional Units

Phase Directional Units

There are three 3-phase quadrature polarized directional units, one for each phase . The respective phase current is compared to the opposite phase-to-phase voltage. That is, phase I_A is referenced to V_{BC} to determine directionality. This is shown in Figure 5-6. The current is shown at the maximum torque angle.

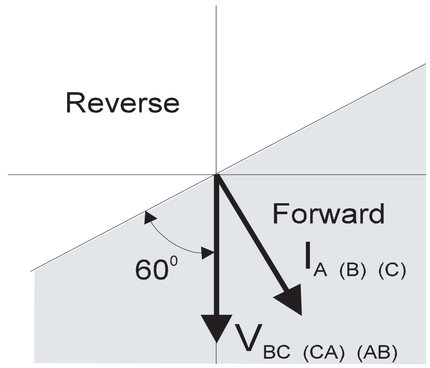


Figure 5-6. Three Phase Directional Units

Ground Directional Units

There are four ground directional units, two forward and two reverse. These are zero sequence voltage polarizing units and zero sequence current polarizing (taken from a transformer) units. The voltage unit compares the V_0 and I_0 as shown in Figure 5-7(a). The transformer current unit compares I_P and I_0 as shown in Figure 5-7(b). The current is shown at the maximum torque angle.

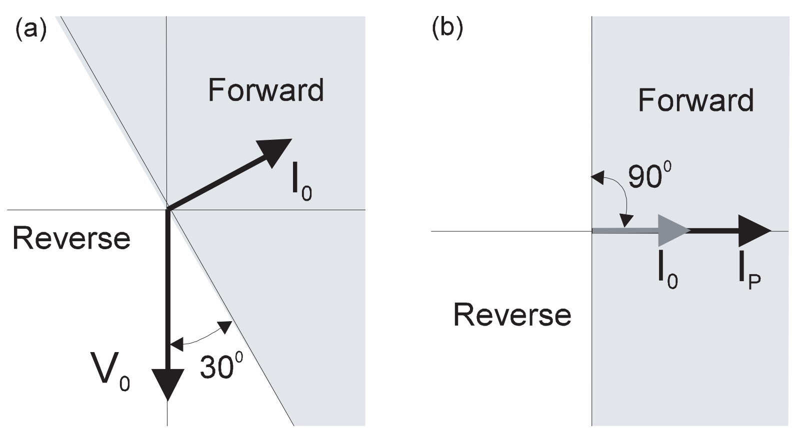


Figure 5-7. (a) Zero Sequence Voltage Polarization
(b) Transformer Zero Sequence Current Polarization

Negative Sequence Units

There are two negative sequence voltage polarization units, forward and reverse. The negative sequence voltage unit compares the V_2 and I_2 as shown in Figure 5-8.

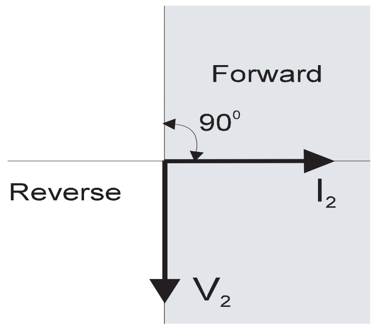


Figure 5-8. Negative Sequence Directional Unit

Directional Unit Sensitivity

The sensitivity and speed of the directional units depends on the fault energy (torque) seen by the relay. Figure 5-9(a) shows the tested results of the forward ground directional unit sensitivity. This illustrates how the operating bandwidth in degrees around the maximum torque angle decreases with reducing fault energy expressed in volt-amperes (in this case $3V_0$ x $3I_0$). Figure 5-9(b) shows the forward and reverse operating regions for 2.5 VA of fault energy. Normal operations occur in the quadrant around the maximum torque angle. This feature provides additional security against incorrect directional sensing for remote low energy faults influenced by unbalanced phase voltages at the relay.

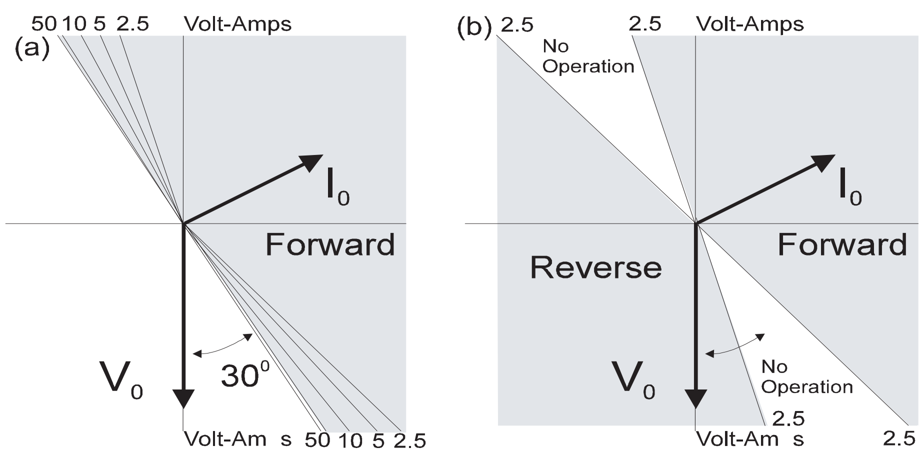


Figure 5-9. Sensitivity of Ground Directional Unit

These are typical and will vary slightly depending on the fault voltage and current values. It should also be noted that the corresponding forward and reverse units are very close in their tested characteristics.

The zero sequence voltage directional unit minimum sensitivity was found to be approximately 0.83 VA ($3V_0$ x $3I_0$) at $3I_0$ = 0.25 A and 0.6 VA at $3V_0$ = 1.0 V. The next table shows the measured minimum sensitivity for each of the directional units.

Table 5-1. Directional Unit Sensitivity

Unit (V and I Compared)	Minimum Sensitivity in volt-amperes (or I^2)	
	Reference Quantity	**I = 0.25 A**
3 phase (V_{BC} x I_A)	(V = 1.73) < 2.0	< 2.8
Negative Sequence ($3V_2$ x $3I_2$)	(V = 1.0) < 1.0	< 1.0
Zero Sequence Voltage ($3V_0$ x $3I_0$)	(V = 1.0) < 1.0	< 1.0
Current (I_P x $3I_0$)	(IP = 0.5) < 1.0	< 1.0

Operation of the units can be determined using the equation **T = VIcos (ϕ)** where ϕ is the angle between the maximum torque angle and applied current angle and **T** is the torque to be compared to the minimum sensitivity defined above.

Overcurrent Units

Operating Units (Type 50)

There are 15 instantaneous overcurrent measuring units.

Three high set phase, one zero sequence (ground) and one negative sequence units. All the high set units can be directionally supervised.

Three medium set phase, one zero sequence (ground) and one negative sequence units.

Three low set phase, one zero sequence (ground) and one negative sequence units. The negative sequence unit has a fixed setting of 0.5 A.

Operating Characteristics

The operating characteristics for all the instantaneous overcurrent units are approximately the same. These characteristics as determined by test are shown in Figure 5-10. The units operated very close to the set pickup value and had a pickup/dropout ratio of approximately one.

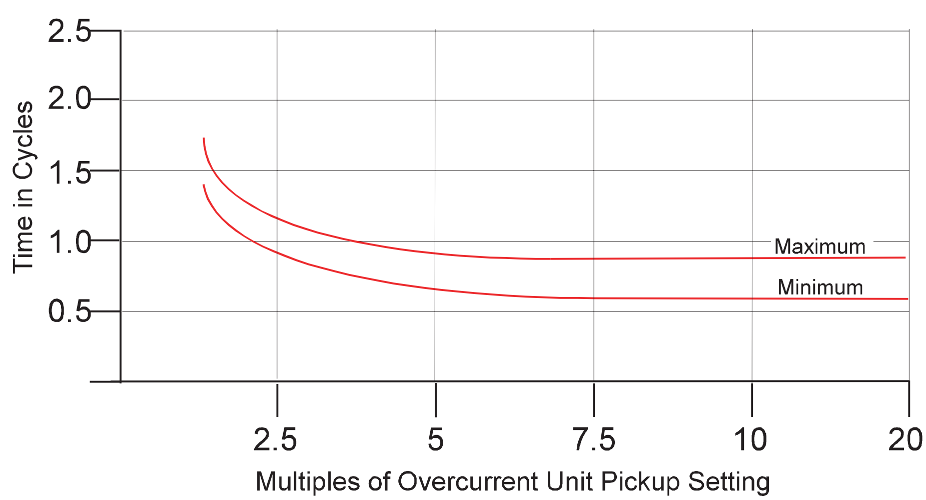


Figure 5-10. Typical Operating Characteristics for Instantaneous Overcurrent Units

Inverse Time Overcurrent

TD 51 Inverse Units

There are 5 inverse overcurrent units: three phase, one zero sequence (ground) and one negative sequence units. The units are DFT units and run in the CPU. Tests were performed on all units to verify accuracy. The principle of operation is based on IEEE Standard C37.112 and is discussed in Section 6.

TD 51P Tests on Phase A Unit

The inverse time overcurrent curves for CO-8 family emulation with the appropriate settings constants is shown in Figure 5-11. These curves were computed using the constants and the equation found in the Settings and Application Section. The constants for all CO relays are found there.

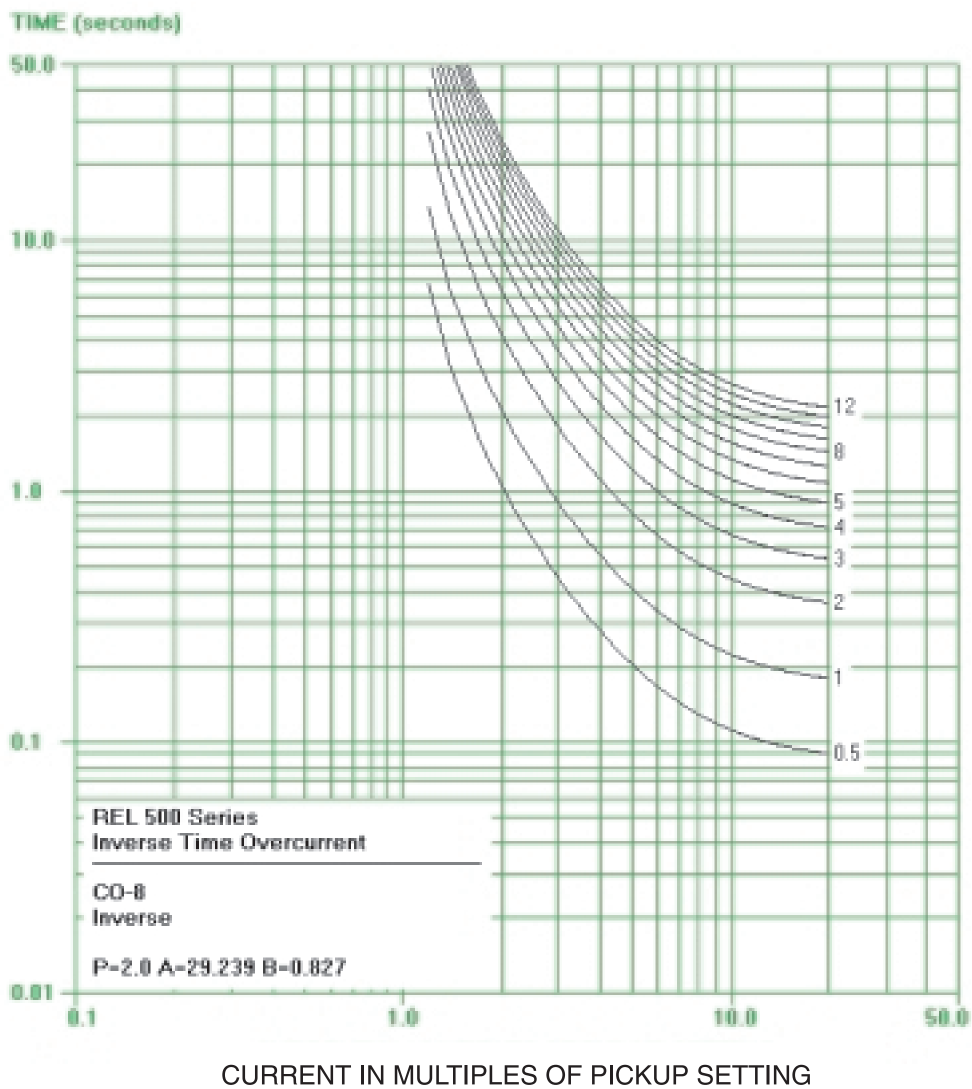


Figure 5-11. CO-8 Emulation

Table 5-2. Inverse Time Overcurrent Operating Test

Inverse Time Overcurrent - (CO-8) P=2.0, A=29.239, B=0.827 TD=1				
Multiples of Pickup	**Pickup Setting, Amps 2**	**3**	**5**	**Calculated Time**
2	2.23	2.15	2.21	2.115
% Error	*5.4*	*1.65*	*4.5*	
3	0.92	0.96	0.90	0.896
%E	*2.6*	*7.1*	*0.4*	
5	0.49	0.47	0.46	0.409
%E	*19.5*	*14.6*	*12.2*	
9	0.25	0.26	0.26	0.239
%E	*4.1*	*8.3*	*8.3*	
12	0.25	0.26	0.28	0.206
%E	*21.3*	*26.2*	*35.9*	

Inverse Time Overcurrent - (CO-8) P=2.0, A=29.239, B=0.827 TD=5				
Multiples of Pickup	**Pickup Setting, Amps 2**	**3**	**5**	**Calculated Time**
2	10.29	10.15	10.06	10.57
% Error	*2.6*	*3.9*	*4.8*	
3	4.30	4.29	4.45	4.48
%E	*4.0*	*4.0*	*0.6*	
5	1.99	1.99	2.05	2.045
%E	*2.7*	*2.7*	*0.2*	
9	1.16	1.17	1.15	1.193
%E	*2.7*	*1.9*	*3.6*	
12	0.99	1.04	1.02	1.032
%E	*4.1*	*0.7*	*1.2*	

Inverse Time Overcurrent - (CO-8) P=2.0, A=29.239, B=0.827 TD=11				
Multiples of Pickup	**Pickup Setting, Amps 2**	**3**	**5**	**Calculated Time**
2	23.21	23.60	23.51	23.26
% Error	*0.2*	*1.5*	*1.1*	
3	9.40	9.79	9.80	9.86
%E	*4.6*	*0.7*	*0.6*	
5	4.34	4.38	4.44	4.5
%E	*3.5*	*2.7*	*1.3*	
9	2.44	2.51	2.53	2.62
%E	*6.8*	*4.2*	*3.4*	
12	2.15	2.19	2.22	2.27
%E	*5.2*	*3.5*	*2.2*	

Voltage Units

Phase Undervoltage Units

There are three undervoltage-measuring units. Undervoltage unit pickup values were tested with less than 0.5% error and a pickup/dropout ratio of 0.978 (pickup is lower than dropout). Figure 5-12 shows the time to pickup after instant voltage drops to a voltage expressed as percent of the pickup setting.

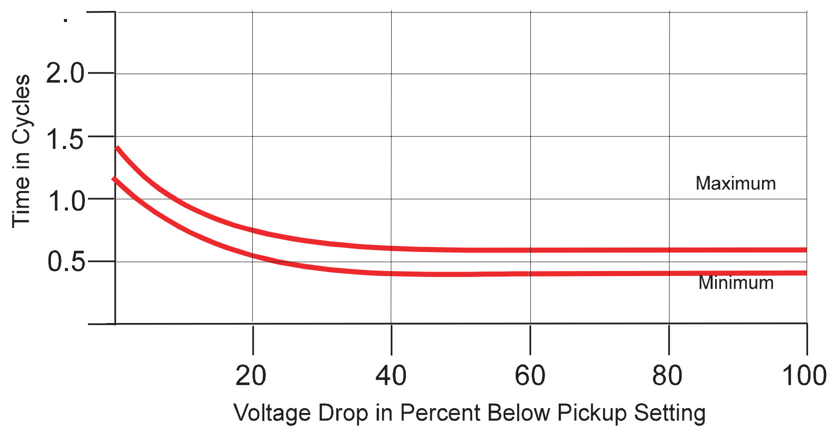


Figure 5-12. Operating Characteristics of the Phase Undervoltage Units

Ground Overvoltage Unit

There is one ground overvoltage measuring unit. The ground ($3V_0$) overvoltage unit pickup values were tested with less than 1.0% error and a pickup/dropout ratio of 1.05. Figure 5-13 shows the time to pickup after instant voltage increase expressed in multiples of the pickup setting.

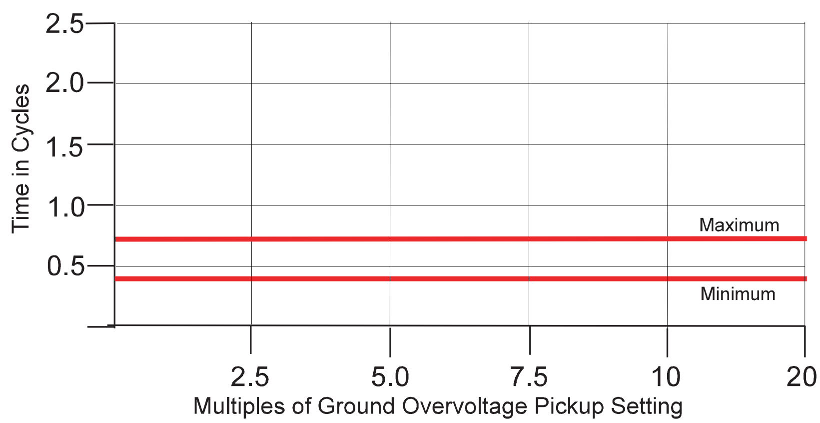


Figure 5-13. Operating Characteristics of the Ground Overvoltage Unit

Operational Logic

There are two logic processors, the digital signal processor (DSP) and the central orocessing unit (CPU). The DSP computes the measuring units and the high speed logic every relay sample at 20 samples per cycle. The CPU computes a number of logic functions that include pilot, time-delayed tripping and a number of other logic functions.

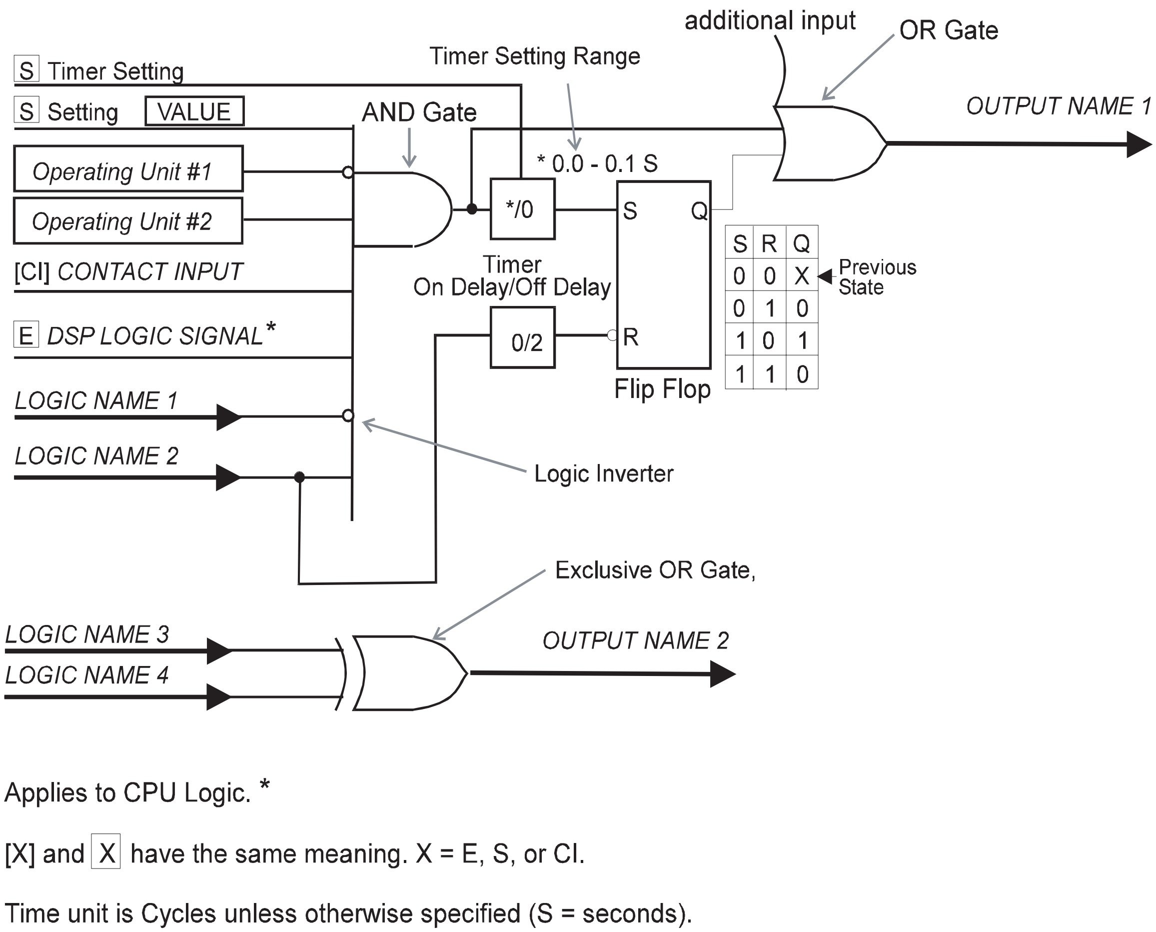


Figure 5-14. Logic Legend

High Speed DSP Logic

The following DSP Logic modules are executed in order of the figure number. Inpits to each module are defined on the left of the logic drawing and output logic signals are on the right. The inputs consist of of measuring units, binary (contact) inputs, settings and logic signals that were developed in (output from) a previous module. An output logic signal either operates an output contact, used as input to a subsequent DSP or CPU logic module, or made available for programmable output.

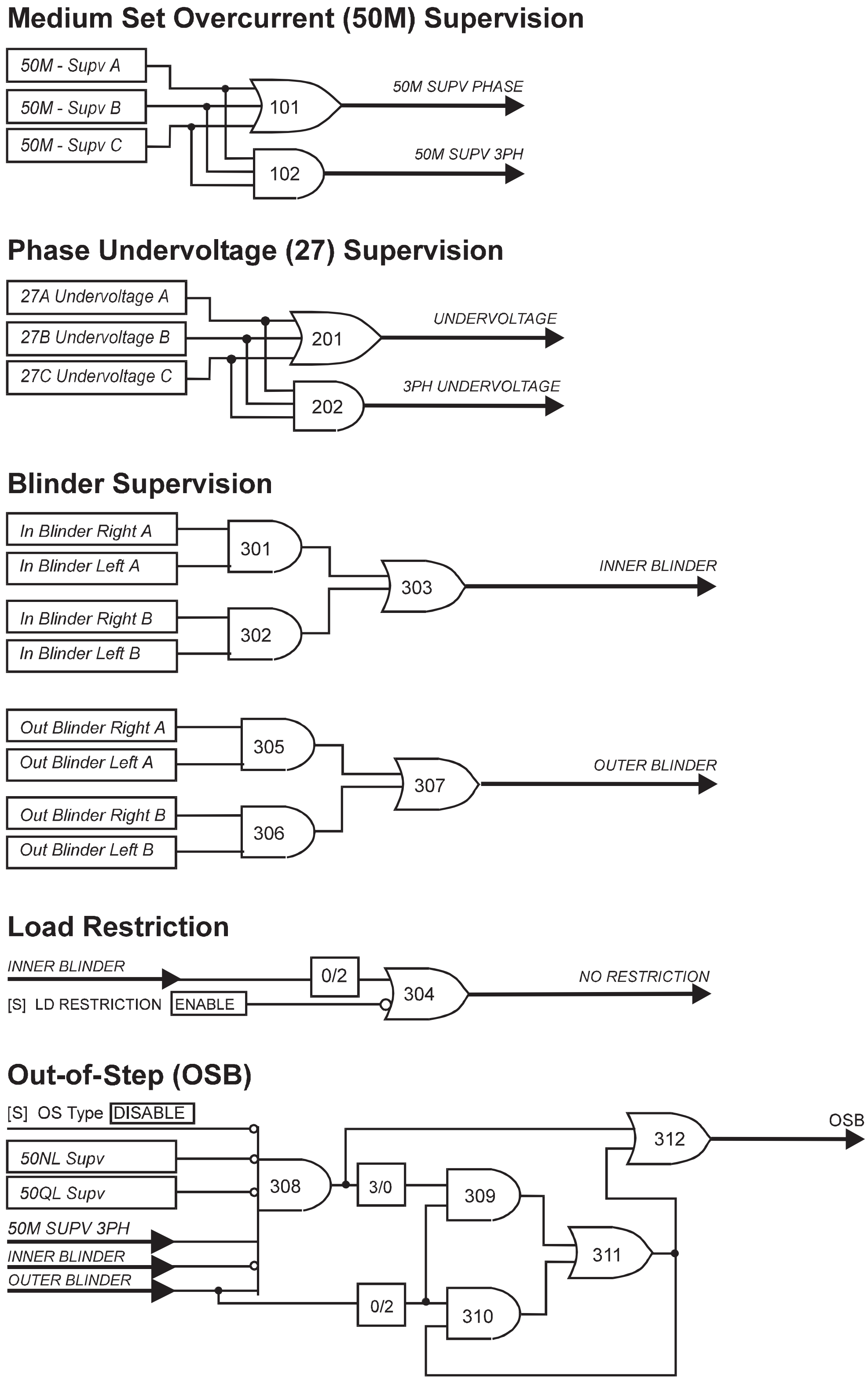
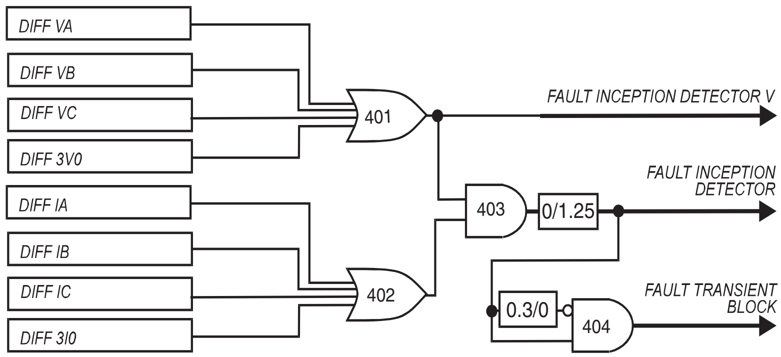


Figure 5-15. Supervision Logic, Group 1

High Speed Supervision Logic

Fault Inception



Loss of Potential

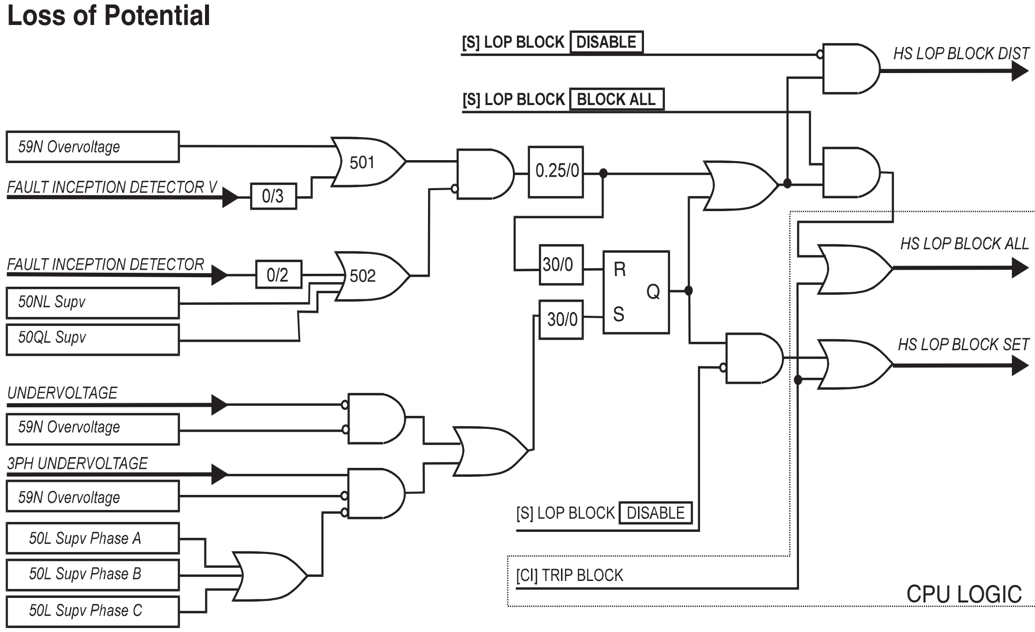
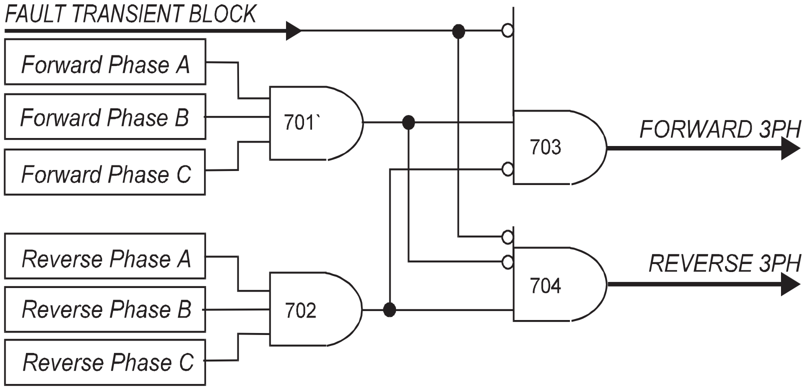
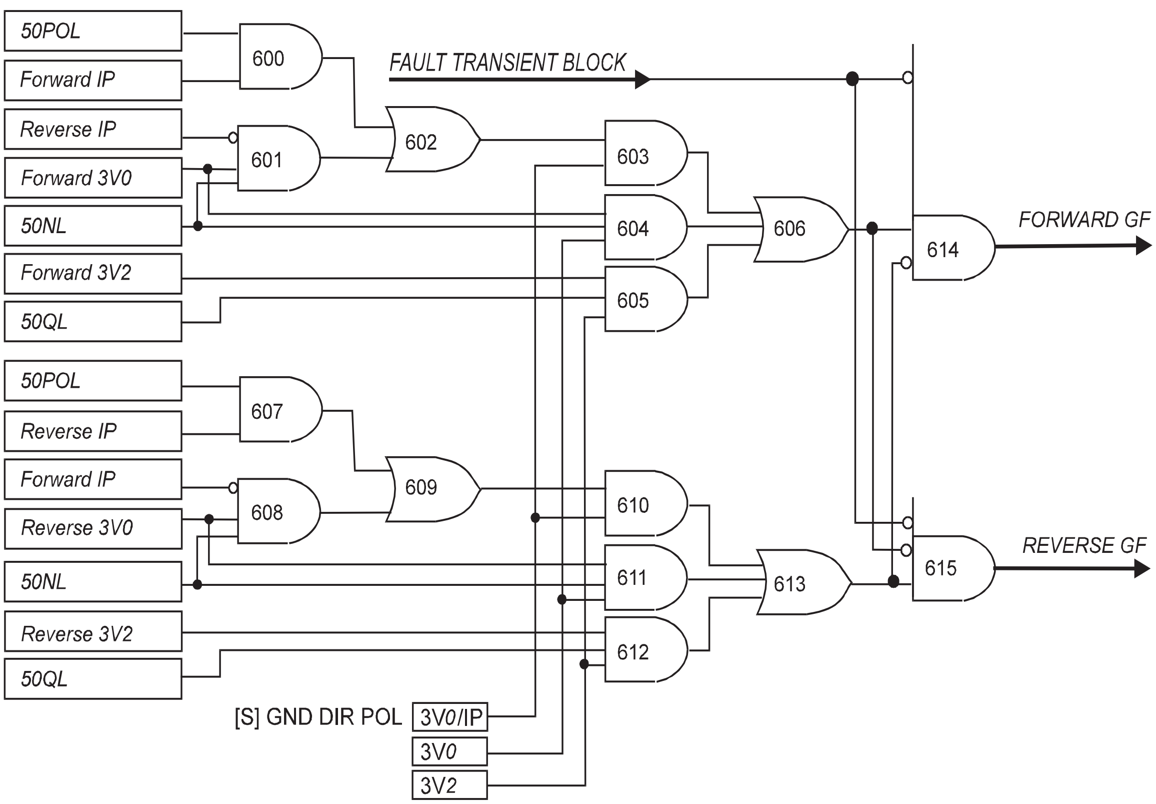


Figure 5-16. Supervision Logic, Group 2

Phase Directional Logic



Ground Directional Logic



Zero Sequence Ground Fault

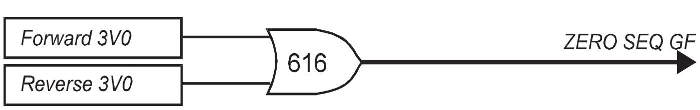


Figure 5-17. Directional Supervision Logic

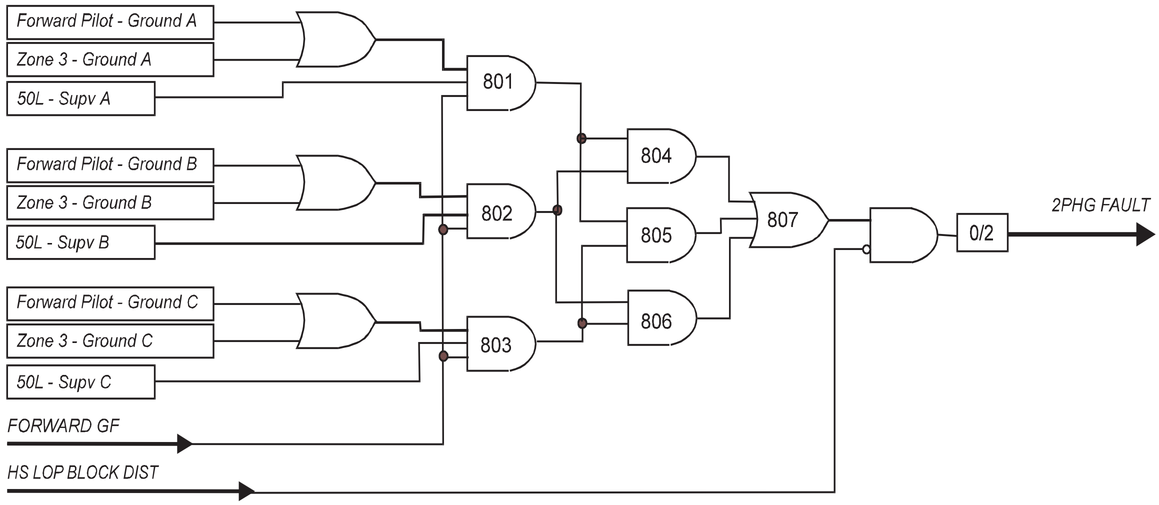


Figure 5-18. Two-Phase-to-Ground Fault Logic

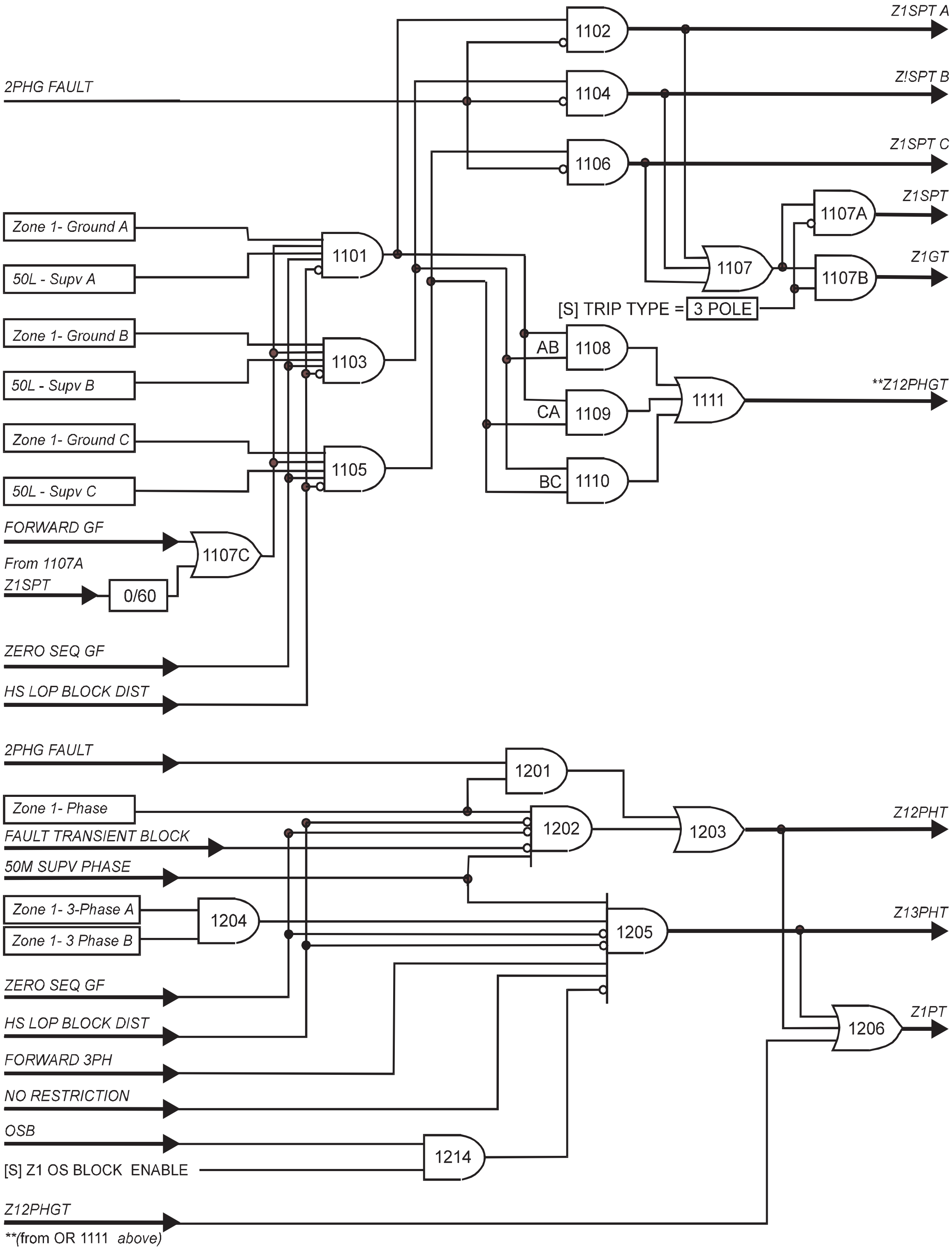


Figure 5-19. Zone-1 Logic

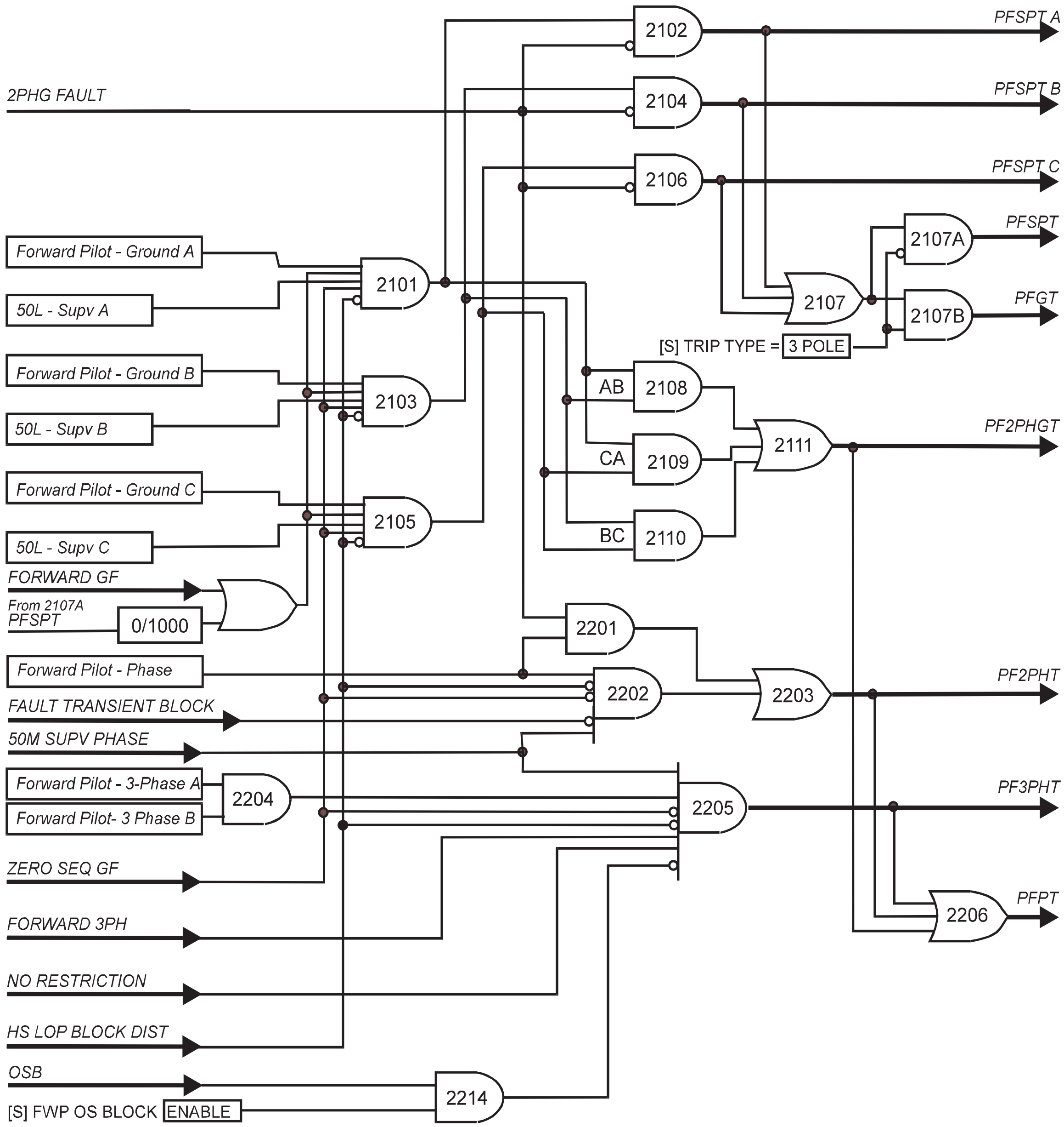


Figure 5-20. Forward Pilot Logic

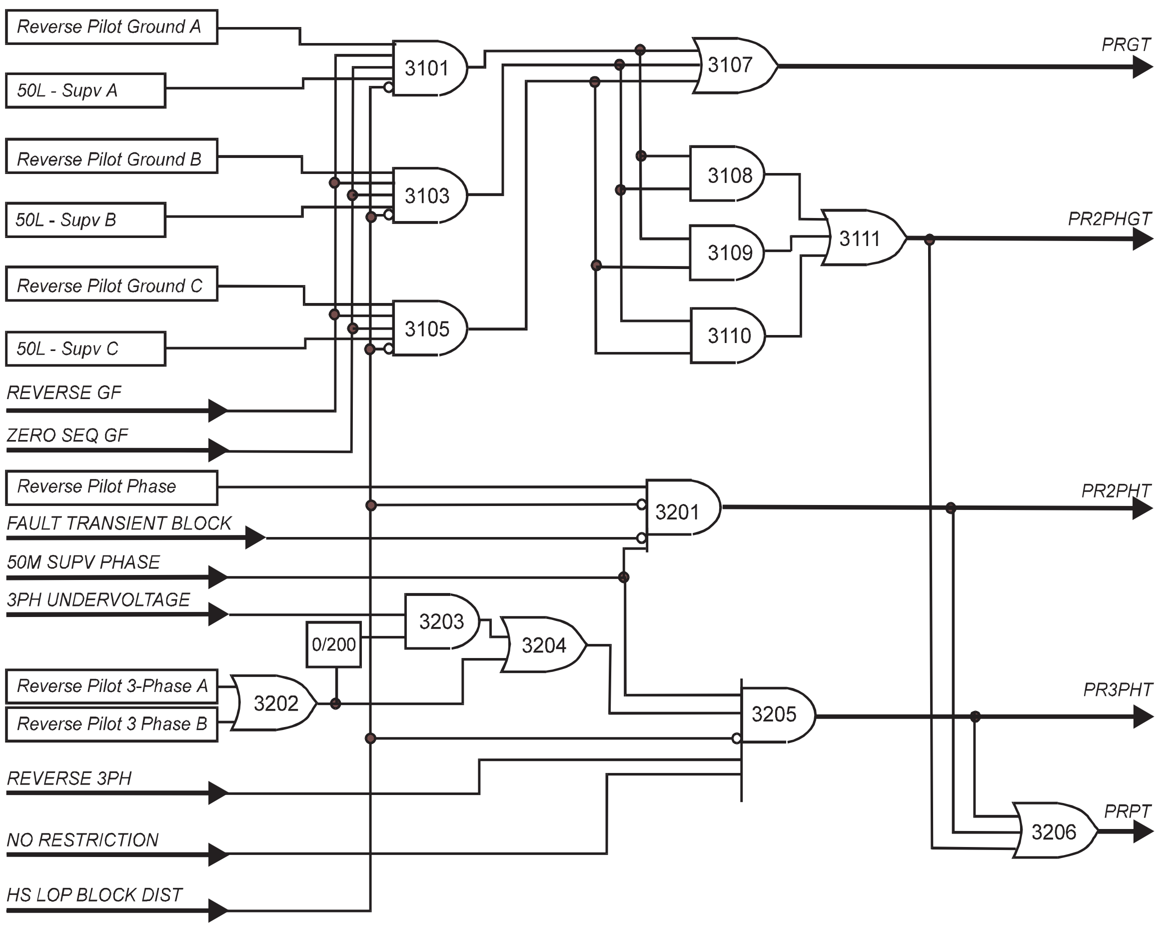


Figure 5-21. Reverse Pilot Logic

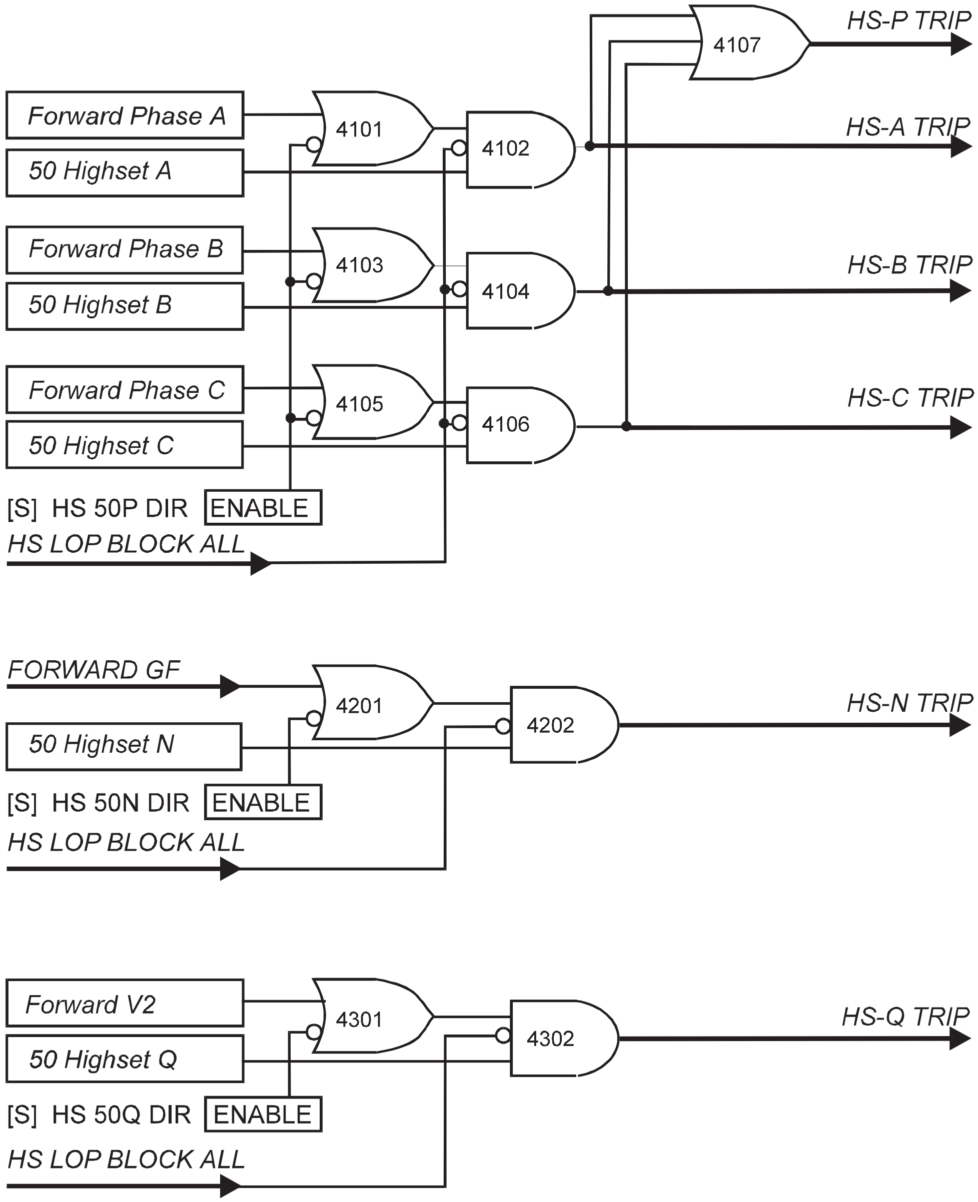
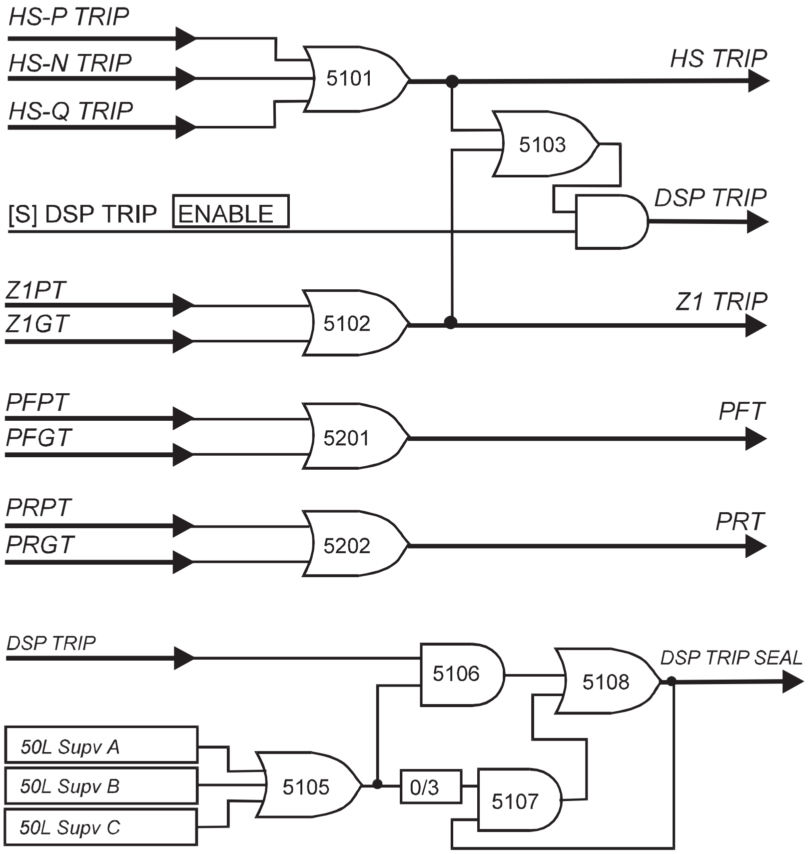


Figure 5-22. Highset Overcurrent Trip Logic

Three Pole Trip Logic



Phase Selection Logic

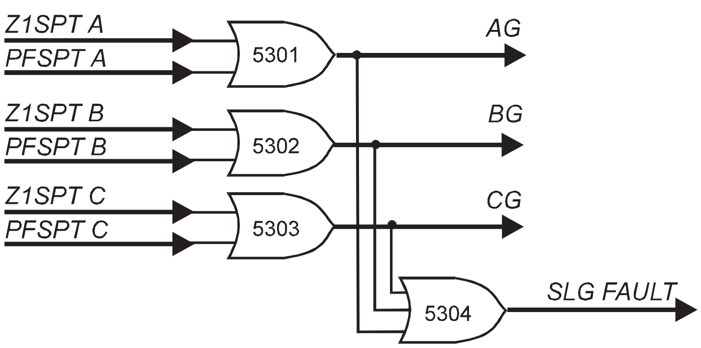
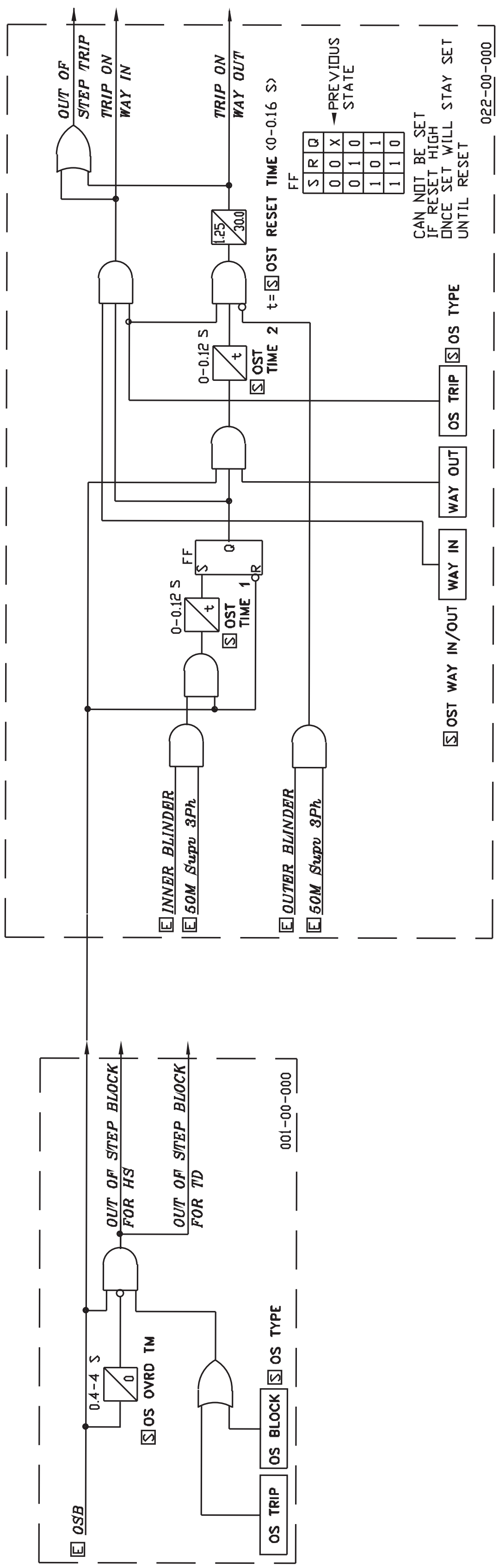


Figure 5-23. Trip and Phase Selection

CPU Logic

The following logic is executed from the CPU using input from the DSP logic modules. Logic module execution frequency times range from 1/4 cycle to 5/4 cycles based on the operating time requirements of the logic function. Pilot logic is executed every ¼ cycle while Zone-2 trip time is counted (checked) every 5/4 cycles.

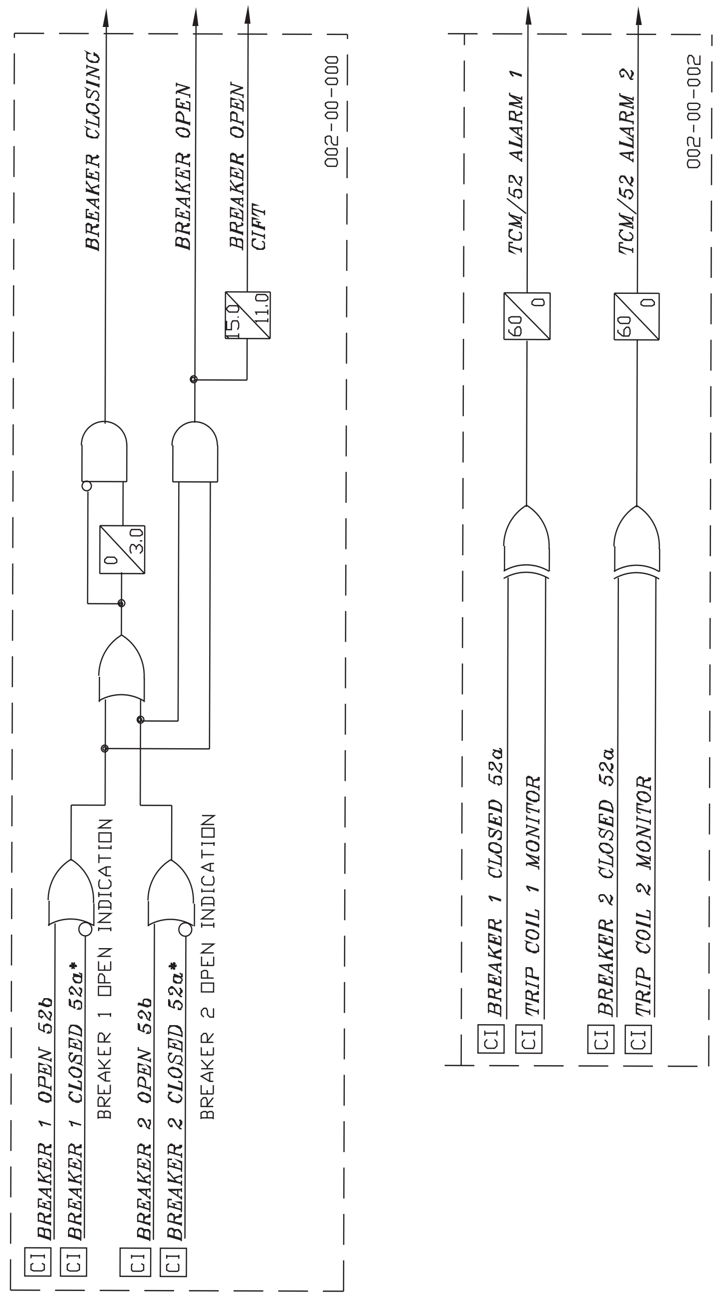


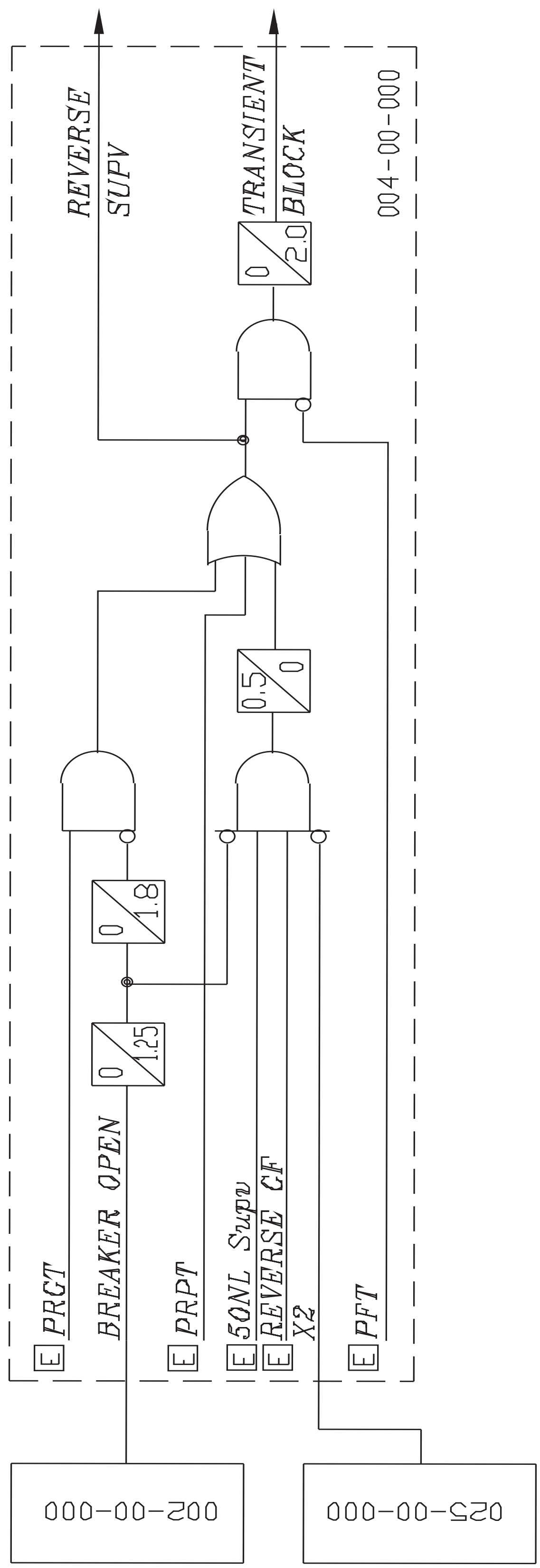
OUT OF STEP TRIP
TRIP ON WAY IN
TRIP ON WAY OUT
S R Q
0 0 X
0 1 0
1 0 1
1 1 0
PREVIOUS STATE
FF
CAN NOT BE SET IF RESET HIGH
ONCE SET WILL STAY SET UNTIL RESET
022-00-000
t= S OST RESET TIME (0-0.16 S)
1.25
30.0
0-0.12 S
OST TIME 2
OS TRIP
S OS TYPE
WAY OUT
WAY IN
S OST WAY IN/OUT
0-0.12 S
S OST TIME 1
E INNER BLINDER
E 50M Supv 3Ph
E OUTER BLINDER
E 50M Supv 3Ph
OUT OF STEP BLOCK FOR HS
OUT OF STEP BLOCK FOR TD
001-00-000
0.4-4 S
S OS OVRD TM
S OS TYPE
OS BLOCK
OS TRIP
E OSB

If 52b is used for breaker status then Breaker 1 open 52b and Breaker 2 open 52b must be mapped to the same input for single breaker applications.

If 52a is used for breaker status then Breaker 1 closed 52a and Breaker 2 closed 52a must be mapped to the same input for single breaker applications.

*Breaker 1 closed 52a and Breaker 2 closed 52a will have a logic value of 1 is not mapped to an input per Relay Inputs and Outputs discussed in Section 3.




REVERSE
SUPV
TRANSIENT
BLOCK
004-00-000
0
2.0
0.5
0
0
1.8
0
1.25
E PRGT
BREAKER OPEN
E PRPT
E 50NL Supv
E REVERSE CF
X2
E PFT
002-00-000
025-00-000