GE Consumer & Industrial
Multilin

C90^{Plus} **Controller**
Automation Logic Controller

Instruction manual

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C90^{Plus} Controller

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C90^Plus Controller

Chapter 1: Getting started

Please read this section to help guide you through the initial setup of the C90^Plus Controller.

Important procedures

It is highly recommended that the following sections are reviewed before placing the C90^Plus in service.

Cautions and warnings

Before attempting to install or use the device, it is imperative that all caution and danger indicators in this document are reviewed to help prevent personal injury, equipment damage, or downtime. The following icons are used to indicate notes, cautions, and dangers.

Figure 1: Note icons used in the documentation

NOTE   CAUTION   DANGER

The standard **note** icon emphasizes a specific point or indicates minor problems that may occur if instructions are not properly followed.

The **caution** icon indicates that possible damage to equipment or data may occur if instructions are not properly followed.

The **danger** icon provides users with a warning about the possibility of serious or fatal injury to themselves or others.

Inspection checklist

Use the following procedure to unpack and inspect the C90^Plus.

1. Open the system packaging and inspect the unit for physical damage.

2. View the rear nameplate and verify that the correct model has been ordered.

3. Ensure that the following items are included:
   – Reference Guide (if ordered)
   – GE EnerVista CD (includes software and documentation)

4. For product information, instruction manual updates, and the latest software updates, please visit the GE Multilin website at http://www.GEmultilin.com.

5. If there is any noticeable physical damage, or any of the contents listed are missing, please contact GE Multilin immediately.

GE Multilin contact information and call center for product support:

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Markham, Ontario
Canada L6E 1B3

Telephone: 1-905-294-6222
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E-mail: multilin.tech@ge.com
Website: http://www.GEmultilin.com

Manual organization

The documentation for the C90^{Plus} consists of three primary publications:

- Reference Guide
- Communications Guide
- Quick Reference Guide

This Reference Guide contains detailed information on wiring, programming, connecting, and testing the C90^{Plus} Controller. The Communications Guide contains detailed information on the Modbus, DNP, IEC 61850, and IEC 61870-5-104 communications protocols used in the C90^{Plus}. The Quick Reference Guide provides basic instructions on the installation and setup of the C90^{Plus}.

Reading a lengthy instruction manual on a new product is not a task most people enjoy. To speed things up, this introductory chapter provides guidelines for basic relay usability. Important wiring considerations and precautions should be observed for reliable operation. Detailed information regarding accuracy, output relay contact ratings, and so forth are detailed in the specifications. The remainder of this manual should be read and kept for reference to ensure maximum benefit from the C90^{Plus} Controller. For further information, please consult your local sales representative or GE Multilin. Comments about new features or modifications for your specific requirements are welcome and encouraged.

The path to settings and actual values are indicated as follows in the manual:

Actual Values > Automation > Control > Synchrocheck

This 'path representation' illustrates the location of a specific actual value or setpoint with regards to its previous menus and sub-menus in the EnerVista software. The example above indicates the following path.

Figure 2: Typical EnerVista menu tree
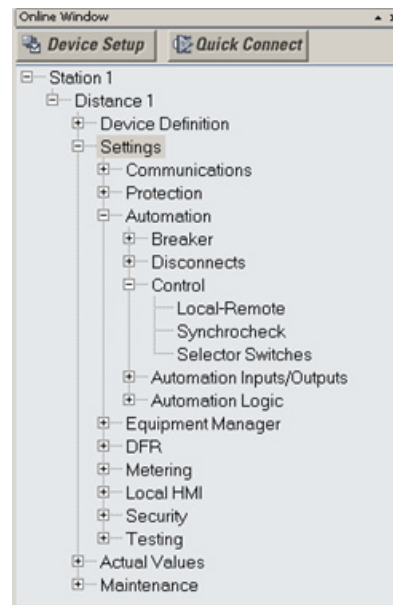
Introduction to the UR^{Plus}-series

Historically, substation protection, control, and metering functions were performed with electromechanical equipment. This first generation of equipment was gradually replaced by analog electronic equipment, most of which emulated the single-function approach of their electromechanical precursors. Both of these technologies required expensive cabling and auxiliary equipment to produce functioning systems.

Recently, digital electronic equipment has begun to provide protection, control, and metering functions. Initially, this equipment was either single function or had very limited multi-function capability, and did not significantly reduce the cabling and auxiliary equipment required. However, recent digital relays have become quite multi-functional, reducing cabling and auxiliaries significantly. These devices also transfer data to central control facilities and human-machine interfaces using electronic communications. The functions performed by these products have become so broad that many users now prefer the term IED (Intelligent Electronic Device).

It is obvious to station designers that the amount of cabling and auxiliary equipment installed in stations can be even further reduced, to 20% to 70% of the levels common in 1990, to achieve large cost reductions. This requires placing even more functions within the IEDs.

Users of power equipment are also interested in reducing cost by improving power quality and personnel productivity, and as always, in increasing system reliability and efficiency. These objectives are realized through software which is used to perform functions at both the station and supervisory levels. The use of these systems is growing rapidly.

High speed communications are required to meet the data transfer rates required by modern automatic control and monitoring systems. In the near future, very high speed communications will be required to perform protection signaling with a performance target response time for a command signal between two IEDs, from transmission to reception, of less than 3 milliseconds. This has been established by the IEC 61850 standard.

IEDs with the capabilities outlined above will also provide significantly more power system data than is presently available, enhance operations and maintenance, and permit the use of adaptive system configuration for protection and control systems. This new generation of equipment must also be easily incorporated into automation systems, at both the station and enterprise levels. The GE Multilin Advanced Universal Protection System (UR^Plus-series) has been developed to meet these goals.

The C90^Plus is the advanced automation controller for the UR^Plus-series platform.

Hardware architecture

The C90^Plus is a microprocessor-based device. It has a modular design consisting of a chassis containing discrete modules that interface over a common bus. Each module is dedicated to a specific purpose. Several of the modules are required for basic operation of the device, while others are optional.

The power supply module receives AC or DC power from an external supply and produces conditioned 12 V DC power for all of the modules in the chassis. The power supply also generates 48 V DC power for external contact wetting. The output contact indicating a critical failure of the unit also resides on this module.

The AC module measures AC currents and voltages derived from CTs and VTs. These signals are sampled and digitized and sent over the C90^Plus bus to the CPU module for further processing. A version is available that accepts nominal 5 A current and another that accepts nominal 1 A current.

Input and output modules monitor digital (on and off) signals from external devices (field contacts or other IEDs), control external devices such as breakers, and send digital signals to other devices. Input and output modules are subdivided into protection inputs and outputs and automation inputs and outputs, with several flavors of each type.

The CPU module contains the firmware for the C90^Plus. The firmware contains the algorithms required for the various functions provided by the device. The CPU receives analog and digital data from the AC and input/output modules. The data is processed by the CPU and resulting control actions are sent back to the input-output modules. The CPU has one rear Ethernet port that is used for configuration and record retrieval and one rear RS485 port supporting the Modbus and DNP protocols. The CPU also contains the IRIG-B port required for clock synchronization.

The communications module is required for communicating with external devices over Ethernet using the IEC 61850, DNP 3.0, or IEC60870-5-104 protocols. This module is also required for peer-to-peer GSSE/GOOSE messaging. This module contains its own microprocessor which is dedicated to handling communications tasks. It also contains two redundant Ethernet ports. Each port supports 100Base-FX over multi-mode fiber and 10/100Base-TX over twisted pair, with auto-negotiation. These ports may additionally be configured for single IP or dual IP redundancy.

NOTE

The C90^Plus requires one power supply module, one CPU module, and one AC module. Communications modules are optional.

The front panel interface consists of an annunciator display, a main display, and an EnerVista USB port. The annunciator display collects alarm indications from the C90^Plus internal functions and presents them using a standard annunciator format. Alarms and their corresponding messages are entirely user-configurable. The main display allows the user to view metering data collected by the C90^Plus. It also provides access to the control functions via dedicated control pushbuttons. The USB port allows the user to interface with the C90^Plus using the EnerVista software running on a portable PC. The C90^Plus operates independently from the front panel interface.

Figure 3: C90Plus block diagram

Protection
Automation
Equipment manager
Digital fault recorder
Metering
Local HMI

Contact inputs
Virtual inputs
CT inputs
VT inputs
GOOSE
GSSE

Contact outputs
Virtual outputs

GOOSE
GSSE

EnerVista software   HMI / SCADA   IED

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Figure 4: C90Plus hardware overview

AC modules
facilitate field
upgrades

Analog
measurement
of contact state

Communications
module
- 10/100 Base-T
- 100 Base-FX

Single AC module for
½ breaker scheme

Single grounding
stud for simplified
wiring

Rugged chassis
(–42°C to 85°C)

Two-tiered daggered
terminal blocks; easy
access to lower
terminals

Maintenance
Ethernet port

Separation between
communications and
DC wiring

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Firmware architecture

The C90^{Plus} is organized into six major functions.

- Protection
- Automation

- Metering
- Digital fault recorder (DFR)
- Equipment manager
- Front panel interface (HMI)

These functions operate autonomously from one another. Each function has its own configuration parameters and each generates it own output signals. All functions share the hardware and the communications facilities within the device.

The protection function contains the necessary elements required to detect faults in the power system and send tripping signals to isolate the fault. This will be the primary sub-system for many users. The protection function also has its own dedicated FlexLogic™ engine which runs at the same scan rate as the protection (16 times per power system cycle). Protection FlexLogic™ is used to create custom logic schemes for protection purposes.

Automation is divided into two major sub-groupings: control schemes and automation logic. Control schemes are hard-coded general purpose schemes responsible for automatic control within the substation. These include breaker and disconnect switch control, interlocking, and synchrocheck. Automation logic is intended for development of custom or advanced automatic schemes in the case the user requires a level of functionality beyond that found in the hard-coded schemes. Automation logic generally requires a lower execution rate than protection logic but has greatly expanded functionality and lines of logic.

The metering function generates a wide range of real-time power system measurements including voltage, current, frequency, complex power, and energy. It also incorporates a data logger that provides historical recording of selected metering quantities and includes statistical (maximum, minimum, and average) and alarming capabilities. The metering function also provides synchrophasor capabilities in accordance with IEEE C37.118-2005.

The digital fault recorder incorporates transient recorder, disturbance recorder and fault report capabilities. The transient recorder is intended to capture short events such as a fault at a high sampling rate (up to 256 samples per cycle). The disturbance recorder captures longer events such as a power swing at a lower sampling rate. The channel assignments and triggering of these features can be independently configured. The fault report facility provides a comprehensive record of the key measurements associated with an event including fault type, fault location, pre-fault and post-fault quantities, and clearing time.

The equipment manager function monitors important parameters of the station battery under normal operation and can be used to detect incipient failures.

Despite their logic separation, signals can be exchanged between these functions. For instance, it is useful for the digital fault recorder to record the output of protection functions. Consequently a fixed, pre-determined set of signals is available as inputs to each function. These are illustrated in the following figure.

The C90^{Plus} also includes shared operand functionality. Output signals from the various functions can be assigned as shared operands available to all functions. These signals can then be assigned as inputs within other functions.

For example, assume that the PHASE TOC1 OP protection FlexLogic™ operand is required as a signal within the automation function. This signal would be assigned as a shared operand. As such, the PHASE TOC1 OP operand would subsequently become available to the automation function by appearing in the list of available operands.

Figure 5: Functional architecture
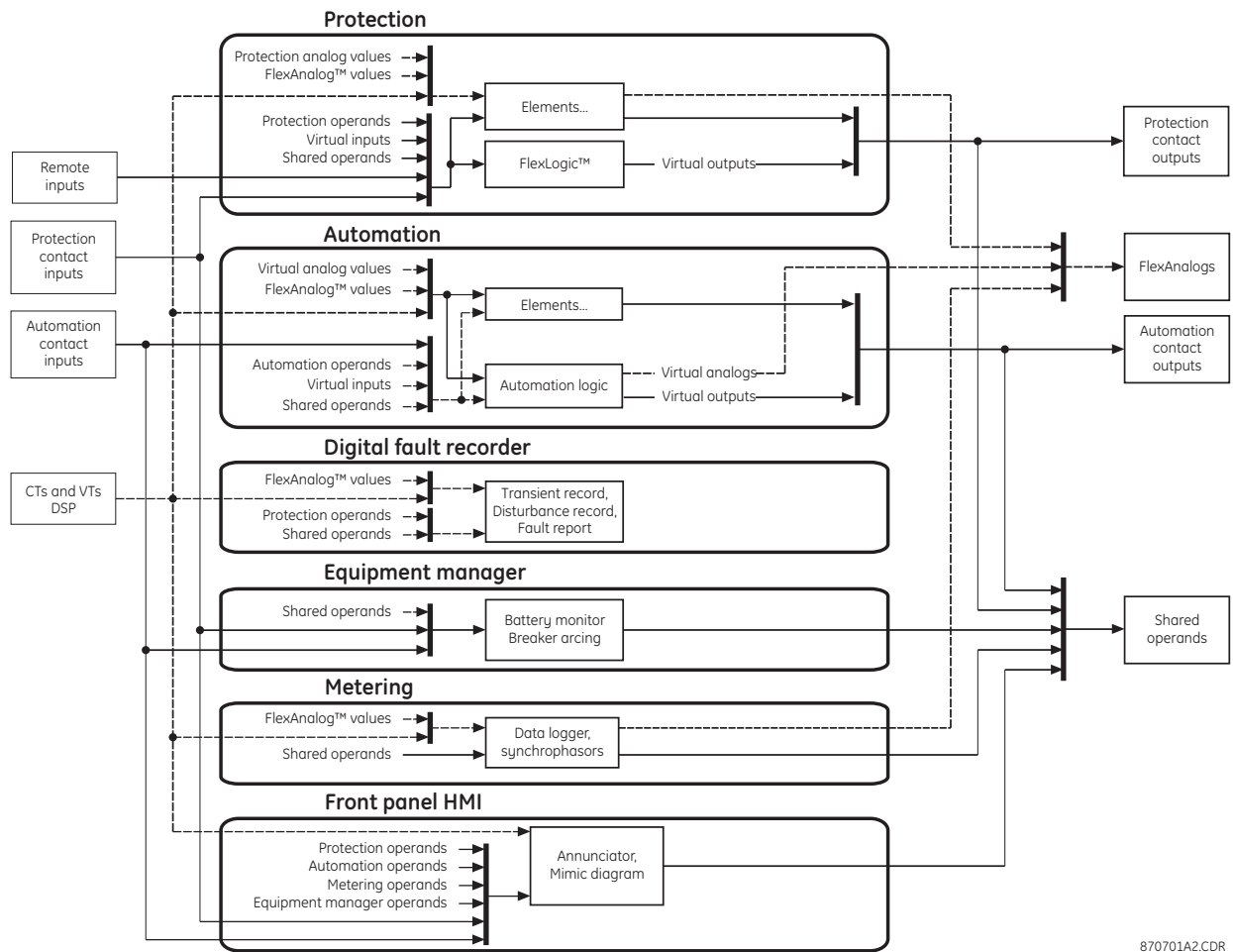
Communications overview

The EnerVista UR^{Plus} Setup software can communicate with the relay through three ports: the front panel USB port, the rear Ethernet port, and the rear RS485 port. Both rear ports are located in slot D.

Figure 6: Communications overview
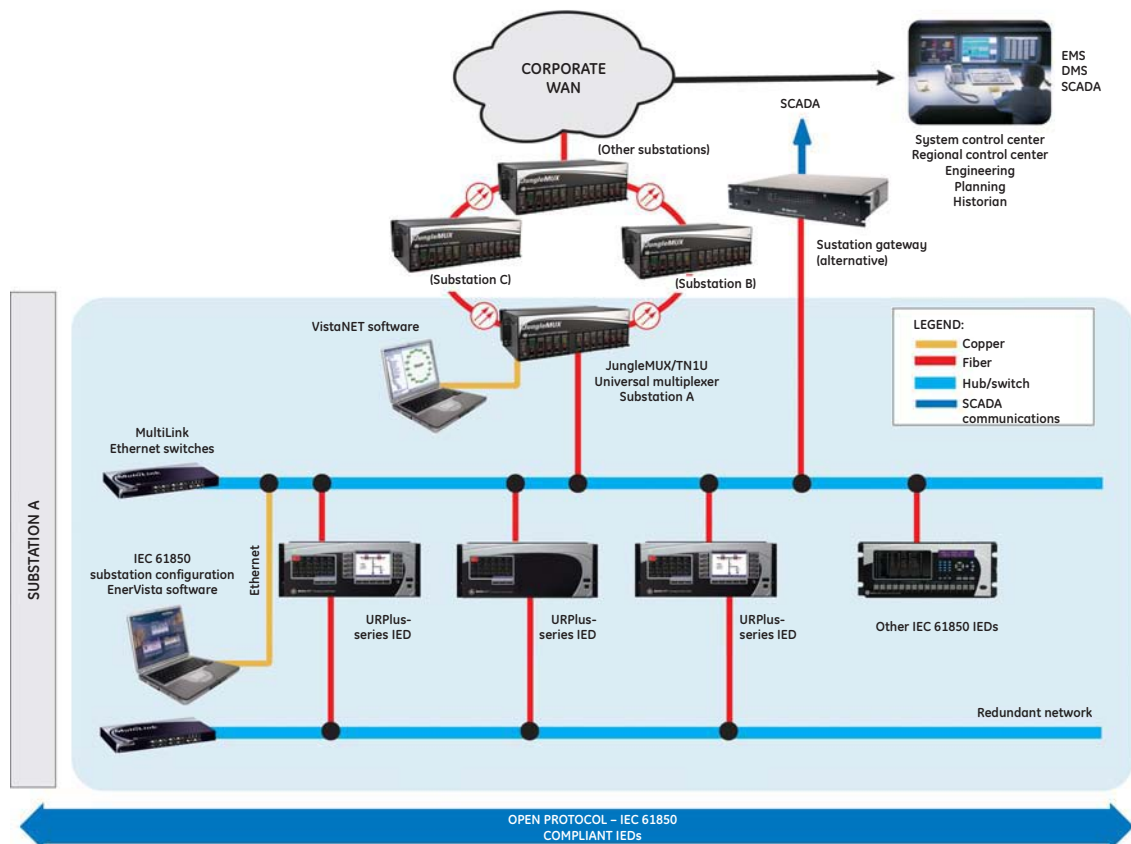
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To communicate through the C90^Plus rear RS485 port from a computer's RS232 port, the GE Multilin RS232/RS485 converter box is required. This device (catalog number F485) connects to the computer using a straight-through serial cable. A shielded twisted-pair (20, 22, or 24 AWG) connects the F485 converter to the C90^Plus rear communications port. The converter terminals (+, –, GND) are connected to the C90^Plus communication module (+, –, COM) terminals. Refer to the CPU communications ports section in chapter 3 for option details. The line should be terminated with an R-C network (that is, 120 Ω, 1 nF) as described in the chapter 3.

Communications via Ethernet requires a connection to an Ethernet network using a standard copper or fiber cable. The Ethernet port can also connect directly to a PC using a cross-over cable.

To communicate via the faceplate USB port, a standard USB serial cable is used.

EnerVista software

The EnerVista software suite is an industry-leading set of programs that simplifies every aspect of the C90^Plus. The EnerVista suite provides tools to monitor the status of your protected asset, maintain the relay, and integrate information measured by the C90^Plus into DCS or SCADA monitoring systems. Convenient COMTRADE and sequence of events viewers are an integral part of the EnerVista UR^Plus Setup software included with every C90^Plus. This allows the user to carry out post-mortem event analysis to ensure proper protection system operation.

Software requirements

The EnerVista UR^{Plus} Setup software interface is used to communicate with the C90^{Plus}. The EnerVista UR^{Plus} Setup software interface is the preferred method to edit settings and view actual values because the PC monitor can display more information in a simple comprehensible format.

The following minimum requirements must be met for the EnerVista UR^{Plus} Setup software to properly operate on a PC.

- Pentium class or higher processor (Pentium II 300 MHz or higher recommended)
- Windows 2000, XP
- Internet Explorer 4.0 or higher
- 128 MB of RAM (256 MB recommended)
- 200 MB of available space on system drive and 200 MB of available space on installation drive
- Video capable of displaying 800 × 600 or higher in high-color mode (16-bit color)
- USB 2.0 and/or Ethernet port for communications to the relay

Installing the EnerVista UR^{Plus} Setup software

After ensuring the minimum requirements for using EnerVista UR^{Plus} Setup software (see previous section), use the following procedure to install the EnerVista UR^{Plus} Setup from the enclosed GE EnerVista CD.

1. Insert the GE EnerVista CD into your CD-ROM drive.
2. Click the **Install Now** button and follow the installation instructions to install the no-charge EnerVista software.
3. When installation is complete, start the EnerVista Launchpad application.
4. Click the IED Setup section of the Launch Pad window.

5. In the EnerVista Launch Pad window, click the **Add Product** button and select the "C90^{Plus} Controller" from the Install Software window as shown below. Select the "Web" option to ensure the most recent software release, or select "CD" if you do not have a web connection, then click the **Add Now** button to list software items for the C90^{Plus}.
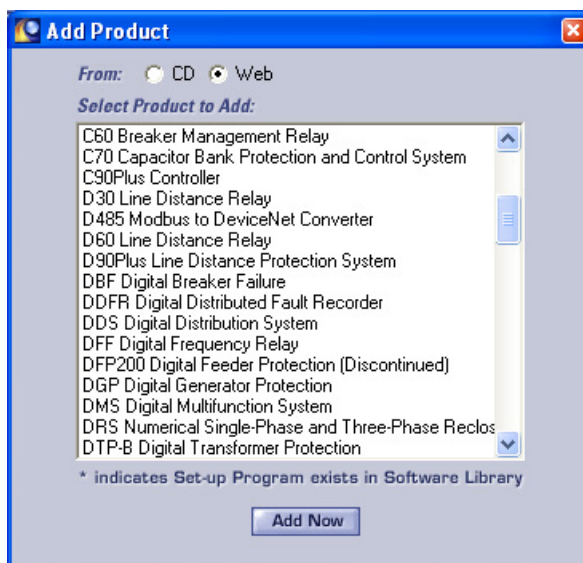
EnerVista Launchpad will obtain the software from the Web or CD and automatically start the installation program.

6. Select the complete path, including the new directory name, where the EnerVista UR^{Plus} Setup will be installed.

7. Click on **Next** to begin the installation. The files will be installed in the directory indicated and the installation program will automatically create icons and add EnerVista UR^{Plus} Setup to the Windows start menu.

8. Click **Finish** to end the installation. The UR^{Plus}-series device will be added to the list of installed IEDs in the EnerVista Launchpad window, as shown below.

Software access

The user can connect remotely to the C90^{Plus} through the rear RS485 port or the rear Ethernet port with a PC running the EnerVista UR^{Plus} Setup software. The C90^{Plus} can also be accessed locally with a laptop computer through the front panel USB port or the rear Ethernet port using the Quick Connect feature.

- To configure the C90^{Plus} for remote access via the rear RS485 port, refer to the Configuring Serial Communications section.
- To configure the C90^{Plus} for remote access via the rear Ethernet port, refer to the Configuring Ethernet Communications section.
- To configure the C90^{Plus} for local access with a laptop through either the front USB port or rear Ethernet port, refer to Using the Quick Connect feature via the USB port.

Configuring serial communications

Before starting, verify that the serial cable is properly connected to the RS485 terminals on the back of the device. The faceplate USB port is intended for local use and is not described in this section; see the Using the Quick Connect Feature section for details on configuring the USB port.

1. Verify that the latest version of the EnerVista UR^{Plus} Setup software is installed (available from the GE EnerVista CD or online from http://www.GEmultilin.com). See the Software Installation section for installation details.
2. Select the "C90^{Plus}" device from the EnerVista Launchpad to start EnerVista UR^{Plus} Setup.
3. Click the **Device Setup** button to open the Device Setup window and click the **Add Site** button to define a new site.
4. Enter the desired site name in the "Site Name" field. If desired, a short description of site can also be entered along with the display order of devices defined for the site. In this example, we will use "Location 1" as the site name. Click the **OK** button when complete.
5. The new site will appear in the upper-left list in the EnerVista UR^{Plus} Setup window. Click the **Device Setup** button then select the new site to re-open the Device Setup window.
6. Click the **Add Device** button to define the new device.
7. Enter the desired name in the "Device Name" field and a description (optional) of the site.
8. Select "Serial" from the **Interface** drop-down list. This will display a number of interface parameters that must be entered for proper serial communications.
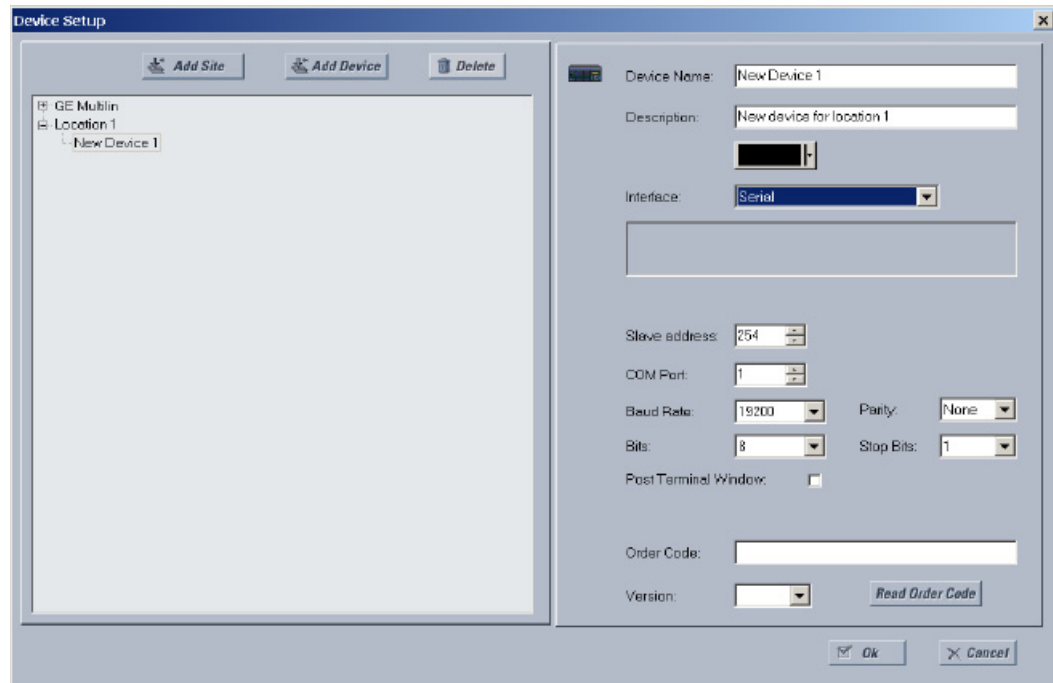
9. Enter the relay slave address, COM port, baud rate, and parity settings from the **Settings > Communications > Serial Ports** tree item in their respective fields.

10. Click the **Read Order Code** button to connect to the UR^{Plus} device and upload the order code. If the software is unable to upload the order code due to a communications error, ensure that the EnerVista UR^{Plus} Setup serial communications values entered in the previous step correspond to the relay setting values.

11. Click "OK" when the relay order code has been received. The new device will be added to the Site List window (or Online window) located in the top left corner of the main EnerVista UR^{Plus} Setup window.

The site device has now been configured for serial communications. Proceed to the Connecting to the C90^{Plus} section to begin communications.

Configuring Ethernet communications

Before starting, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay. To setup the relay for Ethernet communications, it will be necessary to define a site, then add the relay as a device at that site.

1. Verify that the latest version of the EnerVista UR^{Plus} Setup software is installed (available from the GE EnerVista CD or online from http://www.GEmultilin.com). See the Software Installation section for installation details.

2. Select the "UR^{Plus}" device from the EnerVista Launchpad to start EnerVista UR^{Plus} Setup.

3. Click the **Device Setup** button to open the Device Setup window, then click the **Add Site** button to define a new site.

4. Enter the desired site name in the "Site Name" field. If desired, a short description of site can also be entered along with the display order of devices defined for the site. In this example, we will use "Location 2" as the site name.Click the **OK** button when complete.

5. The new site will appear in the upper-left list in the EnerVista UR^{Plus} Setup window. Click the **Device Setup** button then select the new site to re-open the Device Setup window.

6. Click the **Add Device** button to define the new device.

7. Enter the desired name in the "Device Name" field and a description (optional) of the site.

8. Select "Ethernet" from the **Interface** drop-down list. This will display a number of interface parameters that must be entered for proper Ethernet functionality.
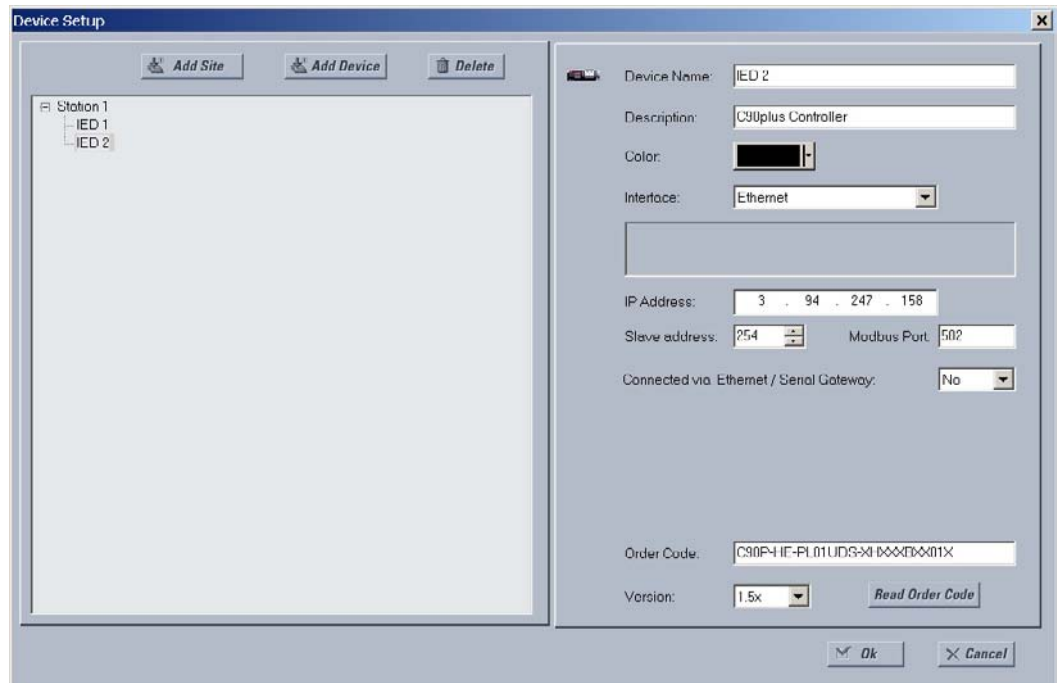
9. Enter the relay IP address specified in the **Settings > Communications > Network > Addressing** menu in the "IP Address" field.

10. Enter the relay slave address and Modbus port address values from the respective settings in the **Settings > Communications > Modbus > Protocol** menu.

11. Click the **Read Order Code** button to connect to the C90^{Plus} device and upload the order code. If an communications error occurs, ensure that the three EnerVista UR^{Plus} Setup values entered in the previous steps correspond to the relay setting values.

12. Click **OK** when the relay order code has been received. The new device will be added to the Site List window (or Online window) located in the top left corner of the main EnerVista UR^{Plus} Setup window.

The site device has now been configured for Ethernet communications. Proceed to the Connecting to the C90^{Plus} section to begin communications.

Using the Quick Connect feature via the USB port

Before starting, verify that the standard USB cable is properly connected from the laptop computer to the front panel USB port.

1. Verify that the latest version of the EnerVista UR^{Plus} Setup software is installed (available from the GE EnerVista CD or online from http://www.GEmultilin.com). See the Software Installation section for installation details.

2. Select the "UR^{Plus}" device from the EnerVista Launchpad to start EnerVista UR^{Plus} Setup.

3. Click the **Quick Connect** button to open the Quick Connect dialog box.

4. Select the **Serial interface** and the correct COM Port, then click **Connect**.

5. The EnerVista UR^{Plus} Setup software will create a site named "Quick Connect" with a corresponding device also named "Quick Connect" and display them on the upper-left corner of the screen. Expand the sections to view data directly from the C90^{Plus} device.

Each time the EnerVista UR^{Plus} Setup software is initialized, click the **Quick Connect** button to establish direct communications to the C90^{Plus}. This ensures that configuration of the EnerVista UR^{Plus} Setup software matches the C90^{Plus} model number.

Connecting to the C90^{Plus}

This example will show how to connect to the C90^{Plus} and configure the breaker settings.

1. Open the Breakers window through the site list tree.
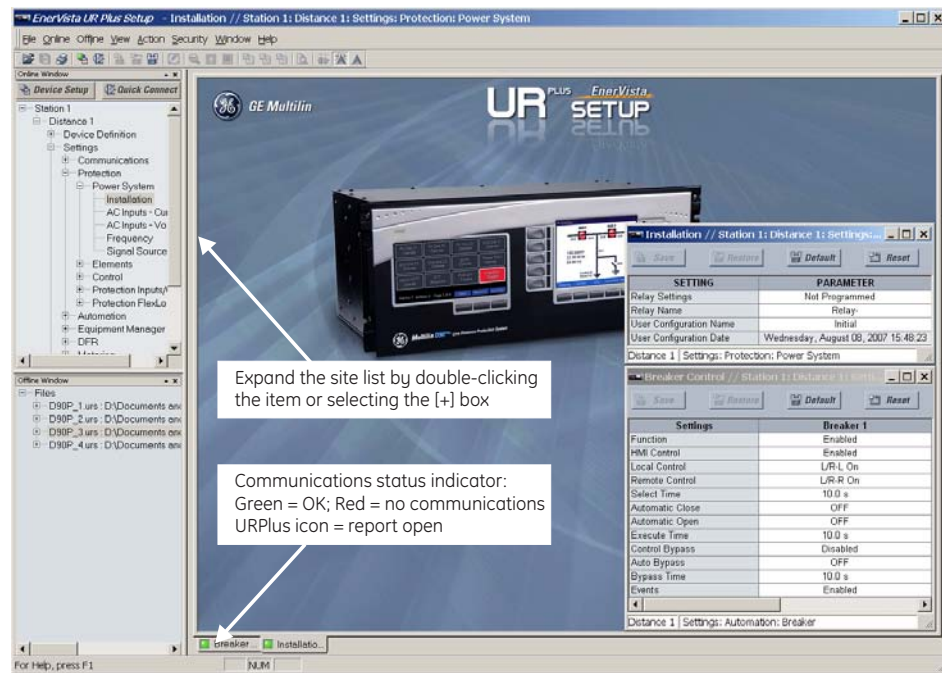
The breaker configuration window will open and a status indicator will be displayed on the lower left of the EnerVista UR^{Plus} Setup window.

2. If the status indicator is red, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay and that the relay has been properly setup for communications.

    If a relay icon appears in place of the status indicator, than a report (such as an oscillography or event record) is open. Close the report to re-display the green status indicator.

3. The breaker settings can now be edited, printed, or changed according to user specifications.

Refer to chapter 4 in this manual and the EnerVista UR^{Plus} Setup help file for more information about the using the EnerVista UR^{Plus} Setup software interface.

C90^{Plus} Controller

Chapter 2: Product description

This chapter provides a basic functional overview and the technical specifications for the C90^{Plus}.

C90^{Plus} overview

The C90^{Plus} Controller is a powerful logic controller specifically designed for use in substation environments and for the unique automation requirements of industrial and utility power systems. The C90^{Plus} provides unmatched logic processing ability combined with a powerful math engine with deterministic execution of logic equations regardless of the configuration of the number of lines of logic.

The C90^{Plus} provides the tools and functionality necessary for creating customized automation and control schemes that include:

*   Advanced bay control and interlocking.
*   Breaker monitoring and control.
*   Automatic bus transfer schemes.
*   Load shedding and load restoration schemes.

Additional key benefits of the C90^{Plus} are listed below.

*   Deterministic execution of logic regardless of the number of configured equations.
*   Substation hardened controller that surpasses the transient, ESD, and RFI immunity of a standard PLC.
*   Local front panel interface provides real time control and annunciation of station events.
*   Configurable alarm annunciator eliminates the need for separate annunciator panel.
*   Intuitive and easy-to-use large front panel color display with preconfigured information on metering, fault records, event records, and separate control screen for bay control.
*   High-end fault and disturbance recording, including internal relay operating signals, eliminating the need for redundant recording devices.
*   Reduced installation space requirements through compact design.

- True convergence of protection, metering, automation, control functions, multiple input and output options, and extensive communications capability.

Front panel interface

An intuitive and easy-to-use color graphical display is provided in the C90^{Plus} front panel. The display provides easy access and visualization of device information, ranging from the large display of metered values such as voltage, current, demand, energy, and sequence components, to a comprehensive display of fault reports, sequence of events, and transient recorded waveforms. The front panel interface also displays device health information with critical and non-critical alarm status.

This advanced functionality allows the user to access comprehensive information without having to navigate through conventional displays and keypads. Information is displayed through two dedicated display panels. One serves as a digital annunciator and the other reflects display and control functions.

Annunciator

The C90^{Plus} provides an embedded, configurable color LCD annunciator on the front panel of the device, eliminating the need for LEDs and separate annunciators in the panel.

Any contact, direct, or remote input, or internally generated operand can be assigned to the annunciator. Up to 288 targets may be assigned. The display can be configured for 12, 24, or 48 alarms per page to a maximum of 24 pages. A separate self-test message page on the annunciator panel displays easy to understand error messages about device health. This page also provides a graphical representation of the error messages, greatly assisting in identifying and correcting problems.

Figure 7: Typical annunciator display
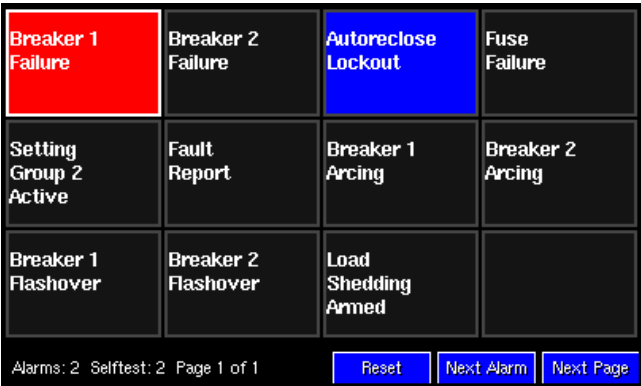
Control functions

The front panel interface contains a mimic diagram that provides status and control for two breakers and up to six disconnect switches. Many different bay configurations can be realized through the setting of the device. Tagging of a device and substitution of device status can also be carried out through front panel. Status and control of the autoreclose function is also available through the mimic diagram.

Figure 8: Front panel control overview
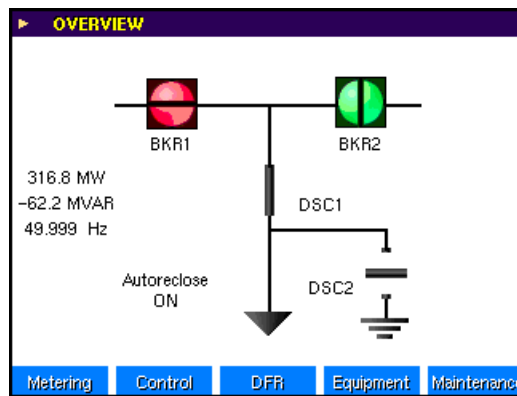
Front panel USB port

The front panel of the C90^Plus provides a USB 2.0 port for simple data transfer and access. This makes downloading and uploading faster and more convenient.

Figure 9: Front panel USB connection

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Protection features

The C90^Plus is designed for superior performance and ease-of-use, providing a single platform solution for automation logic control. The scalable platform consists of protection, control, automation, monitoring, communication, digital fault recorder (DFR) and security functionality. The incrementally scalable concept allows customization in building the device to suit specific user requirements. The truly convergent platform integrates multiple devices eliminating external devices and reduces the footprint of relay panels resulting in reduced wiring, commissioning and capital costs.

Overvoltage and undervoltage protection

Long lines under lightly loaded conditions or no-load may experience voltages exceeding the rated per unit voltage level of the line. The C90^Plus also provides additional voltage functions including neutral overvoltage, negative-sequence overvoltage, and phase undervoltage.

Overcurrent functions

The C90^Plus provides overcurrent functions for phase, neutral, and ground which can run parallel with distance protection or can be programmed to provide primary protection under conditions when distance elements are blocked during fuse-failure conditions.

- Instantaneous and timed overcurrent elements for phase, neutral, ground, and negative-sequence protection.
- Directional supervision is available for phase, neutral, and negative-sequence elements.
- Time overcurrent elements can individually be set to use IEEE, IEC, or custom FlexCurves™.

Autoreclose

The C90^{Plus} provides multi-shot autoreclosing for single-pole or three-pole autoreclose on all types of faults with independently programmable dead times for each shot. Autoreclosing also can be dynamically blocked by user programmable logic. Four different autoreclose modes are available enabling the users to select the reclosing mode of their practice.

Breaker failure

The C90^{Plus} can be used to carry out fully independent breaker failure protection over the breakers associated to the line when connected to a substation with a breaker-and-a-half or ring bus arrangement. The C90^{Plus} provides the required current source inputs, digital inputs and outputs, and elements to perform two independent breaker failure functions.

Multi-breaker configurations

The C90^{Plus} supports multi-breaker busbar configurations such as breaker-and-a-half or ring bus arrangements, providing dual breaker autoreclose, dual synchrocheck elements, and dual independent breaker failure elements.

Figure 10: Breaker-and-a-half configuration example
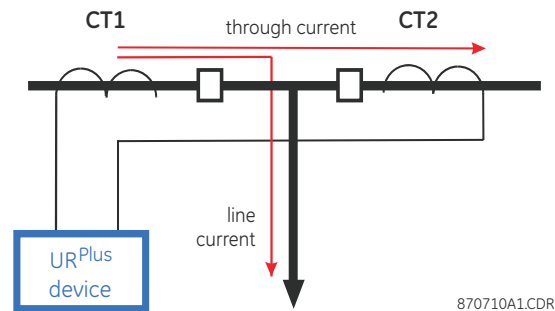
Automation features

A separate automation engine with powerful Boolean and math functions allows the user to easily engineer complex custom automation schemes. This includes advanced interlocking schemes, remedial action schemes, and advanced load shedding schemes.

Execution of the automation logic is independent of protection elements and protection logic. The automation capability is segmented into seven independent modules to simplify implementation and testing of complex schemes in which each module is independently editable and password protected. While building and compiling these modules, intelligent error detection automatically notifies the users of errors such as overflows, type mismatch, division by zero, and square root of a negative number, allowing the user to achieve maximum optimization. The programming interface complies with the global standard IEC 61131 for industrial control programming and also allows for embedded comments. Easy to use on-line and off-line debugging and simulation tools provide extensive testing capabilities of complex schemes. This includes forcing of input variables, simulation of analog values and visualization of live logic states and live analog values.

Synchrocheck and breaker control, disconnect switch control, and local/remote breaker control are available as hard-coded schemes as part of the C90^{Plus} automation capabilities.

Synchronism check

The synchrocheck elements are typically used at locations where the two parts of the system are interconnected through at least one other point in the system, which are to be joined by the closure of one or more circuit breakers. The C90^{Plus} provides the required voltage source inputs, digital inputs and outputs, and elements to monitor differences in voltage magnitudes, phase angles, and frequencies to perform synchronism check across two breakers. The C90^{Plus} can be used to carry out full independent control over the breakers associated to the line when connected to a substation with a breaker-and-a-half or ring bus arrangement.

Scalable hardware

The C90^{Plus} is available with a multitude of input and output configurations to suit the most demanding application needs. The expandable modular design allows for easy configuration and future upgrades. Types of digital outputs include trip-rated form-A and solid-state (SSR) relays available with optional circuit continuity monitoring and current detection to verify continuity and health of the associated circuitry.

Equipment manager features

Critical assets, such as circuit breakers and the station battery, are monitored with the powerful C90^{Plus} condition monitoring and diagnostic features. The C90^{Plus} processes the interrupted current of the breaker, the auxiliary contact status of the breakers, spring compressor operating time and frequency, compressor motor current, SF6 pressure stages and the circuit breaker trip and close coil monitoring to alert the operator an impending circuit breaker problem. Up to two breakers, associated trip, close coils and station battery can be monitored in real time. These features are available through the front panel interface in real time allowing the operating personnel to detect any abnormality and take corrective actions. A comprehensive equipment-monitoring feature of C90^{Plus} reduces the downtime of your assets and improves the availability of the power system.

NOTE

Only the battery monitor and breaker arcing current features are supported in the current version of the C90^{Plus}.

Figure 11: Circuit breaker monitoring example
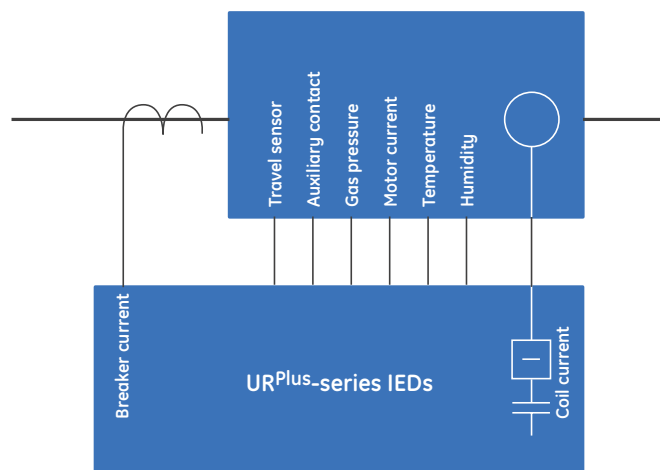
Metering and monitoring features

Voltage, current, and power metering are built into the protection platform as a standard feature. Current parameters are available as total waveform RMS magnitude, or as fundamental frequency only RMS magnitude and angle (phasor).

Measured values include:

- Voltage phasors.
- Voltage symmetrical components.
- Current phasors.
- Current symmetrical components.
- Current true one-cycle RMS values.
- Active, reactive, and apparent power.
- Power factor (all power values per phase and total).
- Four-quadrant energy.
- Frequency.
- Synchrophasors.
- Data logger.

The measured signals are available for larger local display in the color LCD, accessible remotely using communications.

Figure 12: Phasors display example
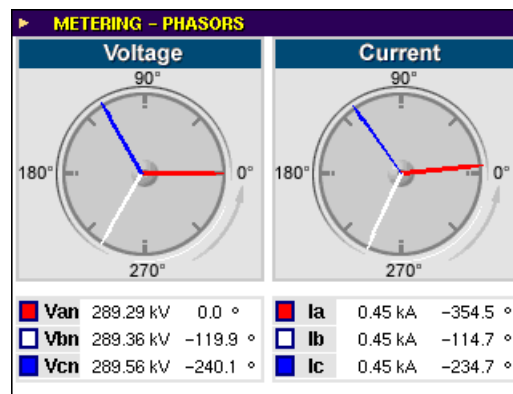
Energy metering

The metered values for real, reactive, and apparent power, as well as power factor, are displayed via the front panel interface or through the EnerVista UR^Plus Setup software.

Phasors

The metered values and phasor representations for phase current, ground current, phase voltage, and auxiliary voltage are displayed via the front panel interface or through the EnerVista UR^Plus Setup software.

Sequence components metering

The metered values and phasor representations for negative-sequence current and voltage, positive-sequence current and voltage, and zero-sequence current and voltage are displayed via the front panel interface or through the EnerVista UR^Plus Setup software.

Digital fault recorder

The powerful data acquisition and computing platform of the C90^Plus provides high-resolution recording of power system parameters replacing the need for an expensive stand-alone digital fault recorder (DFR), resulting in capital costs savings for the end user. The digital fault recorder features a high-resolution transient recorder (fast scan), a long-term disturbance recorder (slow scan), and a longer sequence of events with up to 8000 events. The internal clock used for time-tagging events can be synchronized with an IRIG-B signal or via the SNTP protocol over the Ethernet port. This precise time stamping allows the sequence of events to be determined throughout the system.

Figure 13: Typical front panel fault report display

Sequence of events recorder

The C90^Plus contains an advanced sequence of events recorder with the capability to record up to 8000 events.

Sequence of events information can be accessed either through the front panel interface or through the EnerVista Launchpad software. The very high sampling rate and large amount of storage capacity available for data recording in the C90^Plus can eliminate the need for installing costly standalone sequence of events recording equipment.

Fault reports and fault locator

The C90^Plus supports a fault report and associated fault location data. The fault report stores data pertinent to an event that is triggered and provides the distance to the fault location. A maximum of 64 records is stored in the nonvolatile memory providing a comprehensive summary of events associated with a fault.

Transient recorder

The transient recorder captures critical system data during a transient event. It is tailored to capture shorter duration events such as faults at a high resolution. The transient recorder can be programmed to sample at 256 samples per cycle. The C90^Plus can store up to 64 records in nonvolatile memory with up to one minute of storage capacity for all 40 analog channels and 128 digital channels. The transient recorder incorporates integrated triggering. Any monitored channel may be configured to trigger the recorder.

Disturbance recorder

Longer-term events are monitored by disturbance recorders, which include voltage sag, swell and overloading. Any computed analog channel or digital channel can trigger the disturbance recorder. The C90^Plus can store up to 64 records in nonvolatile memory with up to five minutes of storage capacity.

Communications

The C90^Plus incorporates powerful communications capabilities required for the demanding applications anticipated in future substations. The communications module is dedicated to processing the IEC 61850, DNP 3.0, and IEC 60870-5-104 protocols. This module provides redundant Ethernet ports each with 10/100Base-TX and 100Base-FX connectors.

Modbus RTU and DNP3.0 are also available as default protocols through the RS485 port or the CPU Ethernet ports (slot D).

Specifications

NOTE

Specifications are subject to change without notice.

Protection specifications

AUTORECLOSURE

Applications:	two breakers
Tripping schemes:	single-pole and three-pole
Reclose attempts:	up to 4 before lockout
Reclosing mode:	selectable
Breaker sequence:	selectable

AUXILIARY OVERVOLTAGE

Pickup level:	0.000 to 1.100 pu in steps of 0.001
Dropout level:	<98% of pickup
Level accuracy:	±0.5% of reading from 10 to 208 V
Pickup delay:	0 to 600.00 seconds in steps of 0.01
Reset delay:	0 to 600.00 seconds in steps of 0.01
Timing accuracy:	±3% of operate time or ±4 ms (whichever is greater)
Operate time:	<2 cycles at 1.10 × pickup at 60 Hz

AUXILIARY UNDERVOLTAGE

Pickup level:	0.000 to 1.100 pu in steps of 0.001
Dropout level:	>102% of pickup
Level accuracy:	±0.5% of reading from 10 to 208 V
Curve shapes:	GE IAV Inverse, Definite Time
Curve multiplier:	0.00 to 600.00 in steps of 0.01
Timing accuracy:	±3% of operate time or ±4 ms (whichever is greater)

BREAKER FAILURE

Mode:	single-pole, three-pole
Current supervision:	phase current, neutral current
Supervision pickup:	0.001 to 30.000 pu in steps of 0.001
Supervision dropout:	<98% of pickup
Supervision accuracy:	±2% of rated for 0.1 to 2.0 × CT; ±2.5% of reading for >2.0 × CT
Time accuracy:	±3% or 4 ms, whichever is greater

BREAKER FLASHOVER

Operating quantity:	phase current, voltage, and voltage difference
Pickup level voltage:	0 to 1.500 pu in steps of 0.001
Dropout level voltage:	97 to 98% of pickup
Pickup level current:	0 to 1.500 pu in steps of 0.001
Dropout level current:	97 to 98% of pickup
Level accuracy:	±0.5% or ±0.1% of rated, whichever is greater
Pickup delay:	0 to 65.535 seconds in steps of 0.001
Time accuracy:	±3% or ±42 ms, whichever is greater
Operate time:	<42 ms at 1.10 × pickup at 60 Hz

CONTACT INPUTS

Input rating:..300 V DC maximum
On threshold:...70% of nominal voltage setting or 20 V (whichever is greater)
Off threshold:..30% of nominal voltage setting or 15 V (whichever is greater)
Maximum current:...10 mA during turn on, 0.5 mA steady-state
Nominal voltage:...24 to 250 V
Input impedance:..active
Recognition time:..<1 ms
Debounce timer:..1.5 to 16.0 ms in steps of 0.25
Chatter detection timer:..................................1 to 100 seconds
Chatter state changes:....................................10 to 100

CONTACT OUTPUTS: CRITICAL FAILURE RELAY

Make and carry for 0.2 s: ....10 A
Continuous carry:..6 A
Break at L/R of 40 ms: ....0.250 A at 125 V DC; 0.125 A at 250 V DC
Operate time:..<8 ms
Contact material: ....silver alloy

CONTACT OUTPUTS: FORM-A RELAY

Make and carry for 0.2 s: ....30 A as per ANSI C37.90
Continuous carry:..6 A
Break at L/R of 40 ms: ....0.250 A at 125 V DC; 0.125 A at 250 V DC
Operate time:..<4 ms
Contact material: ....silver alloy

CONTACT OUTPUTS: SOLID-STATE RELAY

Make and carry for 0.2 s: ....30 A as per ANSI C37.90
Continuous carry:..6 A
Break at L/R of 40 ms: ....10 A at 250 V DC
Operate time:..<100 µs
Contact material: ....silver alloy

DISTURBANCE DETECTOR (50DD)

Type: ....sensitive current disturbance detector
Range: ....0.004 to 0.04 pu (twice the current cut-off level threshold)

FLEXCURVES™

Number: ....4 (A through D)
Reset points:..40 (0 through 1 of pickup)
Operate points: ....80 (1 through 20 of pickup)
Time delay: ....0 to 65535 ms in steps of 1

FLEXMATRIX

Principle:..aggregates and conditions signals for tripping and auxiliary functions
Timing accuracy:..±1 ms

FLEX STATES

Number: ....up to 256 logical variables grouped under 16 Modbus addresses
Programmability:...any logical variable, contact, or virtual input

GROUND INSTANTANEOUS OVERCURRENT

Pickup level:..0.000 to 30.000 pu in steps of 0.001

Dropout level: ....<98% of pickup

Level accuracy: ....±0.5% of reading or ±1% of rated (whichever is greater) at 0.1 to 2.0 × CT rating; ±1.5% of reading at > 2.0 × CT rating

Overreach: ....<2%

Pickup delay: ....0.00 to 600.00 seconds in steps of 0.01

Reset delay:...0.00 to 600.00 seconds in steps of 0.01

Operate time:..<16 ms at 3 × pickup at 60 Hz

Timing accuracy:...for operation at 1.5 × pickup; ±3% or ±4 ms (whichever is greater)

GROUND TIME OVERCURRENT

Current:...phasor or RMS

Pickup level:..0.000 to 30.000 pu in steps of 0.001

Dropout level: ....<98% of pickup

Level accuracy: ....±0.5% of reading or ±1% of rated (whichever is greater) at 0.1 to 2.0 × CT; ±1.5% of reading at >2.0 × CT

Curve shapes:...IEEE Moderately, Very, and Extremely Inverse; IEC (and BS) A, B, C, and Short Inverse; GE IAC Inverse, Short Inverse, Very Inverse, and Extremely Inverse; I^2t; FlexCurves™ (programmable); Definite Time (0.01 s base curve)

Curve multiplier:...0.01 to 600.00 in steps of 0.01

Reset type:..instantaneous/timed (per IEEE)

Timing accuracy:...±3.5% of operating time or ±1 cycle (whichever is greater) for 1.03 to 20 × pickup

NEGATIVE-SEQUENCE DIRECTIONAL OVERCURRENT

Directionality: ....co-existing forward and reverse

Polarizing:...voltage

Polarizing voltage:...V_2

Operating current:...I_2

Level sensing: ....$|I\_0| - K \times |I\_1|$ for zero-sequence; $|I\_2| - K \times |I\_1|$ for negative-sequence

Restraint, K:...0.000 to 0.500 in steps of 0.001

Characteristic angle:...0 to 90° in steps of 1

Limit angle:...40 to 90° in steps of 1, independent for forward and reverse

Angle accuracy: ....±2°

Offset impedance:...0.00 to 250.00 ohms in steps of 0.01

Pickup level:...0.05 to 30.00 pu in steps of 0.01

Dropout level: ....<98%

Operation time:...<16 ms at 3 × pickup at 60 Hz

NEGATIVE-SEQUENCE INSTANTANEOUS OVERCURRENT

Pickup level:...0.000 to 30.000 pu in steps of 0.001

Dropout level: ....<98% of pickup

Level accuracy: ....±0.5% of reading or ±1% of rated (whichever is greater) at 0.1 to 2.0 × CT; ±1.5% of reading at >2.0 × CT

Overreach: ....<2%

Pickup delay: ....0.00 to 600.00 seconds in steps of 0.01

Reset delay:..0.00 to 600.00 seconds in steps of 0.01

Operate time:...<20 ms at 3 × pickup at 60 Hz

Timing accuracy:..for operation at 1.5 × pickup, ±3% or ±4 ms (whichever is greater)

NEGATIVE-SEQUENCE OVERVOLTAGE
Pickup level: ....0.000 to 1.250 pu in steps of 0.001

Dropout level: ....<98% of pickup

Level accuracy: ....±0.5% of reading from 10 to 208 V

Pickup delay: ....0 to 600.00 seconds in steps of 0.01

Reset delay: ....0 to 600.00 seconds in steps of 0.01

Timing accuracy: ....±3% or ±20 ms, whichever is greater

Operate time: ....< 30 ms at 1.10 × pickup at 60 Hz

NEGATIVE-SEQUENCE TIME OVERCURRENT
Pickup level: ....0.000 to 30.000 pu in steps of 0.001

Dropout level: ....<98% of pickup

Level accuracy: ....±0.5% of reading or ±1% of rated (whichever is greater) for 0.1 to 2.0 × CT; ±1.5% of reading for >2.0 × CT

Curve shapes: ....IEEE Moderately, Very, and Extremely Inverse; IEC (and BS) A, B, C, and Short Inverse; GE IAC Inverse, Short Inverse, Very Inverse, and Extremely Inverse; I^2t; FlexCurves™ (programmable); Definite Time (0.01 s base curve)

Curve multiplier: ....0.01 to 600.00 in steps of 0.01

Reset type: ....instantaneous/timed (per IEEE) and linear

Timing accuracy: ....±3.5% of operating time or ±1 cycle (whichever is greater) for 1.03 to 20 × pickup

NEUTRAL DIRECTIONAL OVERCURRENT
Directionality: ....co-existing forward and reverse

Polarizing: ....voltage, current, dual

Polarizing voltage: ....V_0 or VX

Polarizing current: ....IG

Operating current: ....I_0

Level sensing: ....3 × (|I_0| − K × |I_1|), IG; independent for forward and reverse

Restraint (K): ....0.000 to 0.500 in steps of 0.001

Characteristic angle: ....−90 to 90° in steps of 1

Limit angle: ....40 to 90° in steps of 1, independent for forward and reverse

Angle accuracy: ....±2°

Offset impedance: ....0.00 to 250.00 ohms in steps of 0.01

Pickup level: ....0.002 to 30.000 pu in steps of 0.01

Dropout level: ....<98%

Operation time: ....<16 ms at 3 × pickup at 60 Hz

NEUTRAL INSTANTANEOUS OVERCURRENT
Pickup level: ....0.000 to 30.000 pu in steps of 0.001

Dropout level: ....<98% of pickup

Level accuracy: ....±0.5% of reading or ±1% of rated (whichever is greater) at 0.1 to 2.0 × CT rating; ±1.5% of reading at > 2.0 × CT rating

Overreach: ....<2%

Pickup delay: ....0.00 to 600.00 seconds in steps of 0.01

Reset delay: ....0.00 to 600.00 seconds in steps of 0.01

Operate time: ....<20 ms at 3 × pickup at 60 Hz

Timing accuracy: ....for operation at 1.5 × pickup, ±3% or ±4 ms (whichever is greater)

NEUTRAL OVERVOLTAGE
Pickup level: ....0.000 to 1.250 pu in steps of 0.001

Dropout level: ....<98% of pickup

Level accuracy: ....±0.5% of reading from 10 to 208 V

Pickup delay: ....0.00 to 600.00 seconds in steps of 0.01 (definite time) or user-defined curve

Reset delay: ....0.00 to 600.00 seconds in steps of 0.01

Timing accuracy: ....±3% or ±20 ms (whichever is greater)

Operate time: ....<3 cycles at 1.10 × pickup

NEUTRAL TIME OVERCURRENT

Current:..phasor or RMS
Pickup level:...0.000 to 30.000 pu in steps of 0.001
Dropout level: ....<98% of pickup
Level accuracy: ....±0.5% of reading or ±1% of rated (whichever is greater) at 0.1 to 2.0 × CT; ±1.5% of reading at >2.0 × CT
Curve shapes:..IEEE Moderately, Very, and Extremely Inverse; IEC (and BS) A, B, C, and Short Inverse; GE IAC Inverse, Short Inverse, Very Inverse, and Extremely Inverse; I^2t; FlexCurves™ (programmable); Definite Time (0.01 s base curve)
Curve multiplier:..0.01 to 600.00 in steps of 0.01
Reset type:...instantaneous/timed (per IEEE)
Timing accuracy:...±3.5% of operating time or ±1 cycle (whichever is greater) for 1.03 to 20 × pickup

NON-VOLATILE LATCHES

Type: ....set-dominant or reset-dominant
Number: ....16 (individually programmed)
Output:...stored in non-volatile memory
Execution sequence:...as input prior to protection, control, and FlexLogic™

PHASE DIRECTIONAL OVERCURRENT

Relay connection:..90° (quadrature)
Quadrature voltage:..phase A (V_{BC}), phase B (V_{CA}), phase C (V_{AB}) for ABC phase sequence; phase A (V_{CB}), phase B (V_{AC}), phase C (V_{BA}) for ACB phase sequence
Polarizing voltage threshold:............................0.000 to 3.000 pu in steps of 0.001
Current sensitivity threshold:...........................0.05 pu
Characteristic angle:...0 to 359° in steps of 1
Angle accuracy: ....±2°
Tripping operation time:....................................<12 ms, typically (reverse load, forward fault)
Blocking operation time:...................................<8 ms, typically (forward load, reverse fault)

PHASE INSTANTANEOUS OVERCURRENT

Pickup level:...0.000 to 30.000 pu in steps of 0.001
Dropout level: ....<98% of pickup
Level accuracy: ....±0.5% of reading or ±1% of rated (whichever is greater) at 0.1 to 2.0 × CT rating; ±1.5% of reading at > 2.0 × CT rating
Overreach: ....<2%
Pickup delay: ....0.00 to 600.00 seconds in steps of 0.01
Reset delay:..0.00 to 600.00 seconds in steps of 0.01
Operate time:...<16 ms at 3 × pickup at 60 Hz
Timing accuracy:...for operation at 1.5 × pickup, ±3% or ±4 ms (whichever is greater)

PHASE OVERVOLTAGE

Voltage:..phasor only
Pickup level:...0.000 to 1.100 pu in steps of 0.001
Dropout level: ....<98% of pickup
Level accuracy: ....±0.5% of reading from 10 to 208 V
Pickup delay: ....0.00 to 600.00 s in steps of 0.01
Operate time:...<3 cycles at 1.10 × pickup
Timing accuracy:...±3% or ±4 ms (whichever is greater)

PHASE TIME OVERCURRENT

Current:..phasor or RMS
Pickup level:...0.000 to 30.000 pu in steps of 0.001
Dropout level:..<98% of pickup
Level accuracy:..±0.5% of reading or ±1% of rated (whichever is greater) at
0.1 to 2.0 × CT; ±1.5% of reading at >2.0 × CT
Curve shapes:..IEEE Moderately, Very, and Extremely Inverse; IEC (and BS) A,
B, C, and Short Inverse; GE IAC Inverse, Short Inverse, Very
Inverse, and Extremely Inverse; I^2t; FlexCurves™
(programmable); Definite Time (0.01 s base curve)
Curve multiplier:...0.01 to 600.00 in steps of 0.01
Reset type:...instantaneous/timed (per IEEE)
Timing accuracy:...±3.5% of operating time or ±1 cycle (whichever is greater) for
1.03 to 20 × pickup

PHASE UNDERVOLTAGE

Pickup level:...0.000 to 1.100 pu in steps of 0.001
Dropout level:..>102% of pickup
Level accuracy:..±0.5% of reading from 10 to 208 volts
Curve shapes:..GE IAV Inverse; Definite Time (0.1 second base curve)
Curve multiplier:...0.00 to 600.00 in steps of 0.01
Timing accuracy:...for operation at <0.90 × pickup, ±3.5% of operate time or ±4
ms (whichever is greater)

PROTECTION FLEXLOGIC™

Programming:..Reverse Polish Notation with graphical visualization (keypad
programmable)
Lines of code:..512
Internal variables:..64
Supported operations: ....NOT, XOR, OR (2 to 16 inputs), AND (2 to 16 inputs), NOR (2 to
16 inputs), NAND (2 to 16 inputs), latch (reset-dominant),
edge detectors, timers
Inputs:..any logical variable, contact, or virtual input
Number of timers:..32
Pickup delay:...0 to 60000 (ms, seconds, or minutes) in steps of 1
Dropout delay: ....0 to 60000 (ms, seconds, or minutes) in steps of 1

PROTECTION VIRTUAL INPUTS

Input points:..64
Programmability:..self-reset or latched

PROTECTION VIRTUAL OUTPUTS

Output points:...96
Programmability:..output of a protection FlexLogic™ equation or input to a
protection FlexLogic™ equation

REMOTE INPUTS (IEC 61850 GSSE/GOOSE)

Input points:..32, configured from 64 incoming bit pairs
Remote devices:...16
Default states on loss of
    communications:...on, off, latest/off, latest/on

REMOTE OUTPUTS (IEC 61850 GSSE/GOOSE)

Standard output points: 32
User output points:..32

VT FUSE FAILURE SUPERVISION

Elements: ....1 per source
Monitored parameters:....................................V_2, V_1, I_1

Automation specifications

AUTOMATION LOGIC

Number of lines of logic: 4096

Number of blocks: 1

Edit and view capability: .... yes

Logic type: .... cyclic

Programming language: .... proprietary

Execution rate: .... 50 ms

Variable types: .... Boolean, IEEE floating point

Boolean operations: .... NOT, XOR, OR, AND, NOR, NAND

Arithmetic operations: .... add, subtract, multiply, divide, negation, absolute value, square root, exponent, logarithm, sine, cosine, tangent, arcsine, arccosine, arctangent, natural logarithm, base 10 logarithm, modulo, ceiling, floor

Control operations: .... latch, timer, comparator, absolute timer functions

Boolean inputs: .... any contact input, direct input, remote input, virtual input, or automation logic operand

Analog inputs: .... any FlexAnalog™ quantity

Virtual inputs: 64

Virtual outputs: 96

Remote inputs: 64

Remote outputs: 64

Remote devices: 32

AUTOMATION VIRTUAL INPUTS

Input points: 64

Programmability: .... self-reset or latched

AUTOMATION VIRTUAL OUTPUTS

Output points: 96

Programmability: .... output of an automation logic equation or input to an automation logic equation

BREAKER CONTROL

Mode: .... single-pole, three-pole

Control: .... open/close, local/SCADA

Control seal-in: .... 0 to 2000 ms in steps of 1

BREAKER INTERLOCKING

Interlocking inputs: 6

CONTACT INPUTS

Input rating: .... 300 V DC maximum

Selectable thresholds: .... 20 to 300 volts

Maximum current: .... 10 mA during turn on, 0.5 mA steady-state

Nominal voltage: .... 24 to 250 volts

Input impedance: .... active

Recognition time: .... <1 ms

Debounce timer: .... 1.5 to 16.0 ms in steps of 0.25

Chatter detection timer: .... 1 to 100 seconds

Chatter state changes: .... 10 to 100

DISCONNECT CONTROL

Mode: .... single-pole, three-pole

Control: .... open/close, local/SCADA

Control seal-in: .... 0 to 2000 ms in steps of 1

DISCONNECT INTERLOCKING

Interlocking inputs: 3

FREQUENCY RATE OF CHANGE LOAD SHEDDING

Elements: 4

Minimum voltage: ....0.10 to 1.25 pu in steps of 0.01

Pickup level: ....0.10 to 15.00 Hz/s in steps of 0.01

Dropout level: ....pickup – 0.02 Hz/s

Pickup delay: ....0.00 to 99.99 seconds in steps of 0.001

Dropout delay: ....0.00 to 99.99 seconds in steps of 0.001

Level accuracy: ....30 mHz/s or 3.5%, whichever is greater

Time accuracy: ....±3% or ±4 ms, whichever is greater

95% settling time for df/dt: ....<24 cycles

Operate time (typical): ....6 cycles at 2 × pickup; 5 cycles at 3 × pickup; 4 cycles at 5 × pickup

LOAD SHEDDING SOURCE

Minimum voltage pickup: ....0.00 to 1.25 pu in steps of 0.01

Minimum voltage dropout: ....pickup + 0.20 pu

Maximum negative-sequence voltage
    pickup: ....0.00 to 1.25 pu in steps of 0.01

Maximum negative-sequence voltage
    dropout: ....pickup – 0.20 pu

SELECTOR SWITCH

Upper position limit: ....1 to 7 in steps of 1

Selecting mode: ....time-out or acknowledge

Time-out timer: ....3.0 to 60.0 seconds in steps of 0.1

Control inputs: ....step-up and three-bit

Power-up mode: ....restore from non-volatile memory or synchronize to a three-bit control input or synchronize/restore mode

SYNCHROCHECK

Elements: 2

Maximum voltage difference: ....0 to 100000 volts in steps of 1

Maximum angle difference: ....0 to 100° in steps of 1

Maximum frequency difference: ....0.00 to 2.00 Hz in steps of 0.01

Hysteresis for maximum frequency
    difference: ....0.00 to 0.10 Hz in steps of 0.01

Dead source function:: ....none, LV1 & DV2, DV1 & LV2, DV1 or DV2, DV1 xor DV2, DV1 & DV2 (L = live, D = dead)

UNDERFREQUENCY LOAD SHEDDING

Elements: 10

Pickup level: ....45.00 to 65.00 Hz in steps of 0.01

Dropout level: ....pickup level + 0.03 Hz

Pickup delay: ....0.00 to 99.99 seconds in steps of 0.01

Dropout delay: ....0.00 to 99.99 seconds in steps of 0.01

Level accuracy: ....±0.01 Hz

Time accuracy: ....±3% or 4 ms, whichever is greater

Operate time (typical): ....4 cycles at –0.1 Hz/s change; 3.5 cycles at –0.3 Hz/s change; 3 cycles at –0.5 Hz/s change

UNDERVOLTAGE LOAD SHEDDING

Elements: 6

Pickup level: ....0.10 to 1.25 pu in steps of 0.01

Dropout level: ....pickup level + 0.20 pu

Pickup delay: ....0.00 to 99.99 seconds in steps of 0.01

Dropout delay: ....0.00 to 99.99 seconds in steps of 0.01

Level accuracy: ....±0.5% of reading from 10 to 208 volts

Time accuracy: ....±3% or 4 ms, whichever is greater

Operate time (typical): ....2 cycles at 0.90 × pickup

Equipment manager

BATTERY MONITOR

Principle: .... monitors battery voltage and auxiliary alarms

Hysteresis: 5%

Timing accuracy: .... 1 cycle

BREAKER ARCING CURRENT

Elements: .... 1 per breaker

Principle: .... accumulates contact wear (I_xt), measures fault magnitude and duration

Auxiliary contact compensation: .... 0 to 50 ms in steps of 1

Alarm threshold: .... 0 to 50000 kA^2-cycle in steps of 1

Fault duration accuracy: .... 0.25 of power cycle

Metering specifications

CURRENT METERING

Type: .... phase and ground RMS current

Accuracy at 0.1 to 2.0 × CT: .... ±0.25% of reading or ±0.1% of rated, whichever is greater

Accuracy at >2.0 × CT: .... ±1.0% of reading

DATA LOGGER

Channels: .... 1 to 16

Parameters: .... any FlexAnalog value

Statistics: .... maximum and time of maximum, minimum and time of minimum, average

Alarms: .... high, high-high, low, low-low

ENERGY METERING

Type: .... positive and negative watt-hours and var-hours

Accuracy: .... ±2.0% of reading

Range: .... -2.0×10^9 to 2.0×10^9 MWh/Mvarh

Parameters: .... three-phase only

Update rate: .... 50 ms

FREQUENCY METERING

Accuracy at V = 0.8 to 1.2 pu: .... ±0.01 Hz (when voltage signal is used for frequency measurement)

Accuracy at I = 0.1 to 0.25 pu: .... ±0.05 Hz (when current signal is used for frequency measurement)

Accuracy at I > 0.25 pu: .... ±0.01 Hz (when current signal is used for frequency measurement)

POWER METERING

Real power accuracy: .... ±1.0% of reading at $-1.0 \leq PF < 0.8$ and $0.8 < PF \leq 1.0$

Reactive power accuracy: .... ±1.0% of reading at $-0.2 \leq PF \leq 0.2$

Apparent power accuracy: .... ±1.0% of reading

VOLTAGE METERING

Type: .... RMS voltage

Accuracy: .... ±0.5% of reading from 30 to 208 volts

Digital fault recorder specifications

DISTURBANCE RECORDER

Storage capacity:...one record with all available channels at 60 samples per second for 40 seconds

Maximum records: 64

Sampling rate:...1 sample per cycle

Sampling accuracy:..<1 ms per second of recording

Analog channels: 64

Analog channel data:.......................................any FlexAnalog™ quantity

Digital channels:..32

Digital channel data: ....any contact input, direct input, remote input, virtual input, automation logic operand, or FlexLogic™ operand

Triggers:..any digital change of state (user-programmable), undervoltage, overvoltage, undercurrent, overcurrent, underfrequency, overfrequency, rate of change of frequency, 1 user-programmable trigger, 1 block

Storage modes:..automatic overwrite, protected

Triggering modes:...time window from rising edge of trigger, continuous recording as long as trigger is active

Pre-trigger window: ....0 to 100%

Data storage:..non-volatile memory

EVENT RECORDER

Storage capacity:..8192 events

Time tag: ....to 1 ms

Triggers:..any contact input, direct input, remote input, virtual input, logic operand, or self-test event

Data storage:..non-volatile memory

FAULT REPORT

Records:...16

Data:..station and circuit ID, date and time of trip, fault type, active setting group at time of trigger, pre-fault current and voltage phasors (2 cycles before 50DD associated with fault report source), fault current and voltage phasors (1 cycle after trigger), protection elements operated at time of trigger, firmware revision

Triggers:..user-selected operand

Data storage:..non-volatile memory

TRANSIENT RECORDER

Storage capacity: ....one record with all available channels at 32 samples per
                                                                       cycle for 1 minute
Number of records:...1 to 64
Sampling rate:...16 to 128 samples per power cycle
Timestamp accuracy: ....<10 μs per second of recording
Analog channels: ....up to twelve 16-bit, unprocessed, AC input channels
Analog channel data:......................................any FlexAnalog quantity
Digital channels:...up to 128
Digital channel data: ....any contact input, direct input, remote input, virtual input,
                                                                       automation logic operand, or FlexLogic™ operand
Sampled channels: ....up to 24
Sampled channel data:.................................16-bit, unprocessed sampled channels
Triggers: ....any digital channel change of state, undervoltage,
                                                                       overvoltage, undercurrent, overcurrent, underfrequency,
                                                                       overfrequency, rate of change of frequency, one user-
                                                                       programmable, one block
Storage modes: ....automatic overwrite, protected
Triggering modes: ....time window from rising edge of trigger, continuous
                                                                       recording as long as trigger is active
Pre-trigger window:...0 to 100%
Data storage:...non-volatile memory

Front panel interface

ANNUNCIATOR

Inputs: 288
Windows per page:...12 to 48
Pages:..up to 24
Sequence:...manual reset, locking
Off indication:...alarm inactive and reset
Flashing indication:..alarm active and not acknowledged, alarm inactive and not
                                                                       acknowledged
On indication: ....alarm active and acknowledged, alarm inactive and not
                                                                       reset
Priority: ....by active window and page number
Data storage:...non-volatile memory

CONTROL DISPLAY

Devices:...status and control of up to 8 power system devices
Pushbuttons:..20 dedicated user-programmable pushbuttons
Functionality:..supports select-before-operate functionality

DIGITAL FAULT RECORDER DISPLAY

Sequence of events:..displays the stored sequence of events record
Fault reports:..display and retrieval of the critical metrics of a stored fault
                                                                       report
Transient records:...retrieval of a stored transient record
Disturbance records:.......................................retrieval of a stored disturbance record

EQUIPMENT MANAGER DISPLAY

Equipment summary:......................................displays the status of all monitored equipment
Circuit breaker statistics:...............................displays critical statistics for each circuit breaker
Circuit breaker reports:..................................display and retrieval of critical metrics for circuit breaker
                                                                       operation
Battery monitoring:...displays the current battery voltage and alarm states

METERING DISPLAY

Summary:...displays present values of voltage, current, real power, reactive power, power factor, and frequency on a per-phase and total basis

Phasors:...digital and graphical display of present voltage and current magnitudes and angles

Sequence components:...................................displays present magnitudes and angles of current and voltage sequence components

Energy:...four-quadrant display of accumulated energy

Demand:...present and peak demand values for current and real, reactive, and apparent power

MAINTENANCE DISPLAY

State forcing:..permits forcing the state of contact, direct, and remote inputs and outputs, as well as allowing inputs and outputs of device functions to be forced

Virtual circuit breaker:....................................routes breaker control and status to an internal virtual device controllable from the front panel

Self-diagnostics:..displays all device related self-diagnostic messages in a sequence of events format

Input and output status:................................displays the current status of all contact inputs and outputs

Date and time:..the date and time can be set from the front panel

Hardware specifications

AC CURRENT

CT rated primary:...1 to 50000 A

CT rated secondary:..1 A or 5 A

Nominal frequency:...50 or 60 Hz

Relay burden:..<0.2 VA secondary

Conversion range:..0.02 to 46 × CT rating RMS symmetrical

Current withstand:...20 ms at 250 × rated, 1 second at 100 × rated, continuous at 3 × rated

AC VOLTAGE

VT rated secondary:..50.0 to 240.0 V

VT ratio:..1.00 to 24000.0

Nominal frequency:...50 or 60 Hz

Relay burden:..<0.25 VA at 120 V

Conversion range:..1 to 275 V

Voltage withstand:...continuous at 260 V to neutral, 1 minute per hour at 420 V neutral

CONTACT INPUTS

Input rating:..300 V DC maximum

Selectable thresholds:....................................20 to 250 V

Maximum current:...10 mA during turn on, 0.5 mA steady-state

Recognition time:...<1 ms

Debounce timer:..1.5 to 16.0 ms in steps of 0.25

CONTROL POWER EXTERNAL OUTPUT

Capacity:..100 mA DC at 48 V DC

Isolation:..2 kV

CRITICAL FAILURE RELAY

Make and carry for 0.2 s: ....30 A as per ANSI C37.90

Carry continuous:..6 A

Break at L/R of 40 ms: ....0.250 A DC at 125 V DC; 0.125 A DC at 250 V DC; 0.10 A DC maximum at 125 V

Operate time:..<8 ms

Contact material: ....silver alloy

ETHERNET PORTS

Standard: .... 1 port supporting Modbus TCP and DNP 3.0

Optional: .... 2 ports supporting DNP 3.0, IEC 60870-5-104, or IEC 61850 located on communications module

100Base-FX media type: .... 1300 nm, multi-mode, half/full-duplex, fiber optic with ST connector

10/100Base-TX media type: .... RJ45 connector

Power budget: .... 10 dB

Maximum optical input power: .... –14 dBm

Receiver sensitivity: .... –30 dBm

Typical distance: .... 2.0 km

SNTP clock synchronization: .... <10 ms typical

FORM-A RELAY

Make and carry for 0.2 s: .... 30 A per ANSI C37.90

Carry continuous: .... 6 A

Break at L/R of 40 ms: .... 0.250 A DC at 125 V DC; 0.125 A DC at 250 V DC

Operate time: .... <4 ms

Contact material: .... silver alloy

IRIG-B INPUT

Amplitude modulation: .... 1 to 10 V pk-pk

DC shift: .... TTL

Input impedance: .... 50 kΩ

Isolation: .... 2 kV

POWER SUPPLY

Nominal DC voltage: .... 125 to 250 V

Minimum DC voltage: .... 80 V

Maximum DC voltage: .... 300 V

Nominal AC voltage: .... 100 to 240 V at 50/60 Hz

Minimum AC voltage: .... 80 V at 48 to 62 Hz

Maximum AC voltage: .... 275 V at 48 to 62 Hz

Voltage withstand: .... 2 × highest nominal voltage for 10 ms

Voltage loss hold-up: .... 200 ms duration at nominal

Power consumption: .... 30 VA typical, 65 VA maximum

RS485 PORT

Baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200

Protocol: .... Modbus RTU and DNP 3.0

Distance: .... 1200 m

Isolation: .... 2 kV

SOLID-STATE RELAY

Make and carry for 0.2 s: .... 30 A as per ANSI C37.90

Carry continuous: .... 6 A

Break at L/R of 40 ms: .... 10.0 A DC at 250 V DC

Operate time: .... < 100 μs

USB PORT

Standard: .... type B USB connector for EnerVista software

Communications specifications

MODBUS USER MAP

Number: .... up to 256 Modbus addresses

Programmability: .... any setting or actual value in decimal

REMOTE INPUTS (IEC 61850 GSSE/GOOSE)

Input points:...32, configured from 64 incoming bit pairs

Remote devices: 16

Default states on loss of
   communications:...On, Off, Latest/Off, Latest/On

REMOTE OUTPUTS (IEC 61850 GSSE/GOOSE)

Standard output points: 32
User output points:...32

Test specifications

PRODUCTION TESTS

Thermal: ....products go through a 12 hour burn-in process at 60°C

TYPE TESTS

Vibration: ....IEC 60255-21-1, 1G (class Bm)

Shock / bump: ....IEC 60255-21-2, 10G (class Bm)

Conducted immunity:..IEC 61000-4-6 / IEC60255-22-6, class 3 (10 V rms)

Surge: ....IEC 61000-4-5 or IEC 60225-22-5, 1.2/50 test up to level 4 (4 kV)

Burst disturbance (1 MHz oscillatory): ....IEC60255-22-1 up to 2.5 kV at 1 MHz damped

Fast transients:..ANSI/IEEE C37.90.1, EC61000-4-4 class 4, (2 kV, 5 kHz / 4 kV, 2.5 kHz, 2 kV on data control ports and inputs/outputs), IEC 60255-22-4

Radiated immunity: ....IEC 61000-4-3 / IEC 60255-22-3 class 3 (10 V/m) or IEEE C37.90.2 radiated RFI (35 V/m)

Power frequency disturbance:......................IEC 61000-4-8 (30 A/m) class 4

Radiated/conducted emissions:..................IEC 60255-25 / CISPR 11/22 class A

Insulation resistance: ....IEC 60255-5

Dielectric strength:...IEC 60255-5, ANSI/IEEE C37.90

Electrostatic discharge:...................................EN 61000-4-2, IEC60255-22-2 8 kV C, 15 kV A, L4

Voltage dips/interruptions/variations:.......IEC 61000-4-11 (30% 1 cycle), IEC 60255-11

AC ripple:..IEC 61000-4-17 (standard)

Environmental specifications

OPERATING TEMPERATURE

Cold: ....IEC 60028-2-1, 16 hours at –40°C

Dry heat: ....IEC 60028-2-2, 16 hours at 85°C

OTHER ENVIRONMENTAL SPECIFICATIONS

Altitude:..up to 2000 m

Installation category:..II

IP rating:...IP30

Approvals and certification

APPROVALS

UL508 17th edition and C22.2 No.14-05: UL listed for the USA and Canada

CERTIFICATION

CE LVD 2006/95/EC:...EN/IEC 61010-1:2001 / EN60255-5:2000

CE EMC 89/336/EEC:...EN 60255-26:2004-08

C90^{Plus} Controller

Chapter 3: Installation

This section describes the physical and electrical installation of the C90^{Plus}.

Physical installation

The C90^{Plus} is designed as a 19-inch rack horizontal mount unit. The modular design allows the relay to be easily upgraded or repaired by a qualified service person. The faceplate is hinged to allow easy access to the removable modules.

Dimensions

The case dimensions are shown below, along with cutout details for panel mounting. When planning the location of your panel cutout, ensure that provision is made for the faceplate to swing open without interference to or from adjacent equipment.

The C90^{Plus} must be mounted such that the faceplate sits semi-flush with the panel or switchgear door, allowing the operator access to the front panel keys and USB communications port. The C90^{Plus} is secured to the panel with the use of four screws supplied with the relay.

Figure 14: Panel cutout dimensions
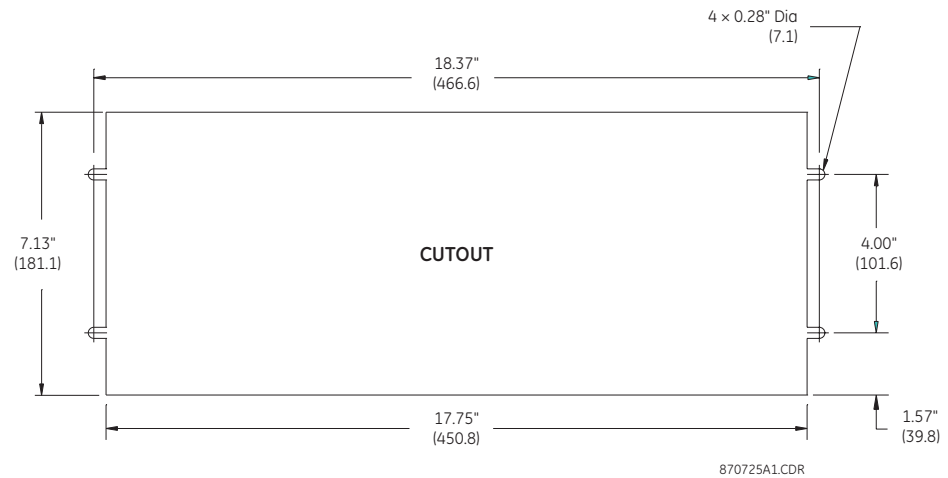
Figure 15: C90Plus dimensions

Module withdrawal and insertion

DANGER
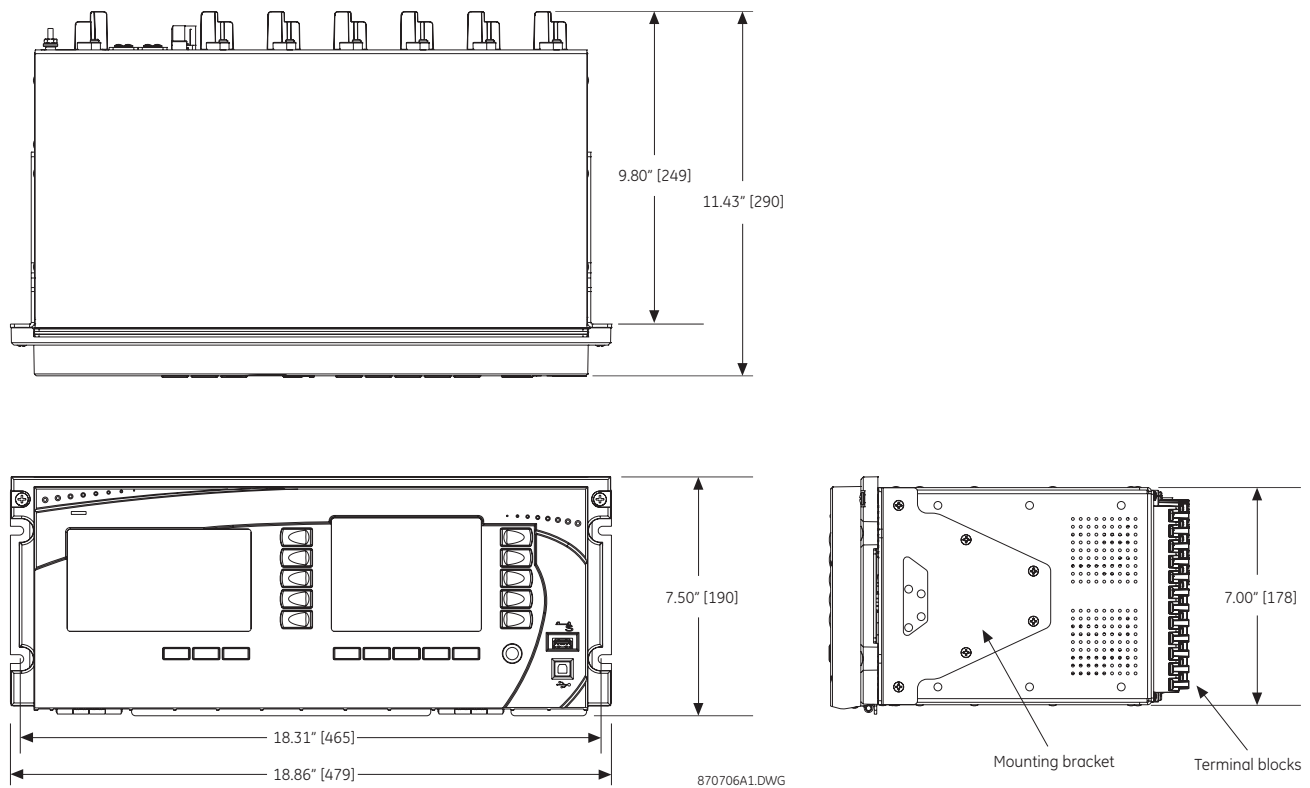
Prior to removal of the AC module, the CT secondary circuit must be shorted in order to prevent an open-circuit condition on a CT.

DANGER

Module withdrawal and insertion may only be performed when control power has been removed from the unit. Inserting an incorrect module type into a slot may result in personal injury, damage to the unit or connected equipment, or undesired operation!

⚠️ **CAUTION**

Proper electrostatic discharge protection (for example, a static strap) must be used when coming in contact with modules while the relay is energized!

The C90^{Plus} is a modular system. This allows for the easy withdrawal and insertion of functional modules. Modules must only be replaced in their original factory configured slots. The faceplate can be opened to the left, once the sliding latch on the right side has been pushed up, as shown below. This allows for easy accessibility of the modules for withdrawal.

Figure 16: Module withdrawal and insertion

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To withdrawal a module, simultaneously pull the ejector-inserter clips located at the top and bottom of each module. Before performing this action, ensure that control power is removed from the relay. Record the original location of the module to ensure that the same or replacement module is inserted into the correct slot.

To insert a module, first ensure that the correct module type is inserted into the correct slot position. The ejector and inserter clips located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module will be fully inserted.

NOTE

Communications modules equipped with Ethernet connectors must be individually disconnected from the module before it can be removed from the chassis.

Rear terminal layout

Terminal number assignments in the C90^{Plus} are represented by three characters, assigned in order by module slot position, row number, and column letter. See the following figures for an example of rear terminal assignments.

Figure 17: Rear terminal view
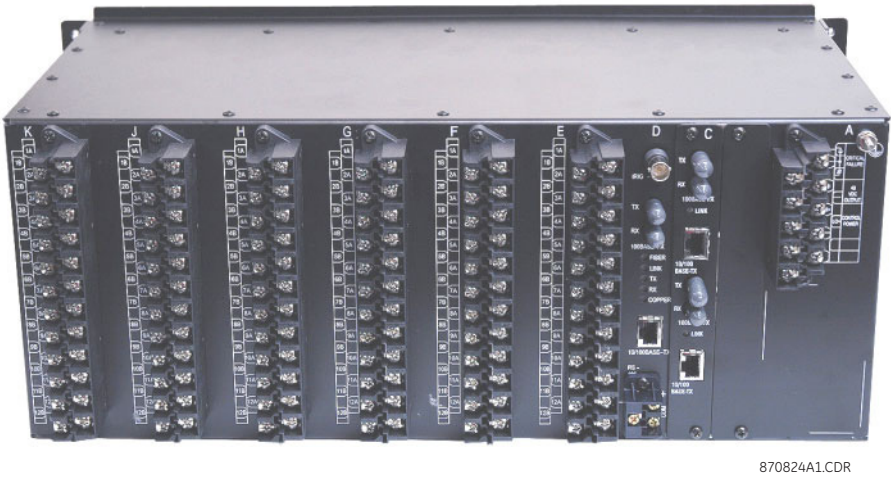
870824A1.CDR

Figure 18: Example of modules in G slot
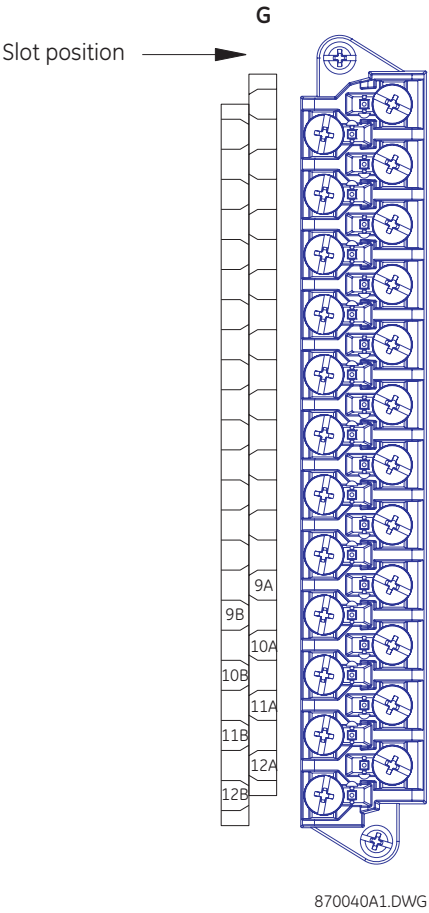
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Electrical installation

This section describes the electrical installation of the C90^{Plus} Controller.

Typical wiring

A typical wiring diagram for the C90^{Plus} is shown below. This diagram provides an example of how to wire the device. Actual wiring will vary according to application.

Figure 19: Typical wiring diagram
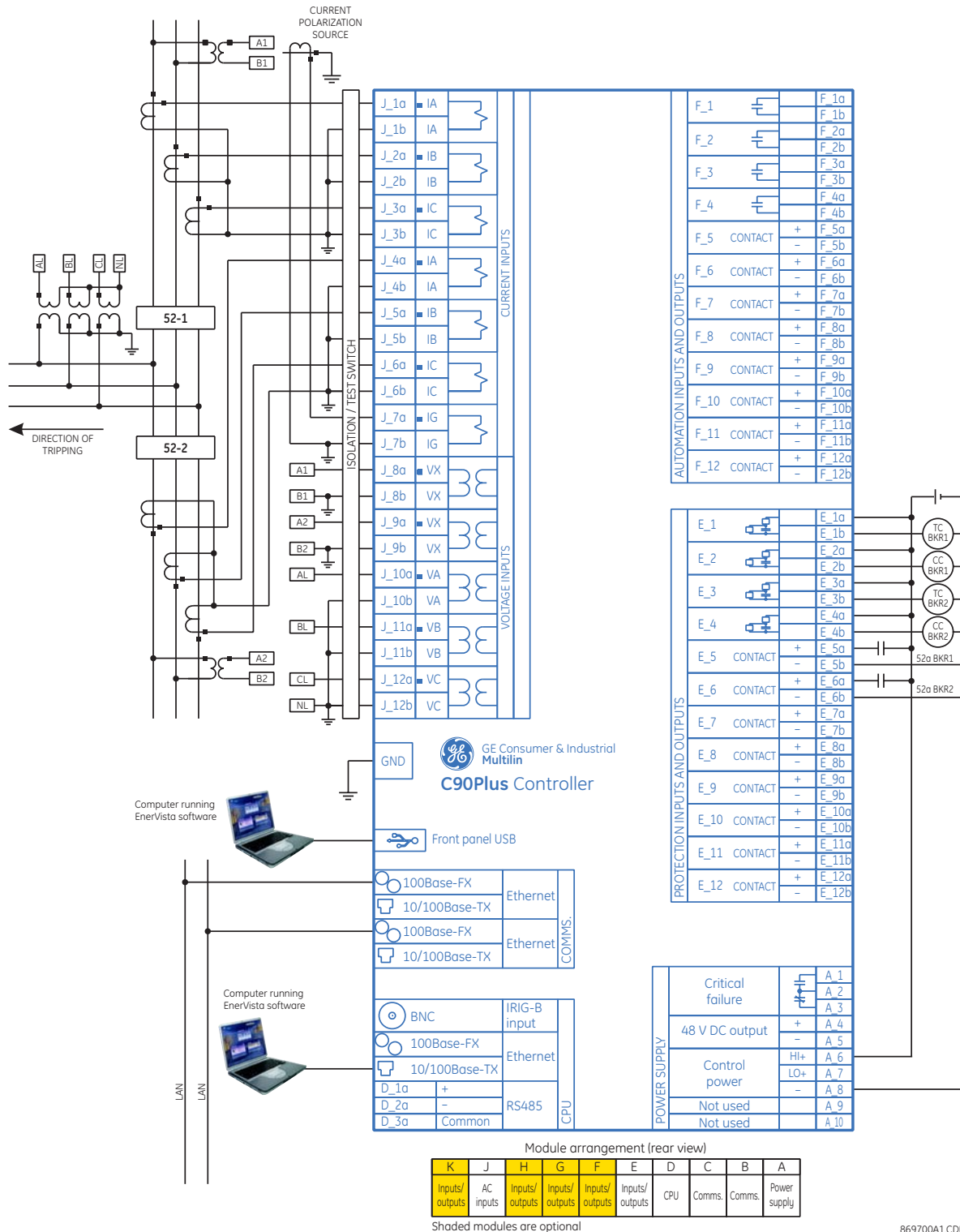
Dielectric strength

The dielectric strength of the UR^{Plus}-series module hardware is shown in the following table.

Table 1: Dielectric strength for UR^{Plus}-series hardware

Function	Terminals		Dielectric strength
	from	to	
Power supply module	high (+), low (+), (–)	chassis	2000 V AC for 1 minute
Power supply module	48 V DC (+) and (–)	chassis	2000 V AC for 1 minute
Power supply module	relay terminals	chassis	2000 V AC for 1 minute
Main CPU	RS485 port	chassis	2000 V AC for 1 minute
Main CPU	RJ45 port	chassis	1500 V AC for 1 minute
Main CPU	IRIG-B port	chassis	2000 V AC for 1 minute
Front panel	USB port	chassis	2000 V AC for 1 minute
Contact inputs/outputs	all	chassis	2000 V AC for 1 minute
AC module	all	chassis	2000 V AC for 1 minute
CPU module	all	chassis	2000 V AC for 1 minute

Filter networks and transient protection clamps are used in the hardware to prevent damage caused by high peak voltage transients, radio frequency interference (RFI), and electromagnetic interference (EMI). These protective components **can be damaged** by application of the ANSI/IEEE C37.90 specified test voltage for a period longer than the specified one minute.

Main processor module

The main processor module contains ports for Ethernet communications, serial RS485 communications, and IRIG-B connection.

Ethernet port

The fiber optic communication ports allow for fast and efficient communications between relays at 100 Mbps. Optical fiber may be connected to the relay supporting a wavelength of 1310 nm in multi-mode.

The optical fiber sizes supported are 50/125 μm and 62.5/125 μm. The fiber optic port is designed such that the response times will not vary for any core that is 62.5 μm or less in diameter. For optical power budgeting, splices are required every 1 km for the transmitter-receiver pair. When splicing optical fibers, the diameter and numerical aperture of each fiber must be the same. In order to engage or disengage the ST type connector, only a quarter turn of the coupling is required.

⚠ **DANGER**

Observing any fiber transmitter output may cause injury to the eye!

⚠ **CAUTION**

Ensure the dust covers are installed when the fiber is not in use. dirty or scratched connectors can lead to high losses on a fiber link.

RS485 port

RS485 data transmission and reception are accomplished over a single twisted-pair with transmit and receive data alternating over the same two wires. Through the use of this port, continuous monitoring and control from a remote computer, SCADA system or PLC is possible.

To minimize errors from noise, the use of shielded twisted pair wire is recommended. Correct polarity must also be observed. For instance, the relays must be connected with all RS485 "+" terminals connected together, and all RS485 "–" terminals connected together.

The COM terminal should be connected to the common wire inside the shield, when provided. To avoid loop currents, the shield should be grounded at one point only. Each relay should also be daisy chained to the next one in the link. A maximum of 32 relays can be connected in this manner without exceeding driver capability. For larger systems, additional serial channels must be added. It is also possible to use commercially available repeaters to increase the number of relays on a single channel to more than 32. Star or stub connections should be avoided entirely.

Lightning strikes and ground surge currents can cause large momentary voltage differences between remote ends of the communication link. For this reason, surge protection devices are internally provided at both communication ports. An isolated power supply with an optocoupled data interface also acts to reduce noise coupling. To ensure maximum reliability, all equipment should have similar transient protection devices installed.

Both ends of the RS485 circuit should also be terminated with an impedance as shown below.

Figure 20: RS485 serial connection
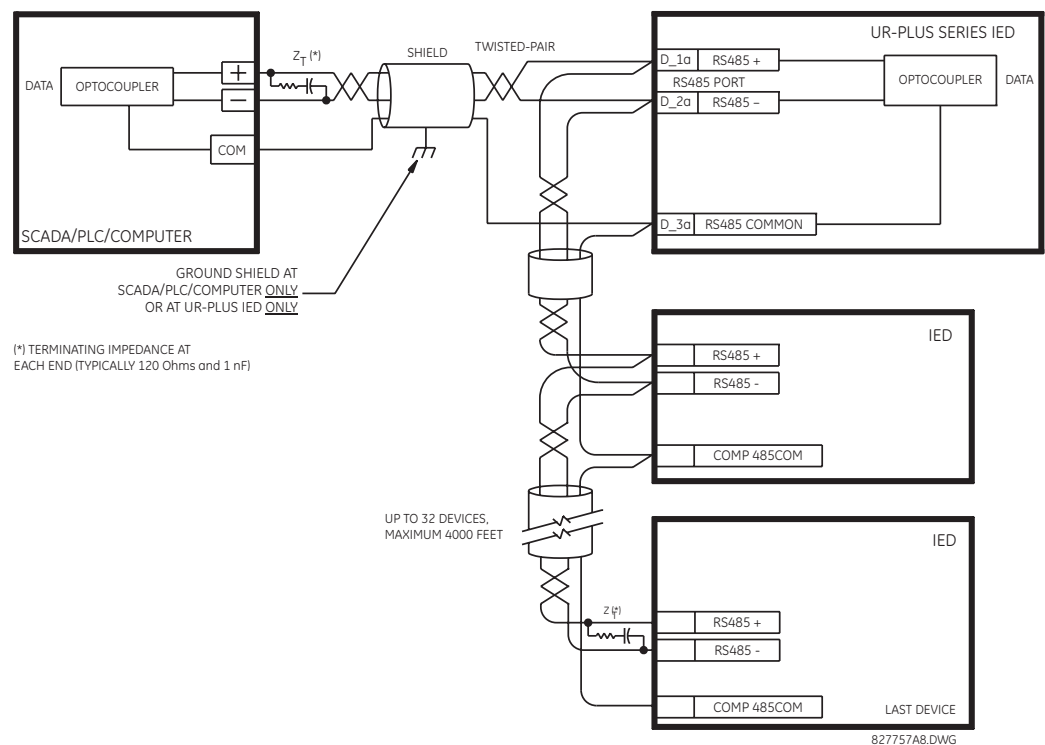
IRIG-B is a standard time code format that allows stamping of events to be synchronized among connected devices within one millisecond. The IRIG time code formats are serial, width-modulated codes which can be either DC level shifted or amplitude modulated (AM). Third party equipment is available for generating the IRIG-B signal; this equipment may use a GPS satellite system to obtain the time reference so that devices at different geographic locations can also be synchronized.

Figure 21: IRIG-B connection
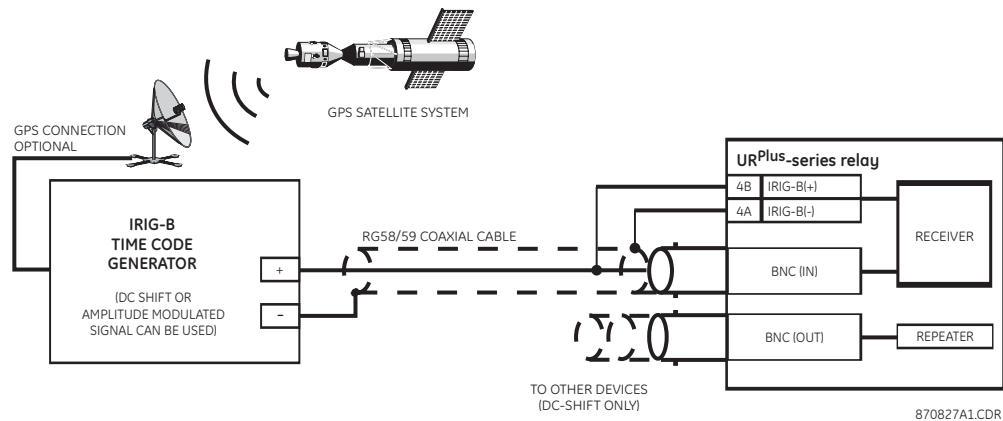
Power supply module

The power supply module provides power to the relay and supplies power for dry contact input connections. It can be connected to any of the following standard power sources.

- DC power: 110 V DC, 125 V DC, 220 V DC, or 250 V DC
- AC power: 115 V AC or 230 V AC

CAUTION

CONTROL POWER SUPPLIED TO THE RELAY MUST BE CONNECTED TO THE MATCHING POWER SUPPLY RANGE OF THE RELAY. IF THE VOLTAGE IS APPLIED TO THE WRONG TERMINALS, DAMAGE MAY OCCUR!

NOTE

The C90^{Plus} system, like almost all electronic relays, contains electrolytic capacitors. These capacitors are well known to be subject to deterioration over time if voltage is not applied periodically. Deterioration can be avoided by powering the relays up once a year.

The power supply module provides 48 V DC power for dry contact input connections and a critical failure relay. The critical failure relay is a form-C that will be energized once control power is applied and the relay has successfully booted up with no critical self-test failures. If on-going self-test diagnostic checks detect a critical failure or control power is lost, the relay will de-energize.

Figure 22: Control power connection
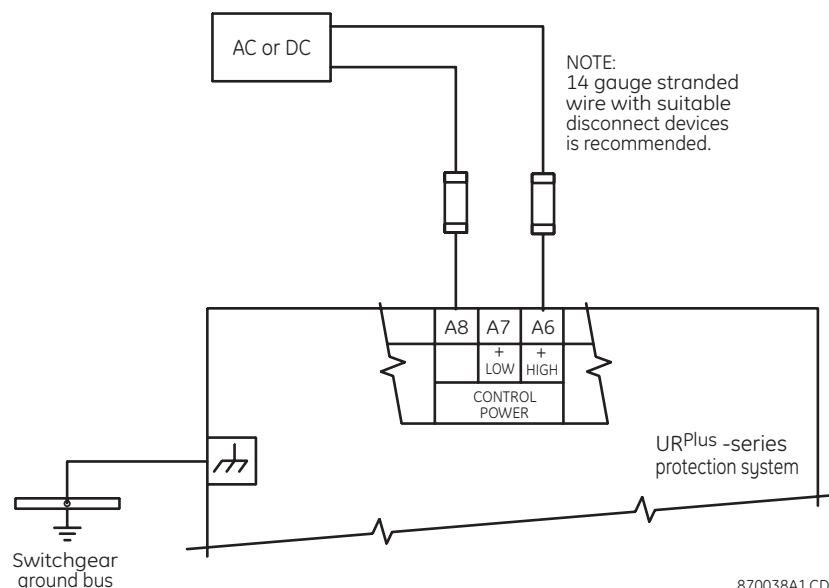
AC modules

An AC module has voltage inputs on channels 8 through 12 inclusive. Channel 10 is intended for connection to a source that represents phase A voltage of the power system (produced by a VT or CVT). Likewise, channel 11 is intended for connection to phase B, and channel 12 is intended for connection to phase C. The phase voltage channels are used for most metering and protection purposes.

Channels 8 and 9 are intended for connection to single-phase sources. In the C90^{Plus}, each of these inputs are typically used to measure the voltage on the side of the breaker opposite to the line terminal. Each of these channels is labeled as an auxiliary voltage (VX). The auxiliary voltage channels are used as inputs for synchrocheck, but can also be used for auxiliary undervoltage or overvoltage elements.

An AC module has current inputs on channels 1 through 7 inclusive. In a single breaker application, channel 1 is intended for connection to a source representing the phase A current of the power system (produced by a CT). Likewise, channel 2 is intended for connection to phase B, and channel 3 is intended for connection to phase C. In a breaker-and-a-half application, channels 1 through 3 are connected to the phase A, B, and C currents from one breaker, while channels 4 through 6 are connected to the phase A, B, and C currents from the second breaker. The phase current channels are used for most metering and protection purposes.

Channel 7 can be used for either of two purposes. First, it can be connected to a CT that is directly measuring system ground current. It can also be connected to the CT residual circuit of a parallel line.

⚠ **CAUTION** **Verify that the connection made to the relay nominal current of 1 A or 5 A matches the secondary rating of the connected CTs. Unmatched CTs may result in equipment damage or inadequate protection.**

⚠ **CAUTION** **The CT secondaries should be connected to the AC terminals of the C90^{Plus} through a shorting-type test switch or shorting-type terminal blocks in order to facilitate safe withdrawal of the AC module.**

There are no internal ground connections on the current inputs. Current transformers with 1 to 50000 A primaries and 1 A or 5 A secondaries may be used.

CT connections for both ABC and ACB phase rotations are identical as shown in the typical wiring diagram.

The exact placement of a zero-sequence core balance CT to detect ground fault current is shown below. Twisted-pair cabling on the zero-sequence CT is recommended.

Figure 23: Zero-sequence core-balance CT installation

UNSHIELDED CABLE

SHIELDED CABLE

Ground connection to neutral
must be on the source side

Source
A   B   C   N   G

Ground
outside CT

LOAD

Source

Stress cone
shields

A   B   C

LOAD

To ground;
must be on
load side

996630A5
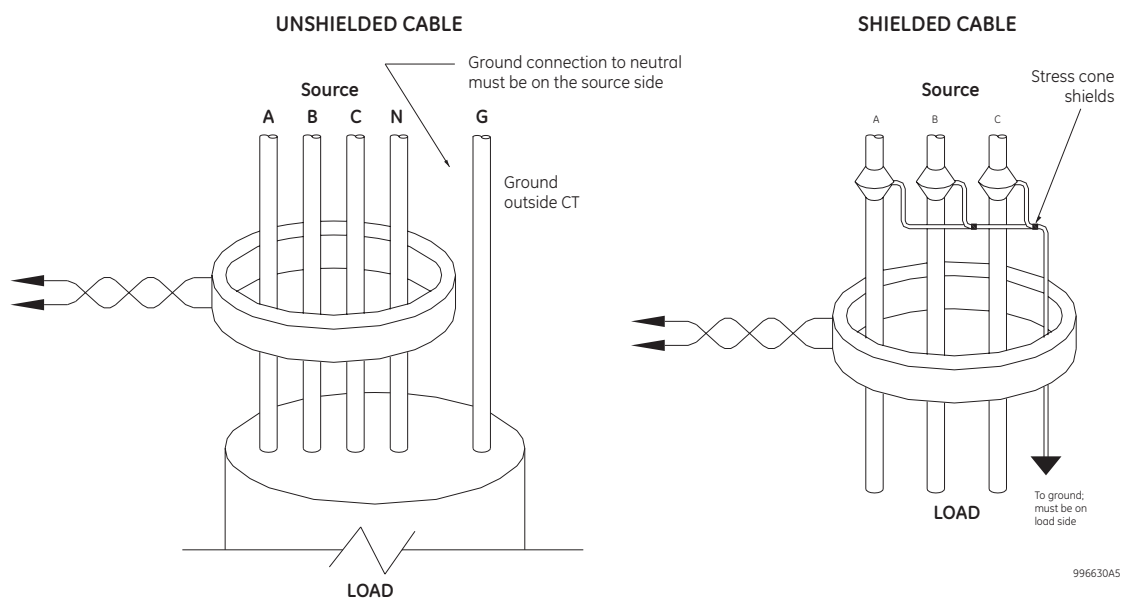
The phase voltage channels are used for most metering and protection purposes. The auxiliary voltage channel is used as an input for features such as synchrocheck, volts per hertz, and auxiliary undervoltage.

A typical AC module wiring diagram is shown below. Substitute the tilde "~" symbol with the slot position of the AC module.

Figure 24: Typical AC module wiring
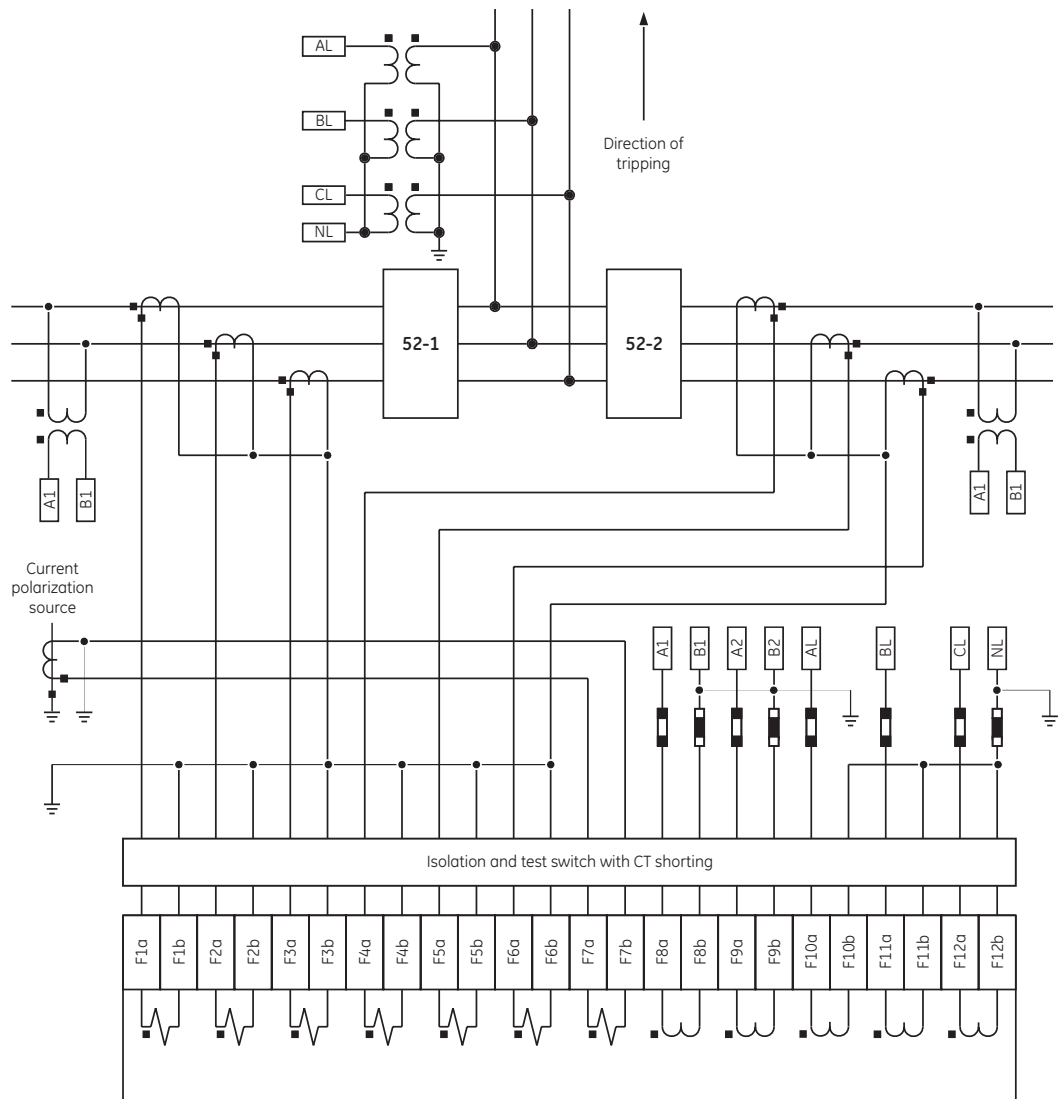
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Contact inputs and outputs

Every input/output module has 24 terminal connections. They are arranged in two terminals per row, with twelve rows in total. A given row of two terminals may be used for the outputs of one relay. There are options of using current or voltage detection for feature supervision, depending on the module ordered.

All inputs and outputs are isolated from one another with each input and output having two dedicated terminals. Since an entire module row is used for a single contact input or output, the name is assigned using the module slot position and row number.

Form-A and solid-state relay output contacts

Some form-A and solid-state relay outputs include circuits to monitor the DC voltage across the output contact when it is open, and the DC current through the output contact when it is closed. Each of the monitors contains a level detector whose output is set to logic 1 (on) when the current in the circuit is above the threshold setting. The voltage

monitor is intended to check the health of the overall trip circuit, and the current monitor can be used to seal-in the output contact until an external contact has interrupted current flow.

Figure 25: Form-A relay contact input functions

Voltage and current monitoring   No monitoring

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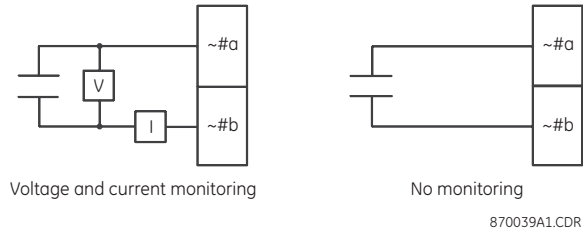
Figure 26: Solid-state relay contact input functions

Voltage and current monitoring

870037A1.DWG
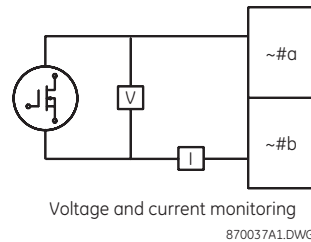
The operation of voltage and current monitors is reflected with the corresponding FlexLogic™ operands (Cont Op ### Von, Cont Op ### Voff, Cont Op ### Ion, and Cont Op ### Ioff) which can be used in protection, control and alarm logic. The typical application of the voltage monitor is breaker trip circuit integrity monitoring; a typical application of the current monitor is seal-in of the control command.

⚠ DANGER

Relay contacts must be considered unsafe to touch when the unit is energized! If the relay contacts need to be used for low voltage accessible applications, it is the customer's responsibility to ensure proper insulation levels!

NOTE

When current monitoring is used to seal-in the form-A and solid-state relay contact outputs, the FlexLogic™ operand driving the contact output should be given a reset delay of 10 ms to prevent damage of the output contact (in situations when the element initiating the contact output is bouncing, at values in the region of the pickup value).

Contact inputs wiring

Contact inputs are not polarity sensitive. A dry contact has one side connected to terminal A_5. This is the positive 48 V DC voltage rail supplied by the power supply module. The other side of the dry contact is connected to either of the contact input terminals. The other contact input terminal is connected to the DC negative terminal (A_4) of the power supply module. When a dry contact closes, a 10 mA current will initially flow through the associated circuit. Once the relay has validated the state change of the contact the input current is reduced to 1 mA.

A wet contact has one side connected to the positive terminal of an external DC power supply. The other side of this contact is connected to the one of the contact input terminals. In addition, the negative side of the external source must be connected to the other contact input terminal. The maximum external source voltage for this arrangement is 300 V DC. The voltage threshold at which each group of four contact inputs will detect a closed contact input is programmable as from 20 to 250 V DC.

Figure 27: Dry and wet contact input connections
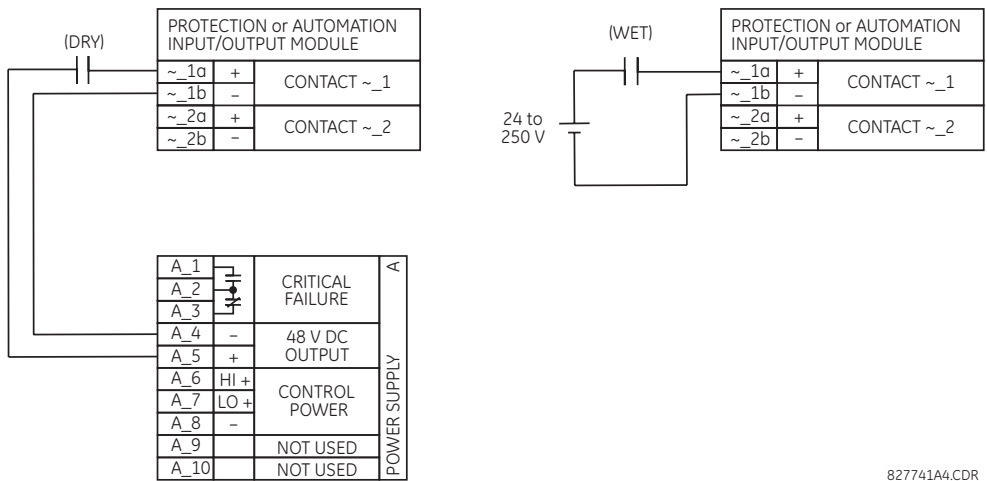
> **NOTE**
>
> Wherever a tilde "~" symbol appears, substitute with the slot position of the module.

Contact outputs wiring

Contact outputs may be ordered as form-A or solid-state. Depending on the module ordered, these contacts may be connected for external circuit supervision. These contacts are provided with voltage and current monitoring circuits used to detect the loss of DC voltage in the circuit, and the presence of DC current flowing through the contacts when the form-A contact closes. If enabled, the current monitoring can be used as a seal-in signal to ensure that the form-A contact does not attempt to break the energized inductive coil circuit and weld the output contacts.

> **NOTE**
>
> There is no provision in the relay to detect a DC ground fault on 48 V DC control power external output. We recommend using an external DC supply.

GE Consumer & Industrial
Multilin

C90^{Plus} Controller

Chapter 4: Interfaces

This section describes the methods of interfacing with the C90^{Plus}.

Front panel overview

The front panel provides a convenient means to interface with the C90^{Plus}. The front panel interface consists of a color LCD display (annunciator) and two sets of user-programmable pushbuttons. This interface provides immediate access to all major C90^{Plus} functions.

There are three groupings of pushbuttons. The pushbuttons located at the bottom of the display are for navigation, while the pushbuttons located at both sides of the display are dedicated for control functions.

The annunciator is a color LCD display that provides alarm and trip information. The annunciator also provides indication of any active self-diagnostic messages and includes a product information screen.

Figure 28: Front panel interface

Configurable color annunciator
display eliminates the need
for LEDs and hard-coded labels

User-programmable
pushbuttons
for bay control

Large, high-resolution color
display for comprehensive
visualization

Rugged chassis
(–42°C to 85°C)

Alarm navigation panel

Navigation keys for
single-click viewing
of IED information

High-speed
USB port for
fast data transfer

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The front panel also contains a high-speed USB port that is dedicated for communications with a PC running the EnerVista software.

Front panel interface operation

The front panel interface is a color TFT panel with pushbuttons for menu navigation and dedicated pushbuttons for control functions. This display provides convenient access to operational data generated by the C90^{Plus}. It also enables local control of power system devices that are connected to the IED.

The control pushbuttons are shown only in the control menu. Otherwise, the menu navigation pushbuttons will be shown. The number of control pushbuttons is dependent on the number of disconnects and breakers in the selected mimic diagram.

Figure 29: Front panel interface operation
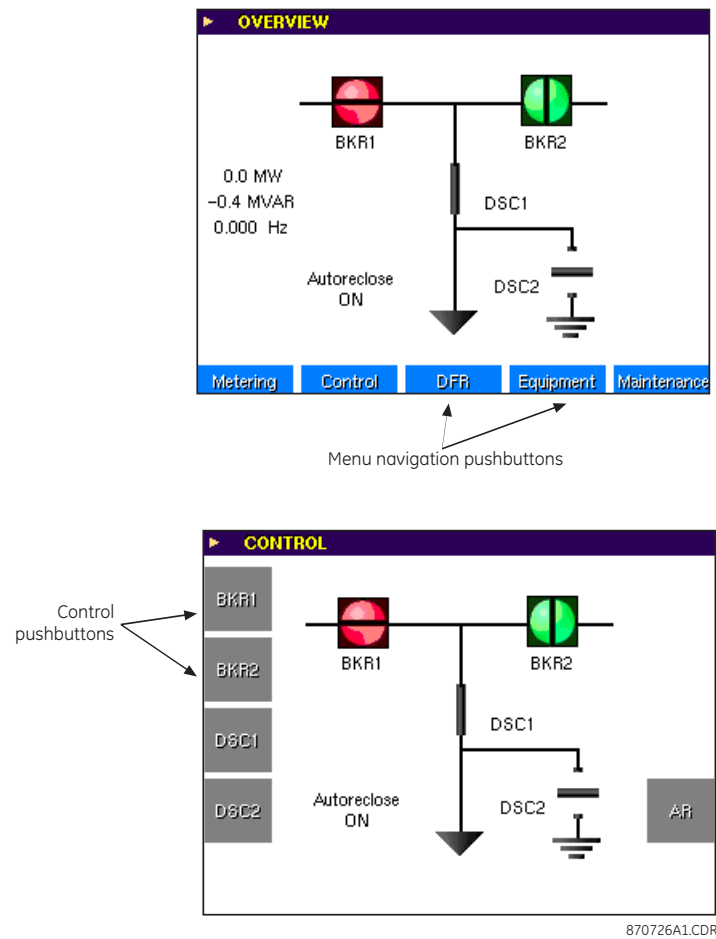
Figure 30: Menu Structure

Metering	Control	DFR	Equipment	Maintenance
▷ Summary ▷ Energy ▷ Phasors ▷ Sequence components	▷ MIMIC diagram and control pushbuttons	▷ Summary ▷ SOE ▷ Fault report ▷ Transient record ▷ Disturbance record	▷ Battery monitor	▷ Input/output status

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Metering menu

The system metering quantities are available from the front panel in the metering menu. These values are derived automatically from the metering source. The following metering screens are available.

- Summary screen: Displays the system voltage, current, real, and reactive power on a per-phase basis.

- Demand screen: Displays demand values for current, real, and reactive power. The peak value for current demand is recorded here and can be reset from this screen.

- Energy screen: Four quadrant energy values can be displayed and reset from this screen.
- Phasor screen: The phasor components of the system voltage (phase-neutral) and current are graphically displayed.
- Sequence screen: The sequence components of the system voltage and currents are graphically displayed.

Control menu

The user can access the mimic diagram and dedicated control pushbuttons from the control menu. The mimic page provides status of circuit breakers and disconnect switches. Operation of these devices is also available through the control pushbuttons.

Figure 31: Mimic page - select example
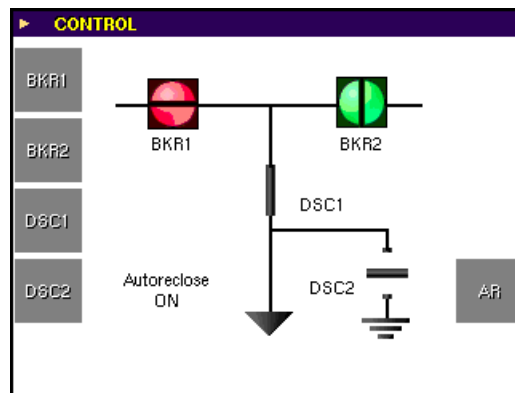
Figure 32: Mimic page - operate example
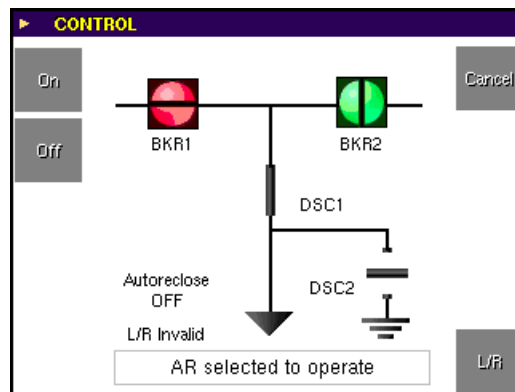
The front panel control pushbuttons can be placed under password security. When password security is enabled, the front panel will request the command password before performing any actions.

Figure 33: Command password entry screen
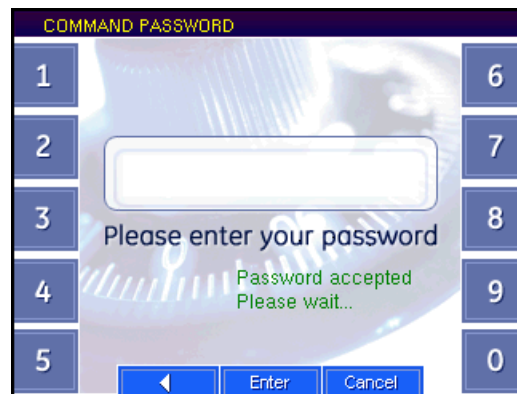
Digital fault recorder menu

The digital fault recorder menu provides access to various records stored within the C90^{Plus}, including sequence of events, fault report, transient records, and disturbance records. The status of each function is displayed on the summary page.

- A green indicator indicates that the function is enabled and the more than 20% of the memory is available.

- A yellow indicator indicates that the available memory is between zero and 20%.

- A red indicator indicates that the memory if full.

If the function is configured for protected mode then the enabled indicator will also switch to red indicating that new records will be captured. If the function is configured for automatic, then the element will overwrite old records and the enabled LED will remain green.

Figure 34: Digital fault recorder - example summary page

The sequence of events record can be accessed from this page. Using the navigations keys, the user can scroll or page through the events list. Two cursors are provided for measurement of the time difference between events.

Figure 35: Example sequence of events record

Principal fault information measured by C90^Plus can also be accessed from the digital fault recorder menu.

Figure 36: Example fault record

The digital fault recorder menu transient record menu lists all of the records currently stored in the C90^Plus. It also indicates the status of the trigger, where:

- Green indicates that the trigger is not active.
- Red indicates an active trigger.

Records can be retrieved and deleted and triggers can be manually generated from this screen.

Figure 37: Example transient record

The digital fault recorder menu disturbance record menu lists all disturbance records currently stored in the C90^Plus. It also indicates the status of the trigger, where:

- Green indicates that the trigger is not active.
- Red indicates an active trigger.

Records can be retrieved and deleted and triggers can be manually generated from this screen.

Figure 38: Example disturbance record

Equipment manager menu

This menu provides access to the equipment manager battery monitor function. There are three status indicators, colored red, yellow, and green.

- A green indication denotes no alarms for the device.
- A yellow indication denotes at least one non-critical alarm and no critical alarms.
- A red indication denotes at least one critical alarm.

The battery monitor page displays the state of all battery monitor alarms for a particular device. Alarms can also be reset from this page.

Figure 39: Equipment manager battery monitor alarms example

Annunciator

The annunciator is a color TFT panel located that emulates the functionality found in a conventional annunciator unit.

Annunciator operation

The annunciator provides indications on the status of system alarm points. It also displays self-test messages and product information for the unit.

Figure 40: Typical annunciator display
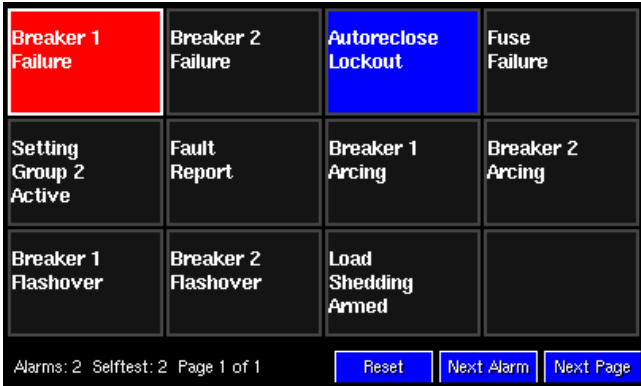
There are three control buttons at the bottom of the display.

- The **Next Page** button cycles through the pages of alarms and to the self-test page.
- The **Next Alarm** button cycles horizontally through the current alarms, from left to right, starting with the first row of alarms. A graphical frame borders the current status box to indicate the selected alarm. The front panel display is dynamically controlled according to the selected alarm.
- The **Ack** button controls the state of the alarms.

The annunciator alarm sequence conforms to ISA 18.1-1979 (R1992) standard, type M.

Figure 41: Annunciator alarm sequence
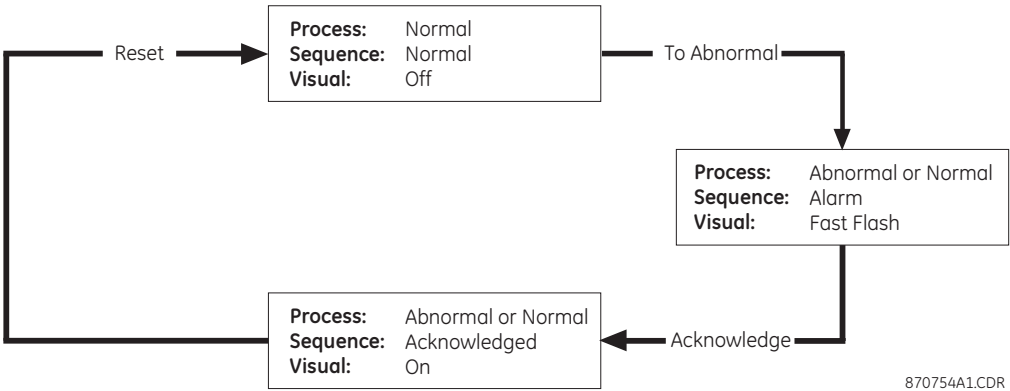
Table 2: Annunciator states

State	Description
Off	Grey text on a darker grey background.
Fast flash	Alternating between the off state and the on state twice per second
On	Bright white text on a colored background.

In the event of an alarm, the page containing the alarm becomes the active page. If there are multiple pages with alarms, the page with the lowest page number is the active page. If there are alarms on multiple pages and alarms on some pages already acknowledged (but not cleared) by the user, the pages with active alarms move ahead of the pages with acknowledged alarms.

Display of the alarm pages is prioritized according to active window (unacknowledged or flashing alarm) and then the page number (that is, if two pages have an unacknowledged alarm, the page with the lowest number is displayed).

Self-test page

The self-test page displays any active self test alarms as well as the time of occurrence and the severity of the alarm (yellow for non-critical and red for critical). Self-test alarms will reset automatically.

Figure 42: Self-test page example
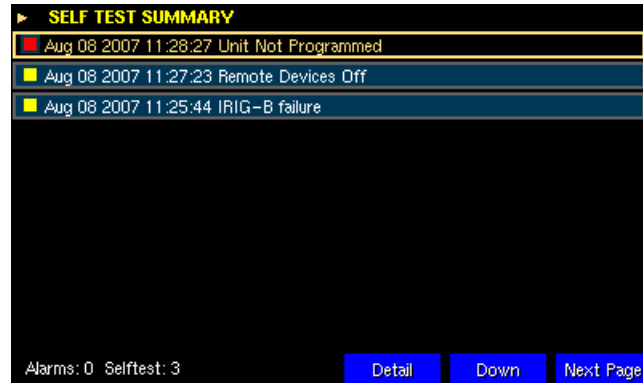
Product information page

The product information page contains all of the constituent data describing the makeup of the IED, including the order code, firmware and configuration filenames, and serial numbers of each module.

Figure 43: Example product information page
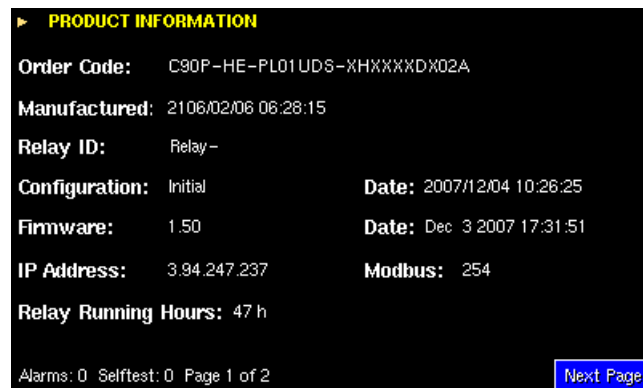
C90^Plus Controller

Chapter 5: Communications

This section describes how to program the C90^Plus communications settings.

Communications overview

The C90^Plus has one Ethernet port (port 1) on the main CPU module and two additional Ethernet ports (ports 2 and 3) on the communications module. Each port supports 100Base-FX over multi-mode fiber and 10/100Base-TX over twisted-pair, with auto-negotiation. Port 1 is primarily intended for configuration and file retrieval purposes and has a dedicated IP address. Ports 2 and 3 are intended for SCADA and peer-to-peer messaging. Additionally, there is one serial RS485 port. The following protocols are available, depending on the configuration of the unit.

- Ethernet port 1: Modbus TCP
- Ethernet port 2: Modbus TCP, DNP 3.0, IEC 60870-5-104, IEC 61850
- Ethernet port 3: Modbus TCP, DNP 3.0, IEC 60870-5-104, IEC 61850
- RS485 port: Modbus, DNP 3.0

Network topology

The topology shown below allows several C90^Plus devices to communicate with a PC running EnerVista software or with a gateway for remote access. This allows device configuration, monitoring, and file transfers (transient records, sequence of events, etc.) to be carried out over Ethernet. Communications processor cards are not required and no redundancy is provided.

Figure 44: Simple network topology without communications cards
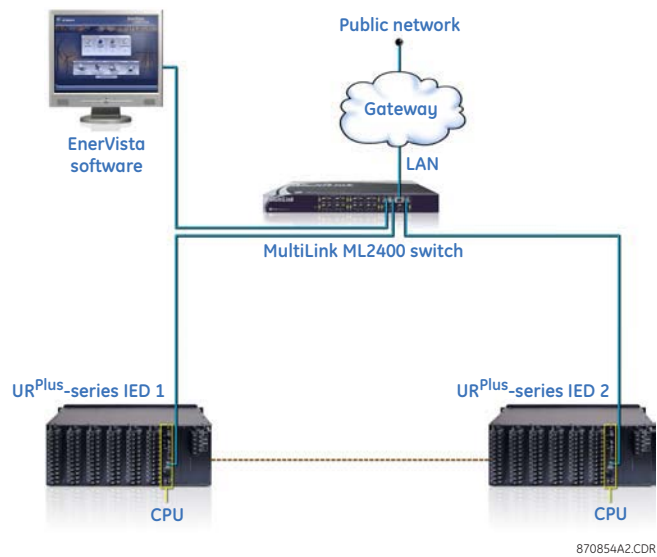
The topology shown below allows SCADA, GOOSE, configuration, and monitoring functions to share a single network. No redundancy is provided in this configuration. A communications processor is required in each C90^{Plus} device to facilitate SCADA and GOOSE messaging. Ports 2 and 3 can be configured for single or dual IP redundancy. This network topology is backwardly compatible with UR-series devices that are configured with a single Ethernet port.

Figure 45: Simple single network topology with no redundancy
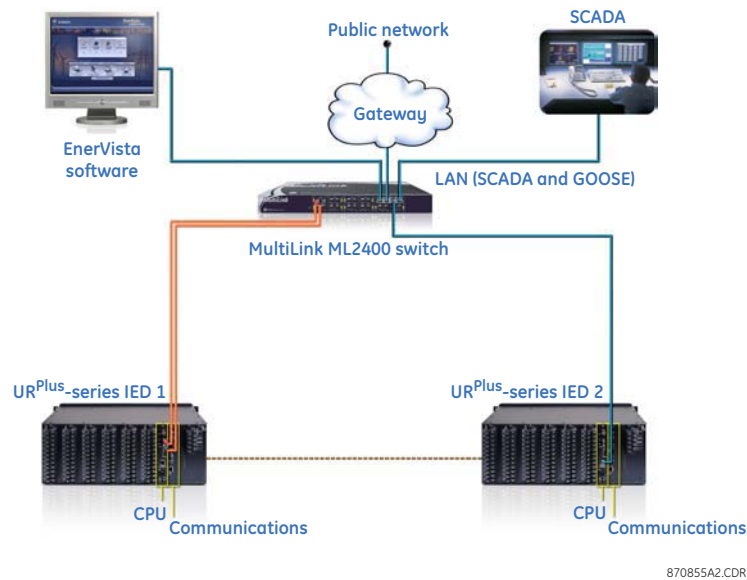
The topology below illustrates a single network for SCADA, GOOSE, configuration, and monitoring functions. This configuration provides redundant hardware and media redundancy. All communications are handled by port 2 under normal circumstances. Failure of a fiber or Ethernet switch causes the communications to be re-routed to port 3. Ports 2 and 3 are configured for single IP redundancy in this case. This network topology is backwardly compatible with UR-series devices that are configured with dual Ethernet ports.

Figure 46: Simple single network topology with redundancy
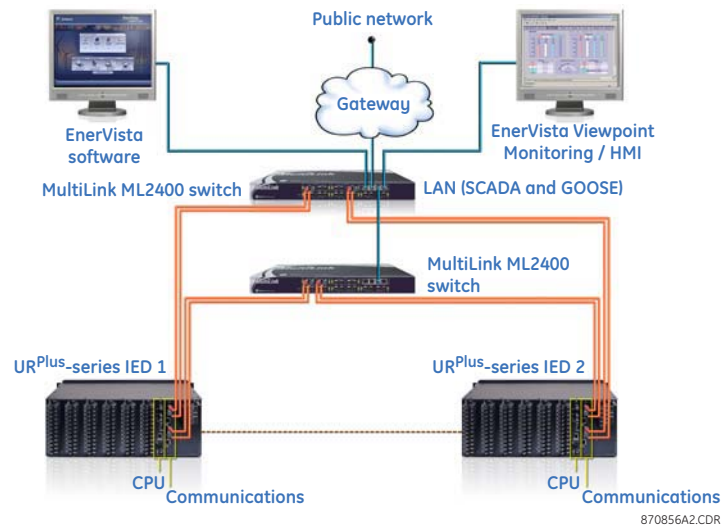
The topology below illustrates a dual LAN network. Configuration, and monitoring functions are provided on LAN 1 with no redundancy. LAN 2 is dedicated to SCADA and GOOSE communications and includes redundant hardware and media. Ports 2 and 3 are configured for single IP redundancy.

Figure 47: Simple dual network topology
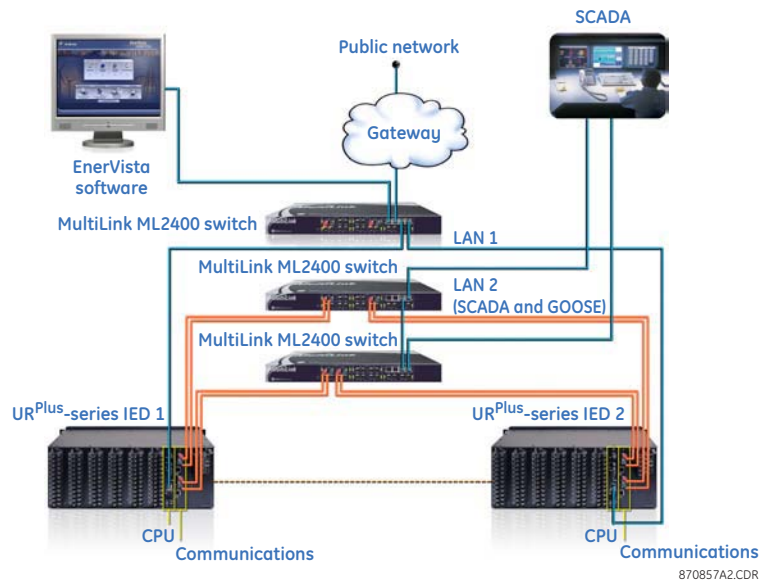
The topology below illustrates a dual redundant LAN network. Ports 2 and 3 are always active. Each C90^{Plus} device will serve clients on either network as required. GOOSE messages are transmitted and received on both LANs simultaneously. Ports 2 and 3 are configured for dual IP redundancy.

Figure 48: Simple dual redundant network topology

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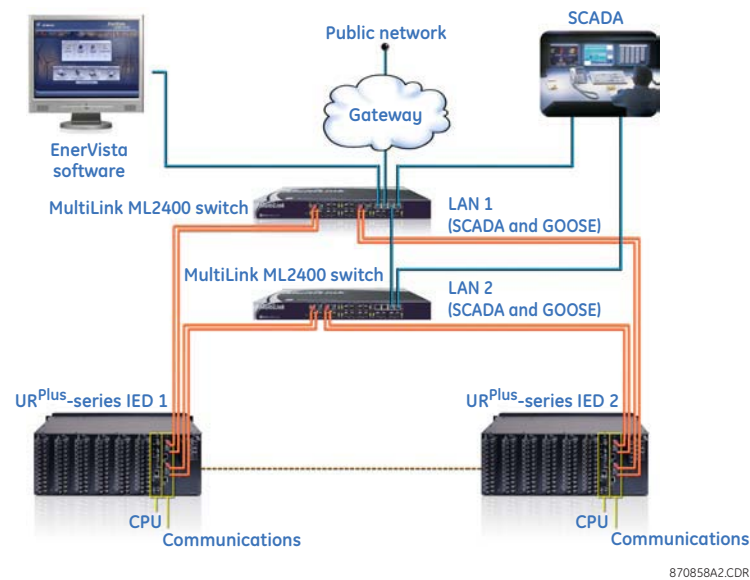
The topology below illustrates a dedicated LAN for configuration and monitoring functions and dual redundant LANs for SCADA and GOOSE traffic. Each C90^{Plus} device will service clients on either network as required. GOOSE messages are transmitted and received on both LANs simultaneously. Ports 2 and 3 are configured for dual IP redundancy.

Figure 49: Simple three network topology

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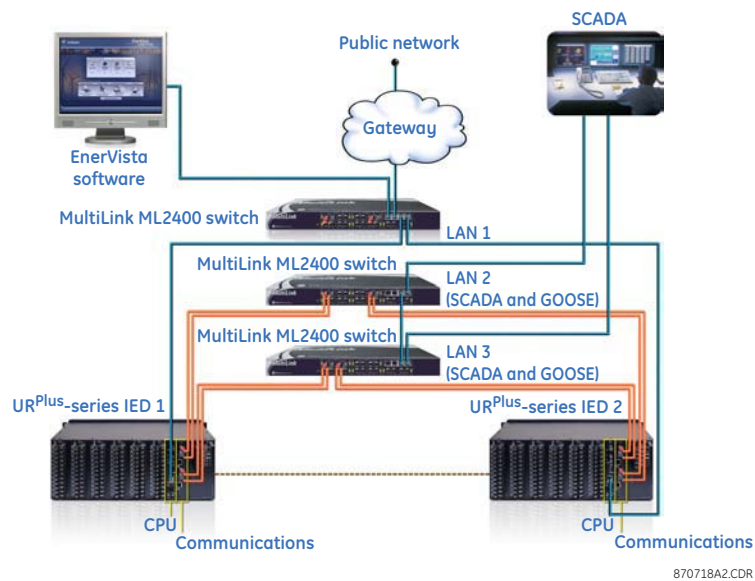
Network settings

Settings are available to configure the Ethernet configuration, as well as the TFTP and SNTP protocols.

Ethernet ports

The Ethernet ports can be configured for single or dual IP redundancy.

The single IP redundancy configuration provides compatibility with UR-series relays and other devices with single-IP redundancy, and provides a maximum level of switchover performance. In this configuration, the port 2 IP address, subnet mask, and gateway address are used and the port 3 settings are ignored. All communications traffic will normally be routed on port 2. If a failure occurs (determined at the hardware layer upon detecting loss of link signal on the active channel) then the traffic is re-routed to port 3. Switchover to port 3 takes place in less than 10 ms from the moment that the physical layer detects a failure. The device reverts from port 3 to port 2 as soon as port 2 becomes available, regardless of the state of port 3. Switchover to port 2 takes place in less than 500 ms. A link pulse is maintained in the transmit direction on both ports regardless of which port is in use. This ensures that communications are established with minimal delays. An Ethernet broadcast message is transmitted immediately upon switching ports, thereby forcing all Ethernet switches in the network to immediately update their routing tables.

In the dual IP redundancy configuration, each port has a unique IP address, subnet mask, and gateway address. Multiple client-server connections may be opened on each port simultaneously. If a failure occurs (determined at the application layer by the loss of link signal) on a port, all client-server connections on that port will be immediately closed. Subsequently these connections will be available on the healthy port. Peer-to-peer messaging is configurable for main or alternate transmission. Ports 2 or 3 can be configured as the main port. Under normal conditions, GOOSE messages are sent on the main port. If the physical layer detects a failure on this port then transmission will be immediately transferred to the alternate port.

Select the **Settings > Communications > Network > Ethernet** menu item to open the Ethernet configuration window.

Figure 50: Ethernet port configuration settings

The IP addresses are used with the DNP, Modbus/TCP, IEC 61580, IEC 60870-5-104, TFTP, and HTTP protocols. These settings are used only in advanced network configurations and should normally be left at their default values, but may be changed if required (for example, to allow access to multiple UR^{Plus}-series devices behind a router).

NOTE

When the NSAP address or any user map setting (when used with DNP) is changed, it will not become active until power to the relay has been cycled (off-to-on).

The following settings are available for each Ethernet port, except for **OSI Network Address (NSAP)** and **ESH Configuration Time**, which are not port-specific, and the **Port 2 Redundancy**, which applies only to Ethernet port 2.

Port 1 IP Address, Port 2 IP Address, Port 3 IP Address

Range: standard IP address range
Default: 3.94.244.210

These settings specify the dedicated IP address for each Ethernet port.

Port 1 IP Subnet Mask, Port 2 IP Subnet Mask, Port 3 IP Subnet Mask

Range: standard IP address range
Default: 255.255.252.0

These settings specify the dedicated subnet mask for each Ethernet port.

Port 1 Gateway IP Address, Port 2 Gateway IP Address, Port 3 Gateway IP Address

Range: standard IP address range
Default: 3.94.244.1

These settings specify the dedicated gateway address for each Ethernet port.

Port 1 Ethernet Mode, Port 2 Ethernet Mode, Port 3 Ethernet Mode

Range: Auto, 10/100 Base-TX, 100 Base-TX
Default: 3.94.244.1

These settings select the Ethernet connection hardware type, either 10/100Base-TX (twisted-pair) or 100Base-FX (fiber optic). The "Auto" selection is used to automatically detect the Ethernet hardware type.

Port 2 Redundancy

Range: Single IP, Dual IP
Default: Dual IP

This settings selects single-IP or dual-IP operation for Ethernet ports 2 and 3. In single-IP mode, the link status of both ports is continuously monitored but only one port is active at a time. Each port uses the same source MAC address and IP parameters specified for Ethernet port #2. In dual-IP mode, Ethernet ports 2 and 3 operate independently with their own MAC addresses and IP parameters. Changes to this setting are implemented immediately.

OSI Network Address (NSAP)

Range: 20 alphanumeric characters
Default: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 49 00 00 00

This setting specifies the NSAP address used with the IEC 61850 protocol over the OSI (CLNP/TP4) stack.

ESH Configuration Timer

Range: 0 to 32767 seconds in steps of 1
Default: 120 seconds

The End System to Intermediate System Routing Exchange protocol used with ISO 8473 mandates that the end system construct and transmit an End System Hello (ESH) signal for each NSAP it serves, based on an internal timer. This setting specifies the transmission time for the ESH signal. This setting takes affect when the C90^{Plus} is rebooted.

TFTP protocol

The Trivial File Transfer Protocol (TFTP) can be used to transfer files from the C90^{Plus} over a network. The C90^{Plus} operates as a TFTP server. TFTP client software is available from various sources, including Microsoft Windows XP. The dir.txt file obtained from the C90^{Plus} contains a list and description of all available files (event records, oscillography, etc.).

Select the **Settings > Communications > Network > TFTP** menu item to open the serial port configuration window.

Figure 51: TFTP configuration settings
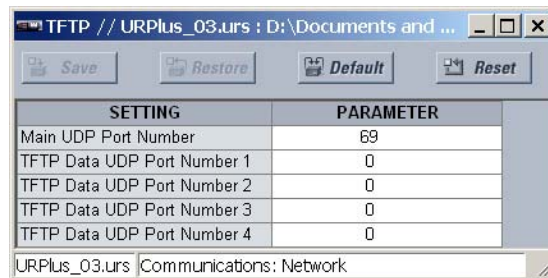
The following settings are available for the TFTP protocol.

Main UDP Port Number
Range: 1 to 65535 in steps of 1
Default: 69
This setting specifies the main UDP port number.

TFTP Data UDP Port Number 1, TFTP Data UDP Port Number 2, TFTP Data UDP Port Number 3, TFTP Data UDP Port Number 4
Range: 0 to 65535 in steps of 1
Default: 0
These settings specify data for UDP port numbers 1 through 4.

SNTP protocol

The C90^{Plus} supports the Simple Network Time Protocol specified in RFC-2030. With SNTP, the C90^{Plus} can obtain clock time over an Ethernet network. The C90^{Plus} acts as an SNTP client to receive time values from an SNTP/NTP server, usually a dedicated product using a GPS receiver to provide an accurate time. Both unicast and broadcast SNTP are supported.

If SNTP functionality is enabled at the same time as IRIG-B, the IRIG-B signal provides the time value to the C90^{Plus} clock for as long as a valid signal is present. If the IRIG-B signal is removed, the time obtained from the SNTP server is used. If either SNTP or IRIG-B is enabled, the C90^{Plus} clock value cannot be changed using the front panel keypad.

The UR^{Plus}-series relays do not support the multicast or anycast SNTP functionality.

Select the **Settings > Communications > Network > SNTP** menu item to open the SNTP protocol configuration window.

Figure 52: SNTP protocol configuration settings

The following settings are available to configure the SNTP protocol.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the SNTP protocol.

Server IP Address

Range: standard IP address

Default: 0.0.0.0

This setting specifies the SNTP/NTP server IP address.

To use SNTP in unicast mode, this setting must be programmed to the SNTP/NTP server IP address. Once this address is set, the C90^{Plus} attempts to obtain time values from the SNTP/NTP server. Since many time values are obtained and averaged, it generally takes three to four minutes until the C90^{Plus} clock is closely synchronized with the SNTP/NTP server. It may take up to two minutes for the C90^{Plus} to signal an SNTP self-test error if the server is offline.

To use SNTP in broadcast mode, program this setting to "0.0.0.0". The C90^{Plus} then listens to SNTP messages sent to the *all ones* broadcast address for the subnet. The C90^{Plus} waits up to eighteen minutes (1024 seconds) without receiving an SNTP broadcast message before signaling an SNTP self-test error.

UDP Port Number

Range: 0 to 65535 in steps of 1

Default: 123

This setting specifies the UDP port number for use with the SNTP protocol.

Ethernet Interface

Range: 1, 2, or 3

Default: 1

This setting selects the Ethernet port to use for SNTP communications.

Ethernet actual values

Select the **Actual Values > Communications > Communication** menu item to open the communications actual values window.

Figure 53: Communications actual values

The following actual values are related to the Ethernet communications feature.

Port 1 Ethernet Actual Mode, Port 2 Ethernet Actual Mode, Port 3 Ethernet Actual Mode
Range: 10/100 BASE-TX, 10/100 BASE-FX

This actual value indicates the Ethernet hardware type on each of the three ports.

Port 1 Ethernet Duplex, Port 2 Ethernet Duplex, Port 3 Ethernet Duplex
Range: Full Duplex, Half Duplex

This actual value indicates the Ethernet duplex mode on each of the three ports.

Port 1 Ethernet Speed, Port 2 Ethernet Speed, Port 3 Ethernet Speed
Range: 10 Mbps, 100 Mbps

This actual value indicates the network speed on each of the three Ethernet ports.

Port 1 Ethernet Link Status, Port 2 Ethernet Link Status, Port 3 Ethernet Link Status
Range: Online, Offline

This actual value indicates the connection status on each of the three Ethernet ports.

Modbus communications

The Modicon Modbus protocol is supported by the C90^Plus. Modbus is available via the RS485 serial link (Modbus RTU) or via Ethernet (Modbus/TCP). The C90^Plus always acts as a slave device, meaning that it never initiates communications; it only listens and responds to requests issued by a master device. A subset of the Modbus protocol format is supported that allows extensive monitoring, programming, and control functions using read and write register commands.

Refer to GE publication GEK-113253 for additional details on the Modbus protocol and the Modbus memory map.

Modbus protocol

The Modbus server can simultaneously support two clients over serial RS485 and four clients over Ethernet. The server is capable of reporting any indication or measurement and operating any output present in the device. A user-configurable input and output map is also implemented.

The C90^Plus operates as a Modbus slave device only.

Select the **Settings > Communications > Modbus > Protocol** menu item to open the Modbus protocol configuration window.

Figure 54: Modbus protocol configuration settings
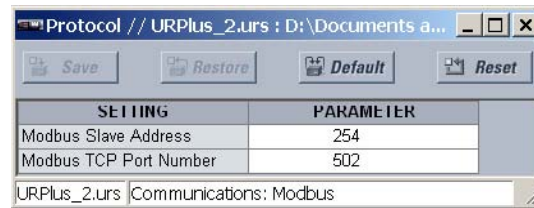
The following Modbus protocol settings are available.

Modbus Slave Address

Range: 0 to 65519 in steps of 1

Default: 254

This setting specifies the Modbus slave address for the C90^{Plus}. Each device must have a unique address from 1 to 254. Address 0 is the broadcast address to which all Modbus slave devices listen. Addresses do not have to be sequential, but no two devices can have the same address or conflicts resulting in errors will occur. Generally, each device added to the link should use the next higher address starting at 1.

Modbus TCP Port Number

Range: 0 to 1024 in steps of 1

Default: 502

This setting specifies the Modbus TCP port number for Ethernet communications.

Modbus user map

The Modbus user map provides read-only access for up to 256 registers. To obtain a memory map value, enter the desired address in the **Parameter** field (this value must be converted from hexadecimal to decimal format). The corresponding value (if programmed) is displayed in the value field. A value of "0" in subsequent register address lines automatically returns values for the previous address lines incremented by 1. An address value of "0" in the initial register means none and values of "0" will be displayed for all registers. Different address values can be entered as required in any of the register positions.

Select the **Settings > Communications > Modbus > User Map** menu item to open the Modbus user map configuration window.

Figure 55: Modbus user map configuration settings

The following Modbus user map settings are available for each of the 256 registers.

Modbus Type

Range: None, Settings, Actuals

Default: None

This setting indicates if the Modbus user map address represents a setting or an actual value.

Parameter

Range: Modbus memory map address in decimal representation

Default: 0

This setting represents the value of the programmed Modbus memory map address.

DNP communications

The DNP protocol allows for the optimization of control and data acquisition between the equipment in the substation and the central control center. The protocol is scalable; that is, it is designed to be compatible with the latest high speed LAN technology yet still be implemented over slower speed serial links.

The DNP protocol improves upon many master-slave protocols by improving overall communication performance requirements and provides time-stamping with millisecond accuracy.

Refer to GE publication GEK-113253 for additional details on the DNP protocol.

DNP protocol

The DNP server can simultaneously support one client over serial RS485 and three clients over Ethernet. Level 3 is supported for parsing requests and generating responses. It is capable of reporting any indication or measurement and operating any output present in the device. Both direct-operate and select-before-operate modes of control are supported. Three user-configurable input and output maps are implemented.

Select the **Settings > Communications > DNP > Protocol** menu item to open the DNP protocol configuration window.

Figure 56: DNP protocol configuration settings

The following settings are available for DNP protocol communications.

DNP Channel 1 Port, DNP Channel 2 Port

Range: None, COM1-RS485, Network-TCP, Network-UDP

Default: None

These settings specify the communications port assigned to the DNP protocol for each channel. Once DNP is assigned to a serial port, the Modbus protocol is disabled on that port. When this setting is set to "Network-TCP", the DNP protocol can be used over TCP/IP on channels 1 or 2. When this value is set to "Network - UDP", the DNP protocol can be used over UDP/IP on channel 1 only.

Changes to the these settings take effect only after power has been cycled to the relay.

DNP Channel Address

Range: 0 to 65519 in steps of 1

Default: 1

This setting specifies the DNP slave address. This number identifies the C90^{Plus} on a DNP communications link. Each DNP slave should be assigned a unique address.

DNP Client Address 1 through DNP Client Address 5
Range: any standard IP address
Default: 0.0.0.0

These settings force the C90^Plus to respond to a maximum of five specific DNP masters.

DNP TCP/UDP Port Number
Range: 1 to 65535 in steps of 1
Default: 20000

This setting specifies the TCP/UDP port used for DNP communications.

DNP Unsolicited Response Function
Range: Enabled, Disabled
Default: Disabled

Program this setting to "Disabled" for RS485 applications, since there is no collision avoidance mechanism.

DNP Unsolicited Response Timeout
Range: 0 to 60 seconds in steps of 1
Default: 5 seconds

This setting specifies how long the C90^Plus waits for a DNP master to confirm an unsolicited response.

DNP Unsolicited Response Maximum Re-Tries
Range: 1 to 255 in steps of 1
Default: 10

This setting specifies the number of times the C90^Plus retransmits an unsolicited response without receiving confirmation from the master. A value of "255" allows infinite re-tries.

DNP Unsolicited Response Destination Address
Range: 0 to 65519 in steps of 1
Default: 1

This setting specifies the DNP address to which all unsolicited responses are sent. The IP address to which unsolicited responses are sent is determined by the C90^Plus from the current TCP connection or the most recent UDP message.

DNP Current Scale Factor, DNP Voltage Scale Factor, DNP Power Scale Factor, DNP Energy Scale Factor, DNP Other Scale Factor
Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000
Default: 1

These settings scale the analog input current values. For example, if the **DNP Current Scale Factor** is "10", all DNP analog input points that represent currents will be returned with values 10 times smaller (for example, a value of 700 amps on the C90^Plus will be returned as 70). Likewise, if the **DNP Voltage Scale Factor** is "0.01", all DNP analog input points that represent voltages will be returned with values 100 times larger (for example, a value of 17 volts on the C90^Plus will be returned as 1700).

These settings are useful when analog input values must be adjusted to fit within certain ranges in DNP masters.

DNP Current Default Deadband, DNP Voltage Default Deadband, DNP Power Default Deadband, DNP Energy Default Deadband, DNP Other Default Deadband
Range: 0 to 65535 in steps of 1
Default: 30000

These settings determine when to trigger unsolicited responses containing analog Input data. These settings group the C90^Plus analog input data into types: current, voltage, power, energy, and other. Each setting represents the default deadband value for all

analog input points of that type. For example, to trigger unsolicited responses from the C90^{Plus} when any current values change by 15 amps, the **DNP Current Default Deadband** setting should be set to "15".

These settings are the deadband default values. DNP object 34 points can be used to change deadband values from the default for each individual DNP analog input point. Whenever power is removed and re-applied to the C90^{Plus}, the default deadbands will be in effect.

DNP Time Sync IIN Period

Range: 1 to 10080 minutes in steps of 1
Default: 1440 minutes

This setting determines how often the Need Time Internal Indication (IIN) bit is set by the C90^{Plus}. Changing this time allows the DNP master to send time synchronization commands more or less often, as required.

DNP Message Fragment Size

Range: 30 to 2048 in steps of 1
Default: 240

This setting determines the size, in bytes, at which message fragmentation occurs. Large fragment sizes allow for more efficient throughput; smaller fragment sizes cause more application layer confirmations to be necessary which can provide for more robust data transfer over noisy communication channels.

DNP Object 1 Variation, DNP Object 2 Variation, DNP Object 20 Variation, DNP Object 21 Variation, DNP Object 22 Variation, DNP Object 23 Variation, DNP Object 30 Variation, DNP Object 32 Variation

Range: 1, 2 (objects 1 and 2); 1,2, 5, 6 (objects 20, 22, and 23); 1, 2, 9, 10 (object 21); 1, 2, 3, 4, 5 (object 30); 1, 2, 3, 4, 5, 6 (object 32)
Default 1 (objects 20, 21, 22, 23, 30, and 32); 2 (objects 1 and 2)

These settings allow the user to select the DNP default variation number for object types 1, 2, 20, 21, 22, 23, 30, and 32. The default variation refers to the variation response when variation 0 is requested or in class 0, 1, 2, or 3 scans.

DNP Number of Paired Controls

Range: 0 to 32 in steps of 1
Default: 0

The DNP binary outputs typically map one-to-one to IED data points. That is, each DNP binary output controls a single physical or virtual control point in an IED. In the C90^{Plus}, DNP binary outputs are mapped to virtual inputs. However, some legacy DNP implementations use a mapping of one DNP binary output to two physical or virtual control points to support the concept of trip and close (for circuit breakers) or raise and lower (for tap changers) using a single control point. That is, the DNP master can operate a single point for both trip and close, or raise and lower, operations. The C90^{Plus} can be configured to support paired control points, with each paired control point operating two virtual inputs. This setting allows configuration of from 0 to 32 binary output paired controls. Points not configured as paired operate on a one-to-one basis.

DNP TCP Connection Timeout

Range: 10 to 300 seconds in steps of 1
Default: 120 seconds

This setting specifies a time delay for the detection of dead network TCP connections. If there is no data traffic on a DNP TCP connection for greater than the time specified by this setting, the connection will be aborted by the C90^{Plus}. This frees up the connection to be re-used by a client.

Power to the C90^Plus must be re-cycled after changing this setting for the changes to take effect.

DNP user point list

The binary and analog inputs points for the DNP protocol can configured to a maximum of 256 points. The value for each point is user-programmable and can be configured by assigning FlexLogic™ operands for binary inputs or FlexAnalog™ parameters for analog inputs.

The DNP point lists always begin with point 0 and end at the first "Off" value. Since DNP point lists must be in one continuous block, any points assigned after the first "Off" point are ignored. Changes to the DNP point lists will not take effect until the C90^Plus is restarted.

Select the **Settings > Communications > DNP > User Point List** menu item to open the DNP user point list configuration window.

Figure 57: DNP user point list configuration settings

The following settings are available for points 0 through 255.

DNP Binary Input Point 0
Range: any FlexLogic™ operand
Default: Off

This setting represents DNP binary input point 0 and is configured by assigning an appropriate FlexLogic™ operand. Up to 256 binary input points can be configured for the DNP protocol.

DNP Analog Input Point 0
Range: any FlexAnalog™ parameter
Default: Off

This setting represents DNP analog input point 0 and is configured by assigning an appropriate FlexAnalog™ parameter. Up to 256 analog input points can be configured for the DNP protocol.

IEC 60870-5-104 communications

The IEC 60870-5-104 server can support three clients simultaneously. It is capable of reporting any indication or measurement and operating any output present in the device. These point lists are shared with the DNP protocol.

IEC 60870-5-104 protocol settings

Select the **Settings > Communications > IEC 60870-5-104 > Protocol** menu item to open the IEC 60870-5-104 protocol configuration window.

Figure 58: IEC 60870-5-104 protocol configuration settings

The following settings are available for the IEC 60870-5-104 protocol.

IEC TCP Port Number
Range: 0 to 65535 in steps of 1
Default: 2404

This setting specifies the TCP port number to use for IEC 60870-5-104 communications.

IEC Client Address 1 through IEC Client Address 5
Range: standard IP address format
Default: 0.0.0.0

These settings specify the IP addresses for five IEC 60870-5-104 clients.

IEC Common Address of ASDU
Range: 0 to 65535 in steps of 1
Default: 0

This setting specifies the local address of the C90^{Plus} for IEC 60870-5-104 transactions. The address is common to all data in a single ASDU (Application Service Data Unit). The combination of ASDU common address and IOA (Information Object Address) uniquely identifies each data item in a system.

IEC Cyclic Data Period
Range: 1 to 65535 seconds in steps of 1
Default: 60 seconds

This setting specifies the period for cyclic data transmission.

IEC Current Default Threshold, IEC Voltage Default Threshold, IEC Power Default Threshold, IEC Energy Default Threshold, IEC Other Default Threshold

Range: 0 to 65535 in steps of 1

Default: 30000

These settings are used to determine when to trigger spontaneous responses containing M_ME_NC_1 analog data. These settings group the C90^Plus analog data into types: current, voltage, power, energy, and other. Each setting represents the default threshold value for all M_ME_NC_1 analog points of that type. For example, to trigger spontaneous responses from the C90^Plus when any current values change by 15 amps, the **IEC Current Default Threshold** setting should be set to "15". Note that these settings are the default values of the deadbands. P_ME_NC_1 (parameter of measured value, short floating point value) points can be used to change threshold values, from the default, for each individual M_ME_NC_1 analog point. Whenever power is removed and re-applied to the C90^Plus, the default thresholds will be in effect.

IEC 60870-5-104 point lists

The MSP and MME points for IEC 60870-5-104 protocol can configured to a maximum of 256 points. The value for each point is user-programmable and can be configured by assigning FlexLogic™ operands for binary MSP points or FlexAnalog™ parameters for analog MME points.

The IEC 60870-5-104 point lists always begin with point 0 and end at the first "Off" value. Since IEC 60870-5-104 point lists must be in one continuous block, any points assigned after the first "Off" point are ignored. Changes to the IEC 60870-5-104 point lists will not take effect until the C90^Plus is restarted.

Select the **Settings > Communications > IEC 60870-5-104 > User Point List** menu item to open the IEC 60870-5-104 user point list configuration window.

Figure 59: IEC 60870-5-104 user point list configuration settings

The following settings are available.

Binary Input Point 0 to Binary Input Point 255

Range: any FlexLogic™ operand
Default: Off

These settings represent the IEC 60870-5-104 binary MSP points and are configured by assigning an appropriate FlexLogic™ operand. Up to 256 MSP points can be configured for the IEC 60870-5-104 protocol.
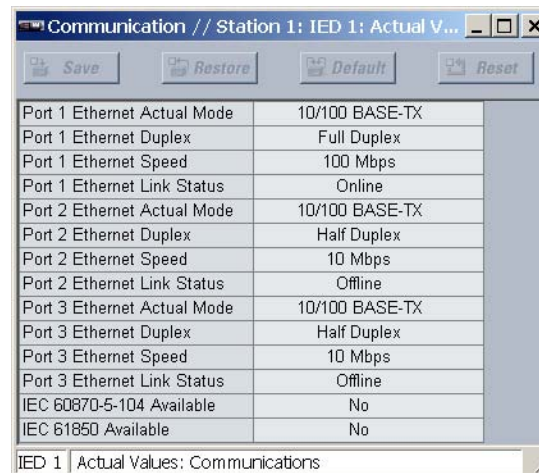
Analog Input Point 0 to Analog Input Point 255

Range: any FlexAnalog™ parameter
Default: Off

These settings represent the IEC 60870-5-104 analog MME points and are configured by assigning an appropriate FlexAnalog™ parameter. Up to 256 MME points can be configured for the IEC 60870-5-104 protocol.

IEC 60870-5-104 actual values

Select the **Actual Values > Communications > Communication** menu item to open the communications actual values window.

Figure 60: Communications actual values

There is one actual value related to the IEC 60870-5-104 communications feature.

IEC 60570-5-104 Available

Range: Yes, No

This actual value indicates whether the IEC 60870-5-104 communications feature is available.

IEC 61850 communications

The C90^{Plus} supports the Manufacturing Message Specification (MMS) protocol as specified by IEC 61850. MMS is supported over two protocol stacks: TCP/IP over Ethernet and TP4/CLNP (OSI) over Ethernet. Polling, unbuffered reporting, and buffered reporting are supported. Direct operate and select-before-operate are also supported.

GSSE/GOOSE configuration

IEC 61850 provides two fast mechanisms to exchange information between peers in a substation. One is used for transferring status information only, and is called Generic Substation Status Event (GSSE). The other includes support for a variety of in-formation types including measured values. It is called the Generic Object Oriented Substation Event (GOOSE) mechanism.

GOOSE or GSSE messages are multicast repeatedly across a substation LAN. All devices on the LAN can receive these messages, but only those devices that require the data are configured to act on them. Because there is no handshaking between devices, GOOSE and GSSE messages can transfer changes very rapidly, making them suitable for performing interlocking and other time-critical substation functions. The IEC 61850 server supports both GOOSE and GSSE protocols in publisher and subscriber roles. In dual-IP redundant configurations, the IED transmits and listens on both ports simultaneously. At the receiving end, the message is processed only if the StNum parameter is different than the previously received message.

NOTE

Since GSSE/GOOSE messages are multicast Ethernet by specification, they will not usually be forwarded by network routers. However, GOOSE messages may be forwarded by routers if the router has been configured for VLAN functionality.

General transmission configuration

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > General** menu item to open the GSSE/GOOSE general transmission configuration window.

Figure 61: General transmission configuration settings
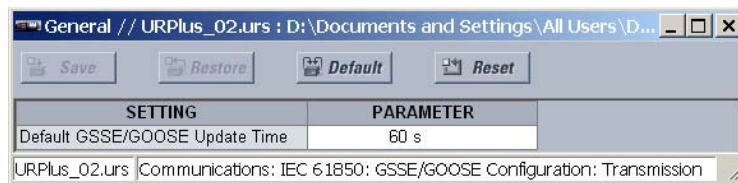
The following setting is available for GSSE/GOOSE general transmission configuration.

Default GSSE/GOOSE Update Time
Range: 1 to 60 seconds
Default: 1 second

This setting specifies the time between GSSE or GOOSE messages when there are no remote output state changes to be sent. When remote output data changes, GSSE or GOOSE messages are sent immediately. This setting controls the steady-state *heartbeat* time interval.

This setting is applicable to GSSE, fixed C90^Plus GOOSE, and configurable GOOSE.

GSSE transmission configuration

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > GSSE** menu item to open the GSSE transmission configuration window.

Figure 62: GSSE transmission configuration settings
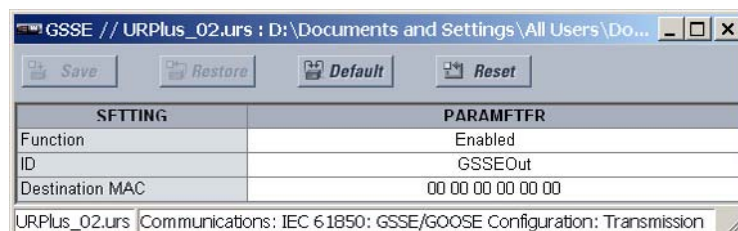
The following settings are available for GSSE transmission configuration.

Function

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the GSSE transmission functionality.

ID

Range: up to 65 ASCII characters
Default: GSSEOut

This setting represents the IEC 61850 GSSE application ID name string sent as part of each GSSE message. This name string identifies the GSSE message to the receiving device.

Destination MAC

Range: standard MAC address format
Default: 00 00 00 00 00 00

This setting specifies the destination Ethernet MAC address for the GSSE transmission. This address must be a multicast address and the least significant bit of the first byte must be set.

Fixed GOOSE transmission configuration

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > Fixed GOOSE** menu item to open the fixed GOOSE transmission configuration window.

Figure 63: Fixed GOOSE transmission configuration settings
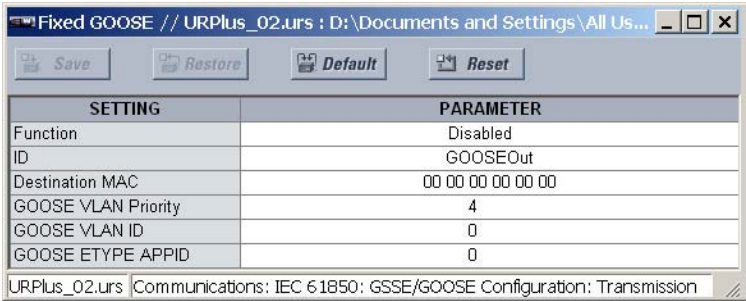
The following settings are available for fixed GOOSE transmission configuration.

Function

Range: Enabled, Disabled
Default: Enabled

This setting enables and disabled the fixed GOOSE transmission functionality.

ID

Range: up to 65 ASCII characters
Default: GOOSEOut

This setting represents the IEC 61850 GOOSE application ID (GoID) name string sent as part of each GOOSE message. This name string identifies the GOOSE message to the receiving device.

Destination MAC

Range: standard MAC address format
Default: 00 00 00 00 00 00

This setting specifies the destination Ethernet MAC address for the fixed GOOSE transmission. This address must be a multicast address and the least significant bit of the first byte must be set.

GOOSE VLAN Priority

Range: 0 to 7 in steps of 1

Default: 4

This setting indicates the Ethernet priority of GOOSE messages. This allows GOOSE messages to have higher priority than other Ethernet data. This setting is required by IEC 61850.

GOOSE VLAN ID

Range: 0 to 4096 in steps of 1

Default: 0

This setting allows the selection of a specific VLAN ID for each GOOSE sending device. This value can be left at its default if the feature is not required.

GOOSE ETYPE APPID

Range: 0 to 16383 in steps of 1

Default: 0

This setting allows the selection of a specific application ID for each GOOSE sending device. This value can be left at its default if the feature is not required. This setting is required by IEC 61850.

Configurable GOOSE transmission

The configurable GOOSE settings allow the C90^{Plus} to be configured to transmit a number of different datasets within IEC 61850 GOOSE messages. Up to eight (8) different configurable datasets can be configured and transmitted, allowing for the optimization of data transfer between devices. This is useful for intercommunication between C90^{Plus} IEDs and devices from other manufacturers that support IEC 61850.

Items programmed for dataset 1 will have changes in their status transmitted as soon as the change is detected. Dataset 1 should be used for high-speed transmission of data that is required for applications such as transfer tripping, blocking, and breaker fail initiation. At least one digital status value needs to be configured in dataset 1 to enable transmission of all data configured for dataset 1. Configuring analog data only to dataset 1 will not activate transmission.

Items programmed for datasets 2 through 8 will have changes in their status transmitted at a maximum rate of every 100 ms. Datasets 2 through 8 regularly analyze their configured data items every 100 ms to determine if any changes have been made. If changes to the data items are detected, they are transmitted through a GOOSE message. If no changes are detected during this 100 ms period, no GOOSE message is sent.

The integrity GOOSE message is sent at the pre-configured rate for all datasets, even if no changes in the data items are detected. This enhanced GOOSE functionality prevents the C90^{Plus} from flooding a communications network with GOOSE messages due to an oscillation that is triggering a message.

The C90^{Plus} can detect if a data item within a GOOSE dataset is erroneously oscillating. This oscillation be caused by events such as errors in logic programming, inputs improperly being asserted and de-asserted, or failed station components. If erroneous oscillation is detected, the C90^{Plus} will stop sending GOOSE messages from the dataset for a minimum period of one second. Should the oscillation persist after the one second time-out, the C90^{Plus} will continue to block transmission of the dataset.

The configurable GOOSE feature is recommended for applications that require GOOSE data transfer between UR^{Plus}-series IEDs and devices from other manufacturers. Fixed GOOSE is recommended for applications that require GOOSE data transfer between UR^{Plus}-series IEDs. IEC 61850 GOOSE messaging contains a number of configurable parameters, all of which must be correct for successful data transfer. It is critical that the configured datasets at the transmission and reception devices are an exact match in terms of data structure, and that the GOOSE addresses and name strings match exactly. Manual configuration is

possible, but third-party substation configuration software may be used to automate the process. The EnerVista UR^{Plus} Setup software can produce IEC 61850 ICD files and import IEC 61850 SCD files produced by a substation configurator.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > Tx Configurable GOOSE** menu item to open the configurable GOOSE transmission configuration window.

Figure 64: Configurable GOOSE transmission configuration settings
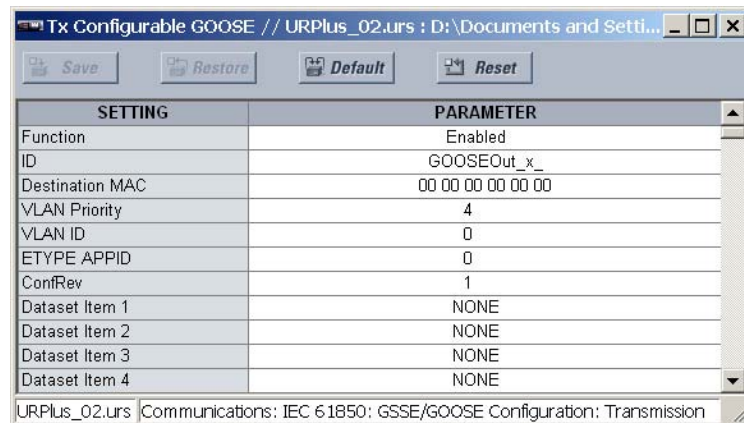
The following settings are available for each dataset for configurable GOOSE transmission.

Function

Range: Enabled, Disabled

Default: Enabled

This setting enables and disabled the configurable GOOSE transmission functionality.

ID

Range: up to 65 ASCII characters

Default: GOOSEOut

This setting represents the IEC 61850 GOOSE application ID (GoID) name string sent as part of each GOOSE message. This name string identifies the GOOSE message to the receiving device.

Destination MAC

Range: standard MAC address format

Default: 00 00 00 00 00 00

This setting specifies the destination Ethernet MAC address for the configurable GOOSE transmission. This address must be a multicast address and the least significant bit of the first byte must be set.

VLAN Priority

Range: 0 to 7 in steps of 1

Default: 4

This setting indicates the Ethernet priority of GOOSE messages. This allows GOOSE messages to have higher priority than other Ethernet data. This setting is required by IEC 61850.

VLAN ID

Range: 0 to 4096 in steps of 1

Default: 0

This setting allows the selection of a specific VLAN ID for each GOOSE sending device. This value can be left at its default if the feature is not required.

ETYPE APPID

Range: 0 to 16383 in steps of 1

Default: 0

This setting allows the selection of a specific application ID for each GOOSE sending device. This value can be left at its default if the feature is not required. This setting is required by IEC 61850.

ConfRev

Range: 0 to 16383 in steps of 1

Default: 0

This setting allows the selection of a specific application ID for each GOOSE sending device. This value can be left at its default if the feature is not required. This setting is required by IEC 61850.

Dataset Item 1, Dataset Item 2, Dataset Item 3,..., Dataset Item 64

Range: all valid MMS data item references for transmitted data

Default: 0

These settings are used to select an MMS data item for each configurable GOOSE dataset item.

To create a configurable GOOSE dataset that contains an IEC 61850 Single Point Status indication and its associated quality flags, the following dataset items can be selected: "GGIO1.ST.Ind1.stVal" and "GGIO1.ST.Ind1.q". The C90^{Plus} will then create a dataset containing these two data items. The status value for GGIO1.ST.Ind1.stVal is determined by the operand assigned to GGIO1 indication 1. Changes to this operand will result in the transmission of GOOSE messages containing the defined dataset.

Configurable GOOSE reception

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Reception > Rx Configurable GOOSE** menu item to open the configurable GOOSE reception configuration window.

Figure 65: Configurable GOOSE reception configuration settings

The following settings are available for each dataset for configurable GOOSE reception.

Dataset Item 1, Dataset Item 2, Dataset Item 3,..., Dataset Item 64

Range: all valid MMS data item references for transmitted data

Default: 0

These settings are used to select an MMS data item for each configurable GOOSE dataset item.

Remote devices

Remote inputs and outputs provide a means of exchanging digital state information between Ethernet-connected devices. The IEC 61850 GSSE (Generic Substation State Event) and GOOSE (Generic Object Oriented Substation Event) standards are used for this purpose.

The sharing of digital point state information between GSSE/GOOSE equipped relays is essentially an extension to FlexLogic™, allowing for distributed FlexLogic™ by making operands available to and from devices on a common communications network. In addition to digital point states, GSSE/GOOSE messages identify the originator of the message and provide other information required by the communication specification. All devices listen to network messages and capture data only from messages that have originated in selected devices.

IEC 61850 GSSE messages are compatible with UCA GOOSE messages and contain a fixed set of digital points. IEC 61850 GOOSE messages can, in general, contain any configurable data items. When used by the remote inputs and outputs feature, IEC 61850 GOOSE messages contain the same data as GSSE messages.

Both GSSE and GOOSE messages are designed to be short, reliable, and have high priority. GOOSE messages have additional advantages over GSSE messages due to their support of VLAN (virtual LAN) and Ethernet priority tagging functionality. The GSSE message structure contains space for 128 bit pairs representing digital point state information. The IEC 61850 specification provides 32 DNA bit pairs that represent the state of two pre-defined events and 30 user-defined events. All remaining bit pairs are UserSt bit pairs, which are status bits representing user-definable events. The C90^{Plus} implementation provides 32 of the 96 available UserSt bit pairs.

The IEC 61850 specification includes features that are used to cope with the loss of communication between transmitting and receiving devices. Each transmitting device will send a GSSE/GOOSE message upon a successful power-up, when the state of any included point changes, or after a specified interval (the default update time) if a change-of-state has not occurred. The transmitting device also sends a hold time which is set greater than three times the programmed default time required by the receiving device.
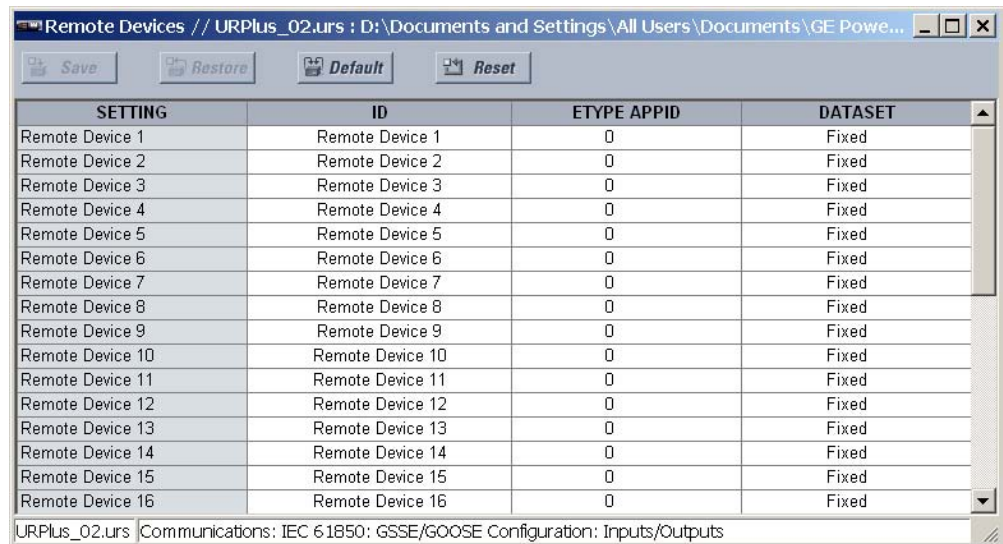
Receiving devices are constantly monitoring the communications network for messages they require, as recognized by the identification of the originating device carried in the message. Messages received from remote devices include the message time allowed to live. The receiving relay sets a timer assigned to the originating device to this time interval, and if it has not received another message from this device at time-out, the remote device is declared to be non-communicating, so it will use the programmed default state for all points from that specific remote device. If a message is received from a remote device before the time allowed to live expires, all points for that device are updated to the states contained in the message and the hold timer is restarted. The status of a remote device, where "Offline" indicates non-communicating, can be displayed.

The C90^{Plus} provides for 64 remote inputs and 64 remote outputs.

In a UR^{Plus}-series IED, the device ID that identifies the originator of the message is programmed in the **IED Name** setting.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote Devices** menu item to open the remote devices configuration window.

Figure 66: Remote devices configuration settings

The following settings are available for each of the 16 remote devices.

ID

Range: up to 20 alphanumeric characters
Default: Remote Device 1

Sixteen remote devices, numbered from 1 to 16, can be selected for setting purposes. A receiving relay must be programmed to capture messages from only those originating remote devices of interest. This setting is used to select specific remote devices by entering an exact identification (ID) assigned to those devices.

ETYPE APPID

Range: 0 to 16383 in steps of 1
Default: 0

This setting is only used with GOOSE messages; it is not applicable to GSSE messages. This setting identifies the Ethernet application identification in the GOOSE message. It should match the corresponding settings on the sending device.

DATASET

Range: Fixed, GOOSE 1 through GOOSE 8
Default: Fixed

This setting provides for the choice of the UR^{Plus}-series fixed (DNA/UserSt) dataset (that is, containing DNA and UserSt bit pairs), or one of the configurable datasets.

The dataset for the received data items must be made up of existing items in an existing logical node. For this reason, logical node GGIO3 is instantiated to hold the incoming data items. GGIO3 is not necessary to make use of the received data. The remote input data item mapping takes care of the mapping of the inputs to remote input FlexLogic™ operands. However, GGIO3 data can be read by IEC 61850 clients.

Remote inputs   Remote inputs create FlexLogic™ operands at the receiving relay and are extracted from GSSE/GOOSE messages originating in remote devices. The relay provides 32 remote inputs, each of which can be selected from a list consisting of 64 selections: DNA-1 through DNA-32 and UserSt-1 through UserSt-32. The function of DNA inputs is defined in the IEC 61850 specification and is presented in the table below. The function of UserSt inputs is defined by the user selection of the FlexLogic™ operand whose state is represented in the GSSE/GOOSE message. A user must program a DNA point from the appropriate FlexLogic™ operand.

Table 3: IEC 61850 DNA Assignments

DNA	IEC 61850 definition	FlexLogic™ operand
1	Test	IEC 61850 TEST MODE
2	ConfRev	IEC 61850 CONF REV

Remote input 1 must be programmed to replicate the logic state of a specific signal from a specific remote device for local use. This programming is performed via the three settings indicated below.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote Inputs** menu item to open the remote inputs configuration window.

Figure 67: Remote inputs configuration settings

The following settings are available for each of the 32 remote inputs.

Name

Range: up to 12 alphanumeric characters
Default: Rem Ip 1

This setting allows the user to assign descriptive text to the remote input.

Device

Range: 1 to 16 inclusive
Default: Remote Device 1

This setting selects the number (1 to 16) of the remote device which originates the required signal, as previously assigned to the remote device via the **Remote Device 1 ID** setting.

Bit Pair

Range: None, DNA-1 to DNA-32, UserSt-1 to UserSt-32, Config Item 1 to Config Item 64
Default: None

This setting selects the specific bits of the GSSE/GOOSE message required.

Default State

Range: On, Off, Latest/On, Latest/Off
Default: Off

This setting selects the logic state for this point if the local relay has just completed startup or the remote device sending the point is declared to be non-communicating. The following choices are available.

- The "On" value defaults the input to logic 1.
- The "Off" value defaults the input to logic 0.

– The "Latest/On" value freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to logic 1. When communication resumes, the input becomes fully operational.

– The "Latest/Off" value freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to logic 0. When communication resumes, the input becomes fully operational.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enabled and disables the logging of remote input events in the sequence of events recorder.

Remote outputs: DNA bit pairs

Remote outputs (1 to 32) are FlexLogic™ operands inserted into GSSE/GOOSE messages that are transmitted to remote devices on a LAN. Each digital point in the message must be programmed to carry the state of a specific FlexLogic™ operand. The above operand setting represents a specific DNA function (as shown in the following table) to be transmitted.

Table 4: IEC 61850 DNA Assignments

DNA	IEC 61850 definition	FlexLogic™ operand
1	Test	IEC 61850 TEST MODE
2	ConfRev	IEC 61850 CONF REV

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote Outputs DNA** menu item to open the remote inputs configuration window.

Figure 68: Remote outputs DNA bit pair configuration settings
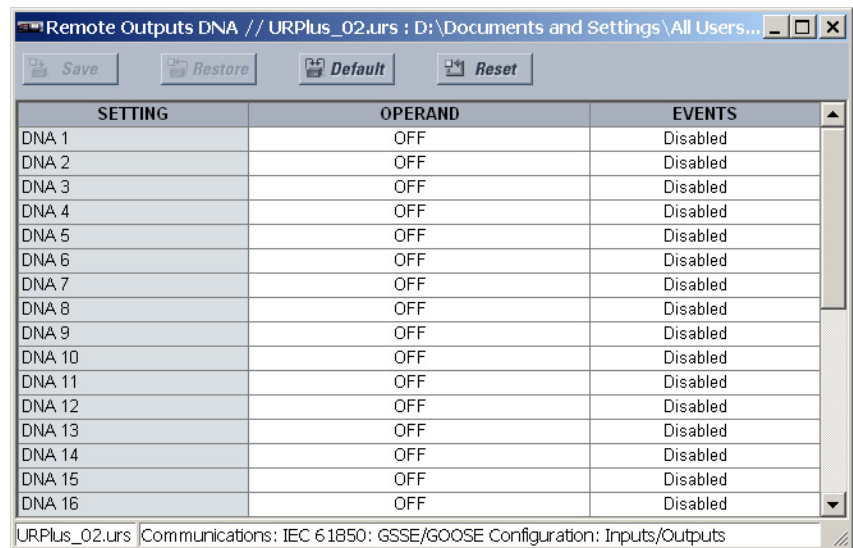
The following settings are available for each of the 32 remote outputs.

Operand

Range: any automation logic or FlexLogic™ operand
Default: Off

This setting specifies the FlexLogic™ operand assigned to DNA point 1.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of remote output DNA bit pair events in the sequence of events recorder.

Remote outputs: UserSt bit pairs

Remote outputs 1 to 32 originate as GSSE/GOOSE messages to be transmitted to remote devices. Each digital point in the message must be programmed to carry the state of a specific FlexLogic™ operand. The setting above is used to select the operand which represents a specific UserSt function (as selected by the user) to be transmitted.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote Outputs UserSt** menu item to open the remote inputs configuration window.

Figure 69: Remote output UserSt bit pair configuration settings

The following settings are available for each of the 32 bit pairs.

Operand

Range: any FlexLogic™ operand
Default: Off

This setting specifies the FlexLogic™ operand assigned to UserSt point 1.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of remote output UserSt bit pair events in the sequence of events recorder.

IEC 61850 server configuration

Select the **Settings > Communications > IEC 61850 > Server Configuration** menu item to open the IEC 61850 server configuration window.

Figure 70: IEC 61850 server configuration settings
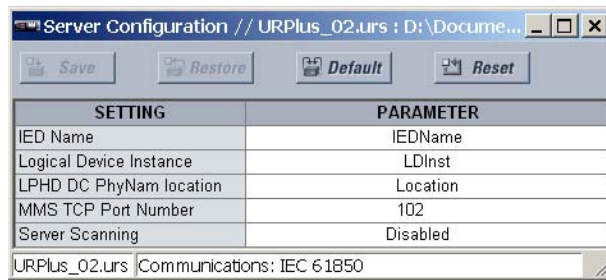
The following settings are available.

IED Name

Range: up to 32 alphanumeric characters

Default: IEDName

This setting represents the MMS domain name where all IEC/MMS logical nodes are located. Changes to this setting and the GOOSE dataset will not take effect until the unit is restarted. The setting value can be composed of up to 32 characters, including upper and lowercase letters, numbers, and the underscore (_) character. The first character in the string must be a letter.

Logical Device Instance

Range: up to 32 alphanumeric characters

Default: LDInst

This setting represents the IEC 61850 logical device where all IEC/MMS logical nodes are located. The setting value can be composed of up to 32 characters, including upper and lowercase letters, numbers, and the underscore (_) character. The first character in the string must be a letter.

LPHD DC PhyNam Location

Range: up to 80 ASCII characters

Default: Location

This setting represents a string that appears within the PhyName of the LPHD node. It can be composed of up to 80 characters, including upper and lowercase letters, numbers, and the underscore (_) character. The first character in the string must be a letter.

MMS TCP Port Number

Range: 1 to 65535 in steps of 1

Default: 102

This setting specifies the TCP port number for MMS connections.

Server Scanning

Range: Disabled, Enabled

Default: Disabled

This setting should be "Disabled" when IEC 61850 client/server functionality is not required. IEC 61850 has two modes of functionality: GOOSE/GSSE inter-device communication and client/server communication. If the GOOSE/GSSE functionality is required without the IEC 61850 client server feature, then server scanning can be disabled to increase CPU resources. When server scanning is disabled, there will be not updated to the IEC 61850 logical node status values in the C90^{Plus}. Clients will still be able to connect to the server (C90^{Plus} device), but most data values will not be updated. This setting does not affect GOOSE/GSSE operation.

Logical node prefixes

The IEC 61850 logical node name prefix settings are used to create name prefixes to uniquely identify each logical node. For example, the logical node "PTOC1" may have the name prefix "abc". The full logical node name will then be "abcMMXU1". Valid characters for the logical node name prefixes are upper and lowercase letters, numbers, and the underscore (_) character, and the first character in the prefix must be a letter. This conforms to the IEC 61850 standard.

Additional details regarding the logical node naming rules are provided in IEC 61850 parts 6 and 7-2. It is recommended that a consistent naming convention be used for an entire substation project.

Select the **Settings > Communications > IEC 61850 > Logical Node Prefixes** menu item to open the IEC 61850 logical node prefixes configuration window.

Figure 71: IEC 61850 logical node prefix configuration settings
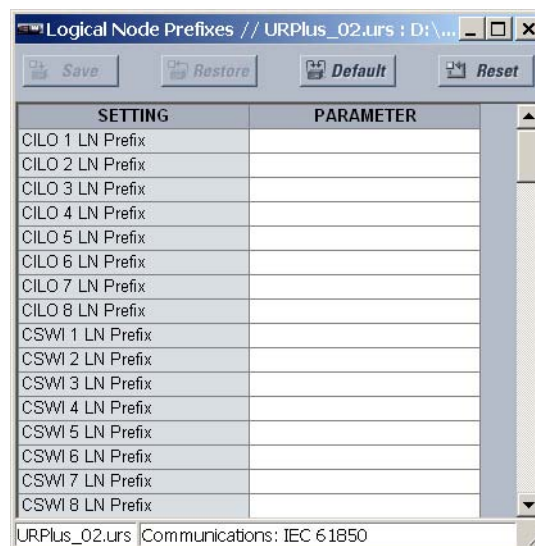
The following IEC 61850 logical node name prefix settings are available.

CILO1 LN Prefix through CILO8 LN Prefix

Range: six character ASCII string
Default: empty

These settings specify the prefixes for the interlocking logical nodes 1 through 8.

CSWI1 LN Prefix through CSWI8 LN Prefix

Range: six character ASCII string
Default: empty

These settings specify the prefixes for the switch controller logical nodes 1 through 8.

GGIO1 LN Prefix through GGIO4 LN Prefix

Range: six character ASCII string
Default: empty

These settings specify the prefixes for generic input and output logical nodes 1 through 4.

LPHD1 LN Prefix

Range: six character ASCII string
Default: empty

These settings specify the prefixes for the physical device information logical nodes.

MMXU1 LN Prefix through MMXU3 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for measured quantity logical nodes 1 through 3.

PFRC1 LN Prefix through PFRC4 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for the frequency rate of change logical nodes 1 through 4.

PIOC1 LN Prefix through PIOC14 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for instantaneous overcurrent logical nodes 1 through 14.

PTOC1 LN Prefix through PTOC18 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for time overcurrent logical nodes 1 through 18.

PTOV1 LN Prefix through PTOV8 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for overvoltage logical nodes 1 through 8.

PTRC1 LN Prefix, PTRC2 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for the protection trip conditioning 1 and 2 logical nodes.

PTUV1 LN Prefix through PTUV10 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for undervoltage logical nodes 1 through 10.

PTUF1 LN Prefix through PTUF10 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for underfrequency logical nodes 1 through 9.

RBRF1 LN Prefix, RBRF2 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for breaker failure logical nodes 1 and 2.

RDIR1 LN Prefix, RDIR2 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for the directional element logical nodes 1 and 2.

RFLO1 LN Prefix

Range: six character ASCII string

Default: empty

This setting specifies the prefix for the fault locator logical node.

RREC1 LN Prefix

Range: six character ASCII string

Default: empty

This setting specifies the prefix for the autoreclose logical node.

RSYN1 LN Prefix, RSYN2 LN Prefix

Range: six character ASCII string

Default: empty

This setting specifies the prefix for the synchrocheck logical nodes 1 and 2.

XCBR1 LN Prefix, XCBR2 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for the circuit breaker 1 and 2 logical nodes.

XSWI1 LN Prefix through XSWI6 LN Prefix

Range: six character ASCII string

Default: empty
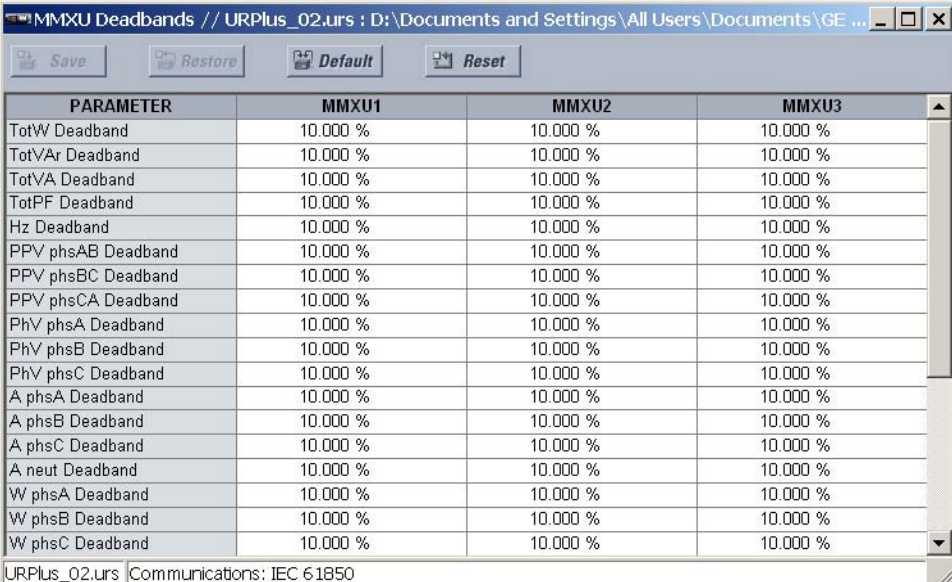
These settings specify the prefixes for the circuit disconnect switch 1 through 6 logical nodes.

MMXU deadbands

The MMXU deadband settings represent the deadband values used to determine when the update the MMXU "mag" and "cVal" values from the associated "instmag" and "instcVal" values. The "mag" and "cVal" values are used for the IEC 61850 buffered and unbuffered reports. These settings correspond to the associated "db" data items in the CF functional constraint of the MMXU logical node, as per the IEC 61850 standard. According to IEC 61850-7-3, the db value "shall represent the percentage of difference between the maximum and minimum in units of 0.00%". Thus, it is important to know the maximum value for each MMXU measured quantity, since this represents the 100.00% value for the deadband.

Select the **Settings > Communications > IEC 61850 > MMXU Deadbands** menu item to open the MMXU deadbands configuration window.

Figure 72: IEC 61850 MMXU deadband configuration settings

The following settings are available for each of the four MMXU nodes.

Total Watt Deadband

Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

This setting specifies the real power deadband value. The maximum value representing 100% of deadband is 46 × phase CT primary × 275 × VT ratio.

Total Var Deadband

Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

This setting specifies the reactive power deadband value. The maximum value representing 100% of deadband is 46 × phase CT primary × 275 × VT ratio.

Total VA Deadband

Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

This setting specifies the apparent power deadband value. The 100% deadband value is 46 × phase CT primary × 275 × VT ratio.

Total Power Factor Deadband

Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

This setting specifies the power factor deadband value. The 100% deadband value is 2.

PPV Phase AB Deadband, PPV Phase BC Deadband, PPV Phase CA Deadband

Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

These settings specify the Vab, Vbc, and Vca per-phase voltage deadband values. The 100% deadband value is 275 × VT ratio.

PhV Phase A Deadband, PhV Phase B Deadband, PhV Phase C Deadband

Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

These settings specify the Va, Vb, and Vc phase voltage deadband values. The 100% deadband value is 275 × VT ratio.

Current Phase A Deadband, Current Phase B Deadband, Current Phase C Deadband

Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

These settings specify the Ia, Ib, and Ic phase current deadband values. The 100% deadband value is 46 × phase CT primary.

Current Neutral Deadband

Range: 0.001 to 100.00% in steps of 0.001
Default: 10.000%

This setting specifies the neutral current deadband value. The 100% deadband value is 46 × ground CT primary.

Watt Phase A Deadband, Watt Phase B Deadband, Watt Phase C Deadband

Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

These settings specify the real per-phase power deadband values. The maximum value representing 100% of deadband is 46 × phase CT primary × 275 × VT ratio.

Var Phase A Deadband, Var Phase B Deadband, Var Phase C Deadband
Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

These settings specify the reactive per-phase power deadband values. The maximum value representing 100% of deadband is 46 × phase CT primary × 275 × VT ratio.

VA Phase A Deadband, VA Phase B Deadband, VA Phase C Deadband
Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

These settings specify the apparent per-phase power deadband values. The maximum value representing 100% of deadband is 46 × phase CT primary × 275 × VT ratio.

Power Factor Phase A Deadband, Power Factor Phase B Deadband, Power Factor Phase C Deadband
Range: 0.001 to 100.000% in steps of 0.001
Default: 10.000%

These settings specify the per-phase power factor deadband values. The maximum value representing 100% of deadband is 2.

GGIO1 status configuration

The GGIO1 logical node provides access to as many 128 digital status points and associated timestamps and quality flags. It is intended that clients use GGIO1 in order to access digital status values from the C90^Plus. Configuration settings are provided to allow the selection of the number of digital status indications available in GGIO1 (8 to 128) and to select logic operands to drive the status of the GGIO1 status indications. Clients can utilize the IEC 61850 buffered and unbuffered reporting features available from GGIO1 to build sequence of events (SOE) logs and HMI display screens. Buffered reporting should generally be used for SOE logs since the buffering capability reduces the chances of missing data state changes. Unbuffered reporting should generally be used for local status display.

Select the **Settings > Communications > IEC 61850 > GGIO1 Status Configuration** menu item to open the GGIO1 status configuration window.

Figure 73: IEC 61850 GGIO1 status configuration
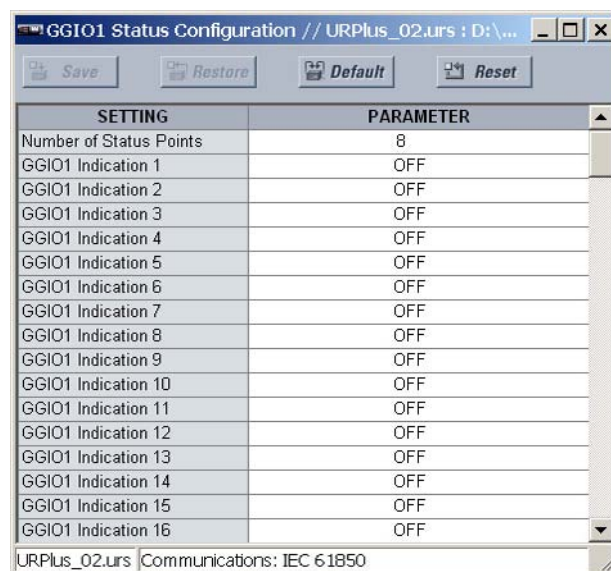
The following settings are available.

Number of Status Points

Range: 8 to 128 in steps of 8

Default: 8

This setting specifies the number of "Ind" points (single point status indications) that are instantiated in the GGIO1 logical node. Changes to this setting will not take effect until the C90^{Plus} is restarted.

GGIO1 Indication 1, GGIO1 Indication 2,..., GGIO1 Indication 128

Range: any logic operand

Default: OFF

These settings assign operands to represent GGIO1 status indications.

GGIO2 control configuration

The GGIO2 logical node is available to provide access to the C90^{Plus} virtual inputs. Virtual inputs are single-point control (binary) values that can be written by clients. They are generally used as control inputs. GGIO2 provides access to virtual inputs through the IEC 61850 standard control model (ctlModel) services:

• Status only

• Direct control with normal security

• SBO control with normal security

Configuration settings are available to select the control model for each point. Each virtual input used through GGIO2 should be enabled and the corresponding SPSCO ctlModel setting programmed to the appropriate control configuration.

Select the **Settings > Communications > IEC 61850 > GGIO2 Control Configuration** menu item to open the GGIO2 control configuration window.

Figure 74: IEC 61850 GGIO2 control configuration
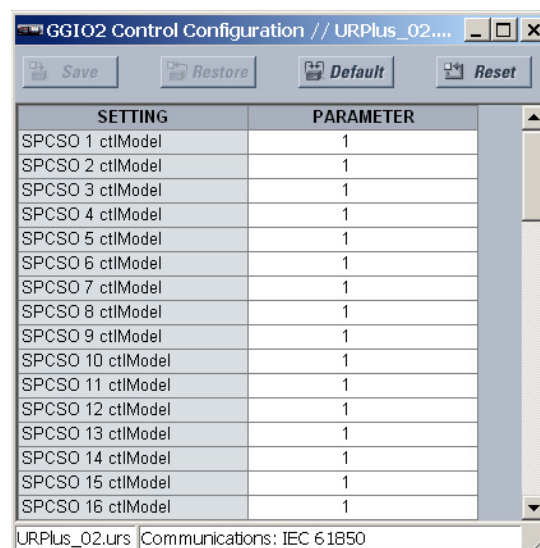
The following setting is available for each of the 64 GGIO2 control points. Each control point is mapped to a corresponding C90^{Plus} virtual input. For example, GGIO2 control point SPCSO 3 is mapped to virtual input 3.

SPCSO 1 ctlModel

Range: 0, 1, 2

Default: 1

The GGIO2 control configuration settings are used to set the control model for each input. The available choices are "0" (status only), "1" (direct control), and "2" (SBO with normal security).

GGIO4 analog configuration

The GGIO4 logical node provides access to as many as 32 analog value points, as well as associated timestamps and quality flags. The data content must be configured before the data can be used. GGIO4 provides analog values for access by clients.

It is intended that clients use GGIO4 to access generic analog values from the C90^{Plus}. Configuration settings allow the selection of the number of analog values available in GGIO4 (4 to 32) and the choice of the FlexAnalog™ values that determine the value of the GGIO4 analog inputs. Clients can utilize polling or the IEC 61850 unbuffered reporting feature available from GGIO4 in order to obtain the analog values provided by GGIO4.

Select the **Settings > Communications > IEC 61850 > GGIO4 Analog Configuration** menu item to open the GGIO4 analog configuration window.

Figure 75: IEC 61850 GGIO4 analog configuration
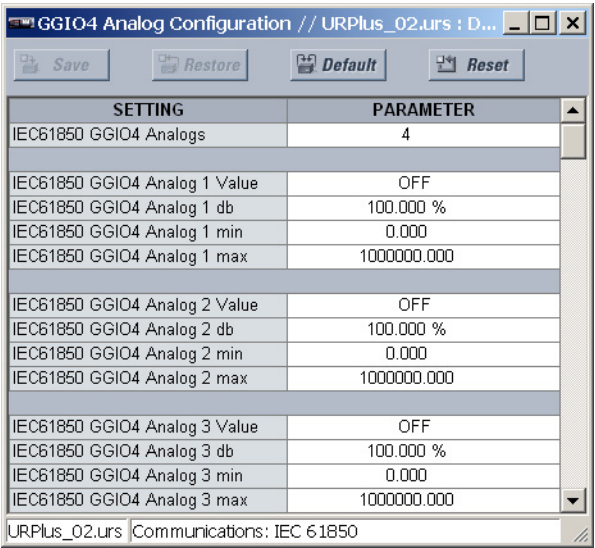
The following settings are available.

IEC 61850 GGIO4 Analogs

Range: 4 to 32 in steps of 4

Default: 4

This setting specifies how many analog data points will exist in GGIO4. When this value is changed, the C90^{Plus} must be rebooted to allow the GGIO4 logical node to be re-instantiated and contain the newly configured number of analog points.

IEC 61850 GGIO4 Analog 1 Value

Range: any FlexAnalog™ value

Default: OFF

These settings select the FlexAnalog™ value to drive the instantaneous value of each GGIO4 analog status value (GGIO4.MX.AnIn1.instMag.f).

IEC 61850 GGIO4 Analog 1 Deadband

Range: 0.000 to 100.000 in steps of 0.001

Default: 0.000

These settings specify the deadband for each analog value. Refer to IEC 61850-7-1 and IEC 61850- 7-3 for additional details. The deadband is used to determine when to update the deadbanded magnitude from the instantaneous magnitude and is represented as a percentage of the difference between the maximum and minimum values.

IEC 61850 GGIO4 Analog 1 Minimum

Range: –1000000000.000 to 1000000000.000 in steps of 0.001

Default: 0.000

These settings specify the minimum value for each analog value. Refer to IEC 61850-7-1 and IEC 61850-7-3 for additional details. This minimum value is used to determine the deadband. The deadband is used in the determination of the deadbanded magnitude from the instantaneous magnitude.

These settings are stored as IEEE 754 / IEC 60559 floating point numbers. Because of the large range of these settings, not all values can be stored. Some values may be rounded to the closest possible floating point number.

IEC 61850 GGIO4 Analog 1 Maximum

Range: –1000000000.000 to 1000000000.000 in steps of 0.001

Default: 0.000

These settings specify the maximum value for each analog value. Refer to IEC 61850-7-1 and IEC 61850-7-3 for additional details. This maximum value is used to determine the deadband. The deadband is used in the determination of the deadbanded magnitude from the instantaneous magnitude.

These settings are stored as IEEE 754 / IEC 60559 floating point numbers. Because of the large range of these settings, not all values can be stored. Some values may be rounded to the closest possible floating point number.

Report control configuration

IEC 61850 buffered and unbuffered reporting is provided in the GGIO1 logical nodes (for binary status values) and MMXU1 to MMXU3 (for analog measured values). Report settings can be configured using the EnerVista UR^{Plus} Setup software, substation configurator software, or via an IEC 61850 client.

Select the **Settings > Communications > IEC 61850 > Report Control Configuration** menu item to open the IEC 61850 report configuration window.

Figure 76: IEC 61850 report control configuration
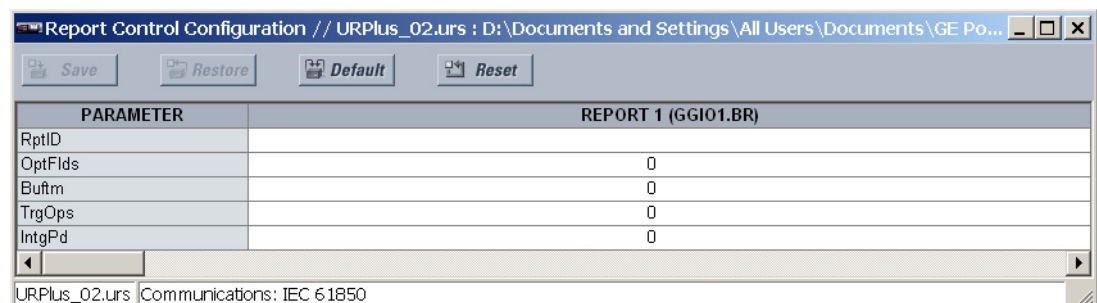
The following settings are available for each report. Up to 10 reports can be configured. Changes to the report configuration will not take effect until the C90^{Plus} is restarted.

RptID

Range: up to 66 alphanumeric characters

Default: empty

This setting specifies the name fo the IEC 61850 report.

OptFlds

Range: 0 to 65535 in steps of 1

Default: 0

This setting specifies a bitmask that selects the option fields. The following bits are supported by the C90^{Plus}.

–   Bit 1: sequence-number.

–   Bit 2: report-time-stamp.

–   Bit 3: reason-for-inclusion.

–   Bit 4: data-set-name.

–   Bit 5: data-reference.

–   Bit 6: buffer-overflow (for buffered reports only).

–   Bit 7: entryID (for buffered reports only).

–   Bit 8: conf-revision.

–   Bit 9: segmentation.

BufTm

Range: 0 to 4294967295 in steps of 1

Default: 0

This setting specifies the buffer time.

TrgOps

Range: 0 to 65535 in steps of 1

Default: 0

This setting specifies a bitmask that selects the trigger options. The following bits are supported by the D60.

–   Bit 1: data-change.

–   Bit 4: integrity.

–   Bit 5: general interrogation.

IntgPd

Range: 0 to 4294967295 in steps of 1

Default: 0

This setting specifies the integrity period.
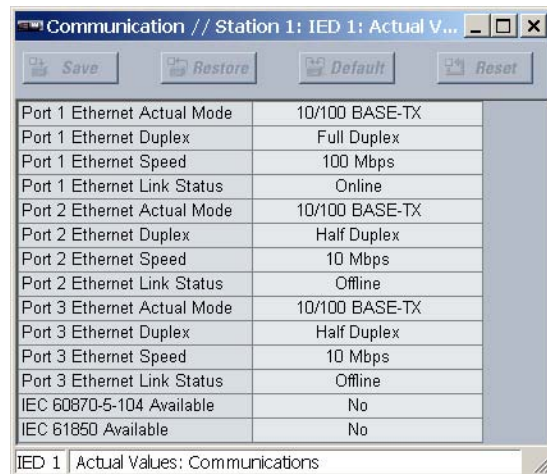
NOTE

Please disconnect any IEC 61850 client connection to the C90^{Plus} prior to making setting changes to the report configuration. Disconnecting the rear Ethernet connection from the C90^{Plus} will disconnect the IEC 61850 client connection.

IEC 61850 actual values

Select the **Actual Values > Communications > Communication** menu item to open the communications actual values window.

Figure 77: Communications actual values

The following actual value is related to the IEC 61850 communications feature.

IEC 61850 Available

Range: Yes, No

This actual value indicates whether the IEC 61850 communications feature is available.

FlexStates

The FlexStates feature provides a mechanism where any of 256 selected FlexLogic™ operand states can be used for efficient monitoring. The feature allows user-customized access to the FlexLogic™ operand states in the relay. The state bits are packed so that sixteen (16) states may be read out in a single Modbus register. The state bits can be configured so that all of the states which are of interest to the user are available in a minimum number of Modbus registers.

The state bits may be read out in the FlexStates register array beginning at Modbus address 0900h. Sixteen states are packed into each register, with the lowest-numbered state in the lowest-order bit. There are sixteen registers in total to accommodate the 256 state bits.

FlexState settings

Select the **Settings > Communications > Flex States** menu item to open the FlexStates configuration window.

Figure 78: Flex States configuration settings
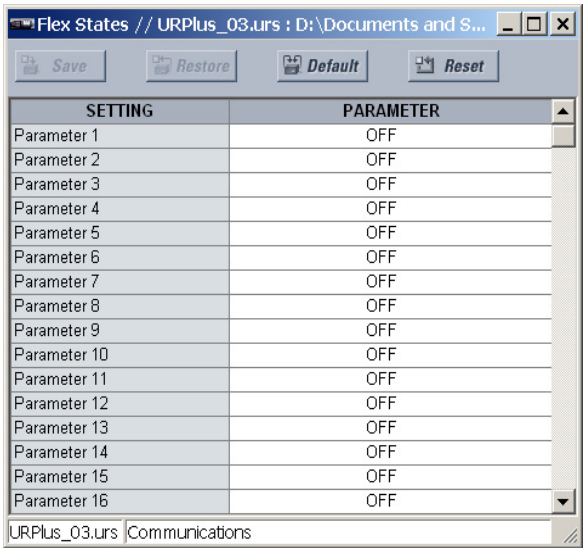
The following settings are available.

Parameter 1 through Parameter 256
Range: any FlexLogic™ operand
Default: Off

These settings assign FlexLogic™ parameters to each of the 256 FlexStates. The FlexState register array begins at Modbus address 0900h.

FlexState actual values

Select the **Actual Values > Communications > FlexStates** menu item to open the FlexStates actual values window.

Figure 79: FlexStates actual values
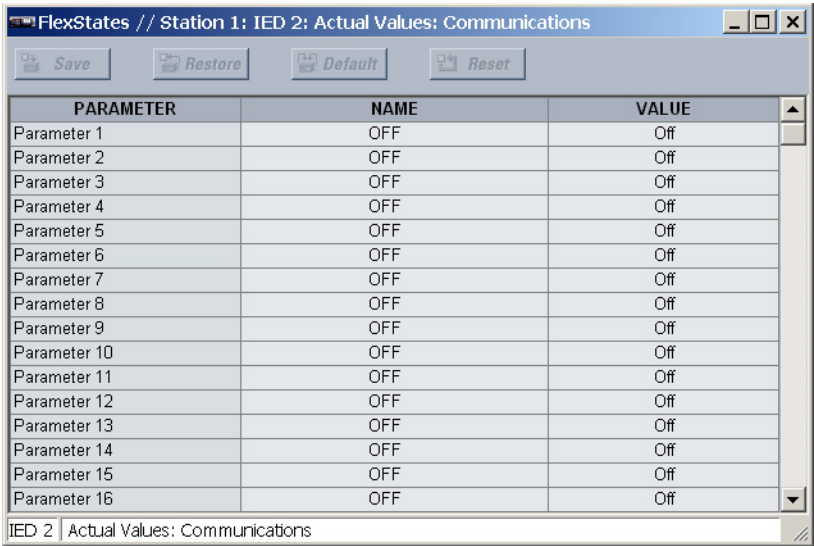
The following actual values are available for each FlexState parameter.

Name

Range: any FlexLogic™ operand

This actual value indicates the FlexLogic™ operand assigned to the FlexState parameter

Value

Range: OFF, ON

This actual value indicates the logic state (ON, OFF) of the FlexState parameter.

Real time clock

The date and time can be synchronized a known time base and to other relays using an IRIG-B signal. It has the same accuracy as an electronic watch, approximately ±1 minute per month. If an IEEE 1344 compliant IRIG-B generator is connected to the C90^Plus, then no additional information is required. Otherwise, only the current year needs to be entered. Use the Set Date and Time command to manually set the relay clock.

The daylight savings time (DST) settings can be used to allow the C90^Plus clock can follow the DST rules of the local time zone. Note that when IRIG-B time synchronization is active, the DST settings are ignored. The DST settings are used when the C90^Plus is synchronized with SNTP, or when neither SNTP nor IRIG-B is used.

Select the **Settings > Communications > Real Time Clock** menu item to open the real time clock configuration window.

Figure 80: Real time clock configuration settings

The following settings are available to configure the real time clock.

IRIG-B Signal Type

Range: None, DC Shift, Amplitude Modulated
Default: None

This setting selects the type of IRIG-B signal. Select "None" to disable IRIG-B.

Real Time Clock Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of real time clock events in the sequence of events recorder.

Time Zone Offset

Range: –24.0 to 24.0 hours in steps of 0.5

Default: 0.0 hours

This setting specifies the local time zone offset from Universal Coordinated Time (Greenwich Mean Time) in hours. This setting has two uses. When the C90^{Plus} is time synchronized with IRIG-B, or has no permanent time synchronization, the offset is used to calculate UTC time for IEC 61850 features. When the C90^{Plus} is time synchronized with SNTP, the offset is used to determine the local time for the C90^{Plus} clock, since SNTP provides UTC time.

DST Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the daylight saving time function.

DST Start Month

Range: January through December (all months of the year)

Default: April

This setting specifies the start month for daylight saving time.

DST Start Day

Range: Sunday through Saturday (all days of the week)

Default: Sunday

This setting specifies the day of the week to start daylight saving time.

DST Start Day Instance

Range: First, Second, Third, Fourth, Last

Default: First

This setting specifies the which instance of the day of the week to start daylight saving time. For example, if daylight saving time begins on the second Monday in April, program this setting to "Second".

DST Start Hour

Range: 0 to 23 in steps of 1

Default: 2

This setting specifies the hour to start daylight saving time. For example, if daylight saving time begins at 2:00 AM, program this setting to "2".

DST Stop Month

Range: January through December (all months of the year)

Default: November

This setting specifies the stop month for daylight saving time.

DST Stop Day

Range: Sunday through Saturday (all days of the week)

Default: Sunday

This setting specifies the day of the week to stop daylight saving time.

DST Stop Day Instance

Range: First, Second, Third, Fourth, Last

Default: First

This setting specifies the which instance of the day of the week to start daylight saving time. For example, if daylight saving time ends on the fourth Monday in November, program this setting to "Fourth".

DST Stop Hour

Range: 0 to 23 in steps of 1

Default: 2

This setting specifies the hour at which daylight saving time ends. For example, if daylight saving time ends at 4:00 AM, program this setting to "4".

User-programmable self-tests

All major self-test alarms are reported automatically with their corresponding events and FlexLogic™ operands. If desired, most of the minor alarms can be disabled.

Select the **Settings > Communications > User-Programmable Self-Tests** menu item to open the user-programmable self-test configuration window.

Figure 81: User-programmable self-test configuration settings
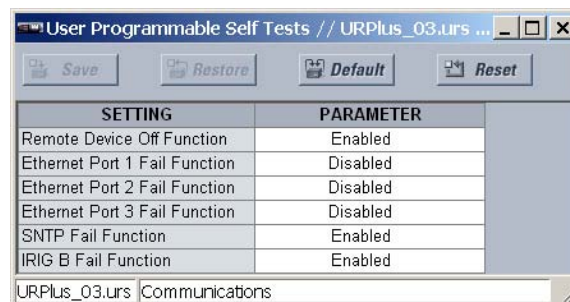
The following settings are available to configure the real time clock.

Ethernet Port 1 Fail Function

Range: Enabled, Disabled

Default: Enabled

When this setting is "Disabled", the ETHERNET PORT 1 FAILURE alarm will not assert a FlexLogic™ operand or write to the event recorder. Moreover, it will not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is "Enabled", the ETHERNET PORT 1 FAILURE alarm continues to function along with other major and minor alarms. Refer to the *Relay self-tests* section in for additional information on major and minor self-test alarms.

Ethernet Port 2 Fail Function

Range: Enabled, Disabled

Default: Disabled

When this setting is "Disabled", the ETHERNET PORT 2 FAILURE alarm will not assert a FlexLogic™ operand or write to the event recorder. Moreover, it will not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is "Enabled", the ETHERNET PORT 2 FAILURE alarm continues to function along with other major and minor alarms. Refer to the *Relay self-tests* section in for additional information on major and minor self-test alarms.

Ethernet Port 3 Fail Function

Range: Enabled, Disabled

Default: Disabled

When this setting is "Disabled", the ETHERNET PORT 3 FAILURE alarm will not assert a FlexLogic™ operand or write to the event recorder. Moreover, it will not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is "Enabled", the

ETHERNET PORT 3 FAILURE alarm continues to function along with other major and minor alarms. Refer to the *Relay self-tests* section in for additional information on major and minor self-test alarms.

SNTP Fail Function

Range: Enabled, Disabled

Default: Enabled

When this setting is "Disabled", the SNTP FAILURE alarm will not assert a FlexLogic™ operand or write to the event recorder. Moreover, it will not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is "Enabled", the SNTP FAILURE alarm continues to function along with other major and minor alarms. Refer to the *Relay self-tests* section in for additional information on major and minor self-test alarms.

IRIG-B Fail Function

Range: Enabled, Disabled

Default: Enabled

When this setting is "Disabled", the IRIG-B FAILURE alarm will not assert a FlexLogic™ operand or write to the event recorder. Moreover, it will not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is "Enabled", the IRIG-B FAILURE alarm continues to function along with other major and minor alarms. Refer to the *Relay self-tests* section in for additional information on major and minor self-test alarms.

Serial port

The C90^Plus is equipped with one serial RS485 communication port. The RS485 port has settings for baud rate and parity. It is important that these parameters agree with the settings used on the computer or other equipment that is connected to these ports. This ports may be connected to a computer running the EnerVista UR^Plus Setup software. This software can download and upload setting files, view measured parameters, and upgrade the device firmware. A maximum of 32 C90^Plus-series devices can be daisy-chained and connected to a DCS, PLC, or PC using the RS485 port.

Select the **Settings > Communications > Network > Serial Ports** menu item to open the serial port configuration window.

Figure 82: Serial port configuration settings

The following settings are available to configure the RS485 port.

Baud Rate

Range: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200

Default: 19200

This setting specifies the baud rate (bits per second) for the RS485 port.

Parity

Range: None, Odd, Even

Default: None

This setting specifies the parity for the RS485 port.

Minimum Response Time

Range: 0 to 1000 ms in steps of 10

Default: 0 ms

The minimum time before the port will transmit after receiving data from a host can be set. This allows operation with hosts which hold the RS485 transmitter active for some time after each transmission.

C90^{Plus} Controller

Chapter 6: Protection

This section describes how to program the C90^{Plus} protection features.

Protection overview

The C90^{Plus} Controller is an advanced logic controller specifically designed for use in substation environments and for the unique automation requirements of industrial and utility power systems. The C90^{Plus} provides powerful logic processing with deterministic execution of logic equations regardless of the amount of configured logic.

The C90^{Plus} provides the tools and functionality necessary for creating customized automation and control schemes that include complete bay control, breaker monitoring and control, auto-restoration schemes, automatic bus transfer schemes, and load shedding schemes.

In addition, overcurrent and undervoltage protection, fault diagnostics, power metering, and RTU functions are provided. The C90^{Plus} provides phase, neutral, and ground time overcurrent protection. The time overcurrent functions can be programmed with multiple curve shapes or FlexCurves™ for optimum coordination.

Introduction to protection elements

In the design of the UR^{Plus}-series protection system, the term *element* is used to describe a feature based around a comparator. The comparator is provided with an input (or set of inputs) that is tested against a programmed setting (or group of settings) to determine if the input is within the defined range that will set the output to logic 1, also referred to as *setting the flag*. A single comparator may make multiple tests and provide multiple outputs. For example, the time overcurrent comparator sets a pickup flag when the current input is above the setting and sets an operate flag when the input current has been at a level above the pickup setting for the time specified by the time-current curve settings. All comparators (except the digital element, which uses a logic state as the input) use analog parameter actual values as the input.

Protection elements are arranged into two classes, *grouped* and *control*. Each element classed as a grouped element is provided with six alternate sets of settings, in setting groups numbered 1 through 6. The performance of a grouped element is defined by the setting group that is active at a given time. The performance of a control element is independent of the selected active setting group.

The main characteristics of an element are shown on the element logic diagram. This includes the inputs, settings, fixed logic, and the output operands generated.

Some settings for current and voltage elements are specified in per-unit (pu) calculated quantities. Per-unit quantities are calculated as follows.

$$pu\,quantity = \frac{actual\,quantity}{base\,quantity}$$

<div align="right">**Eq. 1**</div>

For current elements, the base quantity is the nominal secondary or primary current of the CT. Where the current source is the sum of two CTs with different ratios, the base quantity will be the common secondary or primary current to which the sum is scaled (that is, normalized to the larger of the two rated CT inputs). For example, if CT1 is 300 / 5 A and CT2 is 100 / 5 A, then CT2 is scaled to the CT1 ratio for summation. In this case, the base quantity is 5 A secondary or 300 A primary.

For voltage elements the base quantity is the nominal primary voltage of the protected system which corresponds (based on VT ratio and connection) to secondary VT voltage applied to the device. For example, on a system with a 13.8 kV nominal primary voltage and with 14400:120 V delta-connected VTs, the secondary nominal voltage (1 pu) is:

$$\frac{13800\,V}{14400\,V} \times 120\,V = 115\,V$$

<div align="right">**Eq. 2**</div>

For wye-connected VTs, the secondary nominal voltage (1 pu) is:

$$\frac{13800\,V}{14400\,V} \times \frac{120\,V}{\sqrt{3}} = 66.4\,V$$

<div align="right">**Eq. 3**</div>

Many settings are common to most elements and are discussed below:

- **Function** settings: These settings program the element to be operational when selected as "Enabled". The factory default is "Disabled". Once programmed to "Enabled", any element associated with the function becomes active and all options become available.

- **Name** settings: These settings are used to uniquely identify an element.

- **Source** settings: These settings select the parameter or set of parameters to be monitored.

- **Pickup** settings: For simple elements, these settings are used to program the level of the measured parameter above or below which the pickup state is established. In more complex elements, a set of settings may be provided to define the range of the measured parameters which will cause the element to pickup.

- **Pickup Delay** setting: This setting sets a time-delay-on-pickup, or on-delay, for the duration between the pickup and operate output states.

- **Reset Delay** setting: This setting is used to set a time-delay-on-dropout, or off-delay, for the duration between the operate output state and the return to logic 0 after the input transits outside the defined pickup range.

- **Block** setting: The default output operand state of all comparators is a logic 0 or *flag not set*. The comparator remains in this default state until a logic 1 is asserted at the RUN input, allowing the test to be performed. If the RUN input changes to logic 0 at any time, the comparator returns to the default state. The RUN input is used to supervise the comparator. The BLOCK input is used as one of the inputs to RUN control.

- **Events** setting: This setting is used to control whether the pickup, dropout or operate states are recorded by the event recorder. When set to "Disabled", element pickup, dropout or operate are not recorded as events. When set to "Enabled", events are created as follows:
  - **<Element> PKP** (pickup)
  - **<Element> DPO** (dropout)
  - **<Element> OP** (operate)

The dropout event is created when the measure and decide comparator output transits from the pickup state (logic 1) to the dropout state (logic 0). This could happen when the element is in the operate state if the reset delay time is not zero.

Power system

Installation settings

Select the **Settings > Protection > Power System > Installation** menu item to open the installation settings window.

Figure 83: Installation settings
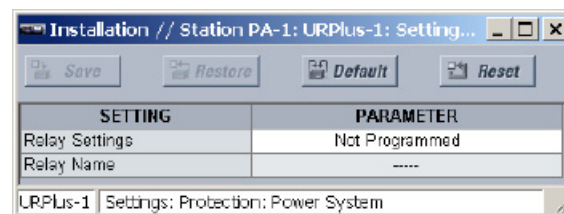
The following settings are available.

Relay Settings

Range: Programmed, Not Programmed
Default: Not Programmed

To safeguard against the installation of a device without any entered settings, the C90^Plus will not allow signaling of any output relay until this setting value is "Programmed". This setting is defaulted to "Not Programmed" when at the factory. The **UNIT NOT PROGRAMMED** self-test error message is displayed until the relay is put into the programmed state.

Relay Name

Range: up to 20 alphanumeric characters
Default: -----

This setting allows the user to uniquely identify a relay. This name will appear on all generated reports.

AC input modules

CT and VT input channels are contained in AC modules. The following input channel types are available.

- Three-phase voltage.
- Single-phase auxiliary voltage.
- Three-phase current.

- Single-phase ground current.

The AC modules calculate total waveform RMS levels, fundamental frequency phasors, and symmetrical components, as allowed by the hardware in each channel. These modules may calculate other parameters as directed by the CPU module.

An AC module contains twelve input channels, numbered 1 through 12. The channel numbering corresponds to the module terminal numbering 1 through 12 and is arranged as follows.

- Channels 1, 2, and 3 form a three-phase current input.
- Channels 4, 5, and 6 form a second three-phase current input.
- Channel 7 is a single-phase current input.
- Channels 8 and 9 are single-phase voltage inputs.
- Channels 10, 11, and 12 form a three-phase voltage input.

Channel groups are ordered sequentially from the block of lower-numbered channels to the block of higher-numbered channels, and from the AC module with the lowest slot position letter to the module with the highest slot position letter, as follows:

Banks are ordered sequentially from the block of lower-numbered channels to the block of higher-numbered channels, and from the AC module with the lowest slot position letter to the module with the highest slot position letter, as follows.

Figure 84: AC module bank configuration

870832A1.CDR
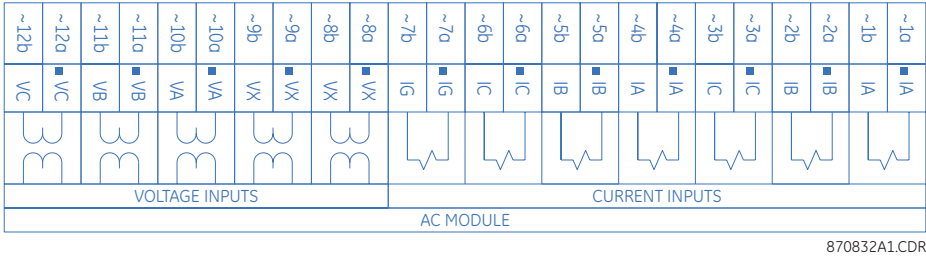
For three-phase channel groups, the number of the lowest numbered channel identifies the group. For example, J1 represents the three-phase channel set of J1, J2, and J3, where J is the slot letter and 1 is the first channel of the set of three channels. The first channel in the group is identified as phase A, the second channel as phase B, and the third channel as phase C.

Current inputs

Select the **Settings > Protection > Power System > AC Inputs - Current** menu item to open the current inputs configuration window.

Figure 85: Current inputs configuration settings
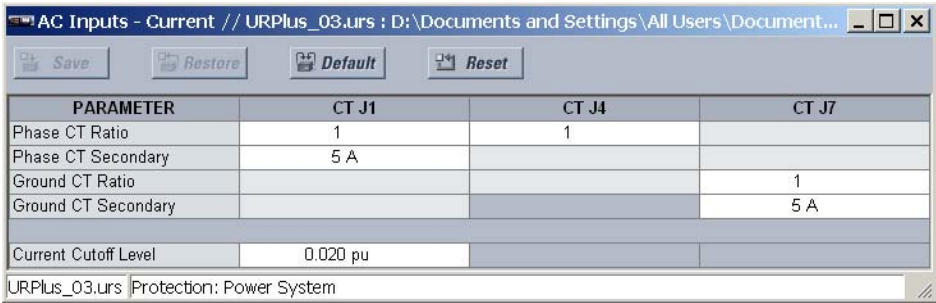
The current inputs configuration window allows the user to specify the parameters for each current input (represented by the module slot position letter). The **Phase CT Ratio** and **Auxiliary CT Ratio** settings are used for calculation of primary metering values and for ratio

matching when multiple CT inputs are added within a source. The **Phase CT Nominal** and **Auxiliary CT Nominal** settings are used to derive secondary current values from per-unit settings used in protection elements. This setting will typically be "1 A" or "5 A", depending on the hardware. However, the user may enter an alternate value. For example, if a value of "4 A" is chosen, an instantaneous overcurrent element with a pickup of 2 pu. would operate at 8 A secondary.

Since the phase CTs are connected in a wye (star) configuration, the calculated phasor sum of the three phase currents (IA + IB + IC = neutral current = 3I0) is used as the input for the neutral overcurrent elements. In addition, a zero-sequence (core-balance) CT which senses current in all of the circuit primary conductors, or a CT in a neutral grounding conductor may also be used.

The following current input settings are available.

Connection

Range; 3-Phase, 1-Phase
Default: 3-Phase

This setting specifies the connection for the F7 current input. If configured to "3-Phase", then current inputs F7 through F9 are grouped as a three-phase bank and only the phase CT settings are available; the F8 and F9 columns will not be displayed. If the F7 connection is configured as "1-Phase", then the auxiliary CT settings will be shown for the F7 through F9 current inputs and the F8 and F9 columns will be displayed.

This setting is fixed to "3-Phase" for the 5VT/7CT and 4VT/4CT/1SCT modules.

Phase CT Ratio

Range: 1 to 65000 in steps of 1
Default: 1

This setting specifies the phase CT ratio for the corresponding current input. It is used for calculation of primary metering values and for ratio matching when multiple CT inputs are added within a source.

Phase CT Nominal

Range: 0.00 to 30.00 amps in steps of 0.01
Default: 5.00 amps

This setting specifies the nominal phase CT current for the corresponding current input. It is used to derive secondary current values from per-unit settings used in protection elements.

Auxiliary CT Ratio

Range: 1 to 65000 in steps of 1
Default: 1

This setting specifies the auxiliary CT ratio for the corresponding current input. It is used for calculation of primary metering values and for ratio matching when multiple CT inputs are added within a source. This setting is not available if the **Connection** setting is "3-Phase".

Auxiliary CT Nominal

Range: 0.00 to 30.00 amps in steps of 0.01
Default: 5.00 amps

This setting specifies the nominal auxiliary CT current for the corresponding current input. It is used to derive secondary current values from per-unit settings used in protection elements. This setting is not available if the **Connection** setting is "3-Phase".

Current Cutoff Level

Range: 0.002 to 0.020 pu in steps of 0.001
Default: 0.020 pu

This setting modifies the current cut-off threshold. Very low currents (1 to 2% of the rated value) are very susceptible to noise. Some customers prefer very low currents to display as zero, while others prefer the current be displayed even when the value reflects noise rather than the actual signal. The C90^Plus applies a cut-off value to the magnitudes and angles of the measured currents. If the magnitude is below the cut-off level, it is substituted with zero. This applies to phase and ground current phasors as well as true RMS values and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Raw current samples available via oscillography are not subject to cut-off.

NOTE

Lower the **Current Cutoff Level** setting with care as the C90^Plus accepts lower signals as valid measurements. Unless dictated otherwise by a specific application, the default setting of "0.020 pu" is recommended.

Voltage inputs

Select the **Settings > Protection > Power System > AC Inputs - Voltage** menu item to open the voltage input configuration window.

Figure 86: Voltage input configuration settings

This menu allows the user to specify the parameters for each voltage input. The **Phase VT Ratio** and **Auxiliary VT Ratio** settings are used for calculation of primary metering values or matching primary voltage in a synchrocheck application. The **Phase VT Nominal** and **Auxiliary VT Nominal** settings are used to derive secondary voltage values from the per-unit settings used in protection elements. Protection functions that require phase-to-neutral or zero-sequence quantities will not function correctly for delta VT configurations.

The following voltage input settings are available.

Phase VT Connection

Range: Wye, Delta
Default: Wye

This setting specifies the phase VT connection type for the corresponding voltage input. An open-delta source VT connection would be entered as "Delta".

Phase VT Ratio

Range: 1.00 to 2400.00 in steps of 0.001
Default: 1.00

This setting specifies the phase VT ratio for the corresponding voltage input. It is typically used for calculation of primary metering values or matching primary voltage in a synchrocheck application.

Phase VT Nominal

Range: 50 to 240 volts in steps of 1

Default: 120 volts

This setting specifies the nominal phase VT voltage for the corresponding voltage input. It is typically used to derive secondary voltage values from the per-unit settings used in protection elements.

The typical **Phase VT Nominal** setting is the phase-to-phase secondary voltage appearing at the relay input terminals when nominal voltage is applied to the VT primary. For example, on a system with a 13.8 kV nominal primary voltage and with a 14400:120 V VT in a delta connection, the secondary voltage is (13800 V / 14400) × 120 = 115 V. Thus, the **Phase VT Nominal** setting would be 115 volts.

Auxiliary VT Connection

Range: Vag, Vbg, Vcg, Vab, Vbc, Vca, Vn

Default: Vag

This setting specifies the auxiliary VT connection type for the corresponding voltage input.

Auxiliary VT Ratio

Range: 1.00 to 2400.00 in steps of 0.001

Default:

This setting specifies the auxiliary VT ratio for the corresponding voltage input. It is typically used for calculation of primary metering values or matching primary voltage in a synchrocheck application.

Auxiliary VT Nominal

Range: 50 to 240 volts in steps of 1

Default: 120 volts

This setting specifies the nominal auxiliary VT voltage for the corresponding voltage input. It is typically used to derive secondary voltage values from the per-unit settings used in protection elements.

Voltage Cutoff Level

Range: 0.1 to 1.0 volts secondary in steps of 0.1

Default: 1.0 volts secondary

This setting specifies the voltage cut-off threshold. Very low secondary voltage measurements (at the fractional volt level) can be affected by noise. Some customers prefer these low voltages to be displayed as zero, while others prefer the voltage to be displayed even when the value reflects noise rather than the actual signal. The C90^{Plus} applies a cut-off value to the magnitudes and angles of the measured voltages. If the magnitude is below the cut-off level, it is substituted with zero. This operation applies to phase voltages, auxiliary voltages, and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Raw samples of the voltages available via oscillography are not subject cut-off.

NOTE

Lower the **Voltage Cutoff Level** setting with care as the C90^{Plus} accepts lower signals as valid measurements. Unless dictated otherwise by a specific application, the default setting of "1.0 V" is recommended.

Calculating the power cut-off level

The **Current Cutoff Level** and the **Voltage Cutoff Level** settings are used to determine the metered power cut-off levels. The power cut-off level is calculated as shown below. For delta connections, the power cut-off is calculated as follows.

$$\text{Three-phase power cut-off} = \frac{\sqrt{3} \times \text{Current Cutoff Level} \times \text{Voltage Cutoff Level} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}}$$

Eq. 4

For wye connections, the three-phase and per-phase power cut-off values are calculated as follows.

$$\text{Three-phase power cutoff} = \frac{3 \times \text{Current Cutoff Level} \times \text{Voltage Cutoff Level} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}}$$

Eq. 5

$$\text{Per-phase power cutoff} = \frac{\text{Current Cutoff Level} \times \text{Voltage Cutoff Level} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}}$$

Eq. 6

where VT primary = VT secondary × VT ratio and CT primary = CT secondary × CT ratio.

For example, given the following settings:

Figure 87: Typical power system settings

We have:

- CT primary = **Phase CT Ratio** × **Phase CT Secondary** = 20 × 5 A = 100 A
- VT primary = **Phase VT Ratio** × **Phase VT Secondary** = 208 × 66.4 V = 13811.2 V

The power cut-off is therefore:

$$\text{Three-phase power cut-off} = \frac{\sqrt{3} \times \text{Current Cutoff Level} \times \text{Voltage Cutoff Level} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}}$$

$$= \frac{\sqrt{3} \times 0.02 \text{ pu} \times 1.0 \text{ V} \times 100 \text{ A} \times 13811.2 \text{ V}}{66.4 \text{ V}}$$

$$= 720.5 \text{ W}$$

Eq. 7

Any calculated power value below this cut-off will not be displayed. As well, the three-phase energy data will not accumulate if the total power from all three phases does not exceed the power cut-off.

Power system frequency

Select the **Settings > Protection > Power System > Frequency** menu item to open the power system frequency configuration window.

Figure 88: System frequency configuration settings
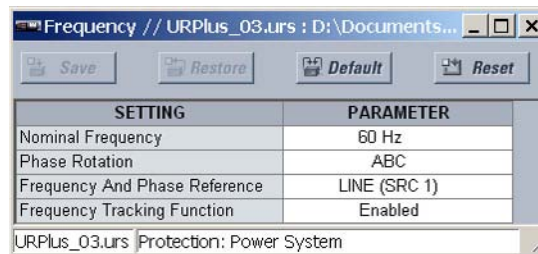
The following settings are available.

Nominal Frequency

Range: 50 Hz, 60 Hz
Default: 60 Hz

The power system **Nominal Frequency** value is used as a default to set the digital sampling rate if the system frequency cannot be measured from available signals. This may happen if the signals are not present or are heavily distorted. Before reverting to the nominal frequency, the frequency tracking algorithm holds the last valid frequency measurement for a safe period of time while waiting for the signals to reappear or for the distortions to decay.

Phase Rotation

Range: ABC, ACB
Default: ABC

The phase sequence of the power system is required to properly calculate sequence components and power parameters. This setting matches the power system phase sequence and informs the relay of the actual system phase sequence, either ABC or ACB. The C90^{Plus} AC inputs (labeled as A, B, and C) must be connected to system phases A, B, and C for correct operation.

Frequency and Phase Reference

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

The **Frequency and Phase Reference** setting determines which signal source is used (and hence which AC signal) for phase angle reference. The AC signal used is prioritized based on the inputs configured for the signal source. Phase voltages takes precedence, followed by auxiliary voltage, then phase currents, and finally ground current. For three-phase selection, phase A is used for angle referencing ($V_{ANGLE\_REF} = V_A$), while the Clarke transformation of the phase signals is used for frequency metering and tracking ($V_{FREQ} = (2V_A – V_B – V_C) / 3$) for better performance during fault, open pole, and VT and CT fail conditions.

The phase reference and frequency tracking AC signals are selected based upon the source configuration, regardless of whether or not a particular signal is actually applied to the relay.

The reference signal phase angle will always display zero degrees and all other phase angles are relative to this signal. If the pre-selected reference signal is not measurable at a given time, the phase angles are not referenced.

The phase angle referencing is done via a phase locked loop, which can synchronize independent UR^{Plus}-series devices if they have the same AC signal reference. These results in very precise correlation of time tagging in the event recorder between different UR^{Plus}-series devices provided the relays have an IRIG-B connection.

Frequency Tracking
Range: Disabled, Enabled
Default: Enabled

This setting should only be programmed to "Disabled" in very unusual circumstances; consult GE Multilin for special variable-frequency applications.

About AC sources

The C90^{Plus} may be used on systems with breaker-and-a-half or ring bus configurations. In these applications, each of the two three-phase sets of individual phase currents (one associated with each breaker) can be used as an input to a breaker failure element. The sum of both breaker phase currents and 3I_0 residual currents may be required for the circuit relaying and metering functions. For a three-winding transformer application, it may be necessary to calculate watts and vars for each of the three windings, using voltage from different sets of VTs. These requirements can be satisfied with a single C90^{Plus} IED equipped with sufficient CT and VT input channels by selecting the appropriate parameter measurement. A mechanism is provided to specify the AC parameter (or group of parameters) used as the input to the protection and control comparators and some metering elements.

Selection of the measurement parameters is partially performed by the design of a measuring element or protection/control comparator by identifying the type of parameter (fundamental frequency phasor, harmonic phasor, symmetrical component, total waveform RMS magnitude, phase-phase or phase-ground voltage, etc.) to measure. The user completes the process by selecting the instrument transformer input channels to use and some of the parameters calculated from these channels. The input parameters available include the summation of currents from multiple input channels. For the summed phase, 3I_0, and ground currents, currents from CTs with different ratios are adjusted to a single ratio before summation.

A mechanism called a *source* configures the routing of CT and VT input channels to measurement sub-systems. Sources, in the context of the UR^{Plus}-series relays, refer to the logical grouping of current and voltage signals such that one source contains all the signals required to measure the load or fault in a particular power apparatus. A given source may contain all or some of the following signals: three-phase currents, single-phase ground current, three-phase voltages, and an auxiliary voltage from a single VT for checking for synchronism.

To illustrate the concept of sources, as applied to current inputs only, consider the breaker-and-a-half scheme below. In this application, the current flow is indicated by the arrows. Some current flows through the upper bus bar to some other location or power equipment, and some current flows into transformer winding 1. The current into the line is the phasor sum (or difference) of the currents in CT1 and CT2 (whether the sum or difference is used depends on the relative polarity of the CT connections). The protection elements require access to the net current for line protection, but some elements may need access to the individual currents from CT1 and CT2.

Figure 89: Breaker-and-a-half scheme
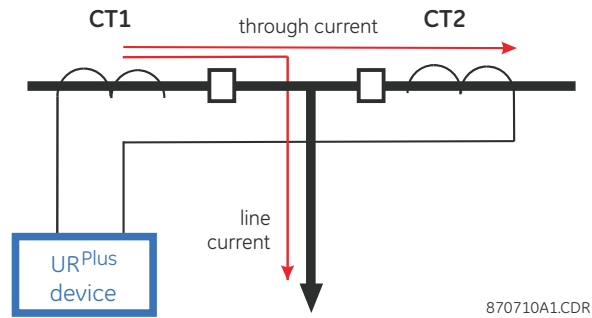
In conventional analog or electronic relays, the sum of the currents is obtained from an appropriate external connection of all CTs through which any portion of the current for the element being protected could flow. Auxiliary CTs are required to perform ratio matching if the ratios of the primary CTs to be summed are not identical. In the C90^Plus Controller, provisions have been included for all the current signals to be brought to the C90^Plus device where grouping, ratio correction and summation are applied internally via configuration settings. A major advantage of using internal summation is that the individual currents are available to the protection device; for example, as additional information to calculate a restraint current, or to allow the provision of additional protection features that operate on the individual currents such as breaker failure.

Given the flexibility of this approach, it becomes necessary to add configuration settings to the platform to allow the user to select which sets of CT inputs will be added to form the net current into the protected device.

The internal grouping of current and voltage signals forms an internal source. This source can be given a specific name through the settings, and becomes available to protection and metering element in the C90^Plus. Individual names can be assigned to each source to clearly identify them for later use. For example, in the scheme shown above, a source configured as the sum of CT1 and CT2 can be assigned the name "Line Current".

Once the sources have been configured, they are available as selections for the choice of input signal for the protection elements and as metered quantities.

CT/VT input channel configuration

The previous section explains how the input channels are identified and configured to the specific application instrument transformers and the connections of these transformers. The specific parameters to be used by each measuring element and comparator, and some actual values are controlled by selecting a specific source.

The source is a logical group of current and voltage input channels selected by the user to facilitate this selection. With this mechanism, a user does not have to make multiple selections of voltage and current for those elements that need both parameters, such as a distance element or a watt calculation. It also gathers associated parameters for display purposes. The basic idea of arranging a source is to select a point on the power system where information is of interest. An application example of the grouping of parameters in a source is a transformer winding, on which a three-phase voltage is measured, and the sum of the currents from CTs on each of two breakers is required to measure the winding current flow.

Signal source settings

Select the **Settings > Protection > Power System > Signal Sources** menu item to open the protection sources configuration window.

Figure 90: Protection sources configuration settings

Settings are available for all three sources. The "LINE", "BKR1", and "BKR2" text items can be replaced by with a user-defined name to uniquely identify the associated source.

It is possible to select the sum of two CTs for a protection source. The first channel displayed is the CT to which all others will be referred. For example, the selection "J1+J4" indicates the sum of each phase from channels J1 and J4, scaled to whichever CT has the higher ratio.

The approach used to configure the protection sources is detailed below.

1. Specify the ratio and nominal secondary current for each CT input.
2. Specify the connection type, ratio, and nominal secondary voltage for each VT input.
3. Specify the configuration for each source, including the CTs to be summed together.

The following settings are available for each protection source.

Name
Range: up to 20 alphanumeric characters
Default: LINE
This setting specifies a name for the protection source.

Phase CT
Range: None, J1, J4, J1+J4, etc.
Default: J1+J4
This setting selects a phase CT or sum of phase CTs to represent the protection source.

Ground CT
Range: None, J7
Default: J7
This setting selects a ground CT to represent the protection source.

Phase VT
Range: None, J10
Default: J10
This setting selects a phase VT to represent the protection source.

Auxiliary VT
Range: None, J8, J9
Default: None
This setting selects an auxiliary VT to represent the protection source.

Internal disturbance detection

The disturbance detection element (ANSI 50DD) is a sensitive current disturbance detector that detects any disturbance on the protected system. This element is intended for use in conjunction with measuring elements, blocking of current based elements (to prevent maloperation as a result of the wrong settings), and starting oscillography data capture. A disturbance detector is provided for each source.

The disturbance detector responds to the changes in magnitude of the sequence currents. The disturbance detector also responds to the change in currents of twice the current cut-off level. The default cut-off threshold is 0.02 pu. As such, the disturbance detector responds to a change of 0.04 pu by default. The **Current Cutoff** setting (located in the **Settings > Protection > Power System > AC Input - Current** menu) controls the metering sensitivity of the disturbance detector.

The source 1 disturbance detector logic is shown below. The logic is identical for all three sources.

Figure 91: Disturbance detector logic scheme
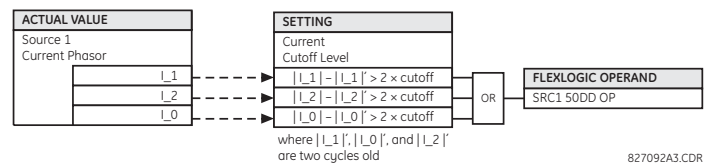
Example use of sources

Consider a C90^{Plus} connected as shown below. This configuration could be used on a transmission line connected into a breaker-and-a-half system. The following figure shows the arrangement of sources used to provide the functions required in this application, and the AC module inputs used to provide the data.

Figure 92: Example use of sources
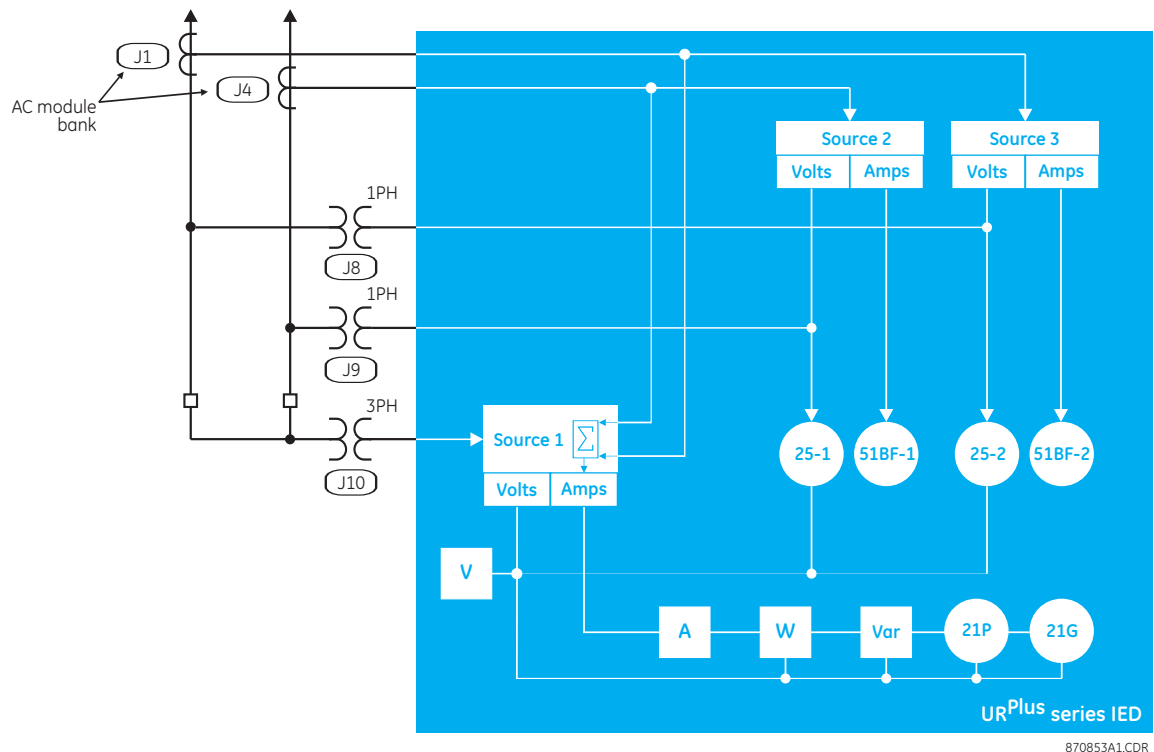
Grouped protection elements

Each protection element can be assigned up to six different sets of settings according to setting group designations 1 to 6. The performance of these elements is defined by the active setting group at a given time. Multiple setting groups allow the user to conveniently

change protection settings for different operating situations (for example, altered power system configuration or season of the year). The active setting group can be preset or selected via the **Settings > Protection > Control > Setting Groups** menu item.

Current elements

Overview of time overcurrent curves

The inverse time overcurrent curves used by the time overcurrent elements are the IEEE, IEC, GE Type IAC, and I^2t standard curve shapes. This allows for simplified coordination with downstream devices. If however, none of these curve shapes is adequate, FlexCurves™ may be used to customize the inverse time curve characteristics. The definite time curve is also an option that may be appropriate if only simple protection is required.

The following overcurrent curve types are available.

- IEEE Extremely Inverse
- IEEE Very Inverse
- IEEE Moderately Inverse
- IEC Curve A (BS142)
- IEC Curve B (BS142)
- IEC Curve C (BS142)
- IAC Extremely Inverse
- IAC Very Inverse
- IAC Inverse
- IAC Short Inverse
- I^2t
- FlexCurves™ A, B, C, and D
- Recloser curves
- Definite Time

A multiplier (time dial) setting allows selection of a multiple of the base curve shape (where the time dial multiplier = 1) with the curve shape setting. Unlike the electromechanical time dial equivalent, operate times are directly proportional to the time multiplier setting value. For example, all times for a multiplier of 10 are 10 times the multiplier 1 or base curve values. Setting the multiplier to zero results in an instantaneous response to all current levels above pickup.

Time overcurrent time calculations are made with an internal energy capacity memory variable. When this variable indicates that the energy capacity has reached 100%, a time overcurrent element will operate. If less than 100% energy capacity is accumulated in this variable and the current falls below the dropout threshold of 97 to 98% of the pickup value, the variable must be reduced. Two methods of this resetting operation are available: instantaneous and timed. The instantaneous method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The timed method can be used where the relay must coordinate with electromechanical relays.

IEEE curves   The IEEE time overcurrent curve shapes conform to industry standards and the IEEE C37.112-1996 curve classifications for extremely, very, and moderately inverse curves. The IEEE curves are derived by the operate and reset time equations.

$$T = \text{TDM} \times \left[\frac{A}{\left(\frac{I}{I_{pickup}} \right)^p - 1} + B \right]$$

Eq. 8

$$T_{reset} = \text{TDM} \times \left[\frac{t_r}{1 - \left(\frac{I}{I_{pickup}} \right)^2} \right]$$

Eq. 9

The terms in the above equations are defined as follows.

- $T_{operate}$ represents the operate time in seconds.
- TDM represents the multiplier setting.
- I represents the input current.
- I_{pickup} represents the pickup current setting value.
- A, B. and p are constants and are defined in the table below.
- T_{reset} represents reset time in seconds, assuming the energy capacity is 100% and the reset mode is timed.
- t_r represents the characteristic constant and is defined in the table below.

Table 5: IEEE inverse time curve constants

IEEE curve shape	A	B	p	t_r
Extremely inverse	28.2	0.1217	2.0000	29.1
Very inverse	19.61	0.491	2.0000	21.6
Moderately inverse	0.0515	0.1140	0.020000	4.85

Table 6: IEEE curve trip times (in seconds)

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
IEEE extremely inverse										
0.5	11.341	4.761	1.823	1.001	0.648	0.464	0.355	0.285	0.237	0.203
1.0	22.682	9.522	3.647	2.002	1.297	0.927	0.709	0.569	0.474	0.407
2.0	45.363	19.043	7.293	4.003	2.593	1.855	1.418	1.139	0.948	0.813
4.0	90.727	38.087	14.587	8.007	5.187	3.710	2.837	2.277	1.897	1.626
6.0	136.090	57.130	21.880	12.010	7.780	5.564	4.255	3.416	2.845	2.439
8.0	181.454	76.174	29.174	16.014	10.374	7.419	5.674	4.555	3.794	3.252
10.0	226.817	95.217	36.467	20.017	12.967	9.274	7.092	5.693	4.742	4.065
IEEE very inverse										
0.5	8.090	3.514	1.471	0.899	0.654	0.526	0.450	0.401	0.368	0.345
1.0	16.179	7.028	2.942	1.798	1.308	1.051	0.900	0.802	0.736	0.689
2.0	32.358	14.055	5.885	3.597	2.616	2.103	1.799	1.605	1.472	1.378
4.0	64.716	28.111	11.769	7.193	5.232	4.205	3.598	3.209	2.945	2.756
6.0	97.074	42.166	17.654	10.790	7.849	6.308	5.397	4.814	4.417	4.134
8.0	129.432	56.221	23.538	14.387	10.465	8.410	7.196	6.418	5.889	5.513
10.0	161.790	70.277	29.423	17.983	13.081	10.513	8.995	8.023	7.361	6.891
IEEE moderately inverse										
0.5	3.220	1.902	1.216	0.973	0.844	0.763	0.706	0.663	0.630	0.603
1.0	6.439	3.803	2.432	1.946	1.688	1.526	1.412	1.327	1.260	1.207
2.0	12.878	7.606	4.864	3.892	3.377	3.051	2.823	2.653	2.521	2.414
4.0	25.756	15.213	9.729	7.783	6.753	6.102	5.647	5.307	5.041	4.827
6.0	38.634	22.819	14.593	11.675	10.130	9.153	8.470	7.960	7.562	7.241
8.0	51.512	30.426	19.458	15.567	13.507	12.204	11.294	10.614	10.083	9.654
10.0	64.390	38.032	24.322	19.458	16.883	15.255	14.117	13.267	12.604	12.068

IEC curves   For European applications, the C90^{Plus} offers three standard curves defined in IEC 255-4 and British standard BS142. These are defined as IEC curves A, B, and C. The IEC curves are derived by the operate and reset time equations.

$$T_{operate} = \text{TDM} \times \frac{K}{\left(\dfrac{I}{I_{pickup}}\right)^E - 1}$$

<div align="right">**Eq. 10**</div>

$$T_{reset} = \text{TDM} \times \frac{t_r}{1 - \left(\dfrac{I}{I_{pickup}}\right)^2}$$

<div align="right">**Eq. 11**</div>

The terms in the above equations are defined as follows.

- $T_{operate}$ represents the operate time in seconds.
- TDM represents the multiplier setting.
- I represents the input current.
- I_{pickup} represents the pickup current setting value.
- K and E are constants and are defined in the table below.
- T_{reset} represents reset time in seconds, assuming the energy capacity is 100% and the reset mode is timed.

- t_r represents the characteristic constant and is defined in the table below.

Table 7: IEC (BS) inverse time curve constants

IEC curve shape	K	E	t_r
IEC curve A (BS142)	0.140	0.020	9.7
IEC curve B (BS142)	13.500	1.000	43.2
IEC curve C (BS142)	80.000	2.000	58.2
IEC short inverse	0.050	0.040	0.500

Table 8: IEC (BS) curve trip times (in seconds)

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
IEC curve A										
0.05	0.860	0.501	0.315	0.249	0.214	0.192	0.176	0.165	0.156	0.149
0.10	1.719	1.003	0.630	0.498	0.428	0.384	0.353	0.330	0.312	0.297
0.20	3.439	2.006	1.260	0.996	0.856	0.767	0.706	0.659	0.623	0.594
0.40	6.878	4.012	2.521	1.992	1.712	1.535	1.411	1.319	1.247	1.188
0.60	10.317	6.017	3.781	2.988	2.568	2.302	2.117	1.978	1.870	1.782
0.80	13.755	8.023	5.042	3.984	3.424	3.070	2.822	2.637	2.493	2.376
1.00	17.194	10.029	6.302	4.980	4.280	3.837	3.528	3.297	3.116	2.971
IEC curve B										
0.05	1.350	0.675	0.338	0.225	0.169	0.135	0.113	0.096	0.084	0.075
0.10	2.700	1.350	0.675	0.450	0.338	0.270	0.225	0.193	0.169	0.150
0.20	5.400	2.700	1.350	0.900	0.675	0.540	0.450	0.386	0.338	0.300
0.40	10.800	5.400	2.700	1.800	1.350	1.080	0.900	0.771	0.675	0.600
0.60	16.200	8.100	4.050	2.700	2.025	1.620	1.350	1.157	1.013	0.900
0.80	21.600	10.800	5.400	3.600	2.700	2.160	1.800	1.543	1.350	1.200
1.00	27.000	13.500	6.750	4.500	3.375	2.700	2.250	1.929	1.688	1.500
IEC curve C										
0.05	3.200	1.333	0.500	0.267	0.167	0.114	0.083	0.063	0.050	0.040
0.10	6.400	2.667	1.000	0.533	0.333	0.229	0.167	0.127	0.100	0.081
0.20	12.800	5.333	2.000	1.067	0.667	0.457	0.333	0.254	0.200	0.162
0.40	25.600	10.667	4.000	2.133	1.333	0.914	0.667	0.508	0.400	0.323
0.60	38.400	16.000	6.000	3.200	2.000	1.371	1.000	0.762	0.600	0.485
0.80	51.200	21.333	8.000	4.267	2.667	1.829	1.333	1.016	0.800	0.646
1.00	64.000	26.667	10.000	5.333	3.333	2.286	1.667	1.270	1.000	0.808
IEC short time										
0.05	0.153	0.089	0.056	0.044	0.038	0.034	0.031	0.029	0.027	0.026
0.10	0.306	0.178	0.111	0.088	0.075	0.067	0.062	0.058	0.054	0.052
0.20	0.612	0.356	0.223	0.175	0.150	0.135	0.124	0.115	0.109	0.104
0.40	1.223	0.711	0.445	0.351	0.301	0.269	0.247	0.231	0.218	0.207
0.60	1.835	1.067	0.668	0.526	0.451	0.404	0.371	0.346	0.327	0.311
0.80	2.446	1.423	0.890	0.702	0.602	0.538	0.494	0.461	0.435	0.415
1.00	3.058	1.778	1.113	0.877	0.752	0.673	0.618	0.576	0.544	0.518

IAC curves   The curves for the General Electric type IAC relay family are derived as follows.

$$T_{operate} = TDM \times \left(A + \frac{B}{\left(\frac{I}{I_{pickup}} - C\right)} + \frac{D}{\left(\frac{I}{I_{pickup}} - C\right)^2} + \frac{E}{\left(\frac{I}{I_{pickup}} - C\right)^3} \right)$$

Eq. 12

$$T_{reset} = TDM \times \frac{t_r}{1 - \left(\frac{I}{I_{pickup}}\right)^2}$$

Eq. 13

The terms in the above equations are defined as follows.

- $T_{operate}$ represents the operate time in seconds.
- TDM represents the multiplier setting.
- I represents the input current.
- I_{pickup} represents the pickup current setting value.
- A to E are constants and are defined in the table below.
- T_{reset} represents reset time in seconds, assuming the energy capacity is 100% and the reset mode is timed.
- t_r represents the characteristic constant and is defined in the table below.

Table 9: GE type IAC inverse time curve constants

IAC curve shape	A	B	C	D	E	t_r
IAC extreme inverse	0.0040	0.6379	0.6200	1.7872	0.2461	6.008
IAC very inverse	0.0900	0.7955	0.1000	−1.2885	7.9586	4.678
IAC inverse	0.2078	0.8630	0.8000	−0.4180	0.1947	0.990
IAC short inverse	0.0428	0.0609	0.6200	−0.0010	0.0221	0.222

Multiplier (TDM)	Current (I / I$_{pickup}$)									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
IAC extremely inverse										
0.5	1.699	0.749	0.303	0.178	0.123	0.093	0.074	0.062	0.053	0.046
1.0	3.398	1.498	0.606	0.356	0.246	0.186	0.149	0.124	0.106	0.093
2.0	6.796	2.997	1.212	0.711	0.491	0.372	0.298	0.248	0.212	0.185
4.0	13.591	5.993	2.423	1.422	0.983	0.744	0.595	0.495	0.424	0.370
6.0	20.387	8.990	3.635	2.133	1.474	1.115	0.893	0.743	0.636	0.556
8.0	27.183	11.987	4.846	2.844	1.966	1.487	1.191	0.991	0.848	0.741
10.0	33.979	14.983	6.058	3.555	2.457	1.859	1.488	1.239	1.060	0.926
IAC very inverse										
0.5	1.451	0.656	0.269	0.172	0.133	0.113	0.101	0.093	0.087	0.083
1.0	2.901	1.312	0.537	0.343	0.266	0.227	0.202	0.186	0.174	0.165
2.0	5.802	2.624	1.075	0.687	0.533	0.453	0.405	0.372	0.349	0.331
4.0	11.605	5.248	2.150	1.374	1.065	0.906	0.810	0.745	0.698	0.662
6.0	17.407	7.872	3.225	2.061	1.598	1.359	1.215	1.117	1.046	0.992
8.0	23.209	10.497	4.299	2.747	2.131	1.813	1.620	1.490	1.395	1.323
10.0	29.012	13.121	5.374	3.434	2.663	2.266	2.025	1.862	1.744	1.654
IAC inverse										
0.5	0.578	0.375	0.266	0.221	0.196	0.180	0.168	0.160	0.154	0.148
1.0	1.155	0.749	0.532	0.443	0.392	0.360	0.337	0.320	0.307	0.297
2.0	2.310	1.499	1.064	0.885	0.784	0.719	0.674	0.640	0.614	0.594
4.0	4.621	2.997	2.128	1.770	1.569	1.439	1.348	1.280	1.229	1.188
6.0	6.931	4.496	3.192	2.656	2.353	2.158	2.022	1.921	1.843	1.781
8.0	9.242	5.995	4.256	3.541	3.138	2.878	2.695	2.561	2.457	2.375
10.0	11.552	7.494	5.320	4.426	3.922	3.597	3.369	3.201	3.072	2.969
IAC short inverse										
0.5	0.072	0.047	0.035	0.031	0.028	0.027	0.026	0.026	0.025	0.025
1.0	0.143	0.095	0.070	0.061	0.057	0.054	0.052	0.051	0.050	0.049
2.0	0.286	0.190	0.140	0.123	0.114	0.108	0.105	0.102	0.100	0.099
4.0	0.573	0.379	0.279	0.245	0.228	0.217	0.210	0.204	0.200	0.197
6.0	0.859	0.569	0.419	0.368	0.341	0.325	0.314	0.307	0.301	0.296
8.0	1.145	0.759	0.559	0.490	0.455	0.434	0.419	0.409	0.401	0.394
10.0	1.431	0.948	0.699	0.613	0.569	0.542	0.524	0.511	0.501	0.493

I^{2}t curves   The I^{2}t curves are derived as follows.

$$T_{operate} = \text{TDM} \times \frac{100}{\left(\dfrac{I}{I_{pickup}}\right)^2}$$

Eq. 14

$$T_{reset} = \text{TDM} \times \frac{100}{\left(\dfrac{I}{I_{pickup}}\right)^{-2}}$$

Eq. 15

The terms in the above equations are defined as follows.

- $T_{operate}$ represents the operate time in seconds.

- TDM represents the multiplier setting.
- I represents the input current.
- I_{pickup} represents the pickup current setting value.
- T_{reset} represents reset time in seconds, assuming the energy capacity is 100% and the reset mode is timed.

Table 11: I²t curve trip times (in seconds)

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.01	0.44	0.25	0.11	0.06	0.04	0.03	0.02	0.02	0.01	0.01
0.10	4.44	2.50	1.11	0.63	0.40	0.28	0.20	0.16	0.12	0.10
1.00	44.44	25.00	11.11	6.25	4.00	2.78	2.04	1.56	1.23	1.00
10.00	444.44	250.00	111.11	62.50	40.00	27.78	20.41	15.63	12.35	10.00
100.00	4444.4	2500.0	1111.1	625.00	400.00	277.78	204.08	156.25	123.46	100.00
600.00	26666.7	15000.0	6666.7	3750.0	2400.0	1666.7	1224.5	937.50	740.74	600.00

FlexCurves™

The custom FlexCurve™ shapes are defined as follows.

$$T_{operate} = TDM \times FlexCurve\ time\ at\ \frac{I}{I_{pickup}}\ when\ \frac{I}{I_{pickup}} \geq 1.00$$

Eq. 16

$$T_{reset} = TDM \times FlexCurve\ time\ at\ \frac{I}{I_{pickup}}\ when\ \frac{I}{I_{pickup}} \leq 0.98$$

Eq. 17

The terms in the above equations are defined as follows.

- $T_{operate}$ represents the operate time in seconds.
- TDM represents the multiplier setting.
- I represents the input current.
- I_{pickup} represents the pickup current setting value.
- T_{reset} represents reset time in seconds, assuming the energy capacity is 100% and the reset mode is timed.

Definite time curve

The definite time curve shape operates as soon as the pickup level is exceeded for a specified period of time. The base definite time curve delay is in seconds. The curve multiplier of 0.00 to 600.00 makes this delay adjustable from instantaneous to 600.00 seconds in steps of 10 ms. The definite time curve shapes are defined as follows.

$$T_{operate} = TDM\ in\ seconds,\ when\ I > I_{pickup}$$

Eq. 18

$$T_{reset} = TDM\ in\ seconds$$

Eq. 19

The terms in the above equations are defined as follows.

- $T_{operate}$ represents the operate time in seconds.
- TDM represents the multiplier setting.
- I represents the input current.
- I_{pickup} represents the pickup current setting value.
- T_{reset} represents reset time in seconds, assuming the energy capacity is 100% and the reset mode is timed.

Recloser curves

The C90^Plus uses the FlexCurve™ feature to facilitate the programming of 41 recloser curves. Refer to the *FlexCurves* settings section for additional details on the recloser curves.

Phase time overcurrent

The phase time overcurrent element can provide a desired time delay operating characteristic versus the applied current or be used as a simple definite time element. The phase current input quantities may be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application.

Two methods of resetting operation are available: timed and instantaneous. For example, if the element reset characteristic is set to instantaneous and the element is blocked, the time accumulator will be cleared immediately.

The phase time overcurrent pickup can be dynamically reduced by a voltage restraint feature. This is accomplished via the multipliers corresponding to the phase-to-phase voltages of the voltage restraint characteristic curve. The pickup level is calculated as multiplier value times the programmed pickup. If the voltage restraint feature is disabled, the pickup level always remains at the set value.

Figure 93: Phase time overcurrent voltage restraint characteristic

Select the **Settings > Protection > Elements > Group 1 > Current > Phase TOC** menu item to open the phase time overcurrent configuration window.

Figure 94: Phase time overcurrent configuration settings

The following settings are available for each phase time overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase time overcurrent protection element.

Signal Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the phase time overcurrent protection element.

Input

Range: Phasor, RMS

Default: Phasor

This setting selects how phase current input quantities are interpreted by the C90^{Plus}. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the phase time overcurrent pickup level in per-unit values.

Curve

Range: IEEE Mod Inv, IEEE Very Inv, IEEE Ext Inv, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inv, IAC Ext Inv, IAC Very Inv, IAC Inverse, IAC Short Inv, I2t, Definite Time, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Mod Inv

This setting selects the time inverse overcurrent curve style.

TD Multiplier

Range: 0.00 to 600.00 in steps of 0.01

Default: 1.00

This setting specifies a multiple of the base curve shape specified by the **Curve** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

Reset

Range: Instantaneous, Timed

Default: Instantaneous

The "Instantaneous" reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The "Timed" reset method can be used where the relay must coordinate with electromechanical relays.

Voltage Restraint

Range: Enabled, Disabled

Default:

This setting enables and disabled the phase time overcurrent voltage restraint feature.

Block A

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks phase A of the phase time overcurrent element.

Block B

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks phase B of the phase time overcurrent element.

Block C

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks phase C of the phase time overcurrent element.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of phase time overcurrent events in the sequence of events recorder.

The logic for the phase time overcurrent 1 element is shown below. The logic is identical for all phase instantaneous overcurrent elements.

Figure 95: Phase time overcurrent 1 scheme logic
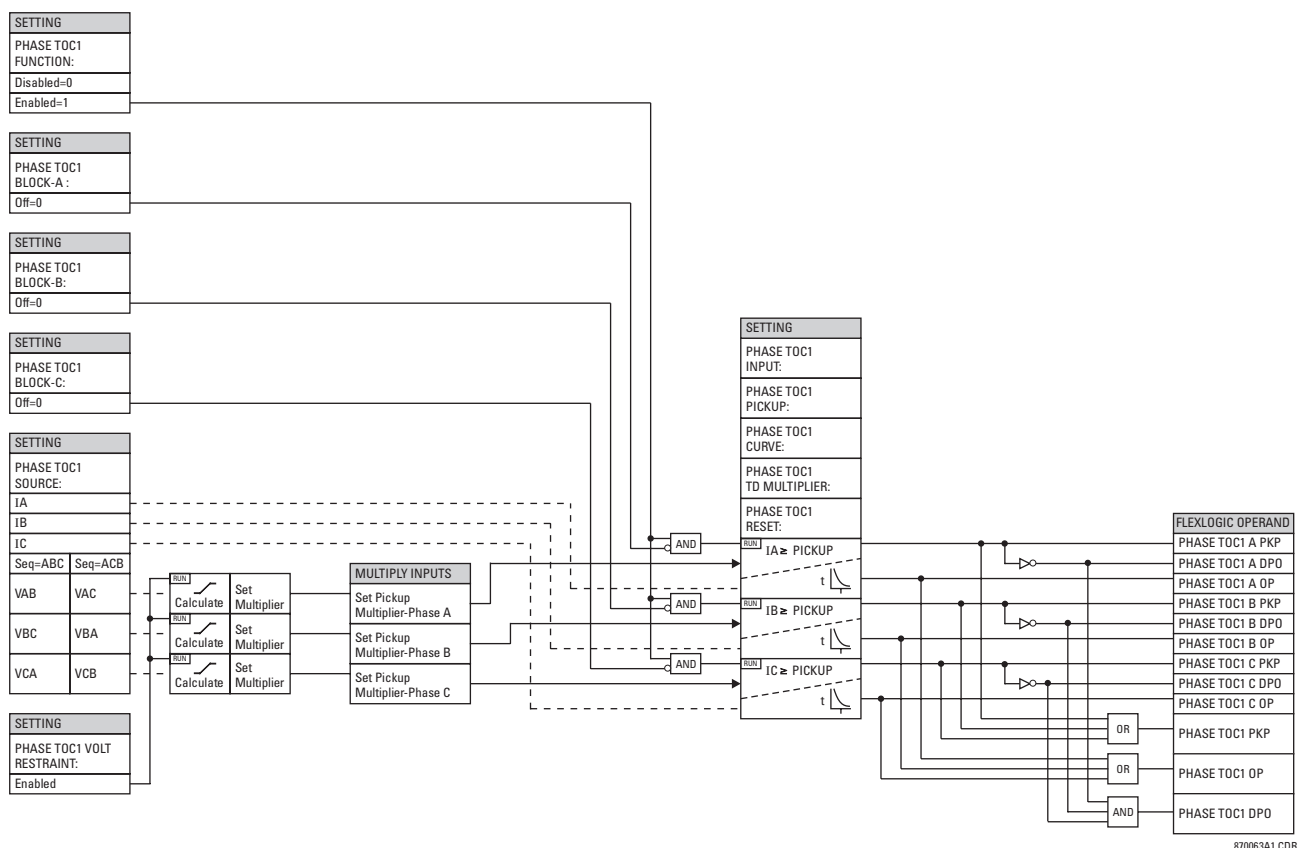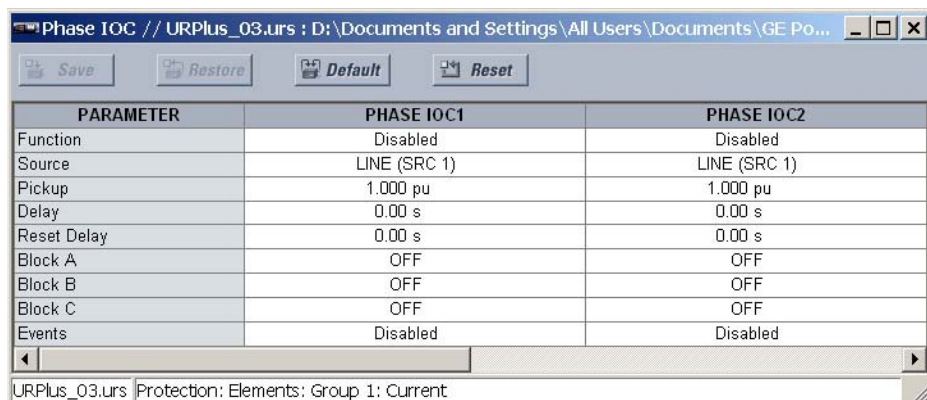
Phase instantaneous overcurrent

The phase instantaneous overcurrent element may be used as an instantaneous element with no intentional delay or as a definite time element. The input current is the fundamental phasor magnitude.

Select the **Settings > Protection > Elements > Group 1 > Current > Phase IOC** menu item to open the phase instantaneous overcurrent configuration window.

Figure 96: Phase instantaneous overcurrent configuration settings

The following settings are available for each phase instantaneous overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase instantaneous overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the phase instantaneous overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the phase instantaneous overcurrent pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting delays the assertion of the PHASE IOC OP operands. It is used to achieve timing coordination with other elements and relays.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a delay for the reset of the phase instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

Block A, Block B, Block C

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to these settings blocks phases A, B, and C, respectively, of the phase instantaneous overcurrent element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of phase instantaneous overcurrent events in the sequence of events recorder.

The logic for the phase instantaneous overcurrent 1 element is shown below. The logic is identical for all phase instantaneous overcurrent elements.

Figure 97: Phase instantaneous overcurrent 1 scheme logic
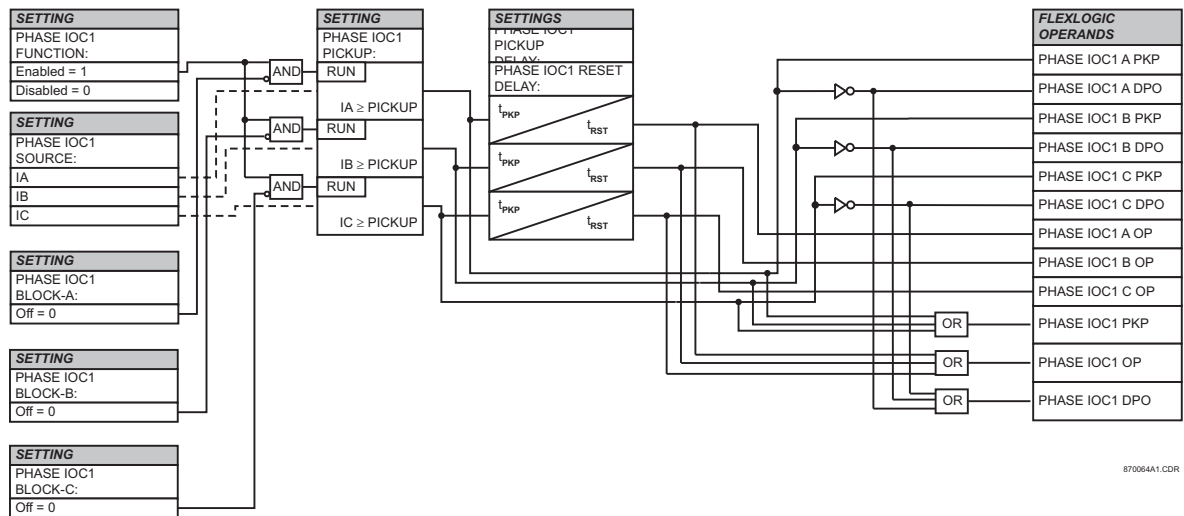
Phase directional overcurrent

The phase directional elements (one for each of phases A, B, and C) determine the phase current flow direction for steady state and fault conditions and can be used to control the operation of the phase overcurrent elements via the block inputs of these elements.

Figure 98: Phase A directional polarization

Phasors for phase A polarization

Vpol = VBC × (1/ECA) = polarizing voltage
IA = operating current
ECA = element characteristic angle at 30°
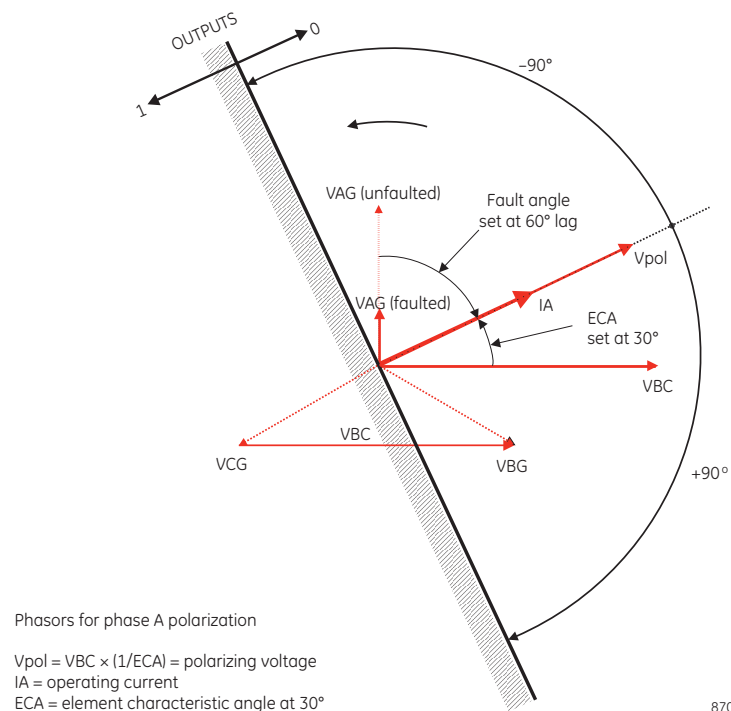
The phase directional overcurrent element is intended to apply a block signal to an overcurrent element to prevent an operation when current is flowing in a particular direction. The direction of current flow is determined by measuring the phase angle between the current from the phase CTs and the line-line voltage from the VTs, based on the 90° or quadrature connection. If there is a requirement to supervise overcurrent elements for flows in opposite directions, such as can happen through a bus-tie breaker, two phase directional elements should be programmed with opposite element characteristic angle (ECA) settings.

To increase security for three phase faults very close to the VTs used to measure the polarizing voltage, a voltage memory feature is incorporated. This feature stores the polarizing voltage the moment before the voltage collapses, and uses it to determine direction. The voltage memory remains valid for one second after the voltage has collapsed.

The main component of the phase directional element is the phase angle comparator with two inputs: the operating signal (phase current) and the polarizing signal (the line voltage, shifted in the leading direction by the characteristic angle, ECA).

The following table shows the operating and polarizing signals used for phase directional control.

Table 12: Phase directional overcurrent operating and polarizing signals

Phase	Operating signal	Polarizing signal	
		ABC phase sequence	ACB phase sequence
A	angle of IA	angle of VBC × (1∠ECA)	angle of VCB × (1∠ECA)
B	angle of IB	angle of VCA × (1∠ECA)	angle of VAC × (1∠ECA)
C	angle of IC	angle of VAB × (1∠ECA)	angle of VBA × (1∠ECA)

When the phase directional overcurrent element is disabled or the operating current is below 5% × CT nominal, the element output is logic 0.

When the phase directional overcurrent element is enabled, the operating current is above 5% × CT nominal, and the polarizing voltage is above the **Voltage Cut Off Level** setting value, the element output is dependent on the phase angle between the operating and polarizing signals. The element output is logic 0 when the operating current is within polarizing voltage ±90°; for all other angles, the element output is logic 1.
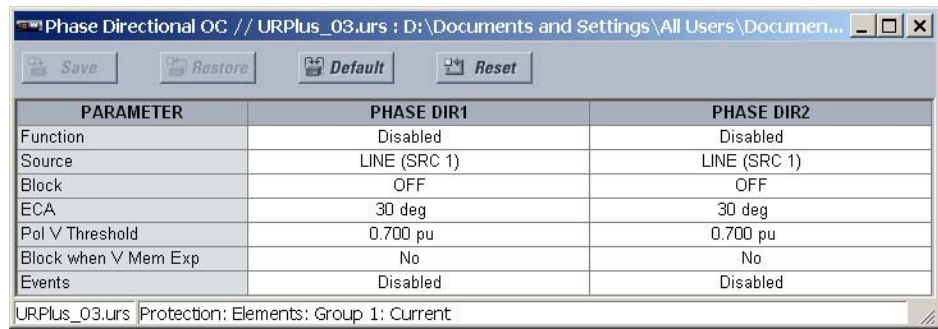
Once the voltage memory has expired, the phase overcurrent elements under directional control can be set to block or trip on overcurrent. When the **Block When Voltage Memory Expires** value is "Yes", the directional element will block the operation of any phase overcurrent element under directional control when voltage memory expires. When the **Block When Voltage Memory Expires** value is "No", the directional element allows tripping of phase overcurrent elements under directional control when voltage memory expires.

In all cases, directional blocking will be permitted to resume when the polarizing voltage becomes greater than the polarizing voltage threshold.

NOTE

The phase directional element responds to the forward load current. In the case of a following reverse fault, the element needs some time – in the order of 8 ms – to establish a blocking signal. Some protection elements such as instantaneous overcurrent may respond to reverse faults before the blocking signal is established. Therefore, a coordination time of at least 10 ms must be added to all the instantaneous protection elements under the supervision of the phase directional element. If current reversal is of a concern, a longer delay – in the order of 20 ms – may be needed.

Select the **Settings > Protection > Elements > Group 1 > Current > Phase Directional OC** menu item to open the phase directional overcurrent configuration window.

Figure 99: Phase directional overcurrent configuration settings

The following settings are available for each phase directional overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase directional overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting is used to select the source for the operating and polarizing signals. The operating current for the phase directional element is the phase current for the selected current source. The polarizing voltage is the line voltage from the phase VTs, based on the 90° or quadrature connection and shifted in the leading direction by the element characteristic angle (ECA).

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the phase directional overcurrent element.

ECA

Range: 0 to 359° in steps of 1

Default: 30°

This setting specifies the element characteristic angle; that is, the angle by which the polarizing voltage is shifted in the leading direction to achieve dependable operation. In the design of the C90^{Plus} protection elements, a block is applied to an element by asserting logic 1 at the blocking input. The phase directional overcurrent element should be programmed via this setting so that the output is logic 1 for current in the non-tripping direction.

Polarizing Voltage Threshold

Range: 0.000 to 3.000 pu in steps of 0.001

Default: 0.700 pu

This setting is used to establish the minimum level of voltage for which the phase angle measurement is reliable. The setting is based on VT accuracy.

Block When Voltage Memory Expires

Range: Yes, No

Default: No

This setting is used to select the required operation upon expiration of voltage memory. When set to "Yes", the directional element blocks the operation of any phase overcurrent element under directional control, when voltage memory expires; when set to "No", the directional element allows tripping of phase overcurrent elements under directional control.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of phase directional overcurrent events in the sequence of events recorder.

The logic for the phase directional overcurrent 1 element is shown below. The logic is identical for all phase directional overcurrent elements.
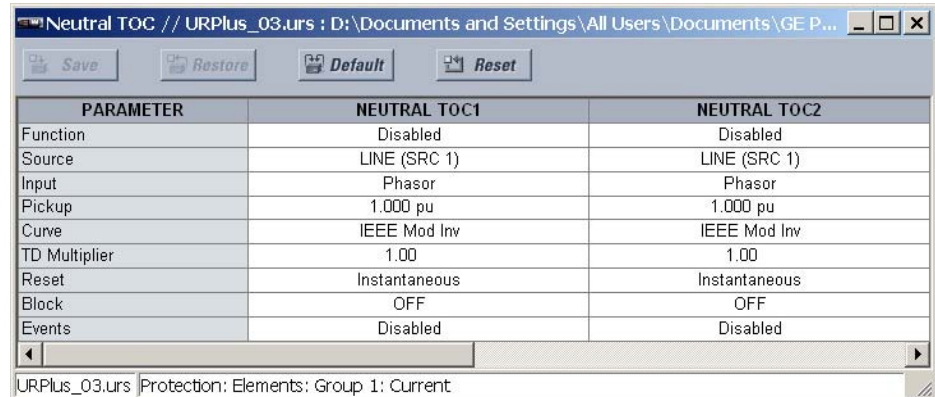
Figure 100: Phase directional overcurrent 1 scheme logic
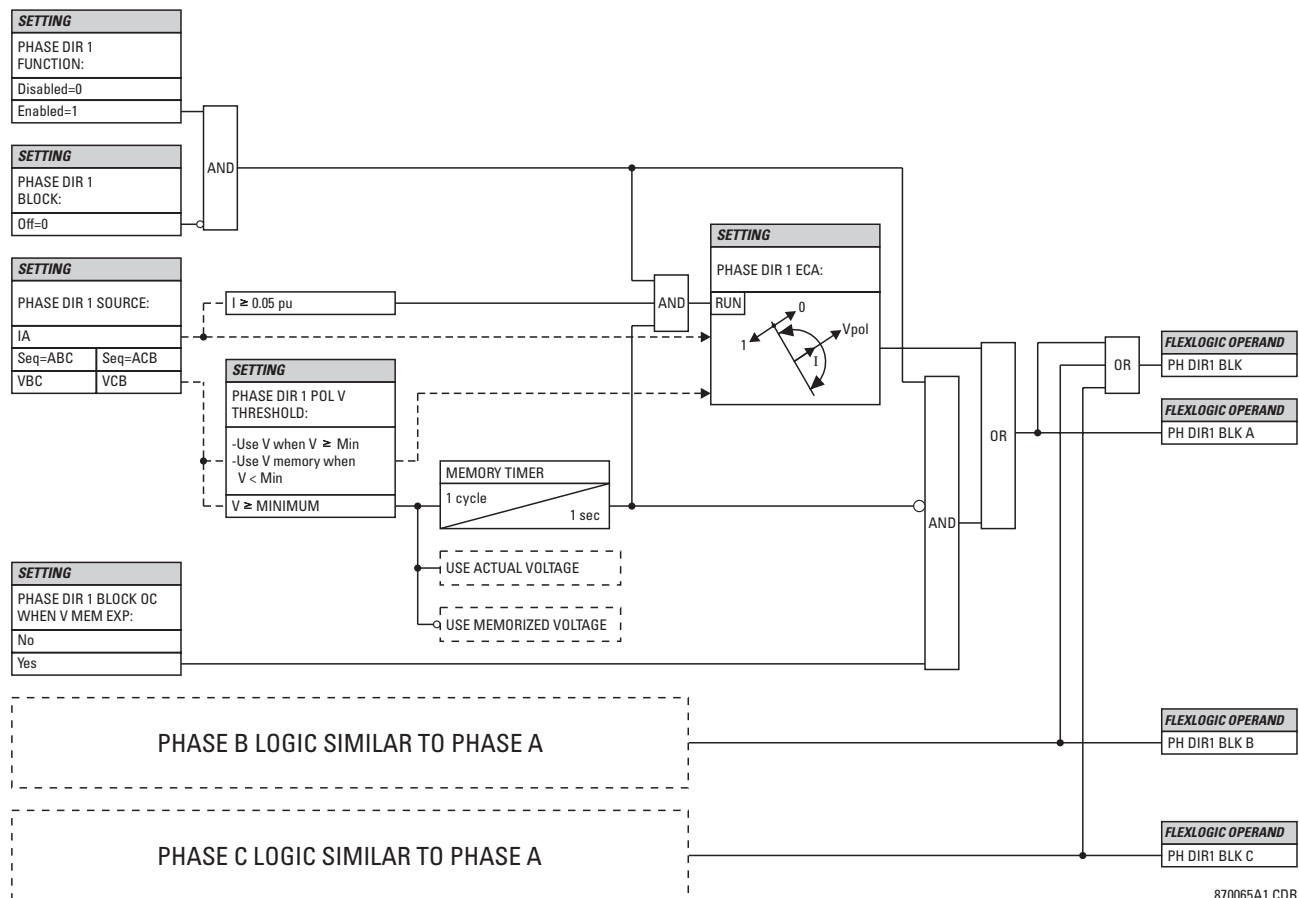
Neutral time overcurrent

The neutral time overcurrent element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple definite time element. The neutral current input value is a quantity calculated as 3I0 from the phase currents and may be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application.

Two methods of resetting operation are available: timed and instantaneous. When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is instantaneous and the element is blocked, the time accumulator will be cleared immediately.

Select the **Settings > Protection > Elements > Group 1 > Current > Neutral TOC** menu item to open the neutral time overcurrent configuration window.

Figure 101: Neutral time overcurrent configuration settings

The following settings are available for each neutral time overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the neutral time overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the neutral time overcurrent protection element.

Input

Range: Phasor, RMS

Default: Phasor

This setting selects how neutral current input quantities are interpreted by the C90^{Plus}. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the neutral time overcurrent pickup level in per-unit values.

Curve

Range: IEEE Mod Inv, IEEE Very Inv, IEEE Ext Inv, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inv, IAC Ext Inv, IAC Very Inv, IAC Inverse, IAC Short Inv, I2t, Definite Time, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Mod Inv

This setting selects the inverse time overcurrent curve style.

TD Multiplier

Range: 0.00 to 600.00 in steps of 0.01
Default: 1.00

This setting specifies a multiple of the base curve shape specified by the **Curve** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

Reset

Range: Instantaneous, Timed
Default: Instantaneous

The "Instantaneous" reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The "Timed" reset method can be used where the relay must coordinate with electromechanical relays.

Block

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks operation of the neutral time overcurrent element.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of neutral time overcurrent events in the sequence of events recorder.

The logic for the neutral time overcurrent 1 element is shown below. The logic is identical for all neutral time overcurrent elements.

Figure 102: Neutral time overcurrent 1 logic
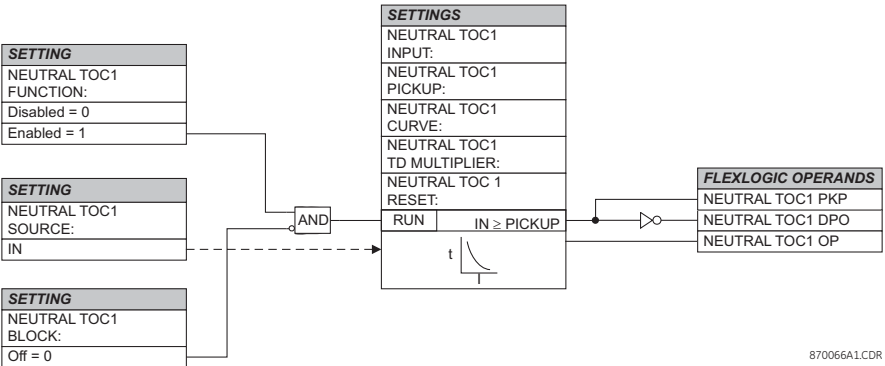
Neutral instantaneous overcurrent

The neutral instantaneous overcurrent element may be used as an instantaneous function with no intentional delay or as a definite time function. The element essentially responds to the magnitude of a neutral current fundamental frequency phasor calculated from the phase currents. A positive-sequence restraint is applied for better performance. A small portion (6.25%) of the positive-sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity of the element as follows.

$$I_{op} = 3 \times (|I\_0| - K \cdot |I\_1|), \text{ where } k = \frac{1}{16}$$

Eq. 20

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from:

- System unbalances under heavy load conditions.
- Transformation errors of current transformers (CTs) during double-line and three-phase faults.
- Switch-off transients during double-line and three-phase faults.

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on how test currents are injected into the relay. For single-phase injection, the operating quantity is:
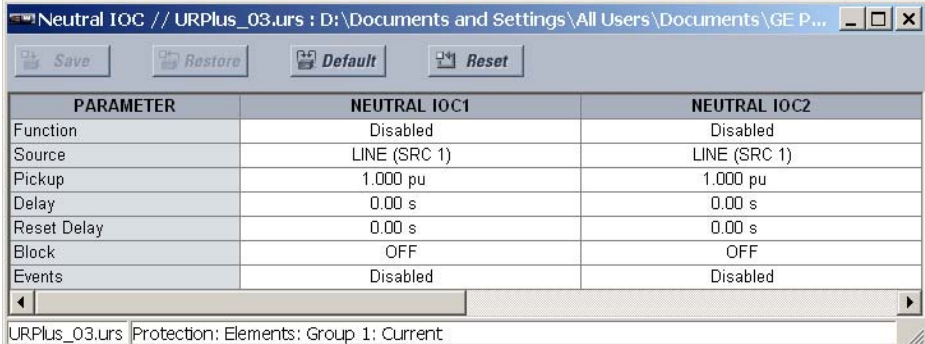
$$I_{op} = 0.9375 \times I_{injected}$$

Eq. 21

For three-phase pure zero-sequence injection, the operating quantity is:

$$I_{op} = 3 \times I_{injected}$$

Eq. 22

Select the **Settings > Protection > Elements > Group 1 > Current > Neutral IOC** menu item to open the neutral instantaneous overcurrent configuration window.

Figure 103: Neutral instantaneous overcurrent configuration settings

The following settings are available for each neutral instantaneous overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the neutral instantaneous overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the neutral instantaneous overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the neutral instantaneous overcurrent pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting delays the assertion of the NEUTRAL IOC OP operands. It is used to achieve timing coordination with other elements and relays.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 0.00 seconds

This setting specifies a delay for the reset of the neutral instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

Block

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks operation of the neutral instantaneous overcurrent element.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of neutral instantaneous overcurrent events in the sequence of events recorder.

The logic for the neutral instantaneous overcurrent 1 element is shown below. The logic is identical for all neutral instantaneous overcurrent elements.

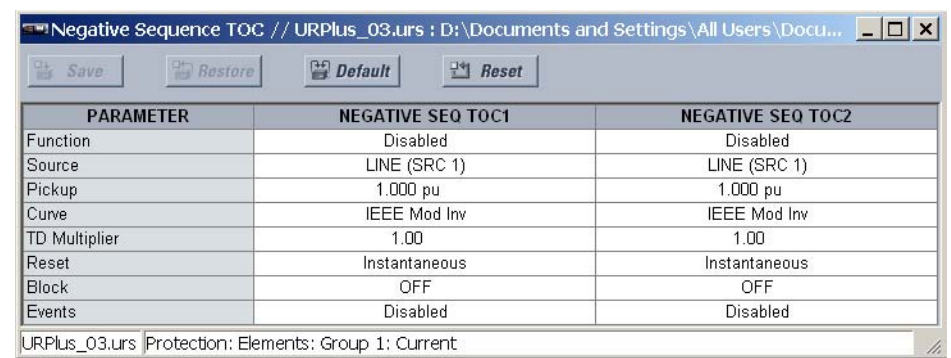**Figure 104: Neutral instantaneous overcurrent 1 scheme logic**
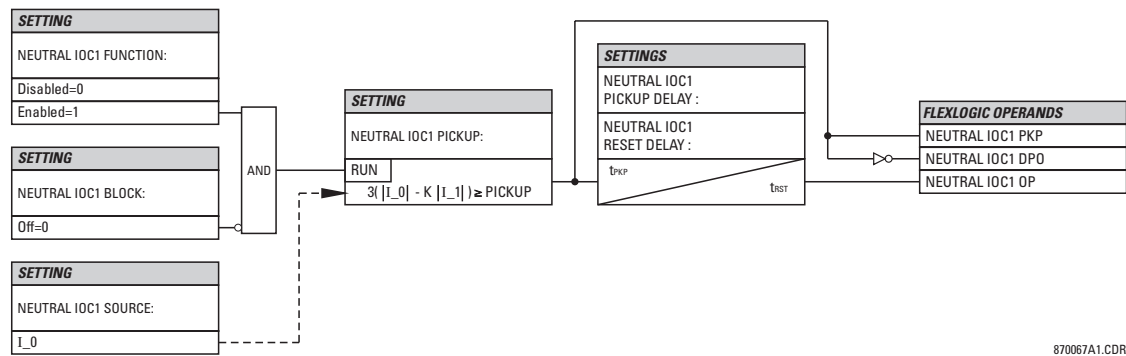
Neutral directional overcurrent

There are two neutral directional overcurrent protection elements available. The element provides both forward and reverse fault direction indications the NEUTRAL DIR OC1 FWD and NEUTRAL DIR OC1 REV operands, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as forward or reverse, respectively (directional unit).

The overcurrent unit responds to the magnitude of a fundamental frequency phasor of the either the neutral current calculated from the phase currents or the ground current. There are two separate pickup settings for the forward- and reverse-looking functions, respectively. If set to use the calculated $3I_0$, the element applies a positive-sequence restraint for better performance: a small user-programmable portion of the positive–sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity.

$$I_{op} = 3 \times \left(\left| I\_0 \right| - K \times \left| I\_1 \right| \right)$$

Eq. 23

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from:

- System unbalances under heavy load conditions.

- Transformation errors of current transformers (CTs) during double-line and three-phase faults.
- Switch-off transients during double-line and three-phase faults.

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay. For single-phase injection, the operating quantity is:

$$I_{op} = (1 - K) \times I_{injected}$$

Eq. 24

For three-phase pure zero-sequence injection, the operating quantity is:

$$I_{op} = 3 \times I_{injected}$$

Eq. 25

The positive-sequence restraint is removed for low currents. If the positive-sequence current is below 0.8 pu, the restraint is removed by changing the constant *K* to zero. This facilitates better response to high-resistance faults when the unbalance is very small and there is no danger of excessive CT errors as the current is low.

The directional unit uses the zero-sequence current (I_0) or ground current (IG) for fault direction discrimination and may be programmed to use either zero-sequence voltage ("Calculated V0" or "Measured VX"), ground current (IG), or both for polarizing. The phasors for the neutral directional overcurrent element directional unit are described below, where V_0 is the zero-sequence voltage, I_0 is the zero-sequence current, ECA is the element characteristic angle, and IG is the ground current, and:

$$V\_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$

Eq. 26

$$I\_0 = \frac{1}{3}I_N = \frac{1}{3}(I_A + I_B + I_C)$$

Eq. 27

Table 13: Phasors for "Calculated 3I_0" configuration

Polarizing mode	Direction	Compared phasors
Voltage	Forward	–V_0 + Z_offset × I_0 and I_0 × 1∠ECA
	Reverse	–V_0 + Z_offset × –I_0 and I_0 × 1∠ECA
Current	Forward	IG and I_0
	Reverse	IG and –I_0
Dual	Forward	–V_0 + Z_offset × I_0 and I_0 × 1∠ECA or IG and I_0
	Reverse	–V_0 + Z_offset × I_0 and I_0 × 1∠ECA or IG and –I_0

The operating current for overcurrent unit for the "Calculated 3I_0" configuration is:

$$I_{op} = 3 \times (|I\_0| - K \times |I\_1|) \quad \text{if } |I\_1| > 0.8\,\text{pu}$$

$$I_{op} = 3 \times |I\_0| \quad \text{if } |I\_1| \leq 0.8\,\text{pu}$$

Eq. 28

Table 14: Phasors for "Measured IG" configuration

Polarizing mode	Direction	Compared phasors
Voltage	Forward	–V_0 + Z_offset × IG/3 and IG × 1∠ECA
	Reverse	–V_0 + Z_offset × –IG/3 and –IG × 1∠ECA

The operating current for overcurrent unit for the "Measured IG" configuration is:

$$I_{op} = |IG|$$

Eq. 29

When the **Polarizing Volt** setting is programmed as "Measured VX", one-third of this voltage is used in place of V_0. The following figure explains the voltage polarized directional unit of the element and illustrates the phase angle comparator characteristics for a phase A to ground fault, with the element characteristic angle equal to 90° (center line of operating

characteristic), forward limit angle equal to 80° (the ± angular limit with the ECA for operation), and reverse limit angle equal to 80° (the ± angular limit with the ECA for operation).

Figure 105: Neutral directional voltage polarized characteristics
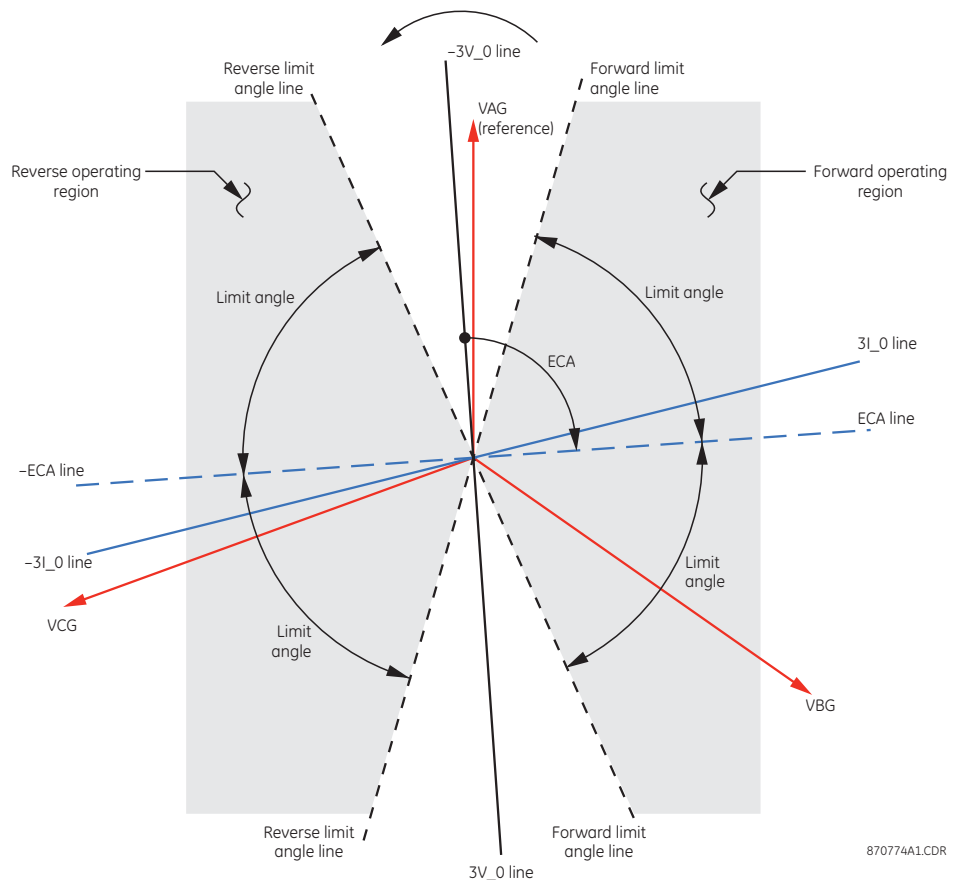
The neutral directional overcurrent element incorporates a current reversal logic. If the reverse direction is indicated for at least 1.25 of a power system cycle, the prospective forward indication will be delayed by 1.5 of a power system cycle. The element is designed to emulate an electromechanical directional device. Larger operating and polarizing signals will result in faster directional discrimination bringing more security to the element operation.

The forward-looking function is designed to be more secure as compared to the reverse-looking function, and therefore, should be used for the tripping direction. The reverse-looking function is designed to be faster as compared to the forward-looking function and should be used for the blocking direction. This allows for better protection coordination.

The above bias should be taken into account when using the neutral directional overcurrent element to directionalize other protection elements.
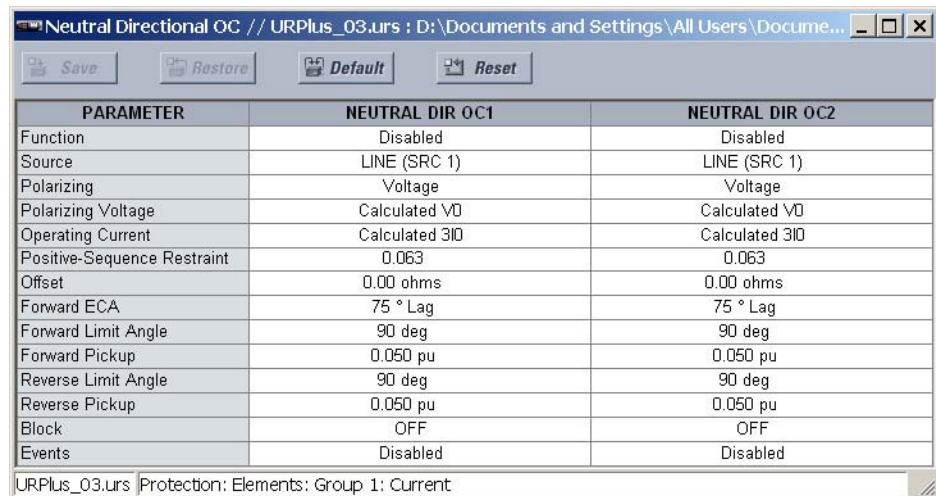
NOTE

Proper application of this element requires that the operating current and the polarizing voltage (or current) be measured from the same side of the transformer.

Select the **Settings > Protection > Elements > Group 1 > Current > Neutral Directional OC** menu item to open the neutral directional overcurrent configuration window.

Figure 106: Neutral directional overcurrent configuration settings

The following settings are available for each neutral directional overcurrent element.

Function

Default: Enabled, Disabled

Default: Disabled

This setting enables and disables the neutral directional overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the neutral directional overcurrent protection element.

Polarizing

Range: Voltage, Current, Dual

Default: Voltage

This setting selects the polarizing mode for the directional unit.

If voltage polarizing is selected, the element uses the zero-sequence voltage angle for polarization. The user can use either the zero-sequence voltage V_0 calculated from the phase voltages, or the zero-sequence voltage supplied externally as the auxiliary voltage Vx, both from the neutral directional **Source** setting.

The calculated V_0 can be used as polarizing voltage only if the voltage transformers are connected in Wye. The auxiliary voltage can be used as the polarizing voltage provided the **Auxiliary VT Connection** setting is "Vn" and the auxiliary voltage is connected to a zero-sequence voltage source (such as open delta connected secondary of VTs).

The zero-sequence (V_0) or auxiliary voltage (Vx), accordingly, must be higher than the **Voltage Cut-Off Level** value to be validated for use as a polarizing signal. If the polarizing signal is invalid, neither forward nor reverse indication is given.

If current polarizing is selected, the element uses the ground current angle connected externally and configured under the neutral directional **Source** setting for polarization. The ground CT must be connected between the ground and neutral point of an adequate local source of ground current. The ground current must be higher than 0.05 pu to be validated as a polarizing signal. If the polarizing signal is not valid, neither forward nor reverse indication is given.

For a choice of current polarizing, it is recommended that the polarizing signal be analyzed to ensure that a known direction is maintained irrespective of the fault location. For example, if using an autotransformer neutral current as a polarizing source,

it should be ensured that a reversal of the ground current does not occur for a high-side fault. The low-side system impedance should be assumed minimal when checking for this condition. A similar situation arises for a wye/delta/wye transformer, where current in one transformer winding neutral may reverse when faults on both sides of the transformer are considered.

If dual polarizing is selected, the element performs both directional comparisons as described above. A given direction is confirmed if either voltage or current comparators indicate so. If a conflicting (simultaneous forward and reverse) indication occurs, the forward direction overrides the reverse direction.

Polarizing Voltage

Range: Calculated V0, Measured VX

Default: Calculated V0

This setting selects the polarizing voltage used by the directional unit when the voltage or dual polarizing mode is set. The polarizing voltage can be programmed to be either the zero-sequence voltage calculated from the phase voltages ("Calculated V0") or supplied externally as an auxiliary voltage ("Measured VX").

Operating Current

Range: Calculated 3I0, Measured IG

Default: Calculated 3I0

This setting indicates whether the $3I\_0$ current calculated from the phase currents, or the ground current shall be used by this protection. This setting acts as a switch between the neutral and ground modes of operation (ANSI devices 67N and 67G). If set to "Calculated 3I0", the element uses the phase currents and applies the positive-sequence restraint; if set to "Measured IG", the element uses ground current supplied to the ground CT of the CT bank configured as the neutral directional "Source". If this setting is "Measured IG", then the **Polarizing** setting must be "Voltage", as it is not possible to use the ground current as an operating and polarizing signal simultaneously.

Positive-Sequence Restraint

Range: 0.000 to 0.500 in steps of 0.001

Default: 0.063

This setting controls the amount of the positive-sequence restraint. Set to 0.063 for backward compatibility with firmware revisions 3.40 and earlier. Set to zero to remove the restraint. Set higher if large system unbalances or poor CT performance are expected.

Offset

Range: 0.00 to 250.00 ohms in steps of 0.01

Default: 0.00 ohms

This setting specifies the offset impedance used by this protection. The primary application for the offset impedance is to guarantee correct identification of fault direction on series compensated lines. In regular applications, the offset impedance ensures proper operation even if the zero-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the zero-sequence impedance of the protected circuit. Practically, it shall be several times smaller. The offset impedance shall be entered in secondary ohms.

Forward ECA

Range: –90 to 90° in steps of 1

Default: –70°

This setting defines the characteristic angle (ECA) for the forward direction in the voltage polarizing mode. The current polarizing mode uses a fixed ECA of 0°. The ECA in the reverse direction is the angle set for the forward direction shifted by 180°.

Forward Limit Angle

Range: 40 to 90° in steps of 1

Default: 90°

This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.

Forward Pickup

Range: 0.002 to 30.000 pu in steps of 0.001

Default: 0.050 pu

This setting defines the pickup level for the overcurrent unit of the element in the forward direction. When selecting this setting it must be kept in mind that the design uses a positive-sequence restraint technique for the "Calculated 3I0" mode of operation.

Reverse Limit Angle

Range: 40 to 90° in steps of 1

Default: 90°

This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.

Reverse Pickup

Range: 0.002 to 30.000 pu in steps of 0.001

Default: 0.050 pu

This setting defines the pickup level for the overcurrent unit of the element in the reverse direction. When selecting this setting it must be kept in mind that the design uses a positive-sequence restraint technique for the "Calculated 3I0" mode of operation.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the neutral directional overcurrent element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of neutral directional overcurrent events in the sequence of events recorder.

The logic for the neutral directional overcurrent 1 element is shown below. The logic is identical for both neutral directional overcurrent elements.

Figure 107: Neutral directional overcurrent 1 scheme logic
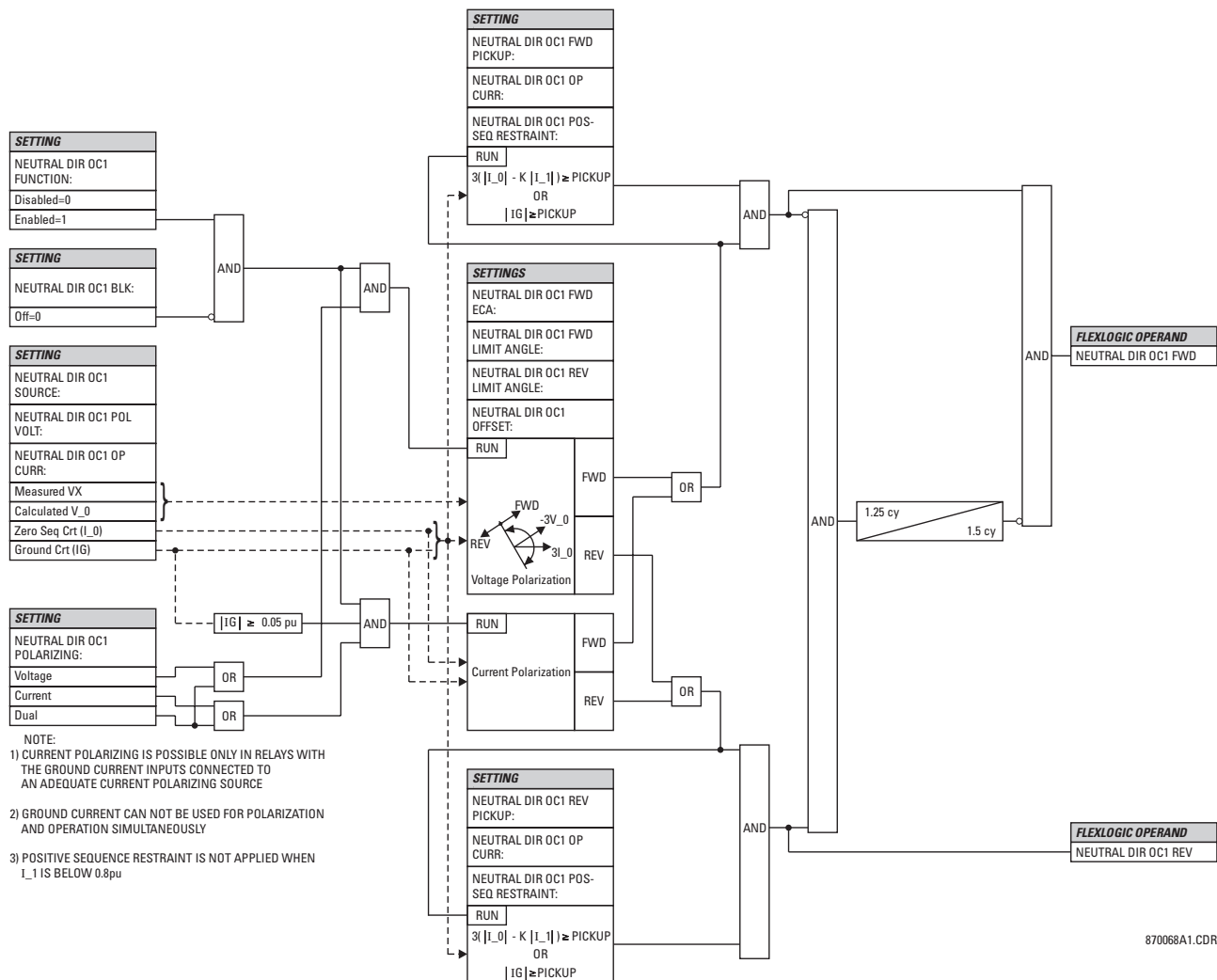
870068A1.CDR

Ground time overcurrent

The ground time overcurrent element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple definite time element. The ground current input value is the quantity measured by the ground input CT and is the fundamental phasor or RMS magnitude. Two methods of resetting operation are available; timed and instantaneous. When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to instantaneous and the element is blocked, the time accumulator will be cleared immediately.

NOTE

These elements measure the current that is connected to the ground channel of an AC module. This channel may be equipped with a standard or sensitive input. The conversion range of a standard channel is from 0.02 to 46 times the CT rating. The conversion range of a sensitive channel is from 0.002 to 4.6 times the CT rating.

Select the **Settings > Protection > Elements > Group 1 > Current > Ground TOC** menu item to open the ground time overcurrent configuration window.

Figure 108: Ground time overcurrent configuration settings

The following settings are available for each ground time overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the ground time overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the ground time overcurrent protection element.

Input

Range: Phasor, RMS

Default: Phasor

This setting selects how ground current input quantities are interpreted by the C90^{Plus}. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the ground time overcurrent pickup level in per-unit values.

Curve

Range: IEEE Mod Inv, IEEE Very Inv, IEEE Ext Inv, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inv, IAC Ext Inv, IAC Very Inv, IAC Inverse, IAC Short Inv, I2t, Definite Time, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Mod Inv

This setting selects the inverse time overcurrent curve style.

TD Multiplier

Range: 0.00 to 600.00 in steps of 0.01

Default: 1.00

This setting specifies a multiple of the base curve shape specified by the **Curve** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

Reset

Range: Instantaneous, Timed

Default: Instantaneous

The "Instantaneous" reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The "Timed" reset method can be used where the relay must coordinate with electromechanical relays.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the ground time overcurrent element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of ground time overcurrent events in the sequence of events recorder.

The logic for the ground time overcurrent 1 element is shown below. The logic is identical for all ground time overcurrent elements.

Figure 109: Ground time overcurrent scheme logic
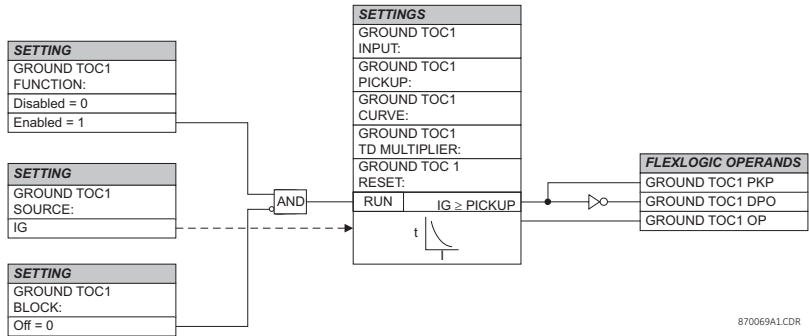
Ground instantaneous overcurrent

The ground instantaneous overcurrent element may be used as an instantaneous element with no intentional delay or as a definite time element. The ground current input is the quantity measured by the ground input CT and is the fundamental phasor magnitude.

NOTE

These elements measure the current that is connected to the ground channel of an AC module. This channel may be equipped with a standard or sensitive input. The conversion range of a standard channel is from 0.02 to 46 times the CT rating. The conversion range of a sensitive channel is from 0.002 to 4.6 times the CT rating.

Select the **Settings > Protection > Elements > Group 1 > Current > Ground IOC** menu item to open the ground instantaneous overcurrent configuration window.

Figure 110: Ground instantaneous overcurrent configuration settings

The following settings are available for each ground instantaneous overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the ground instantaneous overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the ground instantaneous overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the ground instantaneous overcurrent pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting delays the assertion of the GROUND IOC OP operands. It is used to achieve timing coordination with other elements and relays.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a delay for the reset of the ground instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the ground instantaneous overcurrent element.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of ground instantaneous overcurrent events in the sequence of events recorder.

The logic for the ground instantaneous overcurrent 1 element is shown below. The logic is identical for all ground instantaneous overcurrent elements.

Figure 111: Ground instantaneous overcurrent scheme logic
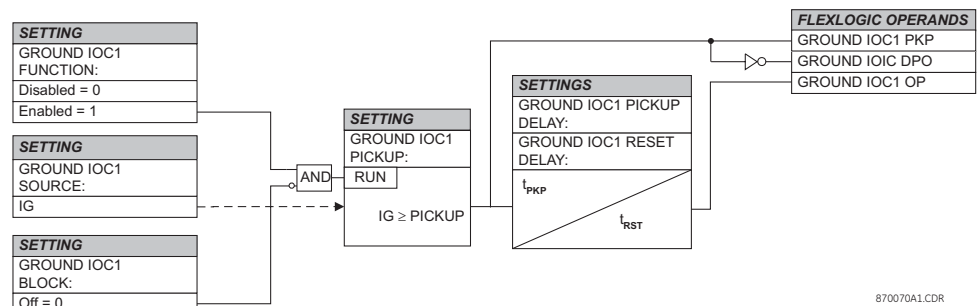
Negative-sequence time overcurrent

The negative-sequence time overcurrent element may be used to determine and clear unbalance in the system. The input for calculating negative-sequence current is the fundamental phasor value.

Two methods of resetting operation are available: timed and instantaneous. When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to instantaneous and the element is blocked, the time accumulator will be cleared immediately.

Select the **Settings > Protection > Elements > Group 1 > Current > Negative Sequence TOC** menu item to open the negative-sequence time overcurrent configuration window.

Figure 112: Negative-sequence time overcurrent configuration settings

PARAMETER	NEGATIVE SEQ TOC1	NEGATIVE SEQ TOC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Pickup	1.000 pu	1.000 pu
Curve	IEEE Mod Inv	IEEE Mod Inv
TD Multiplier	1.00	1.00
Reset	Instantaneous	Instantaneous
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each negative-sequence time overcurrent element.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the negative-sequence time overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the negative-sequence time overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the neutral time overcurrent pickup level in per-unit values.

Curve

Range: IEEE Mod Inv, IEEE Very Inv, IEEE Ext Inv, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inv, IAC Ext Inv, IAC Very Inv, IAC Inverse, IAC Short Inv, I2t, Definite Time, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Mod Inv

This setting selects the inverse time overcurrent curve style.

TD Multiplier

Range: 0.00 to 600.00 in steps of 0.01

Default: 1.00

This setting specifies a multiple of the base curve shape specified by the **Curve** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

Reset

Range: Instantaneous, Timed

Default: Instantaneous

The "Instantaneous" reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The "Timed" reset method can be used where the relay must coordinate with electromechanical relays.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the negative-sequence time overcurrent element.

Events

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of negative-sequence time overcurrent events in the sequence of events recorder.

The logic for the negative-sequence time overcurrent 1 element is shown below. The logic is identical for all negative-sequence time overcurrent elements.

Figure 113: Negative-sequence time overcurrent scheme logic
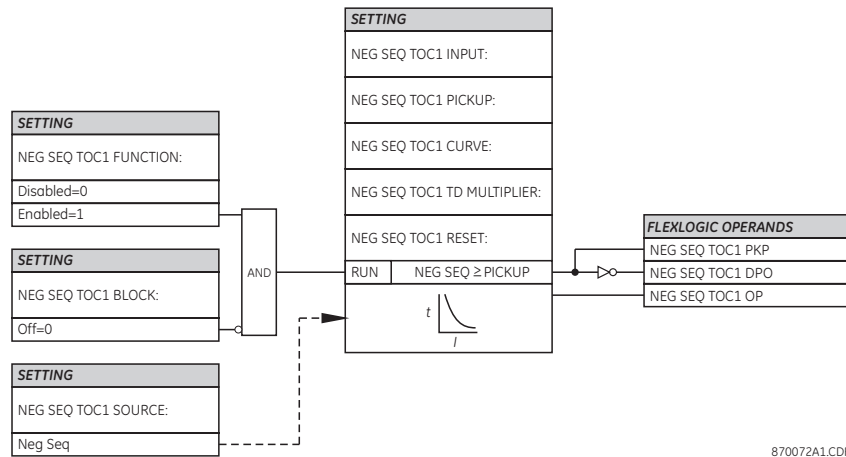
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Negative-sequence instantaneous overcurrent

The negative-sequence instantaneous overcurrent element may be used as an instantaneous function with no intentional delay or as a definite time function. The element responds to the negative-sequence current fundamental frequency phasor magnitude (calculated from the phase currents) and applies a positive-sequence restraint for better performance: a small portion (12.5%) of the positive-sequence current magnitude is subtracted from the negative-sequence current magnitude when forming the operating quantity.

$$I_{op} = \left| I\_2 \right| - K \times \left| I\_1 \right| \quad \text{where } K = \frac{1}{8}$$

Eq. 30

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative-sequence currents resulting from:

- System unbalances under heavy load conditions.
- Transformation errors of current transformers (CTs) during three-phase faults.
- Fault inception and switch-off transients during three-phase faults.

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on how the test currents are injected into the relay. The operating quantity for single-phase injection is:

$$I_{op} = 0.2917 \times I_{injected}$$

Eq. 31

The operating quantity for three-phase injection, opposite rotation, is:

$$I_{op} = I_{injected}$$

Eq. 32

Select the **Settings > Protection > Elements > Group 1 > Current > Negative Sequence IOC** menu item to open the negative-sequence instantaneous overcurrent configuration window.

Figure 114: Negative-sequence instantaneous overcurrent configuration settings

The following settings are available for each negative-sequence instantaneous overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the negative-sequence instantaneous overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the negative-sequence instantaneous overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the negative-sequence instantaneous overcurrent pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting delays the assertion of the NEG SEQ IOC OP operands. It is used to achieve timing coordination with other elements and relays.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a delay for the reset of the phase instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the negative-sequence instantaneous overcurrent element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of negative-sequence instantaneous overcurrent events in the sequence of events recorder.

The logic for the negative-sequence instantaneous overcurrent 1 element is shown below. The logic is identical for all negative-sequence instantaneous overcurrent elements.

Figure 115: Negative-sequence instantaneous overcurrent scheme logic
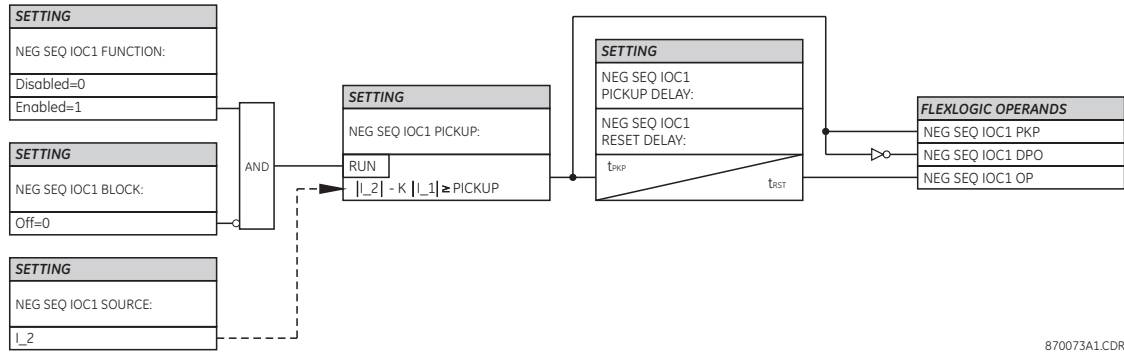
Negative-sequence directional overcurrent

There are two negative-sequence directional overcurrent protection elements available. The element provides both forward and reverse fault direction indications through its output operands NEG SEQ DIR OC1 FWD and NEG SEQ DIR OC1 REV, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as forward or reverse, respectively (directional unit).

The overcurrent unit of the element essentially responds to the magnitude of a fundamental frequency phasor of either the negative-sequence or zero-sequence current as per user selection. The zero-sequence current should not be mistaken with the neutral current, as there is a factor of 3 difference.

A positive-sequence restraint is applied for better performance: a small user-programmable portion of the positive-sequence current magnitude is subtracted from the negative or zero-sequence current magnitude, respectively, when forming the element operating quantity.

$$I_{op} = \left| I\_2 \right| - K \times \left| I\_1 \right| \quad \text{or} \quad I_{op} = \left| I\_0 \right| - K \times \left| I\_1 \right|$$

Eq. 33

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative and zero-sequence currents resulting from:

- System unbalances under heavy load conditions.
- Transformation errors of current transformers (CTs).
- Fault inception and switch-off transients.

The positive-sequence restraint must be considered when testing for pick-up accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay:

- Single-phase injection: $I_{op} = 1/3 \times (1 - K) \times I_{injected}$.
- Three-phase pure zero or negative-sequence injection, respectively: $I_{op} = I_{injected}$.
- The directional unit uses the negative-sequence current and voltage for fault direction discrimination.

The following tables define the negative-sequence directional overcurrent element.

Table 15: Negative-sequence directional overcurrent unit

Mode	Operating current
Negative-sequence	$I_{op} = |I\_2| - K \times I\_1|$
Zero-sequence	$I_{op} = |I\_0| - K \times I\_1|$

Table 16: Negative-sequence directional unit

Mode	Direction	Compared phasors
Negative-sequence	Forward	$-V\_2 + Z\_offset \times I\_2$ and $I\_2 \times 1\angle ECA$
	Reverse	$-V\_2 + Z\_offset \times I\_2$ and $-(I\_2 \times 1\angle ECA)$
Zero-sequence	Forward	$-V\_0 + Z\_offset \times I\_0$ and $I\_0 \times 1\angle ECA$
	Reverse	$-V\_0 + Z\_offset \times I\_0$ and $-(I\_0 \times 1\angle ECA)$

The negative-sequence voltage must be higher than the **Voltage Cut-Off Level** value to be validated for use as a polarizing signal. If the polarizing signal is not validated neither forward nor reverse indication is given. The following figure explains the usage of the voltage polarized directional unit of the element.

Figure 116: Negative-sequence directional characteristics
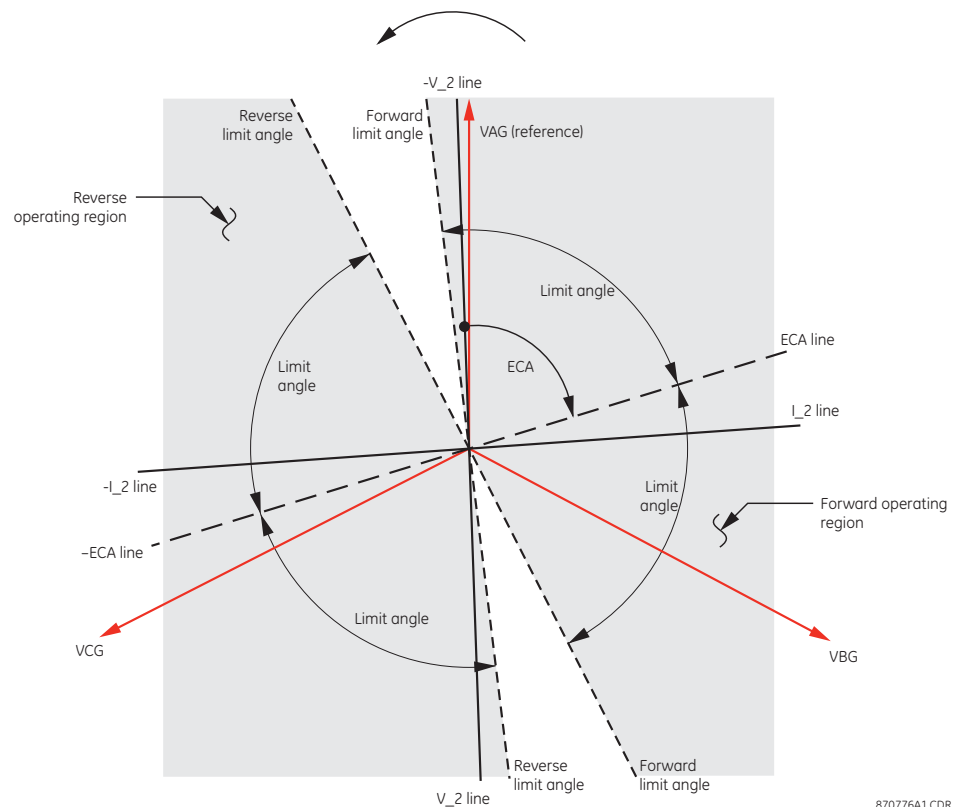
The forward-looking function is designed to be more secure as compared to the reverse-looking function, and therefore, should be used for the tripping direction. The reverse-looking function is designed to be faster as compared to the forward-looking function and should be used for the blocking direction. This allows for better protection coordination. The above bias should be taken into account when using the negative-sequence directional overcurrent element to directionalize other protection elements.

Select the **Settings > Protection > Elements > Group 1 > Current > Negative Sequence Directional OC** menu item to open the negative-sequence directional overcurrent configuration window.

Figure 117: Negative-sequence directional overcurrent configuration settings

PARAMETER	NEGATIVE SEQ DIR OC1	NEGATIVE SEQ DIR OC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Offset	0.00 ohms	0.00 ohms
Type	Neg Sequence	Neg Sequence
Positive-Sequence Restraint	0.063	0.063
Forward ECA	75 ° Lag	75 ° Lag
Forward Limit Angle	90 deg	90 deg
Forward Pickup	0.05 pu	0.05 pu
Reverse Limit Angle	90 deg	90 deg
Reverse Pickup	0.05 pu	0.05 pu
Block	OFF	OFF
Events	Disabled	Disabled

URPlus_03.urs Protection: Elements: Group 1: Current

The following settings are available for each negative-sequence directional overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the negative-sequence directional overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the negative-sequence directional overcurrent protection element.

Offset

Range: 0.00 to 250.00 ohms in steps of 0.01

Default: 0.00 ohms

This setting specifies the offset impedance used by this protection. The primary application for the offset impedance is to guarantee correct identification of fault direction on series compensated lines. In regular applications, the offset impedance ensures proper operation even if the negative-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the negative-sequence impedance of the protected circuit. Practically, it shall be several times smaller. The offset impedance shall be entered in secondary ohms.

Type

Range: Neg Sequence, Zero Sequence

Default: Neg Sequence

This setting selects the operating mode for the overcurrent unit of the element. The choices are "Neg Sequence" and "Zero Sequence". In some applications it is advantageous to use a directional negative-sequence overcurrent function instead of a directional zero-sequence overcurrent function as inter-circuit mutual effects are minimized.

Pos Seq Restraint

Range: 0.000 to 0.500 in steps of 0.001

Default: 0.063

This setting controls the amount of the positive-sequence restraint. Set to 0.063 (in zero-sequence mode) or 0.125 (in negative-sequence mode) for backwards compatibility with UR-series relays using firmware revision 3.40 and older. Set to zero to remove the restraint. Set higher if large system unbalances or poor CT performance are expected.

Forward ECA

Range: 0 to 90° Lag in steps of 1

Default: 75° Lag

This setting specifies the element characteristic angle (ECA) for the forward direction. The element characteristic angle in the reverse direction is the angle set for the forward direction shifted by 180°.

Forward Limit Angle

Range: 40 to 90° in steps of 1

Default: 90°

This setting specifies a symmetrical limit angle (in both directions from the element characteristic angle) for the forward direction.

Forward Pickup

Range: 0.05 to 30.00 pu in steps of 0.01

Default: 0.05 pu

This setting specifies the pickup level for the overcurrent unit in the forward direction. This pickup threshold applies to zero or negative-sequence current based on the **Type** setting. When specifying this setting, it must be kept in mind that the design uses a positive-sequence restraint technique.

Reverse Limit Angle

Range: 40 to 90° in steps of 1

Default: 90°

This setting defines a symmetrical (in both directions from the element characteristic angle) limit angle for the reverse direction.

Reverse Pickup

Range: 0.05 to 30.00 pu in steps of 0.01

Default: 0.05 pu

This setting specifies the pickup level for the overcurrent unit in the reverse direction. This pickup threshold applies to zero or negative-sequence current based on the **Type** setting. When specifying this setting, it must be kept in mind that the design uses a positive-sequence restraint technique.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the negative-sequence directional overcurrent element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of negative-sequence directional overcurrent events in the sequence of events recorder.

The logic for the negative-sequence directional overcurrent 1 element is shown below. The logic is identical for all negative-sequence directional overcurrent elements.

Figure 118: Negative-sequence directional overcurrent scheme logic
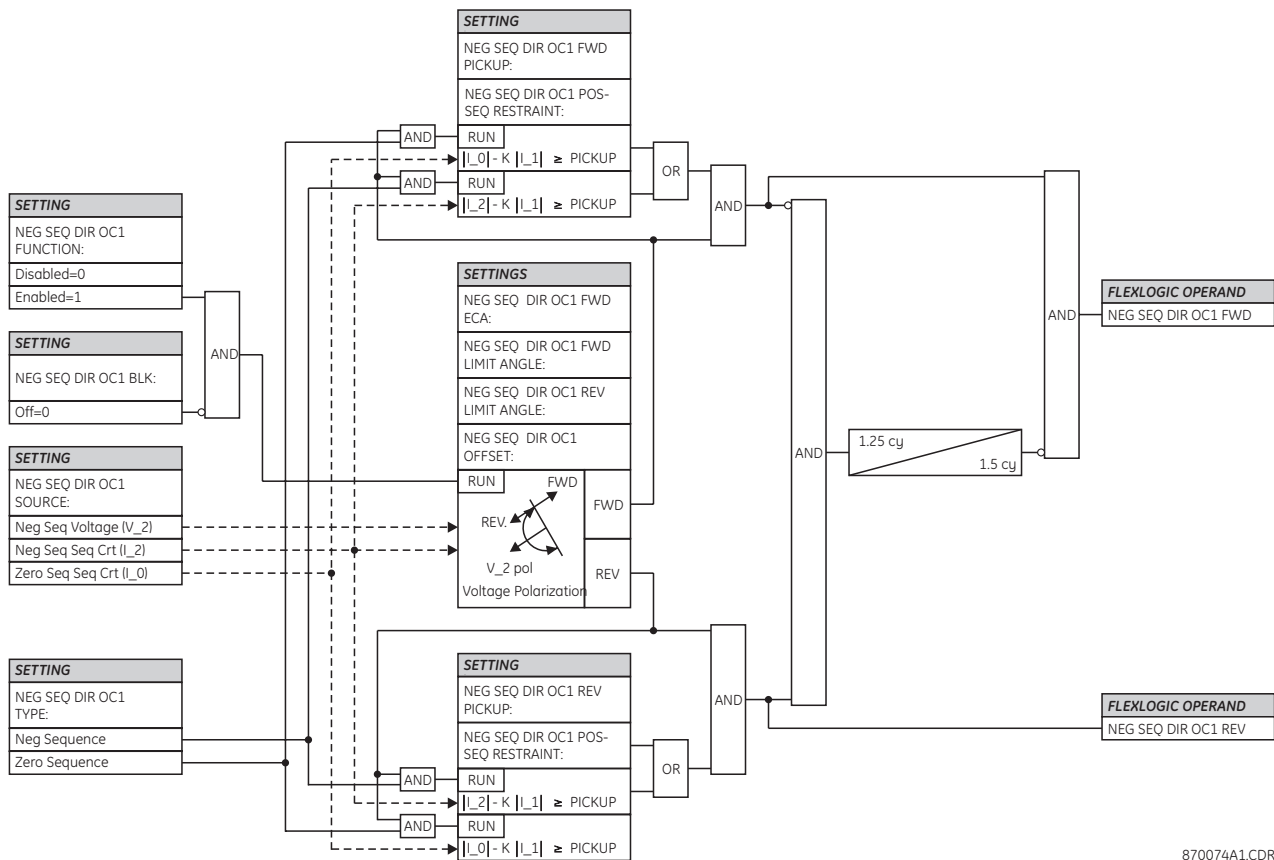
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Voltage elements

These protection elements can be used for a variety of applications, such as undervoltage protection, permissive functions, and source transfer schemes.

For voltage sensitive loads, such as induction motors, a drop in voltage increases the drawn current which may cause dangerous overheating in the motor. The undervoltage protection feature can be used to either cause a trip or generate an alarm when the voltage drops below a specified voltage setting for a specified time delay.

For permissive functions, the undervoltage feature may be used to block the functioning of external devices by operating an output relay when the voltage falls below the specified voltage setting. The undervoltage feature may also be used to block the functioning of other elements through the block feature of those elements.

In source transfer schemes, a transfer signal may be generated to transfer a load from its normal source to a standby or emergency power source in the event of an undervoltage.

The undervoltage elements can be programmed to have a definite time delay characteristic. The definite time curve operates when the voltage drops below the pickup level for a specified period of time. The time delay is adjustable from 0 to 600.00 seconds in steps of 0.01. The undervoltage elements can also be programmed to have an inverse time delay characteristic.

The undervoltage delay setting defines the family of curves shown below.

$$T = \frac{D}{1 - \dfrac{V}{V_{pickup}}}$$

<div align="right">**Eq. 34**</div>

In this equation, T represents the operating time, d represents the undervoltage delay setting ($D = 0.00$ operates instantaneously), V represents the secondary voltage applied to the relay, and V_{pickup} represents the pickup level.

Figure 119: Inverse time undervoltage curves

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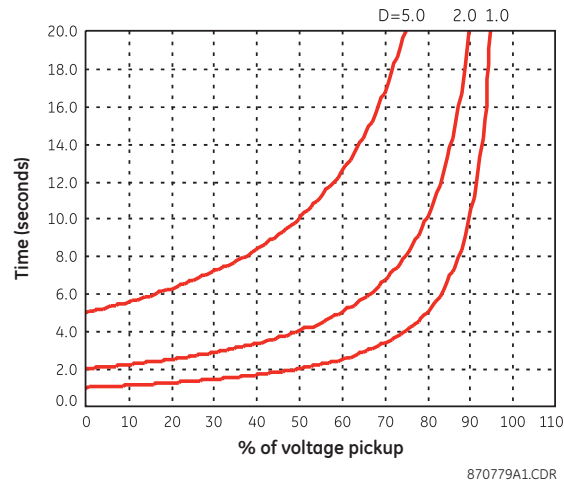
NOTE

At 0% of pickup, the operating time is equivalent to the undervoltage delay setting.

Phase undervoltage

The phase undervoltage element may be used to give a desired time delay operating characteristic versus the applied fundamental voltage (phase-to-ground or phase-to-phase for wye VT connections, or phase-to-phase for delta VT connections) or as a definite time element. The element resets instantaneously if the applied voltage exceeds the dropout voltage.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Phase UV** menu item to open the phase undervoltage configuration window.

Figure 120: Phase undervoltage configuration settings

The following settings are available for each phase undervoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase undervoltage protection element.

Signal Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the phase undervoltage protection element.

Mode

Range: Phase to Ground, Phase to Phase

Default: Phase to Ground

This setting selects the operating mode. Select phase-to-ground or phase-to-phase for wye VT connections, or phase-to-phase for delta VT connections.

Pickup

Range: 0.000 to 1.100 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the phase undervoltage pickup level in per-unit values.

Curve

Range: Definite Time, Inverse Time

Default: Definite Time

This setting selects the desired time-delay operating characteristic versus the applied fundamental voltage or the definite time element.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum operating time of the phase undervoltage element.

Minimum Voltage

Range: 0.000 to 3.000 pu in steps of 0.001

Default: 0.100 pu

This setting specifies the operating voltage in per-unit values below which the element is blocked. A value of "0" will allow a dead source to be considered a fault condition.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks the phase undervoltage element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of phase undervoltage events in the sequence of events recorder.

The logic for the phase undervoltage element is shown below. The logic is identical for all phase undervoltage elements.

Figure 121: Phase undervoltage scheme logic

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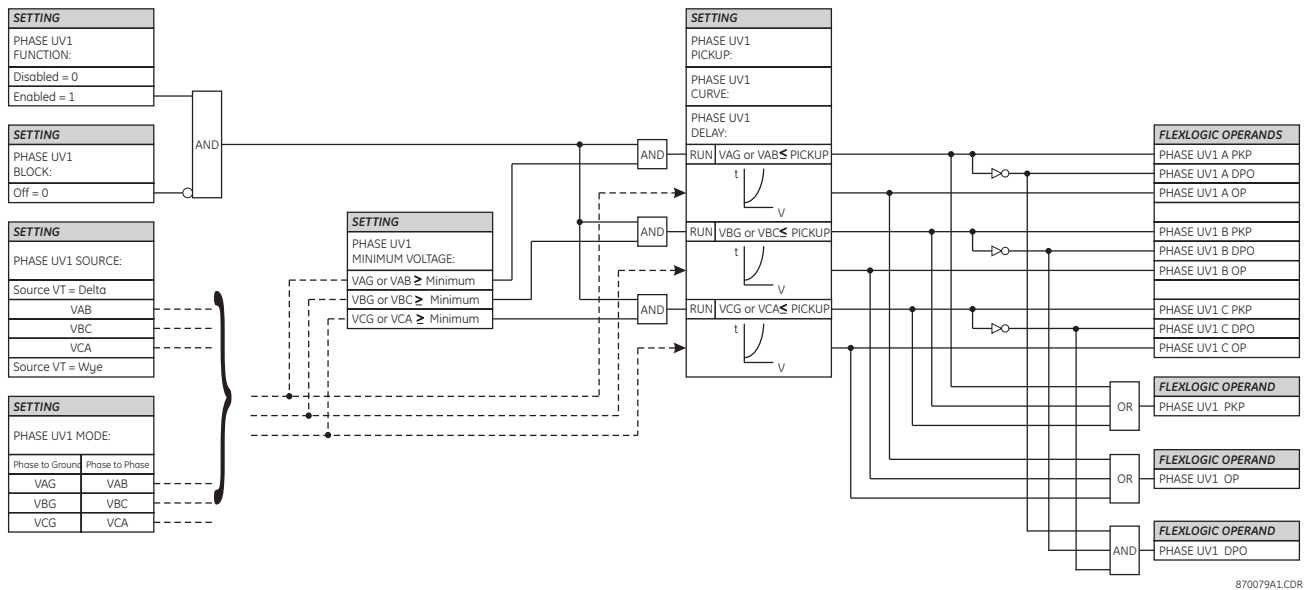
Phase overvoltage

The phase overvoltage element may be used as an instantaneous element with no intentional time delay or as a definite time element. The input voltage is the phase-to-phase voltage, either measured directly from delta-connected VTs or as calculated from phase-to-ground (wye) connected VTs. The specific voltages to be used for each phase are shown in the logic diagram.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Phase OV** menu item to open the phase overvoltage configuration window.

Figure 122: Phase overvoltage configuration settings

The following settings are available for each phase overvoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase overvoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the phase overvoltage protection element.

Pickup

Range: 0.000 to 3.000 pu in steps of 0.001
Default: 1.000 pu

This setting specifies the phase overvoltage pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 1.00 seconds

This setting specifies the minimum operating time of the phase overvoltage element.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 1.00 seconds

This setting specifies the minimum reset time of the phase overvoltage element.

Block

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks the phase overvoltage element.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of phase overvoltage events in the sequence of events recorder.

The logic for the phase overvoltage element is shown below. The logic is identical for all phase overvoltage elements.

Figure 123: Phase overvoltage scheme logic
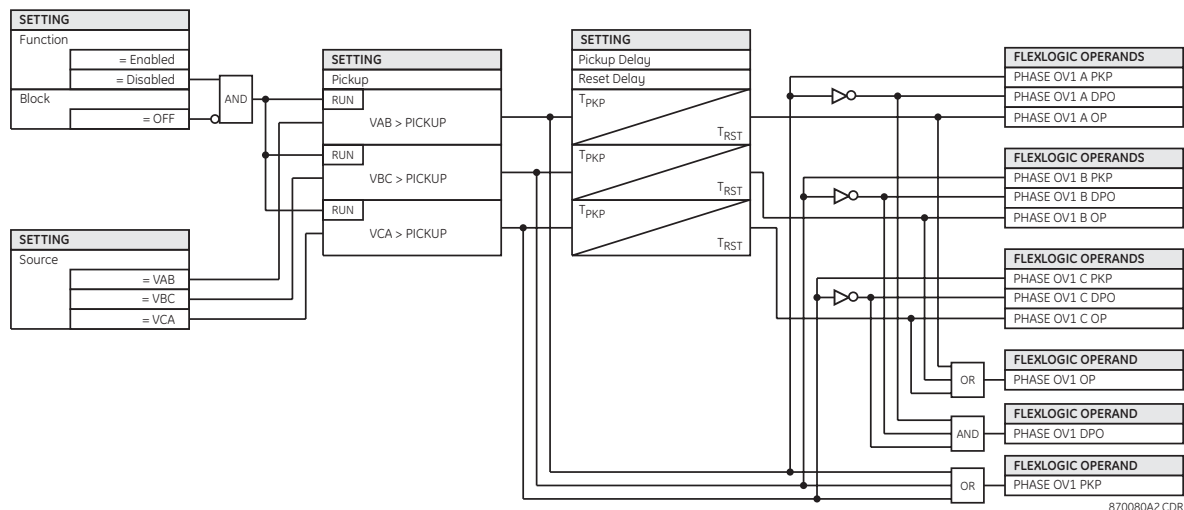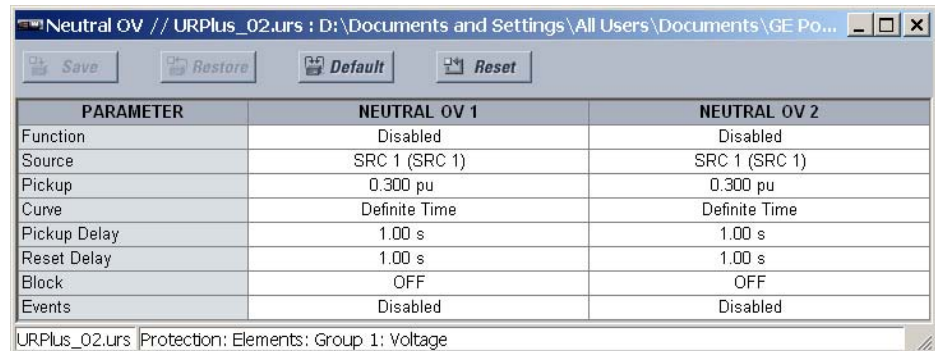
Neutral overvoltage   There are three neutral overvoltage elements available. The neutral overvoltage element can be used to detect asymmetrical system voltage condition due to a ground fault or to the loss of one or two phases of the source. The element responds to the system neutral voltage (3V_0), calculated from the phase voltages. The nominal secondary voltage of the phase voltage channels entered in the **Phase VT Secondary** setting is the per-unit base used when setting the pickup level.

The neutral overvoltage element can provide a time-delayed operating characteristic versus the applied voltage (initialized from FlexCurves™ A, B, or C) or be used as a definite time element. The source assigned to this element must be configured for a phase VT.

VT errors and normal voltage unbalance must be considered when setting this element. This function requires the VTs to be wye-connected.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Neutral OV** menu item to open the neutral overvoltage configuration window.

Figure 124: Neutral overvoltage configuration settings

The following settings are available for each neutral overvoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the neutral overvoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the neutral overvoltage protection element.

Pickup

Range: 0.000 to 1.250 pu in steps of 0.001

Default: 0.300 pu

This setting specifies the neutral overvoltage pickup level in per-unit values.

Curve

Range: Definite Time, FlexCurve A, FlexCurve B, FlexCurve C

Default: Definite Time

This setting specifies the neutral overvoltage pickup level in per-unit values.

Pickup Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum operating time of the neutral overvoltage element. This setting applies only if the **Curve** setting is "Definite Time".

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum reset time of the neutral overvoltage element.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks the neutral overvoltage element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of neutral overvoltage events in the sequence of events recorder.

The logic for the neutral overvoltage element is shown below. The logic is identical for all neutral overvoltage elements.

Figure 125: Neutral overvoltage scheme logic
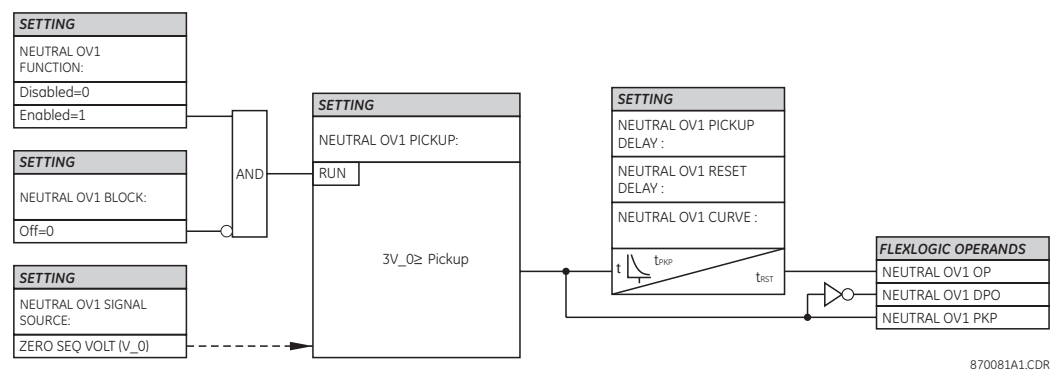
Negative-sequence overvoltage

The negative-sequence overvoltage element may be used to detect loss of one or two phases of the source, a reversed phase sequence of voltage, or a non-symmetrical system voltage condition.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Negative Sequence OV** menu item to open the negative-sequence overvoltage configuration window.

Figure 126: Negative-sequence overvoltage configuration settings

The following settings are available for each negative-sequence overvoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the negative-sequence overvoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the negative-sequence overvoltage protection element.

Pickup

Range: 0.000 to 1.250 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the negative-sequence overvoltage pickup level in per-unit values.

Pickup Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum operating time of the negative-sequence overvoltage element.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum reset time of the negative-sequence overvoltage element.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks the negative-sequence overvoltage element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of negative-sequence overvoltage events in the sequence of events recorder.

The logic for the negative-sequence overvoltage element is shown below. The logic is identical for all negative-sequence overvoltage elements.

Figure 127: Negative-sequence overvoltage scheme logic
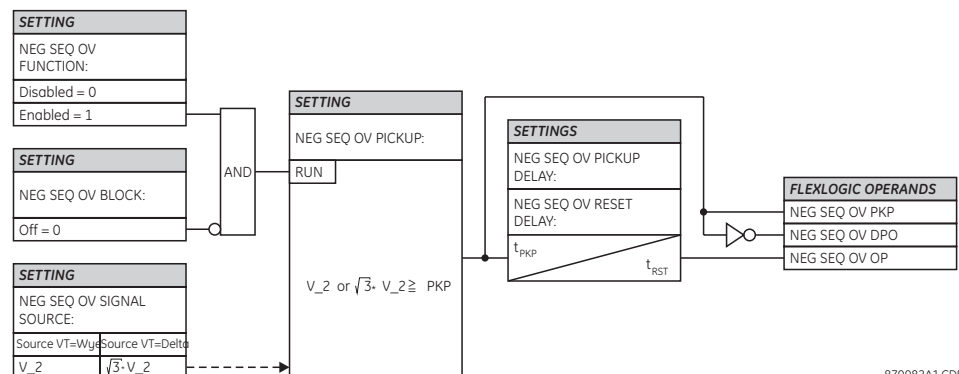
Auxiliary undervoltage
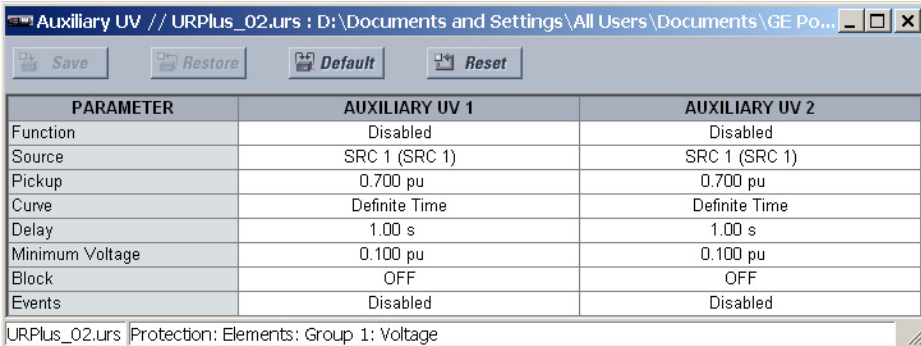
The auxiliary undervoltage element is intended for monitoring undervoltage conditions of the auxiliary voltage. The element pickup selects the voltage level at which the time undervoltage element starts timing. The nominal secondary voltage of the auxiliary voltage channel entered for the **Auxiliary VT Secondary** setting is the per-unit base used when setting the pickup level.

Both the **Pickup** and **Delay** settings establish the operating curve of the undervoltage element. The auxiliary undervoltage element can be programmed to use either definite time delay or inverse time delay characteristics.

The auxiliary undervoltage element resets instantaneously.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Auxiliary UV** menu item to open the auxiliary undervoltage configuration window.

Figure 128: Auxiliary undervoltage configuration settings

PARAMETER	AUXILIARY UV 1	AUXILIARY UV 2
Function	Disabled	Disabled
Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Pickup	0.700 pu	0.700 pu
Curve	Definite Time	Definite Time
Delay	1.00 s	1.00 s
Minimum Voltage	0.100 pu	0.100 pu
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each auxiliary undervoltage element.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the auxiliary undervoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting selects the signal source for the auxiliary undervoltage protection element.

Pickup

Range: 0.000 to 3.000 pu in steps of 0.001
Default: 0.700 pu

This setting specifies the auxiliary undervoltage pickup level in per-unit values.

Curve

Range: Definite Time, Inverse Time
Default: Inverse Time

This setting selects either the desired time-delay operating characteristic versus the applied fundamental voltage or the definite time characteristic for the auxiliary undervoltage element.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 1.00 seconds

This setting selects the minimum operating time of the auxiliary undervoltage element.

Minimum Voltage

Range: 0.000 to 3.000 pu in steps of 0.001
Default: 0.100 pu

This setting specifies the operating voltage below which the auxiliary undervoltage element is blocked.

Block

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks the auxiliary undervoltage element.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of auxiliary undervoltage events in the sequence of events recorder.

The logic for the auxiliary undervoltage element is shown below. The logic is identical for all auxiliary undervoltage elements.

Figure 129: Auxiliary undervoltage scheme logic
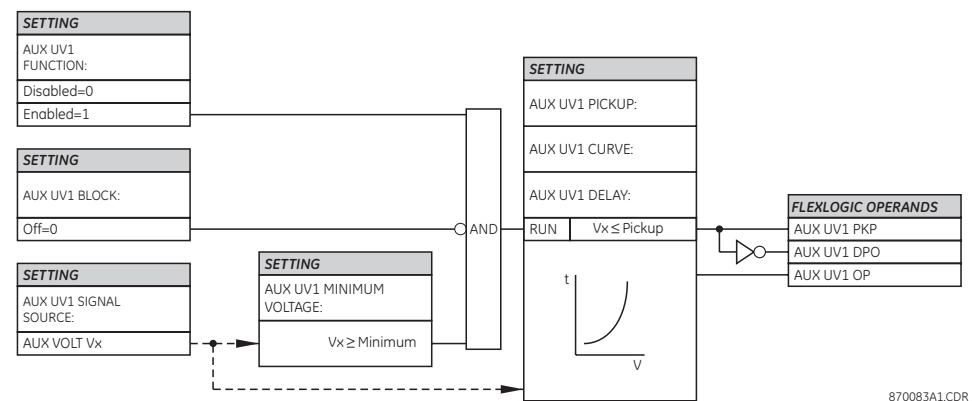
Auxiliary overvoltage

This element is intended for monitoring overvoltage conditions of the auxiliary voltage. A typical application for this element is monitoring the zero-sequence voltage (3V_0) supplied from an open-corner-delta VT connection. The nominal secondary voltage of the auxiliary voltage channel entered in the **Auxiliary VT Secondary** setting is the per-unit base used when setting the pickup level.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Auxiliary OV** menu item to open the auxiliary overvoltage configuration window.

Figure 130: Auxiliary overvoltage configuration settings

PARAMETER	AUXILIARY OV 1	AUXILIARY OV 2
Function	Disabled	Disabled
Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Pickup	0.300 pu	0.300 pu
Pickup Delay	1.00 s	1.00 s
Reset Delay	1.00 s	1.00 s
Block	OFF	OFF
Events	Disabled	Disabled

URPlus_02.urs Protection: Elements: Group 1: Voltage

The following settings are available for each auxiliary overvoltage element.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the auxiliary overvoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting selects the signal source for the auxiliary overvoltage protection element.

Pickup

Range: 0.000 to 1.100 pu in steps of 0.001
Default: 0.300 pu

This setting specifies the auxiliary overvoltage pickup level in per-unit values.

Pickup Delay

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 1.00 seconds

This setting selects the minimum operating time of the auxiliary overvoltage element.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 1.00 seconds

This setting specifies the minimum reset time of the auxiliary overvoltage element.

Block

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks the auxiliary overvoltage element.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of auxiliary overvoltage events in the sequence of events recorder.

The logic for the auxiliary overvoltage element is shown below. The logic is identical for all auxiliary overvoltage elements.

Figure 131: Auxiliary overvoltage scheme logic

870084A1.CDR
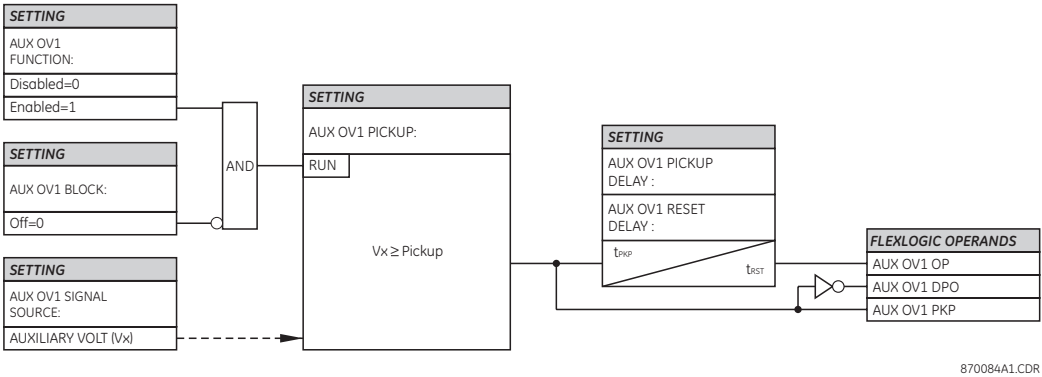
Breaker failure

In general, a breaker failure scheme determines that a breaker signaled to trip has not cleared a fault within a definite time, so further tripping action must be performed. Tripping from the breaker failure scheme should trip all breakers, both local and remote, that can supply current to the faulted zone. Usually operation of a breaker failure element will cause clearing of a larger section of the power system than the initial trip. Because breaker failure can result in tripping a large number of breakers and this affects system safety and stability, a very high level of security is required.

Two schemes are provided: one for three-pole tripping only and one for three pole plus single-pole operation. The philosophy used in these schemes is identical. The operation of a breaker failure element includes three stages: initiation, determination of a breaker failure condition, and output.

Figure 132: Breaker failure main path sequence
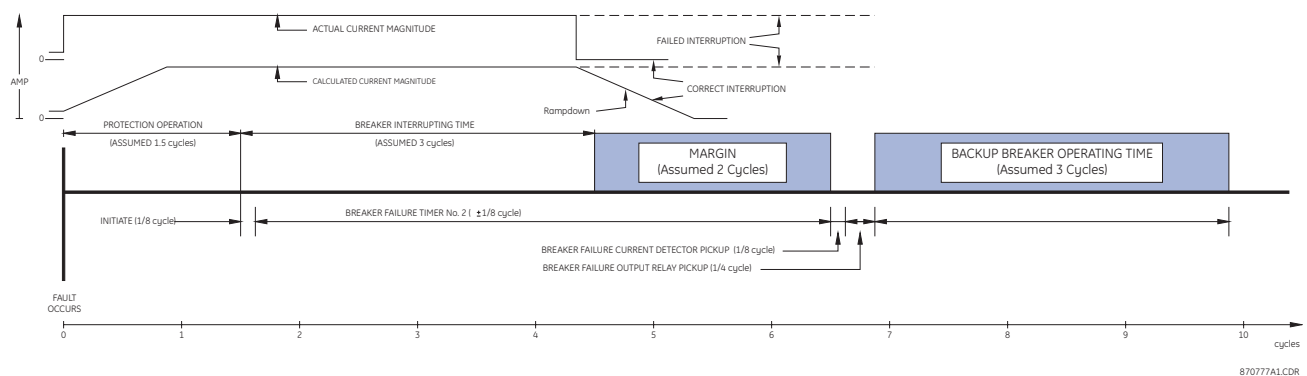
The breaker failure current supervision elements reset in less than 0.7 of a power cycle for any multiple of pickup current as shown below.

Figure 133: Breaker failure current supervision reset time
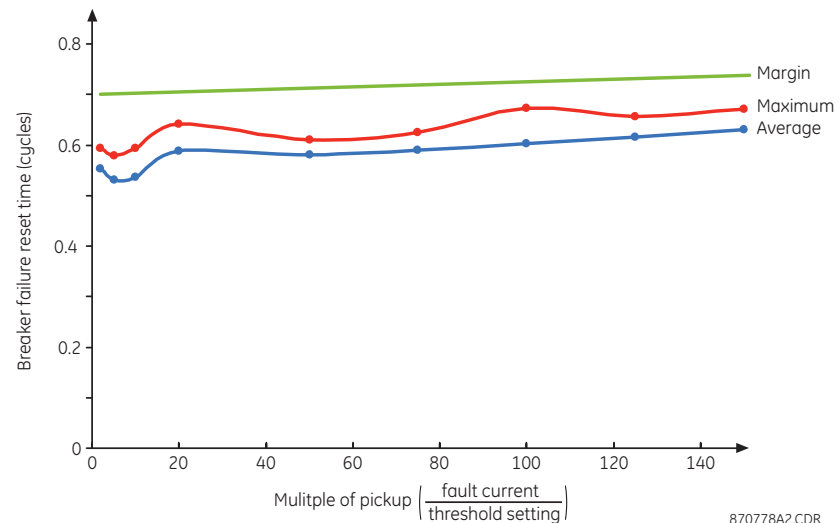
Breaker failure initiation stage

A FlexLogic™ operand representing the protection trip signal initially sent to the breaker must be selected to initiate the scheme, except if this is already programmed as a trip output (the protection trip signal does not include other breaker commands that are not indicative of a fault in the protected zone). The initiating signal should be sealed-in if primary fault detection can reset before the breaker failure timers have finished timing. The seal-in is supervised by current level, so it is reset when the fault is cleared. If desired,

an incomplete sequence seal-in reset can be implemented by using the initiating operand to also initiate a FlexLogic™ timer, set longer than any breaker failure timer, whose output operand is selected to block the breaker failure scheme.

Schemes can be initiated either directly or with current level supervision. It is particularly important in any application to decide if a current-supervised initiate is to be used. The use of a current-supervised initiate results in the breaker failure element not being initiated for a breaker that has very little or no current flowing through it, which may be the case for transformer faults. For those situations where it is required to maintain breaker fail coverage for fault levels below the **Phase Current Supv Pickup** or the **Neutral Current Supv Pickup** setting, a current supervised initiate should not be used. This feature should be utilized for those situations where coordinating margins may be reduced when high speed reclosing is used. Thus, if this choice is made, fault levels must always be above the supervision pickup levels for dependable operation of the breaker fail scheme. This can also occur in breaker-and-a-half or ring bus configurations where the first breaker closes into a fault; the protection trips and attempts to initiate breaker failure for the second breaker, which is in the process of closing, but does not yet have current flowing through it.

When the scheme is initiated, it immediately sends a trip signal to the breaker initially signaled to trip (this feature is usually described as re-trip). This reduces the possibility of widespread tripping that results from a declaration of a failed breaker.

Determination of a breaker failure condition

The schemes determine a breaker failure condition via three paths. Each of these paths is equipped with a time delay, after which a failed breaker is declared and trip signals are sent to all breakers required to clear the zone. The delayed paths are associated with breaker failure timers 1, 2, and 3, which are intended to have delays increasing with increasing timer numbers. These delayed paths are individually enabled to allow for maximum flexibility.

Timer 1 logic (early path) is supervised by a fast-operating breaker auxiliary contact. If the breaker is still closed (as indicated by the auxiliary contact) and fault current is detected after the delay interval, an output is issued. Operation of the breaker auxiliary switch indicates that the breaker has mechanically operated. The continued presence of current indicates that the breaker has failed to interrupt the circuit.

Timer 2 logic (main path) is not supervised by a breaker auxiliary contact. If fault current is detected after the delay interval, an output is issued. This path is intended to detect a breaker that opens mechanically but fails to interrupt fault current; the logic therefore does not use a breaker auxiliary contact.

The timer 1 and 2 paths provide two levels of current supervision, high-set and low-set, that allow the supervision level to change from a current which flows before a breaker inserts an opening resistor into the faulted circuit to a lower level after resistor insertion. The high-set detector is enabled after timeout of timer 1 or 2, along with a timer that will enable the low-set detector after its delay interval. The delay interval between high-set and low-set is the expected breaker opening time. Both current detectors provide a fast operating time for currents at small multiples of the pickup value. The overcurrent detectors are required to operate after the breaker failure delay interval to eliminate the need for very fast resetting overcurrent detectors.

Timer 3 logic (slow path) is supervised by a breaker auxiliary contact and a control switch contact used to indicate that the breaker is in/out of service, disabling this path when the breaker is out of service for maintenance. There is no current level check in this logic as it is intended to detect low magnitude faults and it is therefore the slowest to operate.

Breaker failure scheme outputs

The outputs from the breaker failure scheme are:
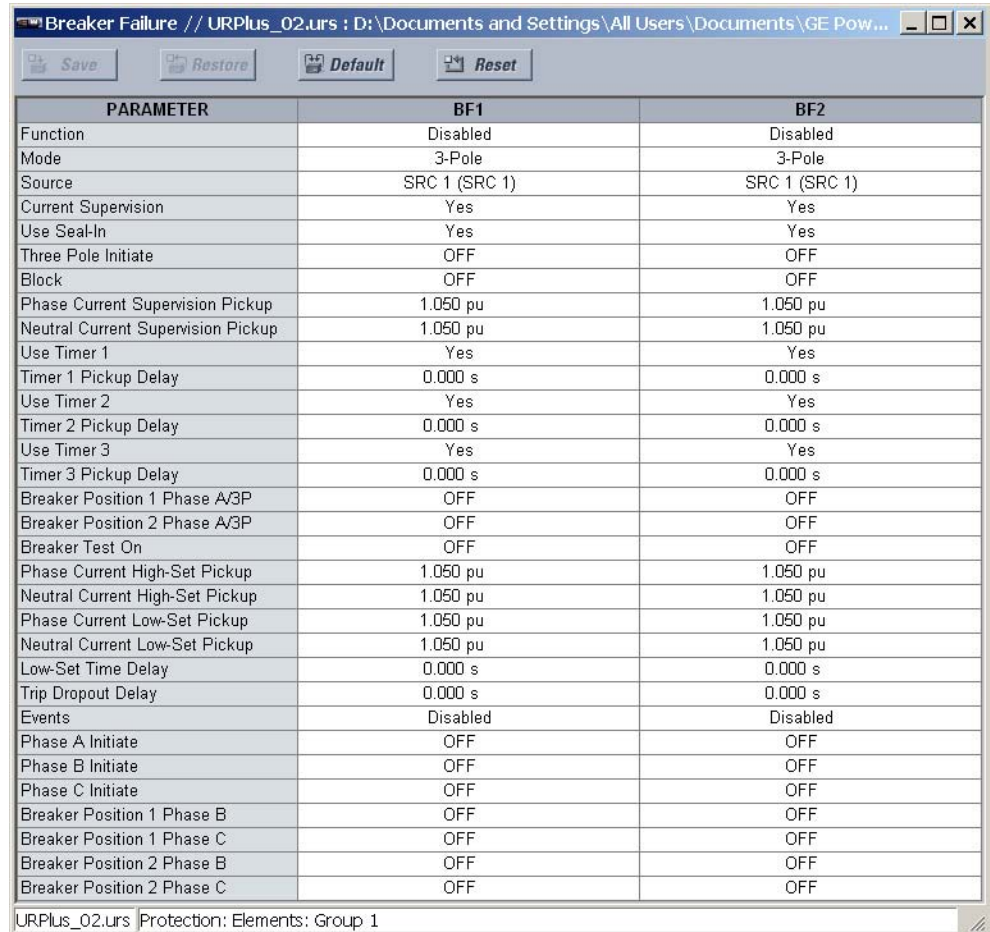
- FlexLogic™ operands that report on the operation of portions of the scheme.
- A FlexLogic™ operand used to re-trip the protected breaker.

- FlexLogic™ operands that initiate tripping required to clear the faulted zone. The trip output can be sealed-in for an adjustable period.
- Illumination of a front panel annunciator message or messages.

Breaker failure settings and logic

Select the **Settings > Protection > Elements > Group 1 > Breaker Failure** menu item to open the breaker failure configuration window.

Figure 134: Breaker failure configuration settings

PARAMETER	BF1	BF2
Function	Disabled	Disabled
Mode	3-Pole	3-Pole
Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Current Supervision	Yes	Yes
Use Seal-In	Yes	Yes
Three Pole Initiate	OFF	OFF
Block	OFF	OFF
Phase Current Supervision Pickup	1.050 pu	1.050 pu
Neutral Current Supervision Pickup	1.050 pu	1.050 pu
Use Timer 1	Yes	Yes
Timer 1 Pickup Delay	0.000 s	0.000 s
Use Timer 2	Yes	Yes
Timer 2 Pickup Delay	0.000 s	0.000 s
Use Timer 3	Yes	Yes
Timer 3 Pickup Delay	0.000 s	0.000 s
Breaker Position 1 Phase A/3P	OFF	OFF
Breaker Position 2 Phase A/3P	OFF	OFF
Breaker Test On	OFF	OFF
Phase Current High-Set Pickup	1.050 pu	1.050 pu
Neutral Current High-Set Pickup	1.050 pu	1.050 pu
Phase Current Low-Set Pickup	1.050 pu	1.050 pu
Neutral Current Low-Set Pickup	1.050 pu	1.050 pu
Low-Set Time Delay	0.000 s	0.000 s
Trip Dropout Delay	0.000 s	0.000 s
Events	Disabled	Disabled
Phase A Initiate	OFF	OFF
Phase B Initiate	OFF	OFF
Phase C Initiate	OFF	OFF
Breaker Position 1 Phase B	OFF	OFF
Breaker Position 1 Phase C	OFF	OFF
Breaker Position 2 Phase B	OFF	OFF
Breaker Position 2 Phase C	OFF	OFF

The following settings are available for each breaker failure element.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the breaker failure protection element.

Mode

Range: 1-Pole, 3-Pole
Default: 1-Pole

This setting selects the breaker failure operating mode: single-pole or three-pole.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting selects the signal source for the breaker failure protection element.

Current Supervision

Range: Yes, No

Default: Yes

If set to "Yes", the breaker failure element will only be initiated if current flowing through the breaker is above the supervision pickup level.

Use Seal-In

Range: Yes, No

Default: Yes

If set to "Yes", the breaker failure element will only be sealed-in if current flowing through the breaker is above the supervision pickup level.

Three Pole Initiate

Range: any FlexLogic™ operand or shared operand

Default: Off

This setting selects the operand that will initiate three-pole tripping of the breaker when asserted.

Block

Range: any FlexLogic™ operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the breaker failure element.

Phase Current Supervision Pickup

Range: 0.001 to 30.000 pu in steps of 0.001

Default: 1.050 pu

This setting specifies the phase current initiation and seal-in supervision level. Generally, this setting should detect the lowest expected fault current on the protected breaker. It can be set as low as necessary (lower than breaker resistor current or lower than load current). High-set and low-set current supervision will ensure correct operation.

Neutral Current Supervision Pickup

Range: 0.001 to 30.000 pu in steps of 0.001

Default: 1.050 pu

This setting specifies the neutral current initiate and seal-in supervision level. Generally, this setting should detect the lowest expected fault current on the protected breaker. Neutral current supervision is used only in the three phase scheme to provide increased sensitivity. This setting is valid only for three-pole tripping schemes.

Use Timer 1

Range: Yes, No

Default: Yes

If this setting value is "Yes", the early path is operational.

Timer 1 Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0 seconds

Timer 1 is set to the shortest time required for breaker auxiliary contact Status-1 to open, from the time the initial trip signal is applied to the breaker trip circuit, plus a safety margin.

Use Timer 2

Range: Yes, No

Default: Yes

If this setting value is "Yes", the main path is operational.

Timer 2 Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001
Default: 0 seconds

Timer 2 is set to the expected opening time of the breaker, plus a safety margin. This safety margin was historically intended to allow for measuring and timing errors in the breaker failure scheme equipment. In microprocessor relays this time is not significant. In the UR^{Plus}-series devices, which use a Fourier transform, the calculated current magnitude will ramp-down to zero one power frequency cycle after the current is interrupted, and this lag should be included in the overall margin duration, as it occurs after current interruption. The breaker failure main path sequence diagram shows a margin of two cycles; this interval is considered the minimum appropriate for most applications.

In bulk oil circuit breakers, the interrupting time for currents less than 25% of the interrupting rating can be significantly longer than the normal interrupting time.

Use Timer 3

Range: Yes, No
Default: Yes

If this setting value is "Yes", the slow path is operational.

Timer 3 Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001
Default: 0 seconds

Timer 3 is set to the same interval as timer 2, plus an increased safety margin. Because this path is intended to operate only for low level faults, the delay can be in the order of 300 to 500 ms.

Breaker Position 1 Phase A/3P

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand that represents the protected breaker early-type auxiliary switch contact (52/a). When using the single-pole breaker failure scheme, this operand represents the protected breaker early-type auxiliary switch contact on pole A. This is normally a non-multiplied form-A contact. The contact may even be adjusted to have the shortest possible operating time.

Breaker Position 2 Phase A/3P

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand that represents the breaker normal-type auxiliary switch contact (52/a). When using the single-pole breaker failure scheme, this operand represents the protected breaker auxiliary switch contact on pole A. This may be a multiplied contact.

Breaker Test On

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand that represents the breaker in-service/out-of-service switch set to the out-of-service position.

Phase Current High-Set Pickup

Range: 0.001 to 30.000 pu in steps of 0.001
Default: 1.050 pu

This setting specifies the phase current output supervision level. Generally, this setting should detect the lowest expected fault current on the protected breaker, before a breaker opening resistor is inserted.

Neutral Current High-Set Pickup

Range: 0.001 to 30.000 pu in steps of 0.001

Default: 1.050 pu

This setting specifies the neutral current output supervision level. Generally, this setting should detect the lowest expected fault current on the protected breaker, before a breaker opening resistor is inserted. Neutral current supervision is used only in the three pole scheme to provide increased sensitivity. This setting is valid only for three-pole breaker failure schemes.

Phase Current Low-Set Pickup

Range: 0.001 to 30.000 pu in steps of 0.001

Default: 1.050 pu

This setting specifies the phase current output supervision level. Generally, this setting should detect the lowest expected fault current on the protected breaker, after a breaker opening resistor is inserted (approximately 90% of the resistor current).

Neutral Current Low-Set Pickup

Range: 0.001 to 30.000 pu in steps of 0.001

Default: 1.050 pu

This setting specifies the neutral current output supervision level. Generally, this setting should detect the lowest expected fault current on the protected breaker, after a breaker opening resistor is inserted (approximately 90% of the resistor current). This setting is valid only for three-pole breaker failure schemes.

Low-Set Time Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting specifies the pickup delay for current detection after opening resistor insertion.

Trip Dropout Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting specifies the time for which the trip output is sealed-in. This timer must be coordinated with the automatic reclosing scheme of the failed breaker, to which the breaker failure element sends a cancel reclosure signal. Reclosure of a remote breaker can also be prevented by holding a transfer trip signal on longer than the reclaim time.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of breaker failure events in the sequence of events recorder.

Phase A Initiate, Phase B Initiate, Phase C Initiate

Range: any FlexLogic™ operand or shared operand

Default: Off

These settings select operands to initiate phase A, B, and C single-pole tripping of the breaker and the phase A, B, or C portion of the scheme, accordingly. These settings are only valid for single-pole breaker failure schemes.

Breaker Position 1 Phase B

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand to represent the protected breaker early-type auxiliary switch contact on pole B. This contact is normally a non-multiplied form-A contact. The contact may even be adjusted to have the shortest possible operating time. This setting is valid only for single-pole breaker failure schemes.

Breaker Position 1 Phase C

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand to represent the protected breaker early-type auxiliary switch contact on pole C. This contact is normally a non-multiplied form-A contact. The contact may even be adjusted to have the shortest possible operating time. This setting is valid only for single-pole breaker failure schemes.

Breaker Position 2 Phase B

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand that represents the protected breaker normal-type auxiliary switch contact on pole B (52/a). This may be a multiplied contact. This setting is valid only for single-pole breaker failure schemes.

Breaker Position 2 Phase C

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand that represents the protected breaker normal-type auxiliary switch contact on pole C (52/a). This may be a multiplied contact. For single-pole operation, the scheme has the same overall general concept except that it provides re-tripping of each single pole of the protected breaker. The approach shown in the following single pole tripping diagram uses the initiating information to determine which pole is supposed to trip. The logic is segregated on a per-pole basis. The overcurrent detectors have ganged settings. This setting is valid only for single-pole breaker failure schemes.

Upon operation of the breaker failure element for a single pole trip command, a three-pole trip command should be given via the BKR FAIL 1 TRIP OP output operand.

The logic for the breaker failure element is shown in the following figures. The logic is identical for both breaker failure elements.

Figure 135: Breaker failure single-pole logic (initiate, sheet 1 of 2)
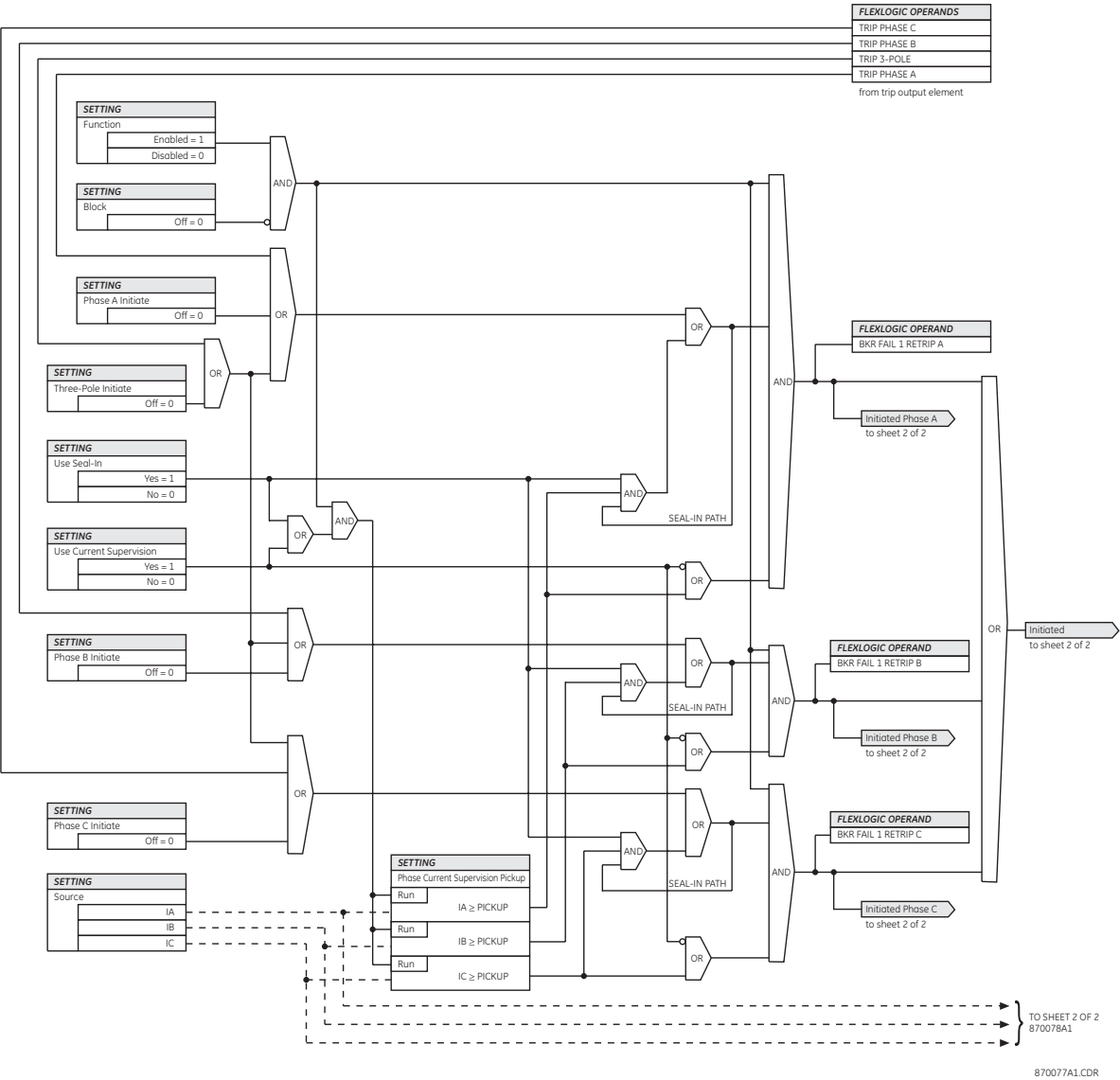
Figure 136: Breaker failure single-pole logic (timers, sheet 2 of 2)
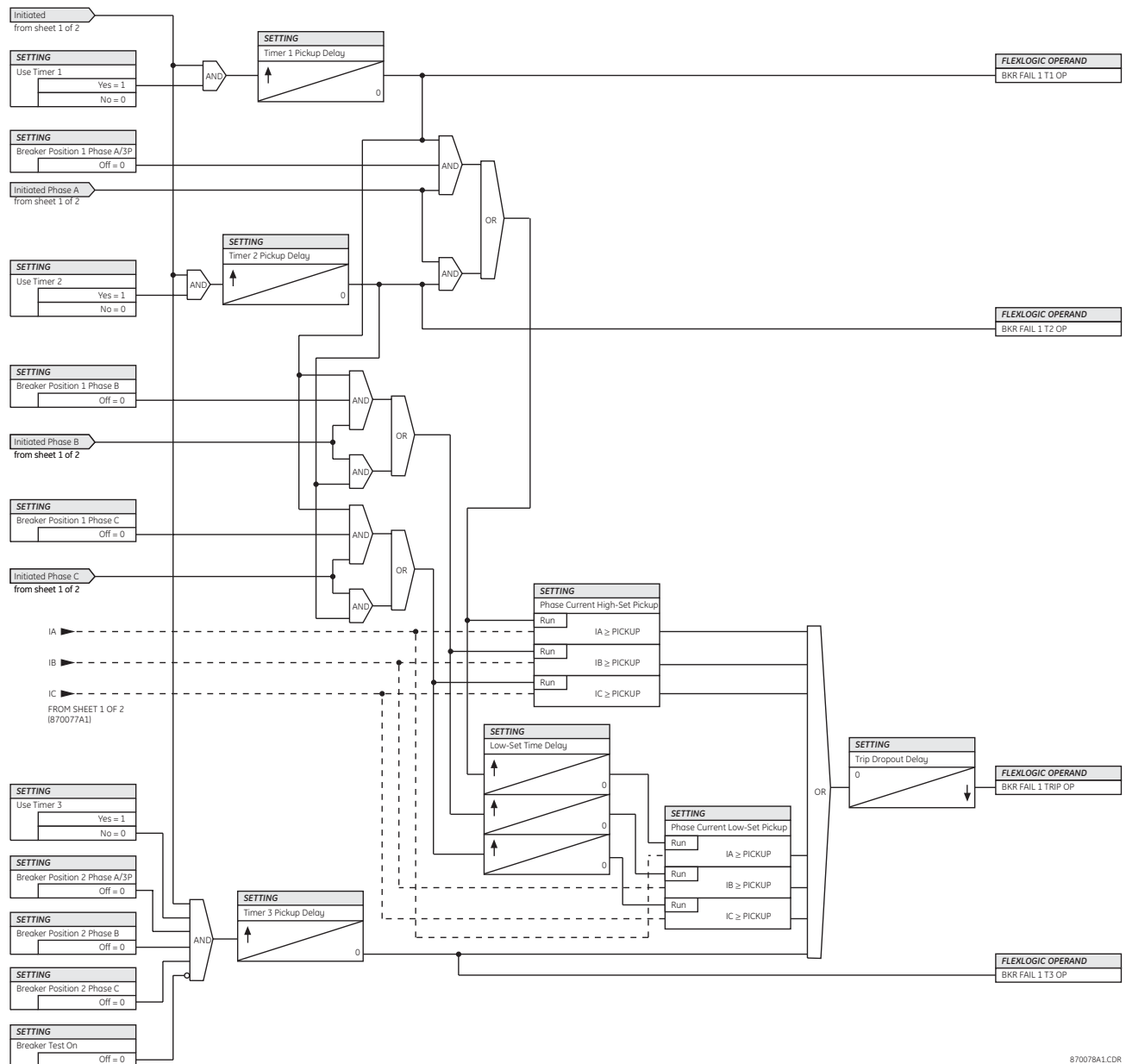
870078A1.CDR

Figure 137: Breaker failure three-pole logic (initiate, sheet 1 of 2)
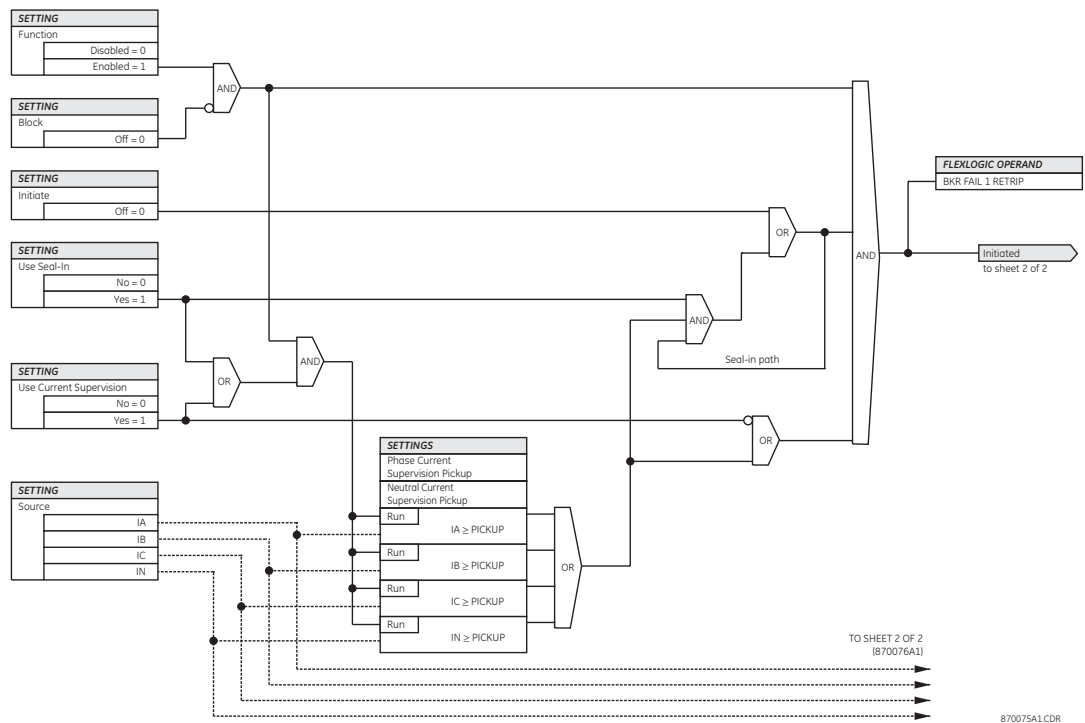
Figure 138: Breaker failure three-pole logic (timers, sheet 2 of 2)
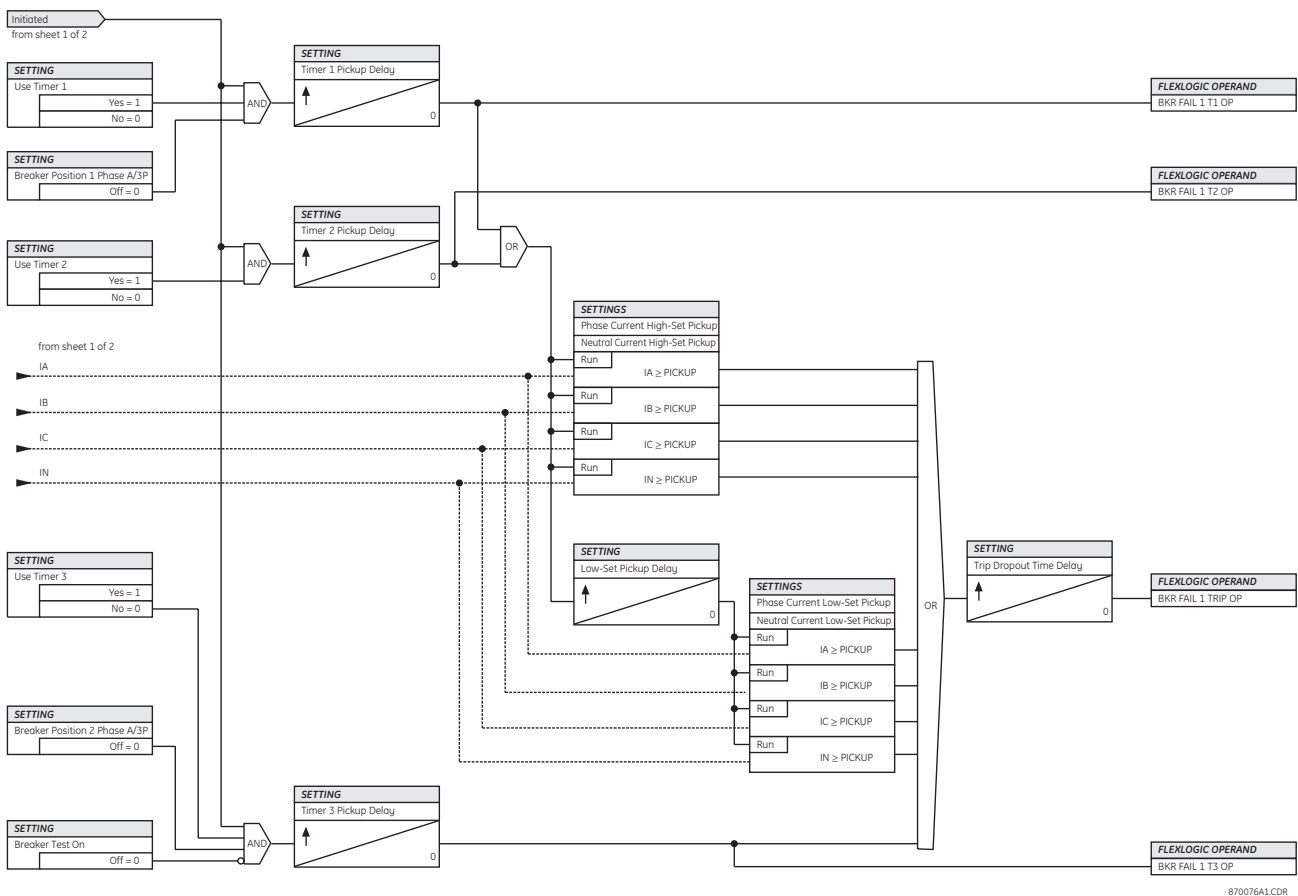
Control elements

Control elements are generally used for control rather than protection.

Setting group control

The setting groups control function activates and deactivates of up to six setting groups.

Select the **Settings > Protection > Control > Setting Group Control** menu item to access the setting group control settings.

Figure 139: Setting group control configuration

The following settings are available for setting groups control.

Function

Range: Enabled, Disabled
Default: Disabled

This setting is used to enable and disable the setting groups control functionality.

Block

Range: any FlexLogic™ operand or shared operand
Default: OFF

This setting prevents the active setting group from changing when the assigned operand is asserted. This can be useful in applications where it is undesirable to change the settings under certain conditions, such as the breaker being open.

Group 2 Activate On, Group 3 Activate On, Group 4 Activate On, Group 5 Activate On, Group 6 Activate On

Range: any FlexLogic™ operand or shared operand
Default: OFF

Each of these settings selects an operand which, when set, will activate the corresponding setting group for use by any grouped element. A priority scheme ensures that only one group is active at a given time. The highest-numbered group activated by these settings takes priority over the lower-numbered groups. There is no activation setting group 1 (the default active group) since group 1 automatically becomes active when there is no other group active.

Group 1 Name, Group 2 Name, Group 3 Name, Group 4 Name, Group 5 Name, Group 6 Name

Range: up to 16 alphanumeric characters
Default: empty

These settings allows to user to assign a name to each of the six settings groups.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of setting group control events in the sequence of events recorder.

The **Current Setting Group** actual value is also displayed in this menu.

FlexLogic™ control of a settings group

The relay can be set up via a protection FlexLogic™ equation to receive requests to activate or de-activate a particular non-default settings group. The following FlexLogic™ equation illustrates requests via remote communications (for example, VIRTUAL INPUT 1 ON) or from a local contact input (for example, CONTACT IP 1 ON) to initiate the use of a particular settings group, and requests from several overcurrent pickup measuring elements to inhibit the use of the particular settings group. The assigned VIRTUAL OUTPUT 1 operand is used to control the "On" state of a particular settings group.

Figure 140: FlexLogic™ control of a settings group
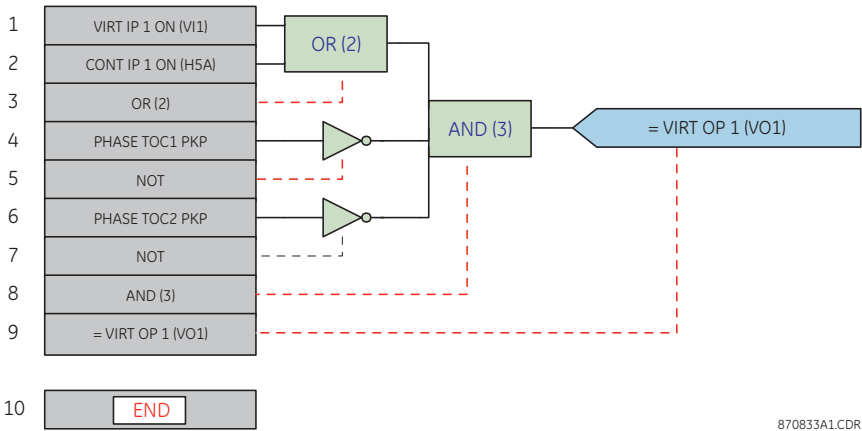
FlexMatrix

The FlexMatrix allows up to sixteen (16) inputs to be aggregated and conditioned for tripping or auxiliary functions. Up to eight (8) output signals can be derived from the input signals. Outputs can be configured for latching (lockout) and can also have a programmable pickup and dropout delay.

In a typical application, the FlexLogic™ operands from protection functions will be assigned as inputs to the FlexMatrix. Each output can be assigned to a specific task such as tripping the breaker or blocking a protection element.

FlexMatrix inputs

Select the **Settings > Protection > Control > FlexMatrix > FlexMatrix Inputs** menu item to access the FlexMatrix input settings.

Figure 141: FlexMatrix input configuration settings
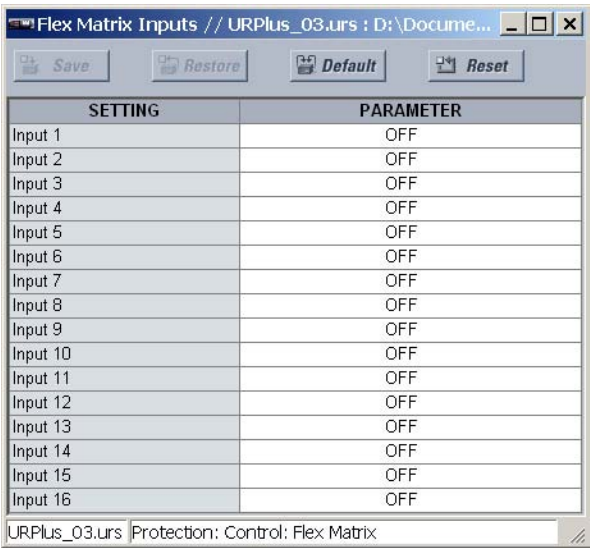
The following setting is available for each of the sixteen (16) FlexMatrix inputs.

Input 1

Range: any FlexLogic™ operand or shared operand
Default: OFF

The operand assigned to this setting can be re-assigned to any or all of the FlexMatrix outputs.

FlexMatrix configuration

Select the **Settings > Protection > Control > FlexMatrix > FlexMatrix** menu item to access the FlexMatrix configuration settings.

Figure 142: FlexMatrix configuration settings

The following setting is available for each of the eight (8) FlexMatrix elements.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables or disables the FlexMatrix element.

Name

Range: 12 alphanumeric characters

Default: Flexmat 1

This setting specifies the name associated with a particular FlexMatrix element.

Input 1 Enable, Input 2 Enable,..., Input 16 Enable

Range: Enabled, Disabled

Default: Disabled

These settings enabled and disabled the sixteen (16) FlexMatrix inputs for each FlexMatrix. These inputs can be assigned FlexLogic™ operands or shared operands, which can then be assigned to any or all of the FlexMatrix outputs.

Block

Range: any FlexLogic™ operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the FlexMatrix element.

Pikup Delay

Range: 0.000 to 60.000 ms in steps of 0.001

Default: 0.000 seconds

This setting specifies the delay by which to extend the FlexMatrix pickup.

Dropout Delay

Range: 0.000 to 60.000 ms in steps of 0.001

Default: 0.000 seconds

This setting specifies the delay by which to extend the FlexMatrix dropout.

Latching

Range: Enabled, Disabled

Default: Disabled

When this setting is enabled, the FlexMatrix output is latched until the reset input is asserted.

Reset

Range: any FlexLogic™ operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting resets the FlexMatrix output when latching is enabled.

Events

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of FlexMatrix events in the sequence of events recorder.

The logic is shown below for FlexMatrix 1. The logic is identical for all eight FlexMatrix elements.

Figure 143: FlexMatrix scheme logic
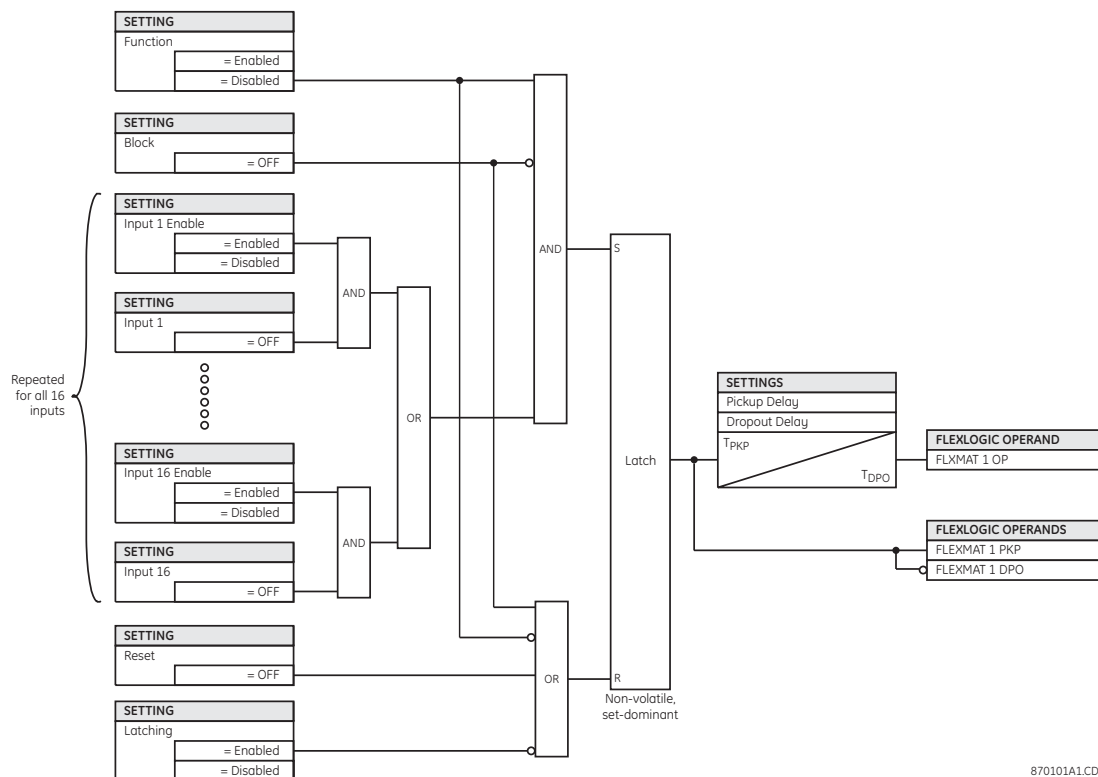
VT fuse failure

Every signal source includes a fuse failure scheme.

The VT fuse failure detector can be used to raise an alarm or block elements that may operate incorrectly for a full or partial loss of AC potential caused by one or more blown fuses. Some elements that might be blocked (via the Block setting) include voltage restrained overcurrent and directional current.

There are two classes of fuse failure that may occur.

- Class A: loss of one or two phases.
- Class B: loss of all three phases.

Different means of detection are required for each class. An indication of class A failures is a significant level of negative-sequence voltage, whereas an indication of class B failures is when positive-sequence current is present and there is an insignificant amount of positive-sequence voltage. These noted indications of fuse failure could also be present when faults are present on the system, so a means of detecting faults and inhibiting fuse failure declarations during these events is provided. Once the fuse failure condition is declared, it will be sealed-in until the cause that generated it disappears.

An additional condition is introduced to inhibit a fuse failure declaration when the monitored circuit is de-energized; positive-sequence voltage and current are both below threshold levels.

Select the **Settings > Protection > Control > VT Fuse Failure** menu item to access the VT fuse failure settings.

Figure 144: VT fuse failure configuration settings
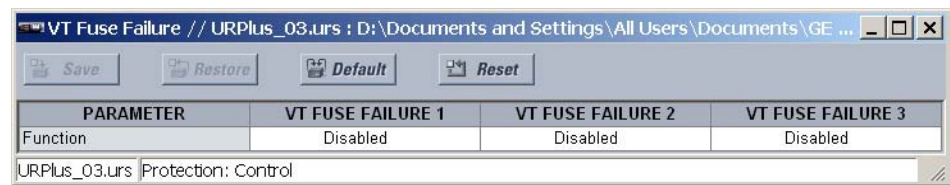
The following setting is available for each VT fuse failure element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the fuse failure feature for each source.

The VT fuse failure logic is shown below.

Figure 145: VT fuse failure scheme logic

869007A1.CDR
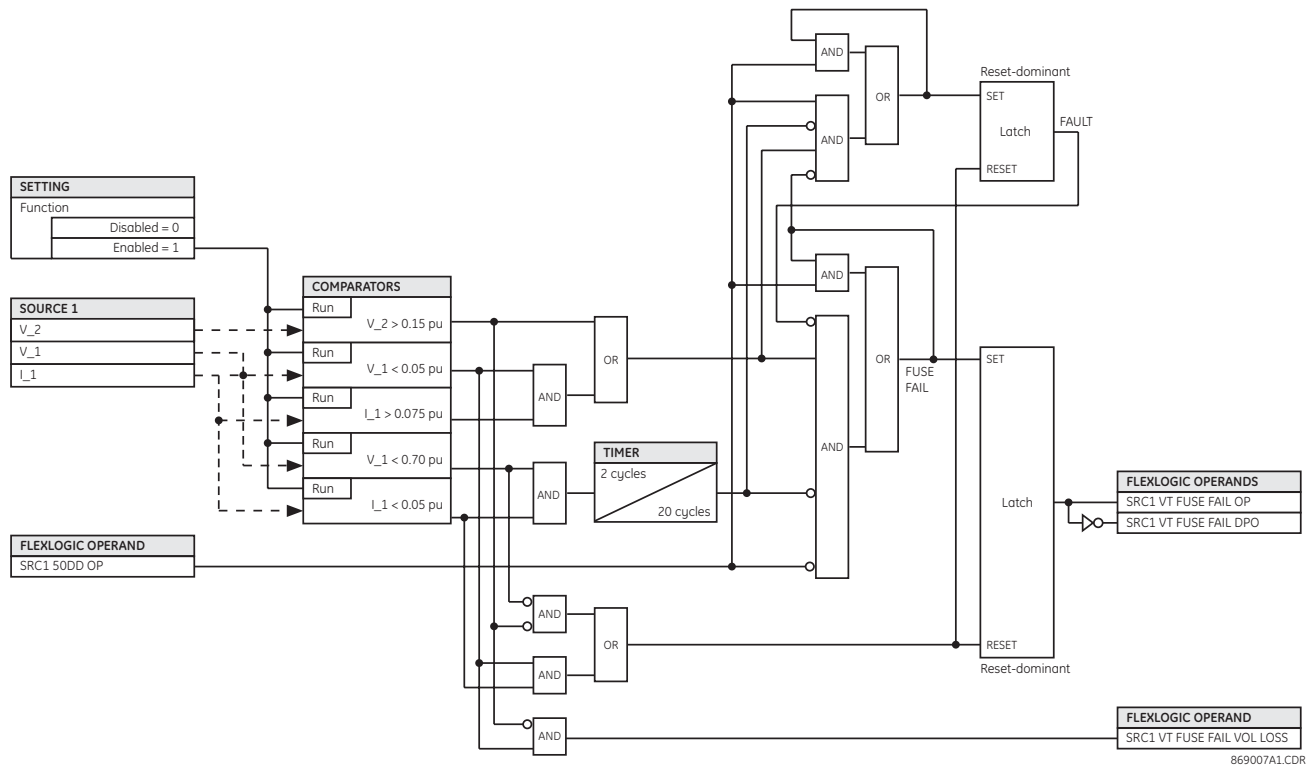
Autoreclose

The autoreclose scheme is intended for use on transmission lines with circuit breakers operated in both the single-pole and three-pole modes, in one or two breaker arrangements. The autoreclose scheme provides four programs with different operating cycles, depending on the fault type. Each of the four programs can be set to trigger up to four reclosing attempts. The second, third, and fourth attempts always perform three-pole reclosing and have independent dead time delays.

When used in two breaker applications, the reclosing sequence is selectable. The reclose signal can be sent to one selected breaker only, to both breakers simultaneously or to both breakers in sequence (one breaker first and then, after a delay to check that the reclose was successful, to the second breaker). When reclosing in sequence, the first breaker should reclose with either the single-pole or three-pole dead time according to the fault type and reclose mode; the second breaker should follow the successful reclosure of the first breaker. When reclosing simultaneously, for the first shot both breakers should reclose with either the single-pole or three-pole dead time, according to the fault type and the reclose mode.

The signal used to initiate the autoreclose scheme is the trip output from protection. This signal can be single-pole tripping for single-phase faults and three phase tripping for multiphase faults. The autoreclose scheme has five operating states.

Table 17: Autoreclose operating states

State	Characteristics
Enabled	Scheme is permitted to operate
Disabled	Scheme is not permitted to operate
Reset	Scheme is permitted to operate and shot count is reset to 0
Reclose in progress	Scheme has been initiated but the reclose cycle is not finished (successful or not)
Lockout	Scheme is not permitted to operate until reset received

Autoreclose programs

The autorecloser provides four programs that can cause from one to four reclose attempts (shots). After the first shot, all subsequent reclosings will always be three-pole. If the maximum number of shots selected is 1 (only one reclose attempt) and the fault is persistent, after the first reclose the scheme will go to lockout upon another initiate signal.

For the three-pole reclose programs (the "3 Pole-A" and "3 Pole-B" mode values), an AR FORCE 3-P FlexLogic™ operand is set. This operand can be used in connection with the tripping logic to cause a three-pole trip for single-phase faults.

Table 18: Autoreclose programs

Mode setting	First shot		Second shot		Third shot		Fourth shot	
	single-phase fault	multi-phase fault	single-phase fault	multi-phase fault	single-phase fault	multi-phase fault	single-phase fault	multi-phase fault
"1 & 3 Pole"	1 POLE	3 POLE	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT
"1 Pole"	1 POLE	LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT
"3 Pole-A"	3 POLE	LOCKOUT	3 POLE or LOCKOUT	LOCKOUT	3 POLE or LOCKOUT	LOCKOUT	3 POLE or LOCKOUT	LOCKOUT
"3 Pole-B"	3 POLE	3 POLE	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT

In the "1 & 3 Pole" mode, the autorecloser starts the 1-P Dead Time timer for the first shot if the autoreclose is single-phase initiated, the 3-P Dead Time 1 timer if the autoreclose is three-pole initiated, and the 3-P Dead Time 2 timer if the autoreclose is three-phase time delay initiated. If two or more shots are enabled, the second, third, and fourth shots are always three-pole and start the 3-P Dead Time 2 through 3-P Dead Time 4 timers.

In the "1 Pole" mode, the autorecloser starts the 1-P Dead Time for the first shot if the fault is single-phase. If the fault is three-phase or a three-pole trip on the breaker occurred during the single-pole initiation, the scheme goes to lockout without reclosing. If two or more shots are enabled, the second, third, and fourth shots are always three-pole and start the 3-P Dead Time 2 through 3-P Dead Time 4 timers.

In the "3 Pole-A" mode, the autorecloser is initiated only for single-phase faults, although the trip is three-pole. The autorecloser uses the 3-P Dead Time 1 for the first shot if the fault is single-phase. If the fault is multi-phase the scheme will go to lockout without reclosing. If two or more shots are enabled, the second, third, and fourth shots are always three-phase and start the 3-P Dead Time 2 through 3-P Dead Time 4 timers.

In the "3 Pole-B" mode, the autorecloser is initiated for any type of fault and starts the 3-P Dead Time 1 for the first shot. If the initiating signal is AR 3P TD INIT, the scheme starts the 3-P Dead Time 2 for the first shot. If two or more shots are enabled, the second, third, and fourth shots are always three-phase and start the 3-P Dead Time 2 through 3-P Dead Time 4 timers.

Autoreclose control

The autoreclose control function complies with the select-before-operate principle as described in IEC-61850-7-2 section 17.2.2. The Addcause parameter shall be derived as shown below.

- Select failed: The control model is not select-before-operate with normal security or the device has been selected locally or by another client.
- Blocked-by-mode: The device is not in service.
- Abortion-by-cancel: The control action is canceled locally or from SCADA.
- Time-limit-over: The T_{select} time is timed out.

The autoreclose control logic is shown below.

Figure 146: Autoreclose control scheme logic
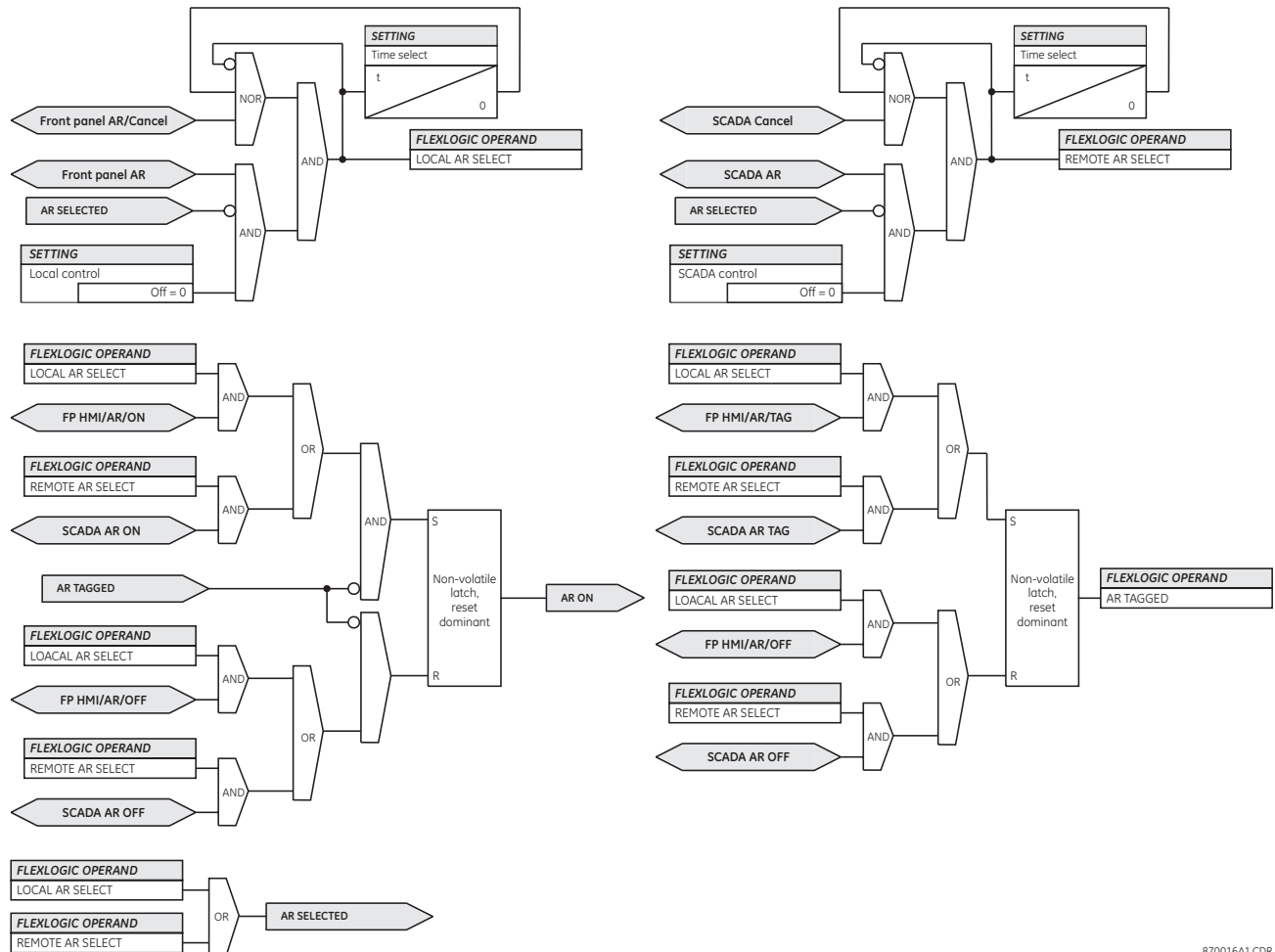
Basic reclosing operation

Reclosing is enabled via settings and dynamically disabled from a line pickup operation, a block signal, or a manual close. Once enabled, a reclose is initiated from the trip output scheme or through the **1-Pole Initiate** and **3-Pole Initiate** user-programmable inputs. There are three initiate programs: single-pole initiate, three-pole initiate, and three-pole time delay initiate. Any of these reclose initiate signals will start the reclose cycle and set the reclose-in-progress (AR RIP) operand. The reclose-in-progress operand is sealed-in until the lockout or reset signal appears.

Figure 147: Autoreclose scheme enable logic
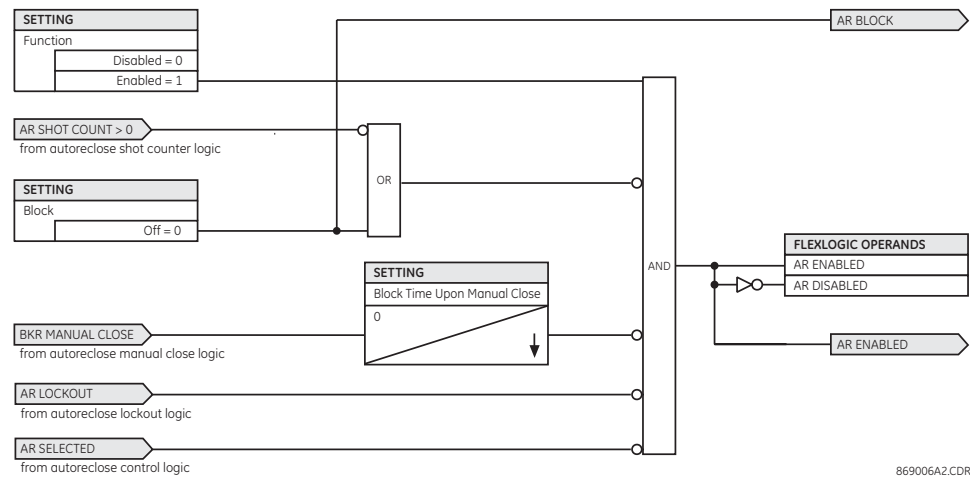
Figure 148: Autoreclose scheme initiate logic
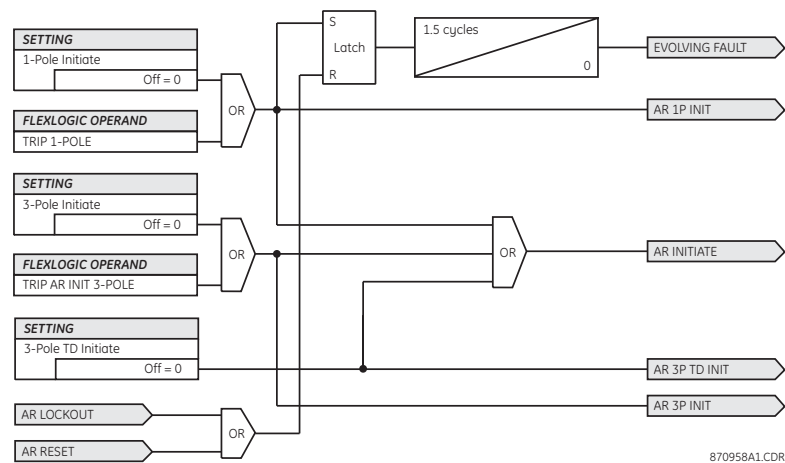
A reclose initiate signal will send the scheme into the reclose-in-progress (RIP) state and assert the AR RIP operand. Once the breaker has opened, the scheme is latched into the reclose-in-progress state and resets only when an AR CLS BKR 1 (autoreclose breaker 1) or AR CLS BKR 2 (autoreclose breaker 2) operand is generated or the scheme goes to the lockout state.

Figure 149: Autoreclose scheme reclose-in-progress logic

870960A1.CDR
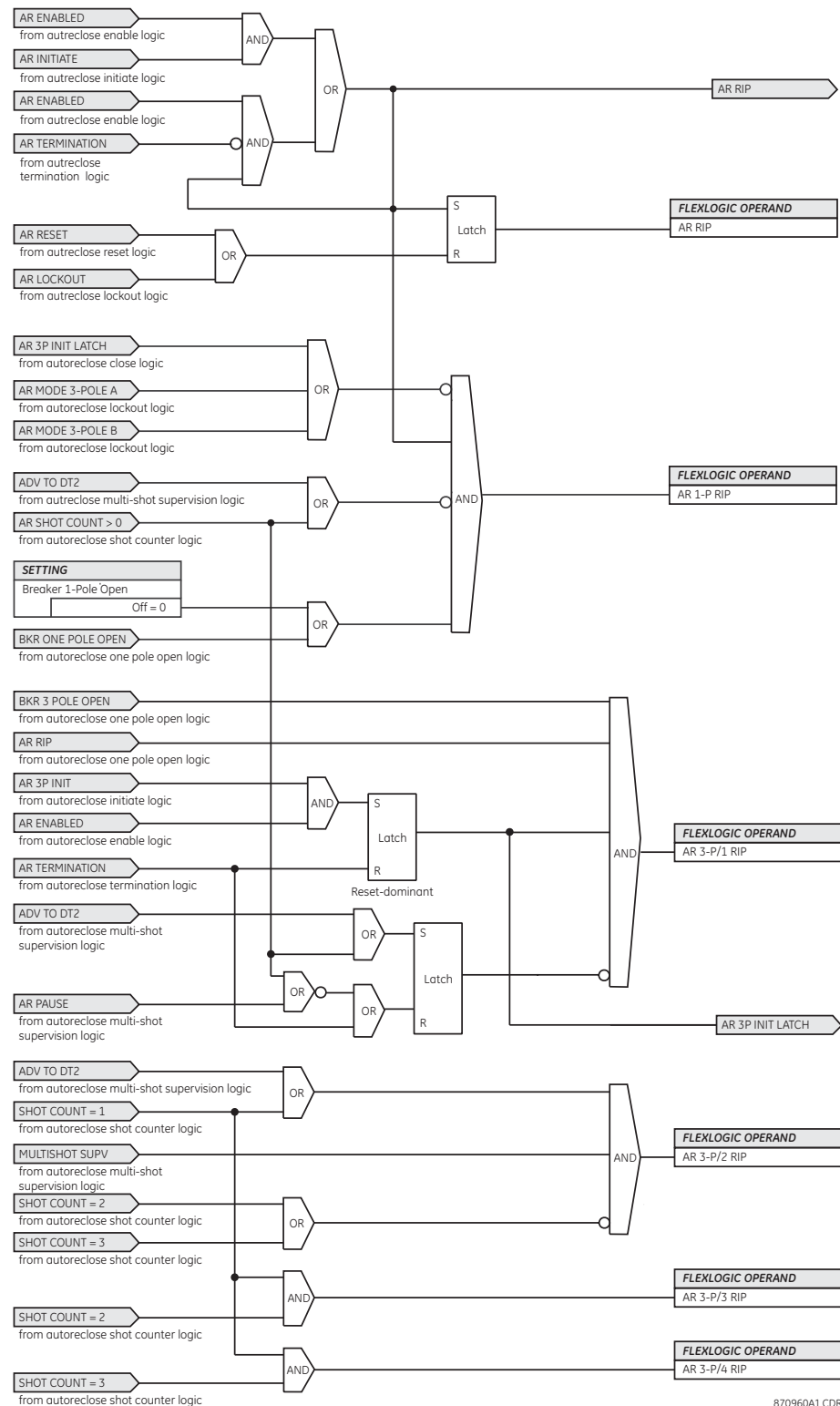
After entering the reclose-in-progress state, a close command will be issued after the dead time delay. The dead time for the initial reclose operation will be determined by either the **1-P Dead Time**, **3-P Dead Time 1**, or **3-P Dead Time 2** setting, depending on the fault type

and the mode selected. After the dead time interval the scheme will assert the AR CLOSE BKR 1 or AR CLOSE BKR 2 operands, as determined by the sequence selected. These operands are latched until the breaker closes or the scheme goes to reset or lockout.

Figure 150: Autoreclose scheme breaker close logic
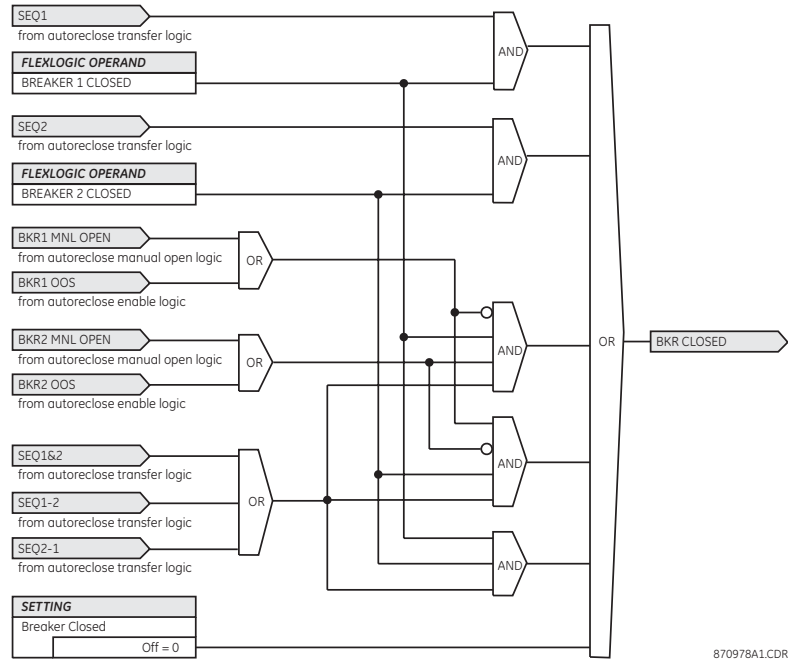
Figure 151: Autoreclose scheme close breaker 1 or 2 logic
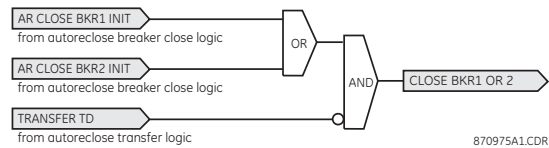
Figure 152: Autoreclose scheme termination
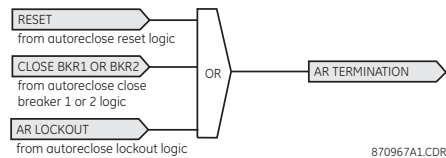
Multi-shot operation

The **Maximum Number of Shots** setting defines the number of reclose attempts. After each reclose the shot counter is incremented.

If **Maximum Number of Shots** is set to "1", the shot counter is set to 1 upon the first reclose. At reclosing, the fault is again detected by protection and reclose is initiated. The breaker is tripped three-pole through the AR SHOT COUNT >0 operand that will set the AR FORCE 3P operand. Because the shot counter has reached the maximum number of shots permitted, the scheme is sent to the lockout state.

If **Maximum Number of Shots** is set to "2", the shot counter is set to 1 upon the first reclose. At reclosing, the fault is again detected by protection and reclose is initiated. The breaker is tripped three-pole through the AR SHOT COUNT >0 operand that will set the AR FORCE 3P operand. After the second reclose the shot counter is set to 2. Upon reclosing, the fault is again detected by protection, the breaker is tripped three-pole, and reclose is initiated again. Because the shot counter has reached the maximum number of shots permitted, the scheme is sent to the lockout state.

Figure 153: Autoreclose scheme shot counter logic

870971A1.CDR
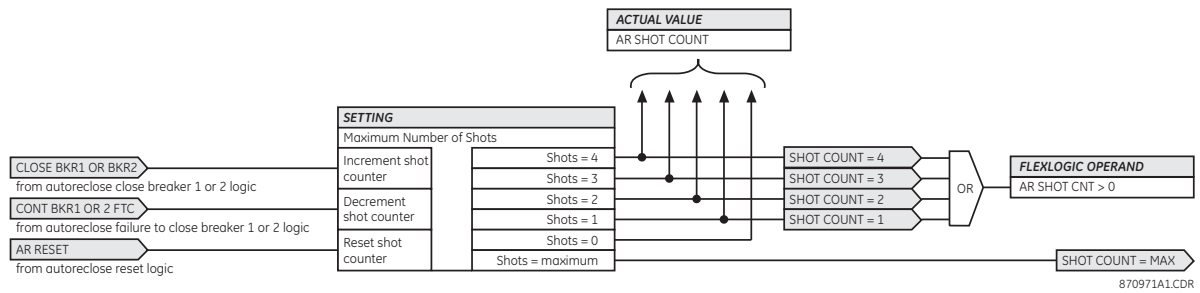
Autoreclose pause input

The autoreclose pause input offers the possibility of freezing the autoreclose cycle until the pause signal disappears. This may be done when a trip occurs and simultaneously or previously, some conditions are detected such as out-of step or loss of guard frequency, or a remote transfer trip signal is received. The pause signal blocks all three dead timers. When the pause signal disappears, the autoreclose cycle is resumed by initiating the AR 3-P DEAD TIME 2 operand.

This feature can be also used when a transformer is tapped from the protected line and a reclose is not desirable until the transformer is removed from the line. In this case, the reclose scheme is paused until the transformer is disconnected. The AR PAUSE input will force a three-pole trip through the **3-P Dead Time 2** path.

Figure 154: Autoreclose multi-shot supervision logic

870963A1.CDR
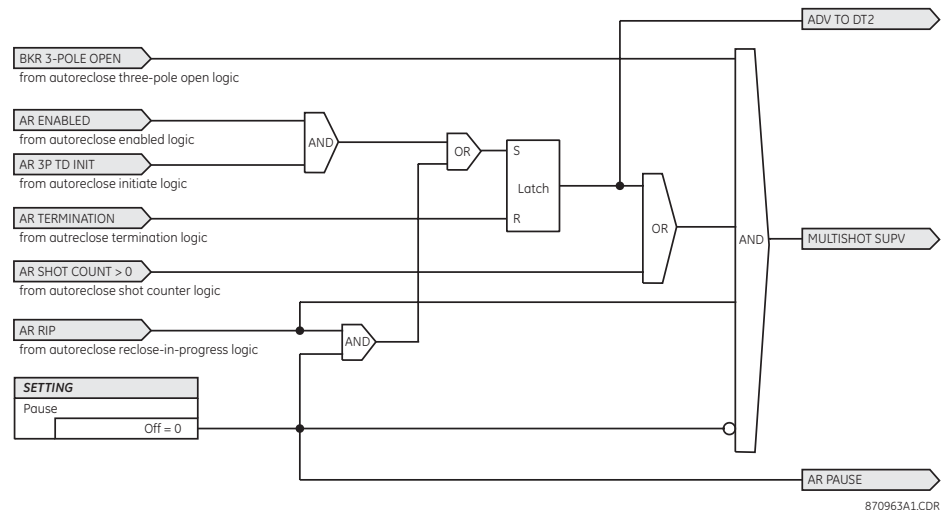
Dual breaker operation

The general operation for two breaker reclosing on a permanent fault is the same as that outlined for the single breaker application, except as follows, which assumes the **Breaker Sequence** setting is "1-2" (reclose breaker 1 before breaker 2). The signal output from the dead time timers passes through the breaker selection logic to initiate reclosing of breaker 1. The CLOSE BREAKER 1 signal will initiate the transfer timer. After the reclose of the first breaker, the fault is again detected by the protection, the breaker is tripped three-pole and the autoreclose scheme is initiated. The INITIATE signal will stop the transfer timer. After the three-pole dead time times out, the CLOSE BREAKER 1 signal will close first breaker again and will start the transfer timer. Since the fault is permanent, the protection will trip again and initiate the autoreclose scheme that is sent to lockout by the SHOT COUNT = MAX signal.

Figure 155: Autoreclose scheme transfer logic

870973A1.CDR
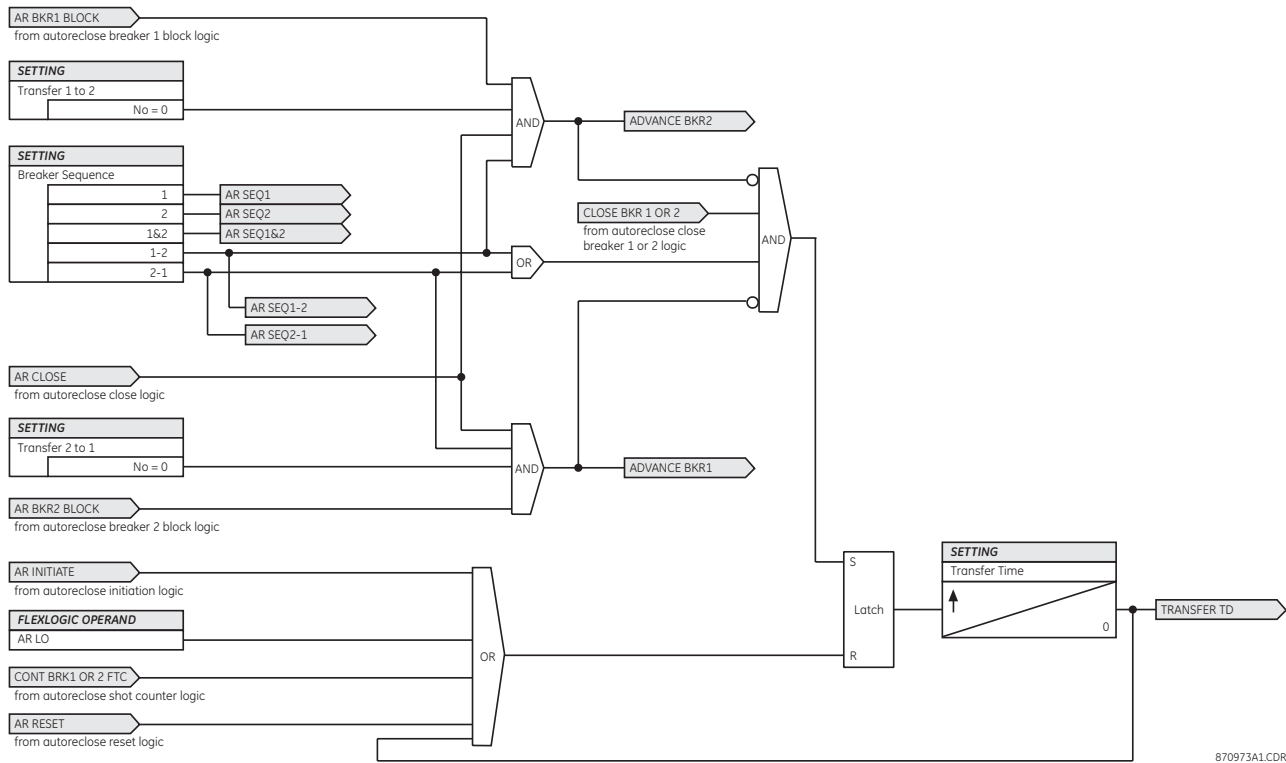
When the 1-2 reclosing sequence is selected and breaker 1 is blocked (the AR BKR1 BLK operand is set) the reclose signal can be transferred direct to breaker 2 if the **Transfer 1 to 2** setting is "Yes". If the setting is "No", the scheme will be sent to lockout by the incomplete sequence timer.

When the 2-1 reclosing sequence is selected and breaker 2 is blocked (the AR BKR2 BLK operand is set) the reclose signal can be transferred direct to breaker 1 if **Transfer 2 to 1** setting is "Yes". If set to "No", the scheme will be sent to lockout by the incomplete sequence timer or if it is out-of-service or open prior to the reclose-in-progress. In this case, the scheme can be configured to transfer close command immediately to the second breaker via the **Transfer 1 to 2** and **Transfer 2 to 1** settings.

For two-breaker reclosing on a transient fault, the reset timer is started when the first reclose output signal is sent to close breaker 1. The CLOSE BREAKER 1 signal initiates the transfer timer that times out and sends the close signal to the second breaker. If the reclosure sequence is successful (both breakers closed and there is no initiating signal), the reset timer will time out and return the scheme to the reset state with the shot counter set to 0. The scheme will now be ready for a new reclose cycle.

A typical reclosing sequence for the "1 & 3 Pole" mode is shown below for a single-pole fault, two shots, with successful reclosure. The following two options are available if the selected breaker sequence is "1–2" or "2–1", and the breaker fails to close after the first or second reclose attempt.

- If the **Breaker 1 Failure Option** or **Breaker 2 Failure Option** is set to "Lockout", the scheme will go to lockout state.
- If the **Breaker 1 Failure Option** or **Breaker 2 Failure Option** is set to "Continue", the reclose process will continue with breaker 2. At the same time, the shot counter will be decreased (since the closing process was not completed).

Figure 156: Autoreclose scheme failure-to-close logic

870974A1.CDR
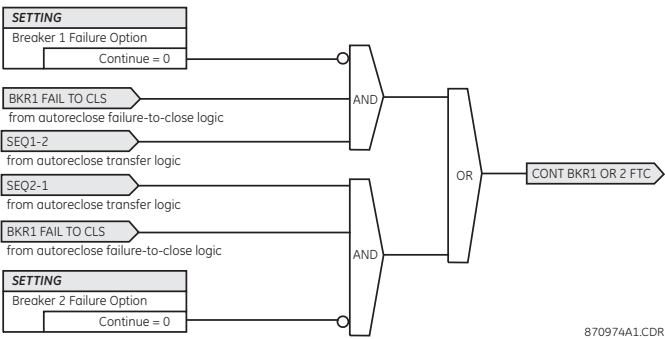
Figure 157: Typical autoreclose sequence
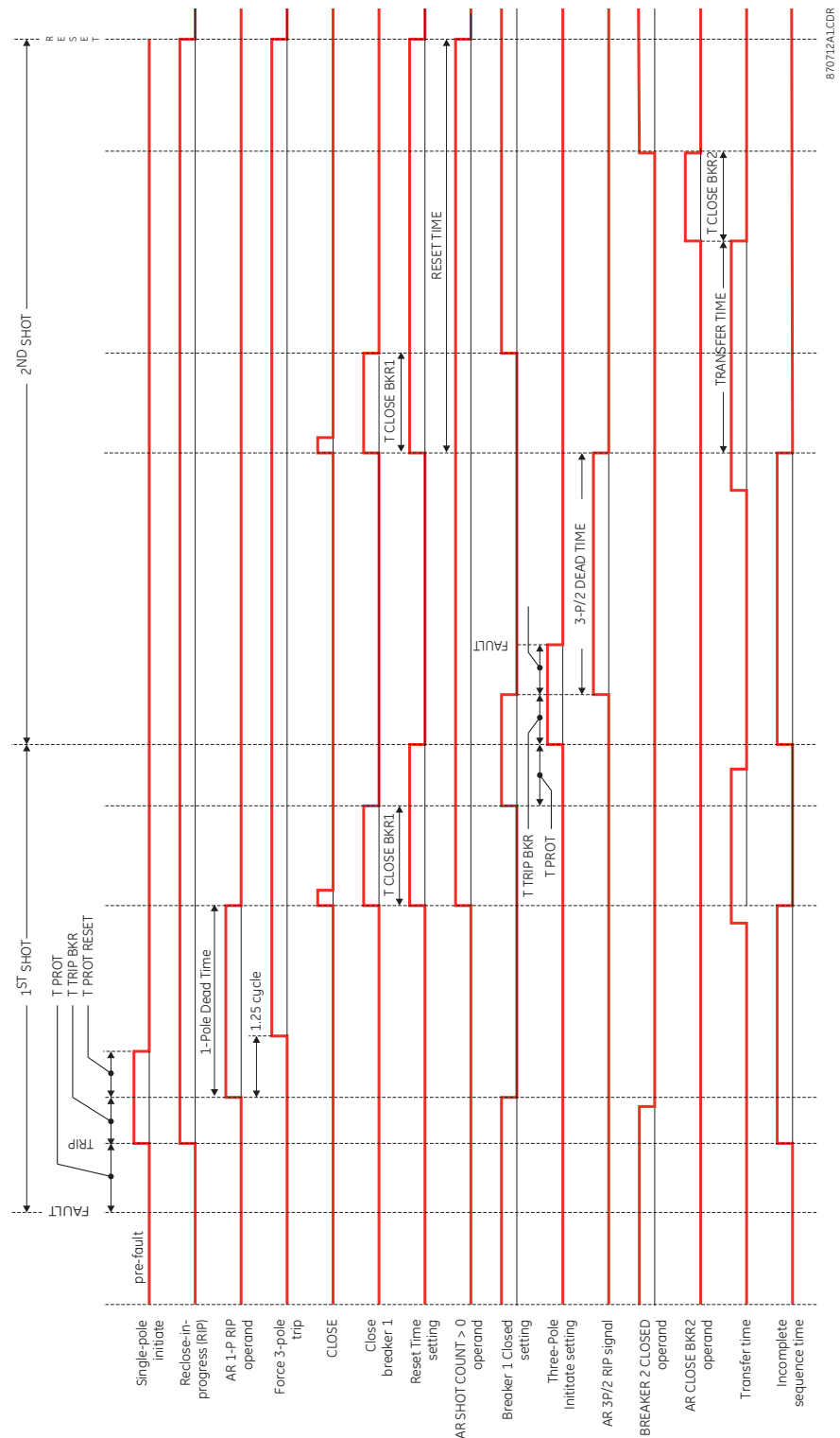
Breaker block
A reclose command to a breaker is inhibited if it receives a user-defined block input or if it is out-of-service. A logic circuit is also provided that inhibits a breaker reclose if that breaker was open in advance of a reclose initiate input to the recloser. This logic circuit resets when the breaker is closed.

Figure 158: Autoreclose scheme breaker block logic
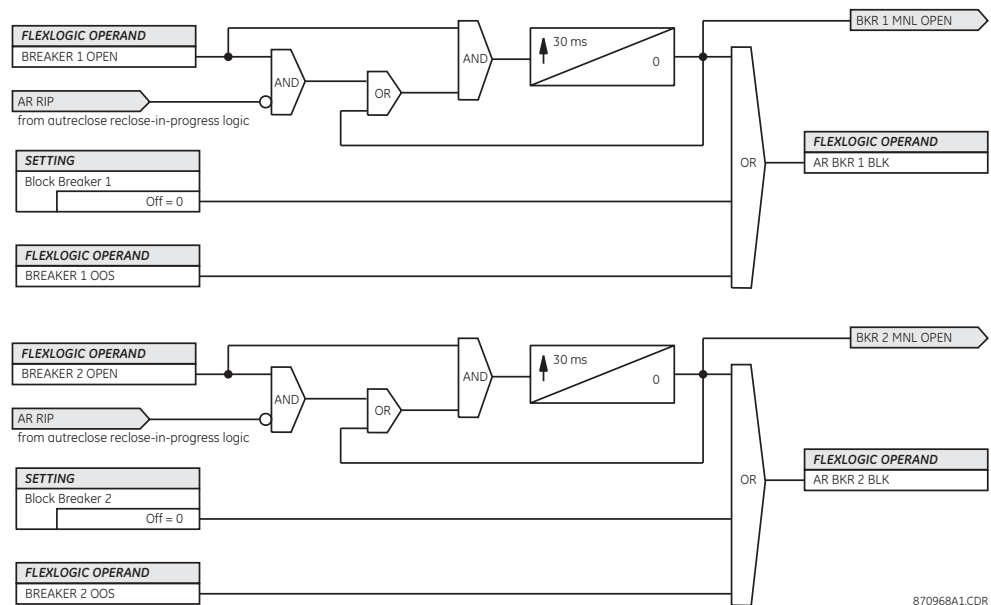
Reset after reclosure

For single breaker reclosing on a transient fault, the reset timer is started when a reclose output signal is sent to close the breaker. If the reclosure sequence is successful (there is no initiating signal and the breaker is closed) the reset timer will time out, returning the scheme to the reset state with the shot counter set to 0 and ready for a new reclose cycle.

In two breaker schemes, if one breaker is in the out-of-service state and the other is closed at the end of the reset time, the scheme will also reset. If at the end of the reset time at least one breaker, which is not in the out-of-service state, is open the scheme will be sent to lockout. The reset timer is stopped if the reclosure sequence is not successful: an initiating signal present or the scheme is in lockout state. The reset timer is also stopped if the breaker is manually closed or the scheme is otherwise reset from lockout.

Figure 159: Autoreclose scheme reset logic
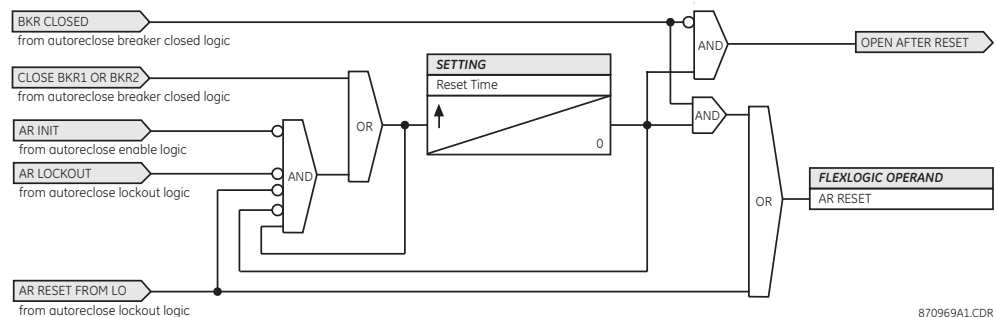
Autoreclose lockout

When a reclose sequence is started by an initiate signal, the autoreclose scheme moves into the reclose-in-progress state and starts the incomplete sequence timer. The setting of this timer determines the maximum time interval allowed for a single reclose shot. If a close breaker 1 or 2 signal is not present before this time expires, the scheme enters the lockout state.

There are four other conditions that can take the scheme to the lockout state.

- Receipt of the Block input while in the reclose-in-progress state.

- The reclosing program logic: when a three-phase initiate is present and the autoreclose mode is either "1 Pole" or "3 Pole-A" (three-pole autoreclose for single-pole faults only).

- Initiation of the scheme when the count is at the maximum allowed.

- If at the end of the reset time at least one breaker, which is not in the out-of-service state, is open the scheme will be sent to lockout. The scheme will be also sent to lockout if one breaker fails to reclose and the setting **Breaker Failure Option** setting is "Lockout".

Once the lockout state is set, it will remain latched until one or more of the following occurs.

- The scheme is intentionally reset from lockout, employing the **Reset** setting of the autorecloser.

- The breaker or breakers are manually closed from the panel switch, SCADA, or other remote control through the **Breaker Manual Close** setting.

- Ten seconds after breaker control detects that the breaker or breakers were closed.

Figure 160: Autoreclose scheme lockout logic

869008A1.CDR
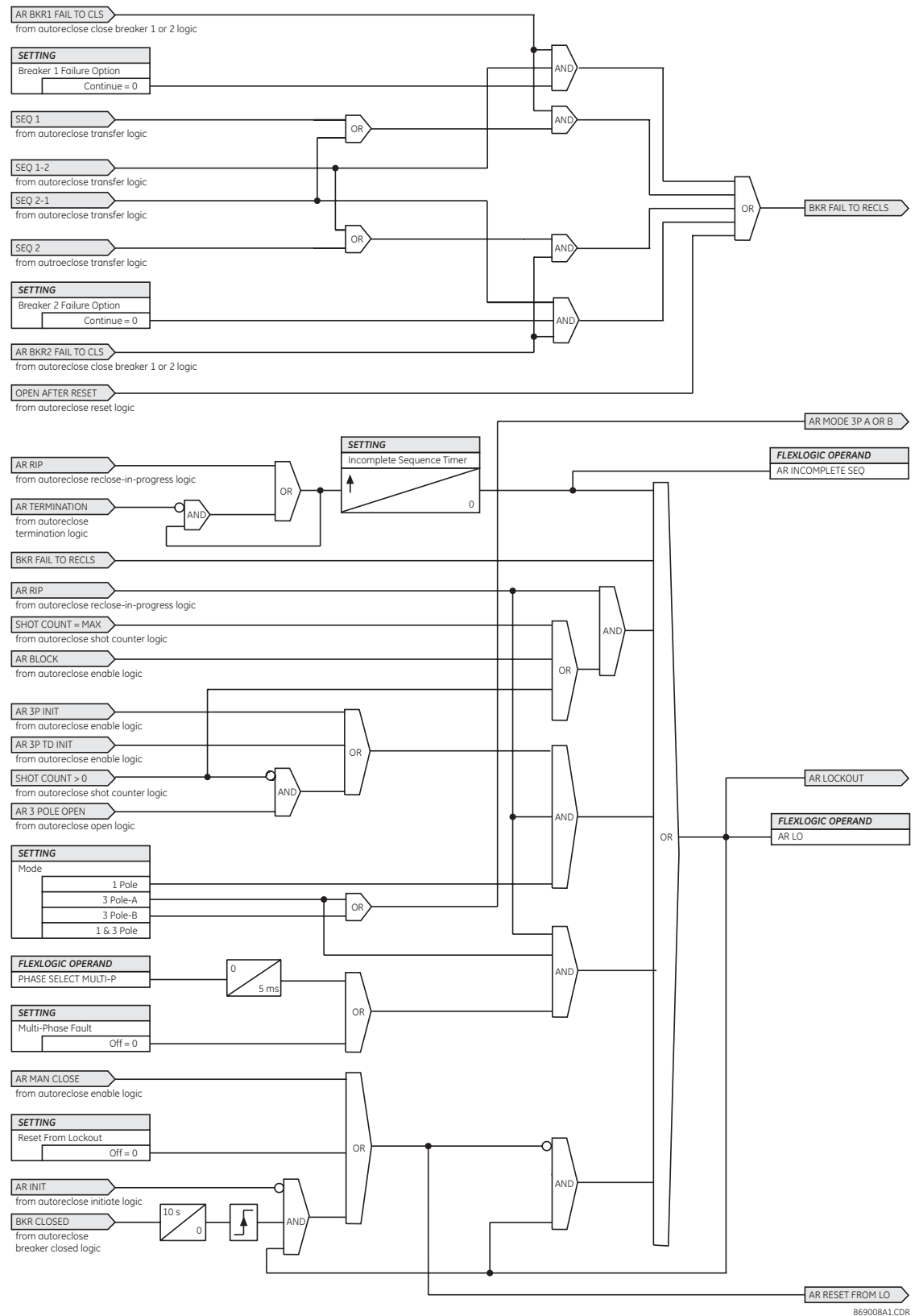
Force three-pole tripping

The reclosing scheme contains logic that is used to signal trip logic that three-pole tripping is required for certain conditions. This signal is activated by any of the following conditions.

- The autoreclose scheme is paused after it was initiated.
- The autoreclose scheme is paused.
- The autoreclose scheme is in the lockout state.
- The autoreclose mode is programmed for three-pole operation.
- The shot counter is not at 0; that is, the scheme is not in the reset state. This ensures a second trip will be three-pole when reclosing onto a permanent single phase fault.
- 1.25 cycles after the single-pole reclose is initiated by the AR 1P INIT signal.

Figure 161: Autoreclose force three-pole trip logic
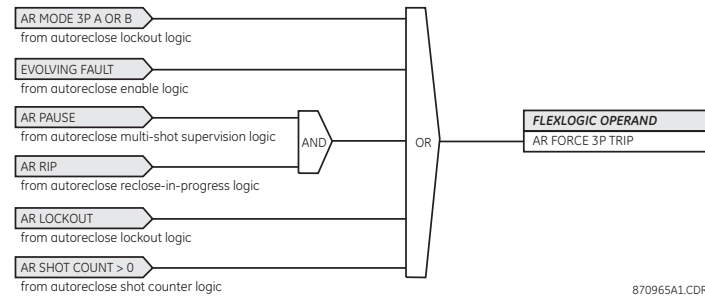
Terminal manual close

The manual close logic receives the manual close signal from each of the breakers and derives a manual close signal for the local terminal. The manual close is declared when:

- Breaker 1 issues a manual close and sequence 2 is not selected and breaker 2 is either open or out-of-service.
- Breaker 2 issues a manual close and sequence 1 is not selected and breaker 1 is either open or out-of-service.

Alternately, a user-defined setting is available to generate this signal.

Figure 162: Autoreclose scheme manual close logic
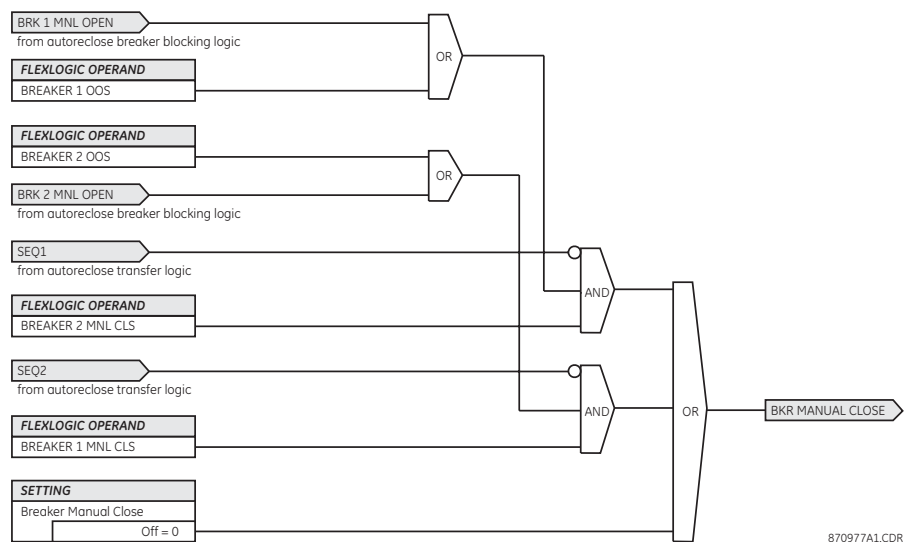
Terminal closed

The close logic uses the status of each breaker to determine whether the terminal is closed. For single breaker applications, it is necessary to monitor the closed status of the particular breaker. For dual breaker applications, the logic checks that either or both breakers are closed and not out-of-service. Alternately, a user-defined setting is available to generate this signal.

Figure 163: Autoreclose scheme closing logic
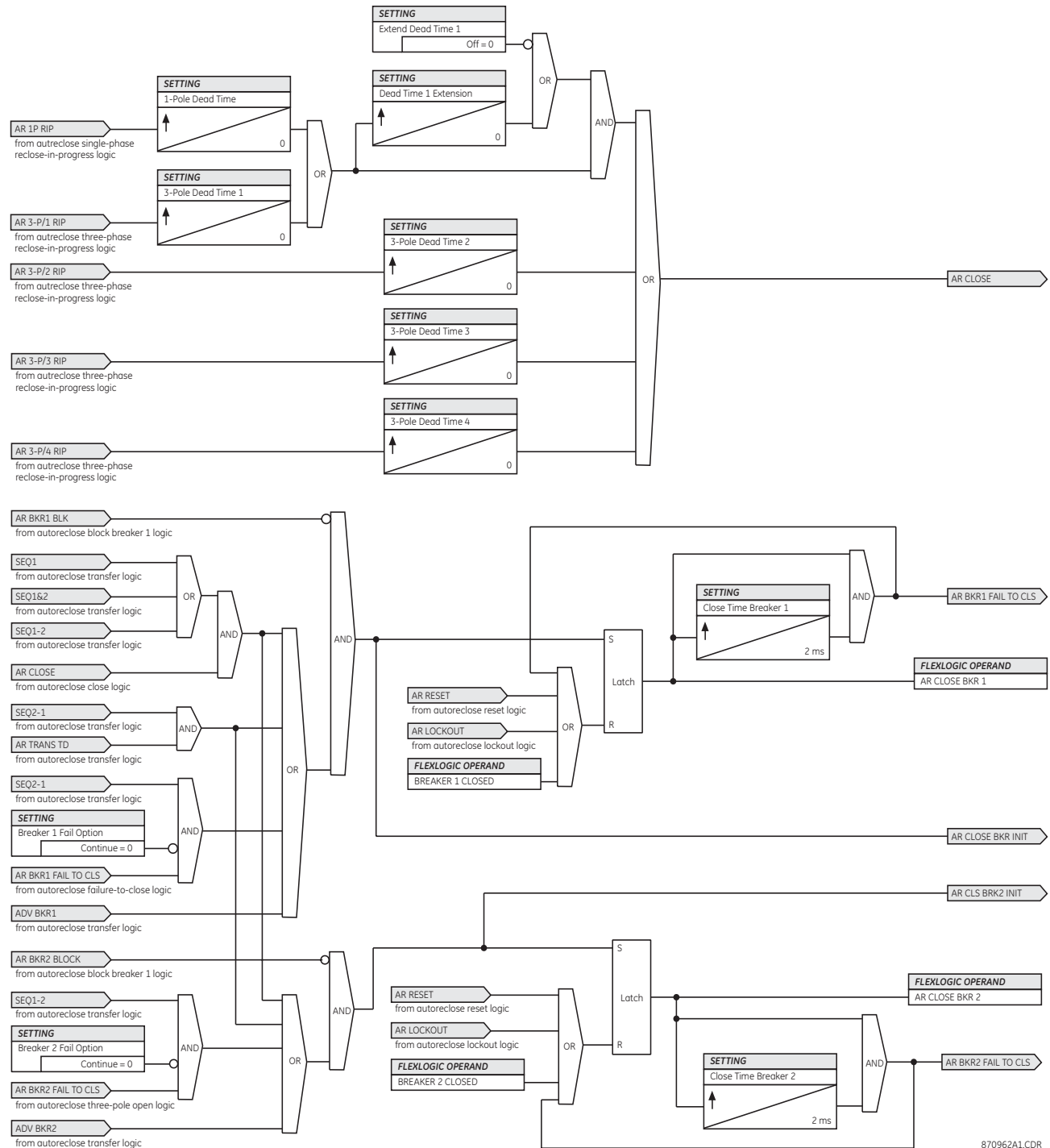
Terminal three-pole open

The autoreclose scheme employs dedicated logic to determine if all three poles are opened at the local terminal. This signal is used in the preceding logic. For single breaker operation, the breaker status is sufficient to derive this signal. For dual breaker operation both breakers must either be open or out-of-service. If one breaker has been opened from a bus protection, the **Bus Fault Initiate** setting can be used to declare the terminal opened when either breaker is opened. Alternately, a user-defined setting is available to generate this signal.

Figure 164: Terminal three-pole open logic
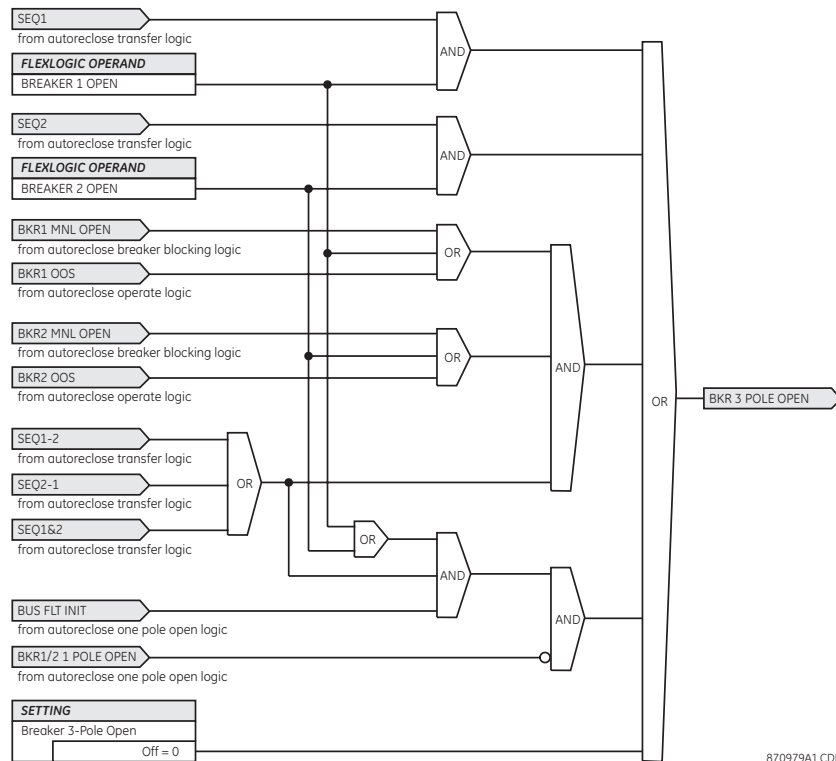
Terminal one-pole open

The autoreclose scheme also has dedicated logic to determine if one pole is opened at the local terminal. For single breaker operation, the BREAKER 1 ONE P OPEN or BREAKER 2 ONE P OPEN operand is used to derive this signal. For the 1&2 sequence, both breakers must either declare one pole open or be open or out-of-service. For the 1-2 sequence, breaker 1 must declare one pole open and breaker 2 must declare one pole open or be open or out-of-service. For the 2-1 sequence, breaker 2 must declare one pole open and breaker 1 must declare one pole open or be open or out-of-service. Alternately, a user-defined setting is available to generate this signal.

Figure 165: Terminal one-pole open logic
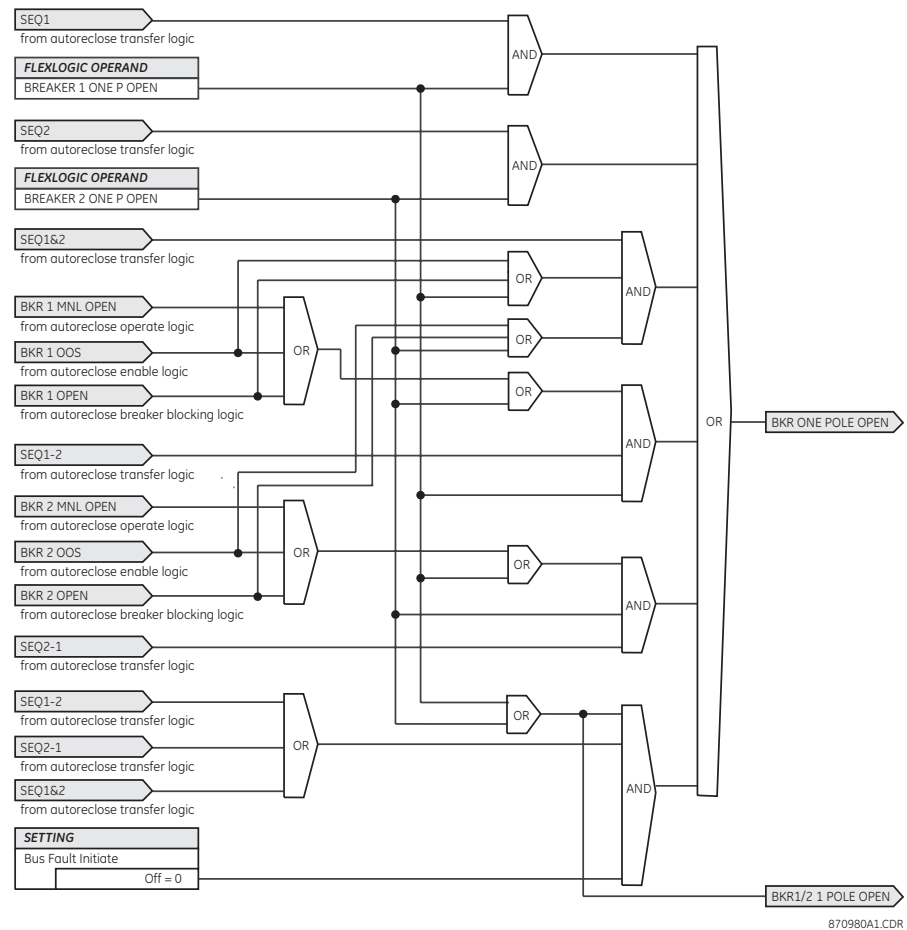
Autoreclose settings   Select the **Settings > Protection > Control > Autoreclose** menu item to access the autoreclose settings.

Figure 166: Autoreclose settings window

The following settings are available for the autoreclose element.

Function

Range: Disabled, Enabled

Default: Disabled

This setting enables and disables the autoreclose scheme.

Mode

Range: 1 & 3 Pole, 1 Pole, 3 Pole-A, 3 Pole-B

Default: 1 & 3 Pole

This setting selects the autoreclose operating mode, which functions in conjunction with signals received at the initiation inputs.

Select Time

Range: 1.0 to 30.0 seconds in steps of 0.1

Default: 5 seconds

This setting determines the maximum permissible time from selection of autoreclose and a control action.

Maximum Number of Shots

Range: 1, 2, 3, 4

Default: 2

This setting specifies the number of reclosures attempted before reclosure goes to lockout when the fault is permanent.

Block Breaker 1

Range: any FlexLogic™ operand or shared operand

Default: Off

This setting selects an operand that will block the reclose command for breaker 1. This condition can include breaker low air pressure, reclose in progress on another line (for the central breaker in a breaker and a half arrangement), or a sum of conditions combined in FlexLogic™.

Close Time Breaker 1

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 0.10 seconds

This setting represents the closing time for breaker 1 from the moment the CLOSE command is sent to the moment the contacts are closed.

Breaker Manual Close

Range: any FlexLogic™ operand or shared operand

Default: Off

This setting selects an operand that represents a manual close command to a breaker associated with the autoreclose scheme.

Block Time Upon Manual Close

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 10.00 seconds

The autoreclose scheme can be disabled for a programmable time delay after an associated circuit breaker is manually commanded to close, preventing reclosing onto an existing fault such as grounds on the line. This delay must be longer than the slowest expected trip from any protection not blocked after manual closing. If the autoreclose scheme is not initiated after a manual close and this time expires, the autoreclose scheme is set to the reset state.

1-Pole Initiate

Range: any FlexLogic™ operand or shared operand

Default: Off

This setting selects an operand used to initiate single-pole autoreclosure.

3-Pole Initiate

Range: any FlexLogic™ operand or shared operand

Default: Off

This setting selects an operand used to initiate three-pole autoreclosure. The first timer (3-Pole Dead Time 1) can be used for a high-speed autoreclosure.

3-Pole TD Initiate

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects an operand used to initiate three-pole autoreclosure. The second timer (**3-Pole Dead Time 2**) can be used for a time-delay autoreclosure.

Multi-Phase Fault

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects an operand used to indicate a multi-phase fault. The operand value should be zero for single-phase to ground faults.

Breaker 1-Pole Open

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects an operand to indicate that the breaker or breakers have opened correctly following a single-phase to ground fault. The autoreclose scheme can then start timing the single-pole dead time. For example, if the reclose sequence is "1-2", breaker 1 should trip single-pole and breaker 2 should trip three-pole).

The scheme has a pre-wired input that indicates breaker status.

Breaker 3-Pole Open

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects an operand to indicate that the breaker or breakers have opened three-pole and the autoreclose scheme can start timing the three-pole dead time. The scheme has a pre-wired input that indicates breaker status.

3-Pole Dead Time 1

Range: 0.00 to 655.35 seconds in steps of 0.01
Default: 0.50 seconds

This setting represents the dead time following the first three-pole trip. This intentional delay can be used for a high-speed three-pole autoreclose. However, it should be set longer than the estimated de-ionizing time following the three-pole trip.

3-Pole Dead Time 2

Range: 0.00 to 655.35 seconds in steps of 0.01
Default: 1.20 seconds

This is the dead time following the second three-pole trip or initiated by the **3-Pole Time Delay Initiate** setting. This intentional delay is typically used for a time delayed three-pole autoreclose (as opposed to high speed three-pole autoreclose).

3 Pole Dead Time 3

Range: 0.00 to 655.35 seconds in steps of 0.01
Default: 2.00 seconds

This setting represents the dead time following the third three-pole trip.

3-Pole Dead Time 4

Range: 0.00 to 655.35 seconds in steps of 0.01
Default: 4.00 seconds

This setting represents the dead time following the fourth three-pole trip.

Extend Dead Time 1

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects an operand that will adapt the duration of the dead time for the first shot to the possibility of non-simultaneous tripping at the two line ends. Typically this is the operand set when the communication channel is out-of-service.

Dead Time 1 Extension

Range: 0.00 to 655.35 seconds in steps of 0.01
Default: 0.50 seconds

This timer is used to set the length of the dead time 1 extension for possible non-simultaneous tripping of the two ends of the line.

Reset

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand that forces the autoreclose scheme from any state to reset. Typically this is a manual reset from lockout, local or remote.

Reset Time

Range: 0.00 to 655.35 seconds in steps of 0.01
Default: 60.00 seconds

A reset timer output resets the recloser following a successful reclosure sequence. The setting is based on the breaker time, which is the minimum time required between successive reclose sequences.

Breaker Closed

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects an operand that indicates that the breaker(s) are closed at the end of the reset time and the scheme can reset.

Block

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects the operand that blocks the autoreclose scheme (it can be a sum of conditions such as time delayed tripping, breaker failure, and differential protection). If the block signal is present before autoreclose scheme initiation the AR DISABLED FlexLogic™ operand will be set. If the block signal occurs when the scheme is in the reclose-in-progress state the scheme will be sent to lockout.

Pause

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting offers the ability to freeze the autoreclose cycle until the pause signal disappears. This may be done when a trip occurs and simultaneously or previously, some conditions are detected such as out-of step or loss of guard frequency, or a remote transfer trip signal is received. The autoreclose cycle is resumed when the pause signal disappears. This feature can also be used when a transformer is tapped from the protected line and a reclose is not desirable until the it is disconnected from the line. In this situation, the reclose scheme is 'paused' until the transformer is disconnected.

Incomplete Sequence Time

Range: 0 to 655.35 seconds in steps of 0.01

Range: 5.00 seconds

This setting is used to set the maximum time interval allowed for a single reclose shot. It is started whenever a reclosure is initiated and is active until the CLOSE BKR1 or CLOSE BKR2 signal is sent. If all conditions allowing a breaker closure are not satisfied when this time expires, the scheme goes to lockout. The minimum permissible setting is established by the **3-Pole Dead Time 2** timer setting. Settings beyond this will determine the wait time for the breaker to open so that the reclose cycle can continue and/or for the **Pause** signal to reset and allow the reclose cycle to continue and/or for the AR BKR1(2) BLK signal to disappear and allow the AR CLOSE BKR1(2) signal to be sent.

Block Breaker 2

Range: any FlexLogic™ operand or shared operand

Default: Off

This setting selects an operand that will block the reclose command for breaker 2. This condition can include breaker low air pressure, reclose in progress on another line (for the central breaker in a breaker and a half arrangement), or a sum of conditions combined in FlexLogic™.

Close Time Breaker 2

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 0.10 seconds

This setting represents the closing time for breaker 2 from the moment the CLOSE command is sent to the moment the contacts are closed.

Transfer 1 to 2

Range: Yes, No

Default: No

This setting establishes how the scheme performs when the breaker closing sequence is "1-2" and Breaker 1 is blocked. When set to "Yes", the closing command will be transferred directly to breaker 2 without waiting for the set transfer time. When set to "No", the closing command will be blocked by the AR BKR1 BLK signal and the scheme will be sent to lockout by the incomplete sequence timer.

Transfer 2 to 1

Range: Yes, No

Default: No

This setting establishes how the scheme performs when the breaker closing sequence is "2-1" and breaker 2 is blocked. When set to "Yes", the closing command will be transferred direct to breaker 1 without waiting the transfer time. When set to "No", the closing command will be blocked by the AR BKR2 BLK signal and the scheme will be sent to lockout by the incomplete sequence timer.

Breaker 1 Failure Option

Range: Continue, Lockout

Default: Continue

This setting establishes how the scheme performs when the breaker closing sequence is "1-2" and breaker 1 has failed to close. When set to "Continue", the closing command will be transferred to breaker 2 which will continue the reclosing cycle until successful (the scheme will reset) or unsuccessful (the scheme will go to lockout). When set to "Lockout" the scheme will go to lockout without attempting to reclose breaker 2.

Breaker 2 Failure Option

Range: Continue, Lockout

Default: Continue

This setting establishes how the scheme performs when the breaker closing sequence is "2-1" and breaker 2 has failed to close. When set to "Continue", the closing command will be transferred to breaker 1 which will continue the reclosing cycle until successful (the scheme will reset) or unsuccessful (the scheme will go to lockout). When set to "Lockout", the scheme will go to lockout without attempting to reclose breaker 1.

1-Pole Dead Time

Range: 0 to 655.35 seconds in steps of 0.01

Default: 1.00 seconds

Set this intentional delay longer than the estimated de-ionizing time after the first single-pole trip.

Breaker Sequence

Range: 1, 2, 1&2, 1-2, 2-1

Default: 1-2

This setting selects the breaker reclose sequence. Select "1" to reclose breaker 1 only, "2" for reclose breaker 2 only, "1&2" to reclose both breakers simultaneously, "1-2" to reclose breakers sequentially with breaker 1 first, and "2-1" to reclose breakers sequentially with breaker 2 first.

Bus Fault Initiate

Range: any FlexLogic™ operand or shared operand

Default: OFF

This setting is used in breaker-and-a-half applications to allow the autoreclose control function to perform reclosing with only one breaker previously opened by bus protection. For line faults, both breakers must open for the autoreclose reclosing cycles to take effect.

Figure 167: Final autoreclose signal flow logic

870981A1.CDR
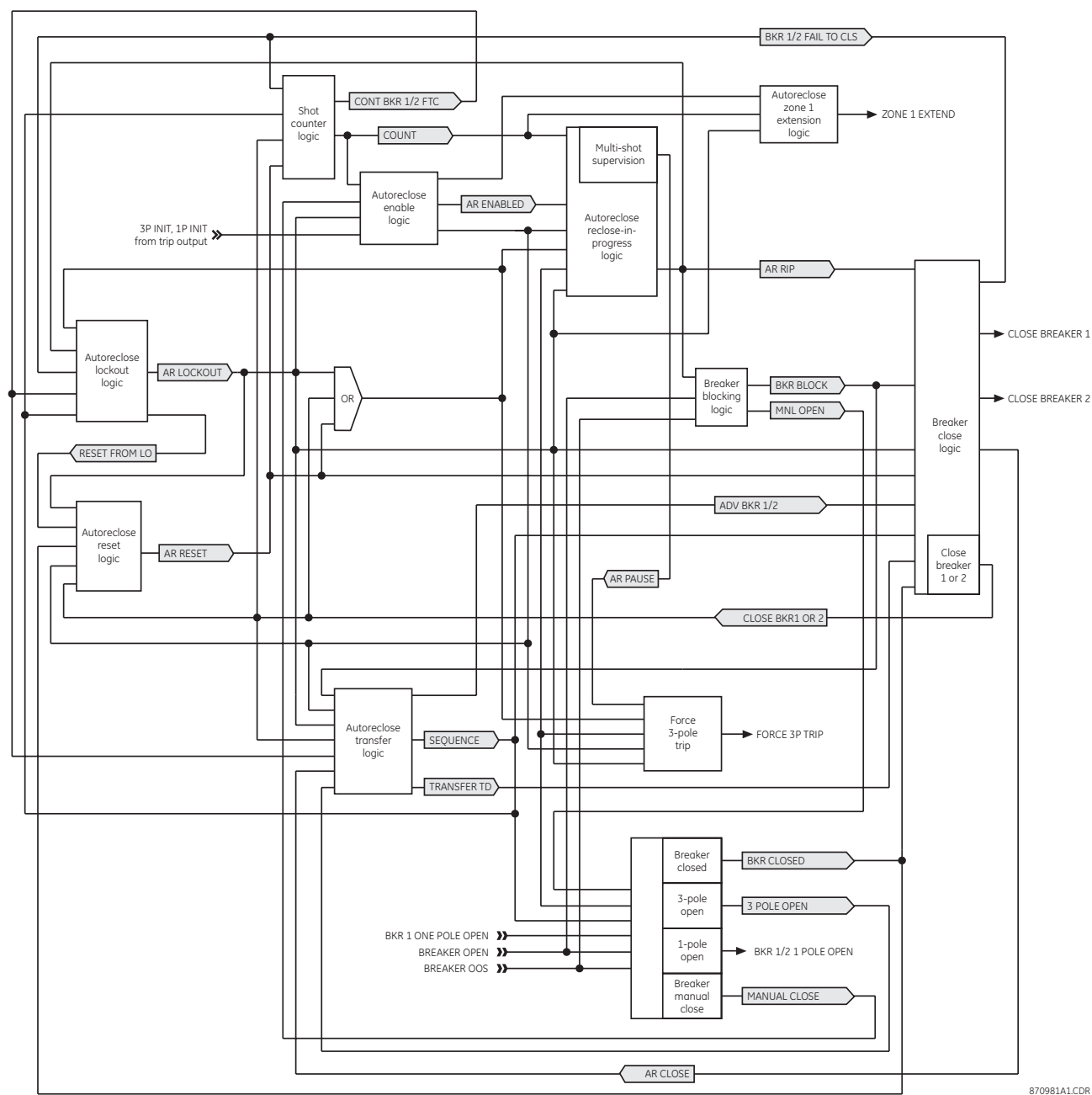
Front panel status and control

If the autoreclose function is enabled, an indication will appear on the screen. This indication indicates the operational status of the autoreclose function as defined below.

Table 19: Autoreclose front panel indications

Indication	FlexLogic™ operand
Autoreclose ON	AR ENABLED
Autoreclose OFF	AR DISABLED
Autoreclose In Progress	AR RIP
Autoreclose Locked Out	AR LO

Autoreclose control is available at the top level screen by pressing the **AR** pushbutton. If local control is not asserted for autoreclose, then the **AR** pushbutton will be grey and not operable. The local control status of a device is obtained from the autoreclose control logic.

Figure 168: Autoreclose control enabled display
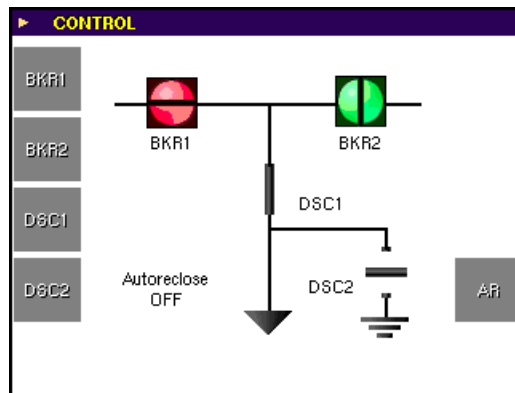
Once autoreclose control is selected, the message **AR selected to operate** is displayed and pushbuttons appear for the autoreclose control options.

Figure 169: Autoreclose control selected display
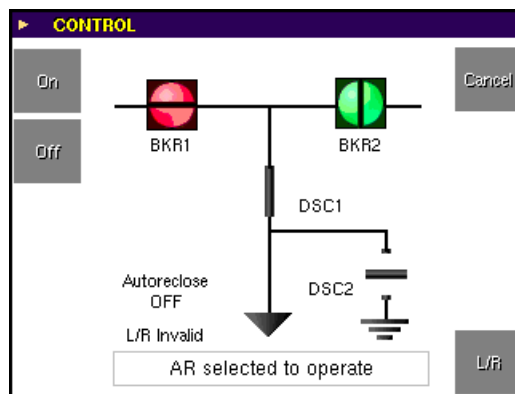
If tagging has been enabled, a **TAG** pushbutton will appear on this screen. When the **TAG** pushbutton is operated, a small T is displayed next to the autoreclose indication, and the on and off operations are inhibited. When a device is tagged, the **TAG** pushbutton changes to an **UNTAG** pushbutton.

Breaker configuration

The breaker configuration element contains the auxiliary logic for status and serves as the interface for opening and closing of the breaker from protection and automation functions. The logic also permits a manual substitution of the position indication.

Select the **Settings > Protection > Control > Breakers** menu item to open the breaker control configuration window.

Figure 170: Breaker configuration settings

The following settings are available each of the breakers.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables the breaker position indications and control logic. If disabled, all outputs and front panel indications are switched off.

Long Name

Range: 20 alphanumeric characters

Default: BKR 1

This setting is used to identify the primary device for control confirmations on the front panel interface and in the event record.

Short Name

Range: up to 6 alphanumeric characters

Default: BKR1

This setting identifies the primary device pushbuttons and indications on the front panel interface.

Substitution

Range: Enabled, Disabled

Default: Disabled

This setting allows the position indication of the breaker to be substituted with a manually entered value.

Combined Protection and Control

Range: Enabled, Disabled
Default: Disabled

If this setting is enabled, the tripping signals from the trip output scheme are logically ORed with the open signal from the breaker control scheme.

External Trip A, External Trip B, External Trip C

Range: any FlexLogic™ operand or shared operand
Default: Off

These settings assign an operand (usually an external contact input) to the breaker trip pole A, B, and C reporting contact.

External Open Command

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting assigns an operand that creates a programmable signal to operate an output relay to open the breaker.

External Close Command

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting assigns an operand that creates a programmable signal to operate an output relay to close the breaker.

Autoreclose Close Supervision

Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects an operand to supervise the closing of the breaker from autoreclose. If no supervision is required, this setting should be programmed as "On".

Breaker Local Input

Range: any FlexLogic™ operand or shared operand
Default: OFF

Closing or opening of the breaker through the breaker interlock element is inhibited if the operand assigned to this setting is asserted.

Indication Mode

Range: 3 Pole, 1 Pole
Default: 3 Pole

If "3 Pole" is selected, the breaker indications are derived from a single status input (or pair of status inputs). If "1 Pole" is selected, the breaker indications are derived from three status inputs (or pairs of status inputs).

Phase A/3P Closed Status

Range: any FlexLogic™ operand or shared operand
Default: Off

The operand selected by this setting is used to derive three-pole or phase A breaker position indications from a normally-opened (52a) status input.

Phase A/3P Opened Status

Range: any FlexLogic™ operand or shared operand
Default: Off

The operand selected by this setting is used to derive three-pole or phase A breaker position indications from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal.

Phase B Closed Status

Range: any FlexLogic™ operand or shared operand
Default: Off

The operand selected by this setting is used to derive the phase B breaker position indication from a normally-opened (52a) status input. This input is not required if the indication mode is single-pole.

Phase B Opened Status

Range: any FlexLogic™ operand or shared operand
Default: Off

The operand selected by this setting is used to derive the phase B breaker position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal. This input is not required if the indication mode is single-pole.

Phase C Closed Status

Range: any FlexLogic™ operand or shared operand
Default: Off

The operand selected by this setting is used to derive the phase B breaker position indication from a normally-opened (52a) status input. This input is not required if the indication mode is single-pole.

Phase C Opened Status

Range: any FlexLogic™ operand or shared operand
Default: Off

The operand selected by this setting is used to derive the phase B breaker position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal. This input is not required if the indication mode is single-pole.

Operate Time

Range: 0.000 to 2.000 seconds in steps of 0.001
Default: 0.070 seconds

This setting specifies a timer that is asserted when both the normally open and normally closed breaker indications are reset. When the timer expires, a bad status is indicated for the breaker. This timer setting should be set equal to the normal operating time for the breaker.

Discrepancy Time

Range: 0.000 to 2.000 seconds in steps of 0.001
Default: 0.070 seconds

This setting specifies a timer that is asserted when the three breaker poles are not all opened or not all closed. This timer setting should be set greater than the longest expected time for which the three breaker poles disagree.

Reset Counter

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting resets the breaker operation counters.

Events

Range: Enabled, Disabled
Default: Disabled

This settings enables the recording of breaker configuration events in the sequence of events record.

Figure 171: Breaker configuration logic, sheet 1 of 4
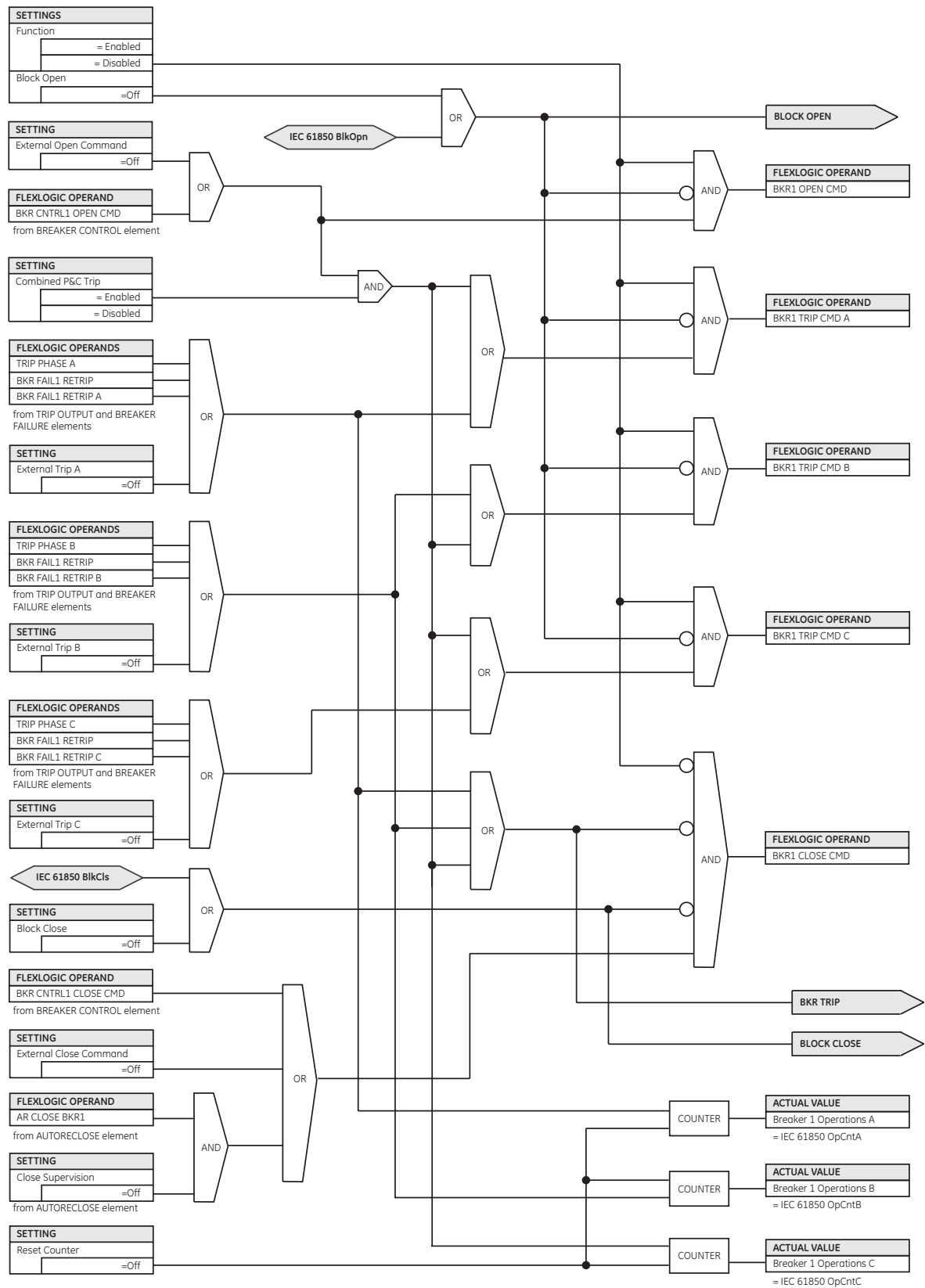
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Figure 172: Breaker configuration logic, sheet 2 of 4
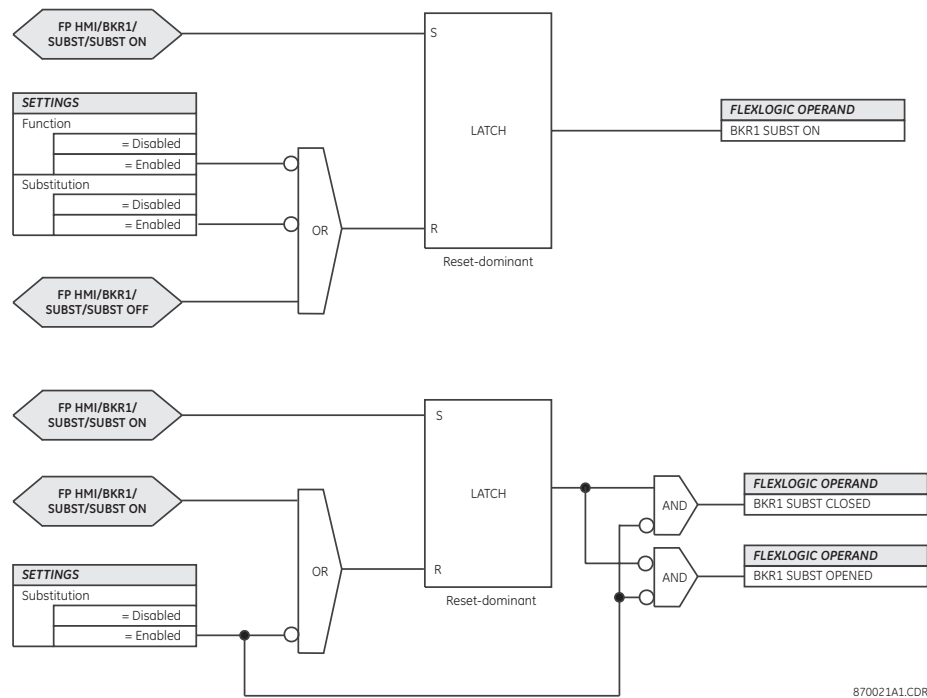
870021A1.CDR

Figure 173: Breaker configuration logic, sheet 3 of 4
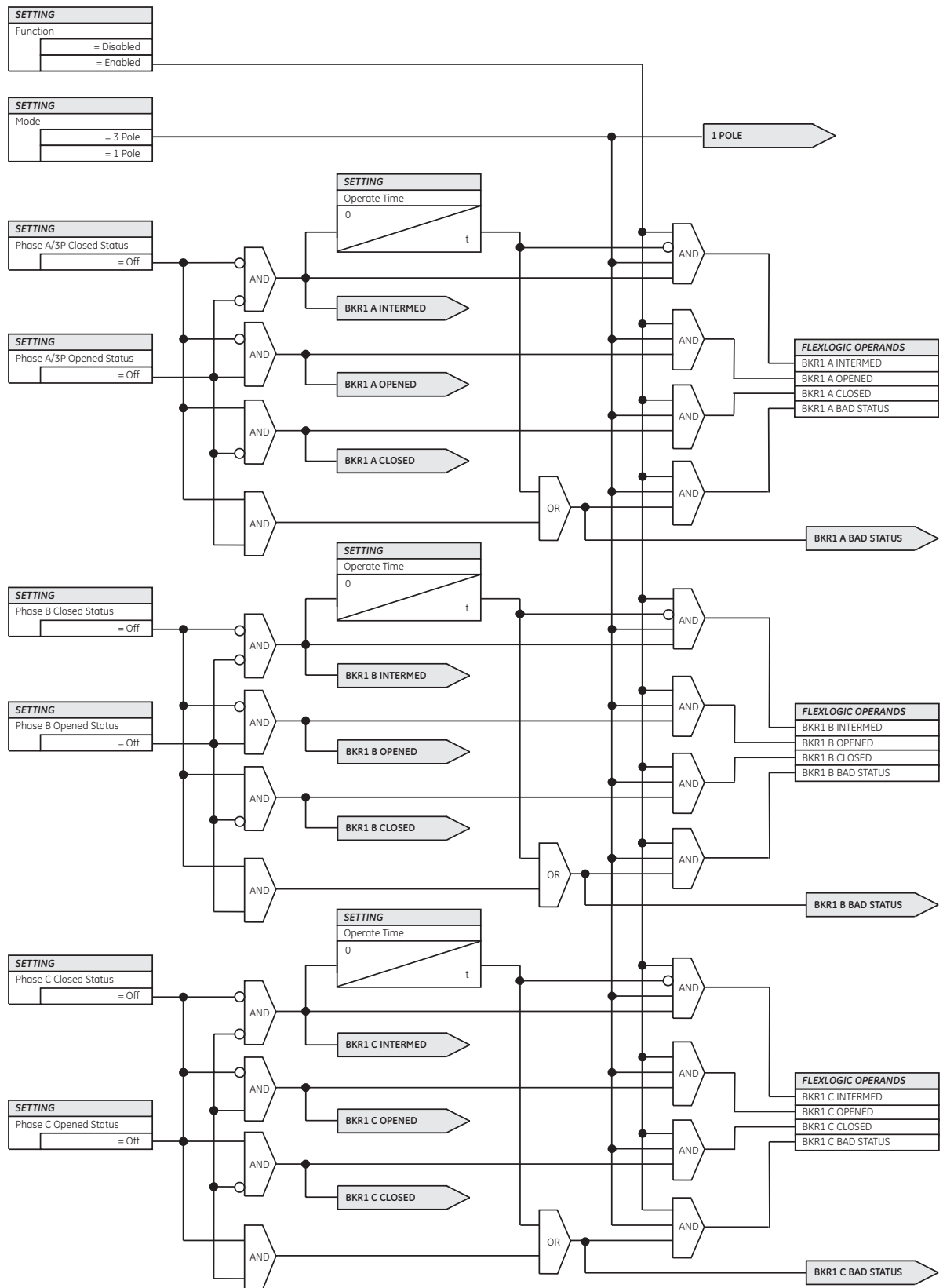
870022A1.CDR

Figure 174: Breaker configuration logic, sheet 4 of 4
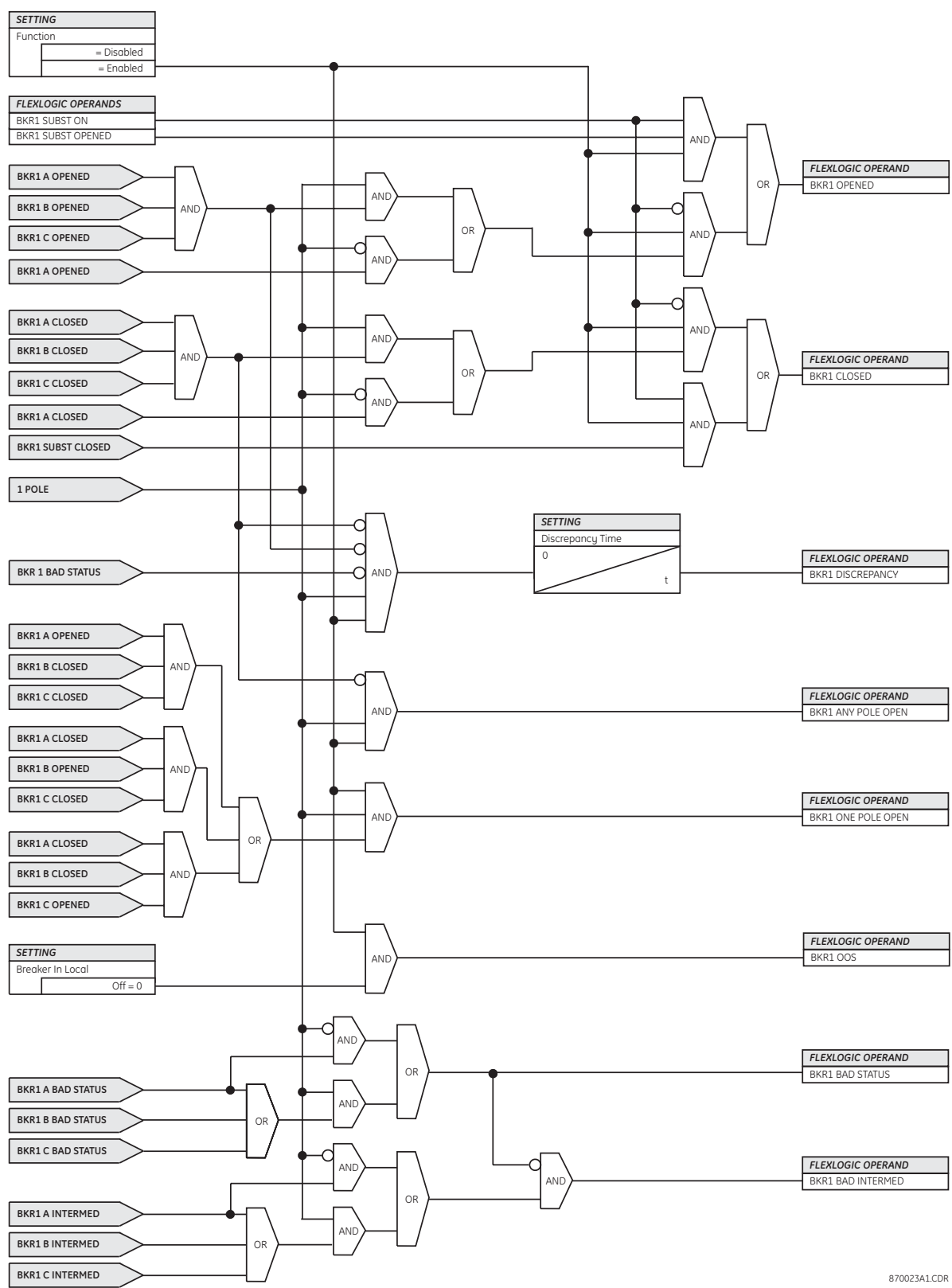
870023A1.CDR

Breaker flashover

The detection of breaker flashover is based on the following condition.
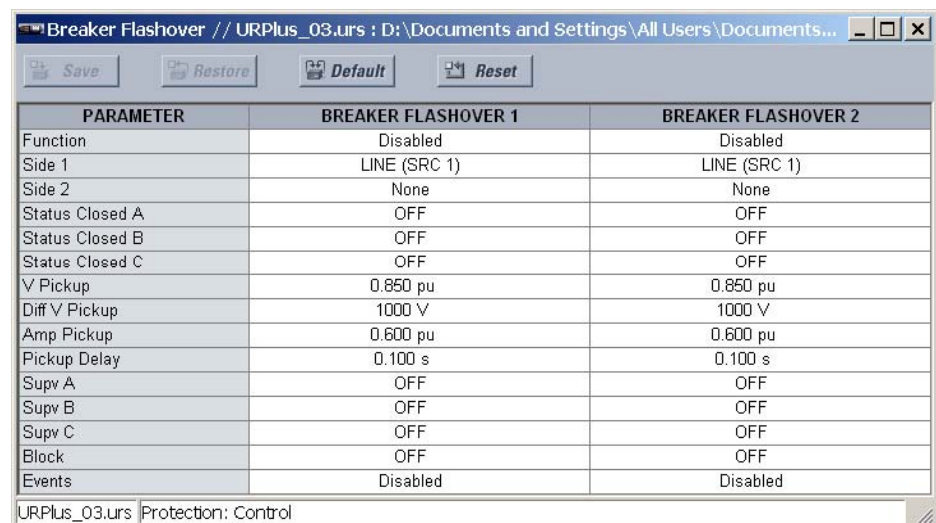
1. Breaker open.
2. Voltage drop measured from either side of the breaker during the flashover period.
3. Voltage difference drop.
4. Measured flashover current through the breaker.

Furthermore, the breaker flashover scheme is applicable for cases where either one or two sets of three-phase voltages are available across the breaker.

Breaker flashover settings

Select the **Settings > Protection > Control > Breaker Flashover** menu item to open the breaker flashover configuration window.

Figure 175: Breaker flashover configuration settings

PARAMETER	BREAKER FLASHOVER 1	BREAKER FLASHOVER 2
Function	Disabled	Disabled
Side 1	LINE (SRC 1)	LINE (SRC 1)
Side 2	None	None
Status Closed A	OFF	OFF
Status Closed B	OFF	OFF
Status Closed C	OFF	OFF
V Pickup	0.850 pu	0.850 pu
Diff V Pickup	1000 V	1000 V
Amp Pickup	0.600 pu	0.600 pu
Pickup Delay	0.100 s	0.100 s
Supv A	OFF	OFF
Supv B	OFF	OFF
Supv C	OFF	OFF
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each breaker flashover element.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disabled the breaker flashover protection element.

Side 1

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting specifies a signal source used to provide three-phase voltages and three-phase currents from one side of the current breaker. The source selected as a setting and must be configured with breaker phase voltages and currents, even if only three (3) VTs are available across the breaker.

Side 2

Range: None, LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting specifies a signal source used to provide another set of three phase voltages whenever six (6) VTs are available across the breaker.

Status Closed A, Status Closed B, Status Closed C

Range: any FlexLogic™ operand or shared operand

Default: OFF

These settings specify operands to indicate the open status of the breaker. A separate operand can be selected to detect individual breaker pole status and provide flashover detection. The recommended setting is 52a breaker contact or another operand defining the breaker poles open status.

Voltage Pickup

Range: 0.000 to 1.500 pu in steps of 0.001

Default: 0.850 pu

This setting specifies a pickup level for the phase voltages from both sides of the breaker. If six VTs are available, opening the breaker leads to two possible combinations – live voltages from only one side of the breaker, or live voltages from both sides of the breaker. Either case will set the scheme ready for flashover detection upon detection of voltage above the selected value. Set this value to 85 to 90% of the nominal voltage.

Voltage Difference Pickup

Range: 0 to 100000 volts in steps of 1

Default: 100 volts

This setting specifies a pickup level for the phase voltage difference when two VTs per phase are available across the breaker. The pickup voltage difference should be below the monitored voltage difference when close or open breaker resistors are left in service. The setting is selected as primary volts difference between the sources.

Current Pickup

Range: 0.000 to 1.500 pu in steps of 0.001

Default: 0.600 pu

This setting specifies the normal load current which can flow through the breaker. Depending on the flashover protection application, the flashover current can vary from levels of the charging current when the line is de-energized (all line breakers open), to well above the maximum line (feeder) load (line/feeder connected to load).

Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.100 seconds

This setting specifies the time delay to operate the breaker flashover element after a pickup condition is detected.

Supervision A, Supervision B, Supervision C

Range: any FlexLogic™ operand or shared operand

Default: OFF

These settings specify operands (per breaker pole) that supervise the operation of the element per phase. Supervision can be provided by operation of other protection elements, breaker failure, and close and trip commands. A six-cycle time delay applies after the selected operand resets.

Block

Range: any FlexLogic™ operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the breaker flashover element.

Events

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of breaker flashover events in the sequence of events recorder.

The logic for the breaker flashover element is shown below.

Figure 176: Breaker flashover scheme logic
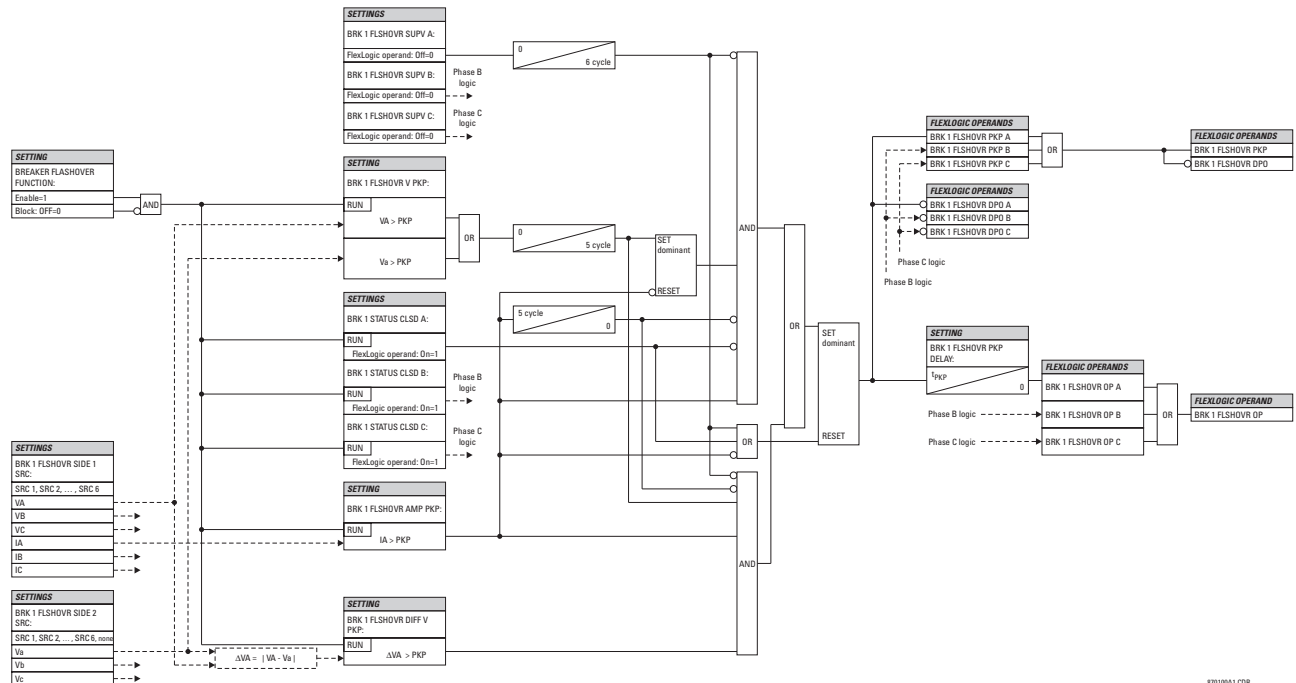
Three VT breaker flashover application

When only one set of VTs is available across the breaker, the **Side 2** setting should be "None". To detect an open breaker condition in this application, the scheme checks if the per-phase voltages were recovered (picked up), the status of the breaker is open (contact input indicating the breaker status is off), and no flashover current is flowing. A contact showing the breaker status must be provided to the relay. The voltage difference will not be considered as a condition for open breaker in this part of the logic.

NOTE

Voltages must be present prior to flashover conditions. If the three VTs are placed after the breaker on the line (or feeder), and the downstream breaker is open, the measured voltage would be zero and the flashover element will not be initiated.

The flashover detection will reset if the current drops back to zero, the breaker closes, or the selected FlexLogic™ operand for supervision changes to high. Using supervision through the **Supervision A** through **Supervision C** settings is recommended by selecting a trip operand that will not allow the flashover element to pickup prior to the trip. The flashover detection can be used for external alarm, re-tripping the breaker, or energizing the lockout relay.

Consider the configuration below.

Figure 177: Breaker flashover application example
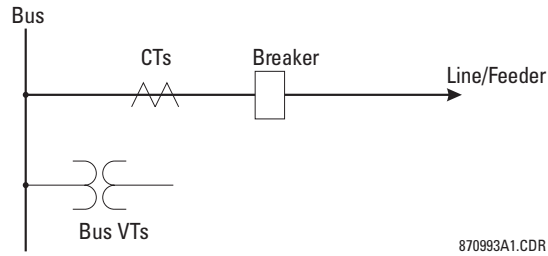
The source 1 (SRC1) phase currents are feeder CTs and phase voltages are bus VTs, and contact input 1 is set as breaker 52a contact. The conditions prior to flashover detection are:

1. 52a status = 0.
2. VAg, VBg, or VCg is greater than the pickup setting.
3. IA, IB, IC = 0; no current flows through the breaker.
4. ΔVA is greater than pickup (not applicable in this scheme).

The conditions at flashover detection are:

1. 52a status = 0.
2. VAg, VBg, or VCg is lower than the pickup setting.
3. IA, IB, or IC is greater than the pickup current flowing through the breaker.
4. ΔVA is greater than pickup (not applicable in this scheme).

Six VT breaker flashover application

The per-phase voltage difference approaches zero when the breaker is closed. The is well below any typical minimum pickup voltage. Select the level of the **Voltage Difference Pickup** setting to be less than the voltage difference measured across the breaker when the close or open breaker resistors are left in service. Prior to flashover, the voltage difference is larger than the **Voltage Difference Pickup** setting. This applies to either the difference between two live voltages per phase or when the voltage from one side of the breaker has dropped to zero (line de-energized), at least one per-phase voltage is larger than the **Voltage Pickup** setting, and no current flows through the breaker poles. During breaker flashover, the per-phase voltages from both sides of the breaker drops below the pickup value defined by the **Voltage Pickup** setting, the voltage difference drops below the pickup setting, and flashover current is detected. These flashover conditions initiate FlexLogic™ pickup operands and start the **Pickup Delay** timer.

This application do not require detection of breaker status via a 52a contact, as it uses a voltage difference larger than the **Voltage Difference Pickup** setting. However, monitoring the breaker contact will ensure scheme stability.

Consider the configuration below.

Figure 178: Breaker flashover application example
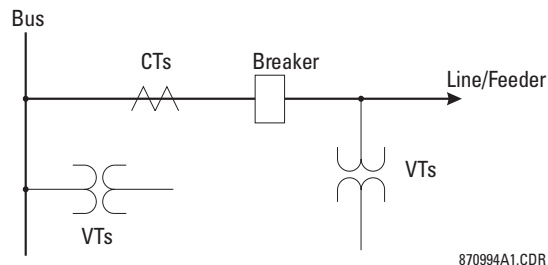
The source 1 (SRC1) phase currents are CTs and phase voltages are bus VTs. The source 2 (SRC2) phase voltages are line VTs. Contact input 1 is set as the breaker 52a contact (optional).

The conditions prior to flashover detection are:

1. ΔVA is greater than pickup.
2. VAg, VBg, or VCg is greater than the pickup setting.
3. IA, IB, IC = 0; no current flows through the breaker.
4. 52a status = 0 (optional).

The conditions at flashover detection are:

1. ΔVA is less than pickup.
2. VAg, VBg, or VCg is lower than the pickup setting.
3. IA, IB, or IC is greater than the pickup current flowing through the breaker.
4. 52a status = 0 (optional).

Digital counters

There are eight identical digital counters in the C90^{Plus}. A digital counter counts the number of state transitions from logic 0 to logic 1. The counter is used to count operations such as element pickup, changes of state of an external contact (for example, a breaker auxiliary switch), or pulses from a watt-hour meter.

Select the **Settings > Protection > Control > Digital Counters** menu item to open the digital counters configuration window.

Figure 179: Digital counters configuration settings
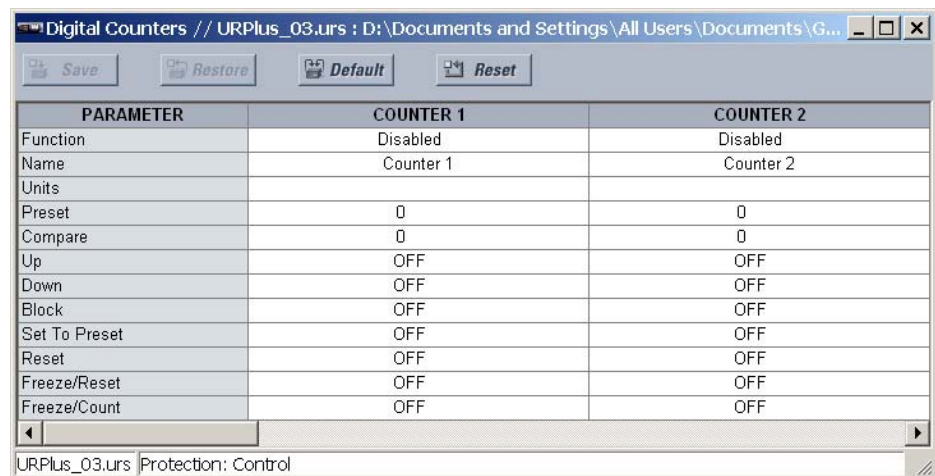
The following settings are available for each digital counter.

Function
Range: Enabled, Disabled
Default: Disabled
This setting enables and disables the digital counter.

Name

Range: up to 12 alphanumeric characters
Default: Counter 1

An alphanumeric name may be assigned to a digital counter for diagnostic, setting, and event recording purposes. The "Counter 1" text in event records and FlexLogic™ operands will be replaced by the text programmed in this setting.

Units

Range: up to 6 alphanumeric characters
Default: empty

This setting assigns a label to identify the unit of measure pertaining to the digital transitions to be counted. The units label will appear in the corresponding actual values status.

Preset

Range: –2 147 483 648 to 2 147 483 647 in steps of 1
Default: 0

This setting specifies the count to a required preset value before counting operations begin, as in the case where a substitute relay is to be installed in place of an in-service relay, or while the counter is running.

Compare

Range: –2 147 483 648 to 2 147 483 647 in steps of 1
Default: 0

This setting specifies the value to which the accumulated count value is compared. Three FlexLogic™ output operands are provided to indicate if the present value is greater than the set value (Counter 1 HI), equal to the set value (Counter 1 EQL), or less than the set value (Counter 1 LO).

Up

Range: any FlexLogic™ operand
Default: Off

This setting selects the FlexLogic™ operand for incrementing the counter. If an enabled up input is received when the accumulated value is at the limit of 2 147 483 647 counts, the counter will rollover to –2 147 483 648 counts.

Down

Range: any FlexLogic™ operand or shared operand
Default: OFF

This setting selects an operand for decrementing the counter. If an enabled down input is received when the accumulated value is at the limit of –2 147 483 648 counts, the counter will rollover to 2 147 483 647 counts.

Block

Range: any FlexLogic™ operand or shared operand
Default: OFF

This setting selects an operand for blocking the counting operation. All counter operands are blocked upon assertion of this operand.

Set To Preset

Range: any FlexLogic™ operand or shared operand
Default: OFF

This setting selects an operand used to set the count to the preset value and functions as follows.

– The counter will be set to the preset value when the counter is enabled and the operand assigned to the **Set To Preset** setting is asserted (logic 1). When the

counter is enabled and the operand assigned to the **Set To Preset** value is logic 0, the counter will be set to 0.

– The counter will be set to the preset value when the counter is running and operand assigned to the **Set To Preset** setting changes the state from 0 to 1. If the operand assigned to the **Set To Preset** setting changes from 1 to 0 while the counter is running, there is no effect on the count.

– The counter will be set to the preset value when a reset or reset/freeze command is sent to the counter and the operand assigned to the **Set To Preset** setting is logic 1. When a reset or reset/freeze command is sent to the counter and the operand assigned to the **Set To Preset** setting is logic 0, the counter will be set to 0.

Reset

Range: any FlexLogic™ operand or shared operand
Default: OFF

This setting selects an operand for setting the count to either 0 or the preset value depending on the state of the operand assigned to the **Set To Preset** setting.

Freeze/Reset

Range: any FlexLogic™ operand or shared operand
Default: OFF

This setting selects an operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and resetting the count to 0.

Freeze/Count

Range: any FlexLogic™ operand or shared operand
Default: OFF

This setting selects an operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and continuing counting. The present accumulated value and captured frozen value with the associated date and time stamp are available as actual values. If control power is interrupted, the accumulated and frozen values are saved into non-volatile memory during the power down operation.

The digital counter logic is shown below. The logic is identical for all digital counters.

Figure 180: Digital counter scheme logic

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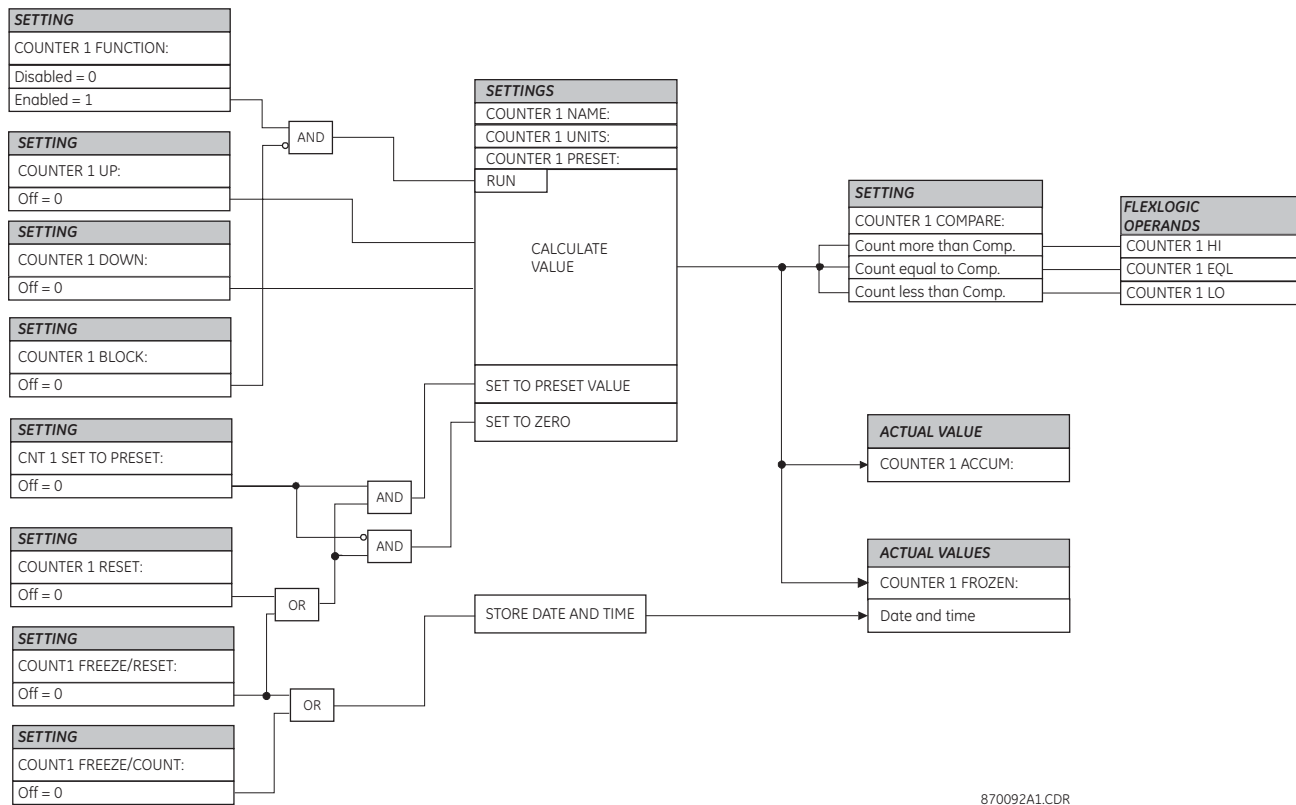
FlexCurves™

There are four user-programmable FlexCurves™ available with the C90^{Plus} system, labeled A, B, C, and D.

The curve shapes for the four FlexCurves are derived from the following equations.

$$T_{operate} = TDM \times \left(T_{flex} \text{ at } \frac{I}{I_{pickup}} \right), \text{ when } \frac{I}{I_{pickup}} \geq 1.00$$

Eq. 35

$$T_{reset} = TDM \times \left(T_{flex} \text{ at } \frac{I}{I_{pickup}} \right), \text{ when } \frac{I}{I_{pickup}} \leq 0.98$$

Eq. 36

In the above equations, $T_{operate}$ represents the operate time in seconds, TDM represents the multiplier setting, I represents the input current, I_{pickup} represents the value of the pickup current setting, T_{flex} represents the FlexCurve™ time in seconds, and T_{reset} represents the reset time in seconds.

FlexCurve™ settings   Select the **Settings > Protection > Control > FlexCurves > FlexCurve A** menu item to access the FlexCurve™ A settings. The same group of settings is available for FlexCurves™ B, C, and D.

Figure 181: FlexCurve configuration settings

The following settings are available for each custom FlexCurve™.

FlexCurve Name

Range: up to 20 alphanumeric characters
Default: FlexCurve A

This setting specifies a user-defined name for the FlexCurve™.

Initialize From

Range: IEEE Moderately Inverse, IEEE Very Inverse, IEEE Extremely Inverse, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inverse, IAC Extreme Inv, IAC Very Inverse, IAC Inverse, IAC Short Inverse, I Squared T, Recloser Curve, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D
Default: IEEE Moderately Inverse

This setting specifies a curve to use as a base for a custom FlexCurve™. When the **Initialize FlexCurve** button is clicked, the pickup settings will be populated with values specified by the curve selected in this setting.

0.00 × Pickup, 0.05 × Pickup,..., 20.00 × Pickup

Range: 0 to 65535 ms in steps of 1
Default: 0 ms

These settings specify the time to reset and operate at the following pickup levels: 0.00 to 0.98 and 1.03 to 20.00. This data is converted into two continuous curves by linear interpolation between data points. To enter a custom FlexCurve™, enter the reset or operate time for each selected pickup point.

NOTE

Special care must be applied when setting the two points that are close to the multiple of pickup of 1; that is, 0.98 pu and 1.03 pu. It is recommended to set the two times to a similar value; otherwise, the linear approximation may result in undesired behavior for the operating quantity that is close to 1.00 pu.

FlexCurve™ software features

The EnerVista UR^Plus^ Setup software allows for easy configuration and management of FlexCurves™ and their associated data points. Click on the **View FlexCurve** button to graphically display the selected FlexCurve™.

Figure 182: FlexCurve™ display example
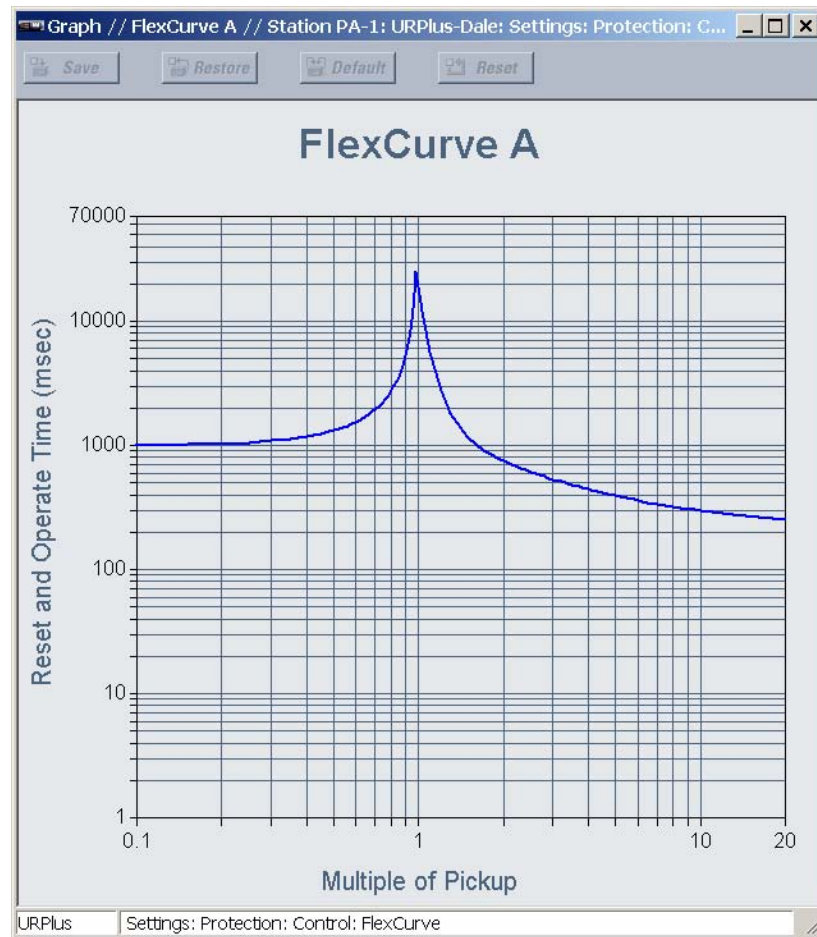
Prospective FlexCurves™ can be configured from a selection of standard curves to provide the best approximate fit, then specific data points can be edited afterwards. Click the **Initialize FlexCurve** button to populate the pickup values with the points from the curve specified by the **Initialize From** setting. These values can then be edited to create a custom curve. Note that the pickup multiples start at zero (implying the reset time), operating time below pickup, and operating time above pickup. Click on the **Clear FlexCurve** button to reset all pickup values to zero.

Curve data can be imported from CSV (comma-separated values) files by clicking on the **Import Data From** button. Likewise, curve data can be saved in CSV format by clicking the **Export Data To** button. CSV is a delimited data format with fields separated by the comma character and records separated by new lines. Refer to IETF RFC 4180 for additional details.

Recloser curve editing

Recloser curve selection is special in that recloser curves can be shaped into a composite curve with a minimum response time and a fixed time above a specified pickup multiples. There are 41 recloser curve types supported. These definite operating times are useful to coordinate operating times, typically at higher currents and where upstream and downstream protective devices have different operating characteristics. The recloser curve configuration window shown below appears when the **Initialize From** setting is set to "Recloser Curve" and the **Initialize FlexCurve** button is clicked.

Figure 183: Recloser curve initialization

Multiplier: Scales (multiplies) the curve operating times

Addr: Adds the time specified in this field (in ms) to each curve operating time value.

Minimum Response Time (MRT): If enabled, the MRT setting defines the shortest operating time even if the curve suggests a shorter time at higher current multiples. A composite operating characteristic is effectively defined. For current multiples lower than the intersection point, the curve dictates the operating time; otherwise, the MRT does. An information message appears when attempting to apply an MRT shorter than the minimum curve time.

High Current Time: Allows the user to set a pickup multiple from which point onwards the operating time is fixed. This is normally only required at higher current levels. The HCT Ratio defines the high current pickup multiple; the HCT defines the operating time.

870838A1.CDR

NOTE

The multiplier and adder settings only affect the curve portion of the characteristic and not the MRT and HCT settings. The HCT settings override the MRT settings for multiples of pickup greater than the HCT ratio.

Composite recloser curve example

A composite curve can be created from the GE_111 standard with MRT = 200 ms and HCT initially disabled and then enabled at eight (8) times pickup with an operating time of 30 ms. At approximately four (4) times pickup, the curve operating time is equal to the MRT and from then onwards the operating time remains at 200 ms (see below).
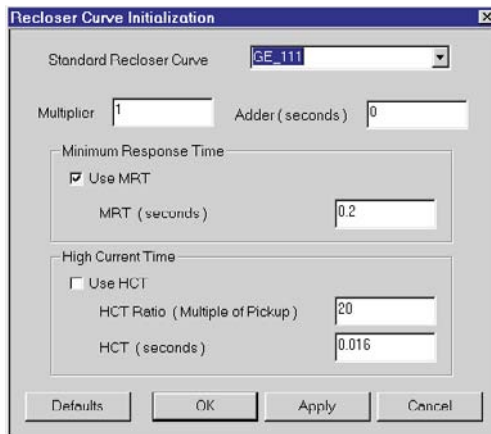
Figure 184: Composite recloser curve with HCT disabled
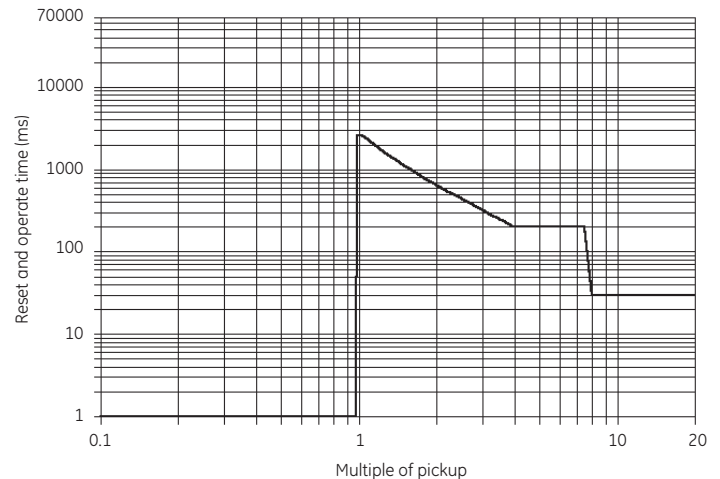
870839A1.CDR

With the HCT feature enabled, the operating time reduces to 30 ms for pickup multiples exceeding 8 times pickup.

Figure 185: Composite recloser curve with HCT enabled
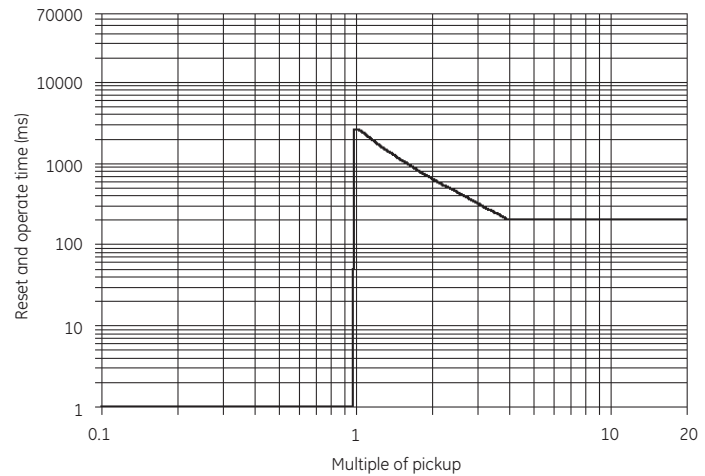
> **NOTE**
>
> Configuring a composite curve with an increase in operating time at increased pickup multiples is not allowed. If this is attempted, the EnerVista UR^Plus Setup software generates an error message and discards the proposed changes.

Protection inputs and outputs

Three groupings of protection inputs and outputs are defined: physical, shared, and virtual. Within these three groupings there are two types: analog and digital.

Protection virtual inputs

There are 64 virtual inputs that can be individually programmed to respond to input signals from the front panel interface and communications protocols. All virtual input operands are defaulted to off (logic 0) unless the appropriate input signal is received.

Select the **Settings > Protection > Protection Inputs/Outputs > Virtual Inputs** menu item to access the protection virtual input configuration settings.

Figure 186: Protection virtual inputs configuration settings

The following settings are available for each protection virtual input. The default values shown are for virtual input 1.

Function

Range: Enabled, Disabled
Default: Disabled

If this setting is "Disabled", the virtual input will be forced to off (logic 0) regardless of any attempt to alter the input. If set to "Enabled", the input operates as shown on the logic diagram and generates output logic operands in response to received input signals and the applied settings.

ID

Range: up to 12 alphanumeric characters
Default: Virt Ip 1

This setting specifies an identifier that may be assigned to each virtual input.

Type

Range: Self-Reset, Latched
Default: Latched

There are two types of operation: self-reset and latched. If this settings is "Self-Reset", the output operand will be asserted (logic 1) for only one evaluation of the protection FlexLogic™ equations and then return to 0 when the input signal transits from off to on. If set to "Latched", the virtual input sets the state of the output operand to the same state as the most recent received input.

NOTE

The self-reset operating mode generates an output operand for a single evaluation of FlexLogic™ equations. If the operand is to be used anywhere other than internally in an automation logic equation, it will likely have to be lengthened in time. A FlexLogic™ timer with a delayed reset can perform this function.

Events

Range: Enabled, Disabled
Default: Disabled

If this setting is "Enabled", every change in the protection virtual input state will trigger an event in the sequence of events recorder.

The protection virtual input logic is shown below. The logic is identical for all protection virtual inputs.

Figure 187: Protection virtual input logic
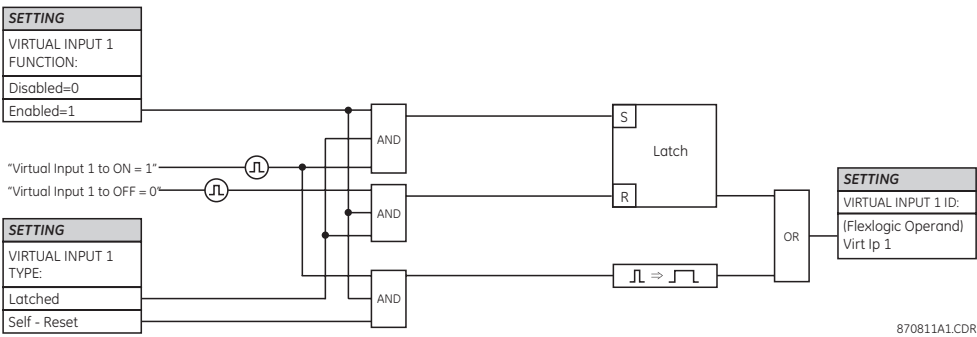
Protection virtual outputs

There are 96 virtual outputs that may be assigned via FlexLogic™. Virtual outputs are resolved in each pass through the evaluation of FlexLogic™ equations.

Select the **Settings > Protection > Protection Inputs/Outputs > Virtual Outputs** menu item to access the protection virtual output configuration settings.

Figure 188: Protection virtual output settings

The following settings are available for each protection virtual output. If not assigned, the virtual output will be forced to off (logic 0).

ID

Range: up to 12 alphanumeric characters
Default: Virt Op 1

This setting specifies an identifier that may be assigned to each protection virtual output.

Events

Range: Enabled, Disabled
Default: Disabled

If this setting is "Enabled", every change in the protection virtual output state will trigger an event in the sequence of events recorder.

Contact input configuration

The C90^{Plus} can monitor the status of up to 40 field contacts. Each input can be wetted from the C90^{Plus} 48 volt auxiliary supply or from an external power supply. Each contact input has a dedicated delay timer for filtering of contact bouncing. The C90^{Plus} can also detect an oscillating input via the chatter feature. Each contact input active impedance circuitry to provide security against false turn-on of an input due to excessive stray capacitance of field wiring.

A raw status is scanned synchronously for all contact inputs at the rate of 0.25 ms as shown below. A new contact input state must be maintained for a user-programmable debounce time for the C90^{Plus} to validate the new contact state. The debounce time is set at 2.0 ms in the figure below; as such, the eighth sample validates the change of state (mark 1 in the figure below). Once validated (de-bounced), the contact input asserts a corresponding FlexLogic™ operand and logs an event (if event logging is enabled).

A time stamp of the first sample in the sequence that validates the new state is used when logging the change of the contact input into the event recorder (mark 2 in the figure below).

Figure 189: Contact input debouncing mechanism and time-stamping
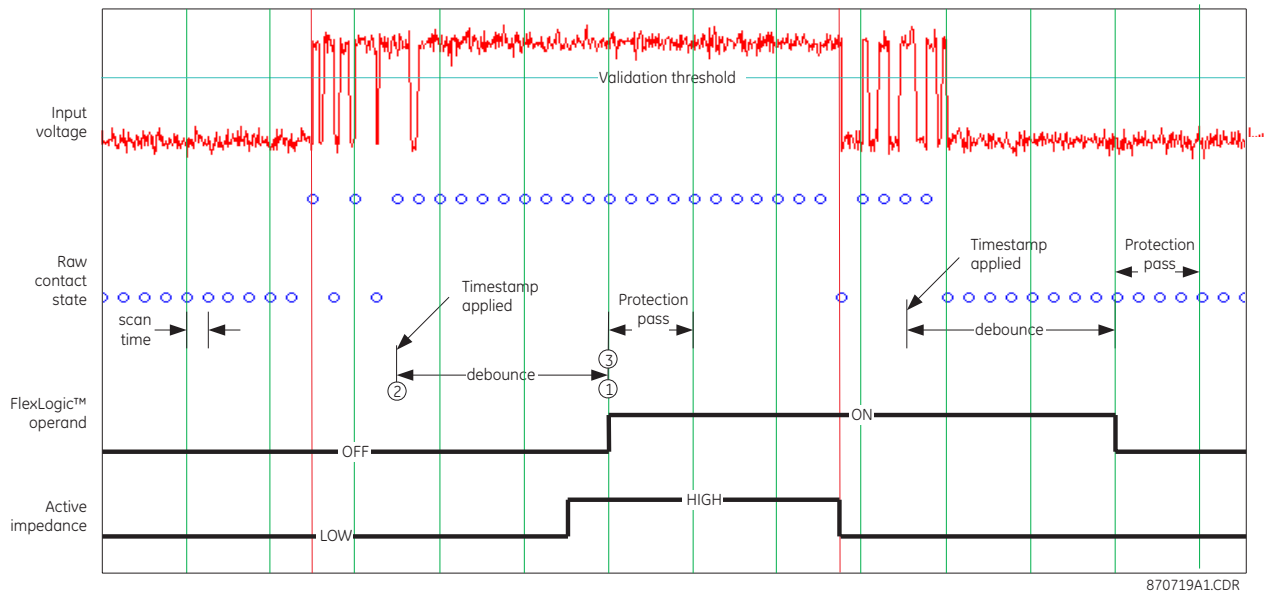
Protection elements, as well as FlexLogic™ equations and timers, are executed sixteen times in a power system cycle. The protection pass duration is controlled by the frequency tracking mechanism. The FlexLogic™ operand reflecting the debounced state of the contact is updated at the protection pass following the validation (mark 3 in the figure above). The update is performed at the beginning of the protection pass so all protection functions and protection FlexLogic™ equations, are fed with the updated states of the contact inputs.

The FlexLogic™ operand response time to the contact input change is equal to the debounce time setting plus a maximum of one protection pass (depending on system frequency if frequency tracking is enabled). If the change of state occurs just after a protection pass, the recognition is delayed until the subsequent protection pass (that is, by the entire duration of the protection pass). If the change occurs just prior to a protection pass, the state is recognized immediately. Statistically, a delay of half the protection pass is expected. Owing to the 0.25 ms scan rate, the time resolution for the input contact is less than 1 ms.

For example, sixteen protection passes per cycle on a 60 Hz system correspond to a protection pass every 1.04 ms. With a contact debounce time setting of 3.0 ms, the FlexLogic™ operand assert time limits are: 3.0 + 0.0 = 3.0 ms and 3.0 + 1.04 = 4.04 ms. These time limits depend on how soon the protection pass runs after the debouncing time.

Regardless of the contact debounce time setting, the contact input event is time-stamped with a 1 ms accuracy using the time of the first scan corresponding to the new state. Therefore, the time stamp reflects a change in the DC voltage across the contact input terminals that was not accidental as it was subsequently validated using the debounce timer. Keep in mind that the associated FlexLogic™ operand is asserted/de-asserted later, after validating the change. The debounce algorithm is symmetrical: the same procedure and debounce time are used to filter the OFF-ON and ON-OFF transitions.

The active impedance feature controls the input impedance presented to the system according to the current state of the input. When the contact input circuitry initially detects a voltage increase, it will draw 10 mA of current. If the state change is due to a transient coupled through the stray capacitance of the field wiring, then the high current sink will charge the capacitance causing the transient to rapidly decay. If voltage increase is due to a state change of the field contact, then the increased current will have no impact on the input voltage, and the state change will be validated. Once the input has been declared to be on, the input circuitry will reduce the current drawn to 1 mA to minimize the power dissipated by the input.

Contact input settings

When the input detects a voltage decrease, the input circuitry will draw 10 mA of current. If the voltage decrease is due to a state change then the voltage will quickly decrease, speeding up the recognition of the reset of the field contact.

Select the **Settings > Protection > Protection Inputs/Outputs > Contact Inputs > Contact Inputs** menu item to access the contact input configuration settings.

Figure 190: Contact input configuration settings

The contact inputs menu contains configuration settings for each contact input. Upon startup, the relay processor determines (from an assessment of the installed modules) which contact inputs are available and then displays settings for only those inputs. The following settings are available for each contact input.

ID

Range: up to 12 alphanumeric characters
Default: Cont Ip 1

An alphanumeric ID may be assigned to a contact input for diagnostic, setting, and event recording purposes. The "CONTACT IP 1" text in event records and FlexLogic™ operands will be replaced by the text programmed in this setting.

Debounce Time

Range: 1.5 to 16.0 ms in steps of 0.25

Default: 2.0 ms

This setting defines the time required for the contact to overcome contact bouncing conditions. As this time differs for different contact types and manufacturers, program it as a maximum contact debounce time (per manufacturer specifications) plus additional margin to ensure proper operation.

Nominal Voltage

Range: 24 to 250 volts in steps of 1

Default: 125 volts

This setting determines the threshold required to validate a closed contact input. This threshold is fixed at 70% of this setting value.

Table 20: Nominal voltage setting for typical battery voltages

Nominal voltage	Validation threshold
24 V	20 V
48 V	33.6 V
125 V	87.5 V
250 V	175 V

Events

Range: Enabled, Disabled

Default: Disabled

If this setting is "Enabled", every change in the contact input state will trigger an event in the sequence of events recorder.

Contact input chatter detection

The C90^{Plus} has a chatter detection feature. When enabled, the IED monitors the number of state changes that occur within a set duration. If this value exceeds a set value, then a trouble condition is declared for the input and the CONTACT INPUT TROUBLE operand is asserted.

The input trouble alarm impacts relay functionality as follows:

- FlexLogic™ operands: operand state will be blocked.
- DNP 3.0 communications: reporting of the input is blocked.
- IEC 60870-5-104 communications: reporting of the input is blocked.
- IEC 61850 GSSE and IEC 61850 GOOSE: reporting of the input is blocked.
- Sequence of events recorder: reporting of the input is blocked.

The trouble condition resets if the input undergoes no state changes for a duration equal to twice the chatter time setting.

Figure 191: Chatter detection example
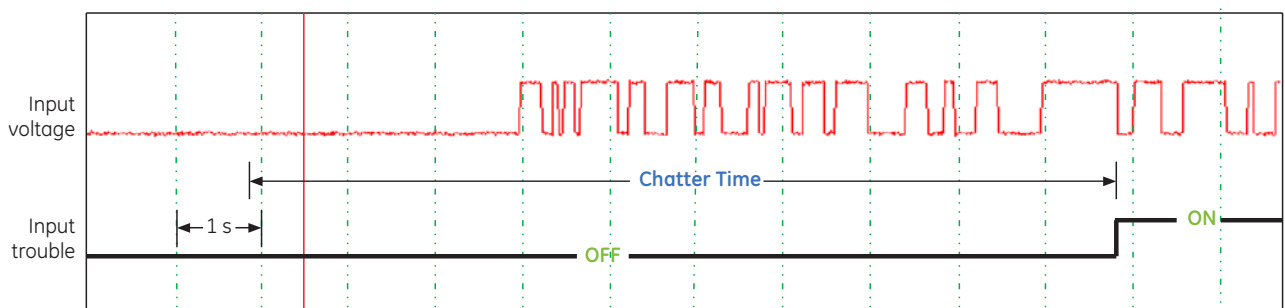
870723A1.CDR

Select the **Settings > Protection > Protection Inputs/Outputs > Contact Inputs > Chatter Detection** menu item to access the contact input chatter detection settings.

Figure 192: Contact input chatter detection configuration

The following settings are available for each contact input.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the chatter detection feature.

Chatter Time

Range: 1 to 100 seconds in steps of 1

Default: 10 seconds

This setting specifies the time window that the relay contacts are monitored for contact input state changes.

Chatter State Changes

Range: 10 to 100 in steps of 1

Default: 30

This setting specifies the number of state changes that must occur in the time window defined by the **Chatter Time** setting before issuing the trouble operand.

Contact outputs

Upon startup of the relay, the main processor will determine from an assessment of the modules installed in the chassis which contact outputs are available and present the settings for only these outputs.

Select the **Settings > Protection > Protection Inputs/Outputs > Contact Outputs** menu item to access the contact output configuration settings.

Figure 193: Protection contact output configuration settings

CONTACT OUTPUT	ID	OPERATE	SEAL-IN	VOLTAGE THRESHOLD	EVENTS
E1	BKR1 TR COIL	BKR1 TRIP CMD 3-POLE	BKR1 TR COIL IOn (E1)	20	Enabled
E2	BKR1 CL COIL	BKR1 CLOSE CMD	BKR1 CL COIL IOn (E2)	20	Enabled
E3	BKR2 TR COIL	BKR2 TRIP CMD 3-POLE	BKR2 TR COIL IOn (E3)	20	Enabled
E4	BKR2 CL COIL	BKR2 CLOSE CMD	BKR2 CL COIL IOn (E4)	20	Enabled

The settings listed below are available for all contact outputs.

ID

Range: up to 12 alphanumeric characters

Default: Cont Op 1

This setting specifies an alphanumeric identifier for the contact output.

Operate

Range: any FlexLogic™ operand or shared operand

Default: as shown above

This setting selects an operand (virtual output, element state, contact input, or virtual input) that will operate the contact output when asserted.

Seal-In

Range: any FlexLogic™ operand or shared operand

Default: as shown above

This setting selects an operand (virtual output, element state, contact input, or virtual input) that will seal-in the contact output when asserted.

Voltage Threshold

Range: 20 to 250 volts in steps of 1

Default: 20

This setting specifies determines the level at which the Contact Op 1 VOn and Contact Op 1 VOff operands function. It is only shown for contact outputs that have monitoring.

Events

Range: Enabled, Disabled

Default: Enabled

If this setting is "Enabled", every change in the contact output state will trigger an event in the sequence of events recorder.

Shared operands

The EnerVista UR^{Plus} Setup software groups the C90^{Plus} system into the following six primary functions. Each function has its own setting parameters and each generates its own outputs in the form of operands.

- Protection
- Automation
- Metering
- Digital fault recorder (DFR)
- Equipment manager
- Front panel interface (HMI)

However, it is often desirable for an output from an element within one function can be available to an element within another function. For instance, it may useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available as to each function as shown below.

Figure 194: Default operand list by function
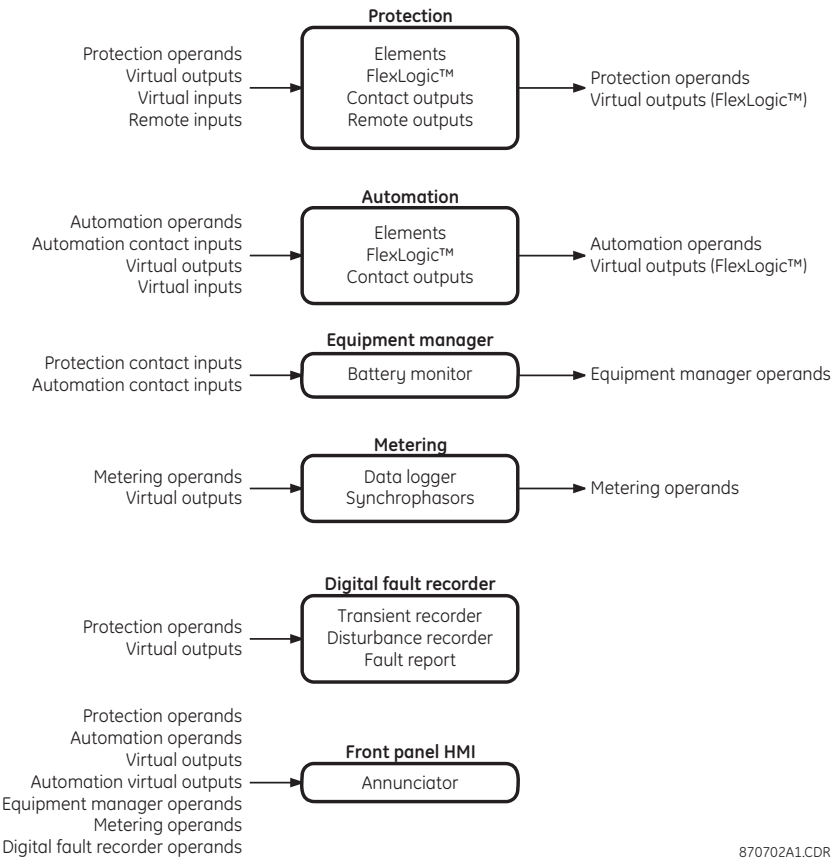
870702A1.CDR

The content of each operand list is dependent on the selected order code.

The shared operands functionality expands upon this system. With this feature, an output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals can then be assigned as inputs to other functions.

For example, assume that the GND TOC1 OP protection operand is required as a signal within the automation function. This operand would then be assigned as a shared operand, and would subsequently become available to the automation function. A total of 64 operands may be assigned as shared operands within each function.

Shared protection operands

Select the **Settings > Protection > Protection Inputs/Outputs > Shared Operands** menu item to select the shared protection FlexLogic™ operands.

Figure 195: Shared operands configuration window
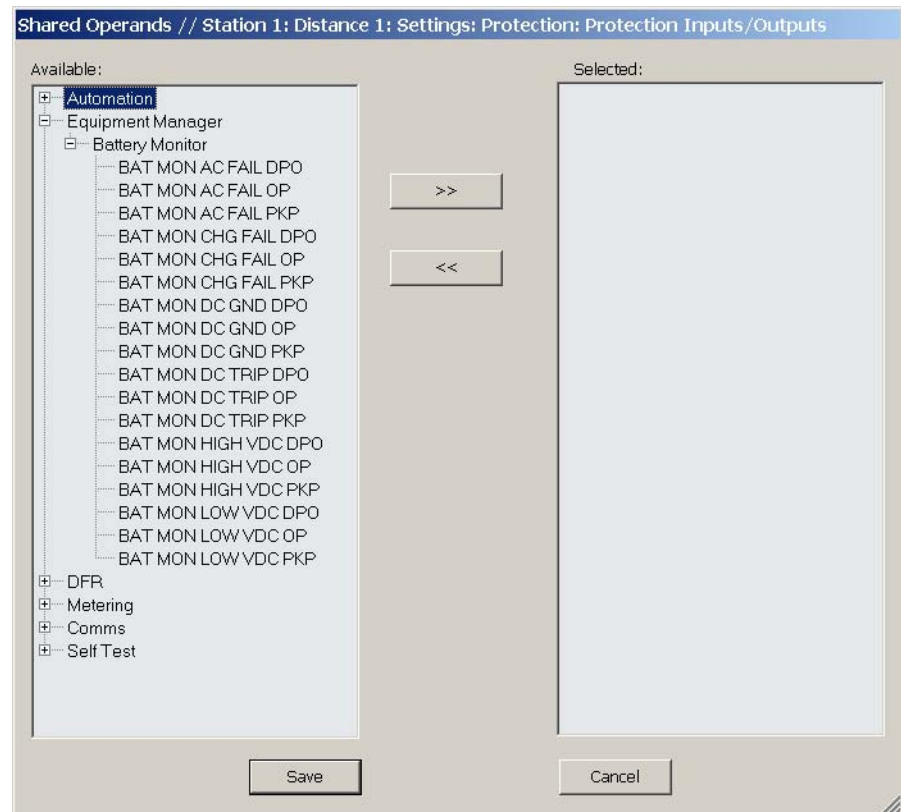
The left side of this screen displays all C90^{Plus} operands that are available to the protection function as shared operands. Select any operands from the other five primary features by clicking on the **>>** button. Operands may be de-assigned as shared operands by pressing the **<<** button.

Protection FlexLogic™

The arrangement of internal digital logic in the C90^{Plus} combines fixed and user-programmable parameters. The logic upon which individual features are designed is fixed, and all other logic, from digital input signals through elements or combinations of elements to digital outputs, is variable. The user has complete control of all variable logic through FlexLogic™. In general, the system receives analog and digital inputs which it uses to produce analog and digital outputs. The major sub-systems of a generic UR^{Plus}-series device involved in this process are shown below.

Figure 196: URPlus-series architecture overview
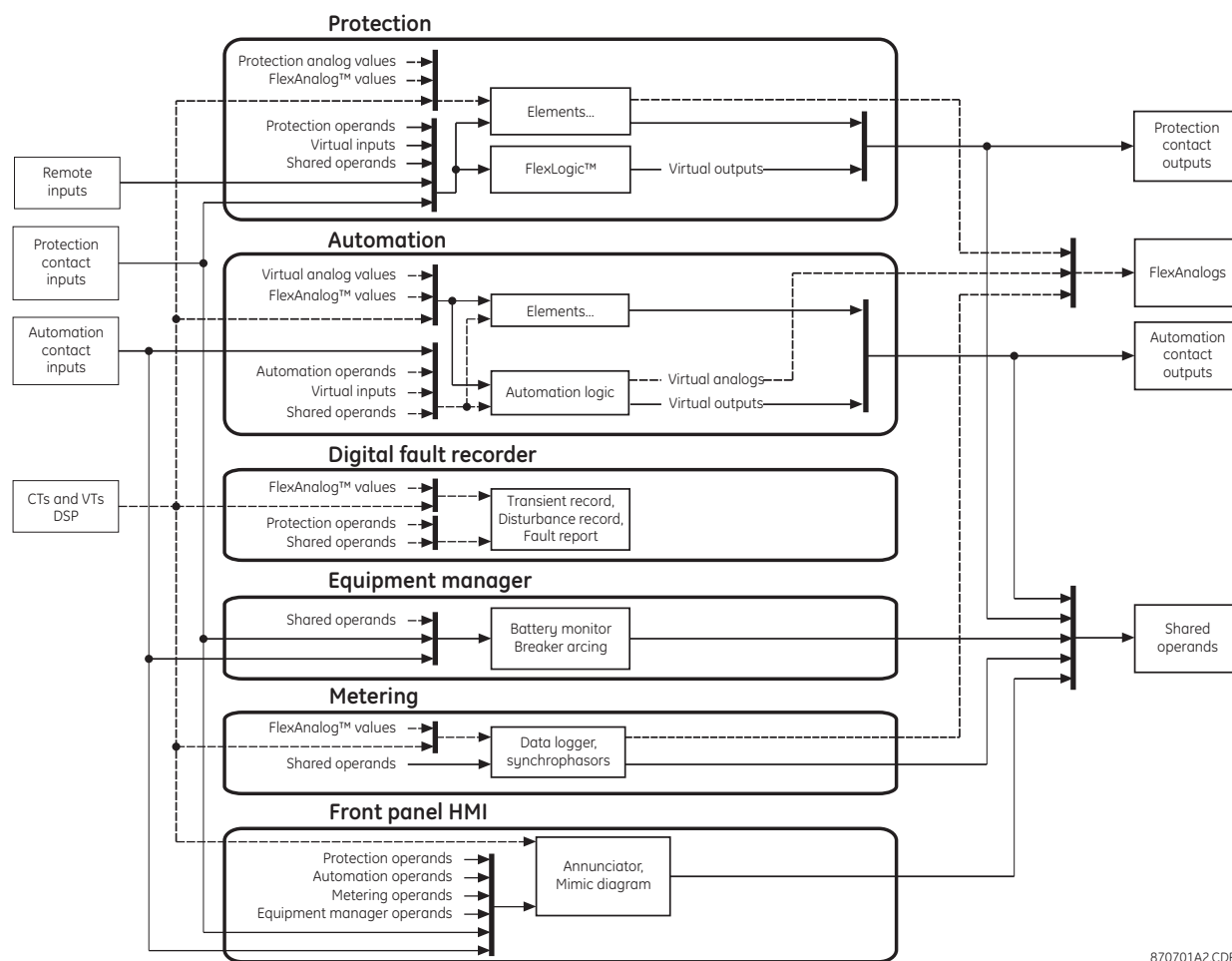
870701A2.CDR

The states of all digital signals used in the C90^{Plus} are represented by flags (or FlexLogic™ operands, which are described later in this section). A logic 1 state is represented by a *set* flag. Any external contact change-of-state can be used to block an element from operating, as an input to a control feature in a FlexLogic™ equation, or to operate a contact output. The state of the contact input can be displayed locally or viewed remotely via the communications facilities provided. If a simple scheme where a contact input is used to block an element is desired, this selection is made when programming the element. This capability also applies to the other features that set flags: elements, virtual inputs, remote inputs, schemes, and human operators.

If more complex logic than presented above is required, it is implemented via FlexLogic™. For example, if it is desired to have the closed state of contact input H7a and the operated state of the phase undervoltage element block the operation of the phase time overcurrent element, the two control input states are programmed in a FlexLogic™ equation. This equation ANDs the two control inputs to produce a virtual output, which is then selected when programming the phase time overcurrent to be used as a blocking input. Virtual outputs can only be created by FlexLogic™ equations.

Traditionally, protective relay logic has been relatively limited. Any unusual applications involving interlocks, blocking, or supervisory functions had to be hard-wired using contact inputs and outputs. FlexLogic™ minimizes the requirement for auxiliary components and wiring while making more complex schemes possible.

The logic that determines the interaction of inputs, elements, schemes and outputs is field programmable through the use of logic equations that are sequentially processed. The use of virtual inputs and outputs in addition to hardware is available internally and on the communication ports for other relays to use (distributed FlexLogic™).

FlexLogic™ allows users to customize the relay through a series of equations that consist of operators and operands. The operands are the states of inputs, elements, schemes and outputs. The operators are logic gates, timers and latches (with set and reset inputs). A system of sequential operations allows any combination of specified operands to be assigned as inputs to specified operators to create an output. The final output of an equation is a numbered register called a virtual output. Virtual outputs can be used as an input operand in any equation, including the equation that generates the output, as a seal-in or other type of feedback.

A FlexLogic™ equation consists of parameters that are either operands or operators. Operands have a logic state of 1 or 0. Operators provide a defined function, such as an AND gate or a timer. Each equation defines the combinations of parameters to be used to set a virtual output flag. Evaluation of an equation results in either a logic 1 state (=ON, flag set) or logic 0 state (=OFF, flag not set). Each equation is evaluated at least four times every power system cycle.

Some types of operands are present in the relay in multiple instances (for example, contact and remote inputs). These types of operands are grouped together (for presentation purposes only) on the faceplate display. The characteristics of the different types of operands are tabulated below.

Table 21: Protection FlexLogic™ operand types

Type	State	Example	Characteristics (input is logic 1 or "on" if…)
Contact input	On	CONT IP1 ON	Voltage is presently applied to the input (external contact closed).
	Off	CONT IP1 OFF	Voltage is presently not applied to the input (external contact open).
Contact output	Voltage on	CONT OP1 VON	Voltage exists across the contact.
	Voltage off	CONT OP1 VOFF	Voltage does not exist across the contact.
	Current on	CONT OP1 ION	Current is flowing through the contact.
	Current off	CONT OP1 IOFF	Current is not flowing through the contact.
Digital counter	Greater than	COUNTER 1 HI	The number of pulses counted is above the set number.
	Equal to	COUNTER 1 EQL	The number of pulses counted is equal to the set number.
	Less than	COUNTER 1 LO	The number of pulses counted is below the set number.
Direct input	On	DIRECT INPUT 1 ON	The direct input is presently in the ON state.
Element (analog)	Pickup	PHASE TOC1 PKP	The tested parameter is presently above the pickup setting of an element which responds to rising values or below the pickup setting of an element which responds to falling values.
	Dropout	PHASE TOC1 DPO	This operand is the logical inverse of the pickup operand.
	Operate	PHASE TOC1 OP	The tested parameter has been above/below the pickup setting of the element for the programmed delay time, or has been at logic 1 and is now at logic 0 but the reset timer has not finished timing.
	Block	PHASE TOC1 BLK	The output of the comparator is set to the block function.
Element (digital)	Pickup	DIG ELEM 1 PKP	The output operand is at logic 1.
	Dropout	DIG ELEM 1 DPO	This operand is the logical inverse of the pickup operand.
	Operate	DIG ELEM 1 OP	The input operand has been at logic 1 for the programmed pickup delay time, or has been at logic 1 for this period and is now at logic 0 but the reset timer has not finished timing.
Fixed	On	ON	Logic 1.
	Off	OFF	Logic 0.
Remote input	On	REMOTE IN 1 ON	The remote input is presently in the on state.
Virtual input	On	VIRT IP 1 ON	The virtual input is presently in the on state.
Virtual output	On	VIRT OP 1 ON	The virtual input is presently in the on state.

Protection FlexLogic™ gates and operators

The characteristics of logic gates used in protection FlexLogic™ equations are tabulated below.

Table 22: Protection FlexLogic™ gate characteristics

Gate	Inputs	Output is logic 1 if...
NOT	1	the input is logic 0
OR	2 to 16	any input is logic 1
AND	2 to 16	all inputs are logic 1
NOR	2 to 16	all inputs are logic 0
NAND	2 to 16	any input is logic 0
XOR	2	only one input is logic 1

The following operators are available for use in protection FlexLogic™™ equations.

Table 23: Protection FlexLogic™ operators

Type	Syntax	Description	Operation
Editor	INSERT	Insert a parameter in the equation list.	---
	DELETE	Delete a parameter from an equation list.	---
End	END	The first END operator signifies the last entry in the FlexLogic™ equation.	---
One shots	POSITIVE ONE SHOT	One shot that corresponds to a positive-going edge.	A *one shot* refers to a single input gate that generates a pulse in response to an edge on the input. The output from a one shot is true (positive) for only one pass through the FlexLogic™ equation. There are a maximum of 64 one shots.
	NEGATIVE ONE SHOT	One shot that corresponds to a negative-going edge.	
	DUAL ONE SHOT	One shot that responds to both the positive and negative-going edges.	
Logic gates	NOT	A logical NOT gate.	Operates on the previous parameter.
	AND(*n*)	An *n*-input AND gate, *n* = 1 to 16.	Operates on the previous *n* parameters.
	OR(n)	An *n*-input OR gate, *n* = 1 to 16.	Operates on the previous *n* parameters.
	NOR(*n*)	An *n*-input NOR gate, *n* = 1 to 16.	Operates on the previous *n* parameters.
	NAND(*n*)	An *n*-input NAND gate, *n* = 1 to 16.	Operates on the previous *n* parameters.
	XOR(2)	A two-input exclusive OR gate.	Operates on the previous 2 parameters.
	LATCH(S,R)	Latch (set, reset), reset-dominant.	Operates on the previous 2 parameters. The parameter preceding LATCH(S,R) is the reset input. The parameter preceding the reset input is the set input.
Timers	TIMER *n*	Timer set with the settings programmed for FlexLogic™ timer *n*, where *n* = 1 to 32.	The timer is started by the preceding parameter. The output of the timer is TIMER #.
Assign outputs	VIRT OP *n*	Assigns the previous FlexLogic™ parameter to virtual output *n*, where *n* = 1 to 96.	The virtual output is set by the preceding parameter

FlexLogic™ rules

When forming a protection FlexLogic™ equation, the sequence in the linear array of parameters must follow these general rules.

1. Logic operands must precede the logic operator that uses the operands as inputs.
2. Logic operators have only one output. The output of an operator must be used to create a virtual output if it is to be used as an input to two or more operators.
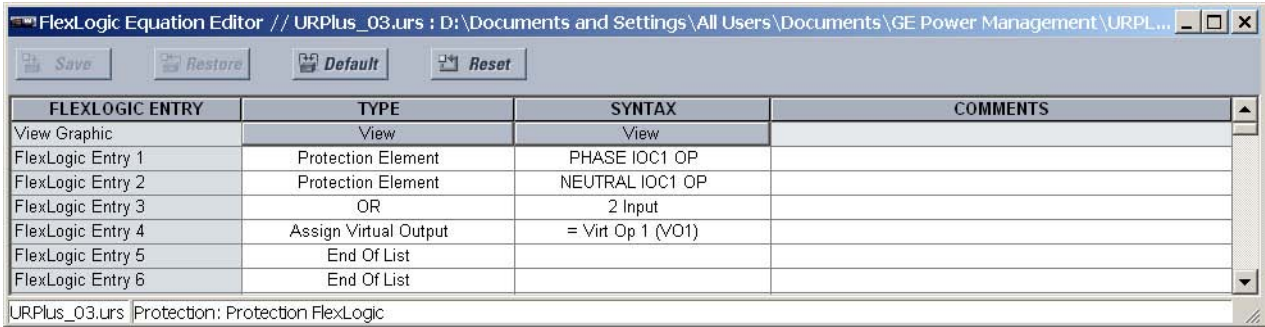
3. Assigning the output of a logic operator to a virtual output terminates the equation.

4. A timer operator (for example TIMER 1) or virtual output assignment (for example, = Virt Op 1) may only be used once. If this rule is broken, a syntax error will be declared.

Protection FlexLogic™ equation editor

A protection FlexLogic™ equation can contain up to 512 entries, including the END operator. If a disabled element is selected as a FlexLogic™ entry, the associated state flag will never be asserted (set to logic 1).

Select the **Settings > Protection > Protection FlexLogic > FlexLogic Equation Editor** menu item to open the protection FlexLogic™ equation editor window.

Figure 197: Protection FlexLogic™ configuration settings

A graphical representation of the protection FlexLogic™ can be displayed by clicking on the **View** button at the top of the equation.

Figure 198: Typical protection FlexLogic™ display
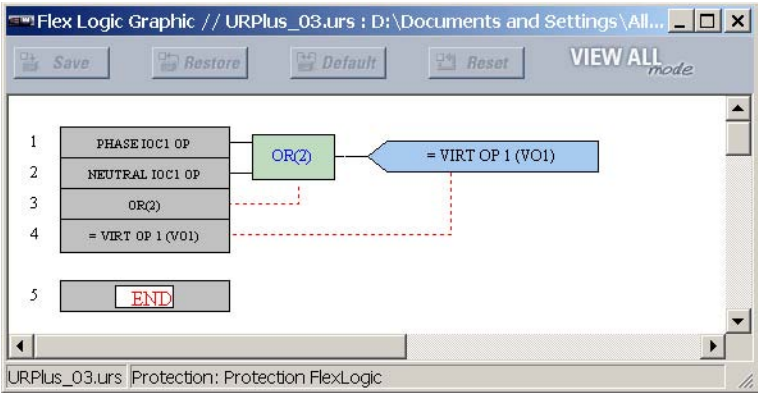
Protection FlexLogic™ timers

There are 32 identical protection FlexLogic™ timers available. These timers can be used as operators in FlexLogic™ equations.

Select the **Settings > Protection > Protection FlexLogic > FlexLogic Timers** menu item to open the protection FlexLogic™ timers configuration window.

Figure 199: Protection FlexLogic™ timers configuration settings
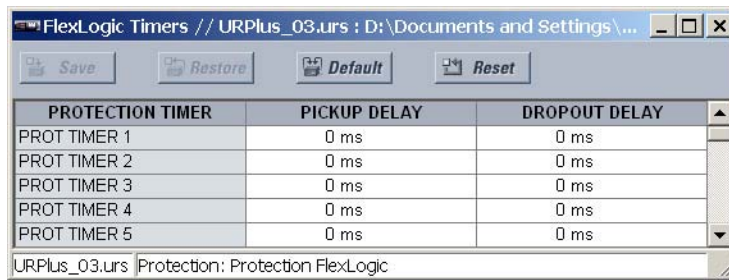
The following settings are available for each protection FlexLogic™ timer.

Pickup Delay

Range: 0 to 3600000000 ms in steps of 1
Default: 0

This setting specifies the time delay to pickup. If a pickup delay is not required, set this value to "0".

Dropout Delay

Range: 0 to 3600000000 ms in steps of 1
Default: 0

This setting specifies the time delay to dropout. If a dropout delay is not required, set this value to "0".

Non-volatile latches

The non-volatile latches provide a permanent logical flag that is stored safely and will not reset upon reboot after the relay is powered down. Typical applications include sustaining operator commands or permanently block relay functions, such as autoreclose, until a deliberate interface action resets the latch. There are sixteen (16) non-volatile latches available for use in protection schemes.

Select the **Settings > Protection > Protection FlexLogic > Non-Volatile Latches** menu item to open the non-volatile latches configuration window.

Figure 200: Non-volatile latches configuration settings
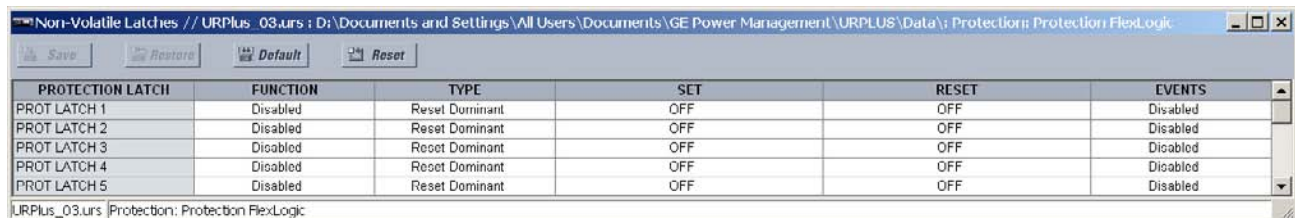
The following settings are available for the protection non-volatile latches.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the corresponding protection non-volatile latch.

Type

Range: Reset Dominant, Set Dominant
Default: Reset Dominant

This setting selects the non-volatile latch as set-dominant or reset-dominant.

Set

Range: any FlexLogic™ operand or shared operand
Default: OFF

If the operand assigned to this setting is asserted, the non-volatile latch will be set.

Reset

Range: any FlexLogic™ operand or shared operand
Default: OFF

If the operand assigned to this setting is asserted, the non-volatile latch will be reset.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of non-volatile latch events in the sequence of events recorder.

The following table summarizes the operation of the non-volatile latches.

Table 24: Non-volatile latch operation table

Type	Latch operation			
	Set	Reset	On	Off
Reset-dominant	ON	OFF	ON	OFF
	OFF	OFF	Previous state	Previous state
	ON	ON	OFF	ON
	OFF	ON	OFF	ON
Set-dominant	ON	OFF	ON	OFF
	ON	ON	ON	OFF
	OFF	OFF	Previous state	Previous state
	OFF	ON	OFF	ON

The logic for protection non-volatile latches is shown below.

Figure 201: Non-volatile latches scheme logic
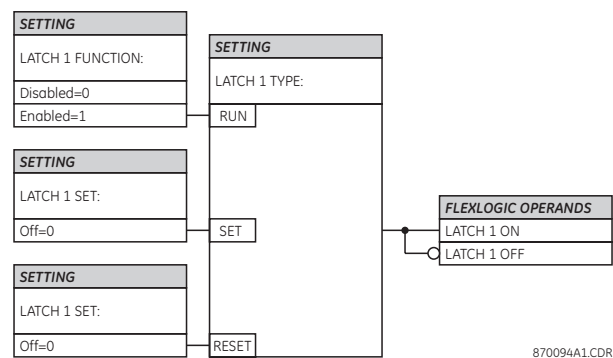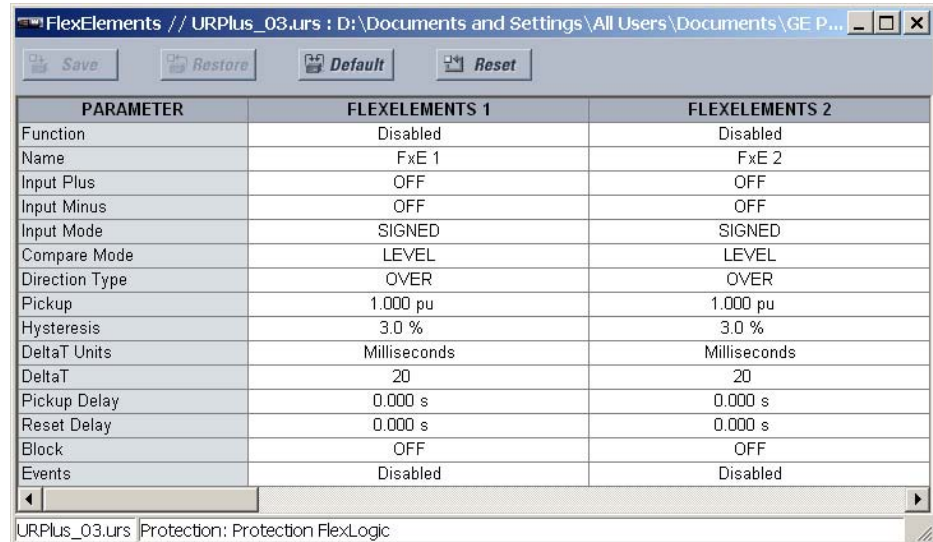
Protection FlexElements™

A FlexElement™ is a universal comparator that can be used to monitor any analog actual value calculated by the relay or a net difference between any two analog actual values of the same type. The effective operating signal can be treated as a signed number or an absolute value. The output from a FlexElement™ can also be used for further logic processing. A total of sixteen (16) FlexElements™ are dedicated for the protection system.

The element can be programmed to respond either to a signal level or to a rate-of-change (delta) over a pre-defined period of time. The output operand is asserted when the operating signal is higher than a threshold or lower than a user-specified threshold.

Select the **Settings > Protection > Protection FlexLogic > FlexElements** menu item to open the protection FlexElements™ configuration window.

Figure 202: Protection FlexElements™ configuration settings

The following settings are available for each protection FlexElement™.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the corresponding FlexElement™.

Name

Range: up to 6 alphanumeric characters

Default: FxE 1

An alphanumeric identifier may be assigned to a FlexElement™ for diagnostic, setting, and event recording purposes. The default "FxE 1" text that appears in event records and logic operands will be replaced by the text programmed in this setting.

Input Plus

Range: any analog actual value parameter or OFF

Default: OFF

This setting specifies the first (non-inverted) input to the FlexElement™. A value of zero is assumed as the input if this setting is "OFF". For proper operation of the element, at least one input must be selected. Otherwise, the element will not assert its output operands.

Input Minus

Range: any analog actual value parameter or OFF

Default: OFF

This setting specifies the second (inverted) input to the FlexElement™. A value of zero is assumed as the input if this setting is set to "OFF". For proper operation of the element at least one input must be selected. Otherwise, the element will not assert its output operands. This input should be used to invert the signal if needed for convenience, or to make the element respond to a differential signal such as for a top-bottom oil

temperature differential alarm. The element will not operate if the two input signals are of different types (for example if one tries to use active power and phase angle to build the effective operating signal).

Input Mode

Range: Signed, Absolute

Default: Signed

If this setting value is "Signed", then the FlexElement™ responds directly to the differential signal. If this setting value is "Absolute", then the FlexElement™ responds to the absolute value of the differential signal. Sample applications for the absolute input mode include monitoring the angular difference between two phasors with a symmetrical limit angle in both directions, monitoring power regardless of its direction, or monitoring a trend regardless of whether the signal increases of decreases.

Compare Mode

Range: Level, Delta

Default: Level

This setting specifies how the element responds to its operating signal. If this setting value is "Level", the element responds directly to its operating signal (as defined by the **Input Plus**, Input Minus, and **Input Mode** settings). If this setting value if "Delta", the element responds to the rate of change of its operating signal (as defined by the **Delta T** and **Delta T Units** settings).

Direction Type

Range: Over, Under

Default: Under

This setting enables the relay to respond to either high or low values of the operating signal.

Figure 203: Relationship of input mode and direction settings
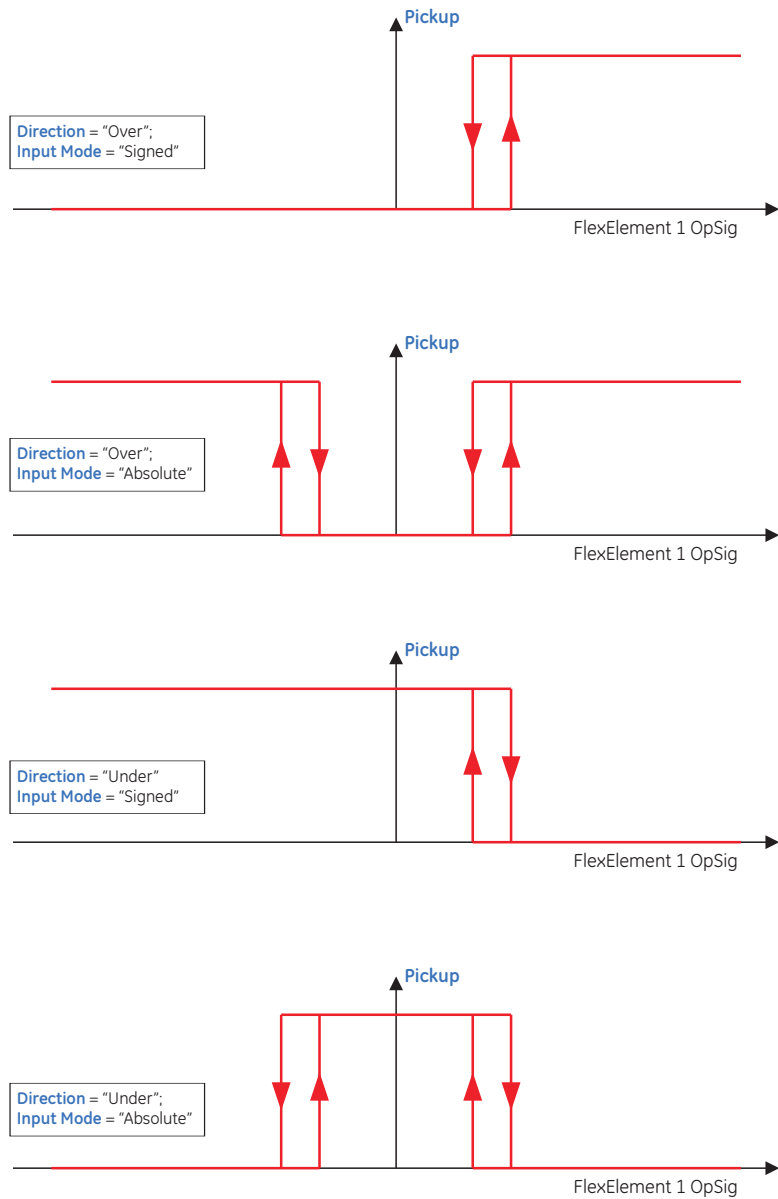
870822A1.CDR

Pickup

Range: –90.000 to 90.000 pu in steps of 0.001
Default: 1.000 pu

This setting specifies the operating threshold for the effective operating signal of the FlexElement™. If the **Direction Type** setting is "Over", the element picks up when the operating signal exceeds the value specified here. If the **Direction Type** setting is "Under", the element picks up when the operating signal falls below the value specified here.

This setting is entered in per-unit values using the following definitions of the base units.

Table 25: Protection FlexElement™ pickup per-unit base units

Element	Base unit
Frequency	1 Hz
Phase angles	360 degrees
Power factor	1.00
Source current	Maximum nominal primary RMS value of the +IN and –IN inputs
Source energy (real)	10000 MWh
Source energy (reactive)	10000 Mvarh
Source power	Maximum value of the product of the voltage and current base values for the +IN and –IN inputs.
Source voltage	Maximum nominal primary RMS value of the +IN and –IN inputs.

Hysteresis

Range: 0.1 to 50.0% in steps of 0.1

Default: 3.0%

This setting controls the element pickup and dropout relation by specifying the width of the hysteresis loop as a percentage of the pickup value. It should be noticed that both the operating signal and the pickup threshold can be negative facilitating applications such as reverse power alarm protection. The FlexElement™ can be programmed to work with all analog actual values measured by the relay.

Figure 204: Direction, pickup, and hysteresis relation
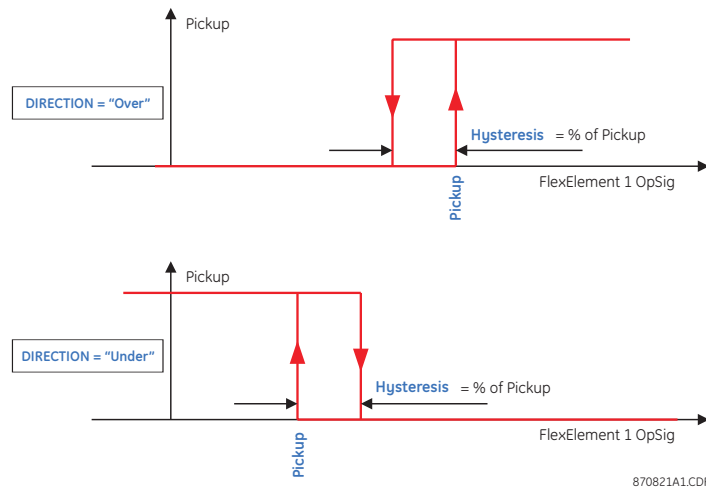
Delta T Units

Range: milliseconds, seconds, minutes

Default: milliseconds

This setting specifies the time unit for the **Delta T** setting. It is applicable only in the delta comparison mode.

Delta T

Range: 20 to 86400 in steps of 1

Default: 20

This setting specifies duration of the time interval for the rate of change mode of operation. It is applicable only in the delta comparison mode.

Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001
Default: 0.000 seconds

This setting specifies the pickup delay of the FlexElement™.

Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001
Default: 0.000 seconds

This setting specifies the reset delay of the FlexElement™.

Block

Range: any FlexLogic™ operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks operation of the FlexElement™.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of FlexElement™ events in the sequence of events recorder.

The logic for FlexElements™ is shown below.

Figure 205: Protection FlexElements™ scheme logic
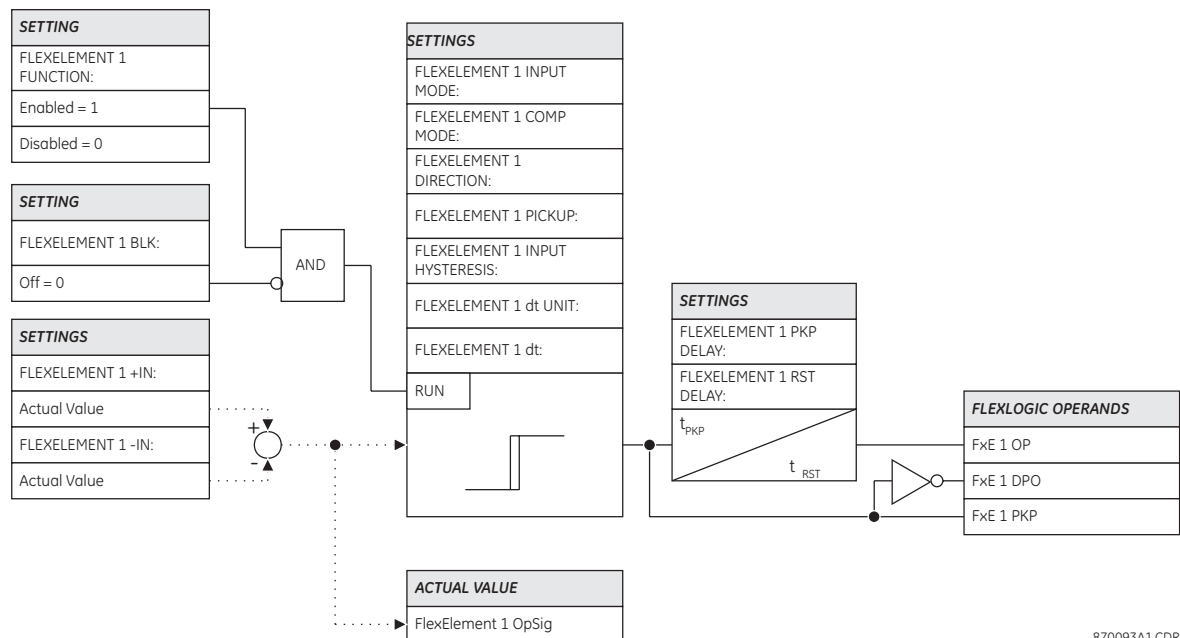
Protection FlexLogic™ operands

The following protection FlexLogic™ operands are available for the C90^{Plus}. They are listed alphabetically by operand syntax. Some operands can be re-named by the user. These include the names of breakers, contact inputs, virtual inputs, and virtual outputs. The default names are indicated in the lists below.

Autoreclose operands

AR 1-P RIP ....Asserted when a single-pole autoreclose is in progress.

AR 3-P/1 RIP .... Asserted when a three-pole autoreclose is in progress via dead time 1.

AR 3-P/2 RIP .... Asserted when a three-pole autoreclose is in progress via dead time 2.

AR 3-P/3 RIP .... Asserted when a three-pole autoreclose is in progress via dead time 3.

AR 3-P/4 RIP .... Asserted when a three-pole autoreclose is in progress via dead time 4.

AR BKR1 BLK .... Asserted when reclosure of breaker 1 is blocked.

AR BKR2 BLK .... Asserted when reclosure of breaker 2 is blocked.

AR CLOSE BKR1 .... Asserted when a close breaker 1 signal is issued.

AR CLOSE BKR2 .... Asserted when a close breaker 2 signal is issued.

AR DISABLED .... Asserted when the autoreclose element is disabled.

AR ENABLED .... Asserted when the autoreclose element is enabled.

AR FORCE 3-P TRIP .... Asserted when a trip is forced to a three-phase trip.

AR INCOMPLETE SEQ .... Asserted when a the incomplete sequence timer times out.

AR LO .... Asserted when the autoreclose element is in the lockout state.

AR RESET .... Asserted when the autoreclose element has been reset manually or by the reset timer.

AR RIP .... Asserted when the autoreclose element is in the reclose-in-progress state.

AR SHOT CNT > 0 .... Asserted when the first close breaker signal has been issued.

AR SHOT CNT = 1 .... Asserted when the shot count is equal to 1.

AR SHOT CNT = 2 .... Asserted when the shot count is equal to 2.

AR SHOT CNT = 3 .... Asserted when the shot count is equal to 3.

AR SHOT CNT = 4 .... Asserted when the shot count is equal to 4.

AR ZONE 1 EXTENT .... Asserted when the zone 1 distance function is be set to the extended over-reach value.

Auxiliary overvoltage operands

AUX OV1 DPO .... Asserted when the auxiliary overvoltage element drops out.

AUX OV1 OP .... Asserted when the auxiliary overvoltage element operates.

AUX OV1 PKP .... Asserted when the auxiliary overvoltage element picks up.

Auxiliary undervoltage operands

AUX UV1 DPO .... Asserted when the auxiliary undervoltage element drops out.

AUX UV1 OP .... Asserted when the auxiliary undervoltage element operates.

AUX UV1 PKP .... Asserted when the auxiliary undervoltage element picks up.

Breaker configuration operands

BKR1 ANY POLE OPEN .... Asserted when at least one pole of breaker 1 is open.

BKR1 BAD STATE .... Asserted when the normally open and normally closed breaker indications disagree.

BKR1 CLOSE CMD .... Asserted when close command is executed on breaker 1.

BKR1 CLOSED .... Asserted when breaker 1 is closed.

BKR1 DISCREPANCY .... Asserted when the three poles of the breaker disagree (that is, when they are not all opened or all closed).

BKR1 INTERMED .... Asserted when the breaker is in transition between the opened and closed states.

BKR1 ONE POLE OPEN .... Asserted when only one pole of breaker 1 is open.

BKR1 OPEN CMD .... Asserted when an open command has been executed on breaker 1.

BKR1 OPENED ....Asserted when breaker 1 is opened.

BKR1 SUBST CLOSED ....Asserted when the status of breaker 1 has been substituted with a closed indication.

BKR1 SUBST ON ....Asserted when breaker status substitution is enabled.

BKR1 SUBST OPENED ....Asserted when the status of the breaker has been substituted with an opened indication.

BKR1 TRIP CMD A ....Asserted when a close command is executed on pole A of breaker 1.

BKR1 TRIP CMD B ....Asserted when a close command is executed on pole B of breaker 1.

BKR1 TRIP CMD C ....Asserted when a close command is executed on pole C of breaker 1.

BKR1A BAD STATE ....Asserted when the normally open and normally closed breaker indications disagree for pole A of breaker 1.

BKR1A CLOSED ....Asserted when breaker 1 pole A is closed.

BKR1A INTERMED ....Asserted when breaker 1 pole A is in transition between the opened and closed states.

BKR1A OPENED ....Asserted when breaker 1 pole A is opened.

BKR1B BAD STATE ....Asserted when the normally open and normally closed breaker indications disagree for pole B of breaker 1.

BKR1B CLOSED ....Asserted when breaker 1 pole B is closed.

BKR1B INTERMED ....Asserted when breaker 1 pole B is in transition between the opened and closed states.

BKR1B OPENED ....Asserted when breaker 1 pole B is opened.

BKR1C BAD STATE ....Asserted when the normally open and normally closed breaker indications disagree for pole C of breaker 1.

BKR1C CLOSED ....Asserted when breaker 1 pole C is closed.

BKR1C INTERMED ....Asserted when breaker 1 pole C is in transition between the opened and closed states.

BKR1C OPENED ....Asserted when breaker 1 pole C is opened.

BKR2 ....The operands listed above are also available for breaker 2.

Breaker failure operands

BKR FAIL 1 RETRIP ....Asserted upon a breaker failure 1 three-pole trip.

BKR FAIL 1 RETRIPA ....Asserted when breaker failure 1 re-trips on phase A (single-pole schemes only).

BKR FAIL 1 RETRIPB ....Asserted when breaker failure 1 re-trips on phase B (single-pole schemes only).

BKR FAIL 1 RETRIPC ....Asserted when breaker failure 1 re-trips on phase C (single-pole schemes only).

BKR FAIL 1 T1 OP ....Asserted when the breaker failure 1 timer 1 operates.

BKR FAIL 1 T2 OP ....Asserted when the breaker failure 1 timer 2 operates.

BKR FAIL 1 T3 OP ....Asserted when the breaker failure 1 timer 3 operates.

BKR FAIL 1 TRIP OP ....Asserted when breaker failure 1 trip has operated.

BKR FAIL 2 ....The same set of operands listed above are available for the breaker failure 2 element.

Breaker flashover operands

BKR 1 FLSHOVR DPO ....Asserted when breaker 1 flashover drops out.

BKR 1 FLSHOVR DPO A ....Asserted when breaker 1 flashover drops out for phase A.

BKR 1 FLSHOVR DPO B ....Asserted when breaker 1 flashover drops out for phase B.

BKR 1 FLSHOVR DPO C ....Asserted when breaker 1 flashover drops out for phase C.

BKR 1 FLSHOVR OP .... Asserted when breaker 1 flashover operates.

BKR 1 FLSHOVR OP A .... Asserted when breaker 1 flashover operates for phase A.

BKR 1 FLSHOVR OP B .... Asserted when breaker 1 flashover operates for phase B.

BKR 1 FLSHOVR OP C .... Asserted when breaker 1 flashover operates for phase C.

BKR 1 FLSHOVR PKP .... Asserted when breaker 1 flashover picks up.

BKR 1 FLSHOVR PKP A .... Asserted when breaker 1 flashover picks up for phase A.

BKR 1 FLSHOVR PKP B .... Asserted when breaker 1 flashover picks up for phase B.

BKR 1 FLSHOVR PKP C .... Asserted when breaker 1 flashover picks up for phase C.

BKR 2 FLSHOVR .... The operands listed above are available for the breaker flashover 2 element.

Protection contact input operands

CONTACT IP 1 ON .... Asserted when the field contact connected to contact input 1 is closed.

CONTACT IP 1 OFF .... Asserted when the field contact connected to contact input 1 is opened.

CONTACT IP 1 TROUBLE OP .... Asserted when there is an internal or external problem with contact input 1.

CONTACT IP 1 TROUBLE DPO .... Asserted when there are no problems with contact input 1.

CONTACT IP 2 to *40* .... The operands listed above are available for the contact inputs 2 through 40.

Digital counter operands

COUNTER 1 EQL .... Asserted when the output of digital counter 1 is equal to the comparison value.

COUNTER 1 HI .... Asserted when the output of digital counter 1 is greater than the comparison value.

COUNTER 1 LO .... Asserted when the output of digital counter 1 is less than the comparison value.

COUNTER 2 to *8* .... The operands listed above are also available for digital counters 2 through 8.

FlexMatrix operands

FLXMAT 1 DPO .... Asserted when FlexMatrix 1 drops out.

FLXMAT 1 OP .... Asserted when FlexMatrix 1 operates.

FLXMAT 1 PKP .... Asserted when FlexMatrix 1 picks up.

FLXMAT 2 to 8 .... The operands listed above are also available for FlexMatrix elements 2 through 8.

FlexElement™ operands

FXE 1 DPO .... Asserted when protection FlexElement™ 1 drops out.

FXE 1 OP .... Asserted when protection FlexElement™ 1 operates.

FXE 1 PKP .... Asserted when protection FlexElement™ 1 picks up.

FXE 2 to 8 .... The operands listed above are also available for protection FlexElements™ 2 through 8.

Ground instantaneous overcurrent operands

GROUND IOC1 DPO .... Asserted when ground instantaneous overcurrent 1 drops out.

GROUND IOC1 OP .... Asserted when ground instantaneous overcurrent 1 operates.

GROUND IOC1 PKP .... Asserted when ground instantaneous overcurrent 1 picks up.

GROUND IOC2 to 12 .... The operands listed above are also available for ground instantaneous overcurrent elements 2 through 12.

Ground time overcurrent operands

GROUND TOC1 DPO......................Asserted when ground time overcurrent 1 drops out.

GROUND TOC1 OP........................Asserted when ground time overcurrent 1 operates.

GROUND TOC1 PKP......................Asserted when ground time overcurrent 1 picks up.

GROUND TOC2 to 6........................The operands listed above are also available for ground time overcurrent elements 2 through 6.

Non-volatile latch operands

LATCH 1 OFF....................................Asserted when non-volatile latch 1 is off (logic 0).

LATCH 1 ON.....................................Asserted when non-volatile latch 1 is on (logic 1).

LATCH 2 to 16 ....The operands listed above are also available for non-volatile latches 2 to 16.

Negative-sequence directional overcurrent operands

NEG SEQ DIR OC1 FWD ....Asserted when the negative-sequence directional overcurrent 1 element forward mode operates.

NEG SEQ DIR OC1 REV ....Asserted when the negative-sequence directional overcurrent 1 element reverse mode operates.

NEG SEQ DIR OC2 FWD ....Asserted when the negative-sequence directional overcurrent 2 element forward mode operates.

NEG SEQ DIR OC2 REV ....Asserted when the negative-sequence directional overcurrent 2 element reverse mode operates.

Negative-sequence instantaneous overcurrent operands

NEG SEQ IOC1 DPO ....Asserted when the negative-sequence instantaneous overcurrent 1 element drops out.

NEG SEQ IOC1 OP ....Asserted when the negative-sequence instantaneous overcurrent 1 element operates.

NEG SEQ IOC1 PKP ....Asserted when the negative-sequence instantaneous overcurrent 1 element picks up.

NEG SEQ IOC2 ....The operands listed above are also available for negative-sequence instantaneous overcurrent 2.

Negative-sequence overvoltage operands

NEG SEQ OV DPO ....Asserted when the negative-sequence overvoltage element drops out.

NEG SEQ OV OP ....Asserted when the negative-sequence overvoltage element operates.

NEG SEQ OV PKP ....Asserted when the negative-sequence overvoltage element has picks up.

Negative-sequence time overcurrent operands

NEG SEQ TOC1 DPO ....Asserted when the negative-sequence time overcurrent 1 element drops out.

NEG SEQ TOC1 OP.........................Asserted when the negative-sequence time overcurrent 1 element operates.

NEG SEQ TOC1 PKP ....Asserted when the negative-sequence time overcurrent 1 element picks up.

NEG SEQ TOC2 ....The operands listed above are also available for negative-sequence time overcurrent 2.

Neutral instantaneous overcurrent operands

NEUTRAL IOC1 DPO ....Asserted when the neutral instantaneous overcurrent 1 element drops out.

NEUTRAL IOC1 OP .... Asserted when the neutral instantaneous overcurrent 1 element operates.

NEUTRAL IOC1 PKP .... Asserted when the neutral instantaneous overcurrent 1 element picks up.

NEUTRAL IOC2 to 12 .... The operands listed above are also available for neutral instantaneous overcurrent 2 through 12.

Neutral overvoltage operands

NEUTRAL OV1 DPO .... Asserted when the neutral overvoltage 1 element drops out.

NEUTRAL OV1 OP .... Asserted when the neutral overvoltage 1 element operates.

NEUTRAL OV1 PKP .... Asserted when the neutral overvoltage 1 element picks up.

NEUTRAL OV2 to 3 .... The operands listed above are also available for neutral overvoltage 2 and 3.

Neutral time overcurrent operands

NEUTRAL TOC1 DPO .... Asserted when the neutral time overcurrent 1 element drops out.

NEUTRAL TOC1 OP .... Asserted when the neutral time overcurrent 1 element operates.

NEUTRAL TOC1 PKP .... Asserted when the neutral time overcurrent 1 element picks up.

NEUTRAL TOC 2 to 6 .... The operands listed above are also available for neutral time overcurrent 2 through 6.

Neutral directional overcurrent operands

NTRL DIR OC1 FWD .... Asserted when the neutral directional overcurrent 1 element forward mode operates.

NTRL DIR OC1 REV .... Asserted when the neutral directional overcurrent 1 element reverse mode operates.

NTRL DIR OC2 FWD .... Asserted when the neutral directional overcurrent 2 element forward mode operates.

NTRL DIR OC2 REV .... Asserted when the neutral directional overcurrent 2 element reverse mode operates.

Phase directional overcurrent operands

PH DIR1 BLK .... Asserted when the phase directional overcurrent 1 element is blocked.

PH DIR1 BLK A .... Asserted when the phase directional overcurrent 1 element is blocked in phase A.

PH DIR1 BLK B .... Asserted when the phase directional overcurrent 1 element is blocked in phase B.

PH DIR1 BLK C .... Asserted when the phase directional overcurrent 1 element is blocked in phase C.

PH DIR 2 .... Same set of operands as shown above for the phase directional overcurrent 2 element.

Phase instantaneous overcurrent operands

PHASE IOC1 DPO .... Asserted when at least one phase of the phase instantaneous overcurrent 1 element drops out.

PHASE IOC1 DPO A .... Asserted when phase A of the phase instantaneous overcurrent 1 element drops out.

PHASE IOC1 DPO B .... Asserted when phase B of the phase instantaneous overcurrent 1 element drops out.

PHASE IOC1 DPO C .... Asserted when phase C of the phase instantaneous overcurrent 1 element drops out.

PHASE IOC1 OP ....Asserted when at least one phase of the phase instantaneous overcurrent 1 element operates.

PHASE IOC1 OP A..........................Asserted when phase A of the phase instantaneous overcurrent 1 element operates.

PHASE IOC1 OP B..........................Asserted when phase B of the phase instantaneous overcurrent 1 element operates.

PHASE IOC1 OP C..........................Asserted when phase C of the phase instantaneous overcurrent 1 element operates.

PHASE IOC1 PKP...........................Asserted when at least one phase of the phase instantaneous overcurrent 1 element picks up.

PHASE IOC1 PKP A........................Asserted when phase A of the phase instantaneous overcurrent 1 element picks up.

PHASE IOC1 PKP B........................Asserted when phase B of the phase instantaneous overcurrent 1 element picks up.

PHASE IOC1 PKP C........................Asserted when phase C of the phase instantaneous overcurrent 1 element picks up.

PHASE IOC2 to 12 ....Same set of operands as shown above for the phase instantaneous overcurrent elements 2 through 12.

Phase overvoltage operands

PHASE OV1 DPO ....Asserted when at least one phase of the phase overvoltage 1 element drops out.

PHASE OV1 DPO A ....Asserted when phase A of the phase overvoltage 1 element drops out.

PHASE OV1 DPO B ....Asserted when phase B of the phase overvoltage 1 element drops out.

PHASE OV1 DPO C ....Asserted when phase C of the phase overvoltage 1 element drops out.

PHASE OV1 OP ....Asserted when at least one phase of the phase overvoltage 1 element operates.

PHASE OV1 OP A...........................Asserted when phase A of the phase overvoltage 1 element operates.

PHASE OV1 OP B...........................Asserted when phase B of the phase overvoltage 1 element operates.

PHASE OV1 OP C...........................Asserted when phase C of the phase overvoltage 1 element operates.

PHASE OV1 PKP ....Asserted when at least one phase of the phase overvoltage 1 element picks up.

PHASE OV1 PKP A ....Asserted when phase A of the phase overvoltage 1 element picks up.

PHASE OV1 PKP B ....Asserted when phase B of the phase overvoltage 1 element picks up.

PHASE OV1 PKP C ....Asserted when phase C of the phase overvoltage 1 element picks up.

PHASE OV2..Same set of operands as shown above for the phase overvoltage 2 element.

Phase time overcurrent operands

PHASE TOC1 DPO..........................Asserted when at least one phase of the phase time overcurrent 1 element drops out.

PHASE TOC1 DPO A.......................Asserted when phase A of the phase time overcurrent 1 element drops out.

PHASE TOC1 DPO B .... Asserted when phase B of the phase time overcurrent 1 element drops out.

PHASE TOC1 DPO C .... Asserted when phase C of the phase time overcurrent 1 element drops out.

PHASE TOC1 OP .... Asserted when at least one phase of the phase time overcurrent 1 element operates.

PHASE TOC1 OP A......................... Asserted when phase A of the phase time overcurrent 1 element operates.

PHASE TOC1 OP B......................... Asserted when phase B of the phase time overcurrent 1 element operates.

PHASE TOC1 OP C......................... Asserted when phase C of the phase time overcurrent 1 element operates.

PHASE TOC1 PKP .... Asserted when at least one phase of the phase time overcurrent 1 element picks up.

PHASE TOC1 PKP A .... Asserted when phase A of the phase time overcurrent 1 element picks up.

PHASE TOC1 PKP B .... Asserted when phase B of the phase time overcurrent 1 element picks up.

PHASE TOC1 PKP C .... Asserted when phase C of the phase time overcurrent 1 element picks up.

PHASE TOC2 to 6 .... Same set of operands as shown above for the phase time overcurrent elements 2 through 6.

Phase undervoltage operands

PHASE UV1 DPO........................... Asserted when at least one phase of the phase undervoltage 1 element drops out.

PHASE UV1 DPO A........................ Asserted when phase A of the phase undervoltage 1 element drops out.

PHASE UV1 DPO B........................ Asserted when phase B of the phase undervoltage 1 element drops out.

PHASE UV1 DPO C........................ Asserted when phase C of the phase undervoltage 1 element drops out.

PHASE UV1 OP.............................. Asserted when at least one phase of the phase undervoltage 1 element operates.

PHASE UV1 OP A........................... Asserted when phase A of the phase undervoltage 1 element operates.

PHASE UV1 OP B........................... Asserted when phase B of the phase undervoltage 1 element operates.

PHASE UV1 OP C........................... Asserted when phase C of the phase undervoltage 1 element operates.

PHASE UV1 PKP............................. Asserted when at least one phase of the phase undervoltage 1 element picks up.

PHASE UV1 PKP A......................... Asserted when phase A of the phase undervoltage 1 element picks up.

PHASE UV1 PKP B......................... Asserted when phase B of the phase undervoltage 1 element picks up.

PHASE UV1 PKP C......................... Asserted when phase C of the phase undervoltage 1 element picks up.

PHASE UV2 .... Same set of operands as shown above for the phase undervoltage 2 element.

Setting group operands

SETTING GROUP ACT 1................ Asserted when setting group 1 is active.

SETTING GROUP ACT 2 ....Asserted when setting group 2 is active.

SETTING GROUP ACT 3 ....Asserted when setting group 3 is active.

SETTING GROUP ACT 4 ....Asserted when setting group 4 is active.

SETTING GROUP ACT 5 ....Asserted when setting group 5 is active.

SETTING GROUP ACT 6 ....Asserted when setting group 6 is active.

Disturbance detector operands

SRC1 50DD OP................................Asserted when the disturbance detector for source 1 operates.

SRC2 50DD OP................................Asserted when the disturbance detector for source 2 operates.

SRC3 50DD OP................................Asserted when the disturbance detector for source 3 operates.

Voltage transformer fuse failure (VTFF) operands

SRC1 VTFF DPO.............................Asserted when the VT fuse failure detector for source 1 drops out.

SRC1 VTFF OP................................Asserted when the VT fuse failure detector for source 1 operates.

SRC1 VTFF VOL LOSS ....Asserted when the VT fuse failure detector for source 1 loses voltage signals (V_2 is less than 15% and V_1 is less than 5% of nominal).

SRC2 to SRC3... ....The set of operands shown above are available VT fuse failure elements for sources 2 through 3.

C90^Plus Controller

Chapter 7: Automation

This section describes how to program the C90^Plus automation features.

Automation controller overview

The C90^Plus automation controller allows the user to easily implement a variety of custom automation schemes. The controller can access both digital and analog inputs and outputs. Operations carried out on digital inputs and outputs are referred to as logical operations, whereas operations carried out on analog inputs and outputs are referred to as math operations. Digital inputs and outputs include physical inputs and outputs residing locally in the C90^Plus, remote inputs and outputs originating in external devices, and outputs generated by internal, hard-coded functions. The results of processing inputs and outputs are stored locally in the form of virtual inputs and outputs. These may, in turn, be assigned to drive contact outputs, annunciator indications, or be used as inputs to internal, hard-coded functions. They are also available via communications to external devices or master programs.

All inputs are read at the beginning of the automation scan, then the logic is processed. After logic processing, the outputs are written. The C90^Plus automation scan rate is 50 ms. A total of 4096 lines can be programmed in the automation controller.

Figure 206: Automation scan


```
┌──────────────────────────────┐
│  Read automation inputs      │
└──────────────────────────────┘
              │
              ▼
┌──────────────────────────────┐
│  Process automation logic    │
└──────────────────────────────┘
              │
              ▼
┌──────────────────────────────┐
│  Write automation outputs    │
└──────────────────────────────┘
```

870812A1.CDR
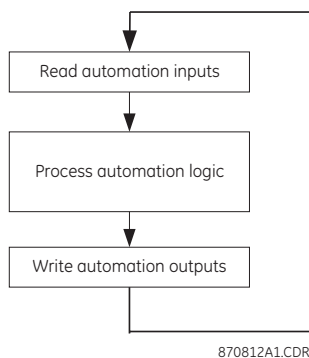
Input and output structure

The input and output structure of the C90^{Plus} is shown below. Three groupings of inputs and outputs are defined: physical, shared, and virtual, with digital and analog types within each grouping.

Figure 207: Input and output structure
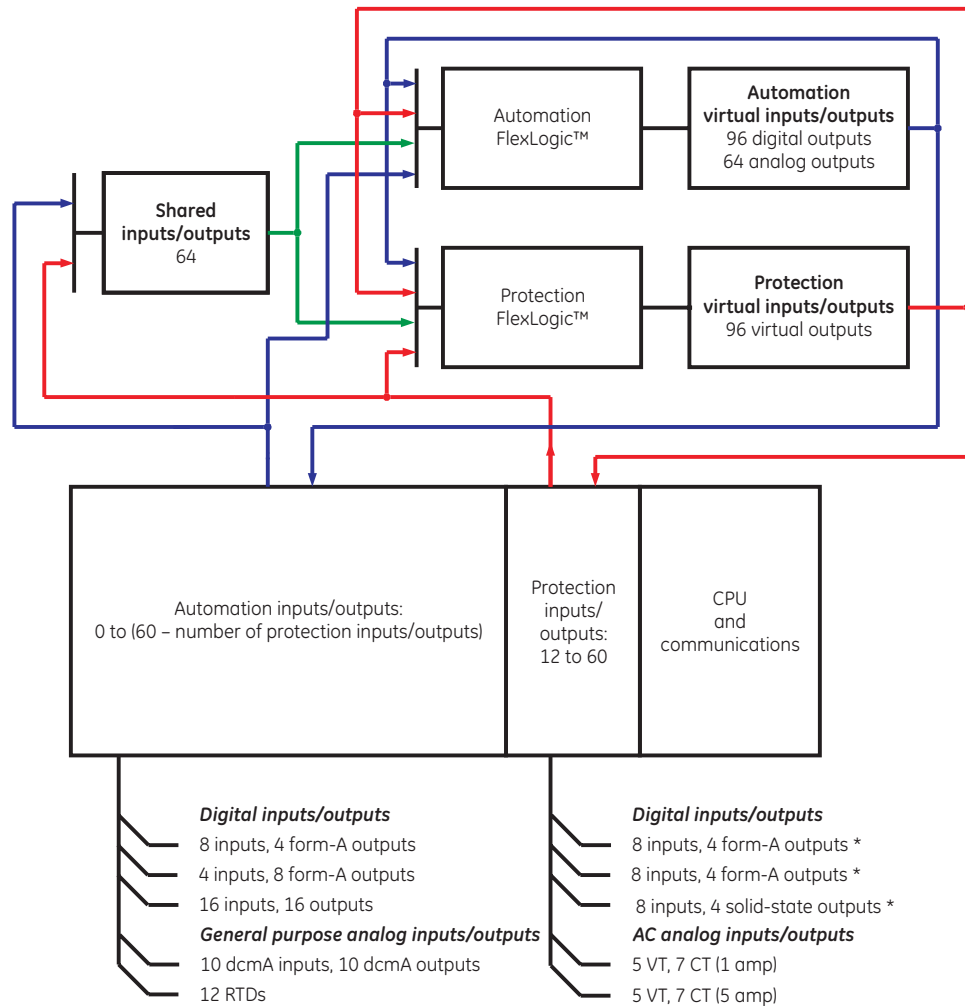
* With integral circuit breaker trip coil voltage and current monitoring

870720A2.CDR

The digital inputs and outputs have the following characteristics.

- Physical inputs and outputs: The C90^{Plus} can accommodate a maximum of five input/output modules.
- Shared inputs and outputs: These are internal registers that are accessible to both the protection and automation functions. This allows protection physical inputs to be passed to the automation function and *vice-versa*.
- Virtual inputs and outputs: A total of 96 points are available in the controller for storage of the intermediate or final results of logic processing (defined as virtual digital outputs).

The analog inputs and outputs have the following characteristics.

- Physical inputs: These are derived from analog input cards designed to measure process variables produced by transducers.

- Shared inputs and outputs: These are internal registers that are accessible to both the protection and automation functions. This allows protection physical inputs to be passed to the automation function and *vice-versa*. The C90^{Plus} can store a total of 64 shared operands. This allows the automation function access to a large variety of analog measurements resident in the protection functions.

- Virtual inputs and outputs: A total of 64 points are available in the controller for storage of the intermediate of final results of math processing (defined as virtual analog outputs).
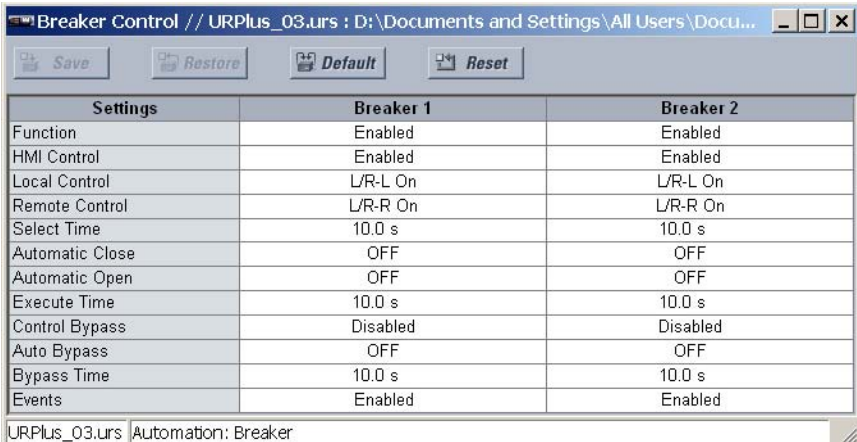
Breakers

Breaker control

The breaker control element contains the auxiliary logic for control of circuit breakers required for SCADA and for the front panel interface. The control function incorporates select-before-operate. Selection is required before a control action is permitted. Selecting a device inhibits service to other clients. Selection is also inhibited if an operation is in progress. The logic permits interlocking to be bypassed if required.

Select the **Settings > Automation > Breaker > Breaker Control** menu item to open the breaker control configuration window.

Figure 208: Breaker control configuration settings window

Settings	Breaker 1	Breaker 2
Function	Enabled	Enabled
HMI Control	Enabled	Enabled
Local Control	L/R-L On	L/R-L On
Remote Control	L/R-R On	L/R-R On
Select Time	10.0 s	10.0 s
Automatic Close	OFF	OFF
Automatic Open	OFF	OFF
Execute Time	10.0 s	10.0 s
Control Bypass	Disabled	Disabled
Auto Bypass	OFF	OFF
Bypass Time	10.0 s	10.0 s
Events	Enabled	Enabled

The following settings are available for each breaker.

Function

Range: Enabled, Disabled
Default: Enabled

This setting enables or disables breaker control.

HMI Control

Range: Enabled, Disabled
Default: Enabled

This setting enables breaker control through the front panel interface and populates the front panel display with breaker control soft-keys.

Local Control

Range: any automation logic operand or shared operand
Default: L/R-L On

When the operand assigned to this setting is asserted, control is enabled from the front panel interface. This setting is normally assigned to the local status of a local/remote switch. If continuous local control is required, this setting may be programmed as "On".

Remote Control

Range: any automation logic operand or shared operand
Default: L/R-R On

When the operand assigned to this setting is asserted, control is enabled from SCADA. This setting is normally assigned to the remote status of a local/remote switch. If continuous remote control is required, this setting may be programmed as "On".

Select Time

Range: 0.00 to 30.00 seconds in steps of 0.01
Default: 10.00 seconds

This setting determines the maximum permissible time from selection of the breaker and a control action.

Automatic Close

Range: any automation logic operand or shared operand
Default: OFF

This setting is used to close the device from an automatic control scheme.

Automatic Open

Range: any automation logic operand or shared operand
Default: OFF

This setting is used to open the device from an automatic control scheme.

Execute Time

Range: 0.0 to 10.0 seconds in steps of 0.1
Default: 10.0 seconds

This setting determines the duration of the open and close commands used to control the breaker.

Control Bypass

Range: Enabled, Disabled
Default: Disabled

When enabled, this setting allows the interlocking to be bypassed from local or remote control.

⚠ **CAUTION**

Non-interlocked control can result in equipment damage.

Automation Bypass

Range: any automation logic operand or shared operand
Default: OFF

When the operand assigned to this setting is asserted, interlocking is bypassed.

⚠ **CAUTION**

Non-interlocked control can result in equipment damage.

Bypass Time

Range: 0.0 to 30.0 seconds in steps of 0.1
Default: 10.0 seconds

This setting determines the time window during which non-interlocked control can occur once bypass has been selected.

The breaker control logic is shown in the following figures.

Figure 209: Breaker control logic, sheet 1 of 3
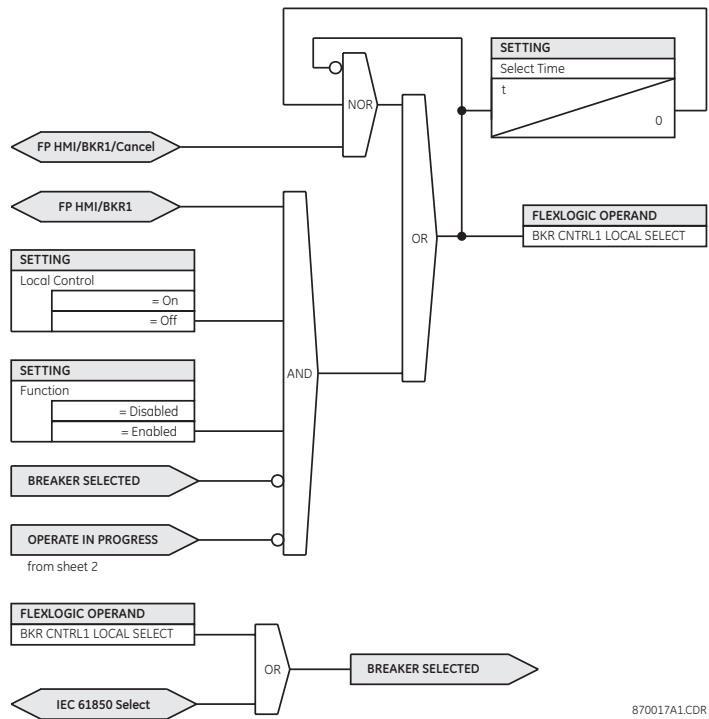
Figure 210: Breaker control logic, sheet 2 of 3
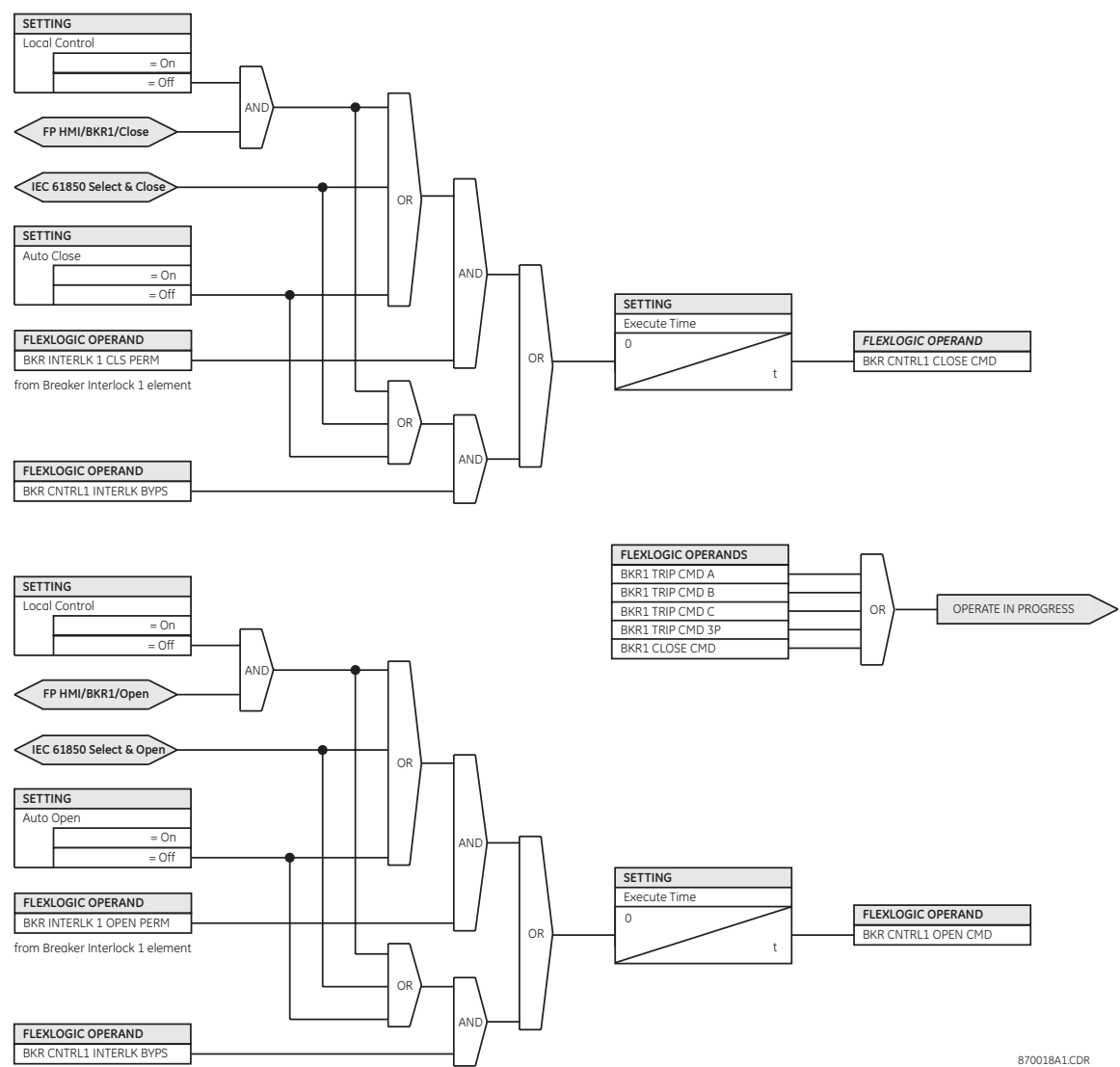
Figure 211: Breaker control logic, sheet 3 of 3
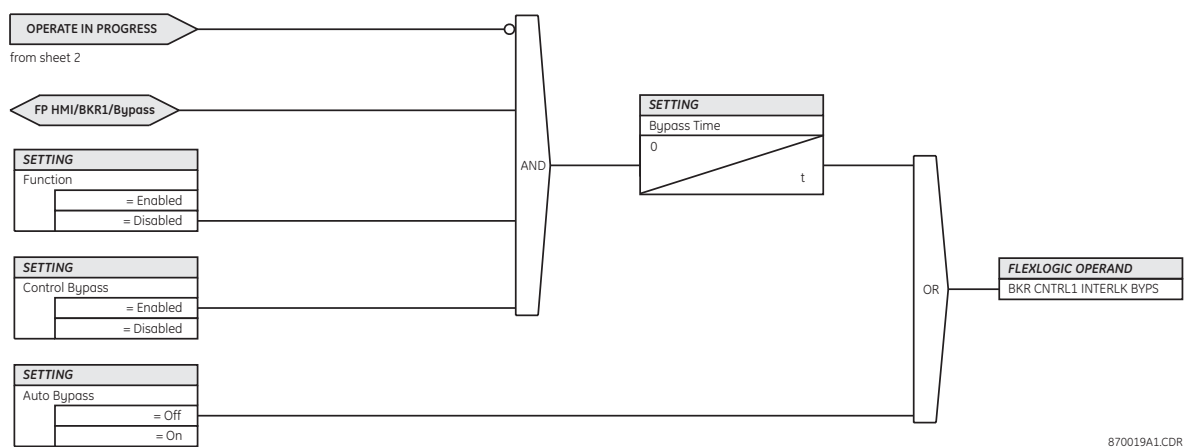
Breaker interlocking

The breaker interlocking element contains the auxiliary logic for interlocking of circuit breakers. Up to three inputs can be assigned for interlocking the open and close controls. An input is also available for supervision by a synchrocheck element. The breaker may also be tagged through the front panel interface or through SCADA. Opening and closing of a tagged device is inhibited in logic.

Select the **Settings > Automation > Breaker > Breaker Interlocking** menu item to open the breaker interlocking configuration window.

Figure 212: Breaker interlocking configuration settings

The following settings are available for each breaker interlocking element.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables the breaker position indications and control logic. If disabled, all outputs and front panel indications are switched off.

Tagging

Range: Enabled, Disabled
Default: Disabled

When enabled, tagging control is enabled and a TAG/UNTAG soft-key is displayed on the front panel interface. When a breaker is tagged both local and remote control of the device is inhibited.

Status Supervision

Range: Enabled, Disabled
Default: Disabled

When enabled, control of the breaker is supervised by its breaker status. An open command cannot be sent to a breaker that currently indicates open and a close command cannot be sent to a breaker that indicates closed.

Close Interlock 1, Close Interlock 2, Close Interlock 3

Range: any automation logic operand or shared operand
Default: OFF

Closing of the device is inhibited if any of the operands assigned to these settings are asserted.

Synchrocheck Permissive

Range: any automation logic operand or shared operand

Default: SYNC 1 SYNC OP

This setting is used to supervise closing of the breaker by a synchrocheck element. If synchrocheck is not required, this setting should be selected as "ON".

Open Interlock 1, Open Interlock 2, Open Interlock 3

Range: any automation logic operand or shared operand

Default: Off

Opening of the device is inhibited if any of the operands assigned to these settings are asserted.

Events

Range: Enabled, Disabled

Default: Enabled

The setting enables or disables the logging of breaker interlocking events in the sequence of events recorder.

The breaker interlocking logic is shown below.

Figure 213: Breaker interlocking logic

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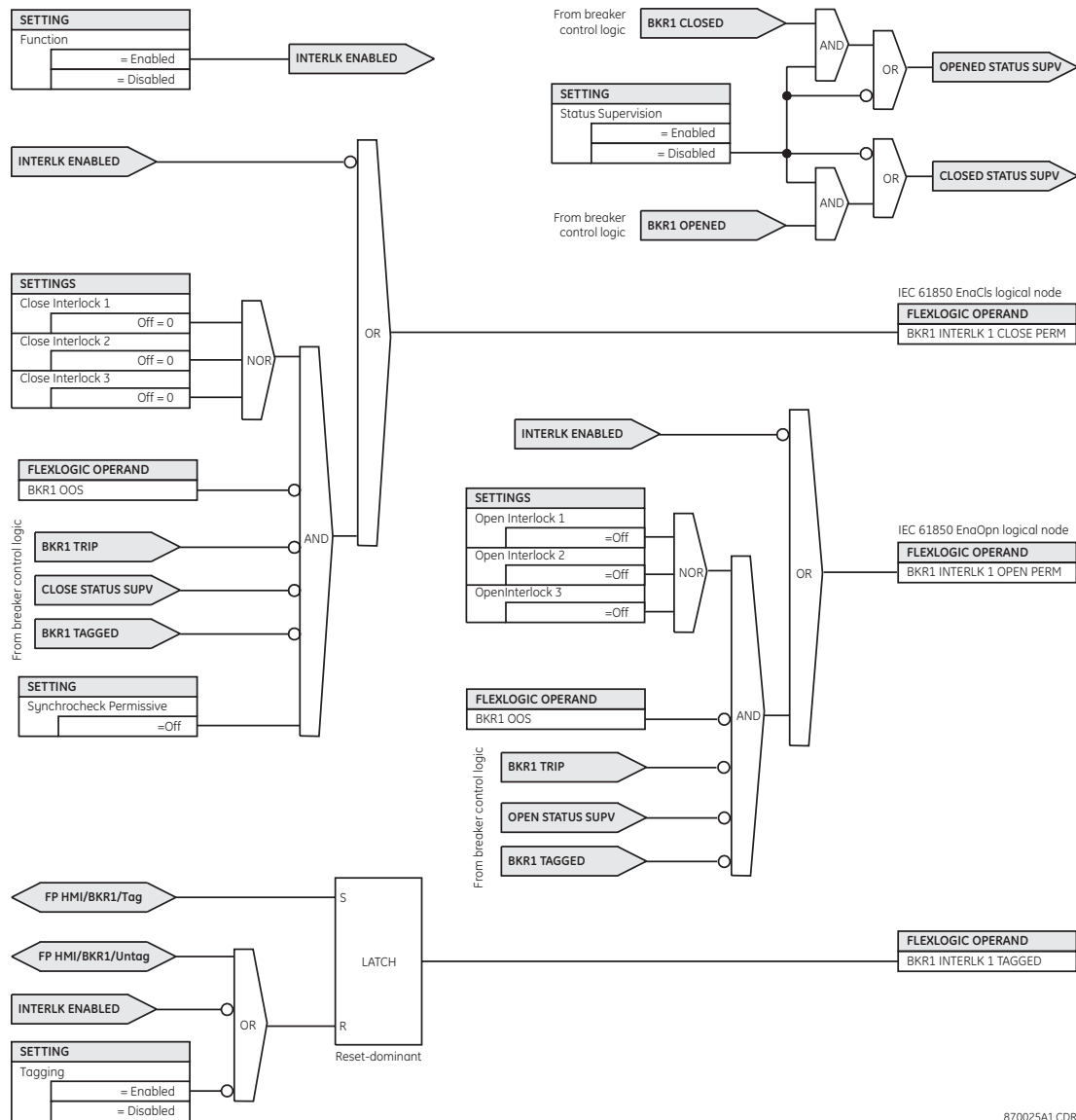
Disconnects

The disconnect element contains the auxiliary logic for status and serves as the interface for opening and closing of the disconnect from protection and automation functions. The logic also permits a manual substitution of the position indication.

Disconnect configuration

Select the **Settings > Automation > Disconnects > Disconnect Configuration** menu item to open the disconnect control configuration window.

Figure 214: Disconnect configuration settings

The following settings are available for each disconnect.

Function

Range: Enabled, Disabled
Default: Enabled

This setting enables the disconnect position indications and control logic. If disabled, all outputs and front panel indications are switched off.

Long Name

Range: up to 12 alphanumeric characters
Default: DISCONNECT 1

This setting identifies the primary device for control confirmations on the front panel interface and in the event record.

Short Name

Range: up to 6 alphanumeric characters
Default: DSC1

This setting identifies the primary device soft-keys and indications on the front panel interface.

Substitution

Range: Enabled, Disabled
Default: Disabled

If this setting is "Enabled", the position indication of the disconnect can be substituted with a manually entered value.

Block Close Command

Range: any automation logic operand or shared operand
Default: OFF

Assertion of the operand assigned to this setting prevents the disconnect from closing.

Block Open Command

Range: any automation logic operand or shared operand
Default: OFF

Assertion of the operand assigned to this setting prevents the disconnect from opening.

Disconnect Local Input

Range: any automation logic operand or shared operand
Default: OFF

Closing or opening of the disconnect through the disconnect interlock element is inhibited if the operand assigned to this setting is asserted.

Indication Mode

Range: 3-Pole, 1-Pole
Default: 3-Pole

If the "3-Pole" value is selected, the disconnect indications are derived from a single status input (or pair of status inputs). If the "1-Pole" value is selected, the disconnect indications are derived from three status inputs (or pairs of status inputs).

Phase A/3P Closed Status

Range: any automation logic operand or shared operand
Default: Off

The operand assigned to this setting is used to derive the three-pole or phase A circuit disconnect position indication from a normally-opened (52a) status input.

Phase A/3P Opened Status

Range: any automation logic operand or shared operand
Default: DSC2 89a On(K10)

The operand assigned to this setting is used to derive the three-pole or phase A circuit disconnect position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal.

Phase B Closed Status

Range: any automation logic operand or shared operand
Default: DSC2 89a Off(K10)

The operand assigned to this setting is used to derive the phase B disconnect position indication from a normally-opened (52a) status input. This setting is not required if the **Indication Mode** is "1-Pole".

Phase B Opened Status

Range: any automation logic operand or shared operand
Default: Off

The operand assigned to this setting is used to derive the phase B disconnect position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal. This setting is not required if the **Indication Mode** is "1-Pole".

Phase C Opened Status

Range: any automation logic operand or shared operand
Default: Off

The operand assigned to this setting is used to derive the phase C disconnect position indication from a normally-opened (52a) status input. This setting is not required if the **Indication Mode** is "1-Pole".

Phase C Closed Status

Range: any automation logic operand or shared operand
Default: Off

The operand assigned to this setting is used to derive the phase C disconnect position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal. This setting is not required if the **Indication Mode** is "1-Pole".

Operate Time

Range: 0.000 to 2.000 seconds in steps of 0.001
Default: 0.070 seconds

This setting specifies a timer that is asserted when both the normally open and normally closed disconnect indications are reset. When the timer expires, a bad status is indicated for the disconnect. This timer setting should be set equal to the normal operating time for the disconnect.

Discrepancy Time

Range: 0.000 to 2.000 seconds in steps of 0.001
Default: 0.070 seconds

This setting specifies a timer that is asserted when the three disconnect poles are not all opened or not all closed. This timer setting should be set greater than the longest expected time for which the three disconnect poles disagree.

Reset Counter

Range: any automation logic operand or shared operand
Default: Off

Assertion of the operand assigned to this setting resets the disconnect operation counters.

Events

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the logging of circuit disconnect events in the sequence of events recorder.

The disconnect configuration logic is shown below. The logic is identical for each available disconnect.

Figure 215: Disconnect scheme logic, sheet 1 of 4
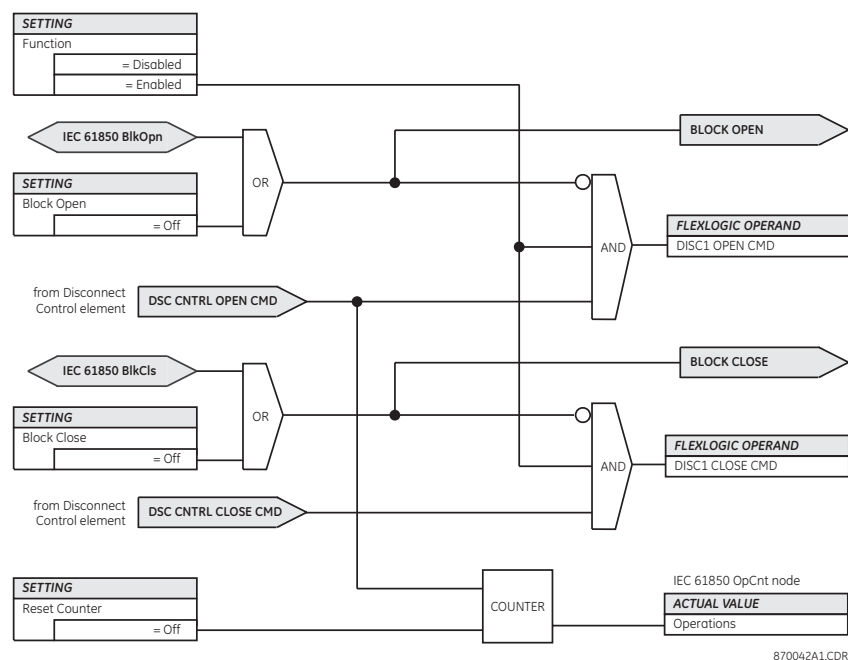
Figure 216: Disconnect scheme logic, sheet 2 of 4
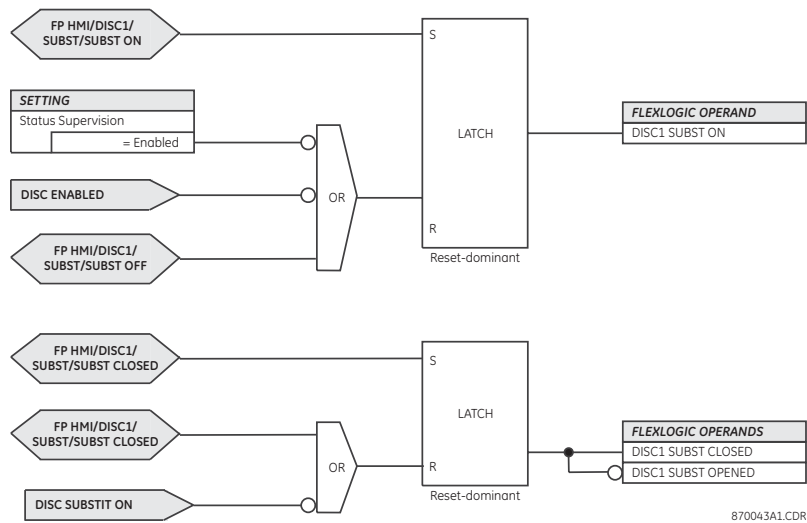
Figure 217: Disconnect scheme logic, sheet 3 of 4
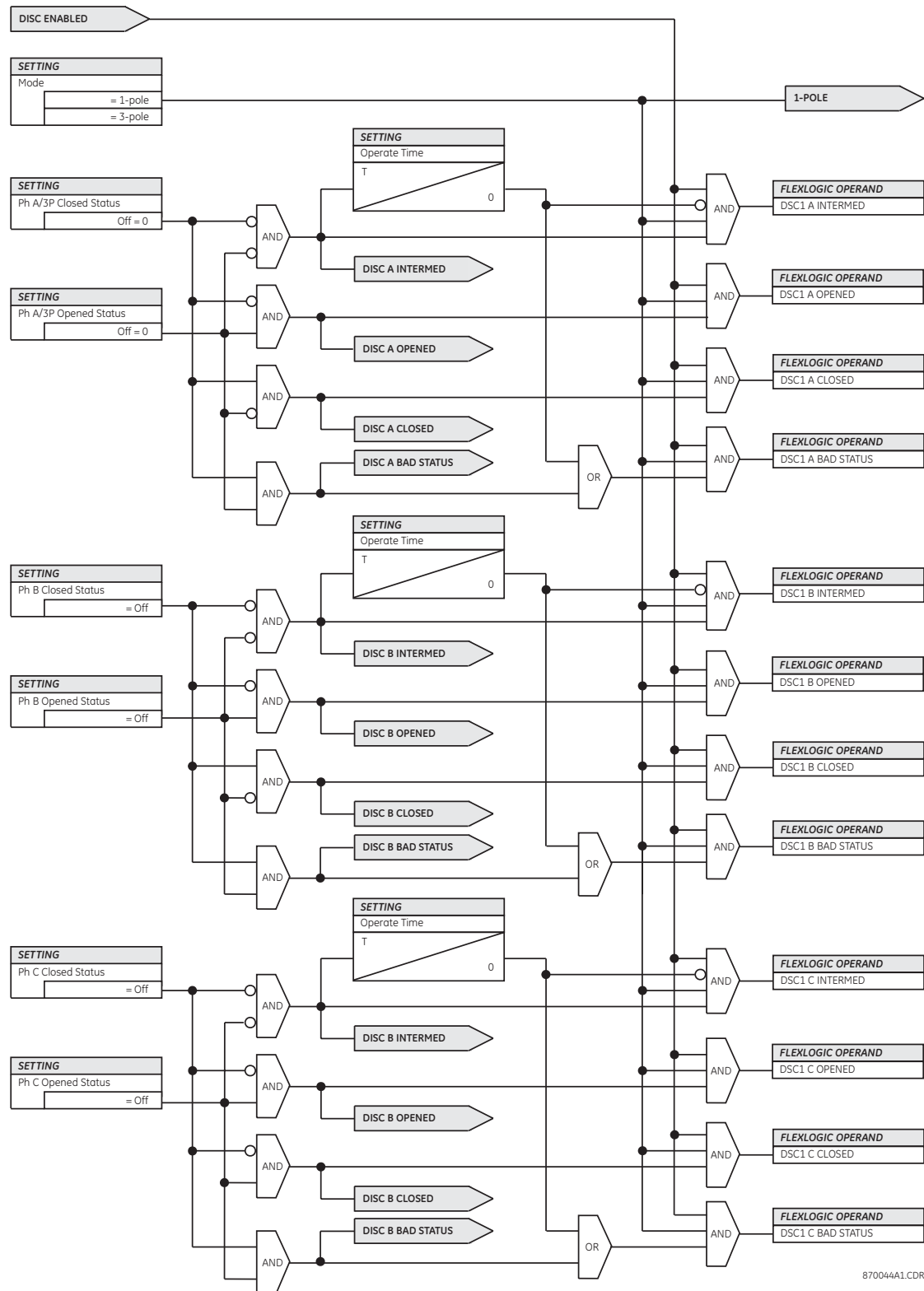
Figure 218: Disconnect scheme logic, sheet 4 of 4
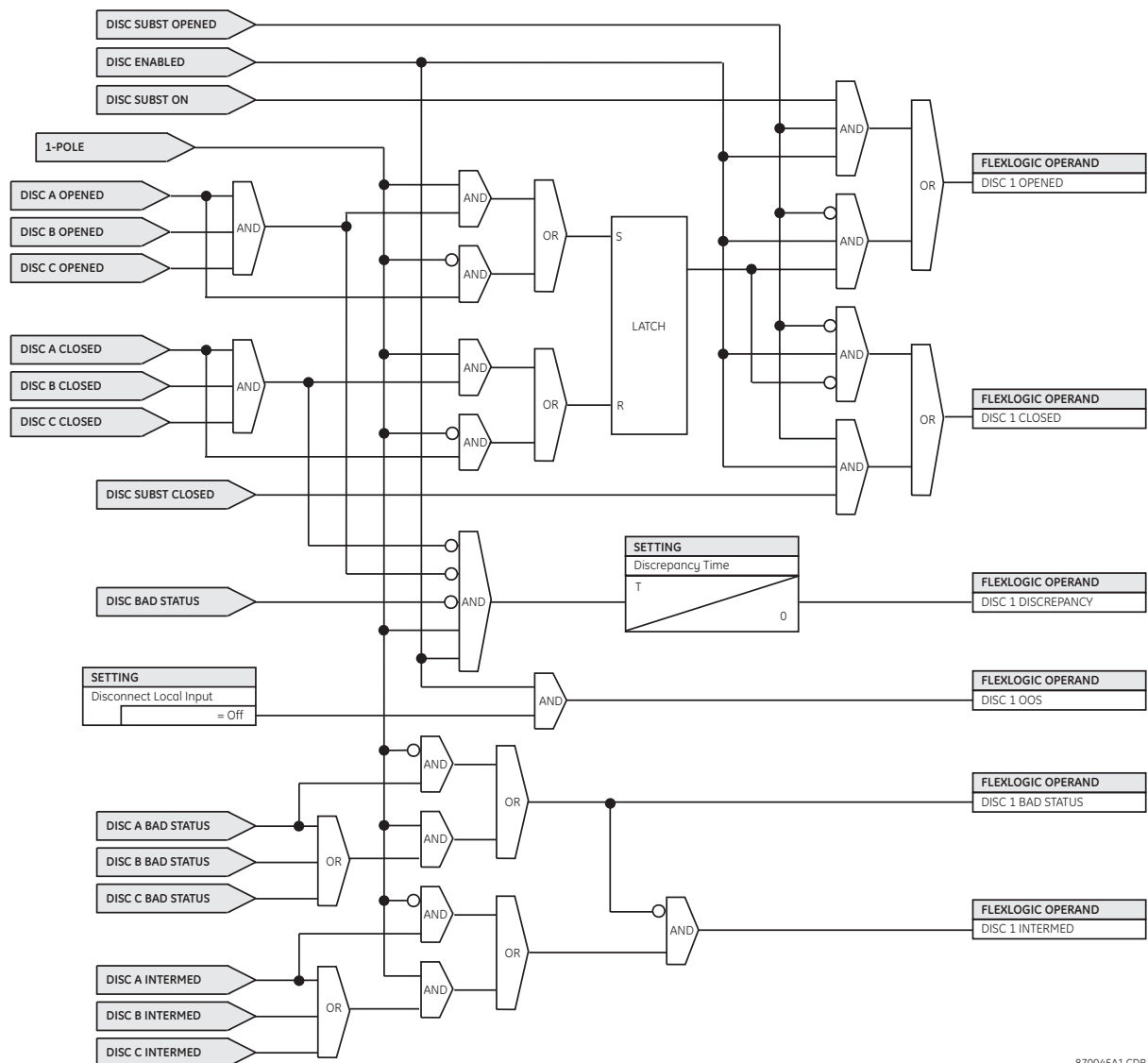
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Disconnect control

The disconnect control element contains the auxiliary logic for control of circuit breakers required for SCADA and the front panel interface. The control function incorporates select-before-operate functionality. Selection is required before a control action is permitted. Selecting a device inhibits service to other clients. Selection is also inhibited if an operation is in-progress. The logic permits interlocking to be bypassed if required.

Select the **Settings > Automation > Disconnects > Disconnect Control** menu item to open the disconnect control configuration window.

Figure 219: Disconnect control configuration settings

The following settings are available for each disconnect.

Function

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the disconnect control feature.

Pushbutton Control

Range: Enabled, Disabled

Default: Enabled

This setting enables control of the device via the front panel and populates the front panel interface with control soft-keys.

Local Control

Range: any automation logic operand or shared operand

Default: L/R-L On

When the operand assigned to this setting is asserted, control is permitted from the front panel interface. This setting is normally assigned to the local status of a local/remote switch. If continuous local control is required, this input may be switched to on.

Remote Control

Range: any automation logic operand or shared operand

Default: L/R-R On

When the operand assigned to this setting is asserted, remote control is permitted from SCADA. This setting is normally assigned to the remote status of a local/remote switch. If continuous remote control is required, this input may be switched to on

Select Time

Range: 0.0 to 30.0 seconds in steps of 0.1

Default: 10.0 seconds

This setting determines the maximum permissible time from selection of the disconnect and a control action.

Automatic Close

Range: any automation logic operand or shared operand

Default: OFF

The operand assigned to this setting is used to close the device from an automatic control scheme.

Automatic Open

Range: any automation logic operand or shared operand
Default: OFF

The operand assigned to this setting is used to open the device from an automatic control scheme.

Execute Time

Range: 0.0 to 10.0 seconds in steps of 0.1
Default: 10.0 seconds

This setting determines the duration of the open and close commands used to control the disconnect.

Control Bypass

Range: Enabled, Disabled
Default: Disabled

When enabled, this setting allows the interlocking to be bypassed from local or remote control.

⚠️ **CAUTION** **Non-interlocked control can result in equipment damage!**

Automatic Bypass

Range: any automation logic operand or shared operand
Default: OFF

When the operand assigned to this setting is asserted, interlocking is bypassed.

⚠️ **CAUTION** **Non-interlocked control can result in equipment damage!**

Bypass Time

Range: 0.0 to 30.0 seconds in steps of 0.1
Default: 10.0 seconds

This setting determines the time window during which non-interlocked control can occur once bypass has been selected.

Events

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the logging of disconnect control events in the sequence of events recorder.

The disconnect control logic is shown below. The logic is identical for all available disconnects.

Figure 220: Disconnect control logic, sheet 1 of 3
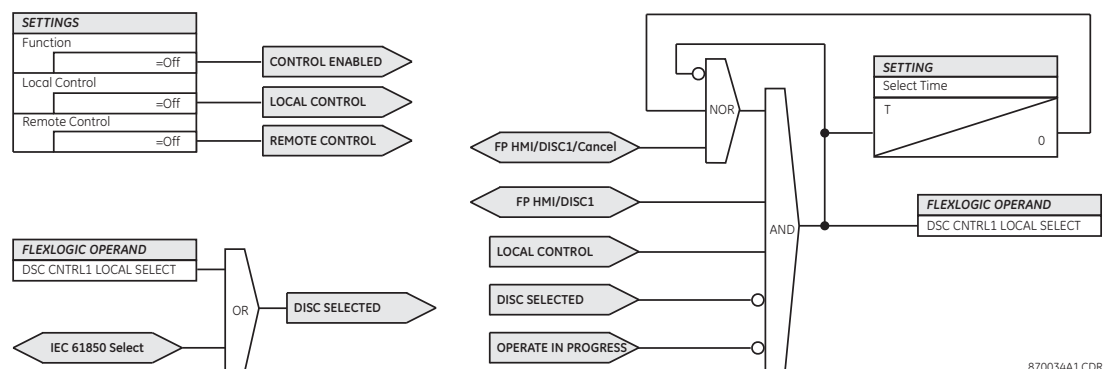
Figure 221: Disconnect control logic, sheet 2 of 3
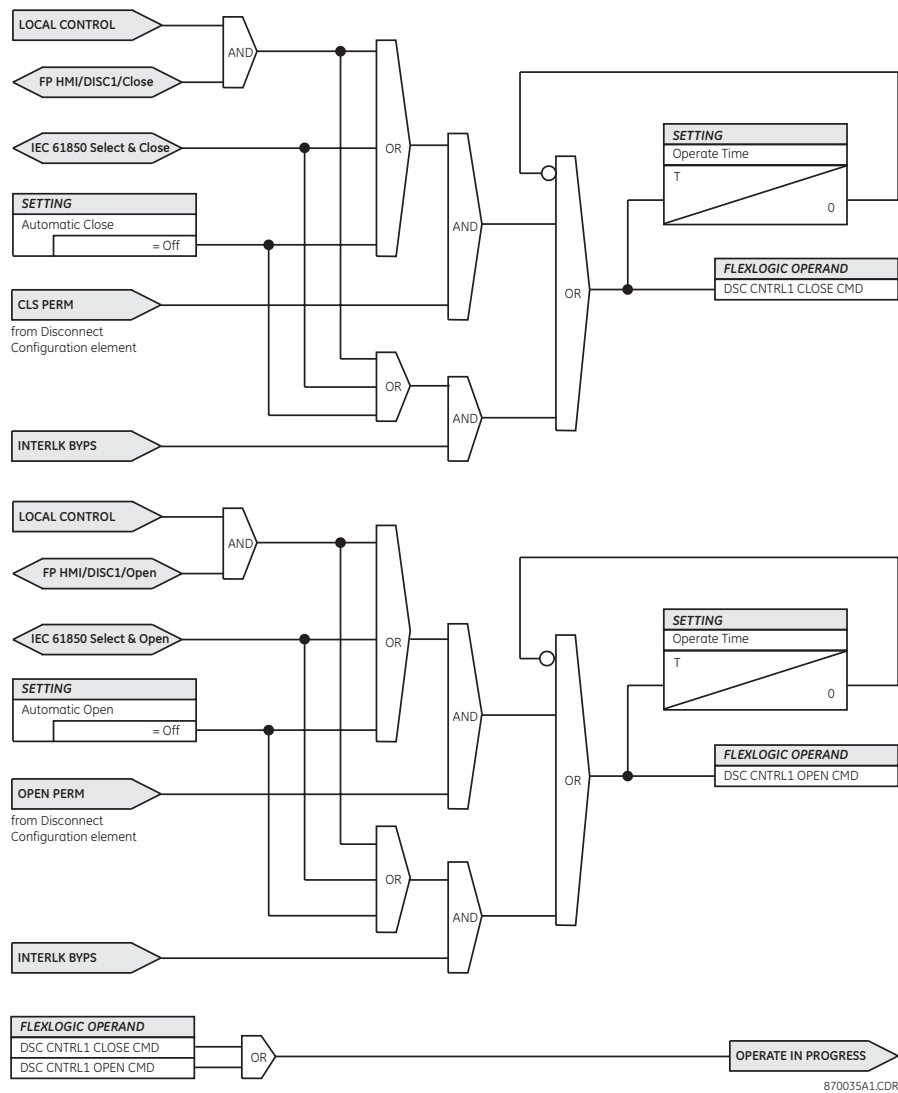
Figure 222: Disconnect control logic, sheet 3 of 3
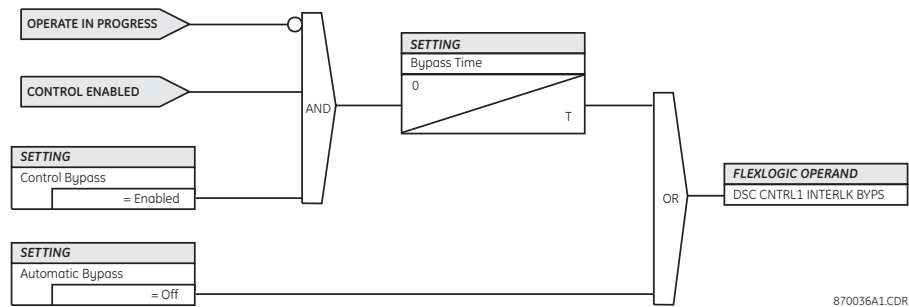
Disconnect interlocking

The disconnect interlocking element contains the auxiliary logic for interlocking of disconnects. Up to three inputs can be assigned for interlocking the open and close controls. An input is also available for supervision by a synchrocheck element. The disconnect may also be tagged through the front panel interface or through SCADA. Opening and closing of a tagged device is inhibited in logic.

Select the **Settings > Automation > Disconnects > Disconnect Interlocking** menu item to open the disconnect control configuration window.

Figure 223: Disconnect interlocking configuration settings
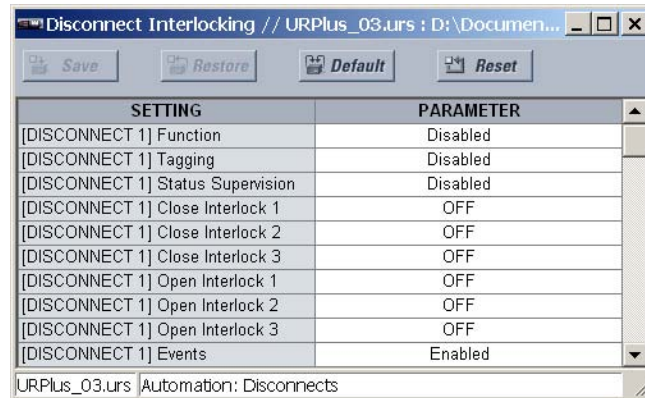
The following settings are available for each disconnect.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables the disconnect position indications and control logic. If "Disabled", all outputs and front panel indications are switched off.

Tagging

Range: Enabled, Disabled
Default: Disabled

When this setting is "Enabled", tagging control is enabled and a TAG/UNTAG soft-key is populated on the front panel interface. When a disconnect is tagged, both local and remote control of the device is inhibited.

Status Supervision

Range: Enabled, Disabled
Default: Disabled

When this setting is "Enabled", control of the disconnect is supervised by its disconnect status. An open command cannot be sent to a disconnect that currently indicates open and a close command cannot be sent to a disconnect that indicates closed.

Close Interlock 1, Close Interlock 2, Close Interlock 3

Range: any automation logic operand or shared operand
Default: OFF

If any of the operands assigned to these settings are asserted, closing of the device is inhibited.

Open Interlock 1, Open Interlock 2, Open Interlock 3
Range: any automation logic operand or shared operand
Default: OFF

If any of the operands assigned to these settings are asserted, opening of the device is inhibited.

Events
Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the logging of disconnect interlocking events in the sequence of events recorder.

The disconnect interlocking logic is shown below. The logic is identical for all available disconnects.

Figure 224: Disconnect interlocking logic
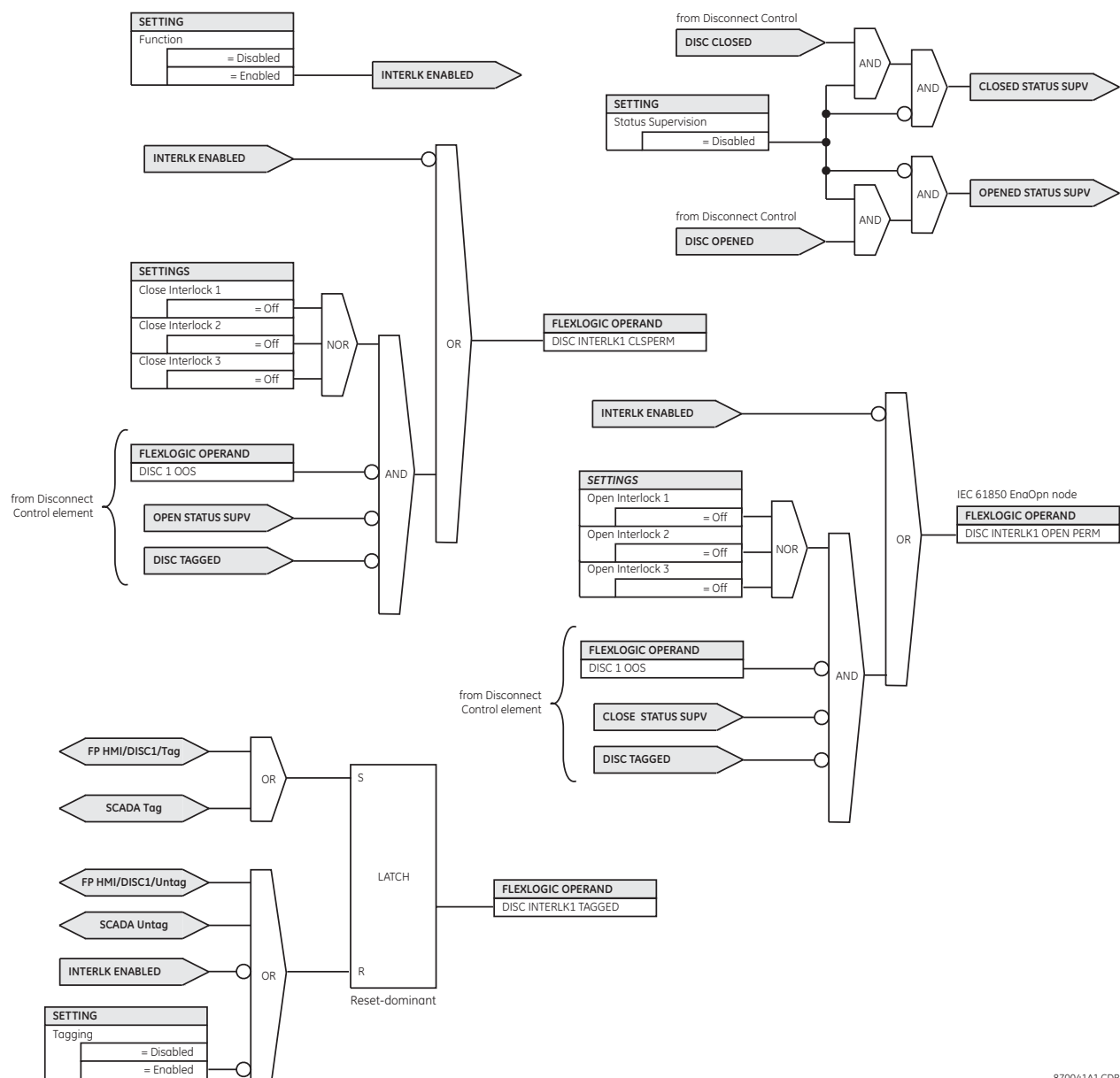
Automation control

Front panel status and control

There can be a maximum of two breakers and six disconnect switches (referred to as devices) plus autoreclose and local-remote status and control. All devices have a short name setting and a full name setting. The short name is used to designate the device and the associated select pushbutton.

The top-level control screen presents the status of each enabled breaker and disconnect. The status of the local-remote function and the autoreclose function is shown if these functions are enabled. All devices are displayed in grey.

If the pushbutton control setting is enabled for a device or function, then the pushbutton on the front panel interface is assigned as shown in the example below. A device that does not have pushbutton control enabled does not have a pushbutton on this screen.

Figure 225: Device selected to operate
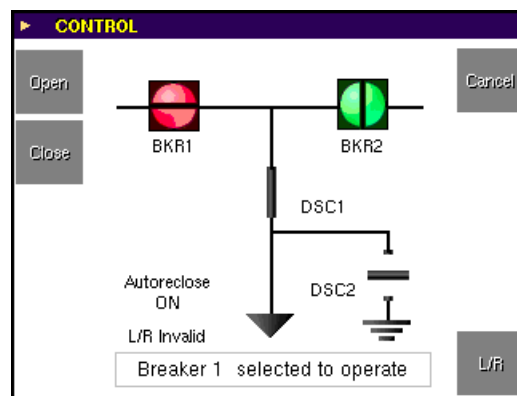
A confirmation message is displayed using the full name for the device to be controlled. If no buttons are pressed, the control action is canceled in after the select time timer expires. The control action can be cancelled by pushing the CANCEL key. Pressing the OPEN or CLOSE keys initiates an open or close control action for the selected device.

If control bypass has been enabled, a BYPASS key will be displayed. Pressing this button will bypass the interlocking logic for the device permitting non-interlocked control of this device. When bypassed control will remain active for a single control operation or until the bypass time timer expires or the cancel button is pressed.

⚠ **CAUTION**

Non-interlocked control can result in equipment damage.

If tagging has been enabled, a TAG key will also be displayed. When the TAG key is operated, a small "T" is displayed next to the device. The open and close operations are inhibited on a tagged device. When a device is tagged, the TAG button changes to UNTAG

If substitution is enabled, the SUBST key will be displayed, When the SUBST key is operated, a new screen is presented that allows the user to enable or disable substitution. Once substitution has been enabled, a small "S" is displayed next to the device. The user can now manually change the indication of the device using the SUBST OPENED and SUBST CLOSED keys.

Figure 226: Breaker 1 tagged
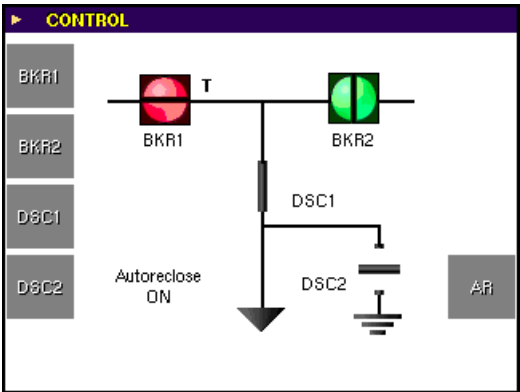
Figure 227: Breaker 1 status substituted
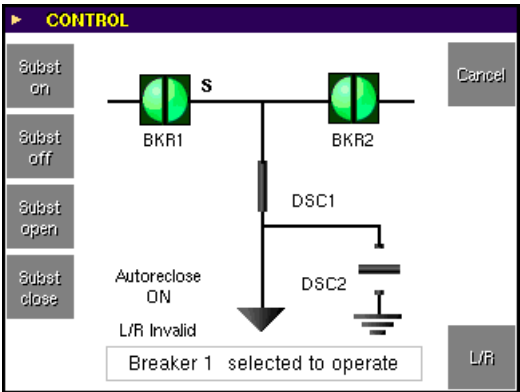
The following indications are provided for breakers and disconnects.

Figure 228: Front panel indicators for breakers and disconnects

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Local-remote control scheme

The local-remote control scheme is used to define the current location for operator control of power system devices (for example, breakers, disconnects, etc.). The function accepts inputs from the front panel interface or from an external source. The automation logic outputs (L/R-L On and L/R-R On) are assigned as inputs to the breaker and disconnect elements. The position of the latch is stored in non-volatile memory.

Select the **Settings > Automation > Control > Local-Remote** menu item to open the local-remote control scheme configuration window.

Figure 229: Local-remote control configuration settings
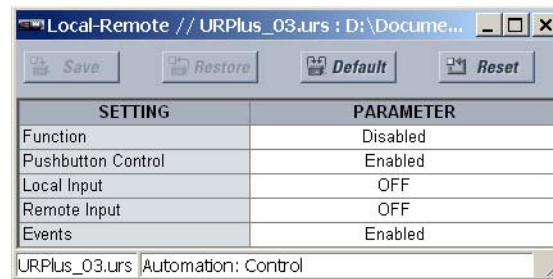
The following settings are available for the local-remote control scheme.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the local-remote control scheme automation logic and front panel indications.

Pushbutton Control

Range: Enabled, Disabled
Default: Enabled

This setting enables local-remote control selection via the front panel interface and populates the front panel display with control soft-keys.

Local Input

Range: any automation logic operand or shared operand
Default: OFF

When the operand assigned to this setting is asserted, the local-remote latch is set to local. This setting is normally used in cases where the local-remote selection is derived from an external switch or from a central location.

Remote Input

Range: any automation logic operand or shared operand
Default: OFF

When the operand assigned to this setting is asserted, the local-remote latch is set to remote. This setting is normally used in cases where the local-remote selection is derived from an external switch or from a central location.

Events

Range: Enabled, Disabled
Default: Enabled

This settings enables and disables the recording of local-remote control scheme events in the sequence of events recorder.

The logic for the local-remote control scheme is shown below.

Figure 230: Local-remote control scheme logic
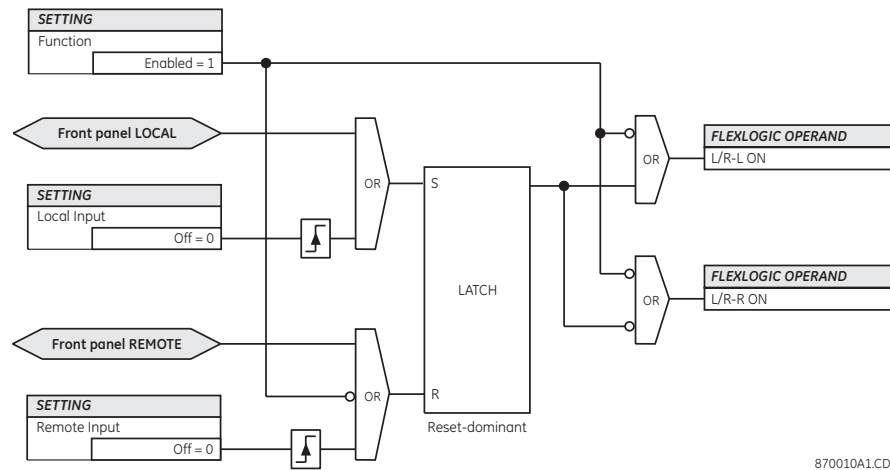
Synchrocheck

The are two identical synchrocheck elements available, numbered 1 and 2.

The synchrocheck (synchronism check) function is intended for supervising the paralleling of two parts of a system which are to be joined by the closure of a circuit breaker. The synchrocheck elements are typically used at locations where the two parts of the system are interconnected through at least one other point in the system.

Synchrocheck verifies that the voltages (V_1 and V_2) on the two sides of the supervised circuit breaker are within set limits of magnitude, angle and frequency differences. The time that the two voltages remain within the admissible angle difference is determined by the setting of the phase angle difference $\Delta\Phi$ and the frequency difference ΔF (slip frequency). It can be defined as the time it would take the voltage phasor V_1 or V_2 to traverse an angle equal to $2 \times \Delta\Phi$ at a frequency equal to the frequency difference ΔF. This time can be calculated by:

$$T = \frac{1}{\frac{360°}{2 \times \Delta F} \times \Delta F}$$

Eq. 37

In this equation, $\Delta\Phi$ represents the phase angle difference in degrees and ΔF represents the frequency difference in hertz.

For example, for default values of $\Delta\Phi = 30°$ and $\Delta F = 0.1$ Hz, the time the angle between the two voltages will be less than the set value is:

$$T = \frac{1}{\frac{360°}{2 \times \Delta\Phi} \times \Delta F} = \frac{1}{\frac{360°}{2 \times 30°} \times 0.1 \ Hz} = 1.66 \ sec.$$

Eq. 38

If one or both sources are de-energized, the synchrocheck programming can allow for closing of the circuit breaker using undervoltage control to bypass the synchrocheck measurements (via the dead source function).

Using the synchrocheck function

The selected sources for synchrocheck inputs V_1 and V_2 (which must not be the same source) may include both a three-phase and an auxiliary voltage. The relay will automatically select the specific voltages to be used by the synchrocheck element in accordance with the following table.

Table 26: Voltages used by the synchrocheck element

V_1 or V_2 (source Y)	V_2 or V_1 (source Z)	Auto-selected combination		Auto-selected voltage
		Source Y	Source Z	
Phase VTs and auxiliary VT	Phase VTs and auxiliary VT	Phase	Phase	V_{AB}
Phase VTs and auxiliary VT	Phase VT	Phase	Phase	V_{AB}
Phase VT	Phase VT	Phase	Phase	V_{AB}
Phase VT and auxiliary VT	Auxiliary VT	Phase	Auxiliary	V_{aux} (as set for source Z)
Auxiliary VT	Auxiliary VT	Auxiliary	Auxiliary	V_{aux} (as set for selected sources)

The voltages V_1 and V_2 are automatically matched so the corresponding voltages from the two sources will be used to measure conditions. A phase-to-phase voltage is used if available in both sources. If one or both of the sources have only an auxiliary voltage, then this voltage will be used.

For example, if an auxiliary voltage is programmed to V_{AG}, the synchrocheck element will automatically select V_{AG} from the other source. If the comparison is required on a specific voltage, the user can externally connect that specific voltage to auxiliary voltage terminals and then use this auxiliary voltage to check the synchronism conditions.

If using a single CT/VT module with both phase voltages and an auxiliary voltage, ensure that only the auxiliary voltage is programmed in one of the sources used for synchrocheck.

NOTE

Exception: synchronism cannot be checked between delta-connected phase VTs and a wye-connected auxiliary voltage.

The C90^{Plus} measures frequency and volts per hertz from an input on a given source with priorities as established by the configuration of input channels to the source. The relay will use the phase channel of a three-phase set of voltages if programmed as part of that source. The relay will use the auxiliary voltage channel only if that channel is programmed as part of the source and a three-phase set is not.

Synchrocheck settings

Select the **Settings > Automation > Control > Synchrocheck** menu item to open the synchrocheck configuration window.

Figure 231: Synchrocheck configuration settings

The following settings are available for each synchrocheck element. The default values shown are for the synchrocheck 1 element.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables the synchrocheck position indications and control logic. If disabled, all synchrocheck outputs and front panel indications are switched off.

Block

Range: any automation logic operand or shared operand
Default: BKR1 CLOSED

Assertion of the operand assigned to this setting will block operation of the synchrocheck element.

V1 Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting selects the source for the V_1 voltage.

V2 Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: BKR 1 (SRC 2)

This setting selects the source for the V_2 voltage.

Maximum Voltage Difference

Range: 0 to 400000 volts in steps of 1
Default: 10000 volts

This setting specifies the maximum primary voltage difference (in volts) between the two sources. A primary voltage magnitude difference between the two input voltages less than this value is within the permissible limit for synchronism.

Maximum Angle Difference

Range: 0 to 100° in steps of 1
Default: 30°

This setting specifies the maximum angular difference (in degrees) between the two sources. An angular difference between the two input voltage phasors less than this value is within the permissible limit for synchronism.

Maximum Frequency Difference

Range: 0.00 to 2.00 Hz in steps of 0.01
Default: 1.00 Hz

This setting selects the maximum frequency difference (in hertz) between the two sources. A frequency difference between the two input voltage systems below this value is within the permissible limit for synchronism.

Frequency Hysteresis

Range: 0.00 to 0.10 Hz in steps of 0.01
Default: 0.06 Hz

This setting specifies the required hysteresis for the maximum frequency difference condition. The condition becomes satisfied when the frequency difference is less than the value specified by the **Maximum Frequency Difference** setting. Once the synchrocheck element has operated, the frequency difference must increase above the sum of this setting and the Maximum Frequency Difference setting to drop out (assuming the other two conditions, voltage and angle, remain satisfied).

Dead Source Select

Range: None, LV1 and DV2, DV1 and LV2, DV1 or DV2, DV1 Xor DV2, DV1 and DV2
Default: LV1 and DV2

This setting selects the combination of dead and live sources that will bypass the synchronism check function and permit the breaker to be closed when one or both of the two voltages (V_1 and V_2) are below the maximum voltage threshold. A dead or live source is declared by monitoring the voltage level. Six options are available:

- – "None": the dead source function is disabled
- – "LV1 and DV2": live V_1 and dead V_2
- – "DV1 and LV2": dead V_1 and live V_2
- – "DV1 or DV2": dead V_1 or dead V_2
- – "DV1 Xor DV2": dead V_1 exclusive-or dead V_2 (one source is dead and the other is live)
- – "DV1 and DV2": dead V_1 and dead V_2

Dead V1 Maximum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01
Default: 0.30 pu

This setting specifies a maximum voltage magnitude for V_1 in per-unit values. At values less than this magnitude, the V_1 voltage input used for synchrocheck will be considered dead or de-energized.

Dead V2 Maximum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01
Default: 0.30 pu

This setting specifies a maximum voltage magnitude for V_2 in per-unit values. At values less than this magnitude, the V_2 voltage input used for synchrocheck will be considered dead or de-energized.

Live V1 Minimum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01
Default: 0.70 pu

This setting specifies a minimum voltage magnitude for V_1 in per-unit values. At values greater than this magnitude, the V_1 voltage input used for synchrocheck will be considered live or energized.

Live V2 Minimum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01
Default: 0.70 pu

This setting specifies a minimum voltage magnitude for V_2 in per-unit values. At values greater than this magnitude, the V_2 voltage input used for synchrocheck will be considered live or energized.

Events

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the logging of synchrocheck events in the sequence of events recorder.

The logic for the synchrocheck element is illustrated below.

Figure 232: Synchrocheck scheme logic
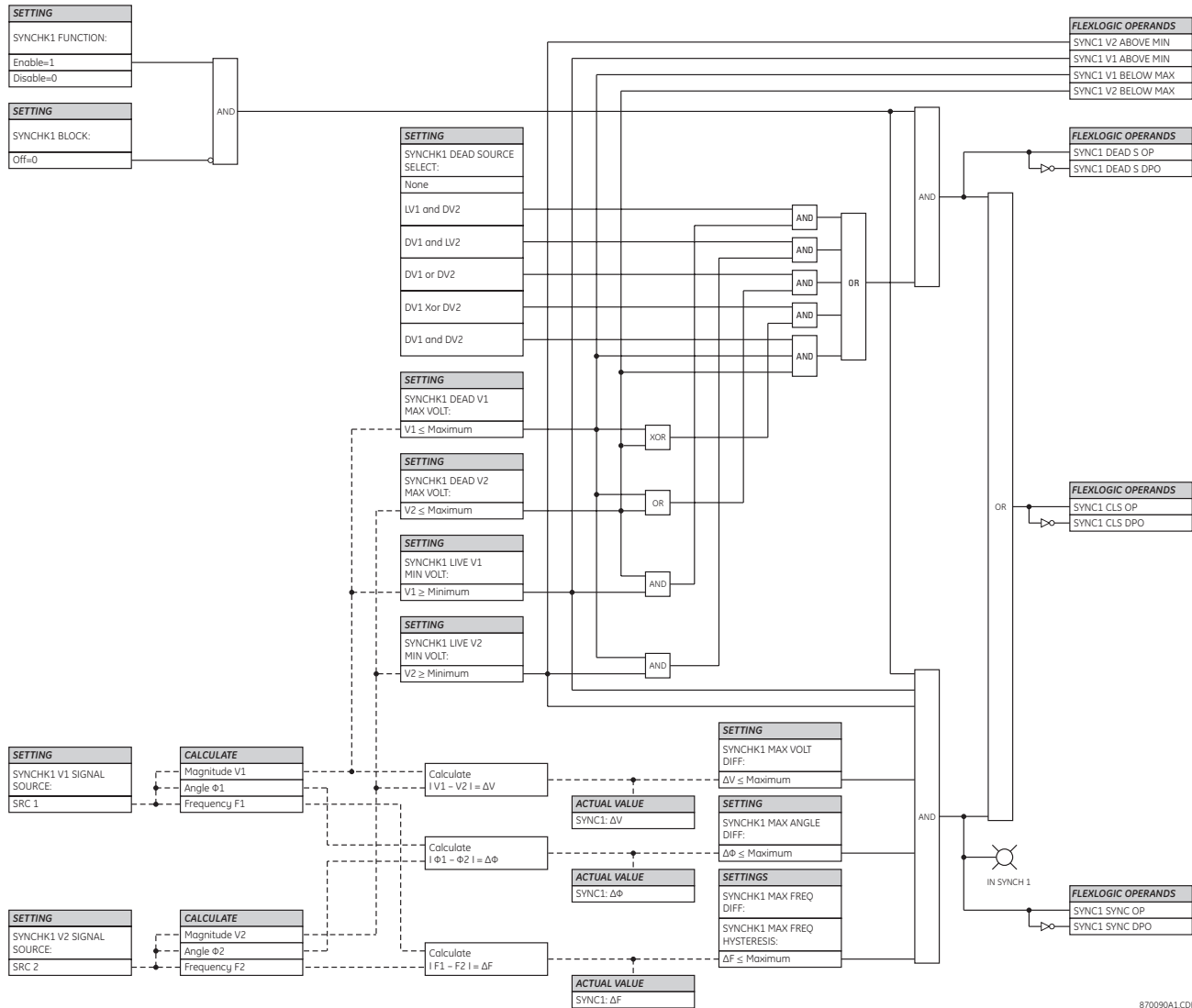
870090A1.CDR

Selector switch

The selector switch element is intended to replace a mechanical selector switch. Typical applications include setting group control or control of multiple logic sub-circuits in user-programmable logic.

Selector switch operation

The selector switch provides for two control inputs. The step-up control allows stepping through selector position one step at a time with each pulse of the control input, such as a user-programmable pushbutton. The three-bit control input allows setting the selector to the position defined by a three-bit word.

The element allows pre-selecting a new position without applying it. The pre-selected position gets applied either after time-out or upon acknowledgement via separate inputs (user setting). The selector position is stored in non-volatile memory. Upon power-up, either the previous position is restored or the relay synchronizes to the current three-bit word (user setting). Basic alarm functionality alerts the user under abnormal conditions; for example, the three-bit control input being out of range.

The following figures illustrate the operation of the selector switch. In these diagrams, "T" represents a time-out setting.

Figure 233: Time-out mode
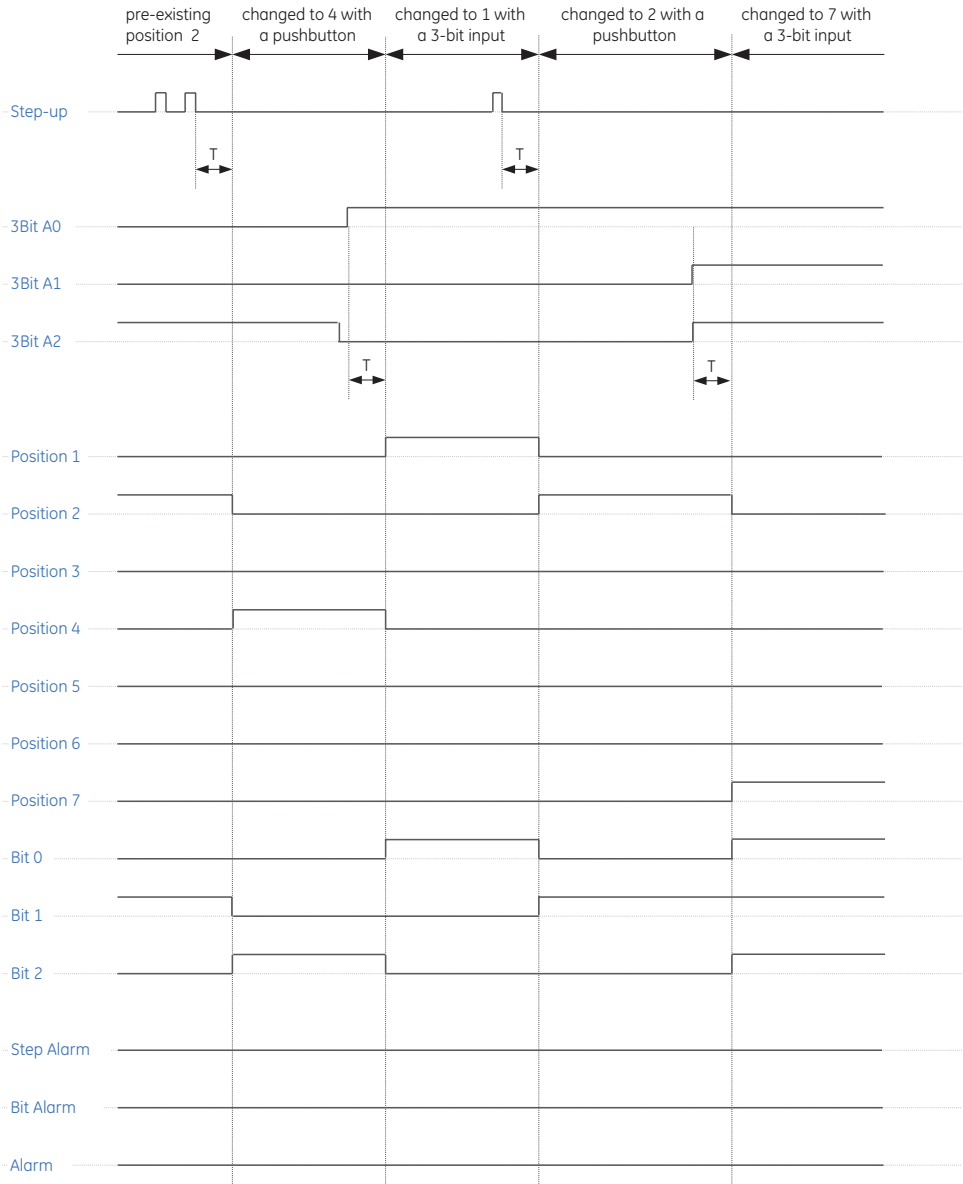
870781A1.CDR

Figure 234: Acknowledge mode

870780A1.CDR
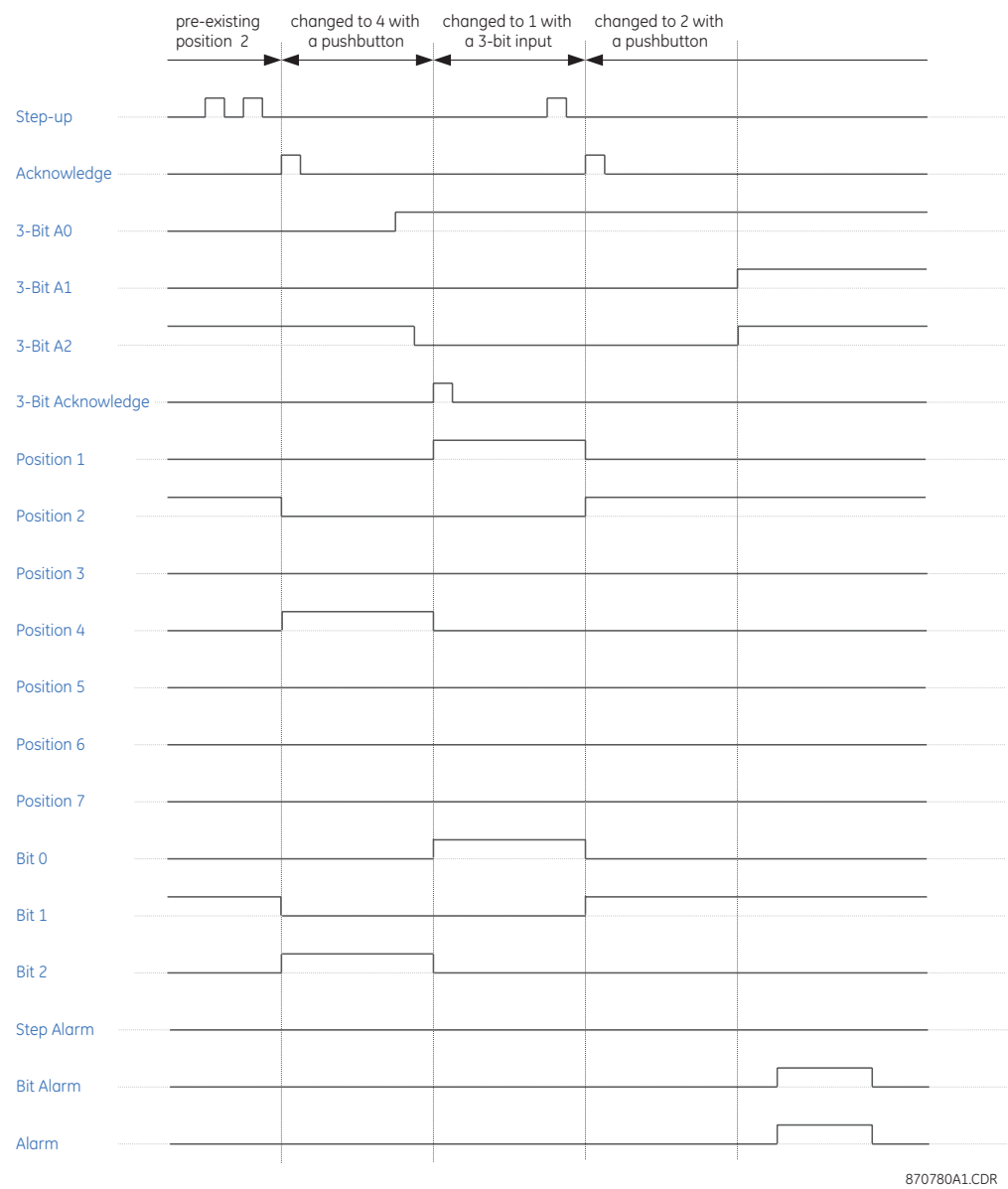
Selector switch settings

Select the **Settings > Automation > Control > Selector Switches** menu item to open the selector switch configuration window.

Figure 235: Selector switch configuration settings

The following settings are available for each selector switch.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the selector switch.

Full Range

Range: 1 to 7 in steps of 1

Default: 7

This setting specifies the upper position of the selector switch. When stepping up through available positions of the selector, the upper position wraps up to the lower position (position 1). When using a direct three-bit control word for programming the selector to a desired position, the change would take place only if the control word is within the range of 1 to the full range. If the control word is outside the range, an alarm is established by activating the SELECTOR ALARM operand for 3 seconds.

Timeout

Range: 3.0 to 60.0 seconds in steps of 0.1

Default: 5.0 seconds

This setting specifies the time-out period for the selector. This value is used by the relay in two ways. When the **Step-Up Mode** is "Time-out", the setting specifies the required period of inactivity of the control input after which the pre-selected position is automatically applied. When the **Step-Up Mode** is "Acknowledge", the setting specifies the period of time for the acknowledging input to appear. The timer is re-started by any activity of the control input. The acknowledging input must come before this timer expires; otherwise, the change will not take place and an alarm will be set.

Step-Up

Range: any automation logic operand or shared operand

Default: OFF

This setting selects a control input for the selector switch. The switch is shifted to a new position at each rising edge of this signal. The position changes incrementally, wrapping up from the last (the **Full Range** value) to the first (position 1). Consecutive pulses of this control operand must not occur faster than every 50 ms. After each rising edge of the assigned operand, the time-out timer is restarted. The pre-selected position is applied after the selector times out (time-out mode), or when the acknowledging signal appears before the element times out (acknowledge mode). Typically, a user-programmable pushbutton is configured as the stepping up control input.

Step-Up Mode

Range: Time-out, Acknowledge
Default: Time-out

This setting defines the selector mode of operation. When set to "Time-out", the selector will change its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require any explicit confirmation of the intent to change the selector's position. When set to "Acknowledge", the selector will change its position only after the intent is confirmed through a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector does not accept the change and an alarm is established by setting the SELECTOR STP ALARM output FlexLogic™ operand for 3 seconds.

Acknowledge

Range: any automation logic operand or shared operand
Default: OFF

This setting selects an acknowledging input for the stepping up control input. The pre-selected position is applied on the rising edge of the assigned operand. This setting is active only under the acknowledge mode of operation. The acknowledging signal must appear within the time defined by the **Timeout** setting after the last activity of the control input. A user-programmable pushbutton is typically configured as the acknowledging input.

3-Bit A0, 3-Bit A1, 3-Bit A2

Range: any automation logic operand or shared operand
Default: OFF

These settings specify a three-bit control input of the selector. The three-bit control word pre-selects the position using the following encoding convention.

Table 27: Selector switch three-bit control word

A2	A1	A0	Position
0	0	0	rest
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5
1	1	0	6
1	1	1	7

The rest position (0, 0, 0) does not generate an action and is intended for situations when the device generating the three-bit control word is having a problem. When in time-out mode, the pre-selected position is applied in the time specified (in seconds) by the **Timeout** setting after the last activity of the three-bit input. When in acknowledge mode, the pre-selected position is applied on the rising edge of the acknowledging input specified by the **3-Bit Acknowledge** setting.

The stepping up control input (selected by the **Step-Up** setting) and the three-bit control inputs (A0, A1, and A2) lock-out mutually. Once the stepping up sequence is initiated, the three-bit control input is inactive; once the three-bit control sequence is initiated, the stepping up input is inactive.

3-Bit Mode

Range: Time-out, Acknowledge
Default: Time-out

This setting selects the selector mode of operation. When set to "Time-out", the selector changes its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require explicit confirmation to change the selector position. When set to "Acknowledge", the selector changes its position only after confirmation through a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector rejects the change and an alarm established by invoking the SELECTOR BIT ALARM FlexLogic™ operand for 3 seconds.

3-Bit Acknowledge

Range: any automation logic operand or shared operand
Default: OFF

This setting selects an acknowledging input for the three-bit control input. The pre-selected position is applied on the rising edge of the assigned operand. This setting is active only under the acknowledge mode of operation. The acknowledging signal must appear within the time defined by the **Timeout** setting after the last activity of the three-bit control inputs. Note that the stepping up control input and three-bit control input have independent acknowledging signals (the SELECTOR 1 ACK and SELECTOR 1 3BIT ACK operands, accordingly).

Power-Up Mode

Range: Restore, Synchronize, Sync/Restore
Default: Restore

This setting selects the selector switch behavior on power up of the relay.

When set to "Restore", the last position of the selector (stored in the non-volatile memory) is restored after powering up the relay. If the position restored from memory is out of range, position 0 (no output operand selected) is applied and an alarm is set (SELECTOR 1 PWR ALARM).

When set to "Synchronize", the selector switch acts as follows. For two power cycles, the selector applies position 0 to the switch and activates the SELECTOR 1 PWR ALARM operand. After two power cycles expire, the selector synchronizes to the position dictated by the three-bit control input. This operation does not wait for time-out or the acknowledging input. When the synchronization attempt is unsuccessful (that is, the three-bit input is not available (0,0,0) or out of range) then the selector switch output is set to position 0 (no output operand selected) and an alarm is established (the SELECTOR 1 PWR ALARM operand is asserted).

The operation of the "Synch/Restore" mode is similar to the "Synchronize" mode. The only difference is that the switch will attempt to restore the position stored in the relay memory after an unsuccessful synchronization attempt. The synch/restore mode is useful for applications where the selector switch is employed to change the setting group in redundant (two relay) protection schemes.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of selector switch events in the sequence of events recorder. If enabled, the following events are logged.

Selector switch events

SELECTOR 1 POS 1.........................Selector 1 changed its position to 1.
SELECTOR 1 POS 2.........................Selector 1 changed its position to 2.
SELECTOR 1 POS 3.........................Selector 1 changed its position to 3.

SELECTOR 1 POS 4 ....Selector 1 changed its position to 4.

SELECTOR 1 POS 5 ....Selector 1 changed its position to 5.

SELECTOR 1 POS 6 ....Selector 1 changed its position to 6.

SELECTOR 1 POS 7 ....Selector 1 changed its position to 7.

SELECTOR 1 STP ALARM ....The selector position pre-selected via the stepping up control input has not been confirmed before the time out.

SELECTOR 1 BIT ALARM ....The selector position pre-selected via the three-bit control input has not been confirmed before the time out.

SELECTOR 2.....................................The set of events shown above are available for selector switch 2.

The logic for the selector switch is shown below.

Figure 236: Selector switch logic

870085A1.CDR
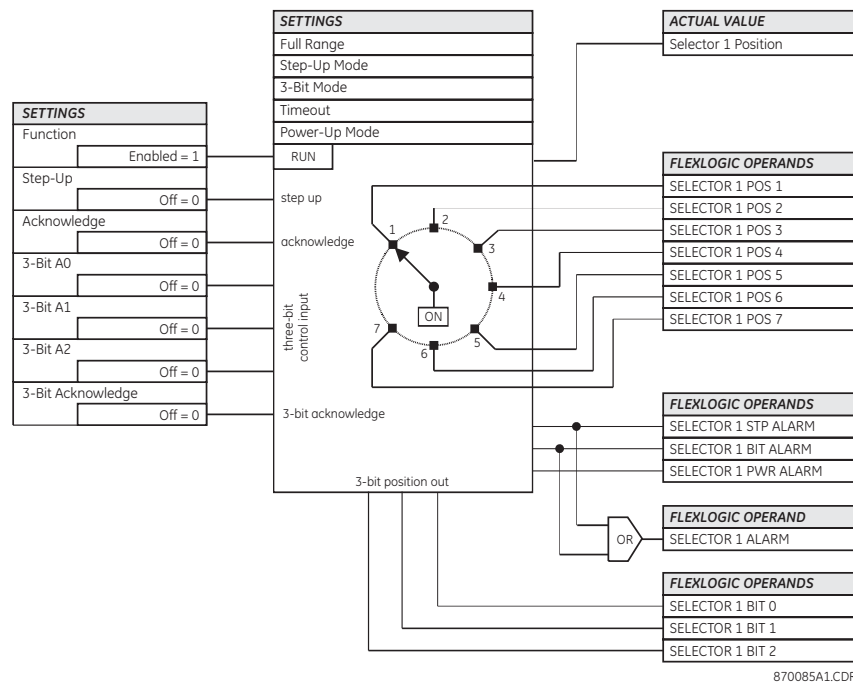
Load shedding

Multiple stages of underfrequency, undervoltage, and frequency rate of change elements can be used to initiate load shedding or remedial actions schemes. These elements can also initiate frequency-based load restoration schemes during lack of generation in the network or due to sudden load drops. The advanced automation capabilities of the C90^{Plus} allow flexible special protection schemes, advanced load shedding schemes, and load restoration schemes to be built.

Load shedding source

Select the **Settings > Automation > Load Shedding > Source** menu item to open the load shedding sources configuration window.

Figure 237: Load shedding source configuration window
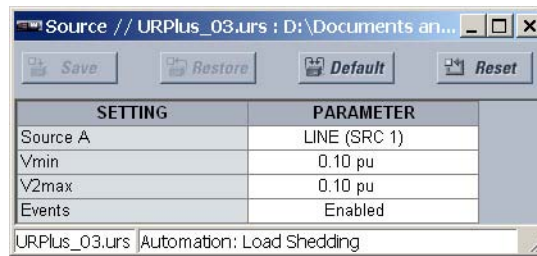
The settings specify the characteristics of the source used for the load shedding functions (underfrequency, undervoltage, and frequency rate of change). The following settings are available.

Source A

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting selects the source to use for the load shedding functions (underfrequency, undervoltage, and frequency rate of change).

Minimum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01
Default: 0.10 pu

This setting specifies the minimum phase-to-phase voltage required on all three phases for operation of the load shedding feature. That is, if any phase-to-phase voltage is less than the value specified by this setting, the LS SOURCE INVALID operand will operate after 100 ms and all load shedding elements will then be blocked. If this setting is programmed to zero, then its logic is effectively ignored and LS SOURCE INVALID operand will not be asserted because of any level of phase-to-phase voltage, including zero.

Maximum V_2

Range: 0.05 to 1.25 pu in steps of 0.01
Default: 0.10 pu

This setting specifies the maximum level of negative-sequence voltage permitted for operation of the load shedding elements. If the negative-sequence voltage reaches or exceeds the values specified by the **Minimum Voltage** setting, then the LS SOURCE INVALID operand will operate after 100 ms and all load shedding elements will then be blocked.

Events

Range: Disabled, Enabled
Default: Enabled

This setting enables and disables the logging of load shedding source events in the sequence of events recorder.

The load shedding source logic is shown below.

Figure 238: Load shedding source logic
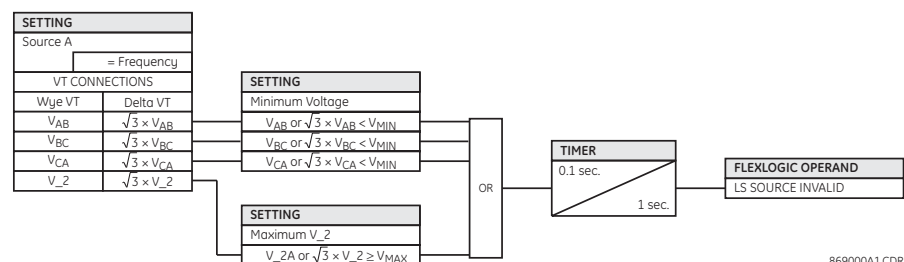
Underfrequency load shedding

There are ten (10) underfrequency load shedding elements.

Select the **Settings > Automation > Load Shedding > Underfrequency** menu item to open the underfrequency load shedding configuration window.

Figure 239: Underfrequency load shedding configuration window
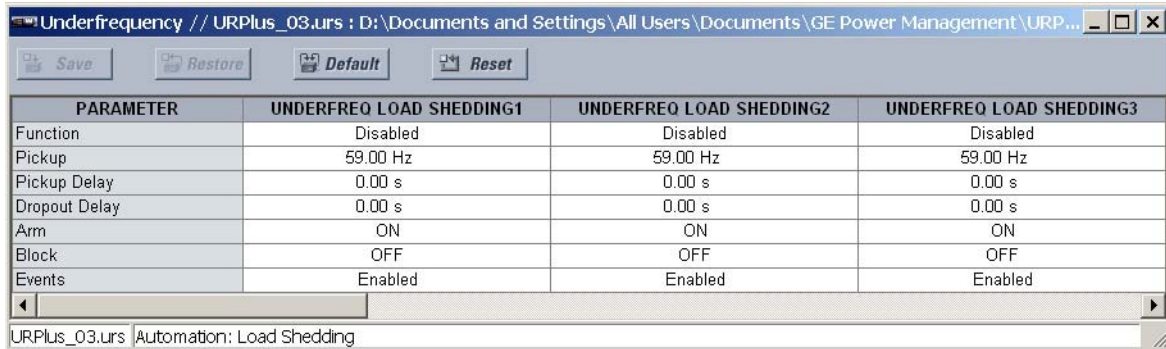
The following settings are available for each underfrequency load shedding element.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the underfrequency load shedding function.

Pickup

Range: 45.00 to 65.00 Hz in steps of 0.01
Default: 59.00 Hz

This setting specifies the pickup level for the underfrequency load shedding element. For example, if the system frequency is 60 Hz and load shedding is required at 59.5 Hz, the setting will be 59.50 Hz.

Pickup Delay

Range: 0.00 to 99.99 seconds in steps of 0.01
Default: 0.00 seconds

This setting specifies a time delay on pickup for the duration between the pickup and operate output states of the underfrequency load shedding element.

Dropout Delay

Range: 0.00 to 99.99 seconds in steps of 0.01
Default: 0.00 seconds

This setting specifies a time delay on dropout for the duration between the operate output state and the return to logic 0 after the input transits outside the defined pickup range.

Arm

Range: any automation logic operand or shared operand
Default: ON

Assertion of the operand assigned to this setting arms the underfrequency load shedding element.

Block

Range: any automation logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the underfrequency load shedding element.

Events

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of underfrequency load shedding events in the sequence of events recorder.

The logic for the underfrequency load shedding function is shown below.

Figure 240: Underfrequency load shedding logic
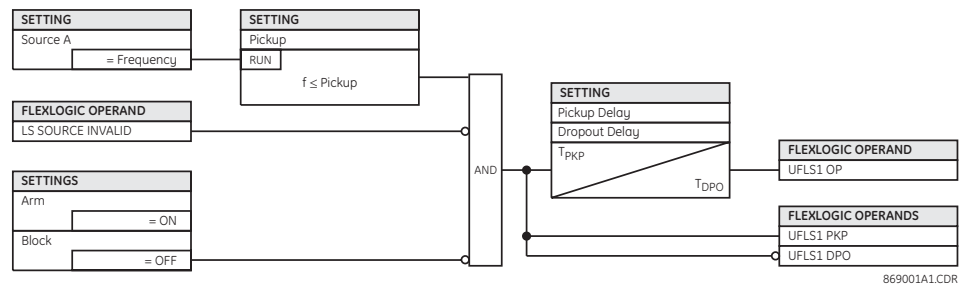
Undervoltage load shedding

There are six (6) undervoltage load shedding elements.

Select the **Settings > Automation > Load Shedding > Undervoltage** menu item to open the undervoltage load shedding configuration window.

Figure 241: Undervoltage load shedding configuration window

The following settings are available for each undervoltage load shedding element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the undervoltage load shedding function.

Pickup

Range: 0.10 to 1.25 pu in steps of 0.01

Default: 0.90 pu

This setting specifies the pickup level for the undervoltage load shedding element.

Pickup Delay

Range: 0.00 to 99.99 seconds in steps of 0.01
Default: 0.00 seconds

This setting specifies a time delay on pickup for the duration between the pickup and operate output states of the undervoltage load shedding element.

Dropout Delay

Range: 0.00 to 99.99 seconds in steps of 0.01
Default: 0.00 seconds

This setting specifies a time delay on dropout for the duration between the operate output state and the return to logic 0 after the input transits outside the defined pickup range.

Arm

Range: any automation logic operand or shared operand
Default: ON

Assertion of the operand assigned to this setting arms the undervoltage load shedding element.

Block

Range: any automation logic operand or shared operand
Default: OFF

Assertion of the operand assigned to this setting blocks operation of the undervoltage load shedding element.

Events

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the logging of undervoltage load shedding events in the sequence of events recorder.

The logic for the undervoltage load shedding function is shown below.

Figure 242: Undervoltage load shedding logic
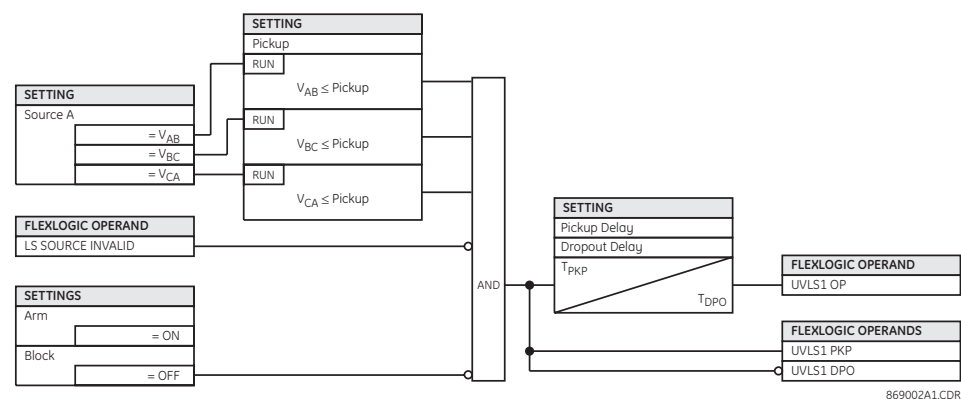
Frequency rate of change load shedding

There are four (4) frequency rate of change load shedding elements.

Select the **Settings > Automation > Load Shedding > Frequency Rate of Change** menu item to open the frequency rate of change load shedding configuration window.

Figure 243: Frequency rate of change load shedding configuration window

The following settings are available for each frequency rate of change load shedding element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the frequency rate of change load shedding function.

Pickup

Range: –1.50 to –0.10 Hz/second in steps of 0.01

Default: –0.50 Hz/second

This setting specifies the pickup level for the frequency rate of change load shedding element.

Pickup Delay

Range: 0.00 to 99.99 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a time delay on pickup for the duration between the pickup and operate output states of the frequency rate of change load shedding element.

Dropout Delay

Range: 0.00 to 99.99 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a time delay on dropout for the duration between the operate output state and the return to logic 0 after the input transits outside the defined pickup range.

Arm

Range: any automation logic operand or shared operand

Default: ON

Assertion of the operand assigned to this setting arms the frequency rate of change load shedding element.

Block

Range: any automation logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the frequency rate of change load shedding element.

Events

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the logging of frequency rate of change load shedding events in the sequence of events recorder.

The logic for the frequency rate of change load shedding function is shown below.

Figure 244: Frequency rate of change load shedding logic
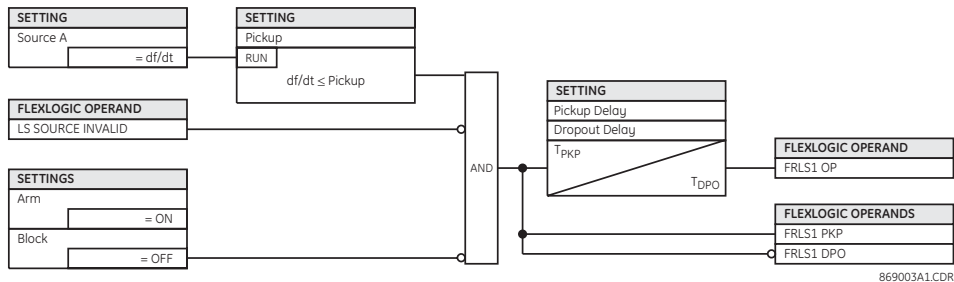
Automation inputs and outputs

Three groupings of automation inputs and outputs are defined: physical, shared, and virtual. Within these three groupings there are two types: analog and digital.

Automation virtual inputs

There are 64 virtual inputs that can be individually programmed to respond to input signals from the front panel interface and communications protocols. All virtual input operands are defaulted to off (logic 0) unless the appropriate input signal is received.

Select the **Settings > Automation > Automation Inputs/Outputs > Virtual Inputs** menu item to access the virtual input configuration settings.

Figure 245: Automation virtual inputs configuration settings

The following settings are available for each automation virtual input. The default values shown are for virtual input 1.

Function

Range: Enabled, Disabled
Default: Disabled

If this setting is "Disabled", the virtual input will be forced to off (logic 0) regardless of any attempt to alter the input. If set to "Enabled", the input operates as shown on the logic diagram and generates output logic operands in response to received input signals and the applied settings.

ID

Range: up to 12 alphanumeric characters
Default: Aut VI 1

This setting specifies an identifier that may be assigned to each virtual input.

Type

Range: Self-Reset, Latched
Default: Latched

There are two types of operation: self-reset and latched. If this settings is "Self-Reset", the output operand will be asserted (logic 1) for only one evaluation of the automation logic equations and then return to 0 when the input signal transits from off to on. If set to "Latched", the virtual input sets the state of the output operand to the same state as the most recent received input.

NOTE

The self-reset operating mode generates an output operand for a single evaluation of the automation logic equations. If the operand is to be used anywhere other than internally in an automation logic equation, it will likely have to be lengthened in time. An automation logic timer with a delayed reset can perform this function.

Events

Range: Enabled, Disabled
Default: Disabled

If this setting is "Enabled", every change in the automation virtual input state will trigger an event in the sequence of events recorder.

The automation virtual input logic is shown below. The logic is identical for all automation virtual inputs.

Figure 246: Automation virtual input logic
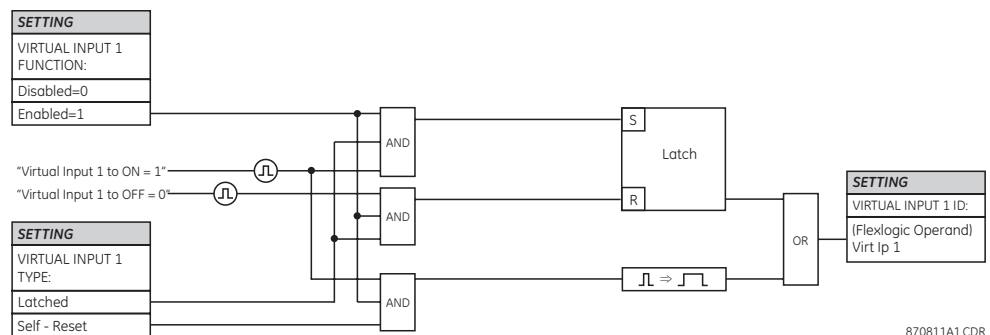
870811A1.CDR

Automation virtual outputs

There are 96 virtual outputs that may be assigned via automation logic. Virtual outputs are resolved in each pass through the evaluation of the automation logic equations.

Select the **Settings > Automation > Automation Inputs/Outputs > Virtual Outputs** menu item to access the automation virtual output configuration settings.

Figure 247: Automation virtual output settings

The following settings are available for each automation virtual output. If not assigned, the virtual output will be forced to off (logic 0).

ID

Range: up to 12 alphanumeric characters
Default: Aut VO 1

This setting specifies an identifier that may be assigned to each automation virtual output.

Events

Range: Enabled, Disabled
Default: Disabled

If this setting is "Enabled", every change in the automation virtual output state will trigger an event in the sequence of events recorder.

For example, if automation virtual output 1 is the trip signal from automation logic and the trip relay is used to signal events, the settings are be programmed as follows.

Figure 248: Automation virtual output programming example

Contact input configuration

The C90^{Plus} can monitor the status of up to 40 field contacts. Each input can be wetted from the C90^{Plus} 48 volt auxiliary supply or from an external power supply. Each digital input has a dedicated delay timer for filtering of contact bouncing. The C90^{Plus} can also detect an oscillating input via the chatter feature. Each contact input active impedance circuitry to provide security against false turn-on of an input due to excessive stray capacitance of field wiring.

A raw status is scanned synchronously for all contact inputs at the rate of 0.25 ms as shown below. A new contact input state must be maintained for a user-programmable debounce time for the C90^{Plus} to validate the new contact state. The debounce time is set at 2.0 ms in the figure below; as such, the eighth sample validates the change of state (mark 1 in the figure below). Once validated (de-bounced), the automation contact input asserts a corresponding automation operand and logs an event (if event logging is enabled).

A time stamp of the first sample in the sequence that validates the new state is used when logging the change of the contact input into the event recorder (mark 2 in the figure below).

Figure 249: Automation contact input debouncing mechanism and time-stamping

870719A1.CDR
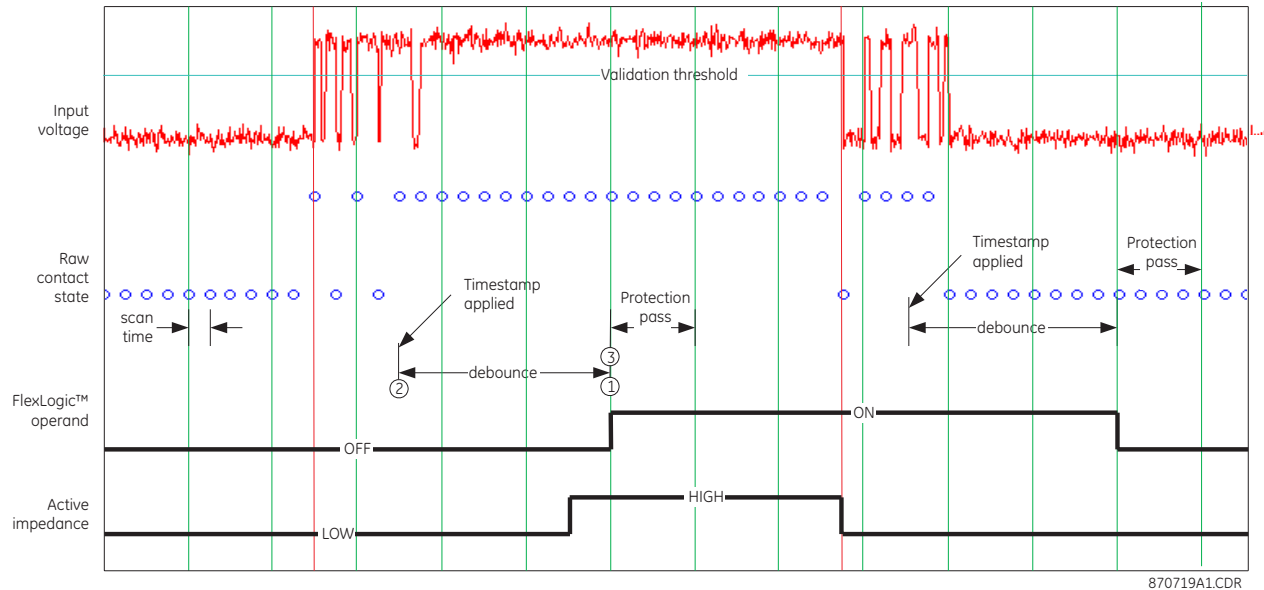
Automation equations and timers, are executed at the automation scan rate. The automation operand reflecting the debounced state of the contact is updated at the automation pass following the validation (mark 3 in the figure above). The update is performed at the beginning of the 1 ms scanning pass so all automation functions and equations are fed with the updated states of the contact inputs.

The automation operand response time to the contact input change is equal to the debounce time setting plus a maximum of one protection pass. If the change of state occurs just after a protection pass, the recognition is delayed until the subsequent protection pass (that is, by the entire duration of the protection pass). If the change occurs just prior to a protection pass, the state is recognized immediately. Statistically, a delay of half the protection pass is expected. Owing to the 0.25 ms scan rate, the time resolution for the contact input is less than 1 ms.

For example, sixteen protection passes per cycle on a 60 Hz system correspond to an protection pass every 1.04 ms. With a contact debounce time setting of 3.0 ms, the automation operand assertion time limits are: 3.0 + 0.0 = 3.0 ms and 3.0 + 1.04 = 4.04 ms. These time limits depend on how soon the protection pass runs after the debouncing time.

Regardless of the contact debounce time setting, the contact input event is time-stamped with a 1 ms accuracy using the time of the first scan corresponding to the new state. Therefore, the time stamp reflects a change in the DC voltage across the digital input terminals that was not accidental as it was subsequently validated using the debounce timer. Keep in mind that the associated automation operand is asserted or de-asserted later, after validating the change. The debounce algorithm is symmetrical: the same procedure and debounce time are used to filter the OFF-ON and ON-OFF transitions.

The active impedance feature controls the input impedance presented to the system according to the current state of the input. When the contact input circuitry initially detects a voltage increase, it will draw 10 mA of current. If the state change is due to a transient coupled through the stray capacitance of the field wiring, then the high current sink will charge the capacitance causing the transient to rapidly decay. If voltage increase is due to a state change of the field contact, then the increased current will have no impact on the input voltage, and the state change will be validated. Once the input has been declared to be on, the input circuitry will reduce the current drawn to 1 mA to minimize the power dissipated by the input.

When the input detects a voltage decrease, the input circuitry will draw 10 mA of current. If the voltage decrease is due to a state change then the voltage will quickly decrease, speeding up the recognition of the reset of the field contact by quickly discharging any input capacitance.

Contact input settings

Select the **Settings > Automation > Automation Inputs/Outputs > Contact Inputs > Contact Inputs** menu item to access the automation contact input configuration settings.

Figure 250: Automation contact input configuration settings

The contact inputs menu contains configuration settings for each input. Upon startup, the relay processor determines (from an assessment of the installed modules) which contact inputs are available and then displays settings for only those inputs. The following settings are available for each contact input.

ID

Range: up to 12 alphanumeric characters
Default: Cont Ip 1

An alphanumeric identifier may be assigned to a contact input for diagnostic, setting, and event recording purposes. The "CONTACT IP 1" text in event records and automation logic operands will be replaced by the text programmed in this setting.

Debounce Time

Range: 1.50 to 16.00 ms in steps of 0.25
Default: 2.00 ms

This setting defines the time required for the contact to overcome contact bouncing conditions. As this time differs for different contact types and manufacturers, program it as a maximum contact debounce time (per manufacturer specifications) plus additional margin to ensure proper operation.

Nominal Voltage

Range: 24 to 250 volts in steps of 1
Default: 125 volts

This setting determines the threshold required to validate a closed contact input. This threshold is fixed at 70% of this setting value.

Table 28: Nominal voltage setting for typical battery voltages

Nominal voltage	Validation threshold
24 V	20 V
48 V	33.6 V
125 V	87.5 V
250 V	175 V

Events

Range: Enabled, Disabled

Default: Enabled

If this setting is "Enabled", every change in the contact input state will trigger an event in the sequence of events recorder.

Contact input chatter detection

The C90^{Plus} has a chatter detection feature. When enabled, the IED monitors the number of state changes that occur within a set duration. If this value exceeds a set value, then a trouble condition is declared for the input and the CONTACT INPUT TROUBLE operand is asserted.

The input trouble alarm impacts relay functionality as follows:

- Automation logic operands: operand state will be blocked.
- DNP 3.0 communications: reporting of the input is blocked.
- IEC 60870-5-104 communications: reporting of the input is blocked.
- IEC 61850 GSSE and IEC 61850 GOOSE: reporting of the input is blocked.
- Sequence of events recorder: reporting of the input is blocked.

The trouble condition resets if the input undergoes no state changes for a duration equal to twice the chatter time setting.

Figure 251: Chatter detection example
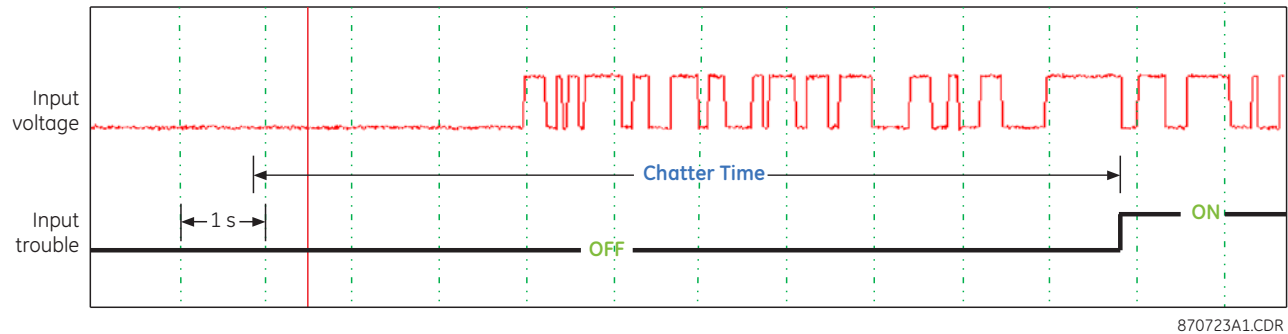
870723A1.CDR

Select the **Settings > Automation > Automation Inputs/Outputs > Contact Inputs > Chatter Detection** menu item to access the contact input chatter detection settings.

Figure 252: Contact input chatter detection configuration
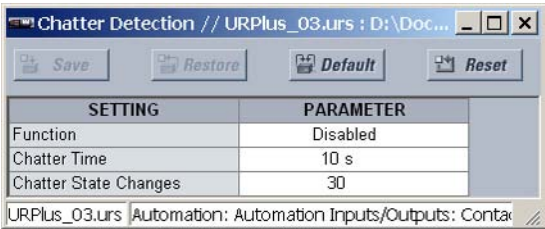
The following settings are available for each automation contact input.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the chatter detection feature.

Chatter Time

Range: 1 to 100 seconds in steps of 1

Default: 10 seconds

This setting specifies the time window that the relay contacts are monitored for contact input state changes.

Chatter State Changes

Range: 10 to 100 in steps of 1

Default: 30

This setting specifies the number of state changes that must occur in the time window defined by the **Chatter Time** setting before issuing the trouble operand.

Contact outputs

Upon startup of the relay, the main processor will determine from an assessment of the modules installed in the chassis which contact outputs are available and present the settings for only these outputs.

Select the **Settings > Automation > Automation Inputs/Outputs > Contact Outputs** menu item to access the contact output configuration settings.

Figure 253: Automation contact output configuration settings

The settings for contact output 1 are shown below. These settings are available for all contact outputs.

ID

Range: up to 12 alphanumeric characters

Default: Cont Op 1

This setting specifies an alphanumeric identifier for the contact output.

Operate

Range: any automation logic operand or shared operand

Default: OFF

This setting selects an operand (virtual output, element state, contact input, or virtual input) that will operate the contact output when asserted.

Seal-In

Range: any automation logic operand or shared operand

Default: OFF

This setting selects an operand (virtual output, element state, contact input, or virtual input) that will seal-in the contact output when asserted.

Voltage Threshold

Range: 20 to 250 volts in steps of 1

Default: 20

This setting specifies determines the level at which the Contact Op 1 VOn and Contact Op 1 VOff operands function. It is only shown for contact outputs that have monitoring.

Events

Range: Enabled, Disabled

Default: Enabled

If this setting is "Enabled", every change in the contact output state will trigger an event in the sequence of events recorder.

For example, consider a trip circuit current being monitored by providing a current threshold detector in series with some form-A contacts as shown below.

Figure 254: Trip circuit monitoring example
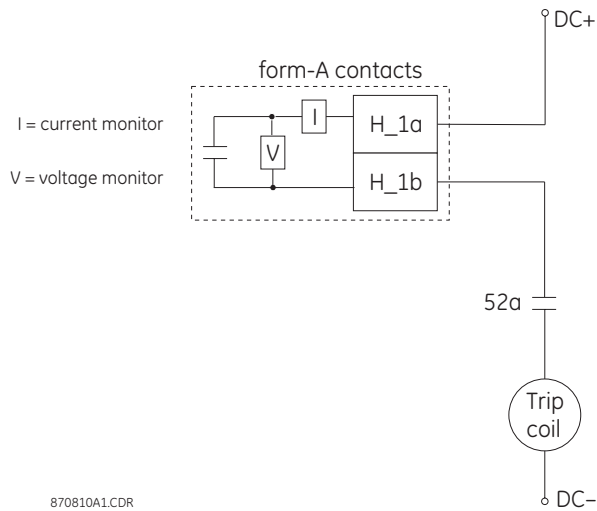
The name of the automation logic operand set by the monitor consists of the contact output identifier followed by the name of the flag. For example, using the default identifiers, we could have Cont Op 1 Ion and Cont Op 1 Von.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact used to interrupt current flow after the breaker has tripped, to prevent damage to the less robust initiating contact. This can be done by monitoring an auxiliary contact on the breaker which opens when the breaker has tripped. However, this scheme is subject to incorrect operation caused by differences in timing between breaker auxiliary contact change-of-state and interruption of current in the trip circuit. The most dependable protection of the initiating contact is provided by directly measuring current in the tripping circuit, and using this parameter to control resetting of the initiating relay. This scheme is often referred to as a *trip seal-in* scheme.

This trip seal-in scheme can be realized in the C90^{Plus} by using the Cont Op 1 Ion automation logic operand to seal-in the contact output as follows.

Figure 255: Trip seal-in scheme settings

Virtual analog outputs

There are 64 virtual analog outputs that may be assigned via automation logic. Virtual analog outputs are resolved in each pass through the evaluation of the automation logic equations.

Select the **Settings > Automation > Automation Inputs/Outputs > Virtual Analogs** menu item to access the virtual analog output configuration settings.

Figure 256: Virtual analog output configuration settings

SETTING	PARAMETER
Virtual Analog 1 Name	Analog 1
Virtual Analog 2 Name	Analog 2
Virtual Analog 3 Name	Analog 3
Virtual Analog 4 Name	Analog 4
Virtual Analog 5 Name	Analog 5
Virtual Analog 6 Name	Analog 6
Virtual Analog 7 Name	Analog 7
Virtual Analog 8 Name	Analog 8
Virtual Analog 9 Name	Analog 9
Virtual Analog 10 Name	Analog 10
Virtual Analog 11 Name	Analog 11
Virtual Analog 12 Name	Analog 12
Virtual Analog 13 Name	Analog 13
Virtual Analog 14 Name	Analog 14
Virtual Analog 15 Name	Analog 15
Virtual Analog 16 Name	Analog 16

The settings for virtual analog output 1 are shown below. The settings are identical for all virtual analog outputs.

Virtual Analog 1 Name
Range: up to 12 alphanumeric characters
Default: Analog 1

This setting specifies an identifier for virtual analog output 1. This value will be included in the actual values and will also be used to reference output to features designed to measure this of parameter.

Shared operands

The EnerVista UR^{Plus} Setup software groups the C90^{Plus} system into the following six primary functions. Each function has its own setting parameters and each generates its own outputs in the form of operands.

- Protection
- Automation
- Metering
- Digital fault recorder (DFR)
- Equipment manager
- Front panel interface (HMI)

However, it is often desirable for an output from an element within one function can be available to an element within another function. For instance, it may useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available as to each function as shown below.

Figure 257: Default operand list by function
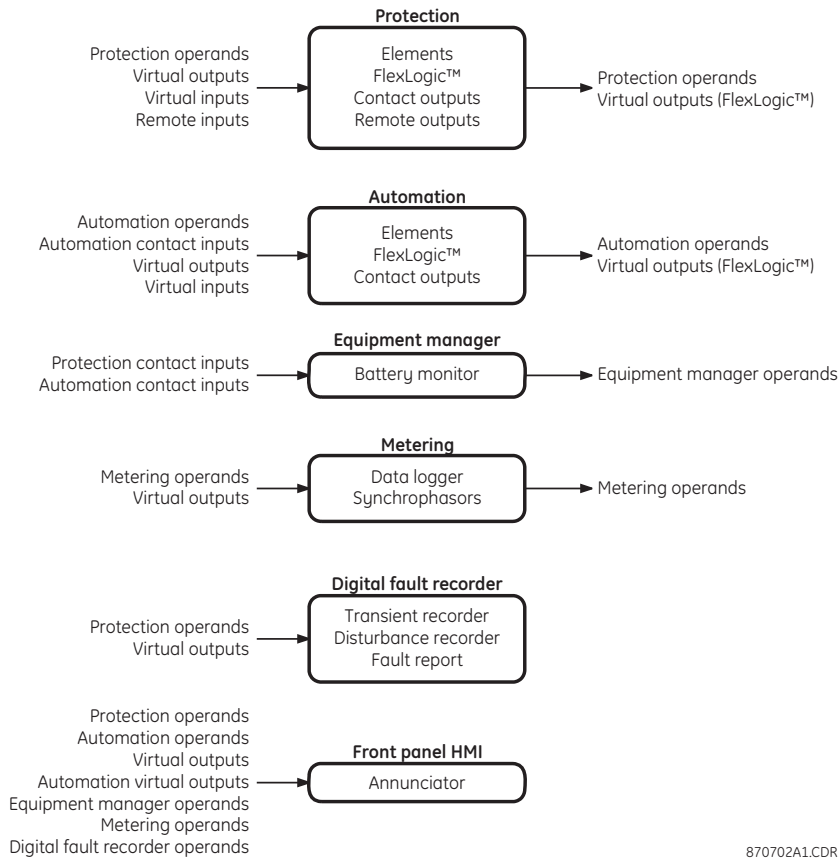
870702A1.CDR

The content of each operand list is dependent on the selected order code.

The shared operands functionality expands upon this system. With this feature, an output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals can then be assigned as inputs to other functions.

For example, assume that the GND TOC1 OP protection operand is required as a signal within the automation function. This operand would then be assigned as a shared operand, and would subsequently become available to the automation function. A total of 64 operands may be assigned as shared operands within each function.

Shared automation operands

Select the **Settings > Automation > Automation Inputs/Outputs > Shared Operands** menu item to select the shared automation logic operands.

Figure 258: Shared operands configuration window
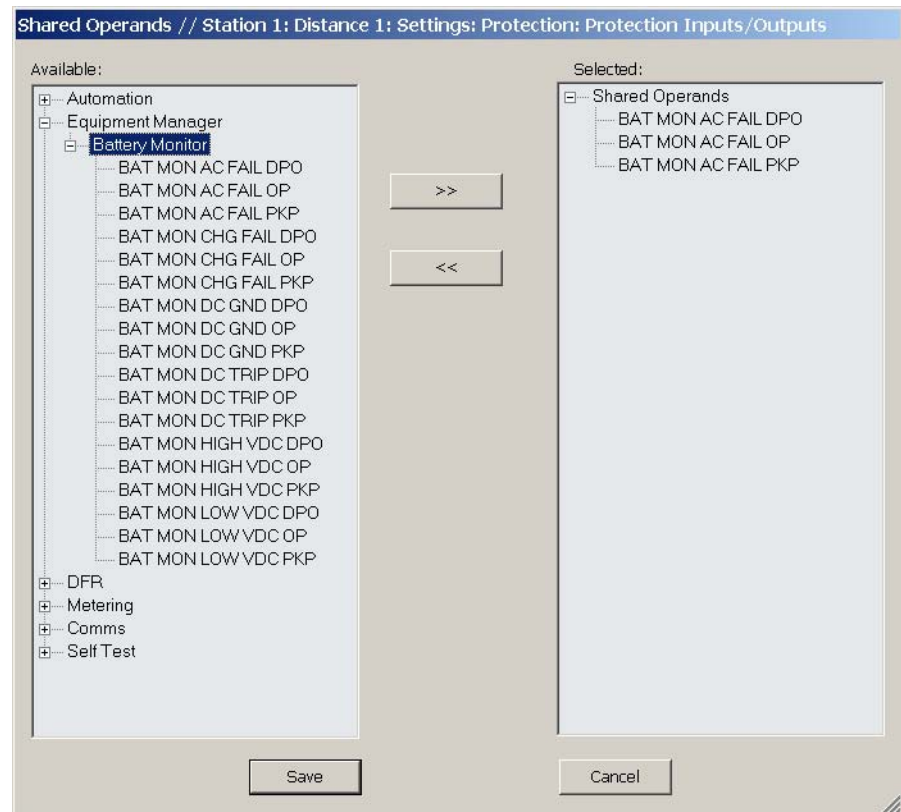
The left side of this screen displays all C90^{Plus} operands that are available to the automation function as shared operands. Select any operands from the other five primary features by clicking on the **>>** button. Operands may be de-assigned as shared operands by pressing the **<<** button.

Automation logic

The C90^{Plus} internal digital logic combines fixed and user-programmable parameters. The logic upon which individual features are designed is fixed, and all other logic, from digital input signals through elements or combinations of elements to digital outputs, is variable. The user has complete control of all variable logic through automation logic. In general, the system receives digital inputs which it uses to produce digital outputs and analog inputs which it uses to produce analog outputs. The major sub-systems of a generic UR^{Plus}-series relay involved in this process are shown below.

Figure 259: URPlus-series architecture overview
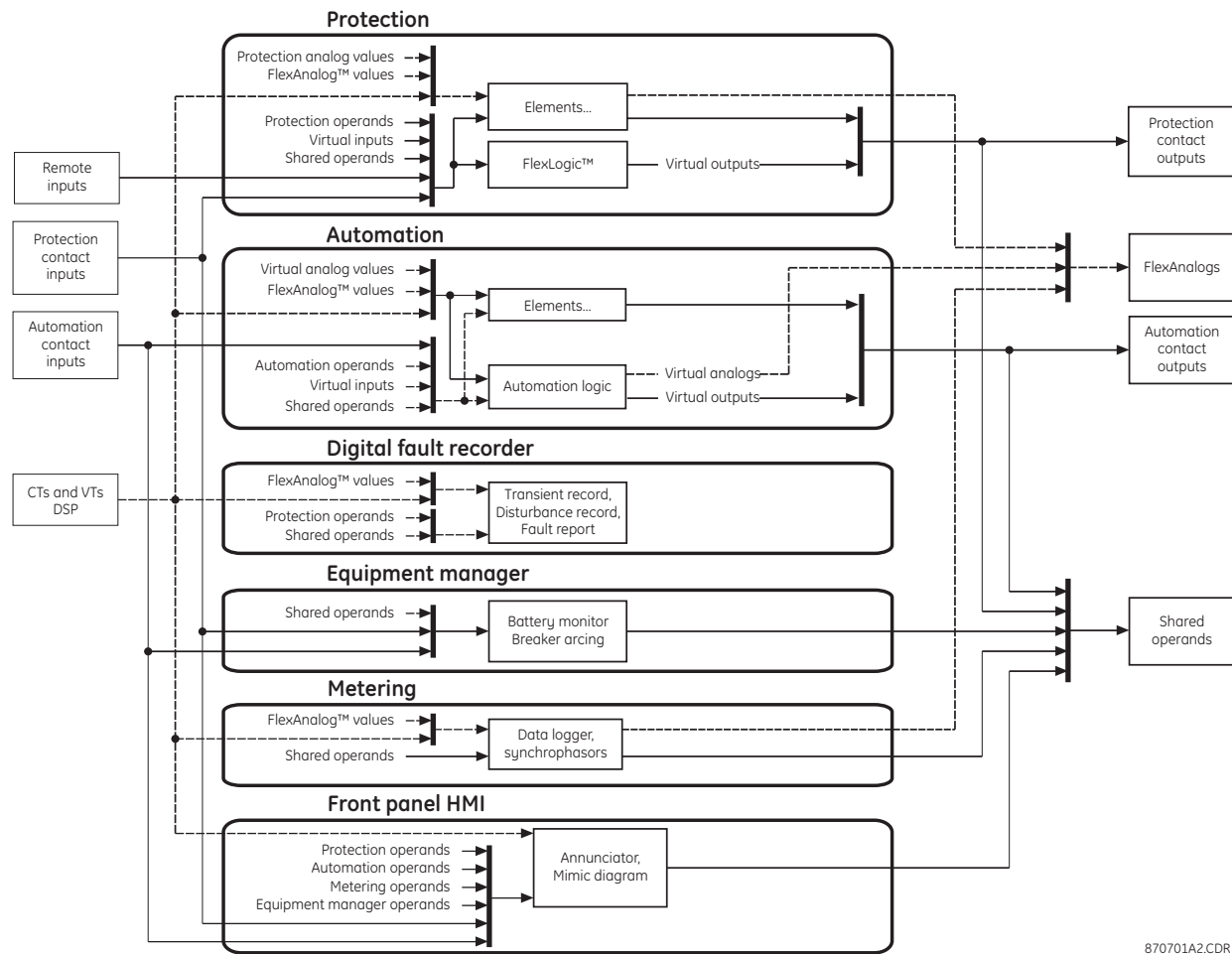
870701A2.CDR

The states of all digital signals used in the C90^{Plus} are represented by flags (or automation logic operands, described later in this section). A logic 1 state is represented by a set flag. Any external contact change-of-state can be used to block an element from operating, as an input to a control feature in an automation logic equation, or to operate a contact output. The state of the contact input can be displayed locally or viewed remotely via the communications facilities provided. If a simple scheme where a contact input is used to block an element is desired, this selection is made when programming the element. This capability also applies to the other features that set flags: elements, virtual inputs, remote inputs, schemes, and human operators.

If more complex logic than presented above is required, it is implemented via automation logic. For example, if it is desired to have the closed state of contact input H7a and the operated state of the phase undervoltage element block the operation of the breaker control element, the two control input states are programmed in an automation logic equation. This equation ANDs the two control inputs to produce a virtual digital output, which is then selected when programming the phase time overcurrent to be used as a blocking input. Virtual digital outputs can only be created by automation logic equations.

Traditionally, protective relay logic has been relatively limited. Any unusual applications involving interlocks, blocking, or supervisory functions had to be hard-wired using contact inputs and outputs. Automation logic minimizes the requirement for auxiliary components and wiring while making more complex schemes possible.

The logic that determines the interaction of inputs, elements, schemes and outputs is field programmable through the use of logic equations that are sequentially processed. The use of virtual inputs and outputs in addition to hardware is available internally and on the communication ports for other relays to use (distributed logic).

Automation logic allows users to customize the relay through a series of equations that consist of operators and operands. The operands are the states of inputs, elements, schemes and outputs. The operators are logic gates, timers and latches (with set and reset inputs). A system of sequential operations allows any combination of specified operands to be assigned as inputs to specified operators to create an output. The final output of an equation is a numbered register called a virtual output. Virtual outputs can be used as an input operand in any equation, including the equation that generates the output, as a seal-in or other type of feedback.

An automation logic equation consists of parameters that are either operands or operators. Operands have a logic state of 1 or 0. Operators provide a defined function, such as an AND gate or a timer. Each equation defines the combinations of parameters to be used to set a virtual output flag. Evaluation of an equation results in either a logic 1 (=ON, flag set) or logic 0 (=OFF, flag not set). Each equation is evaluated at the automation scan rate.

Some types of operands are present in the relay in multiple instances (for example, contact and remote inputs). These types of operands are grouped together (for presentation purposes only) on the faceplate display. The characteristics of the different types of operands are tabulated below.

Table 29: Automation logic operand types

Type	State	Example	Characteristics (input is logic 1 or "on" if...)
Digital input	On	DIG IP1 ON	Voltage is presently applied to the input (external contact closed).
	Off	DIG IP1 OFF	Voltage is presently not applied to the input (external contact open).
Digital output	Voltage on	DIG OP1 VON	Voltage exists across the contact.
	Voltage off	DIG OP1 VOFF	Voltage does not exist across the contact.
	Current on	DIG OP1 ION	Current is flowing through the contact.
	Current off	CONT OP1 IOFF	Current is not flowing through the contact.
Digital counter	Greater than	COUNTER 1 HI	The number of pulses counted is above the set number.
	Equal to	COUNTER 1 EQL	The number of pulses counted is equal to the set number.
	Less than	COUNTER 1 LO	The number of pulses counted is below the set number.
Direct input	On	DIRECT INPUT 1 ON	The direct input is presently in the ON state.
Element	Pickup	DIG ELEM 1 PKP	The output operand is at logic 1.
	Dropout	DIG ELEM 1 DPO	This operand is the logical inverse of the pickup operand.
	Operate	DIG ELEM 1 OP	The input operand has been at logic 1 for the programmed pickup delay time, or has been at logic 1 for this period and is now at logic 0 but the reset timer has not finished timing.
Fixed	On	ON	Logic 1.
	Off	OFF	Logic 0.
Remote input	On	REMOTE IN 1 ON	The remote input is presently in the on state.
Virtual input	On	VIRT IP 1 ON	The virtual input is presently in the on state.
Virtual output	On	VIRT OP 1 ON	The virtual output is presently in the on state.

Automation operators

The following operators are available for the creation of automation logic.

- One-shots
- Boolean operators and latches
- Timers
- Math operators
- Virtual outputs
- Comparators

The following sub-sections provide additional detail on these operators.

About automation one-shots

The automation one-shot syntax is shown in the following table.

Table 30: Automation logic one shots

Syntax	Description
POSITIVE ONE SHOT	One shot that responds to a positive-going edge.
NEGATIVE ONE SHOT	One shot that responds to a negative-going edge.
DUAL ONE SHOT	One shot that responds to both the positive and negative-going edges.

A *one-shot* accepts any digital input or the output of any logical operator. Its output will assert for one scan following a transition of its input. A negative one-shot will operate on a falling edge of its input, and a positive one-shot will operate on a rising edge of its input. A dual one-shot will operate on a rising edge or falling edge of its input. A total of 64 one-shots are available in the C90^{Plus} automation controller.

Figure 260: One-shot used in automation logic

About Boolean operators and latches

The Boolean logic and latch syntax is shown in the following table.

Table 31: Automation logic Boolean operators and latches

Syntax	Description	Output is ON if...
NOT	Logical NOT gate. Operates on the previous operand.	the input is logic 0
OR(2) to OR(16)	Logical OR gates. Operate on the previous 2 to 16 operands.	any input is logic 1
AND(2) to AND(16)	Logical AND gates. Operates on the previous 2 to 16 operands.	all inputs are logic 1
NOR(2) to NOR(16)	Logical NOR gates. Operates on the previous 2 to 16 operands.	all inputs are logic 0
NAND(2) to NAND(16)	Logical NAND gates. Operates on the previous 2 to 16 operands.	any input is logic 0
XOR(2)	Logical exclusive OR gate. Operates on the previous two operands.	only one input is logic 1
LATCH (S,R)	Reset-dominant latch. The operand preceding LATCH(S,R) is the reset input. The operand preceding the reset input is the set input.	there is a positive transition on the set input

Boolean operators perform Boolean logic operations on any digital input or the output of any preceding logical operator. The output of a logic operator may be used in further logic processing. The final output of a sequence of logic operations is stored as a virtual digital output (VDO). The logic operators available in the automation controller are tabulated below.

A *latch* is asserted on a positive transition of its set input and retains this state until the positive transition of its reset input. A latch accepts any digital input or the output of any logical operator to either of its inputs. A total of 256 latches are available in the C90^{Plus} automation controller.

Figure 261: Latch used in automation logic
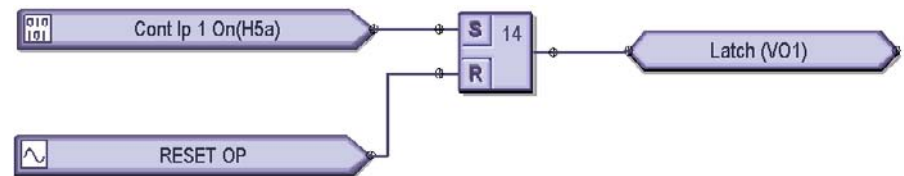
About automation timers

The automation logic timer syntax is shown in the following table.

Table 32: Automation logic timers

Syntax	Description
TIMER(1) to TIMER(64)	The timer is set by the corresponding automation timer setting. The timer is started by the preceding operand.

A *timer* accepts any digital input or the output of any logical operator. The timer output is asserted when its input is asserted for a time equal to or greater than its pickup value. Likewise, the timer output will reset when its input has been reset for a time equal to or greater than its dropout value. A total of 32 timers are available in the C90^{Plus} automation controller.

Figure 262: Timer used in automation logic

Automation math operators

The automation logic math syntax is shown in the following table.

Table 33: Automation math operators

Syntax	Description
ADD(2)	Add the previous 2 operands.
SUB(2)	Subtract the second operand from the first operand.
MULT(2)	Multiply the previous two operands.
DIV(2)	Divide the first operand by the second operand.
NEG	Multiply the previous operand by –1.
ABS	Return the absolute value of the previous operand.
SQRT	Return the square root of the previous operand.
POW(2)	Raise the second operand to a power of the first operand.
EXP	Return the power of *e* (the base of natural logarithms) value of the previous operand.
LOG10	Return the base 10 logarithm value of the previous operand.
LOG	Return the natural logarithm (base *e*) value of the previous operand.
TAN	Return the tangent value of the previous operand.
SIN	Return the sine value of the previous operand.
COS	Return the cosine value of the previous operand.
ATAN2(2)	Return the arctangent value of the second operand divided by the first operand, with a range of –180 to 180°.
ATAN	Return the arctangent value of the previous operand.
ASIN	Return the arcsine value of the previous operand.
ACOS	Return the arccosine value of the previous operand.
FLOOR	Return the largest integer less than or equal to the operand.
CEIL	Return the smallest integer greater than or equal to the operand.
FMOD(2)	Return the remainder of the second operand divided by the first operand.

The automation controller can perform *math* operations on any analog input, any numerical constant, or the output of a preceding math operator. The final output of a sequence of math operations is stored as a virtual analog output (VAO). Numerical constants are IEEE 32-bit floating-point values and are fixed during operation of the controller. The math operators available in the automation controller are tabulated below.

Any analog input or the result of any math operation can be assigned to a *FlexElement*™, which is a general purpose analog comparator. A FlexElement™ compare a single input with a threshold value or can compare two inputs. The output from a FlexElement™ can be used for further logic processing. A total of 16 FlexElements™ are dedicated for the automation controller.

All math calculations are carried out using 32-bit IEEE floating-point numbers as defined by IEEE 754-185. This format has a range of -3.402823×10^{38} to 3.402823×10^{38}.

Consider the following math calculation.

$$\text{Analog VO1} = |V\_0| - |I\_0| \times 10.000$$

This calculation is represented in automation logic in Reverse Polish Notation (RPN). The automation logic for this example is shown below.

Figure 263: Math example
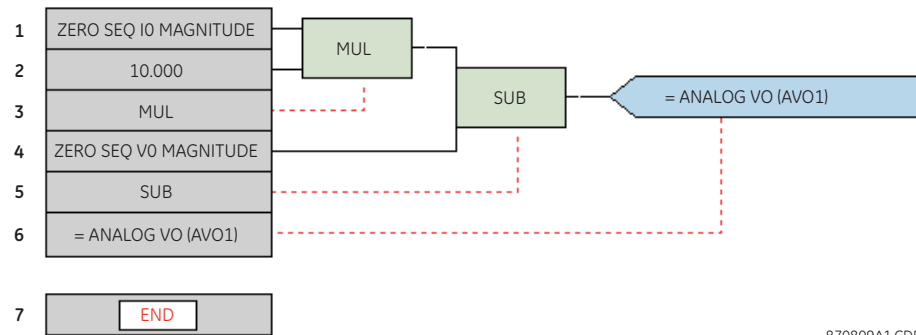
870809A1.CDR

A math operation result that is outside this range described above is defined as an overflow. Additionally, this format includes the representation of infinity and of values that are not real numbers (not-a-number or NaN). For example, math operations using NaN as an input produce NaN as an output. Other abnormal math results are defined as follows.

Table 34: Abnormal math results

Description	Operation	Result
N divided by an infinite	$N \div \infty$	0
the product of two infinites	$\infty \times \infty$	∞
any non-zero number divided by zero	$\text{non-zero} \div 0$	∞
the division of two infinites	$\infty \div \infty$	∞
zero divided by zero	$0 \div 0$	NaN
the difference of two infinites	$\infty - \infty$	NaN
the division of two infinites	$\infty \div \infty$	NaN
the product of an infinite and zero	$\infty \times 0$	NaN

If the result of a math operation yields an overflow, infinity value, or NaN value, then an error message is written to the automation event recorder and the values of affected virtual analog outputs are not updated. The automation controller will process the remaining math and logic operations normally.

About automation virtual outputs

The automation virtual output syntax is shown in the following table.

Table 35: Automation virtual output operators

Syntax	Description
VDO(1) to VDO(96)	Assigns the previous automation logic operand to the corresponding automation virtual digital output.
VAO1 to VAO64	Assigns the previous automation logic operand to the corresponding automation virtual analog output.

About automation comparators

Automation comparators have two inputs that are denoted "+" and "–". Each inputs be assigned to a FlexAnalog value or an analog constant. There are six types of comparators in automation logic.

- Greater than (>)
- Less than (<)

- Equal to (=)
- Not equal to (≠)
- Greater than or equal to (≥)
- Less than or equal to (≤)

The output of the comparator will be logic 1 if the inputs satisfy the condition of the particular comparator. Otherwise, the output will be logic 0. The comparator output can be used as an input to Boolean logic or be assigned to an automation virtual output (AVO).

The following automation logic uses the greater than or equal to and the less than or equal to comparators to test that a value is within a specified range.

Figure 264: Using comparators to verify a value is within a specified range

870990A1.CDR
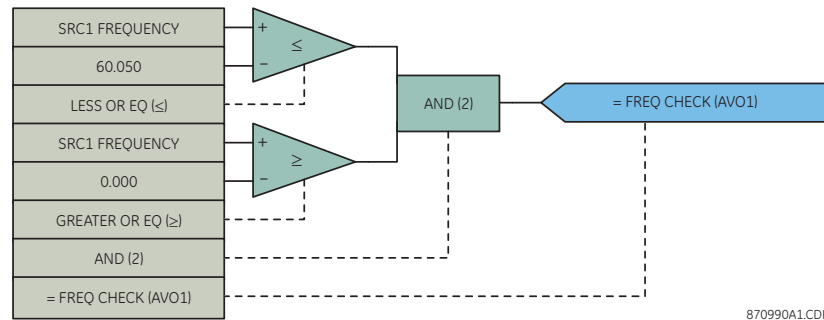
The following automation logic uses the less than comparator to check if two values are approximately equal.

Figure 265: Using comparators to verify approximate equivalence

870991A1.CDR
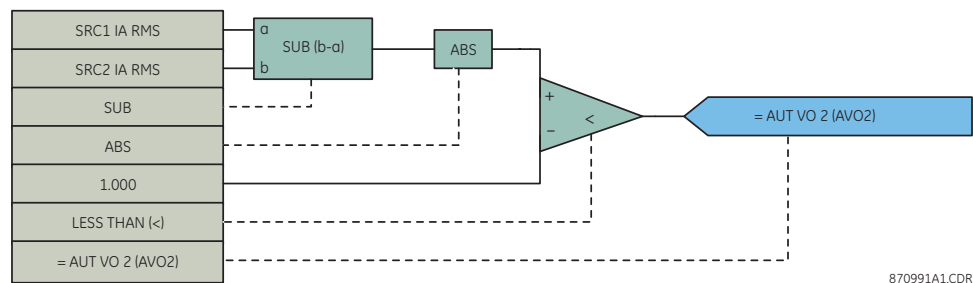
Automation logic equation editor

An automation logic equation can contain up to 4096 entries, including the END operator. If a disabled element is selected as an automation logic entry, the associated state flag will never be asserted (set to logic 1).

Select the **Settings > Automation > Automation FlexLogic > FlexLogic Equation Editor** menu item to open the automation logic equation editor window.

Figure 266: Automation logic configuration settings

A graphical representation of the automation logic can be displayed by clicking on the **View** button at the top of the equation.

Figure 267: Typical automation logic display
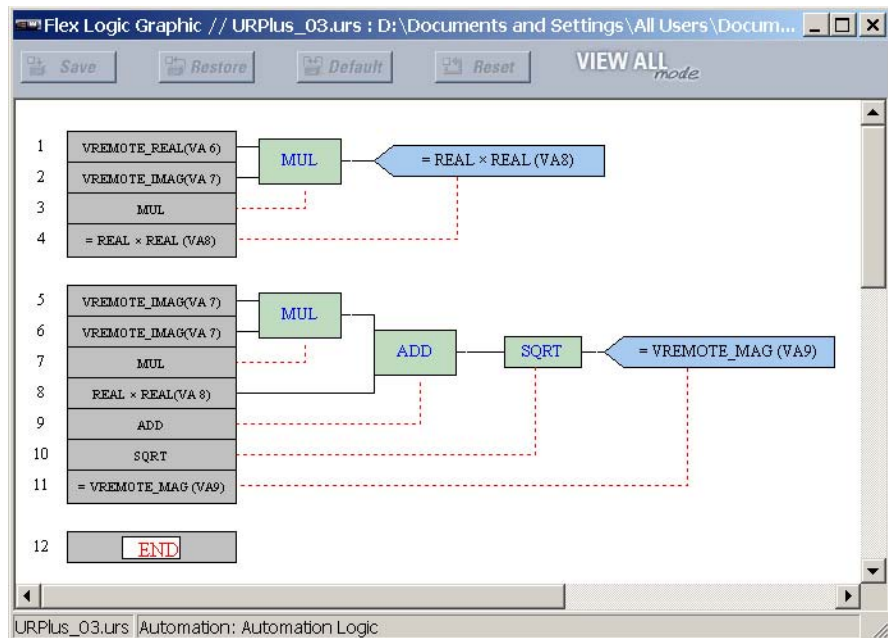
Automation logic rules

When forming an automation logic equation, the sequence in the linear array of parameters must follow these general rules.

1. There are two types of operators: logic operators and math operators.

2. Logic operands must precede the logic operator that uses the operands as inputs.

3. Logic operators have only one output. The output of an operator must be used to create a virtual output if it is to be used as an input to two or more operators.

4. Assigning the output of a logic operator to a virtual output terminates the equation.

5. A timer operator (for example Aut Timer 1) or virtual output assignment (for example, = Virt Op 1) may only be used once. If this rule is broken, a syntax error will be declared.

6. Math operands must precede the math operator that uses the operands as inputs.

7. Math operators have only one output. The output of a math operator must be used to create a virtual analog if it is to be used as an input to two or more operators.

8. Assigning the output of a math operator to a virtual analog terminates the equation.

Automation logic programming example

The following automation logic programming example illustrates the implementation of a voltage regulation scheme with line drop compensation. In this scheme, the C90^{Plus} measures the local end positive-sequence voltage and calculates the remote end positive-sequence line voltage (the load center voltage) to compensate for the voltage drop on the line.

In this example, the line positive-sequence impedance is 100.0 primary ohms at 80° and the PT ratio is 1000:1. The difference between the remote end voltage and the setting voltage (69.9 volts secondary = 69900 volts primary) is assigned to the virtual analog 1 value and named DELTA_V (note that all analog quantities in the automation logic are primary values). The automation logic includes a voltage reduction command represented by virtual input 1 and named V_REDUCT. If voltage reduction is enabled, then the setpoint voltage is reduced by 5%.

The following logic calculates the magnitude and angle of $I_1 \times Z$ and assigns these results to virtual analog 2 and virtual analog 3, respectively.

Figure 268: Magnitude and angle calculation logic for $I_1 \times Z$
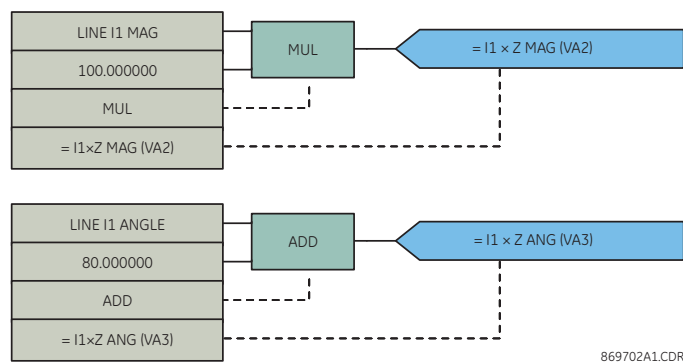
The following logic calculates the real and imaginary parts of the local positive-sequence voltage and assigns these results to virtual analog 4 and virtual analog 5, respectively.

Figure 269: Real and imaginary component calculation logic for local voltage
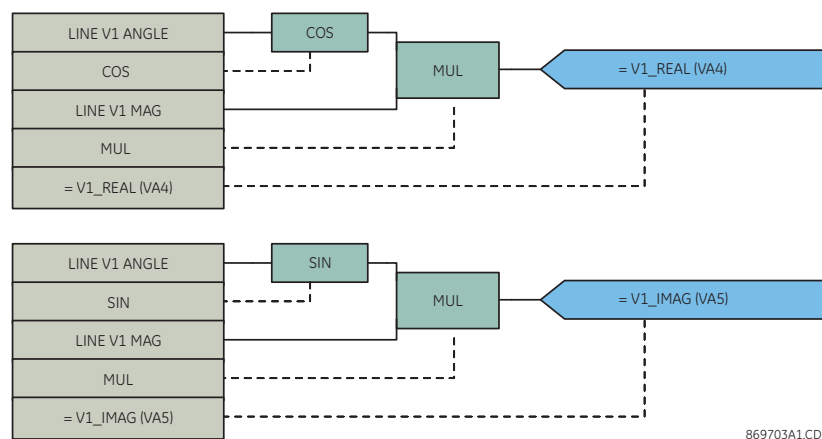
Next, the real and imaginary components of the remote voltage is calculated and assigned to virtual analog 6 and virtual analog 7, respectively.

Figure 270: Real and imaginary component calculation logic for remote voltage
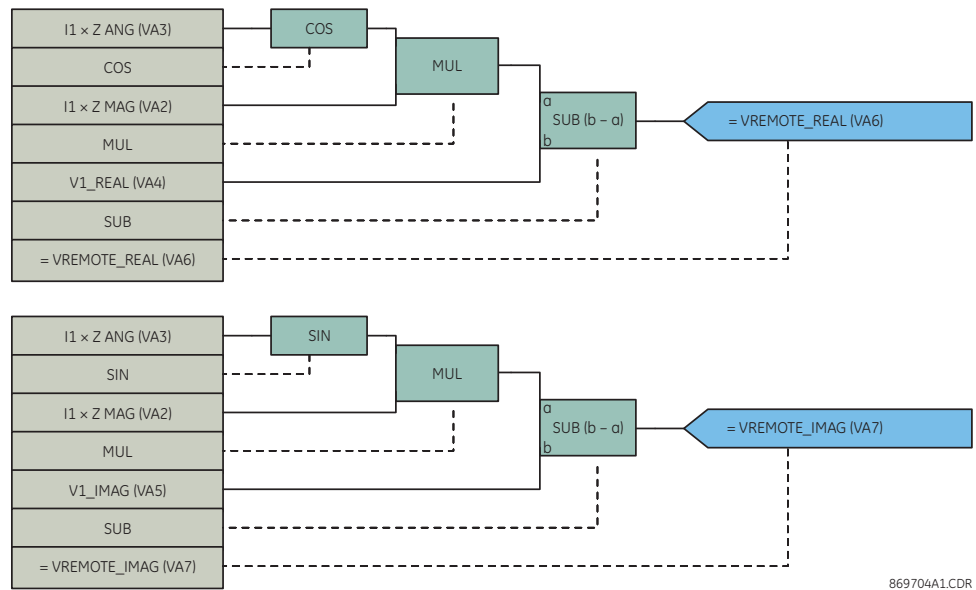
The magnitude of the remote voltage is calculated next and assigned to virtual analog 9. Note that virtual analog 8 is used as an intermediate value in the automation logic.

Figure 271: Remote voltage magnitude calculation logic
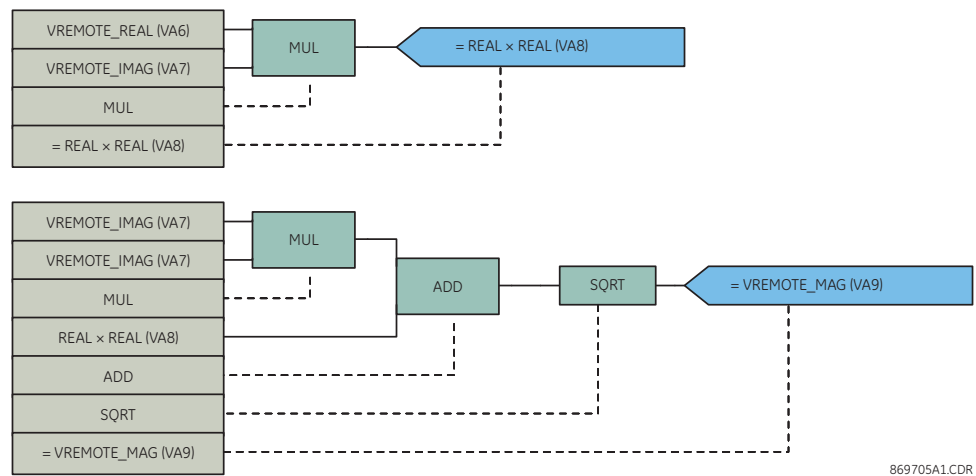
Now that the remote voltage magnitude has been calculated, the following logic calculates the voltage difference between this and the setting voltage.

Figure 272: Voltage difference automation logic
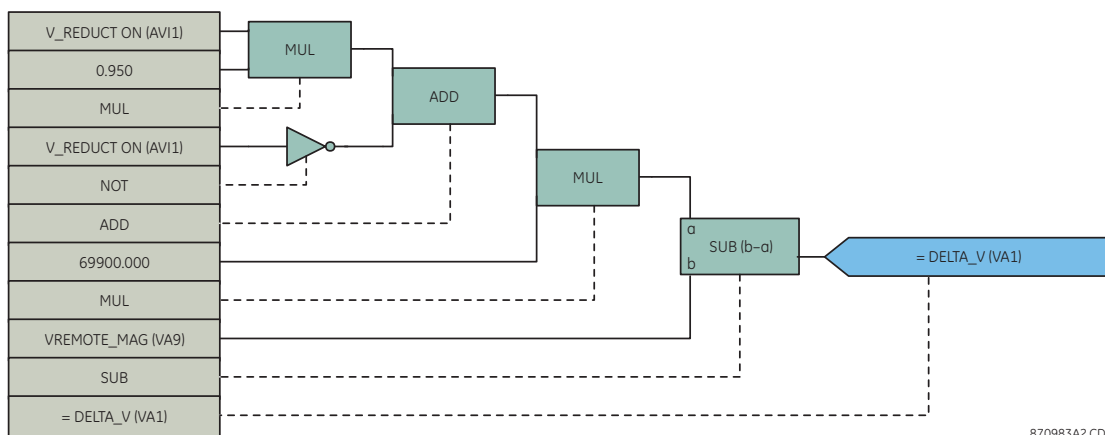
The current on each phase is checked to ensure that it is less than the maximum allowable for a tap changer operation.

Figure 273: Overcurrent check automation logic
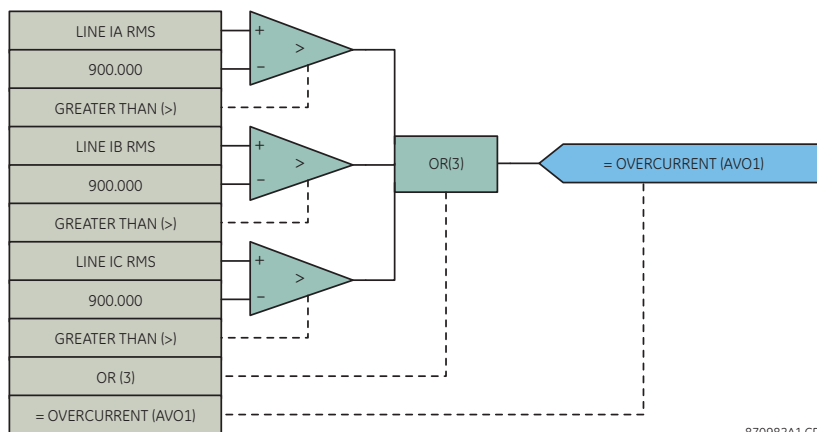
A lockout is implemented with the following logic. The lockout is asserted if the tap changer gas trip contact is picked up (63GT). The lockout is also asserted if the tap changer remains between taps for more than ten seconds. The lockout is latched until manually reset.

Figure 274: Lockout automation logic
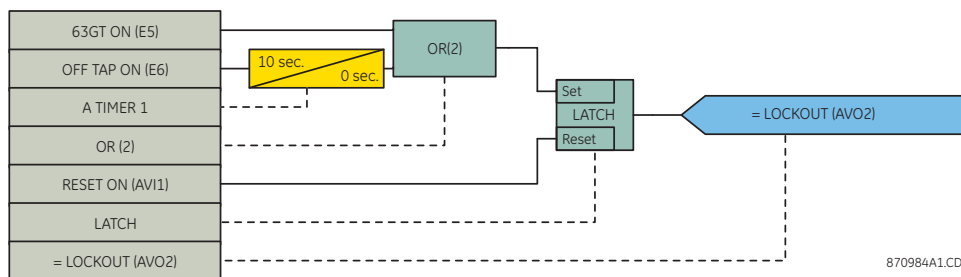
When DELTA_V is greater than 0.5 volts for more than 30 seconds (the sum of timers 2 and 3), the tap changer control is in auto mode, no overcurrent condition exists, and there is no lockout, then a LOWER command is issued via analog virtual output 4. If the voltage remains high, then subsequent LOWER commands are issued at five second intervals.

Figure 275: Lower command automation logic
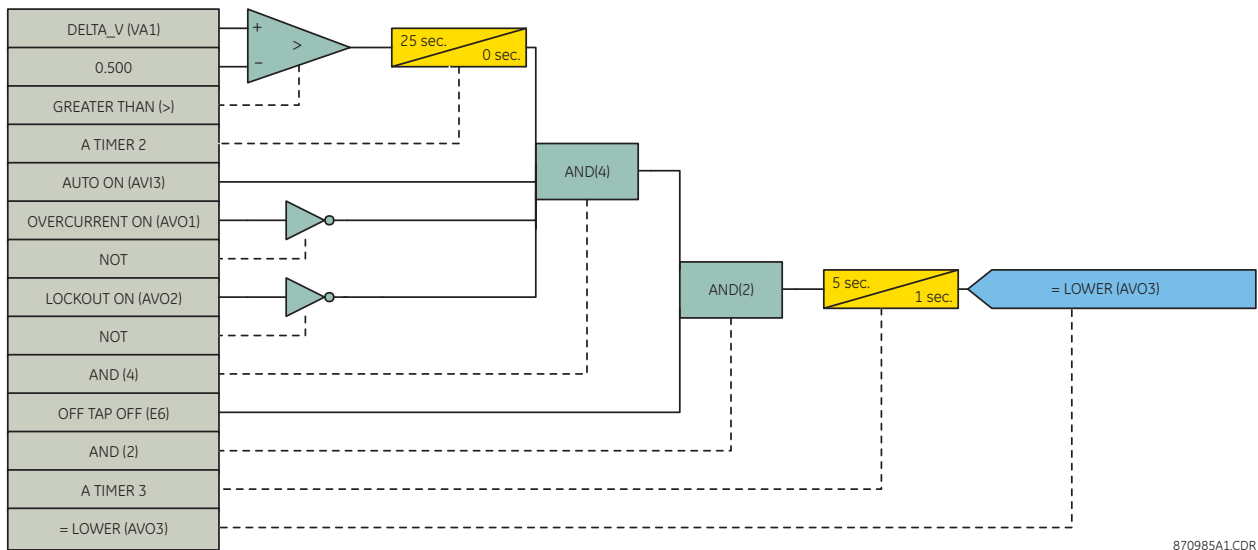
When DELTA_V is less than –0.5 volts for more than 30 seconds (the sum of timers 2 and 3), the tap changer control is in auto mode, no overcurrent condition exists, and there is no lockout, then a RAISE command is issued. If the voltage remains low, then subsequent RAISE commands are issued at five second intervals.

Figure 276: Raise command automation logic
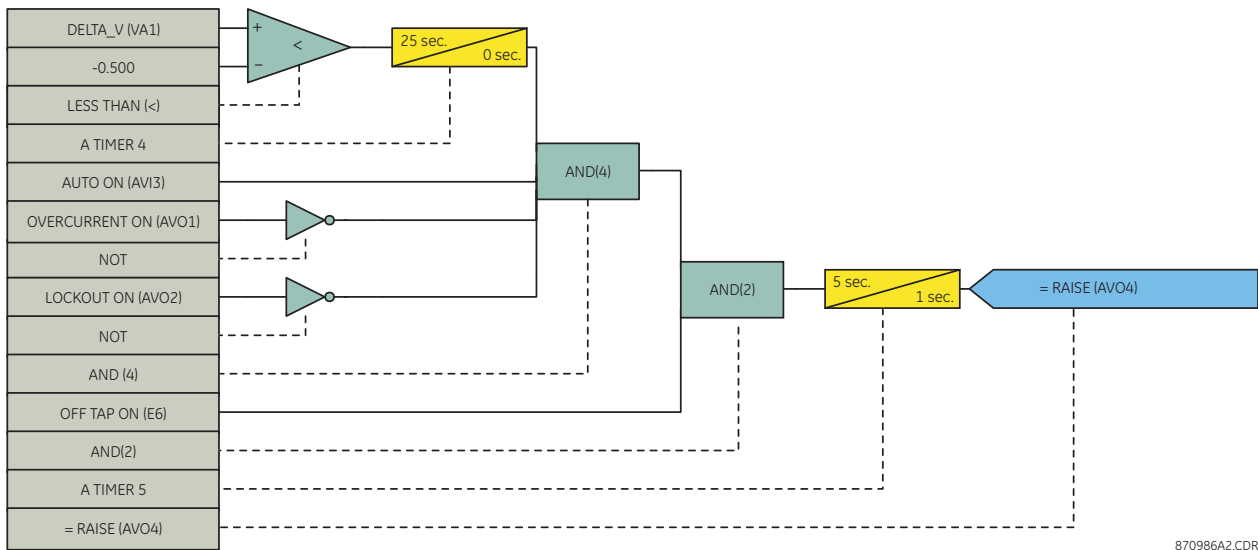
The following automation logic detects excessive tap changer operations. First, a TIMEOUT signal is created that produces a one second pulse once an hour.

Figure 277: Timeout signal automation logic
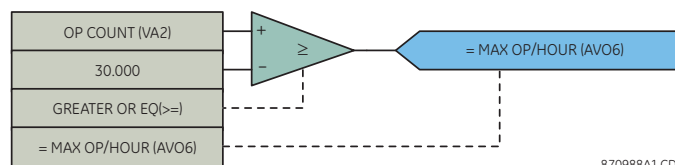
A counter is then implemented to accumulate the number of operations (indicated by the OFF TAP signal). The value of OP COUNT is reset to zero by the TIMEOUT signal once per hour.

Figure 278: Operation counter automation logic
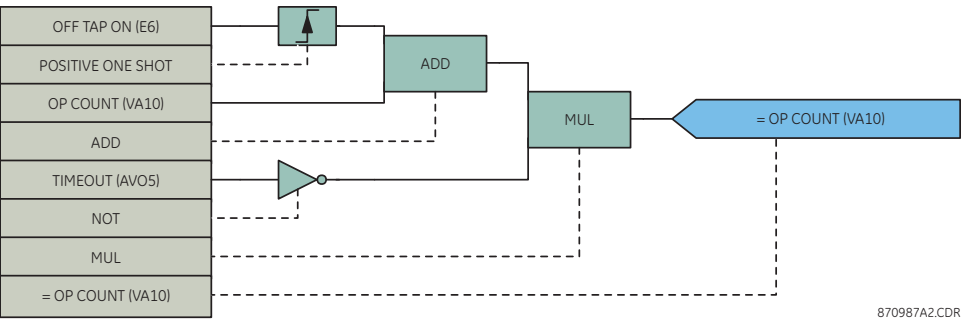
If the number of operations is equal to or greater than the maximum number of permitted operations (30 in this example), then a MAX OP/HOUR alarm is declared.

Figure 279: Maximum operations per hour alarm automation logic
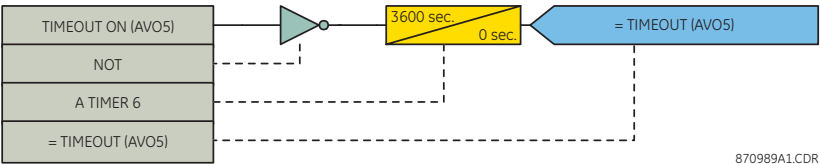
Automation logic timers

There are 32 identical automation logic timers available. These timers can be used as operators in automation logic equations.

Select the **Settings > Automation > Automation FlexLogic > FlexLogic Timers** menu item to open the automation logic timers configuration window.

Figure 280: Automation logic timers configuration settings

The following settings are available for each automation logic timer.

Pickup Delay

Range: 0 to 3600000000 ms in steps of 50

Default: 0 ms

This setting specifies the time delay to pickup. If a pickup delay is not required, set this value to "0 ms".

Dropout Delay

Range: 0 to 3600000000 ms in steps of 50

Default: 0 ms

This setting specifies the time delay to dropout. If a dropout delay is not required, set this value to "0 ms".

Automation logic operands

The following automation logic operands are available for the C90^Plus. They are listed alphabetically by operand syntax. Some operands can be re-named by the user. These include the names of breakers, contact inputs, and virtual outputs. The default names are indicated in the lists below.

Automation virtual output operands

Aut VO 1 ON ....Asserted when automation virtual output 1 is in the ON state (logic 1).

Aut VO Ip 2 to 96............................The operands listed above are available for the contact inputs 2 through 40. These operands will reflect the programmed names for the automation virtual outputs.

Breaker control operands

BKR CNTRL1 CLOSE CMD ....Asserted when a close command is issued on breaker 1 from breaker control.

BKR CNTRL1 INTERLCK BYPS.....Asserted when interlocking is bypassed for breaker 1.

BKR CNTRL1 OPEN CMD..............Asserted when an open command is issued on breaker 1 from breaker control.

BKR CNTRL2 ....The operands listed above are also available for breaker 2.

Breaker interlocking operands

BKR INTERLK1 CLS PERM ....Asserted when all conditions have been satisfied for closing breaker 1.

BKR INTERLK1 OPEN PERM........Asserted when all conditions have been satisfied for opening breaker 1.

BKR INTERLK1 TAGGED...............Asserted when a tag is applied to breaker 1.

BKR INTERLK2..................................The operands listed above are available for the breaker interlocking 2 element.

Automation contact input operands

Cont Ip 1 OFF...................................Asserted when the field contact connected to contact input 1 is opened.

Cont Ip 1 ON ....Asserted when the field contact connected to contact input 1 is closed.

Cont Ip 1 TRBL OP.........................Asserted when there is an internal or external problem with contact input 1.

Cont Ip 1 TRBL DPO......................Asserted when there are no problems with contact input 1.

Cont Ip 2 to 40................................The operands listed above are available for the contact inputs 2 through 40. These operands will reflect the programmed names for the automation contact inputs.

Automation contact output operands

Cont Op 1 IOff .... Asserted when contact output 1 with current monitoring is opened.

Cont Op 1 IOn .... Asserted when contact output 1 with current monitoring is closed.

Cont Op 1 VOff .... Asserted when contact output 1 with voltage monitoring is opened.

Cont Op 1 VOn .... Asserted when contact output 1 with voltage monitoring is closed.

Cont Op 2 to *40* .... The operands listed above are available for the contact inputs 2 through 40. These operands will reflect the programmed names for the automation contact outputs.

Disconnect control operands

DISC CNTRL1 CLOSE CMD .... Asserted when disconnect 1 is closed.

DISC CNTRL1 INTERLCK BYPS ... Asserted when interlocking has been bypassed for disconnect 1.

DISC CNTRL1 LOCAL SELECT ..... Asserted when disconnect 1 has been selected from the front panel HMI.

DISC CNTRL1 OPEN CMD .... Asserted when disconnect 1 is open.

DISC CNTRL1 REMOTE SELECT .. Asserted when disconnect 1 has been selected from SCADA.

DISC CNTRL2 .... The operands listed above are also available for disconnect 2.

Disconnect interlock operands

DISC INTERLK1 CLS PERM .... Asserted when all conditions have been satisfied for closing disconnect 1.

DISC INTERLK1 OPEN PERM ...... Asserted when all conditions have been satisfied for opening disconnect 1.

DISC INTERLK1 TAGGED .... Asserted when a tag is applied to disconnect 1.

DISC INTERLK2 .... The operands listed above are available for the disconnect 2 element.

Disconnect configuration operands

DISC1 ANY POLE OPEN .... Asserted when at least one pole of disconnect 1 is open.

DISC1 BAD STATE .... Asserted when the normally open and normally closed disconnect indications disagree.

DISC1 CLOSE CMD .... Asserted when a close command has been executed on disconnect 1.

DISC1 CLOSED .... Asserted when disconnect 1 has been closed.

DISC1 DISCREPANCY .... Asserted when the three poles of the disconnect disagree (that is, when they are not all opened or all closed).

DISC1 INTERMED .... Asserted when the disconnect is in transition between the opened and closed states.

DISC1 ONE POLE OPEN .... Asserted when only one pole of disconnect 1 is open

DISC1 OPEN CMD .... Asserted when an open command is executed on disconnect 1.

DISC1 OPENED .... Asserted when disconnect 1 is opened.

DISC1 SUBST CLOSED .... Asserted when the status of disconnect 1 has been substituted with a closed indication.

DISC1 SUBST ON .... Asserted when disconnect status substitution is enabled for disconnect 1.

DISC1 SUBST OPENED .... Asserted when the status of disconnect 1 has been substituted with an opened indication.

DISC1A BAD STATE.........................Asserted when the normally open and normally closed breaker
indications disagree for pole A of disconnect 1.

DISC1A CLOSED.............................Asserted when disconnect 1 pole A is closed.

DISC1A INTERMED.........................Asserted when breaker 1 pole A is in transition between the
opened and closed states.

DISC1A OPENED............................Asserted when disconnect 1 pole A is opened.

DISC1B BAD STATE.........................Asserted when the normally open and normally closed breaker
indications disagree for pole B of disconnect 1.

DISC1B CLOSED.............................Asserted when disconnect 1 pole B is closed.

DISC1B INTERMED.........................Asserted when breaker 1 pole B is in transition between the
opened and closed states.

DISC1B OPENED............................Asserted when disconnect 1 pole B is opened.

DISC1C BAD STATE.........................Asserted when the normally open and normally closed breaker
indications disagree for pole C of disconnect 1.

DISC1C CLOSED.............................Asserted when disconnect 1 pole C is closed.

DISC1C INTERMED.........................Asserted when breaker 1 pole C is in transition between the
opened and closed states.

DISC1C OPENED............................Asserted when disconnect 1 pole C is opened.

DISC2 ....The operands listed above are also available for disconnect 2.

Frequency rate of change load shedding operands

FRLS1 DPO......................................Asserted when the frequency rate of change load shedding 1
element drops out.

FRLS1 OP..Asserted when the frequency rate of change load shedding 1
element operates.

FRLS1 PKP......................................Asserted when the frequency rate of change load shedding 1
element picks up.

FRLS2... ....The operands listed above are also available for the frequency
rate of change load shedding 2 to 4 elements.

Local-remote control scheme operands

L/R L ON...Asserted while the local control scheme is enabled.

L/R R ON ....Asserted while the remote control scheme is enabled.

Selector switch operands

SELECTOR 1 ALARM.......................Asserted when the position of selector 1 has been pre-selected
but not acknowledged.

SELECTOR 1 BIT 0 ....Represents the first bit of the three-bit word encoding position
of selector 1.

SELECTOR 1 BIT 1 ....Represents the second bit of the three-bit word encoding
position of selector 1.

SELECTOR 1 BIT 2 ....Represents the third bit of the three-bit word encoding position
of selector 1.

SELECTOR 1 BIT ALARM ....Asserted when the position of selector 1 has been pre-selected
with the three-bit control input but not acknowledged.

SELECTOR 1 POS 1 ....Asserted when selector switch 1 is in position 1.

SELECTOR 1 POS 2 ....Asserted when selector switch 1 is in position 2.

SELECTOR 1 POS 3 ....Asserted when selector switch 1 is in position 3.

SELECTOR 1 POS 4 ....Asserted when selector switch 1 is in position 4.

SELECTOR 1 POS 5 ....Asserted when selector switch 1 is in position 5.

SELECTOR 1 POS 6 ....Asserted when selector switch 1 is in position 6.

SELECTOR 1 POS 7 ....Asserted when selector switch 1 is in position 7.

SELECTOR 1 PWR ALARM .... Asserted when the position of selector switch 1 is undetermined or restored from memory when the relay powers up and synchronizes to the three-bit input.

SELECTOR 1 STP ALARM .... Asserted when the position of selector 1 has been pre-selected with the stepping up control input but not acknowledged.

SELECTOR 2... .... The same set of operands as shown above are available for selector switch 2.

Synchrocheck operands

SYNC 1 CLS DPO .... Asserted when the synchrocheck 1 close has dropped out.

SYNC 1 CLS OP .... Asserted when the synchrocheck 1 close has operated.

SYNC 1 DEAD S DPO .... Asserted when the synchrocheck 1 dead source has dropped out.

SYNC 1 DEAD S OP .... Asserted when the synchrocheck 1 dead source has operated.

SYNC 1 SYNC DPO .... Asserted when the synchrocheck 1 has dropped out while in synchronization.

SYNC 1 SYNC OP .... Asserted when the synchrocheck 1 has operated while in synchronization.

SYNC 1 V1 ABOVE MIN .... Asserted when the synchrocheck 1 V_1 value is above the minimum live voltage.

SYNC 1 V1 BELOW MAX .... Asserted when the synchrocheck 1 V_1 value is below the maximum dead voltage.

SYNC 1 V2 ABOVE MIN .... Asserted when the synchrocheck 1 V_2 value is above the minimum live voltage.

SYNC 1 V2 BELOW MAX .... Asserted when the synchrocheck 1 V_2 value is below the maximum dead voltage.

SYNC 2... .... The set of operands shown above are available for synchrocheck 2.

Underfrequency load shedding operands

UFLS1 DPO .... Asserted when the underfrequency load shedding 1 element drops out.

UFLS1 OP .... Asserted when the underfrequency load shedding 1 element operates.

UFLS1 PKP .... Asserted when the underfrequency load shedding 1 element picks up.

UFLS2... .... The operands listed above are also available for the underfrequency load shedding 2 to 6 elements.

Undervoltage load shedding operands

UVLS1 DPO .... Asserted when the undervoltage load shedding 1 element drops out.

UVLS1 OP .... Asserted when the undervoltage load shedding 1 element operates.

UVLS1 PKP .... Asserted when the undervoltage load shedding 1 element picks up.

UVLS2... .... The operands listed above are also available for the undervoltage load shedding 2 to 6 elements.

C90^Plus Controller

Chapter 8: Equipment manager

A program for equipment monitoring can result in extended equipment life, improved system reliability, and increased equipment availability. Furthermore, effective equipment monitoring allows maintenance to be targeted towards the equipment in the greatest need. The C90^Plus provides a variety of measurements and alarms that can be used to monitor the condition of the DC battery.

Overview of the equipment manager

The C90^Plus equipment manager is broken down into six functions according to the specific equipment sub-system.

- Breaker arcing.
- Breaker timing.
- Coil signature.
- Breaker insulation.
- Breaker auxiliaries.
- Battery monitor.

NOTE

Only the battery monitor and breaker arcing features are supported in the current version of the C90^Plus.

Figure 281: Equipment manager block diagram
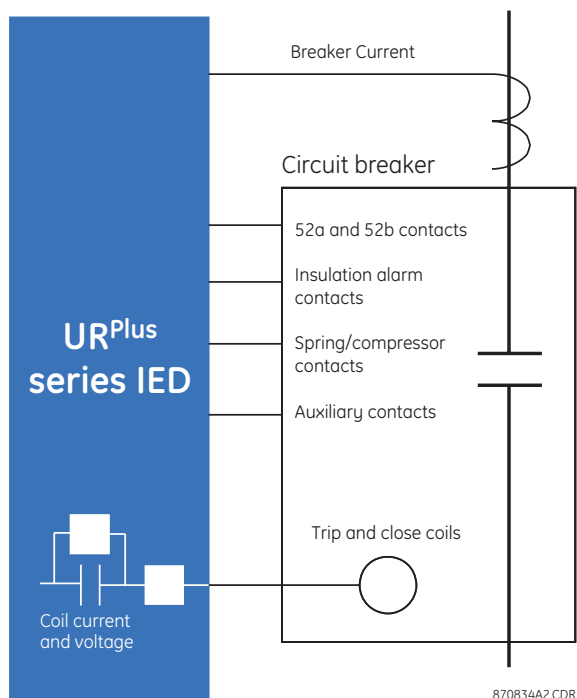
Breaker management

Circuit breaker arcing

The breaker arcing function provides indications of the condition of the circuit breaker interrupter. The primary function is measurement of accumulated contact wear. This is accomplished by integrating the current passing through the breaker during interruption. The function compares the accumulated arcing current with manufacturer data to provide an indication that the breaker requires maintenance. The function also measures the total clearing time, and the maximum interrupted current. This latter value is compared with manufacturer data to determine if the interrupt rating of the breaker has been exceeded.

Figure 282: Breaker arcing current measurement

870714A1.CDR
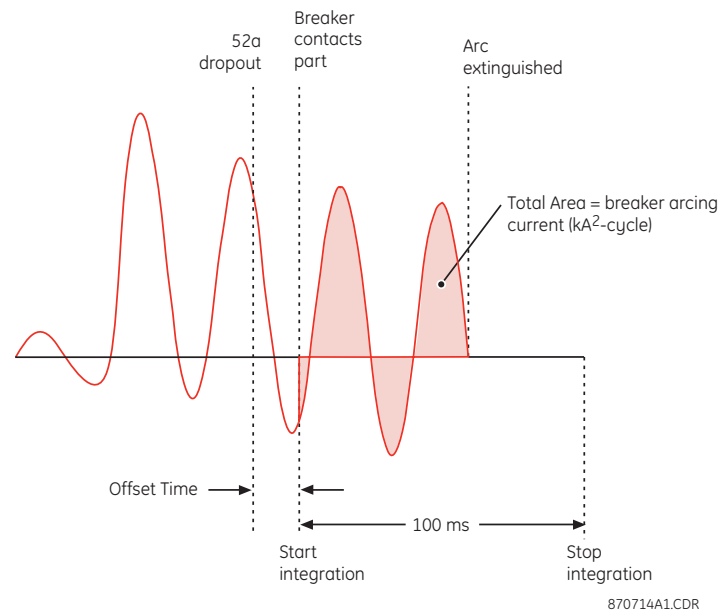
Select the **Settings > Equipment Manager > Breaker > Breaker Arcing** menu item to open the breaker arcing current configuration window.

Figure 283: Breaker arcing current configuration settings

The following settings are available for each breaker arcing current element.

Function

Range: Enabled, Disabled
Default: Disabled

This settings enables or disables the breaker arcing current function.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting selects the signal source for the breaker arcing current element.

Limit

Range: 0 to 50000 kA^2-cycle in steps of 1
Default: 0 kA^2-cycle

This setting specifies the limit of the accumulated current arcing time for maintenance.

Exponent

Range: 1.000 to 5.000 in steps of 0.001
Default: 2.000

This setting specifies the accumulated breaker wear is proportional to the following equation,

$$\sum I^x t$$

Eq. 40

where *x* is the arcing exponent. The typical value for the arcing exponent is 2.

Interruption Rating

Range: 0.0 to 100.0 kA in steps of 0.1
Default: 31.5 kA

This setting specifies the maximum symmetrical interruption rating of the circuit breaker.

Arcing Time Offset

Range: 0 to 50 ms in steps of 1
Default: 0 ms

This setting defines the time difference between the dropout of the 52a auxiliary contact and the parting of the circuit breaker contacts (measured from a circuit breaker timing diagram).

Block

Range: any equipment manager operand or shared operand
Default: OFF

Assertion of the operand assigned to this setting blocks operation of the circuit breaker arcing element.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables or disables the recording of breaker arcing current events in the sequence of events record.

Figure 284: Breaker arcing current logic

870011A2.CDR
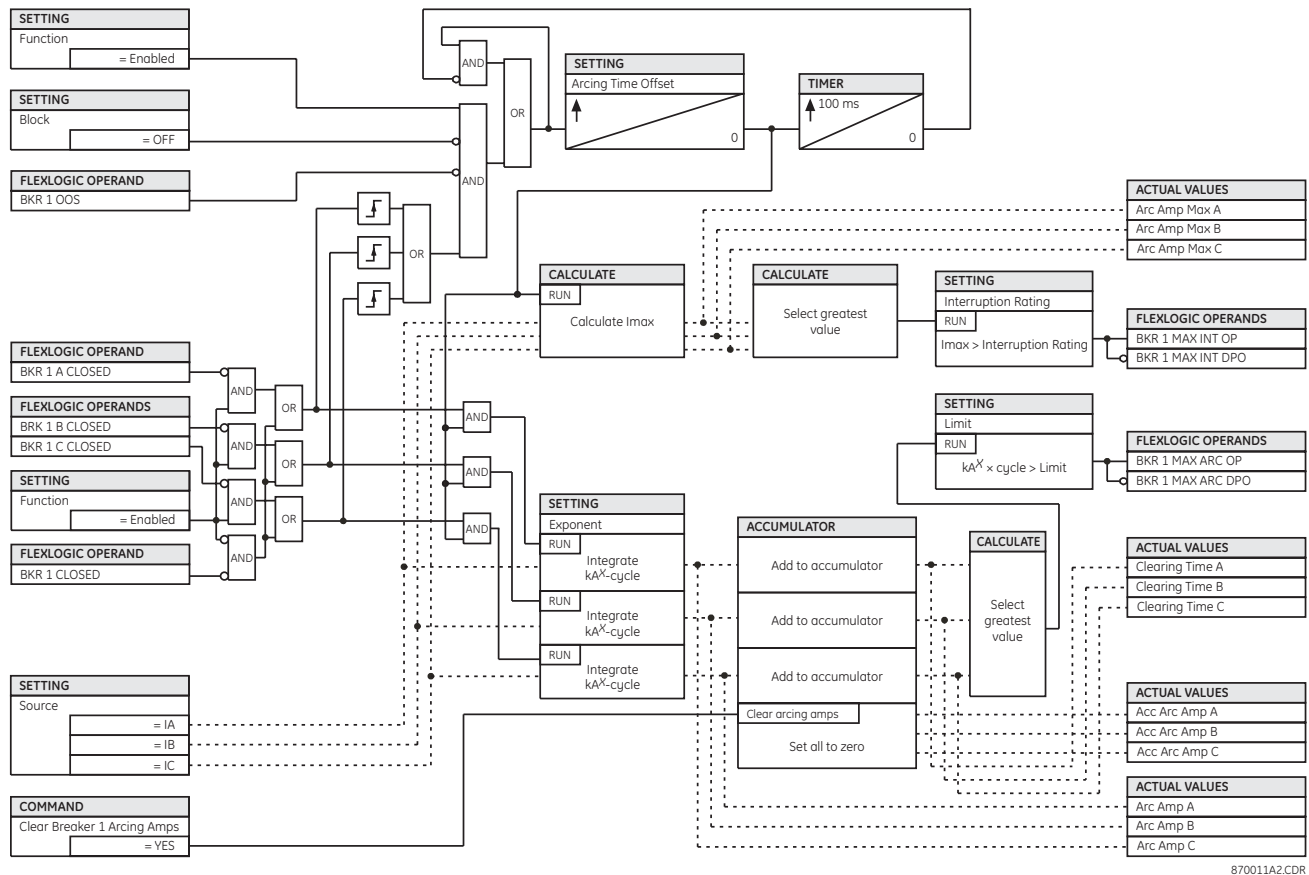
Battery monitor

The battery monitor function monitors the health of the DC battery system. It provides an analog indication of the current DC voltage derived from a contact input wired between the positive and negative rails of the battery system. This signal is used to generate high and low DC voltage alarms. This function also monitors and conditions the auxiliary alarm contacts from the battery charger.

Indications and wiring

The following indications and alarms are provided for the battery monitor function.

Battery monitor alarms and indications

BATTERY VOLTAGE..............................Displays the present value of the battery voltage.

HIGH DC VOLTAGE..............................Indicates the battery DC voltage is greater than the maximum setting value.

LOW DC VOLTAGE..............................Indicates the battery DC voltage is less than the minimum setting value.

SUPPLY FAIL..Indicates the AC supply to the battery charger has failed.

CHARGER FAIL......................................Indicates the battery charger has failed.

BREAKER TRIP.......................................Indicates a DC distribution breaker has operated.

DC GND FLT...Indicates a battery DC ground fault.

Typical wiring for the battery monitor element is shown below.

Figure 285: Battery monitor wiring diagram
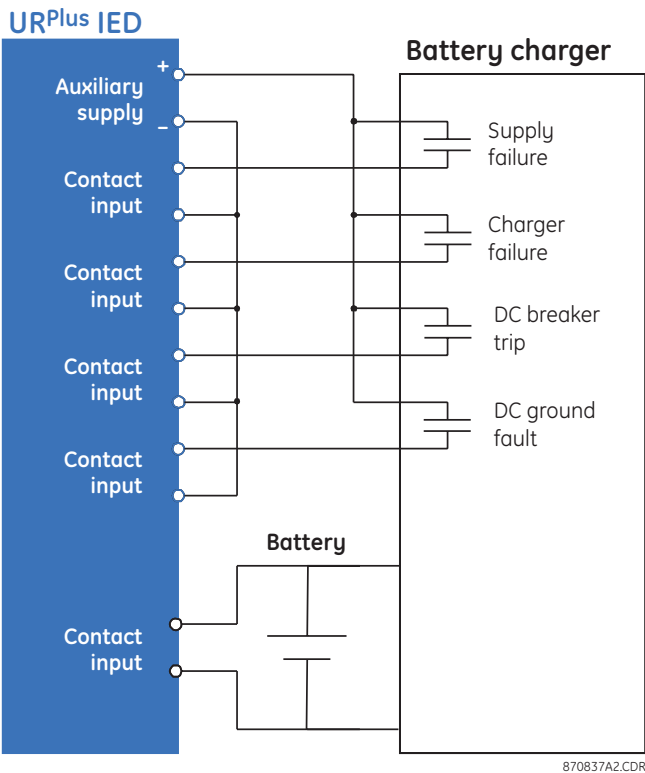
Battery monitor settings

Select the **Settings > Equipment Manager > Battery Monitor** menu item to open the battery monitor configuration window.

Figure 286: Battery monitor configuration settings
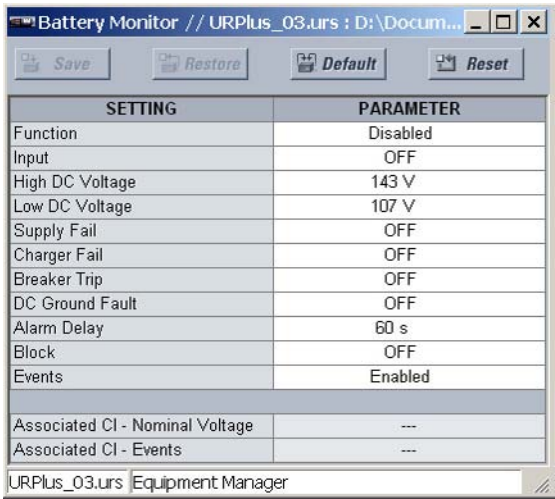
The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the battery monitor element.

Input

Range: any contact input or OFF

Default: OFF

This setting specifies the contact input used to monitor the battery voltage.

High DC Volts

Range: 38 to 275 volts in steps of 1

Default: 143 volts

This setting is used to detect battery overcharging. This can result in loss of life, loss of electrolyte, and thermal runaway. This setting should be set above the expected voltage during an equalization charge.

Low DC Volts

Range: 38 to 275 volts in steps of 1

Default: 107 volts

This setting is used to detect battery undercharging, which can lead to reduced cell capacity and sulfation. An undervoltage condition will also occur due to a charger failure.

Supply Fail

Range: any equipment manager operand or shared operand

Default: OFF

This setting selects the input connected to the AC supply failure contact.

Charger Fail

Range: any equipment manager operand or shared operand

Default: OFF

This setting selects the input connected to the charger critical failure contact.

Breaker Trip

Range: any equipment manager operand or shared operand

Default: OFF

This setting selects the input connected to the DC distribution breaker trip contact.

DC Ground Fault

Range: any equipment manager operand or shared operand

Default: OFF

This setting specifies the input connected to the DC ground fault contact.

Alarm Delay

Range: 2 to 300 seconds in steps of 1

Default: 60 seconds

This setting specifies the time required for a field contact to be asserted before the corresponding alarm is declared.

Block

Range: any equipment manager operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the battery monitor element.

Events

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the logging of battery monitoring events in the sequence of events recorder.

The battery monitoring logic is shown below.

Figure 287: Battery monitor scheme logic

870950A1.CDR

Shared operands

The EnerVista UR^Plus^ Setup software groups the C90^Plus^ system into the following six primary functions. Each function has its own setting parameters and each generates its own outputs in the form of operands.

- Protection
- Automation
- Metering
- Digital fault recorder (DFR)
- Equipment manager
- Front panel interface (HMI)

However, it is often desirable for an output from an element within one function can be available to an element within another function. For instance, it may useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available as to each function as shown below.

Figure 288: Default operand list by function
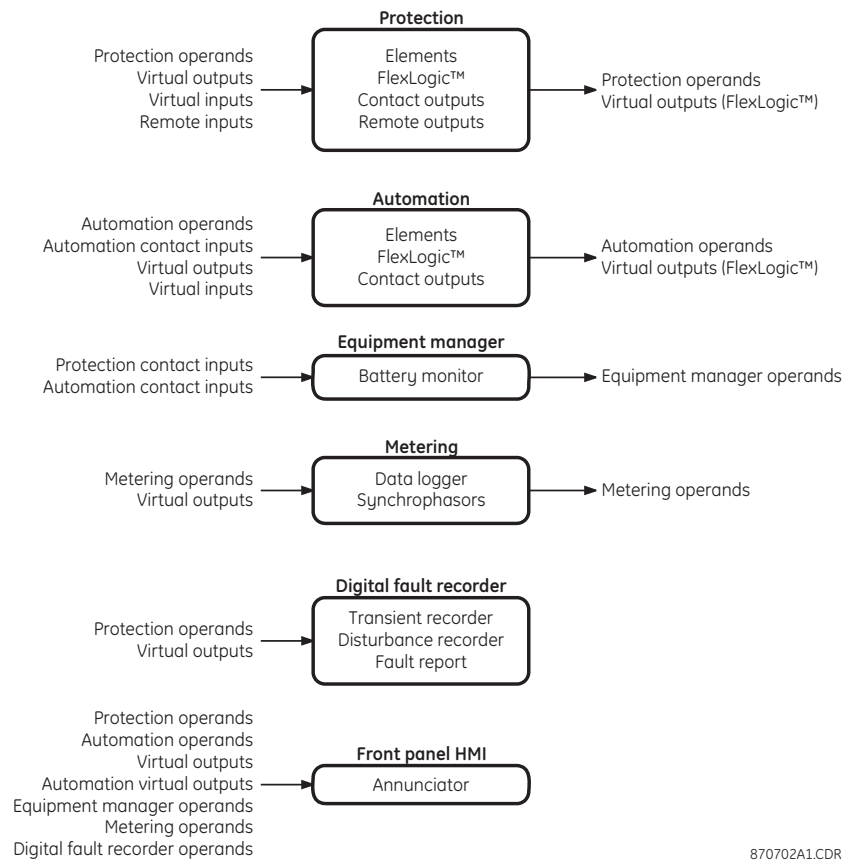
The content of each operand list is dependent on the selected order code.

The shared operands functionality expands upon this system. With this feature, an output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals can then be assigned as inputs to other functions.

For example, assume that the GND TOC1 OP protection operand is required as a signal within the automation function. This operand would then be assigned as a shared operand, and would subsequently become available to the automation function. A total of 64 operands may be assigned as shared operands within each function.

Shared equipment manager operands

Select the **Settings > Equipment Manager > Shared Operands** menu item to select the shared equipment manager operands.

Figure 289: Shared operands configuration window
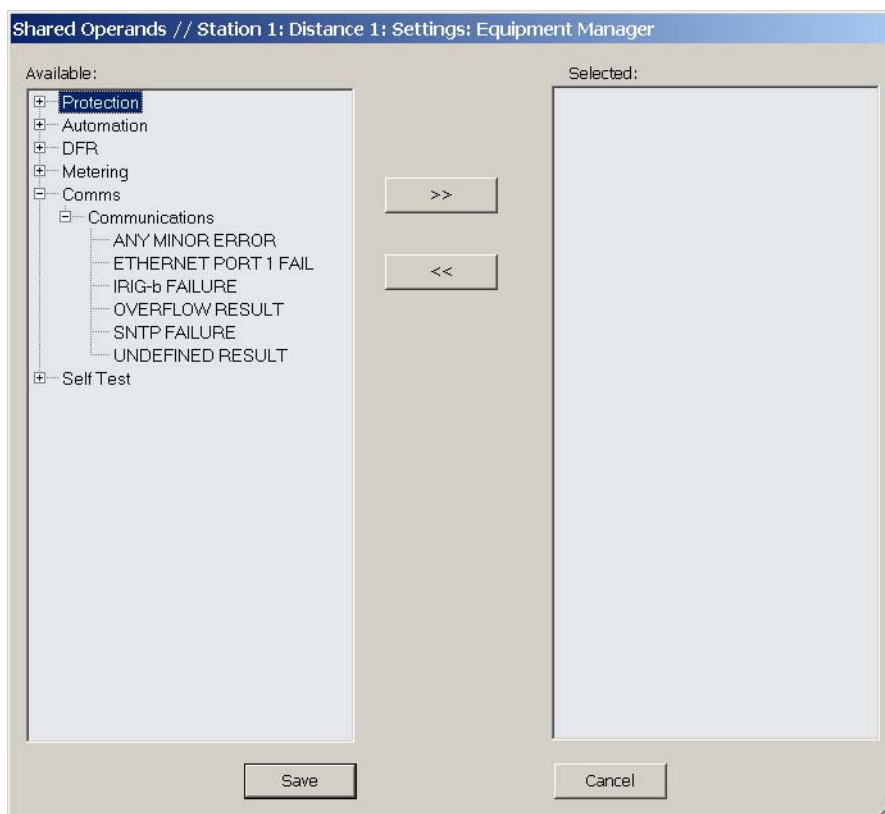
The left side of this screen displays all C90^{Plus} operands that are available to the equipment manager function as shared operands. Select any operands from the other five primary features by clicking on the **>>** button. Operands may be de-assigned as shared operands by pressing the **<<** button.

Equipment manager operands

The following equipment manager operands are available for the C90^{Plus}. They are listed alphabetically by operand syntax.

Battery monitor operands

BAT MON AC FAIL DPO .... Asserted when the AC supply failure monitor drops out.

BAT MON AC FAIL OP .... Asserted when the AC supply failure monitor operates.

BAT MON AC FAIL PKP .... Asserted when the AC supply failure monitor picks up.

BAT MON CHG FAIL DPO .... Asserted when the battery charger failure monitor drops out.

BAT MON CHG FAIL OP .... Asserted when the battery charger failure monitor operates.

BAT MON CHG FAIL PKP .... Asserted when the battery charger failure monitor picks up.

BAT MON DC GND DPO .... Asserted when the DC ground fault monitor drops out.

BAT MON DC GND OP .... Asserted when the DC ground fault monitor operates.

BAT MON DC GND PKP .... Asserted when the DC ground fault monitor picks up.

BAT MON DC TRIP DPO .... Asserted when the DC distribution breaker monitor drops out.

BAT MON DC TRIP OP .... Asserted when the DC distribution breaker monitor operates.

BAT MON DC TRIP PKP .... Asserted when the DC distribution breaker monitor picks up.

BAT MON HIGH VDC DPO .... Asserted when the battery high DC voltage monitor drops out.

BAT MON HIGH VDC OP .... Asserted when the battery high DC voltage monitor operates.

BAT MON HIGH VDC PKP.............Asserted when the battery high DC voltage monitor picks up.

BAT MON LOW VDC DPO.............Asserted when the battery low DC voltage monitor drops out.

BAT MON LOW VDC OP................Asserted when the battery low DC voltage monitor operates.

BAT MON LOW VDC PKP.............Asserted when the battery low DC voltage monitor picks up.

Breaker arcing current operands

BKR 1 ARC DPO..............................Asserted when breaker arcing 1 element drops out.

BKR 1 ARC OP.................................Asserted when breaker arcing 1 element operates.

BKR 1 MAX INT DPO......................Asserted when the maximum symmetrical interruption of the breaker arcing 1 element drops out.

BKR 1 MAX INT OP.........................Asserted when the maximum symmetrical interruption of the breaker arcing 1 element operates.

BKR 2... ....The operands listed above are available for the breaker arcing 2 element.

C90^{Plus} Controller

Chapter 9: Digital fault recorder

The digital fault recorder captures detailed information regarding abnormal occurrences in the power system. The information captured by the DFR is stored in the C90^{Plus} in non-volatile memory and can be accessed through the front panel interface. The DFR consists of four primary functions.

- A sequence of events recorder that provides a time-stamped record of the operation of breakers, protection elements, and alarms. The recording of events is enabled on a per-element basis.
- A fault report that records fault type, magnitude and duration of the fault, and the response of protection functions.
- A transient recorder that records analog and digital signals for short duration events at a high resolution.
- A disturbance recorder that records analog and digital signals for long duration events, such as power swings and voltage sags, at a resolution of one sample per cycle.

Sequence of events recorder

This sequence of events recorder provides a time-stamped record of state changes of signals monitored by the C90^{Plus}. These signals include the state of circuit breakers and disconnect switches, external alarms and indications, and any of the internal functions of the IED. The C90^{Plus} can store a total of 8192 events. Once this memory is filled, the oldest events are overwritten. The events are time-stamped with an accuracy of 1 ms.

Most C90^{Plus} elements contain an **Events** setting. When this setting is enabled, state changes for FlexLogic™ operands associated with the element are written to the sequence of events recorder. If this setting is disabled then state changes for the element are not recorded.

Front panel operation

The sequence of events record can be accessed from the front panel through the digital fault recorder (DFR) page. Using the navigations keys, the user can scroll or page through the events list. Two cursors are provided for measurement of the time difference between events.

Figure 290: Example sequence of events record

Fault report

The C90^{Plus} device supports one fault report and an associated fault locator. The signal source and trigger condition, as well as the characteristics of the line or feeder, are entered in the fault report configuration settings.

The fault report stores data, in non-volatile memory, pertinent to an event when triggered. The captured data contained in the fault report file includes:

- Fault report number.
- Device identification, programmed by the user.
- Firmware revision of the relay.
- Date and time of trigger.
- Cause of trip.
- Line and feeder identification via the name of a configured signal source.
- Active protection setting group at the time of trigger.
- Pre-fault current and voltage phasors (two cycles before 50DD disturbance associated with fault report source).
- Fault current and voltage phasors (once cycle after the trigger).
- Elements operated at the time of triggering.
- Events: nine before the trigger and seven after the trigger.

The captured data also includes the fault type and the distance to the fault location, as well as the reclose shot number (when applicable).

Fault report operation

The fault report trigger can be any FlexLogic™ operand, but in most applications it is expected to be the same operand that is used to drive an output relay to trip a breaker (usually a virtual output). To prevent the overwriting of fault events, the disturbance detector should not be used to trigger a fault report. A FAULT RPT TRIG event is automatically created when the report is triggered.

If a number of protection elements are ORed to create a fault report trigger, the first operation of any element causing the OR gate output to become high triggers a fault report. However, If other elements operate during the fault and the first operated element has not been reset (the OR gate output is still high), the fault report is not triggered again. Considering the reset time of protection elements, there is very little chance that fault report can be triggered twice in this manner.

Each fault report is stored as a file, and the relay capacity is fifteen (15) files. An sixteenth (16th) trigger overwrites the oldest file. Individual fault report features store their files in the same memory space. The sixteenth report will overwrite the first one regardless which fault report feature produced the sixteenth and the first records.

The EnerVista UR^{Plus} Setup software is required to view all captured data. The front panel interface can be used to view the following information:

- Prefault and fault current and voltage phasors.
- Active setting group.
- Date and time of trigger.
- Reclose shot number.
- Fault type.
- Distance location of the fault.
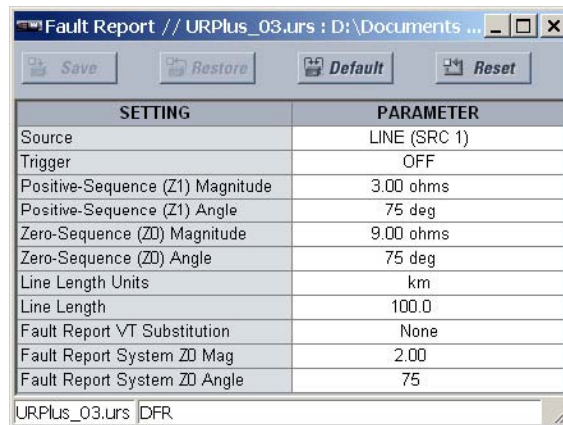
Fault type determination

Fault type determination is required for calculation of fault location. The fault determination algorithm uses the angle between the negative-sequence and positive-sequence components of the relay currents. To improve accuracy and speed of operation, the fault components of the currents are used. That is, the pre-fault phasors are subtracted from the measured current phasors. In addition to the angle relationships, certain extra checks are performed on magnitudes of the negative-sequence and zero-sequence currents.

Fault report settings

Select the **Settings > DFR > Fault Report** menu item to open the fault report configuration window.

Figure 291: Fault report configuration settings

The following settings are available for the fault report.

Fault Report Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: SRC1

This setting selects the source for input currents, voltages, and disturbance detection.

Fault Report Trigger

Range: any FlexLogic™ operand

Default: OFF

This setting assigns the FlexLogic™ operand representing the protection elements requiring operational fault location calculations. The distance to fault calculations are initiated by this signal.

Positive-Sequence (Z1) Magnitude

Range: 0.01 to 250.00 ohms in steps of 0.01

Default: 3.00 ohms

This setting specifies the magnitude of positive-sequence impedance of the transmission line or feeder in secondary ohms.

Positive-Sequence (Z1) Angle

Range: 25 to 90° in steps of 1

Default: 75°

This setting specifies the angle of positive-sequence impedance of the transmission line or feeder in secondary ohms.

Zero-Sequence (Z0) Magnitude

Range: 0.01 to 650.00 ohms in steps of 0.01

Default: 9.00 ohms

This setting specifies the magnitude of zero-sequence impedance of the transmission line or feeder in secondary ohms.

Zero-Sequence (Z0) Angle

Range: 25 to 90° in steps of 1

Default: 75°

This setting specifies the angle of zero-sequence impedance of the transmission line or feeder in secondary ohms.

Line Length Units

Range: km, miles
Default: km

This setting selects the units used for fault location calculations.

Line Length

Range: 0.0 to 2000.0 in steps of 0.1
Default: 100.0

This setting specifies the length of the transmission line or feeder in the defined line length units.

Fault Report VT Substitution

Range: None, I0, V0
Default: None

Program this setting to "None" if the C90^{Plus} is fed from wye-connected VTs. If delta-connected VTs are used, and the C90^{Plus} is supplied with the neutral (3V0) voltage, set to "V0". The method is still exact, as the fault locator would combine the line-to-line voltage measurements with the neutral voltage measurement to re-create the line-to-ground voltages. It required to configure the delta and neutral voltages under the source indicated as input for the fault report. Also, the C90^{Plus} will check if the auxiliary signal configured is marked as "Vn" by the user (under VT setup), and inhibit the fault location if the auxiliary signal is labeled differently.

If the broken-delta neutral voltage is not available to the relay, an approximation is possible by assuming the missing zero-sequence voltage to be an inverted voltage drop produced by the zero-sequence current and the user-specified equivalent zero-sequence system impedance behind the relay: $V0 = -Z0 \times I0$. In order to enable this mode of operation, set the value to "I0".

Fault Report System Z0 Magnitude

Range: 0.01 to 650.00 ohms in steps of 0.01
Default: 2.00 ohms

This setting is used only when the **Fault Report VT Substitution** value is "I0". The magnitude is to be entered in secondary ohms. This impedance is an average system equivalent behind the relay. It can be calculated as zero-sequence Thevenin impedance at the local bus with the protected line/feeder disconnected. The method is accurate only if this setting matches perfectly the actual system impedance during the fault. If the system exhibits too much variability, this approach is questionable and the fault location results for single-line-to-ground faults shall be trusted with accordingly. It should be kept in mind that grounding points in vicinity of the installation impact the system zero-sequence impedance (grounded loads, reactors, zig-zag transformers, shunt capacitor banks, etc.).

Fault Report System Z0 Angle

Range: 25 to 90° in steps of 1
Default: 75°

This setting is used only when the **Fault Report VT Substitution** value is "I0" and represents the corresponding angle for the **Fault Report System Z0 Magnitude** setting above.

The fault locator logic is shown below.

Figure 292: Fault locator scheme logic

870095A1.CDR
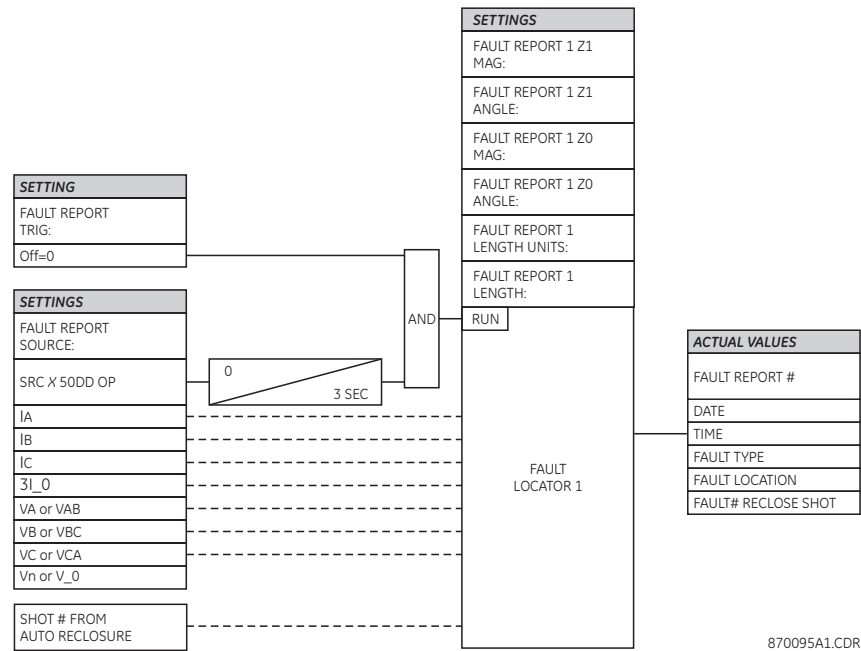
Transient recorder

The transient recorder is designed to capture short duration events, such as faults at a high resolution. Under normal operation, the transient recorder continuously captures pre-fault data and stores this data in memory. When a trigger is received, the transient recorder captures the data during the period of the fault. Both the pre-fault and fault data are stored as records in non-volatile memory within the C90^{Plus}.

The transient recorder captures the instantaneous values of all voltage and current signals connected to the C90^{Plus}. In addition, the user can configure digital and analog channels, each of which can be used to trigger or re-trigger the transient recorder. A re-trigger captures an additional record but with no pre-fault data. Triggered and re-triggered records are merged into a single file, and the maximum number of re-triggers for a particular fault is user-programmable.

Figure 293: Trigger and re-trigger sequence
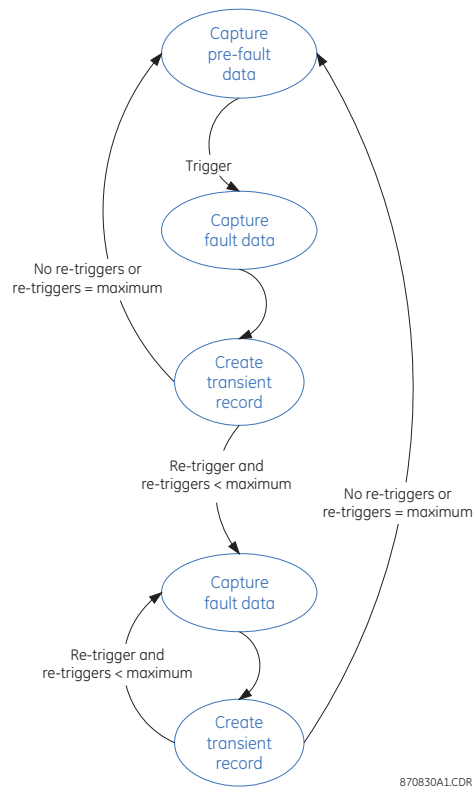
The length of a transient record is also user-configurable. The number of transient records stored by the C90^{Plus} is a function of the record length, the time-resolution of the recording, and of the number of configured channels. The C90^{Plus} automatically calculates the number of transient records based on the user-defined setting values.

The transient recorder has two storage modes: protected and automatic overwrite. When the memory is filled, either no new records are written to memory (protected mode) or the oldest record is overwritten (automatic overwrite mode).

The C90^{Plus} contains a finite amount of memory for record storage. The following table shows how the transient recorder configuration affects the number of available records.

Table 36: Transient records stored by the C90^{Plus} (examples)

Records	Sampling rate	Digital channels	Analog channels	Record length
8	256 samples/cycle	128	16	57
24	256 samples/cycle	128	16	22
48	256 samples/cycle	128	16	11
8	128 samples/cycle	128	16	104
24	128 samples/cycle	128	16	40
48	128 samples/cycle	128	16	20
20	64 samples/cycle	128	16	80
64	64 samples/cycle	128	16	26
24	32 samples/cycle	64	8	135
64	32 samples/cycle	64	8	53
41	16 samples/cycle	64	8	124
64	16 samples/cycle	64	8	81

Front panel indications

The digital fault reporter summary screen provides an indication that the transient recorder is ready to capture data and has memory available. In protected mode, the **Ready to Capture** indication is green when:

- The transient recorder is enabled, and
- the block trigger input is not asserted, and
- memory is available.

Otherwise the indication is red. In automatic overwrite mode, the **Ready to Capture** indication is green when:

- The transient recorder is enabled, and
- the block trigger input is not asserted.

The **Memory Available** indication is green when less than 80% of the memory has been filled. It is yellow when the amount of memory filled is between 80% and 99%, and it is red if 100% of the memory is filled.

Figure 294: Digital fault reporter summary screen
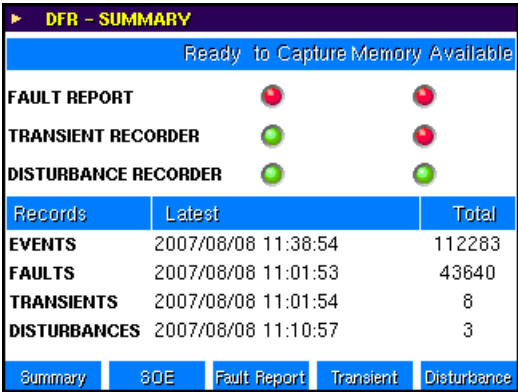
The transient recorder screen shows the individual records stored on the device. This screen also has an indication of any active triggers (red indication) for the transient recorders. If a continuous trigger is permanently active, it will not fill the memory of the recorder. After the first record is generated it is effectively disabled by the trigger logic; however, its status will be displayed on this screen. The user can also force triggering of the recorder from this screen.

Figure 295: Transient recorder screen
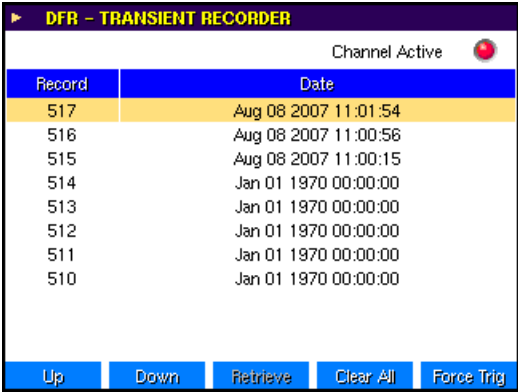
Transient recorder settings

Select the **Settings > DFR > Transient Record** menu item to open the transient recorder function configuration window.

Figure 296: Transient recorder function settings
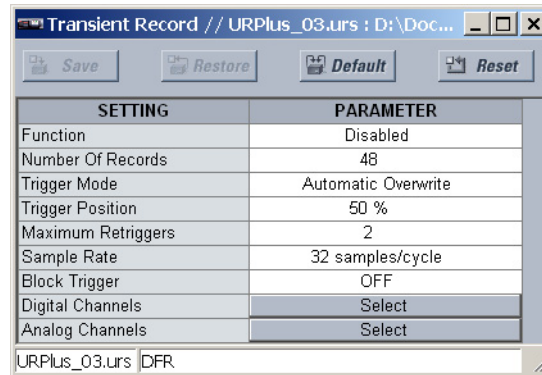
The following settings are available.

Function

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the transient recorder function.

Number Of Records

Range: 1 to 64 in steps of 1
Default: 48

This setting specifies the total number of transient records that can be stored in the C90^{Plus}. A larger setting results in a shorter record length, and *vice-versa*.

Trigger Mode

Range: Automatic Overwrite, Protected
Default: Automatic Overwrite

If this setting is selected as "Automatic Overwrite", then the oldest record will be overwritten once the number of stored records reaches the setting value. If this setting is "Protected", then no new records are stored once the number of records reaches the setting value.

Trigger Position

Range: 1 to 100% in steps of 1
Default: 50%

This setting specifies the amount of pre-trigger data stored in a record expressed as a percentage of record length.

Maximum Re-Triggers

Range: 1 to 4 in steps of 1
Default: 2

This setting selects the maximum number of re-trigger records that can be generated for an event. The value is limited to one less than the number of records that can be stored (up to a maximum of four records).

Sample Rate

Range: 16, 32, 64, 128, or 256 samples per cycle, or OFF

Default: 32

This setting selects the time-resolution of the transient record. A larger setting necessarily results in a shorter record length.

Block Trigger

Range: any FlexLogic™ operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, all triggers to the transient recorder are inhibited.

NOTE

When changes are made to the transient recorder settings, all existing transient records will be cleared!

The transient recorder trigger logic is shown below.

Figure 297: Transient recorder trigger logic
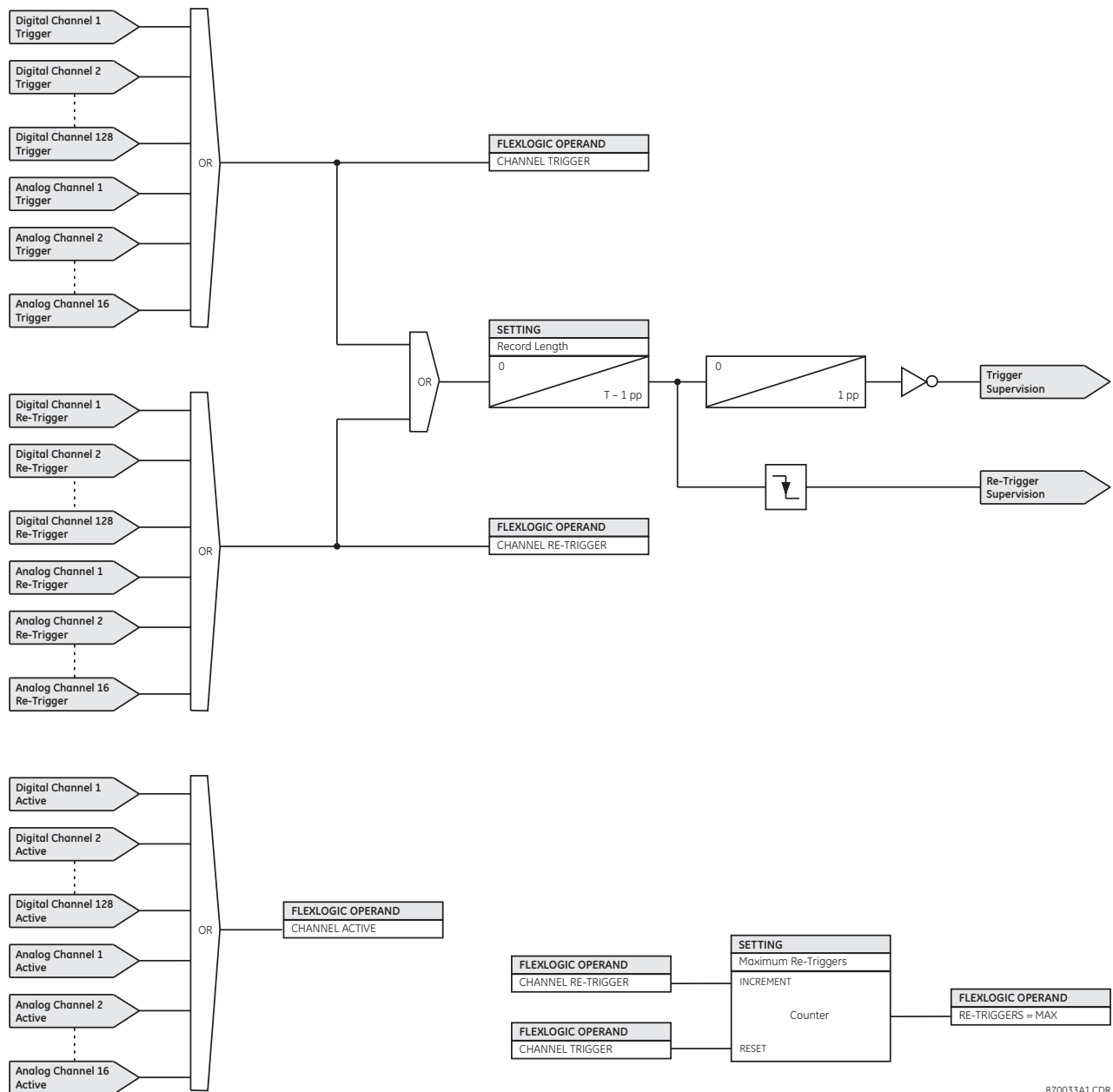
Transient recorder digital channels

Up to 128 digital channels may be assigned to the transient recorder. Each channel may be individually configured by clicking the digital channels **Select** button in the transient recorder window to open the transient recorder digital channels window.

Figure 298: Digital channel configuration settings
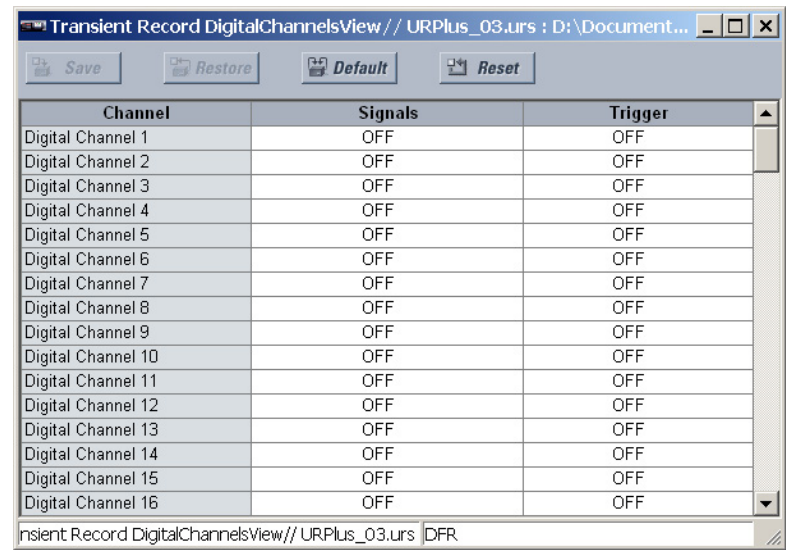
The following settings are available for each digital channel.

Signals

Range: any FlexLogic™ operand or shared operand
Default: OFF

This setting specifies an operand to use as a transient recorder digital channel. The pull-down list of available signals is populated with enabled protection functions. Selected operands will be automatically assigned as channels and as triggers according to their importance and may be de-assigned by the user.

Table 37: Ground time overcurrent 1 signal example

Available signals (operands)	Operand assigned as a...	
	Digital channel	Trigger
GND TOC1 DPO	Yes	No
GND TOC1 OP	Yes	Yes
GND TOC1 PKP	Yes	No

Trigger

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only
Default: Off

This setting selects the trigger function of the digital channel. When set to "Trigger Only" or "Trigger/Re-Trigger", the transient recorder will initiate data capture for an OFF-ON transition of the channel signal. The resulting record will contain both pre-fault and fault data and the channel must return to the off state before it can generate a subsequent trigger.

When set to "Trigger/Re-Trigger" or "Re-Trigger Only", the transient recorder will be re-triggered if the signal is still asserted at the end of the trigger period. The resulting record will contain fault data only. A re-trigger is re-generated at the end of a transient record if the signal is still asserted and if the number of re-triggers is less than the value specified by the **Maximum Re-Triggers** setting.

Figure 299: Digital channel triggering logic
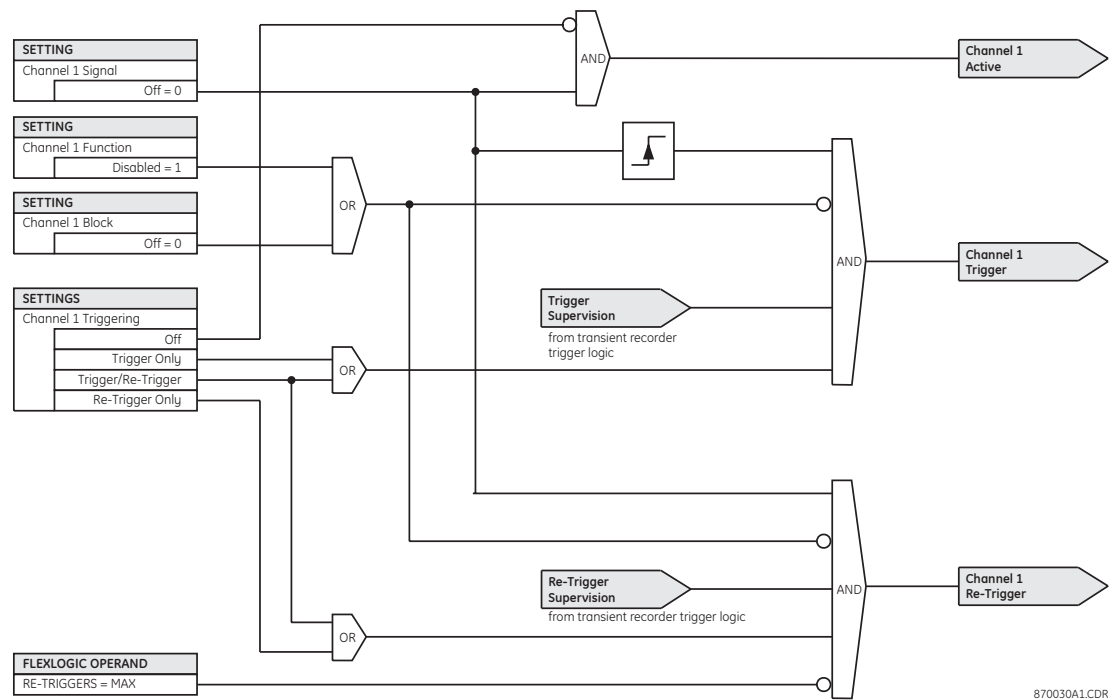
Transient recorder analog channels

Up to 16 analog channels may be assigned to the transient recorder. Each channel may be individually configured by clicking the analog channel **Select** button in the transient recorder window to open the transient recorder analog channels window.

Figure 300: Analog channel configuration settings

The following settings are available for each analog channel.

Available Signal

Range: any FlexAnalog™ quantity

Default: as shown above

This setting selects the FlexAnalog™ value to be recorded for the channel. The size of each record depends in part on the number of parameters selected. Channels set to "Off" are ignored.

High Triggering

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only
Default: Off

This setting selects the high triggering function for the analog channel. When set to "Trigger Only" or "Trigger/Re-Trigger", the transient recorder will initiate data capture when the magnitude of the signal is greater than the value of the **High Pickup** setting. The resulting record will contain pre-fault and fault data. The channel must return to the OFF state before it can generate a subsequent trigger.

When set to "Re-Trigger Only" or "Trigger/Re-Trigger", the transient recorder will be re-triggered when the magnitude of the signal is greater than the value of the **High Pickup** setting. The resulting record will contain fault data only. A re-trigger is again generated at the end of a transient record if the magnitude is greater than the **High Pickup** and if the number of re-triggers is less than the **Maximum Re-Trigger** setting.

High Pickup

Range: 0.0 to 1000000.0 in steps of 0.1
Default: 1000.0

This setting specifies the magnitude of the signal required to produce a trigger or re-trigger. This setting is expressed in primary values. The units are dependent on the value of the **Available Signal** setting.

Low Triggering

Range: Enabled, Disabled
Default: Disabled

This setting selects the low triggering function for the analog channel. When set to "Trigger Only" or "Trigger/Re-Trigger", the transient recorder will initiate data capture when the magnitude of the signal is less than the value of the **Low Pickup** setting. The resulting record will contain both pre-fault and fault data. The channel must return to the off state before it can generate a subsequent trigger.

When set to "Trigger/Re-Trigger" or "Trigger Only", the transient recorder will be re-triggered when the magnitude of the signal is less than the value of the **Low Pickup** setting. The resulting transient record will contain fault data only. A re-trigger is generated again at the end of the record if the magnitude is less than the **Low Pickup** and if the number of re-triggers is less than the **Maximum Re-Trigger** setting.

Low Pickup

Range: 0.0 to 1000000.0 in steps of 0.1
Default: 1000.0

This setting specifies the magnitude of the signal required to produce a trigger or re-trigger. This setting is expressed in primary values. The units are dependent on the value of the **Available Signal** setting.

Block Trigger

Range: any FlexLogic™ operand or shared operand
Default: OFF

When the operand assigned to this setting is asserted, all high and low triggers to the specified analog channel are inhibited.

Figure 301: Analog channel trigger logic
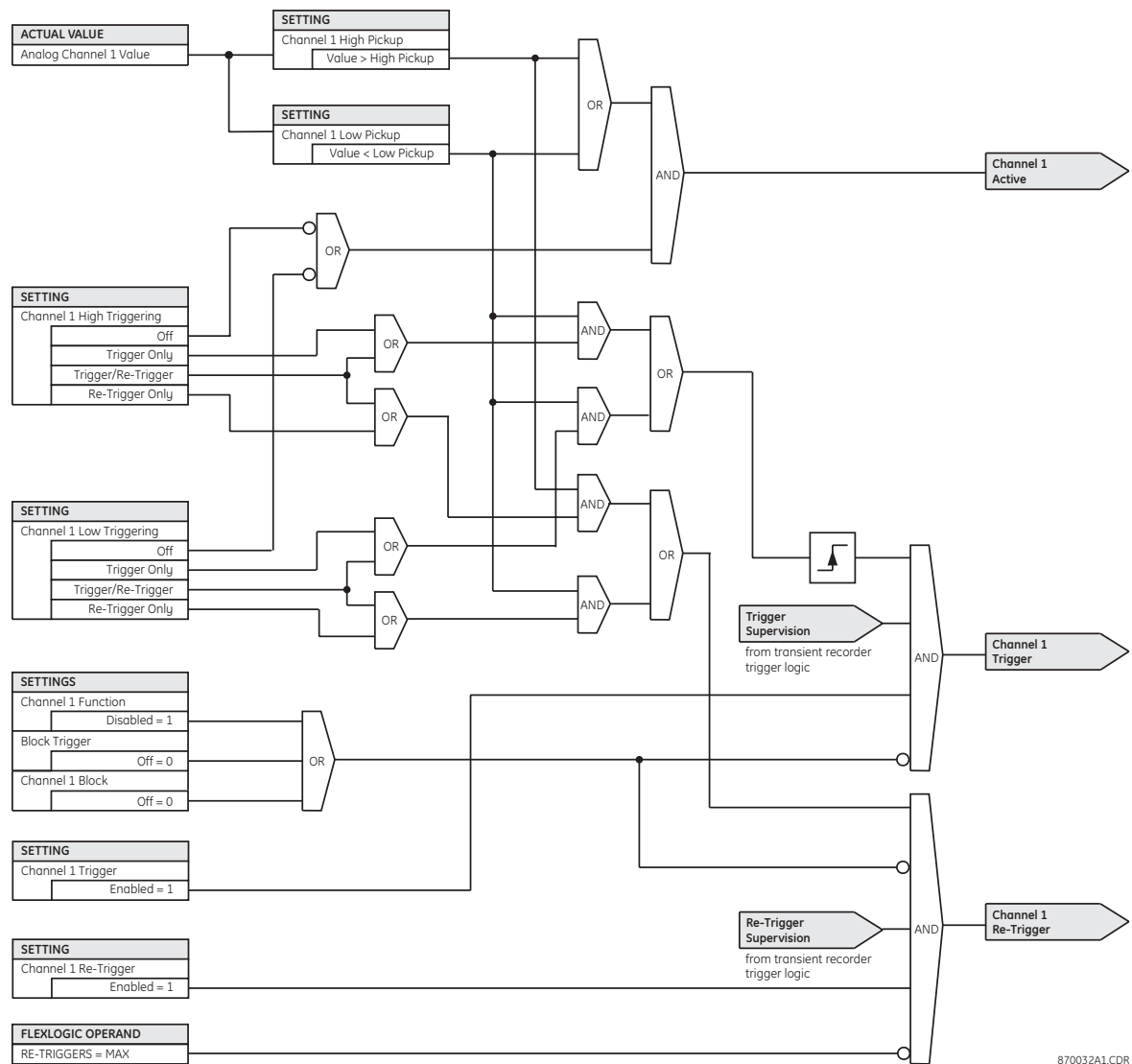
Disturbance recorder

The disturbance recorder is designed to capture short duration events, such as faults at a high resolution. Under normal operation, the disturbance recorder is continuously capturing pre-fault data and storing this data in memory. When a trigger is received, the disturbance recorder will capture the data during the period of the fault. Both the pre-fault and fault data are stored as a record in non-volatile memory within the C90^{Plus}.

The disturbance recorder captures the instantaneous values of all voltage and current signals connected to the C90^{Plus}. In addition, the user can configure digital and analog channels, each of which can be used to trigger or re-trigger the disturbance recorder. A re-trigger captures an additional record but with no pre-fault data. Triggered and re-triggered records are merged into a single file, and the maximum number of re-triggers for a particular fault is user-programmable.

Figure 302: Trigger and re-trigger sequence
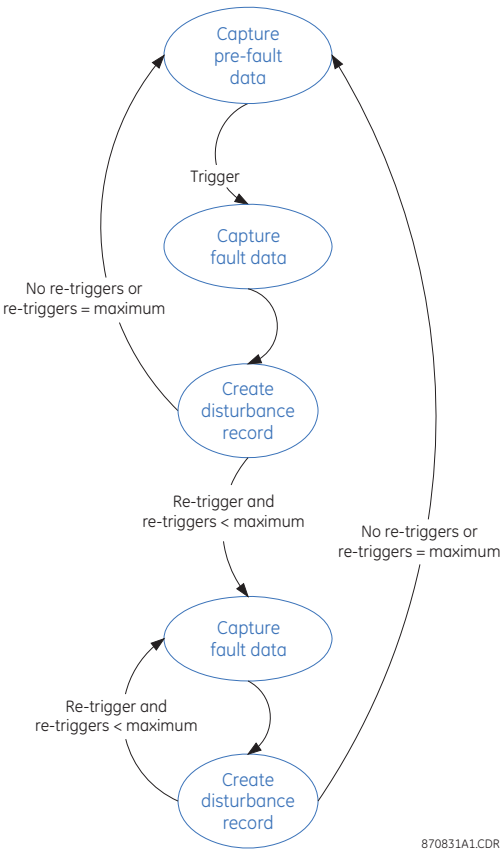
The length of a disturbance record is also user-configurable. The number of disturbance records stored by the C90^{Plus} can store is a function of the record length, the time resolution of the recording, and of the number of configured channels. The C90^{Plus} automatically calculates the number of records based on user settings.

Table 38: Disturbance records stored by the C90^{Plus}

Records	Digital channels	Analog channels	Record length
1	32	64	2393
5	32	64	1025
10	32	64	598
1	32	32	4520
10	32	32	1129
20	32	32	616
2	32	16	8136
5	32	16	3486
10	32	16	2033
20	32	16	1108
5	32	8	5811
10	32	8	3389
20	32	8	1848
30	32	8	1270

The recorder has two storage modes: protected and automatic overwrite. When the memory is filled, either no new records are written to memory (protected mode) or the oldest record is overwritten (automatic overwrite mode).

Front panel indications

The digital fault reporter summary screen provides an indication that the disturbance recorder is ready to capture data and has memory available. In protected mode, the **Ready to Capture** indication is green when:

- The disturbance recorder is enabled, and

- the block trigger input is not asserted, and

- memory is available.

Otherwise the indication is red. In automatic overwrite mode, the **Ready to Capture** indication is green when:

- The disturbance recorder is enabled and

- the block trigger input is not asserted.

The **Memory Available** indication is green when less than 80% of the memory has been filled. It is yellow when the amount of memory filled is between 80% and 99%, and it is red if 100% of the memory is filled.

Figure 303: Digital fault reporter summary screen

The disturbance recorder screen shows the individual records stored on the device. This screen also has an indication of any active triggers (red indication) for the disturbance recorders. If a continuous trigger is permanently active, it will not fill the memory of the recorder. After the first record is generated it is effectively disabled by the trigger logic; however, its status will be displayed on this screen. The user can also force triggering of the recorder from this screen.

Figure 304: Disturbance recorder screen
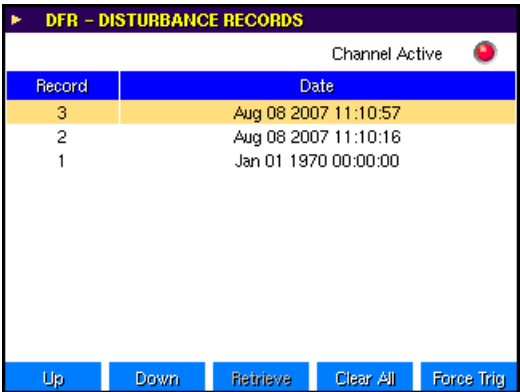
Disturbance recorder function

Select the **Settings > DFR > Disturbance Record** menu item to open the disturbance recorder function configuration window.

Figure 305: Disturbance recorder function settings
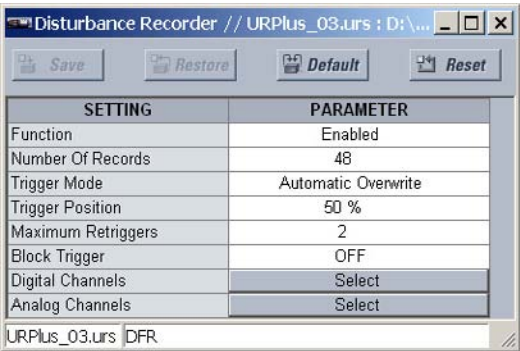
The following settings are available.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the disturbance recorder function.

Number of Records

Range: 1 to 64 in steps of 1
Default: 48

This setting specifies the total number of disturbance records that can be stored in the C90^{Plus}. A larger setting results in a shorter record length, and *vice-versa*.

Trigger Mode

Range: Automatic Overwrite, Protected
Default: Automatic Overwrite

If this setting value is "Automatic Overwrite", then the oldest disturbance record will be overwritten once the number of stored records reaches the setting value. If this value is "Protected", then no new disturbance record are stored once the number of records reaches the setting value.

Trigger Position

Range: 1 to 100% in steps of 1

Default: 50%

This setting specifies the amount of pre-trigger data stored in a disturbance record expressed as a percentage of the disturbance record length.

Maximum Re-Triggers

Range: 1 to 4 in steps of 1

Default: 2

This setting selects the maximum number of re-trigger records that can be generated for a disturbance event. The value is limited to one less than the number of records that can be stored (up to a maximum of four records).

Block Trigger

Range: any FlexLogic™ operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, all triggers to the disturbance recorder are inhibited.

When changes are made to the disturbance recorder settings, all existing disturbance records will be cleared!

NOTE

Figure 306: Disturbance recorder trigger logic
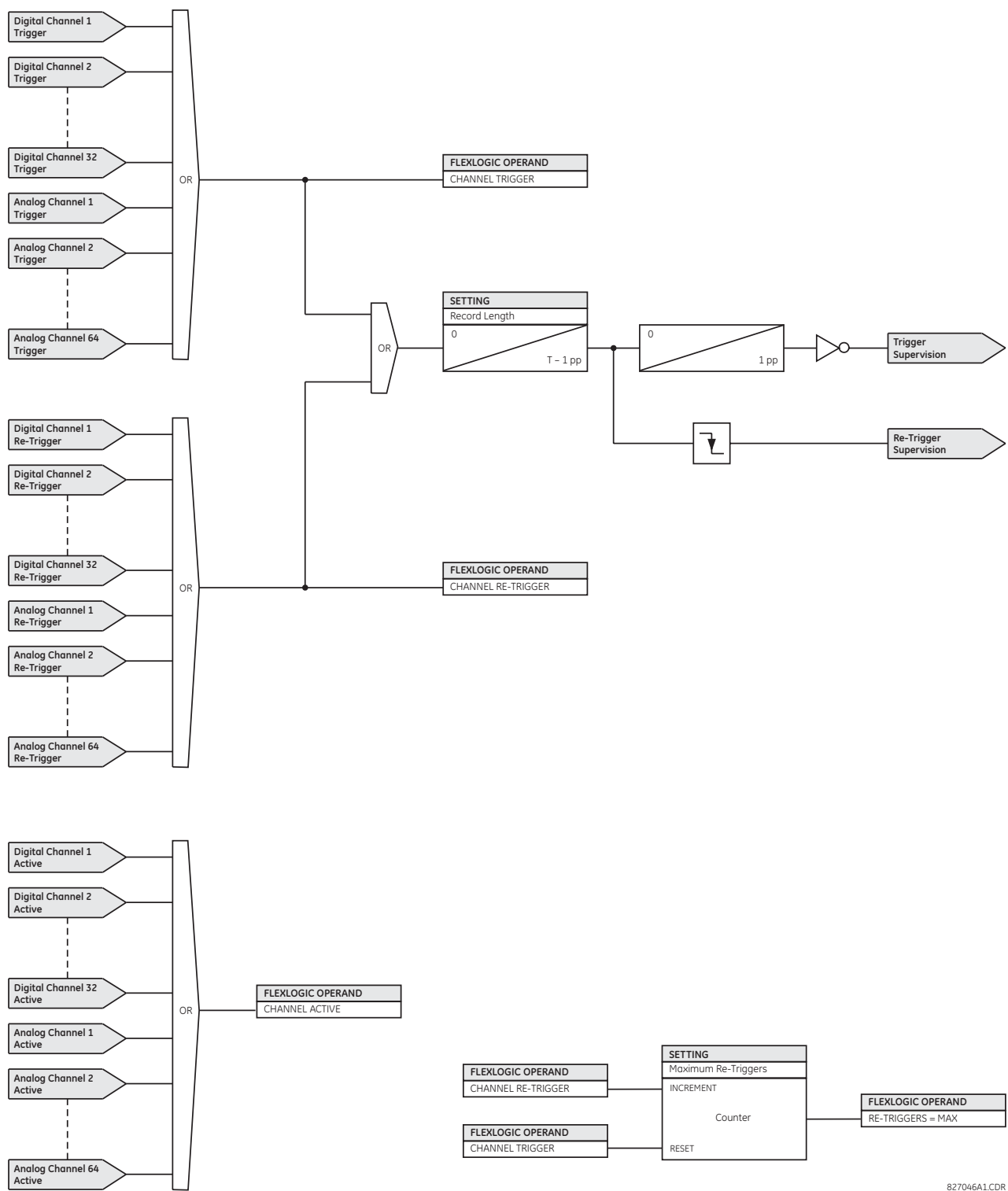
Disturbance recorder digital channels

Up to 32 digital channels may be assigned to the disturbance recorder. Each channel may be individually configured by clicking the digital channels **Select** button in the disturbance recorder window to open the disturbance recorder digital channels window.

Figure 307: Digital channel configuration settings
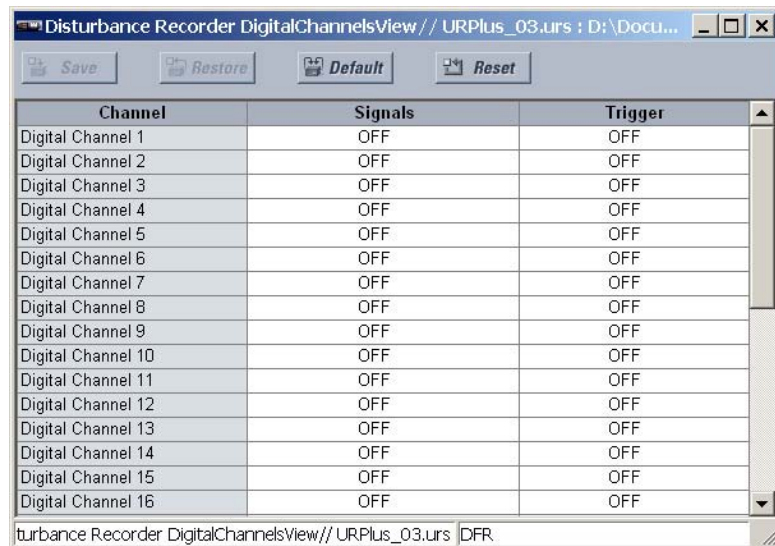
The following settings are available for each disturbance recorder digital channel.

Signals
Range: any FlexLogic™ operand or shared operand
Default: Off

This setting selects an operand to act as a trigger for the digital channel.

The pull-down list of available signals is populated according to the protection functions that have been enabled. Selected signals will be automatically assigned as channels and as triggers according to their importance. These signals may be deactivated by the user. For example, if ground time overcurrent 1 has been enabled, then the following assignments are made.

Table 39: Example disturbance recorder signal assignment

Available signals	Assignment	
	Digital channel	Trigger
GND TOC1 DPO	Yes	No
GND TOC1 OP	Yes	Yes
GND TOC1 PKP	Yes	No

Trigger
Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only
Default: Off

This setting selects the trigger function of the digital channel. When set to "Trigger Only" or "Trigger/Re-Trigger", the disturbance recorder will initiate data capture for an OFF-ON transition of the channel signal. The resulting record will contain both pre-fault and fault data and the channel must return to the off state before it can generate a subsequent trigger.

When set to "Trigger/Re-Trigger" or "Re-Trigger Only", the disturbance recorder will be re-triggered if the signal is still asserted at the end of the trigger period. The resulting record will contain fault data only. A re-trigger is re-generated at the end of a disturbance record if the signal is still asserted and if the number of re-triggers is less than the value specified by the **Maximum Re-Triggers** setting.

Figure 308: Disturbance recorder digital channels input logic
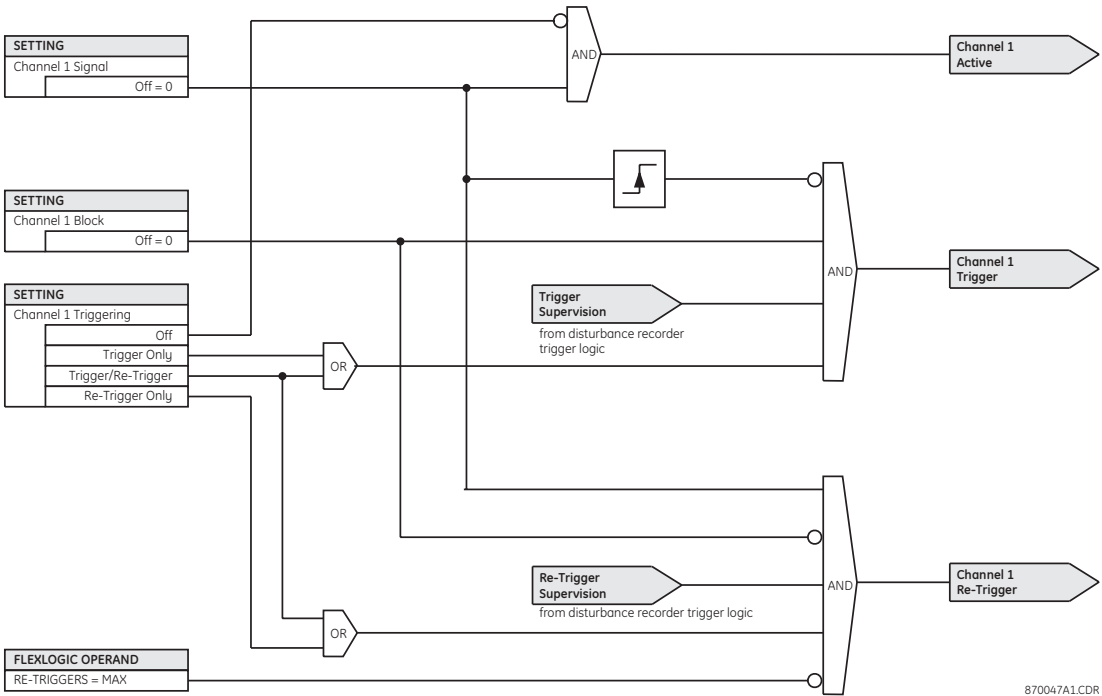
Disturbance recorder analog channels

Up to 64 analog channels may be assigned to the transient recorder. Each channel may be individually configured by clicking the analog channel **Select** button in the disturbance recorder window to open the disturbance recorder analog channels window.

Figure 309: Analog channel configuration settings

The following settings are available for each disturbance recorder analog channel.

Signal

Range: any FlexAnalog™ quantity

Default: Off

This setting specifies the FlexAnalog™ quantity to be recorded for the channel. The size of each disturbance record depends in part on the number of parameters selected. Parameters set to "Off" are ignored.

High Triggering

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only

Default: Off

This setting selects the high triggering function for the analog channel. When set to "Trigger Only" or "Trigger/Re-Trigger", the disturbance recorder will initiate data capture when the magnitude of the signal is greater than the value of the **High Pickup** setting. The resulting record will contain pre-fault and fault data. The channel must return to the OFF state before it can generate a subsequent trigger.

When set to "Re-Trigger Only" or "Trigger/Re-Trigger", the disturbance recorder will be re-triggered when the magnitude of the signal is greater than the value of the **High Pickup** setting. The resulting record will contain fault data only. A re-trigger is again generated at the end of a disturbance record if the magnitude is greater than the **High Pickup** and if the number of re-triggers is less than the **Maximum Re-Trigger** setting.

High Pickup

Range: 0.0 to 1000000.0

Default: 1000.0

This setting specifies the magnitude of the signal required to produce a trigger or re-trigger. This setting is expressed in primary values. The units are dependent on the value of the **Available Signal** setting.

Low Triggering

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only

Default: Off

This setting selects the low triggering function for the analog channel. When set to "Trigger Only" or "Trigger/Re-Trigger", the disturbance recorder will initiate data capture when the magnitude of the signal is less than the value of the **Low Pickup** setting. The resulting record will contain both pre-fault and fault data. The channel must return to the off state before it can generate a subsequent trigger.

When set to "Trigger/Re-Trigger" or "Trigger Only", the disturbance recorder will be re-triggered when the magnitude of the signal is less than the value of the **Low Pickup** setting. The resulting disturbance record will contain fault data only. A re-trigger is generated again at the end of the record if the magnitude is less than the **Low Pickup** and if the number of re-triggers is less than the **Maximum Re-Trigger** setting.

Low Pickup

Range: 0.0 to 1000000.0

Default: 1000.0

This setting specifies the magnitude of the signal required to produce a trigger or re-trigger. This setting is expressed in primary values. The units are dependent on the value of the **Available Signal** setting.

Block Trigger

Range: any FlexLogic™ operand

Default: Off

The FlexLogic™ operand assigned to this setting blocks triggering of the disturbance recorder analog channel.

Figure 310: Analog channel trigger logic

Shared operands

The EnerVista UR^{Plus} Setup software groups the C90^{Plus} system into the following six primary functions. Each function has its own setting parameters and each generates its own outputs in the form of operands.

- Protection
- Automation
- Metering
- Digital fault recorder (DFR)
- Equipment manager
- Front panel interface (HMI)

However, it is often desirable for an output from an element within one function can be available to an element within another function. For instance, it may useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available as to each function as shown below.

Figure 311: Default operand list by function
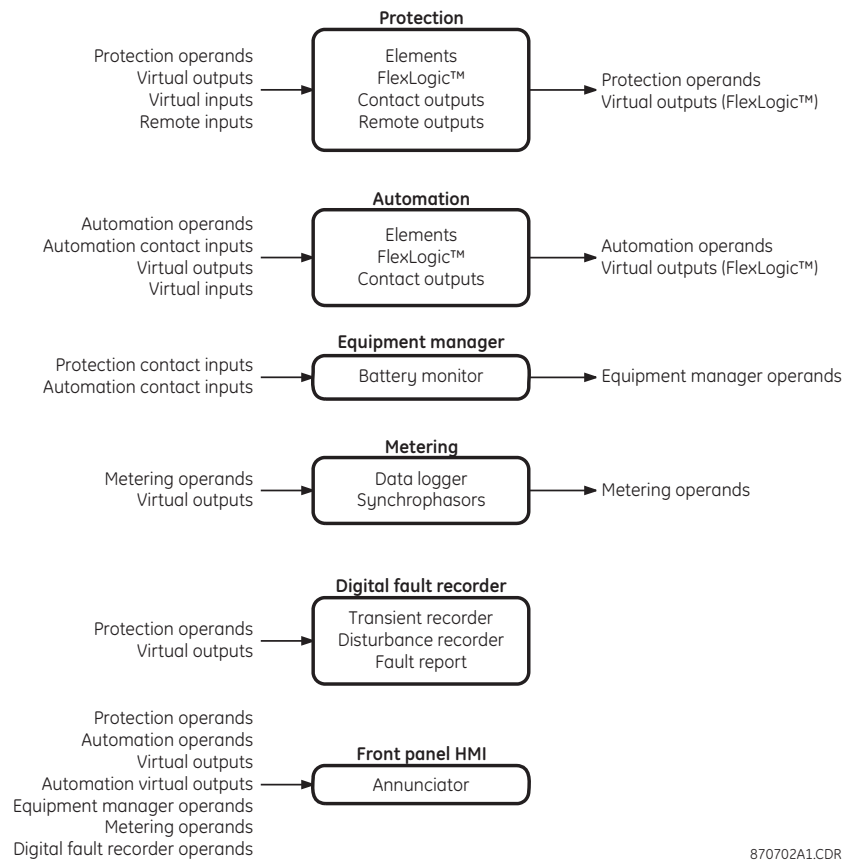
The content of each operand list is dependent on the selected order code.

The shared operands functionality expands upon this system. With this feature, an output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals can then be assigned as inputs to other functions.

For example, assume that the GND TOC1 OP protection operand is required as a signal within the automation function. This operand would then be assigned as a shared operand, and would subsequently become available to the automation function. A total of 64 operands may be assigned as shared operands within each function.

Shared digital fault recorder operands

Select the **Settings > DFR > Shared Operands** menu item to select the shared digital fault recorder operands.

Figure 312: Shared operands configuration window
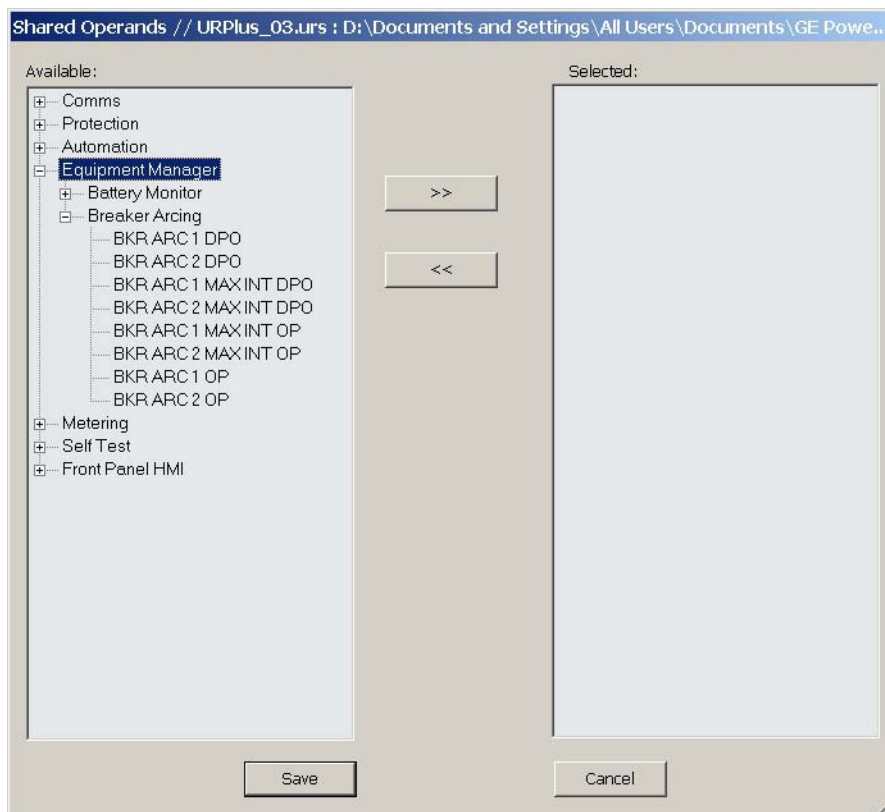
The left side of this screen displays all C90^{Plus} operands that are available to the digital fault recorder function as shared operands. Select any operands from the other five primary features by clicking on the **>>** button. Operands may be de-assigned as shared operands by pressing the **<<** button.

C90^{Plus} Controller

Chapter 10: Metering

This section describes how to program the C90^{Plus} metering features.

Metering source

Select the **Settings > Metering > Metering Source** menu item to open the metering source configuration window.

Figure 313: Metering source configuration settings

The following setting is available.

Name

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
Default: LINE (SRC 1)

This setting selects the source to use for calculating metered quantities available through the front panel interface. For breaker-and-a-half schemes, select a source which summates the current from both breakers to measure the total load on the transmission line.

Phasor measurement unit

The phasor measurement unit menus allow specifying basic parameters of the measurements process such as signal source, ID and station name, calibration data, triggering, recording, and content for transmission on each of the supported phasor measurement unit ports. The reporting ports menus allow specifying the content and rate

of reporting on each of the supported ports. The phasor measurement unit settings are organized in five logical groups: basic communication, calibration, communications, triggering, and recording.

Phasor measurement unit configuration

Select the **Settings > Metering > Phasor Measurement Unit > Phasor Measurement Unit > Basic Configuration** menu item to open the phasor measurement unit configuration window.

Figure 314: Phasor measurement unit configuration settings
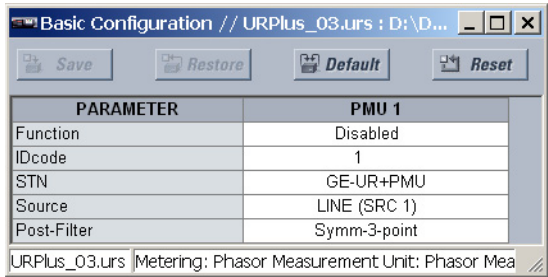
The settings allow for the configuration of basic synchrophasor data, such as functions, source settings, and names. The following settings are available for each phasor measurement unit.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables the phasor measurement unit functionality. Any associated functions (such as the recorder or triggering comparators) will not function if this setting is "Disabled". Use the command frame to force the communication portion of the feature to start/stop transmission of data. When the transmission is turned off, the phasor measurement unit is fully operational in terms of calculating and recording the phasors.

IDcode

Range: 1 to 65534 in steps of 1

Default: 1

This setting assigns a numerical ID to the phasor measurement unit. It corresponds to the IDCODE field of the data, configuration, header, and command frames of the C37.118 protocol. The phasor measurement unit uses this value when sending data, configuration, and header frames and responds to this value when receiving the command frame.

STN

Range: 16 alphanumeric characters

Default: GE-UR+PMU

This setting assigns an alphanumeric ID to the phasor measurement unit station. It corresponds to the STN field of the configuration frame of the C37.118 protocol. This value is a 16-character ASCII string as per the C37.118 standard.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting specifies one of the available C90^Plus signal sources for processing in the phasor measurement unit. Note that any combination of voltages and currents can be configured as a source. The current channels could be configured as sums of physically connected currents. This facilitates phasor measurement unit applications in breaker-and-a-half, ring-bus, and similar arrangements. The phase measurement unit feature calculates voltage phasors for actual voltage (A, B, C, and auxiliary) and current (A, B, C, and ground) channels of the source, as well as symmetrical components (0, 1, and 2) of both voltages and currents. When configuring communication and recording features of the phasor measurement unit, the user could select – from the above superset – the content to be sent out or recorded.

Post-Filter

Range: None, Symm-3-point, Symm-5-point, Symm-7-point

Default: Symm-3-point

This setting specifies amount of post-filtering applied to raw synchrophasor measurements. The raw measurements are produced at the rate of nominal system frequency using one-cycle data windows. This setting is provided to deal with interfering frequencies and to balance speed and accuracy of synchrophasor measurements for different applications. The following filtering choices are available.
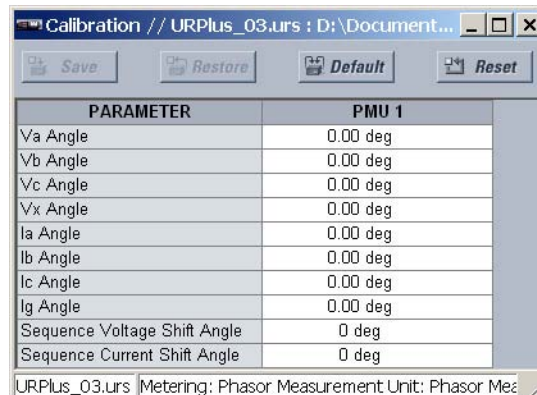
– None: No post-filtering.

– Symm-3-point: Symmetrical three-point filter (one historical point, one present point, one future point).

– Symm-5-point: Symmetrical five-point filter (two historical points, one present point, two future points).

– Symm-7-point: Symmetrical seven-point filter (three historical points, one present point, three future points).

This setting applies to all channels of the phasor measurement unit. It is effectively for recording and transmission on all ports configured to use data for the phasor measurement unit.

Phasor measurement unit calibration

Select the **Settings > Metering > Synchrophasors > PMU Calibration** menu item to open the phasor measurement unit calibration window.

Figure 315: phasor measurement unit calibration settings

PARAMETER	PMU 1
Va Angle	0.00 deg
Vb Angle	0.00 deg
Vc Angle	0.00 deg
Vx Angle	0.00 deg
Ia Angle	0.00 deg
Ib Angle	0.00 deg
Ic Angle	0.00 deg
Ig Angle	0.00 deg
Sequence Voltage Shift Angle	0 deg
Sequence Current Shift Angle	0 deg

The following settings are available for each phasor measurement unit. These settings specify user angle calibration data. This data is combined with the factory adjustments to shift the phasors for better accuracy.

Va Angle, Vb Angle, Vc Angle, Vx Angle

Range: –5.00 to 5.00° in steps of 0.05
Default: 0.00°

These settings recognize applications with protection class voltage and current sources, and allow the user to calibrate each channel (phase A, B, and C voltage, as well as auxiliary voltage) individually to offset errors introduced by VTs, CTs, and cabling. The setting values are effectively added to the measured angles. Therefore, enter a positive correction of the secondary signal lags the true signal; and negative value if the secondary signal leads the true signal.

Ia Angle, Ib Angle, Ic Angle, Ig Angle

Range: –5.00 to 5.00° in steps of 0.05
Default: 0.00°

These settings recognize applications with protection class voltage and current sources, and allow the user to calibrate each channel (ground current and phase A, B, and C currents) individually to offset errors introduced by VTs, CTs, and cabling. The setting values are effectively added to the measured angles. Therefore, enter a positive correction of the secondary signal lags the true signal; and negative value if the secondary signal leads the true signal.

Sequence Voltage Shift Angle

Range: –180 to 180° in steps of 30
Default: 0°

This setting allows correcting positive and negative-sequence voltages for vector groups of power transformers located between the phasor measurement unit voltage point and the reference node. This angle is effectively added to the positive-sequence voltage angle, and subtracted from the negative-sequence voltage angle. Please note the following.

- When this setting value is not "0°", the phase and sequence voltages will not agree. Unlike sequence voltages, the phase voltages cannot be corrected in a general case, and therefore are reported as measured.
- When receiving synchrophasor date at multiple locations, with possibly different reference nodes, it may be more beneficial to allow the central locations to perform the compensation of sequence voltages.
- This setting applies to phasor measurement unit data only. The C90^{Plus} calculates symmetrical voltages independently for protection and control purposes without applying this correction.
- When connected to line-to-line voltages, the phasor measurement unit calculates symmetrical voltages with the reference to the AG voltage, and not to the physically connected AB voltage.

Sequence Current Shift Angle

Range: –180 to 180° in steps of 30
Default: 0°
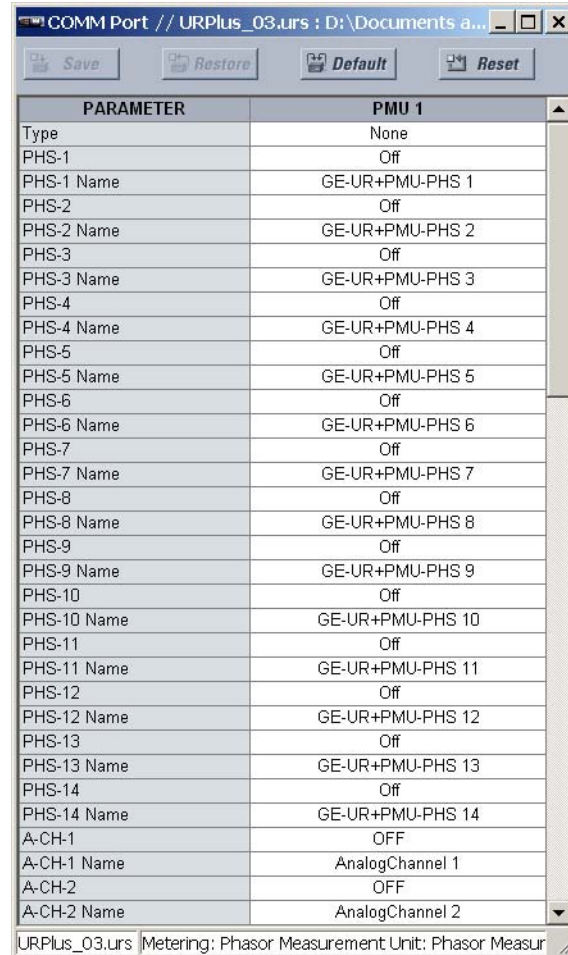
This setting allows correcting positive and negative-sequence currents for vector groups of power transformers located between the phasor measurement unit current point and the reference node. The setting has the same meaning for currents as the **Sequence Voltage Shift Angle** setting has for voltages. Normally, the two correcting angles are set identically, except rare applications when the voltage and current measuring points are located at different windings of a power transformer.

Phasor measurement unit communications

Select the **Settings > Metering > Phasor Measurement Unit > Communication > Comm Port** menu item to open the phasor measurement unit communications window for port 1.

Figure 316: Phasor measurement unit communications configuration

The following settings are available for the communication port on each phasor measurement unit.

Type

Range: None, Network
Default: None

This setting specifies the first communication port for transmission of the phasor measurement unit data. The three ports are configured under individual menus.

PHS-1, PHS-2, PHS-3,..., PHS-14

Range: Off, Va, Vb, Vc, Vx, Ia, Ib, Ic, Ig, V1, V2, V0, I1, I2, I0
Default: Off

These settings select synchrophasors to be transmitted from the superset of all synchronized measurements. The available synchrophasor values are listed below.

– Va: the first voltage channel, either Va or Vab.

– Vb: the second voltage channel, either Vb or Vbc.

– Vc: the third voltage channel, either Vc or Vca.

- – Vx: the fourth voltage channel.
- – Ia: phase A current, physical channel or summation as per the source settings.
- – Ib: phase B current, physical channel or summation as per the source settings.
- – Ic: phase C current, physical channel or summation as per the source settings.
- – Ig: fourth current channel, physical or summation as per the source settings.
- – V1: positive-sequence voltage, referenced to Va.
- – V2: negative-sequence voltage, referenced to Va.
- – V0: zero-sequence voltage.
- – I1: positive-sequence current, referenced to Ia.
- – I2: negative-sequence current, referenced to Ia.
- – I0: zero-sequence current.

These settings allow for optimizing the frame size and maximizing transmission channel usage, depending on a given application. Select "Off" to suppress transmission of a given value.

PHS-1 Name, PHS-2 Name, PHS-3 Name,..., PHS-14 Name

Range: 16 alphanumeric characters

Default: GE-UR+PMU1-V1, GE-UR+PMU1-V2, GE-UR-PMU1+V3,..., GE-UR+PMU1-V14

These settings allow for custom naming of the synchrophasor channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame. These names are typically based on station, bus, or breaker names.

A-CH-1, A-CH-2, A-CH-3,..., A-CH-14

Range: available FlexAnalog™ values

Default: Off

These settings select any analog data measured by the relay to be included as a user-selectable analog channel of the data frame. Up to eight analog channels can be configured to send any FlexAnalog™ value from the relay. Examples include active and reactive power, per phase or three-phase power, power factor, temperature via RTD inputs, and THD. The configured analog values are sampled concurrently with the synchrophasor instant and sent as 16-bit integer values.

A-CH-1 Name, A-CH-2 Name, A-CH-3 Name,..., A-CH-14 Name

Range: 16 alphanumeric characters

Default: AnalogChannel1, AnalogChannel2, AnalogChannel3,..., AnalogChannel14

These settings allow for custom naming of the analog channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.

D-CH-1, D-CH-2, D-CH-3,..., D-CH-14

Range: any metering logic operand or shared operand

Default: Off

These settings select any digital flag measured by the relay to be included as a user-selectable digital channel of the data frame. Up to sixteen analog channels can be configured to send any operand from the relay. The configured digital flags are sampled concurrently with the synchrophasor instant. The values are mapped into a two-byte integer number, with byte 1 LSB corresponding to the digital channel 1 and byte 2 MSB corresponding to digital channel 16.

D-CH-1 Name, D-CH-2 Name, D-CH-3 Name,..., D-CH-14 Name

Range: 16 alphanumeric characters

Default: DigitalChannel1, DigitalChannel2, DigitalChannel3,..., DigitalChannel14

These settings allow for custom naming of the digital channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.

D-CH-1 Normal State, D-CH-2 Normal State, D-CH-3 Normal State,..., D-CH-14 Normal State

Range: On, Off

Default: Off

These settings allow for specifying a normal state for each digital channel. These states are transmitted in configuration frames to the data concentrator.

Phasor measurement unit triggering

Each logical phasor measurement unit (PMU) contains five triggering mechanisms to facilitate triggering of the associated PMU recorder and cross-triggering of other PMUs of the system. They are:

- Overfrequency and underfrequency.

- Overvoltage and undervoltage.

- Overcurrent.

- Overpower.

- High rate of change of frequency.

The pre-configured triggers can be augmented with a user-programmable trigger. This trigger can be built freely using programmable logic of the relay. The entire triggering logic is refreshed once every two power system cycles.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > User Triggering** menu item to open the phasor measurement unit user-programmable trigger window.

Figure 317: User-programmable trigger configuration setting

The following user-programmable trigger setting is available.

Function

Range: any metering operand or shared operand

Default: OFF

This setting selects an operand to use as a user-specified trigger.

All five triggering functions and the user-programmable trigger are consolidated (ORed) and connected to the PMU recorder. Each trigger can be programmed to log its operation into the event recorder. The five triggers drive the STAT bits of the data frame to inform the destination of the synchrophasor data regarding the cause of trigger. The following convention is adopted to drive bits 11, 3, 2, 1, and 0 of the STAT word.

Figure 318: STAT bits logic
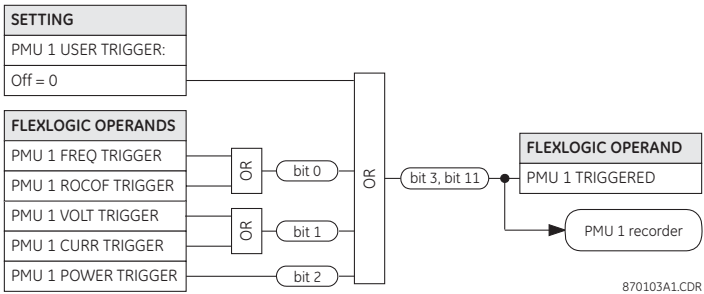
Frequency triggering

The trigger responds to the frequency signal of the phasor measurement unit source. The frequency is calculated from either phase voltages, auxiliary voltage, phase currents and ground current, in this hierarchy, depending on the source configuration as per C90^{Plus} standards. This element requires the frequency is above the minimum measurable value. If the frequency is below this value, such as when the circuit is de-energized, the trigger will drop out.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > Frequency Trigger** menu item to open the phasor measurement unit frequency triggering window.

Figure 319: Frequency triggering configuration settings
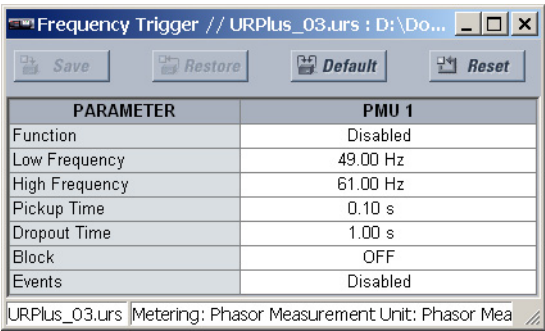
The following settings are available for each phasor measurement unit.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the phasor measurement unit frequency triggering function.

Low Frequency

Range: 20.00 to 70.00 Hz in steps of 0.01
Default: 49.00 Hz

This setting specifies the low threshold for the abnormal frequency trigger. The comparator applies a 0.03 Hz hysteresis.

High Frequency

Range: 20.00 to 70.00 Hz in steps of 0.01
Default: 61.00 Hz

This setting specifies the high threshold for the abnormal frequency trigger. The comparator applies a 0.03 Hz hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 0.10 seconds

This setting may be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 1.00 seconds

This setting may be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks operation of the phasor measurement unit frequency triggering function.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of phasor measurement unit frequency triggering events in the sequence of events recorder.

The logic for the phasor measurement unit frequency triggering function is shown below

Figure 320: Frequency triggering scheme logic
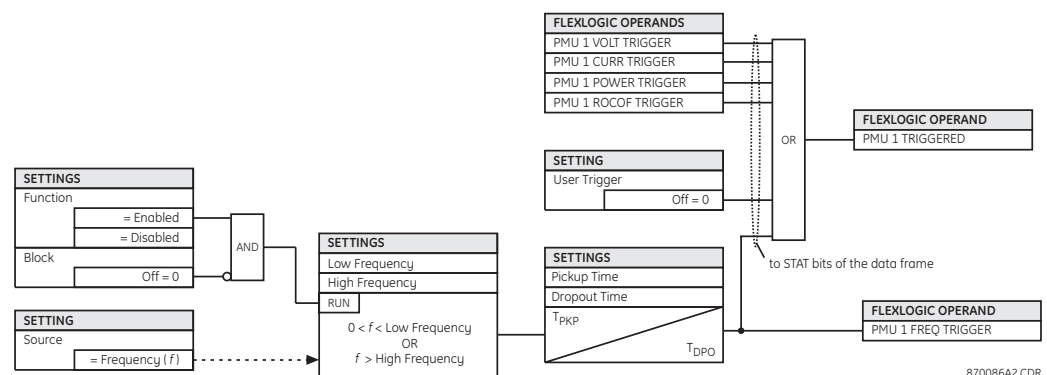
Voltage triggering

This phasor measurement unit voltage triggering function responds to abnormal voltage. Separate thresholds are provided for low and high voltage. In terms of signaling its operation, the element does not differentiate between the undervoltage and overvoltage events. The trigger responds to the phase voltage signal of the phasor measurement unit source. All voltage channels (A, B, and C or AB, BC, and CA) are processed independently and could trigger the recorder. A minimum voltage supervision of 0.1 pu is implemented to prevent pickup on a de-energized circuit, similarly to the undervoltage protection element.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > Voltage Trigger** menu item to open the phasor measurement unit voltage triggering window.

The following settings are available for each phasor measurement unit.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phasor measurement unit voltage triggering function.

Low Voltage

Range: 0.250 to 1.250 pu in steps of 0.001

Default: 0.800 pu

This setting specifies the low threshold for the abnormal voltage trigger, in per-unit values of the phasor measurement unit source. A value of 1 pu is a nominal voltage value defined as the nominal secondary voltage times VT ratio. The comparator applies a 3% hysteresis.

High Voltage

Range: 0.750 to 1.750 pu in steps of 0.001

Default: 1.200 pu

This setting specifies the high threshold for the abnormal voltage trigger, in per-unit values of the phasor measurement unit source. A value of 1 pu is a nominal voltage value defined as the nominal secondary voltage times VT ratio. The comparator applies a 3% hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.10 seconds

This setting may be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting may be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the phasor measurement unit voltage triggering function.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of phasor measurement unit voltage triggering events in the sequence of events recorder.

The logic for the phasor measurement unit voltage triggering function is shown below.

Figure 322: Voltage triggering scheme logic
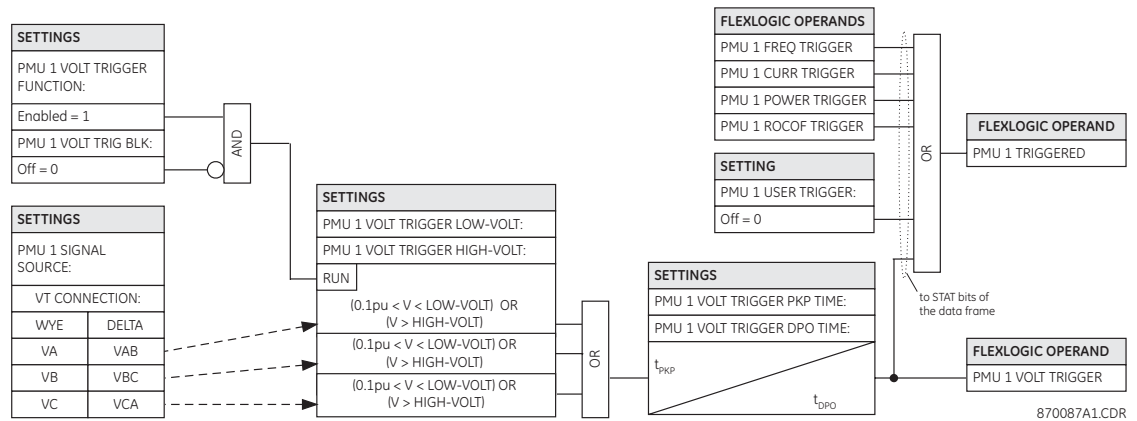
Current triggering

This phasor measurement unit current triggering function responds to elevated current. The trigger responds to the phase current signal of the phasor measurement unit source. All current channel (A, B, and C) are processed independently and could trigger the recorder.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > Current Trigger** menu item to open the phasor measurement unit current triggering window.

Figure 323: Current triggering configuration settings
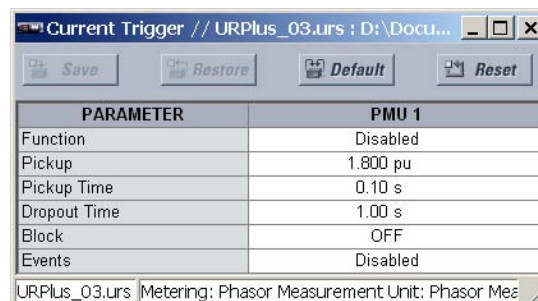
The following settings are available for each phasor measurement unit.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the phasor measurement unit current triggering function.

Pickup

Range: 0.100 to 30.000 pu in steps of 0.001
Default: 1.800 pu

This setting specifies the pickup threshold for the overcurrent trigger, in per-unit values of the phasor measurement unit source. A value of 1 pu is a nominal primary current. The comparator applies a 3% hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 0.10 seconds

This setting may be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 1.00 seconds

This setting may be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand
Default: Off

Assertion of the operand assigned to this setting blocks operation of the phasor measurement unit current triggering function.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of phasor measurement unit current triggering events in the sequence of events recorder.

The logic for the phasor measurement unit current triggering function is shown below.

Figure 324: Phasor measurement unit current triggering logic

870088A1.CDR
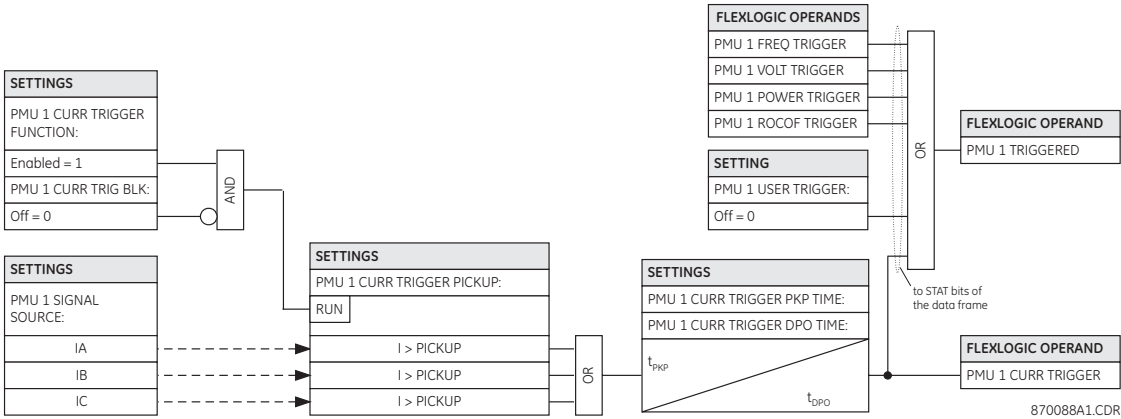
Power triggering

The phasor measurement unit power triggering function responds to abnormal power. Separate thresholds are provided for active, reactive, and apparent powers. In terms of signaling its operation the element does not differentiate between the three types of power. The trigger responds to the single-phase and three-phase power signals of the phasor measurement unit source.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > Power Trigger** menu item to open the phasor measurement unit power triggering window.

Figure 325: Power triggering configuration settings

The following settings are available for each phasor measurement unit.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phasor measurement unit power triggering function.

Active

Range: 0.250 to 3.000 pu in steps of 0.001

Default: 1.250 pu

This setting specifies the pickup threshold for the active power of the source. For single-phase power, 1 pu represents the product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio, and the nominal primary current. For the three-phase power, 1 pu is three times the value for single-phase power. The comparator applies a 3% hysteresis.

Reactive

Range: 0.250 to 3.000 pu in steps of 0.001

Default: 1.250 pu

This setting specifies the pickup threshold for the reactive power of the source. For single-phase power, 1 pu represents the product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio and the nominal primary current. For the three-phase power, 1 pu is three times the value for single-phase power. The comparator applies a 3% hysteresis.

Apparent

Range: 0.250 to 3.000 pu in steps of 0.001

Default: 1.250 pu

This setting specifies the pickup threshold for the apparent power of the source. For single-phase power, 1 pu represents the product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio and the nominal primary current. For the three-phase power, 1 pu is three times the value for single-phase power. The comparator applies a 3% hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.10 seconds

This setting may be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01
Default: 1.00 seconds

This setting may be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand
Default: OFF

Assertion of the operand assigned to this setting blocks operation of the phasor measurement unit power triggering function.

Events

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the logging of phasor measurement unit power triggering events in the sequence of events recorder.

The logic for the phasor measurement unit power triggering function is shown below.

Figure 326: Phasor measurement unit power triggering logic
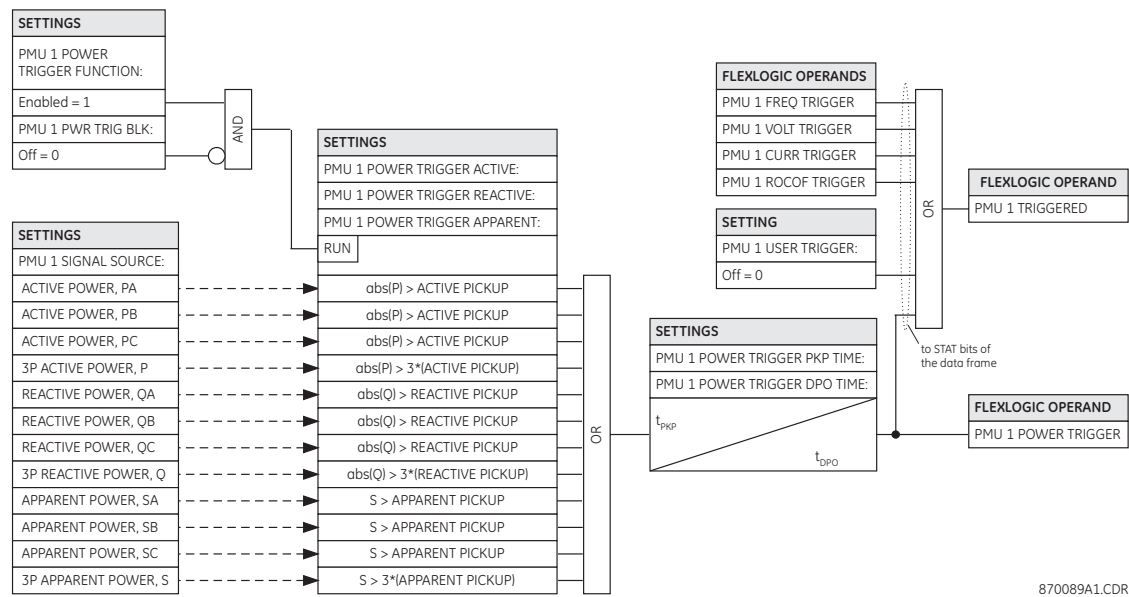
Frequency rate of change triggering

This phasor measurement unit frequency rate of change triggering function responds to the rate of change of frequency. Separate thresholds are provided for rising and dropping frequency. The trigger responds to the rate of change of frequency (df/dt) of the phasor measurement unit (PMU) source.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > df/dt Trigger** menu item to open the phasor measurement unit frequency rate of change triggering window.

Figure 327: Frequency rate of change triggering configuration settings

The following settings are available for each phasor measurement unit.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phasor measurement unit frequency rate of change triggering function.

Raise

Range: 0.10 to 15.00 Hz/s in steps of 0.01

Default: 0.25 Hz/s

This setting specifies the pickup threshold for the rate of change of frequency in the raising direction (positive df/dt). The comparator applies a 3% hysteresis.

Fall

Range: 0.10 to 15.00 Hz/s in steps of 0.01

Default: 0.25 Hz/s

This setting specifies the pickup threshold for the rate of change of frequency in the falling direction (negative df/dt). The comparator applies a 3% hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.10 seconds

This setting can be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting could be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the phasor measurement unit frequency rate of change triggering function.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of phasor measurement unit frequency rate of change triggering events in the sequence of events recorder.

The logic for the phasor measurement unit frequency rate of change triggering function is shown below.

Figure 328: Phasor measurement unit frequency rate of change triggering logic
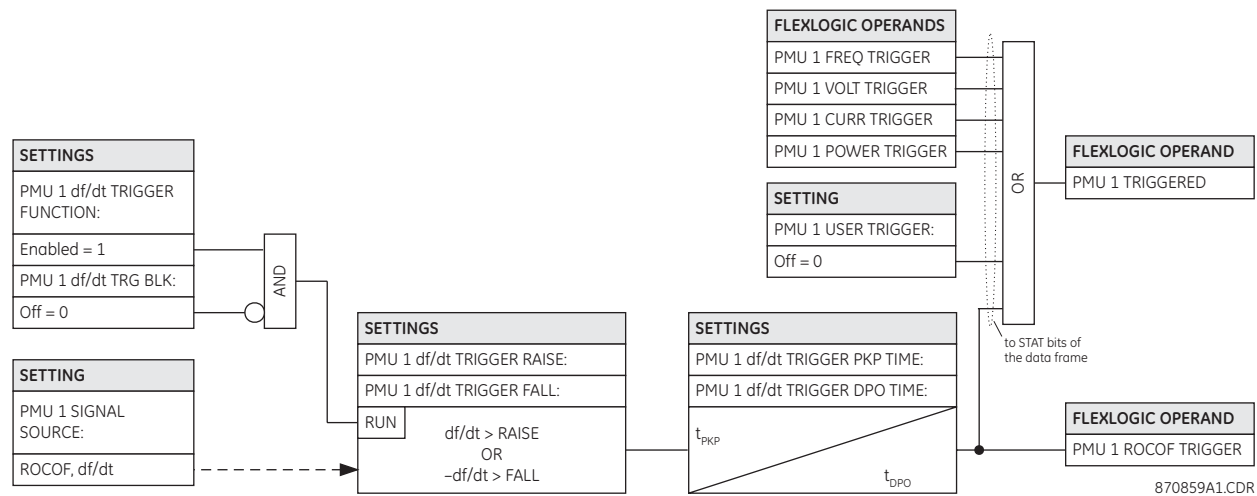
Phasor measurement unit recording

Each logical phasor measurement unit (PMU) is associated with a recorder. The triggering condition is programmed via the **Settings > Metering > Phasor Measurement Unit > Triggering** menu. The recorder works with polar values using resolution as in the phasor measurement unit actual values.

Figure 329: Phasor measurement unit recording
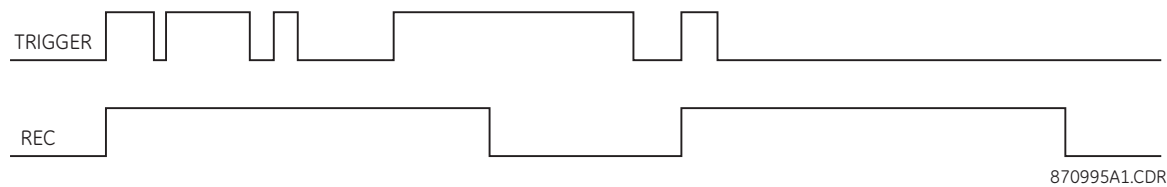
Select the **Settings > Metering > Phasor Measurement Unit > Recording** menu item to open the phasor measurement unit recording window.

Figure 330: Phasor measurement unit recording configuration settings

The following settings are available for each phasor measurement unit.

Recording Rate

Range: 1, 2, 5, 10, 12, 15, 20, 25, 30, 50, or 60 times per second

Default: 10 times per second

This setting specifies the recording rate for the record content. Not all recording rates are applicable to either 50 or 60 Hz systems (for example, recording at 25 phasors a second in a 60 Hz system). The relay supports decimation by integer number of phasors from the nominal system frequency. If the rate of 25 is selected for the 60 Hz system, the relay would decimate the rate of 60 phasors a second by round (60 / 25) = 2; that is, it would record at 60 / 2 = 30 phasors a second.

Number of Timed Records

Range: 2 to 128 in steps of 1

Default: 3

This setting specifies how many timed records are available for a given logical phasor measurement unit. The length of each record equals available memory divided by the content size and number of records. The higher the number of records, the shorter each record. The relay supports a maximum of 128 records.

Trigger Mode

Range: Automatic Overwrite, Protected
Default: Automatic Overwrite

This setting specifies what happens when the recorder uses its entire available memory storage. If set to "Automatic Overwrite", the last record is erased to facilitate new recording, when triggered. If set to "Protected", the recorder stops creating new records when the entire memory is used up by the old un-cleared records.

The following set of figures illustrate the concept of memory management via the **Trigger Mode** setting.

Figure 331: Memory management in automatic overwrite mode
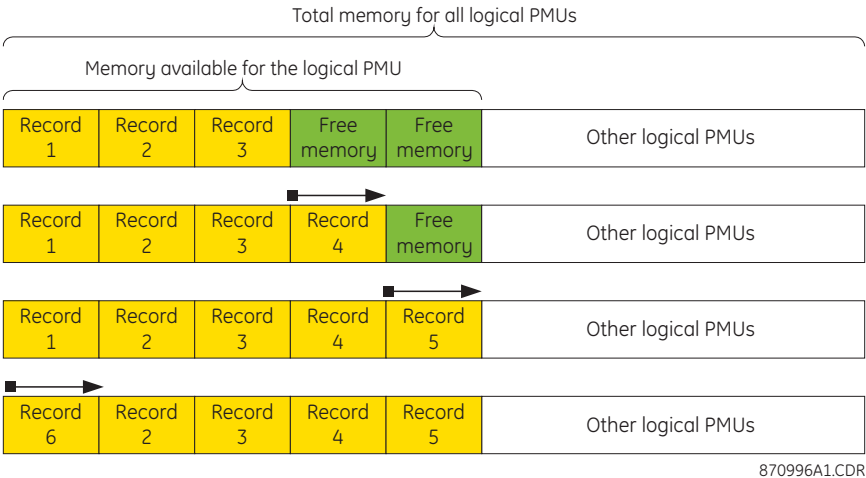
Figure 332: Memory management in protected mode
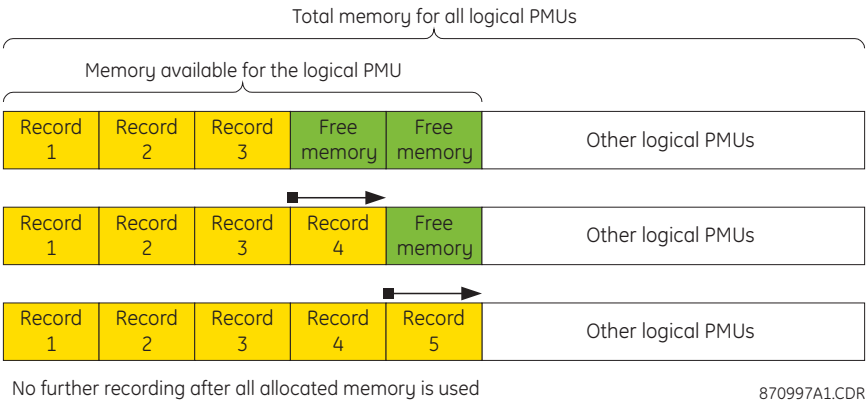
Timed Trigger Position

Range: 1 to 50% in steps of 1
Default: 10%

This setting specifies the amount of pre-trigger data in percent of the entire record. This setting applies only to the timed mode of recording.

Rec PHS-1, Rec PHS-2, Rec PHS-3,…, Rec PHS-14

Range: available synchrophasor values
Default: Off

These settings specify synchrophasors to be recorded from the superset of all synchronized measurements as indicated in the following table. These settings allow for optimizing the record size and content depending on a given application. Select "Off" to suppress recording of a given value.

Table 40: Available synchrophasor values

Value	Description
Va	First voltage channel, either Va or Vab
Vb	Second voltage channel, either Vb or Vbc
Vc	Third voltage channel, either Vc or Vca
Vx	Fourth voltage channel
Ia	Phase A current, physical channel or summation as per the source settings
Ib	Phase B current, physical channel or summation as per the source settings
Ic	Phase C current, physical channel or summation as per the source settings
Ig	Fourth current channel, physical channel or summation as per the source settings
V1	Positive-sequence voltage, referenced to Va
V2	Negative-sequence voltage, referenced to Va
V0	Zero-sequence voltage, referenced to Va
I1	Positive-sequence current, referenced to Ia
I2	Negative-sequence current, referenced to Ia
I0	Zero-sequence current

Rec PHS-1 Name, Rec PHS-2 Name, Rec PHS-3 Name,..., Rec PHS-14 Name

Range: 16 character ASCII string

Default: GE-UR+PMU-PHS1, GE-UR+PMU-PHS2, GE-UR+PMU-PHS3,..., GE-UR+PMU-PHS14

These settings allow for custom naming of the synchrophasor channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame. Typically these names would be based on station, bus, or breaker names.

Rec A-CH-1, Rec A-CH-2, Rec A-CH-3,..., Rec A-CH-14

Range: available FlexAnalog™ values

Default: OFF

These settings specify analog data measured by the relay to be included as a user-selectable analog channel of the record. Up to eight analog channels can be configured to record any FlexAnalog value from the relay. Examples include active and reactive power, per phase or three-phase power, power factor, and THD. The configured analogs are sampled concurrently with the synchrophasor instance.

Rec A-CH-1 Name, Rec A-CH-2 Name, Rec A-CH-3 Name,..., Rec A-CH-14 Name

Range: 16 character ASCII string

Default: AnalogChannel1, AnalogChannel2, AnalogChannel3,..., AnalogChannel14

These settings allow for custom naming of the analog channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.

Rec D-CH-1, Rec D-CH-2, Rec D-CH-3,..., Rec D-CH-14

Range: any metering logic operand or shared operand

Default: OFF

These settings specify any digital flag measured by the relay to be included as a user-selectable digital channel in the record. Up to digital analog channels can be configured to record any operand from the relay. The configured digital flags are sampled concurrently with the synchrophasor instance.

Rec D-CH-1 Name, Rec D-CH-2 Name, Rec D-CH-3 Name,..., Rec D-CH-14 Name

Range: 16 character ASCII string

Default: AnalogChannel1, AnalogChannel2, AnalogChannel3,..., AnalogChannel14

This setting allows custom naming of the digital channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.

Phasor measurement unit reporting over network

The phasor measurement unit Ethernet connection works simultaneously with other communication means over Ethernet. The network reporting feature is programmed via the **Settings > Metering > Phasor Measurement Unit > Reporting Over Network** menu.

Figure 333: Phasor measurement unit reporting over network configuration settings
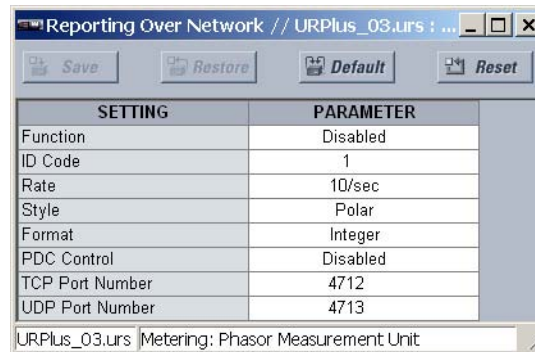
The following settings are available for each phasor measurement unit.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the phasor measurement unit reporting over network feature.

ID Code

Range: 1 to 65534 in steps of 1
Default: 1

This setting specifies an IDCODE for the entire port. Individual phasor measurement unit streams transmitted over this port are identified via their own IDCODEs as per the phasor measurement unit IDCODE settings. This IDCODE is to be used by the command frame to start and stop transmission, and request configuration or header frames.

Rate

Range: 1, 2, 5, 10, 12, 15, 20, 25, 30, 50, or 60 times per second
Default: 10 times per second

This setting specifies the reporting rate for the network (Ethernet) port. This value applies to all phasor measurement unit streams of the device that are assigned to transmit over this port.

Style

Range: Polar, Rectangular
Default: Polar

This setting selects between reporting synchrophasors in rectangular (real and imaginary) or in polar (magnitude and angle) coordinates. This setting complies with bit-0 of the format field of the C37.118 configuration frame.

Format

Range: Integer, Floating
Default: Integer

This setting selects between reporting synchrophasors as 16-bit integer or 32-bit IEEE floating point numbers. This setting complies with bit 1 of the format field of the C37.118 configuration frame. Note that this setting applies to synchrophasors only – the user-selectable FlexAnalog™ channels are always transmitted as 32-bit floating point numbers.

PDC Control

Range: Enabled, Disabled

Default: Disabled

The synchrophasor standard allows for user-defined controls originating at the PDC, to be executed on the phasor measurement unit. The control is accomplished via an extended command frame. The relay decodes the first word of the extended field, EXTFRAME, to drive 16 dedicated FlexLogic™ operands: PDC NETWORK CNTRL 1 (from the least significant bit) to PDC NETWORK CNTRL 16 (from the most significant bit). Other words, if any, in the EXTFRAME are ignored. The operands are asserted for 5 seconds following reception of the command frame. If the new command frame arrives within the 5 second period, the FlexLogic™ operands are updated, and the 5 second timer is re-started.

This setting enables or disables the control. When enabled, all 16 operands are active; when disabled, all 16 operands remain reset.

TCP Port Number

Range: 1 to 65535 in steps of 1

Default: 4712

This setting selects the TCP port number that will be used for network reporting.

UDP Port Number

Range: 1 to 65535 in steps of 1

Default: 4713

This setting selects the UDP port number that will be used for network reporting.

Phasor measurement unit one-shot

The phasor measurement unit one-shot feature allows pre-scheduling a phasor measurement unit measurement at a specific point in time. This functionality can be used to test for accuracy of the phasor measurement unit, and for manual collection of synchronized measurements through the system.

Phasor measurement unit one-shot settings

Select the **Settings > Metering > Phasor Measurement Unit > One-Shot** menu item to open the phasor measurement unit one-shot window.

Figure 334: Phasor measurement unit one-shot configuration settings

The following settings are available for each phasor measurement unit.

Function

Range: Enabled, Disabled
Default: Disabled

This setting enables and disables the phasor measurement unit one-shot feature.

Sequence Number

Range: 0 to nominal frequency – 1, in steps of 1
Default: 1

When the **Device Date** and **Device Time** match the **PMU One-Shot Date** and **PMU One-Shot Time**, the C90^{Plus} compares the present sequence number of the measured synchrophasors with this setting value. When the two numbers match, the function saves the actual values as the one-shot actual values. This allows manual read-out of the synchrophasor values for the pre-set time and pre-set sequence number (via supported communication protocols such as Modbus or DNP and the EnerVista UR^{Plus} Setup software).

When the values are saved as one-shot values, the function also asserts a PMU ONE-SHOT OP metering logic operand. This operand may be configured to drive an output contact and trigger an external measuring device such as a digital scope with the intent to verify the accuracy of the phasor measurement unit under test.

With reference to the figure below, the phasor measurement unit one-shot function (when enabled) controls three metering logic operands.

- The PMU ONE-SHOT EXPIRED operand indicates that the one-shot operation has been executed, and the present time is at least 30 seconds past the scheduled one-shot time.

- The PMU ONE-SHOT PENDING operand indicates that the one-shot operation is pending; that is, the present time is before the scheduled one-shot time.

- The PMU ONE-SHOT OP operand indicates the one-shot operation and remains asserted for 30 seconds afterwards.

When the phasor measurement unit one-shot function is disabled, all three operands are de-asserted. The one-shot function applies to all logical phasor measurement units of a given C90^{Plus} relay.

Figure 335: Phasor measurement unit one-shot operands
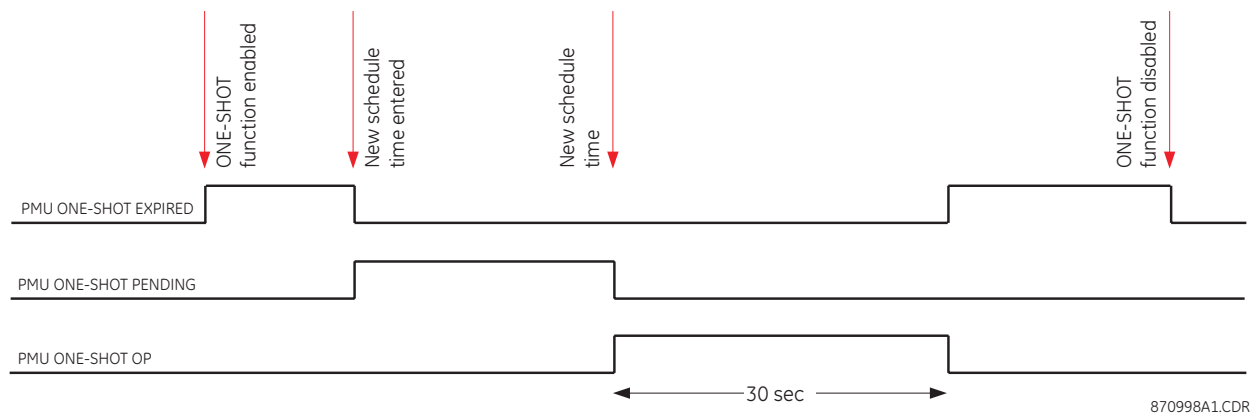
Device Date

Range: date in MM/DD/YYYY format
Default: 01/01/1970

This value reflects the date programmed in the C90^{Plus}. This date cannot be modified from this window.

Device Time

Range: time in HH:MM:SS format
Default: 00:00:00

This value reflects the time programmed in the C90^Plus. This time cannot be modified from this window.

PMU One-Shot Date

Range: date in MM/DD/YYYY format
Default: 01/01/2007

When the phasor measurement unit one-shot feature is enabled, the C90^Plus continuously compares the device date with this value.

PMU One-Shot Time

Range: time in HH:MM:SS format
Default: 00:00:00

When the phasor measurement unit one-shot feature is enabled, the C90^Plus continuously compares the device date with this value.

Manual Date

Range: date in MM/DD/YYYY format
Default: 01/01/2007

The **PMU One-Shot Date** will be updated to the value specified by this setting when the **Set PMU One-Shot Date and Time** command is executed.

Manual Time

Range: time in HH:MM:SS format
Default: 00:00:00

The **PMU One-Shot Time** will be updated to the value specified by this setting when the **Set PMU One-Shot Date and Time** command is executed.

Testing the accuracy of the phasor measurement unit

The phasor measurement unit one-shot feature can be used to test accuracy of the synchrophasor measurement. GPS-synchronized tests sets perform a similar function to PMUs: instead of measuring the phasor from physical signals with respect to the externally provided time reference, they produce the physical signals with respect to the externally provided time reference, given the desired phasor values. Therefore the GPS-synchronized test sets cannot be automatically assumed more accurate then the phasor measurement units under test. This calls for a method to verify both the measuring device (PMU) and the source of signal (test set).

With reference to the figure below, the one-shot feature could be configured to trigger a high-accuracy scope to capture both the time reference signal (rising edge of the 1 pps signal of the IRIG-B time reference), and the measured waveform. The high-accuracy high-sampling rate record of the two signals captured by the scope can be processed using digital tools to verify the magnitude and phase angle with respect to the time reference signal. As both the time reference and the measured signals are raw inputs to the phasor measurement unit under test, their independently captured record, processed using third-party software, is a good reference point for accuracy calculations. Such a record proves useful when discussing the test results, and should be retained as a part of the testing documentation.

Note that the phasor measurement unit under test does not have to be connected to a real GPS receiver as the accuracy is measured with respect to the timing reference provided to the phasor measurement unit and not to the absolute UTC time. Therefore a simple IRIG-B generator could be used instead. Also, the test set does not have to support GPS synchronization. Any stable signal source can be used. If both the phasor measurement unit under test and the test set use the timing reference, they should be driven from the

same IRIG-B signal: either the same GPS receiver or IRIG-B generator. Otherwise, the setpoints of the test set and the phasor measurement unit measurements should not be compared as they are referenced to different time scales.

Figure 336: Testing synchrophasor measurement accuracy
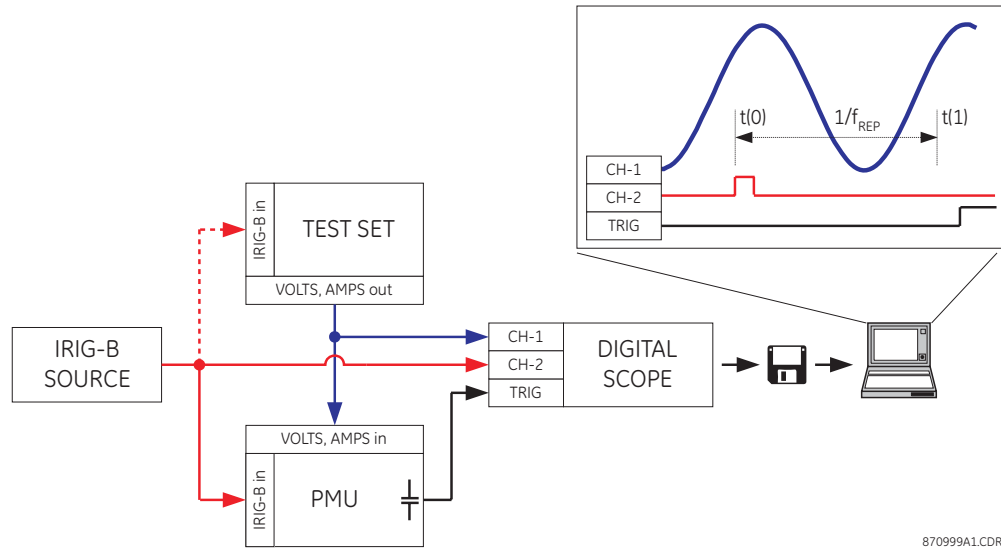
Collecting synchronized measurements *ad hoc*

The phasor measurement unit one-shot feature can be used for *ad hoc* collection of synchronized measurements in the network. Two or more phasor measurement units can be pre-scheduled to freeze their measurements at the same time. When frozen the measurements could be collected using EnerVista UR^{Plus} Setup or a protocol client.

Data logger

The data logger samples and records up to 16 analog parameters at a user-defined sampling rate. This recorded data may be downloaded to the EnerVista UR^{Plus} Setup software and displayed with parameters on the vertical axis and time on the horizontal axis. All data is stored in non-volatile memory, meaning that the information is retained when power to the relay is lost.

For a fixed sampling rate, the data logger can be configured with a few channels over a long period or a larger number of channels for a shorter period. The relay automatically partitions the available memory for the channels in use.

Between the recording intervals, the data logger calculates the maximum, minimum, and the average value of each channel. At the end of the interval either the maximum, minimum, or average value is written to the data logger depending on the mode setting. This ensures that data is not missed if a low rate setting is selected.

In addition, the maximum value, timestamp of maximum, minimum value, time stamp of minimum are calculated for the channel for the duration of recording since the start of recording. A high, low, high-high, and low-low alarm can be configured for each channel.

Data logger function configuration

Select the **Settings > Metering > Data Logger > Function** menu item to open the data logger configuration window.

Figure 337: Data logger configuration settings
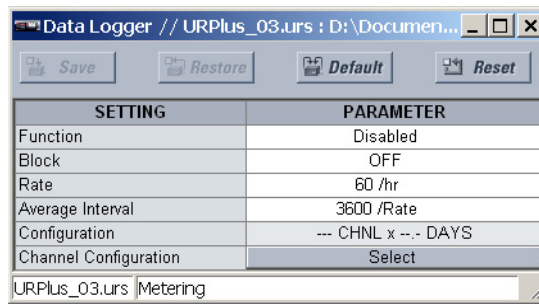
The following settings are available for the data logger.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the data logger.

Block

Range: any metering logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting will block data logger functionality.

Rate

Range: 1 to 3600 samples per hour in steps of 1

Default: 60 samples per hour

This setting determines how often data is written to the data log.

Average Interval

Range: 1/rate to 86400/rate in steps of 1/rate

Default: 3600/rate

This setting selects the time interval for which the average value is calculated. This number is expressed as a multiple of the **Rate** setting. For instance, if the **Rate** is set to "60/hr" and the **Average Interval** is "1440/rate" then a 24-hour average is calculated.

Figure 338: Data logger scheme logic
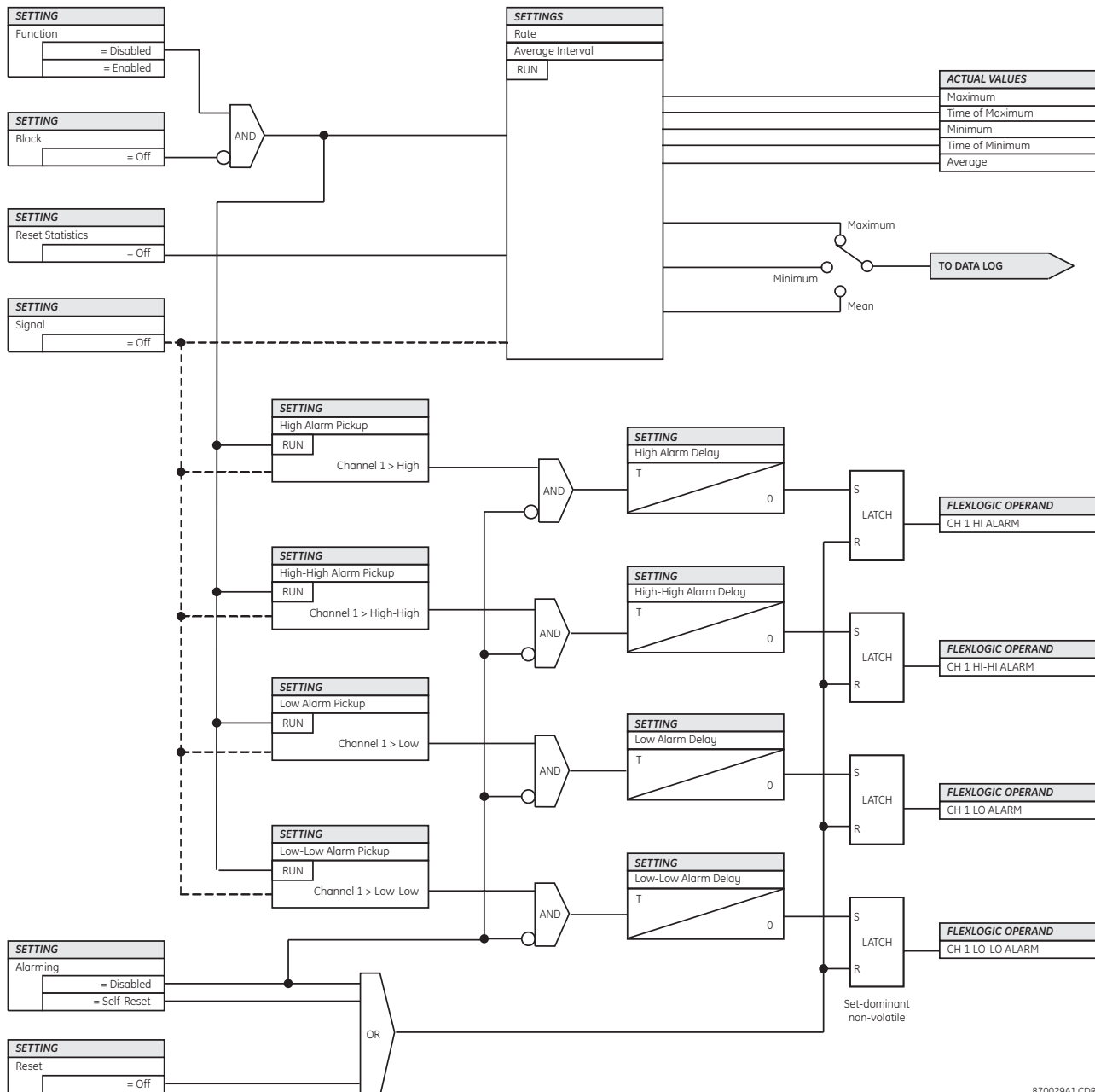
Data logger channel configuration

Select the **Settings > Metering > Data Logger > Channel Configuration** menu item to open the data logger configuration window.

Figure 339: Data logger channel configuration settings

The following settings are available for all sixteen data logger channels.

Signal

Range: any FlexAnalog™ parameter

Default: Off

This setting selects the metering value to be recorded for the data logger channel.

Name

Range: up to 12 alphanumeric characters

Default: Channel 1

This setting specifies the name of the data logger channel.

Mode

Range: Max, Min, Mean

Default: Mean

This setting defines which value (maximum, minimum, or mean) is written to the data logger.

Alarming

Range: Disabled, Self-Reset, Latched

Default: Disabled

If this setting is "Disabled", alarming is inhibited. If selected as "Self-Reset", alarms will reset as soon as the signal drops below the pickup value. If selected as "Latched", the alarms will remain active until the reset input is asserted.

Reset Alarms

Range: any metering logic operand or shared operand

Default: OFF

The alarms are reset when the operand assigned to this setting is asserted and the **Alarming** setting is selected as "Latched".

Reset Statistics

Range: any metering logic operand or shared operand

Default: OFF

The maximum, minimum, time of maximum, and time of minimum statistics are reset when the operand assigned to this setting is asserted.

High Alarm Pickup, Low Alarm Pickup, High-High Alarm Pickup, Low-Low Alarm Pickup
Range: –90.00 to 90.00 pu in steps of 0.01
Default: 1.00 pu

These settings specify the pickup thresholds for the alarm in per-unit values. A fixed hysteresis of 3% is applied.

High Alarm Delay, Low Alarm Delay, High-High Alarm Delay, Low-Low Alarm Delay
Range: 1.0 to 300.0 seconds in steps of 0.1
Default: 1.0 seconds

These settings specify the time delays for the four alarm pickup types.

Shared operands

The EnerVista UR^{Plus} Setup software groups the C90^{Plus} system into the following six primary functions. Each function has its own setting parameters and each generates its own outputs in the form of operands.

- Protection
- Automation
- Metering
- Digital fault recorder (DFR)
- Equipment manager
- Front panel interface (HMI)

However, it is often desirable for an output from an element within one function can be available to an element within another function. For instance, it may useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available as to each function as shown below.

Figure 340: Default operand list by function
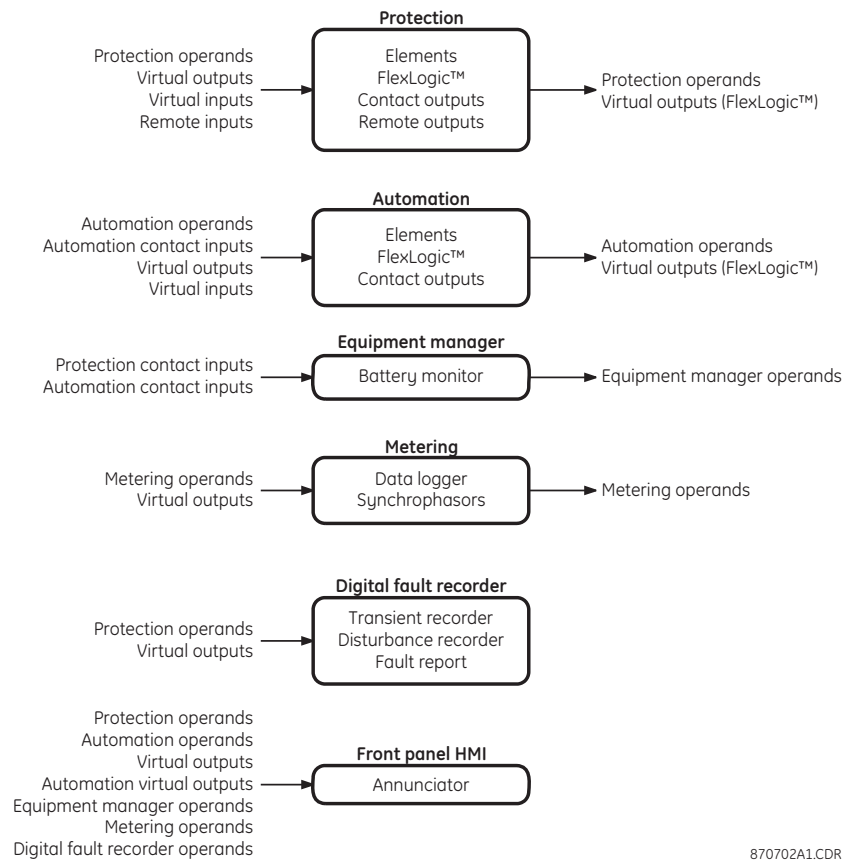
870702A1.CDR

The content of each operand list is dependent on the selected order code.

The shared operands functionality expands upon this system. With this feature, an output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals can then be assigned as inputs to other functions.

For example, assume that the GND TOC1 OP protection operand is required as a signal within the automation function. This operand would then be assigned as a shared operand, and would subsequently become available to the automation function. A total of 64 operands may be assigned as shared operands within each function.

Shared metering operands

Select the **Settings > Metering > Shared Operands** menu item to select the shared metering operands.

Figure 341: Shared operands configuration window
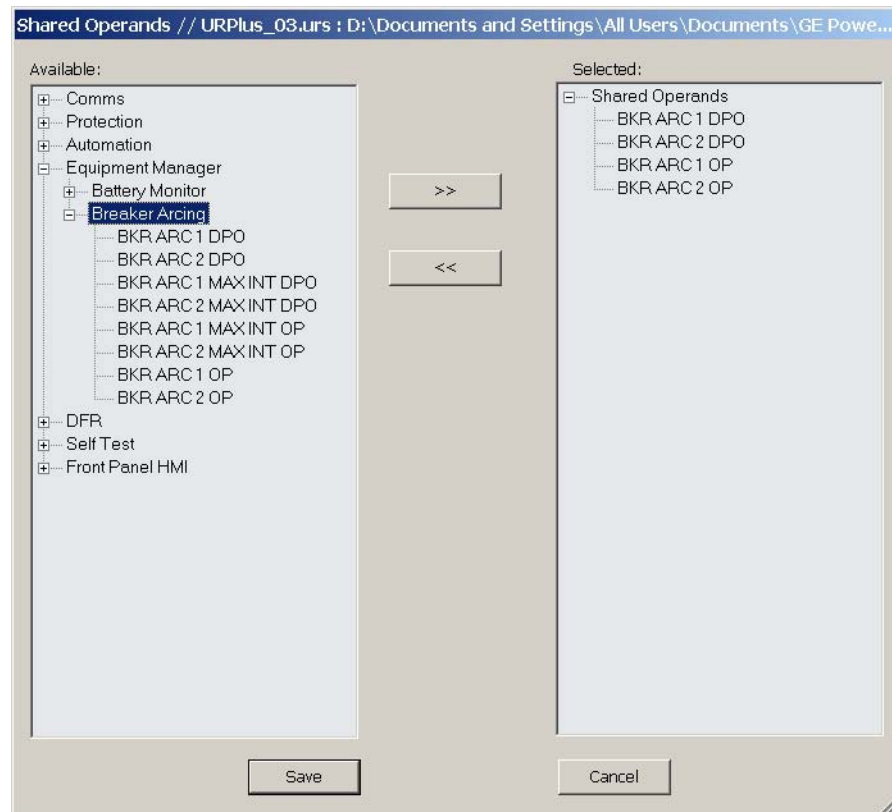
The left side of this screen displays all C90^{Plus} operands that are available to the metering function as shared operands. Select any operands from the other five primary features by clicking on the **>>** button. Operands may be de-assigned as shared operands by pressing the **<<** button.

Metering logic operands

The following metering logic operands are available for the C90^{Plus}. They are listed alphabetically by operand syntax.

Data logger operands

DATA LOG CH1 HI ALM .... Asserted while the data logger channel 1 high alarm is active.

DATA LOG CH1 HI-HI ALM .... Asserted while the data logger channel 1 high-high alarm is active.

DATA LOG CH1 LO ALM .... Asserted while the data logger channel 1 low alarm is active.

DATA LOG CH1 LO ALM .... Asserted while the data logger channel 1 low-low alarm is active.

DATA LOG CH2 .... The operands listed above are also available for data loggers 2 through 16.

Phasor data concentrator operands

PDC NETWORK CONTROL 1 ...... Asserted when phasor data concentrator asserts control bit 1 as received via the network.

PDC 2 .... The operands listed above are also available for phasor data concentrators 2 through 16.

Phasor measurement unit operands

PMU 1 CURR TRIGGER..................Asserted when the overcurrent trigger of phasor measurement
                                    unit 1 operates.

PMU 1 FREQ TRIGGER...................Asserted when the abnormal frequency trigger of phasor
                                    measurement unit 1 operates.

PMU 1 POWER TRIGGER..............Asserted when the overpower trigger of phasor measurement
                                    unit 1 operates.

PMU 1 ROCOF TRIGGER...............Asserted when the rate of change of frequency trigger of
                                    phasor measurement unit 1 operates.

PMU 1 VOLT TRIGGER ....Asserted when the abnormal voltage trigger of phasor
                                    measurement unit 1 operates.

PMU 1 TRIGGERED........................Asserted when the phasor measurement unit 1 triggers. No
                                    events or targets are generated by this operand.

Phasor measurement unit one-shot operands

PMU ONE-SHOT EXPIRED ....Asserted after the one-shot operation executes and the
                                    present time is at least 30 seconds past the scheduled one-shot
                                    time.

PMU ONE-SHOT OP......................Asserted upon one-shot operation and remains asserted for 30
                                    seconds afterwards.

PMU ONE-SHOT PENDING ....Asserted while the one-shot operation is pending. That is, while
                                    the present time is before the scheduled one-shot time.

C90^{Plus} Controller

Chapter 11: Local interface

This section describes how to program the C90^{Plus} local interface features.

Local interface overview

The local interface consists of two displays: an annunciator panel and a front panel HMI.

Figure 342: Front panel interface overview

Annunciator   Front panel HMI

870729A2.CDR
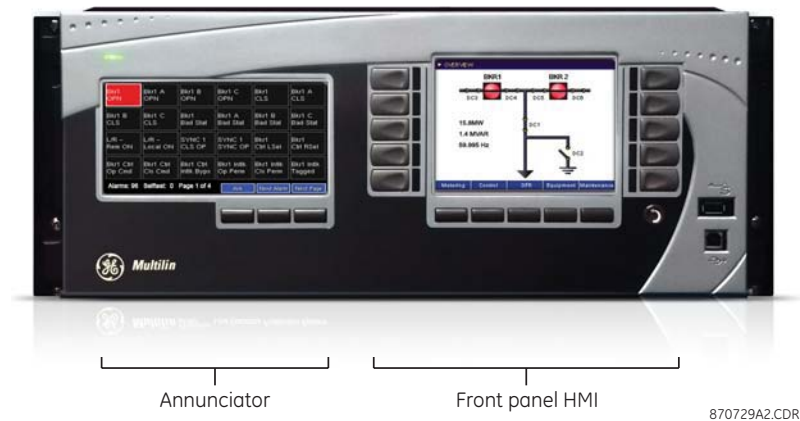
Annunciator panel

The annunciator is a color, TFT panel located that emulates the functionality found in a conventional annunciator unit. The annunciator provides indications on the status of system alarm points. It also displays self-test messages and product information for the unit.

Annunciator operation

The annunciator provides indications on the status of system alarm points. It also displays self-test messages and product information for the unit.

Figure 343: Typical annunciator display
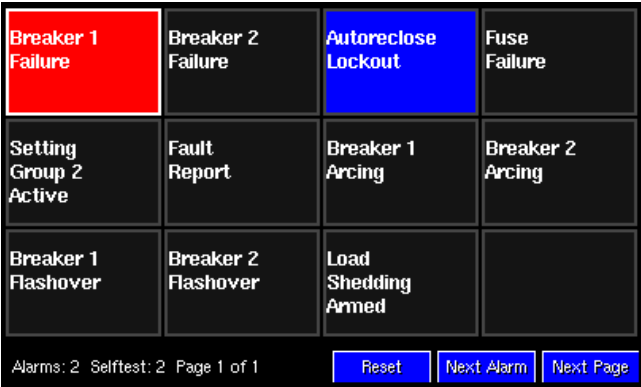
There are three control buttons at the bottom of the display.

- The **Next Page** button cycles through the pages of alarms and to the self-test page.
- The **Next Alarm** button cycles horizontally through the current alarms, from left to right, starting with the first row of alarms. A graphical frame borders the current status box to indicate the selected alarm. The front panel display is dynamically controlled according to the selected alarm.
- The **Ack** button controls the state of the alarms.

The annunciator alarm sequence conforms to ISA 18.1-1979 (R1992) standard, type M.

Figure 344: Annunciator alarm sequence
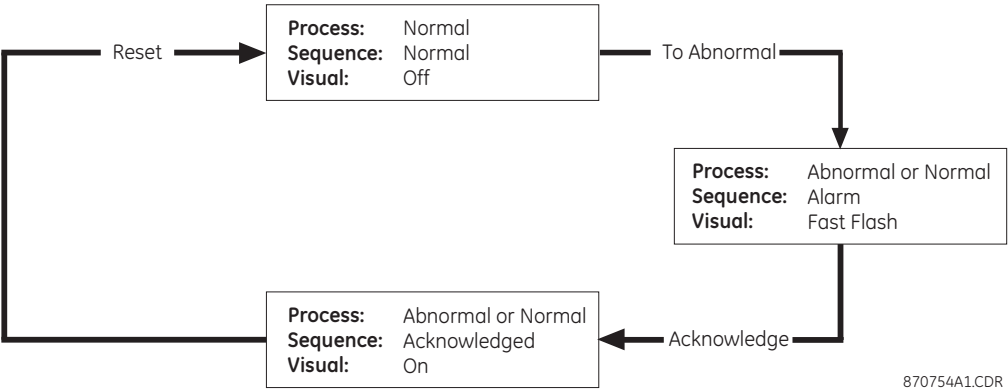
Table 41: Annunciator states

State	Description
Off	Grey text on a darker grey background.
Fast flash	Alternating between the off state and the on state twice per second
On	Bright white text on a colored background.

In the event of an alarm, the page containing the alarm becomes the active page. If there are multiple pages with alarms, the page with the lowest page number is the active page. If there are alarms on multiple pages and alarms on some pages already acknowledged (but not cleared) by the user, the pages with active alarms move ahead of the pages with acknowledged alarms.

Display of the alarm pages is prioritized according to active window (unacknowledged or flashing alarm) and then the page number (that is, if two pages have an unacknowledged alarm, the page with the lowest number is displayed).

Annunciator configuration

Select the **Settings > Local HMI > Annunciator Panel** menu item to open the annunciator configuration page.

Figure 345: Annunciator configuration page

The following settings are available to configure the annunciator. The settings descriptions apply to all 288 alarms, with different default values.

Page Layout

Range: 3 × 4, 4 × 6, 6 × 8
Default: 3 × 4

This setting specifies the number of alarms per page. For instance, if 63 alarms have been configured and the page layout is selected as "4 × 6", then three pages are required (since 63 / (4 × 6) = 2.625, which rounds up to 3). The enumeration of alarm windows is from left to right, top to bottom and lowest page number to highest page number.

Alarm Input

Range: any FlexLogic™ operand or shared operand
Default: see above

This setting specifies the input signal connected to the alarm.

Alarm Name (Line 1)

Range: up to ten alphanumeric characters
Default: see above

This setting specifies the message to display on the first line in the alarm indicator. Up to ten characters can be entered.

Alarm Name (Line 2)

Range: up to ten alphanumeric characters

Default: see above

This setting specifies the message to display on the second line in the alarm indicator. Up to ten characters can be entered.

Alarm Name (Line 3)

Range: up to ten alphanumeric characters

Default: see above

This setting specifies the message to display on the third line in the alarm indicator. Up to ten characters can be entered.

Color

Range: Red, Yellow, Blue

Default: Red

This setting specifies background color of the alarm indicator when the indicator is active.

The **Preview** button displays an on-screen preview of the annunciator window.

Figure 346: Annunciator preview window
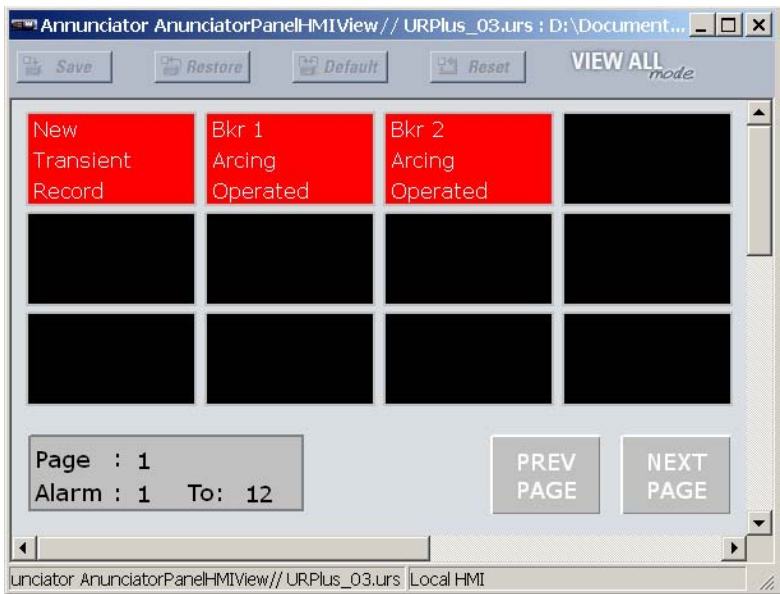
The C90^{Plus} is shipped with a complete range of default annunciator settings. These may be modified according to the specific applications.

Figure 347: Annunciator configuration logic
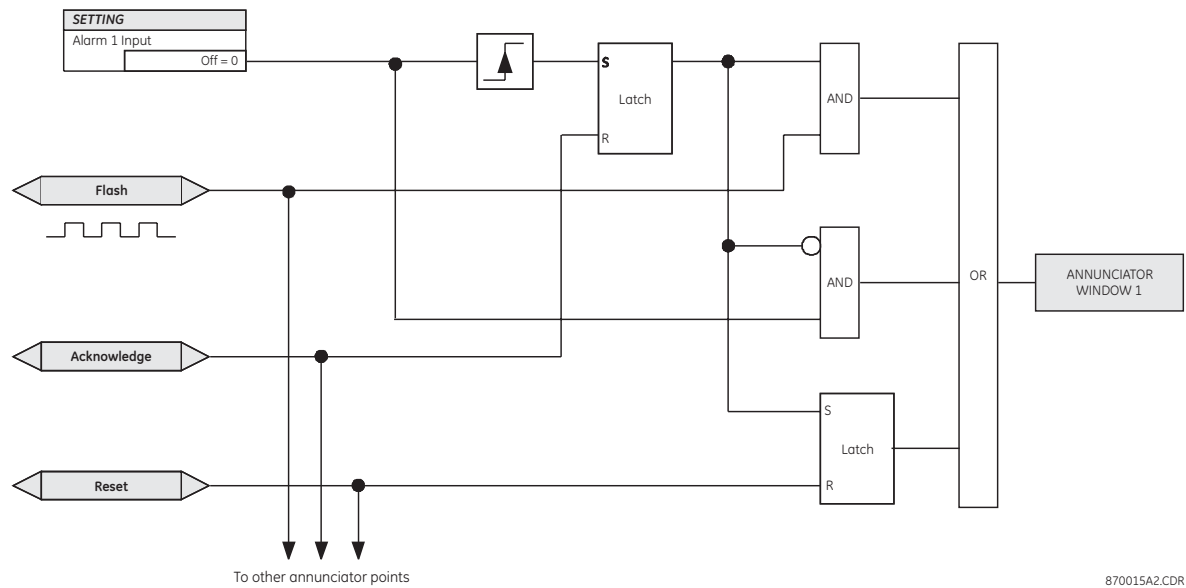
Mimic diagrams

The C90^{Plus} supports a total of twelve pre-defined mimic diagrams as well as a user-configurable mimic diagram. Select the **Settings > Local HMI > Mimic Diagram** menu item to open the mimic diagram selection window.

Figure 348: Mimic diagram selection window
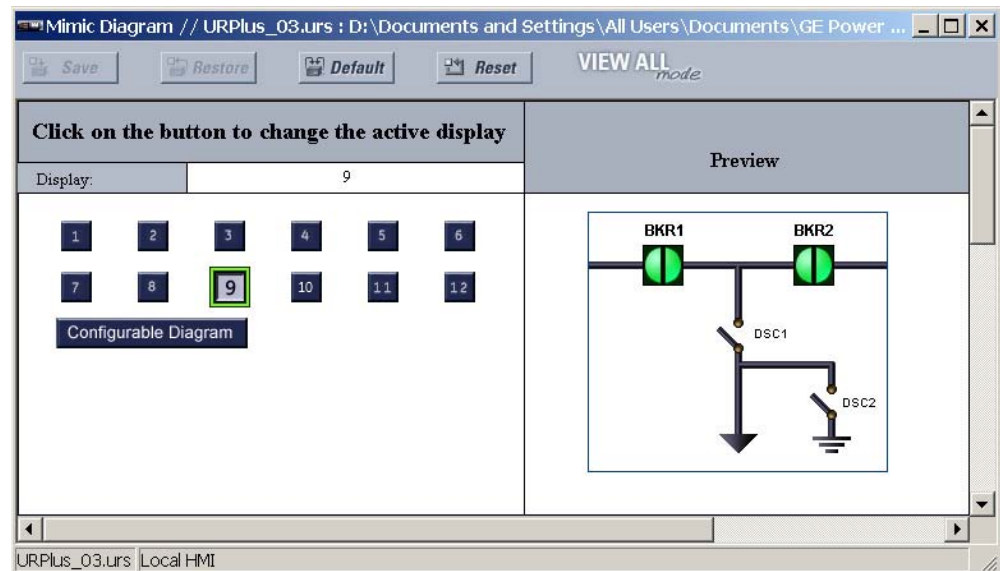
Breakers and disconnect switches are pre-assigned to twelve diagrams shown in the following figures. If a breaker or disconnect switch has not been enabled, then the device will display as a solid block.

Figure 349: Mimic diagram 1, breaker enabled
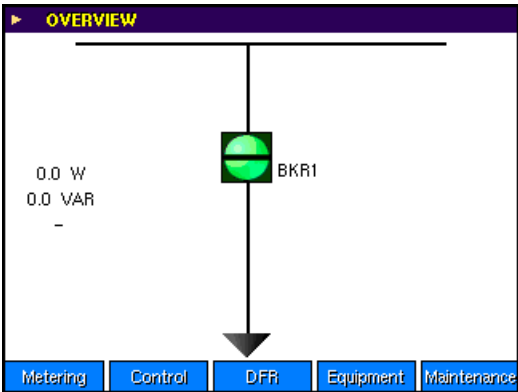
Figure 350: Mimic diagram 2, disconnect 1 enabled
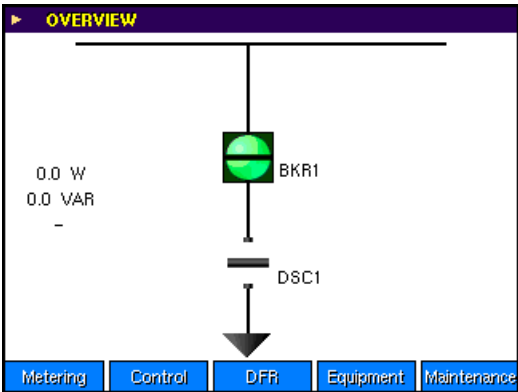
Figure 351: Mimic diagram 3, breaker 1 and disconnects 1 to 2 enabled
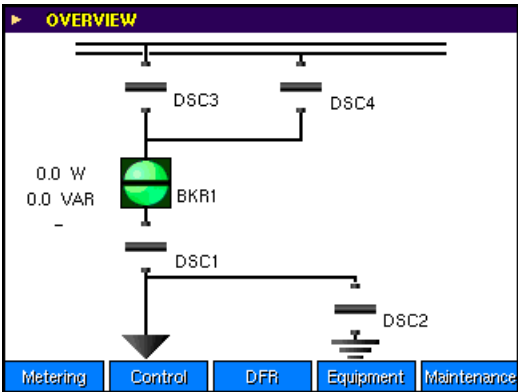
Figure 352: Mimic diagram 4, breaker 1 and disconnects 1 to 4 enabled
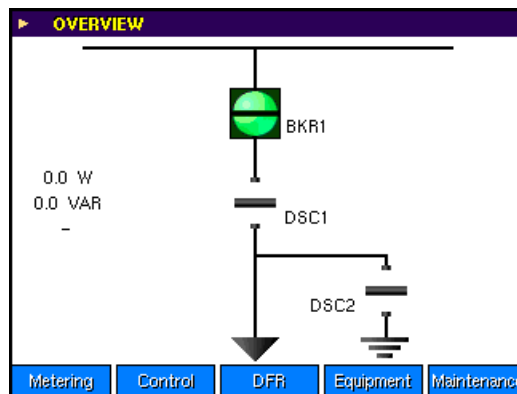
Figure 353: Mimic diagram 5, breaker 1 and disconnects 1 to 5 enabled
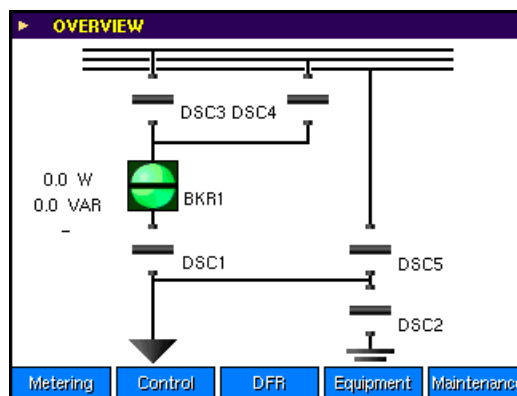
Figure 354: Mimic diagram 6, breaker 1 and disconnects 1 to 6 enabled
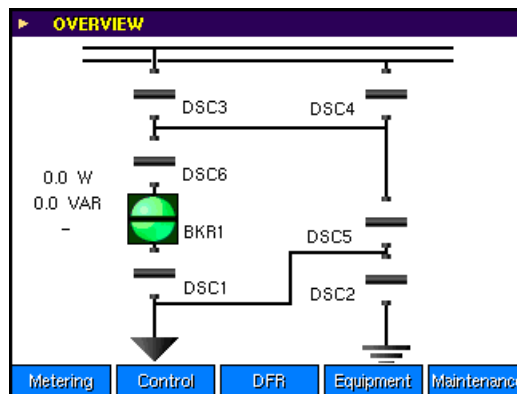
Figure 355: Mimic diagram 7, breakers 1 and 2 enabled
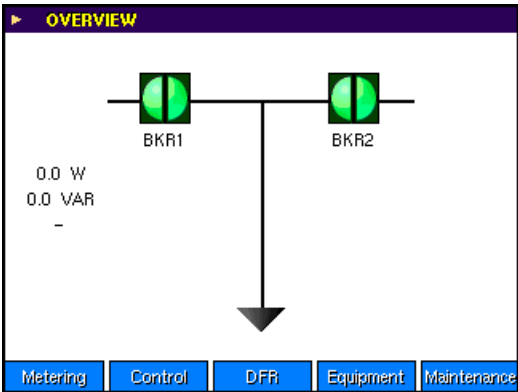
Figure 356: Mimic diagram 8, breakers 1 and 2 and disconnect 1 enabled
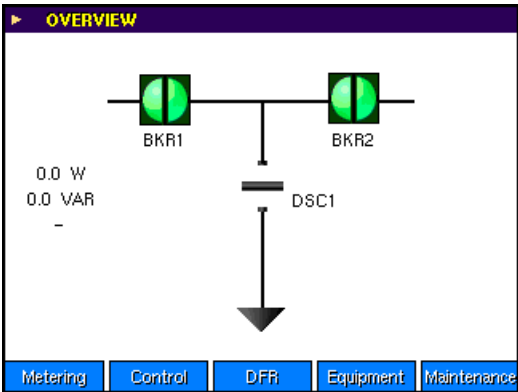
Figure 357: Mimic diagram 9, breakers 1 and 2 and disconnects 1 to 2 enabled
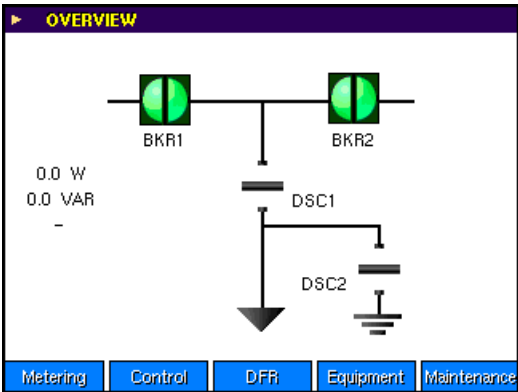
Figure 358: Mimic diagram 10, breakers 1 and 2 and disconnects 3 to 6 enabled
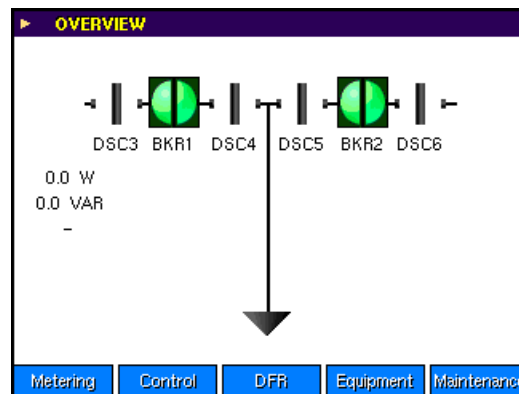
Figure 359: Mimic diagram 11, breakers 1 and 2 and disconnects 1 and 3 to 6 enabled
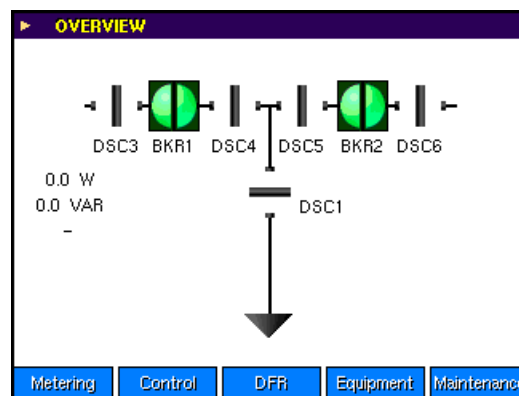
Figure 360: Mimic diagram 12, breakers 1 and 2 and disconnects 1 to 6 enabled
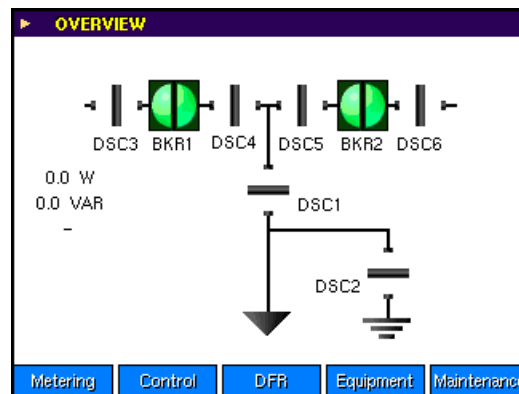
Mimic diagram editor

The mimic diagram editor allows users to create customized single line diagrams (mimic diagrams) for the front panel display. Select the **Settings > Local HMI > Mimic Diagram Editor** menu item to open the mimic diagram editing window.

Figure 361: Mimic diagram editor with example diagram
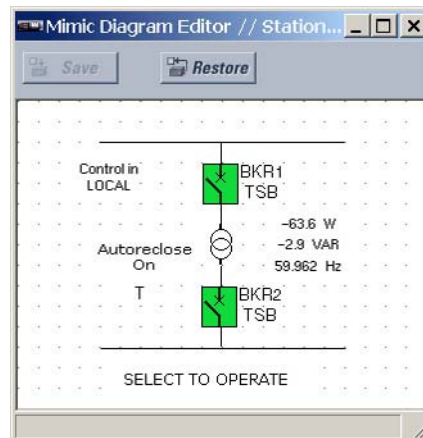
A components library is included on the upper-right side of the EnerVista UR^Plus Setup software. These include dynamic power components, static power components, and text blocks. To create the single line diagram, select the desired component and then click the drawing pane to place the component. Once on the drawing plane, the component can be positioned accordingly.

Figure 362: Mimic diagram components library
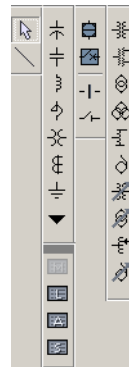
The following functions are available for the mimic diagram editor.

- Circuit breakers
- Disconnect and earthing switches
- Busbars
- Transformers
- Capacitor banks
- Reactors
- CTs and VTs
- Transmission lines
- Grounding

The circuit breakers, disconnects, and earthing switches can be configured to automatically display the actual status of these devices. All other devices are static. As such, they are used for information only and cannot dynamically change states.

Dynamic symbols

The following dynamic symbols are available. The symbols can be displayed in the standard UR^{Plus}-series format or as IEC style symbols.

Figure 363: Mimic diagram editor dynamic symbols

Components	Symbols		Notes
	Standard	IEC	
Circuit breakers in the open position			: Only this symbol is defined in the IEC standard; the others are created
Circuit breakers in the closed position			Created symbols
Circuit breakers with bad status			Created symbols
Tagged circuit breakers	T S	T S T S	Device is tagged (T); status is substituted (S). Created symbols
Switches in the open position			: Only this symbol is defined in the IEC standard; the others are created
Switches in the closed position			Created symbols
Switches with bad status			Created symbols
Switches in the intermediate position			Created symbols
Tagged switches	T S	T S	Device is tagged (T); status is substituted (S). Created symbols

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A maximum of eight (8) dynamic components is allowed for each diagram, including 2 breakers and 6 switches.

When a dynamic symbol selected and added to the diagram, a window will appear to configure the device. This allows the user to specify the name and orientation of the device. For example, the breaker properties device configuration window is shown below.
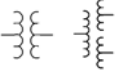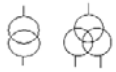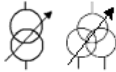
Figure 364: Breaker properties device configuration
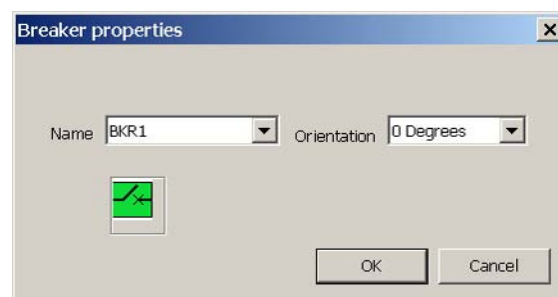
Static symbols

The following static symbols are available. The symbols can be displayed in the standard UR^{Plus}-series format or as IEC style symbols.

Figure 365: Mimic diagram editor dynamic symbols

Components	Symbols	
	Standard	**IEC**
Transformer		
Autotransformer		
Transformer with tap changer		
Autotransformer with tap changer		
Capacitor bank		
Reactor		
VT		
CT		
Grounding		
Busbar and transmission lines		

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For more information on these symbols, please refer to the ANSI/IEEE 315A and IEC 617 standards. There is no limit on the number of static symbols per screen, provided they fit within the screen dimensions.

When a static symbol selected and added to the diagram, a window will appear to configure the device. This allows the user to specify the orientation of the device; the name of a static device cannot be changed. For example, the transformer properties device configuration window is shown below.

Figure 366: Transformer properties device configuration
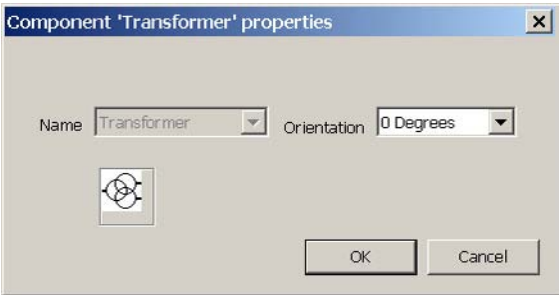
Text blocks

Text blocks are used to display various metered quantities. These text blocks allow the user to display specific analog values in the configurable mimic diagram. The four types of text blocks available are shown below.

Figure 367: Mimic diagram text block symbols

Text block type	Interface symbols	
	Button	Example display
Metered text block		−63.6 W −2.9 VAR 59.962 Hz
Local/remote text block		Control in LOCAL
Autoreclose text block		T Autoreclose On
Select-to-operate text block		SELECT TO OPERATE

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User-programmable pushbuttons

User-programmable pushbuttons provide a simple and error-free method of entering digital state (on, off) information. There are 20 user-programmable pushbuttons available for the C90^{Plus}.

The digital state can be entered locally (by directly pressing the front panel pushbutton) or remotely (via operands) into logic equations, protection elements, and control elements. Typical applications include breaker control, autorecloser blocking, and setting groups changes.

Each pushbutton asserts its own on-state and off-state operands (for example, PUSHBUTTON 1 ON and PUSHBUTTON 1 OFF). These operands are available for each pushbutton and are used to program specific actions. If any pushbutton is active, the ANY PB ON operand will be asserted.

The pushbuttons can be automatically controlled by asserting user-specified operands. The pushbutton reset status is declared when the PUSHBUTTON 1 OFF operand is asserted. The activation and deactivation of user-programmable pushbuttons is dependent on whether latched or self-reset mode is selected.

In latched mode, a pushbutton can be set (activated) by asserting the set operand or by directly pressing the associated front panel pushbutton. The pushbutton maintains the set state until deactivated by the reset command or after a user-specified time delay. The state of each pushbutton is stored in non-volatile memory and maintained through a loss of control power. The pushbutton is reset (deactivated) in latched mode by asserting the reset operand or by directly pressing the associated active front panel pushbutton. The pushbutton can also be programmed to reset automatically through user-specified settings. These settings enable the autoreset timer and specify the associated time delay. The autoreset timer can be used in select-before-operate (SBO) breaker control applications, where the command type (close/open) or breaker location (feeder number) must be selected prior to command execution. The selection must reset automatically if control is not executed within a specified time period.

In self-reset mode, a pushbutton will remain active for the time it is pressed (the pulse duration) plus a user-specified dropout time. If the pushbutton is activated via logic equations, the pulse duration is specified by only the user-specified dropout time. The time the set operand remains assigned has no effect on the pulse duration. The pushbutton is reset (deactivated) in self-reset mode when a user-specified dropout delay expires.

NOTE

The pulse duration of the remote set, remote reset, or local pushbutton must be at least 50 ms to operate the pushbutton. This allows the user-programmable pushbuttons to properly operate during power cycling events and various system disturbances that may cause transient assertion of the operating signals.

The local and remote operation of each user-programmable pushbutton can be inhibited through user settings. If local locking is applied, the pushbutton will ignore set and reset commands executed through the front panel pushbuttons. If remote locking is applied, the pushbutton will ignore set and reset commands executed through logic operands.

The locking functions are not applied to the autorestart feature. In this case, the inhibit function can be used in SBO control operations to prevent the pushbutton function from being activated and ensuring *one-at-a-time* select operation. The locking functions can also be used to prevent the accidental pressing of the front panel pushbuttons. The separate inhibit of the local and remote operation simplifies the implementation of local/ remote control supervision.

Pushbutton states can be logged by the event recorder and displayed as target messages. In latched mode, user-defined messages can also be associated with each pushbutton and displayed when the pushbutton is on or changing to off.

User-programmable pushbuttons settings

Select the **Settings > Local HMI > User-Programmable Pushbuttons** menu item to open the user-programmable pushbuttons settings window.

Figure 368: User-programmable pushbuttons configuration settings

PARAMETER	PB 1	PB 2	PB 3
Function	Latched	Latched	Latched
ID Text			
On Text			
Off Text			
Set	OFF	OFF	OFF
Reset	OFF	OFF	OFF
Autoreset	Disabled	Disabled	Disabled
Autoreset Delay	1.0 s	1.0 s	1.0 s
Remote Lock	OFF	OFF	OFF
Local Lock	OFF	OFF	OFF
Dropout Time	0.0 s	0.0 s	0.0 s
Events	Enabled	Enabled	Enabled

URPlus_03.urs | Local HMI

The following settings are available for each user-programmable pushbutton.

Function

Range: Disabled, Latched, Self-Reset
Default: Disabled

This setting selects the pushbutton operating characteristic. If set to "Disabled", the pushbutton is not active and the corresponding operands (both on-state and off-state operands) are de-asserted. If set to "Self-Reset", the control logic is activated by the pulse (longer than 100 ms) issued when the pushbutton is physically initiated via the front panel interface or virtually initiated via logic.

When in "Self-Reset" mode and activated locally, the pushbutton control logic asserts the corresponding on-state operand as long as the pushbutton remains physically initiated. After the pushbutton is released, the de-assertion of the operand is delayed by the drop out timer. The off-state operand is asserted when the pushbutton element is deactivated. If the pushbutton is activated remotely, the pushbutton control logic asserts the corresponding on-state operand only for the time specified by the **Dropout Time** setting.

If set to "Latched", the pushbutton control logic alternates the state of the corresponding operand between the on-state and off-state on each button press or by virtually activating the pushbutton (assigning set and reset operands). In latched mode, the operand states are stored in non-volatile memory. Should supply power be lost, the correct state of the pushbutton is retained upon subsequent power-up.

ID Text

Range: up to 20 alphanumeric characters
Default: empty

This setting specifies the name (ID) for the user-programmable pushbutton.

On Text

Range: up to 20 alphanumeric characters
Default: empty

This setting specifies the text to display when the pushbutton is in the on position.

Off Text

Range: up to 20 alphanumeric characters
Default: empty

This setting specifies the text to display when the pushbutton is in the off position. This message is not displayed in self-reset mode as the pushbutton operand status is implied to be off upon its release.

Set

Range: any FlexLogic™ operand or shared operand
Default: OFF

When the operand assigned to this setting is asserted, the pushbutton is operated and the PUSHBUTTON 1 ON operand is asserted. The duration of the incoming set signal must be at least 100 ms.

Reset

Range: any FlexLogic™ operand or shared operand
Default: OFF

When the operand assigned to this setting is asserted, the pushbutton is reset and the PUSHBUTTON 1 OFF operand is asserted. This setting is applicable only if the pushbutton is in latched mode. The duration of the incoming set signal must be at least 100 ms.

Autoreset

Range: Disabled, Enabled

Default: Disabled

This setting enables the user-programmable pushbutton autoreset feature. This setting is applicable only if the pushbutton is in latched mode.

Autoreset Delay

Range: 0.2 to 600.0 seconds in steps of 0.1

Default: 1.0 seconds

This setting specifies the time delay for automatic reset of the pushbutton when in the latched mode.

Remote Lock

Range: any FlexLogic™ operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, pushbutton operation from operands assigned to the **Set** or **Reset** settings is inhibited.

Local Lock

Range: any FlexLogic™ operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, pushbutton operation from the front panel interface is inhibited. This locking functionality is not applicable to pushbutton autoreset.

Dropout Time

Range: 0.0 to 60.0 seconds in steps of 0.1

Default: 0.0 seconds

This setting specifies the duration of the pushbutton active status after the pushbutton has been released. This setting applies only to self-reset mode and is required to set the duration of the pushbutton operating pulse.

Events

Range: Disabled, Enabled

Default: Enabled

This setting enables and disables the logging of user-programmable pushbutton events in the sequence of events recorder.

The user-programmable pushbutton 1 logic is shown below. The logic is functionally identical for all user-programmable pushbuttons.

Figure 369: User-programmable pushbutton logic, sheet 1 of 2

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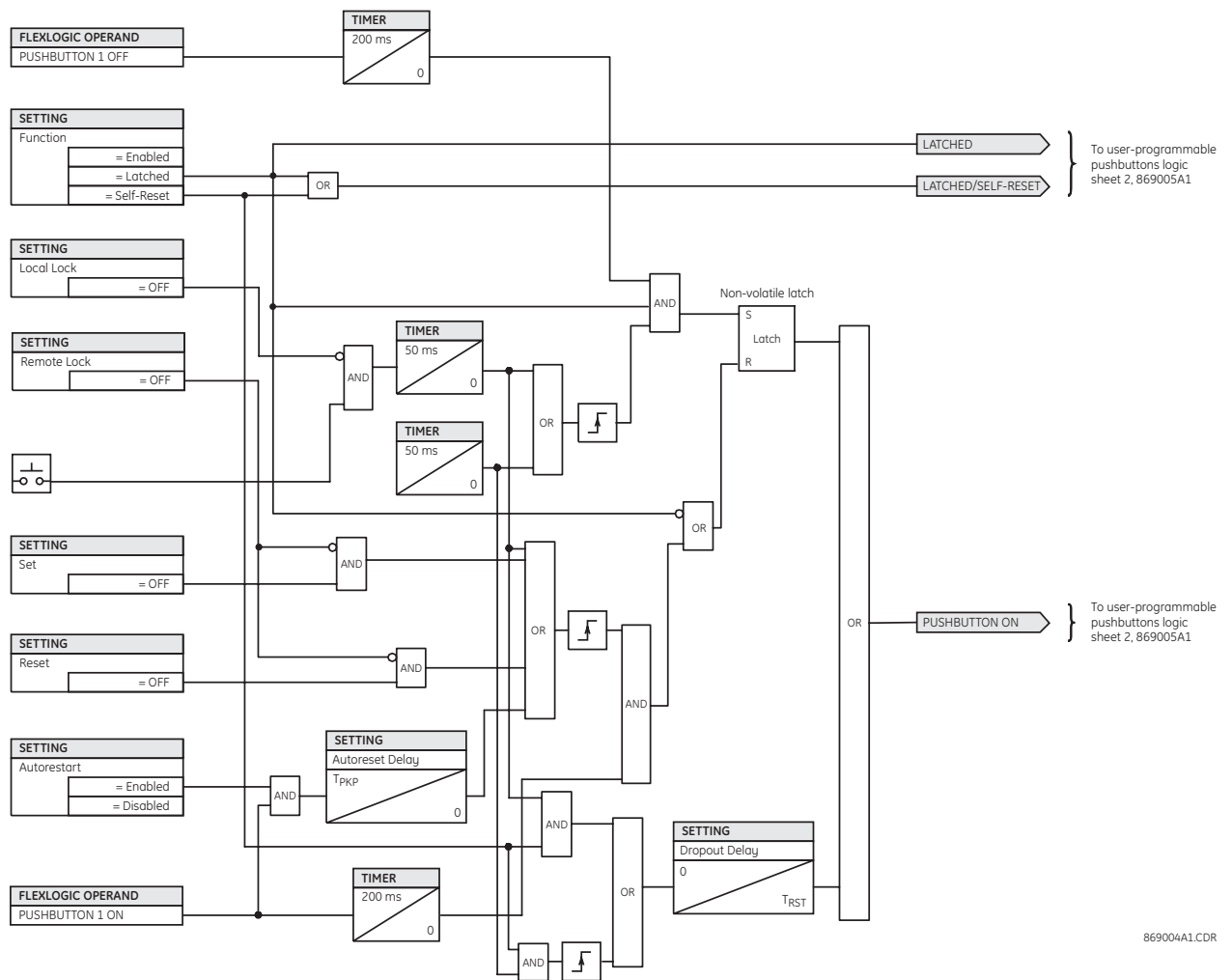
Figure 370: User-programmable pushbutton logic, sheet 2 of 2

869005A1.CDR
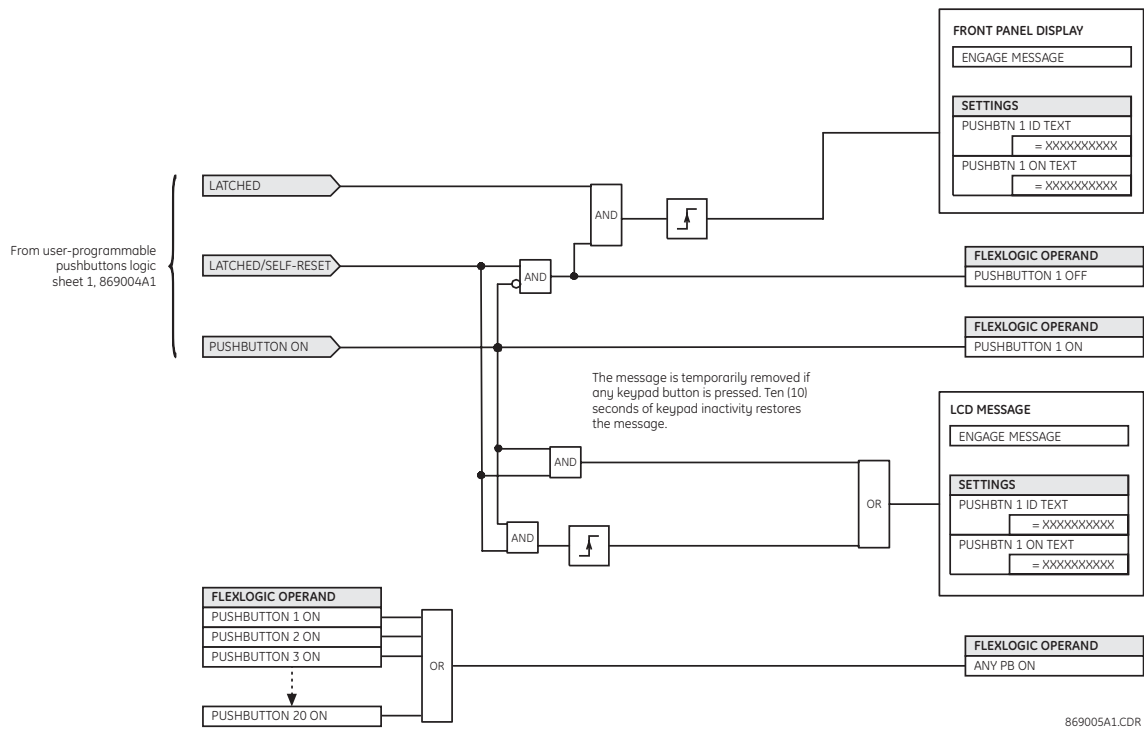
C90^{Plus} Controller

Chapter 12: Security

This section describes how to program the C90^{Plus} security features.

Password security

It is recommended that passwords be programmed for each security level and assigned to specific personnel. There are two user password security access levels: command and setting.

The command access level restricts the user from making any settings changes, but allows the user to perform the following operations.

- Operate breakers via the front panel interface.
- Change the state of virtual inputs.
- Clear event records.
- Clear oscillography records.
- Clear fault reports.
- Change the system date and time.
- Clear energy records.
- Operate control pushbuttons.

The setting access level allows the user to make any changes to any of the setting values and operate in test mode.

The command and setting passwords are not programmed when the relay is shipped from the factory. When a command or setting password is set to null, the password security feature is disabled.

The C90^{Plus} supports password entry from a local or remote connection.

Local access is defined as any access to settings or commands via the faceplate interface. This includes both keypad entry and the faceplate serial USB connection. Remote access is defined as any access to settings or commands via any rear Ethernet port. Any changes to the local or remote passwords enables this functionality.

When entering a settings or command password via EnerVista UR^{Plus} Setup or the serial USB interface, the user must enter the corresponding connection password. If the connection is to the rear of the C90^{Plus}, the remote password must be used. If the connection is to the USB port of the faceplate, the local password must be used.

Password security settings

Select the **Settings > Security > Password Security** menu item to open the password security settings window.

Figure 371: Password security configuration settings

The following settings are available.

Command Password

Range: 0 to 9999999999 in steps of 1 or null
Default: null

The value of the command password is specified here. For the password to be successfully entered, the values in the **Enter New Password** and **Confirm New Password** fields must be identical.

If an entered password is lost (or forgotten), consult the factory with the corresponding **Encrypted Password** value.

Setting Password

Range: 0 to 9999999999 in steps of 1 or null
Default: null

The value of the setting password is specified here. For the password to be successfully entered, the values in the **Enter New Password** and **Confirm New Password** fields must be identical.

If an entered password is lost (or forgotten), consult the factory with the corresponding **Encrypted Password** value.

Password security operation

In the event that an incorrect command or setting password has been entered three times within a three-minute time span, the ACCESS DENIED operand will be asserted and the C90^{Plus} will not allow setting or command access for the next ten minutes. The operand will be de-asserted after the expiration of the ten-minute timeout.

The C90^{Plus} provides a means to raise an alarm upon failed password entry. Should password verification fail while accessing a password-protected level of the relay (either settings or commands), the UNAUTHORIZED ACCESS operand is asserted. The operand can be programmed to raise an alarm via contact outputs or communications. This feature can be used to protect against both unauthorized and accidental access attempts. The UNAUTHORIZED ACCESS operand is reset with the Reset Unauthorized Alarms command. Therefore, to apply this feature with security, the command level should be password-protected. The operand does not generate events. If event recording is required, the operand can be assigned to a digital element programmed with its event log enabled.

EnerVista security management system

The EnerVista security management system is a role-based access control (RBAC) system that allows a security administrator to easily manage the security privileges of multiple users. This allows for access control of UR^{Plus}-series devices by multiple personnel within a substation and conforms to the principles of RBAC as defined in ANSI INCITS 359-2004.

The EnerVista security management system is disabled by default to allow the administrator direct access to the EnerVista software after installation. It is recommended that security be enabled before placing the device in service.

Enabling the security management system

The EnerVista security management system is disabled by default. This allows access to the device immediately after installation. When security is disabled, all users are granted administrator access.

1. Select the **Security > User Management** menu item to open the user management configuration window.
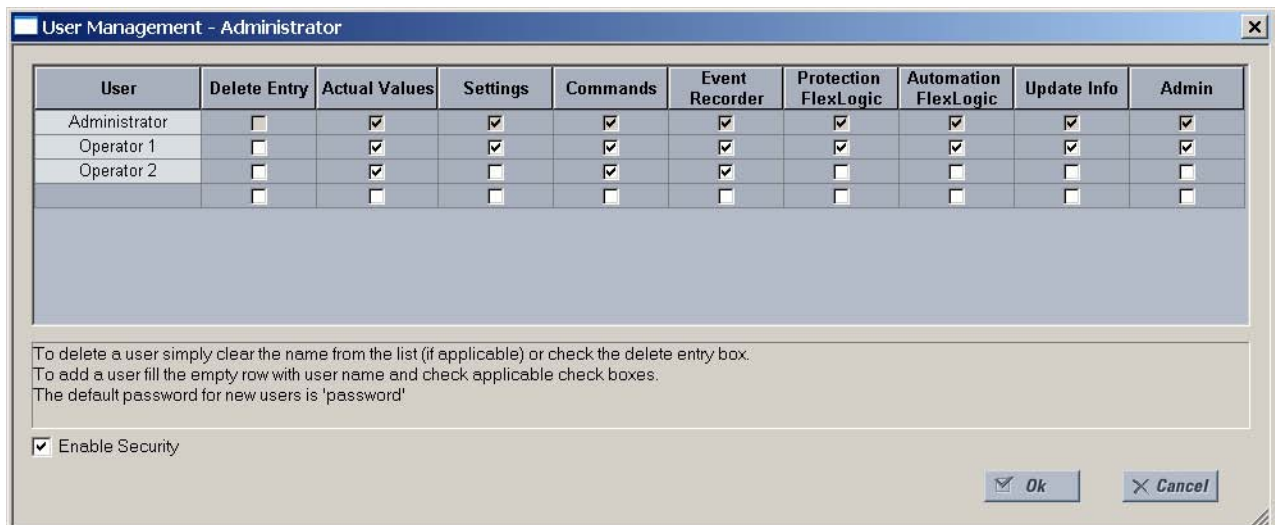
2. Check the **Enable Security** box in the lower-left corner to enable the security management system.

Security is now enabled for the EnerVista UR^{Plus} Setup software. It will now be necessary to enter a username and password upon starting the software.

Adding a new user

The following procedure describes how to add new users to the security management system. The following pre-requisites are required to add new users.

• The user adding the new user must have administrator rights.

• The EnerVista security management system must be enabled.

1. Select the **Security > User Management** menu item to open the user management configuration window.

2. Enter a username in the **User** field. The username must be between 4 and 20 characters in length.

3. Select the user access rights by checking one or more of the fields shown.

Field	Description
Delete Entry	Checking this box will delete the user when exiting the user management configuration window.
Actual Values	Checking this box allows the user to read actual values.
Settings	Checking this box allows the user to read setting values.
Commands	Checking this box allows the user to execute commands.
Event Recorder	Checking this box allows the user to use the digital fault recorder.
Protection FlexLogic	Checking this box allows the user to read protection FlexLogic™ values.
Automation Logic	Checking this box allows the user to read automation logic values.
Update Info	Checking this box allows the user to write to any function to which they have read privileges. When any of the **Settings**, **Event Recorder**, **Protection FlexLogic**, and **Automation Logic** boxes are checked by themselves, the user is granted read access. When any of these are checked in conjunction with the **Update Info** box, they are granted read and write access. The user will not be granted write access to functions that are not checked, even if the **Update Info** field is checked.
Admin	When this box is checked, the user will become an EnerVista UR^{Plus} Setup administrator, therefore receiving all of the administrative rights. Exercise caution when granting administrator rights.

4. Click **OK** to add the new user to the security management system.

Modifying user privileges

The following procedure describes how to modify user privileges in the security management system. The following pre-requisites are required to add new users.

- The user modifying the privileges must have administrator rights.
- The EnerVista security management system must be enabled.

1. Select the **Security > User Management** menu item to open the user management configuration window.

2.   Locate the username in the **User** field.

3.   Modify the user access rights by checking or clearing one or more of the fields shown.

Field	Description
Delete Entry	Checking this box will delete the user when exiting the user management configuration window.
Actual Values	Checking this box allows the user to read actual values.
Settings	Checking this box allows the user to read setting values.
Commands	Checking this box allows the user to execute commands.
Event Recorder	Checking this box allows the user to use the digital fault recorder.
Protection FlexLogic	Checking this box allows the user to read protection FlexLogic™ values.
Automation Logic	Checking this box allows the user to read automation logic values.
Update Info	Checking this box allows the user to write to any function to which they have read privileges. When any of the **Settings**, **Event Recorder**, **Protection FlexLogic**, and **Automation Logic** boxes are checked by themselves, the user is granted read access. When any of these are checked in conjunction with the **Update Info** box, they are granted read and write access. The user will not be granted write access to functions that are not checked, even if the **Update Info** field is checked.
Admin	When this box is checked, the user will become an EnerVista UR^{Plus} Setup administrator, therefore receiving all of the administrative rights. Exercise caution when granting administrator rights.

4.   Click **OK** to save the changes to user to the security management system.

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C90^{Plus} Controller

Chapter 13: Testing

This section describes the C90^{Plus} testing features.

Test mode

The C90^{Plus} provides test settings to verify that functionality using simulated conditions for contact inputs and outputs. To initiate the test mode, the **Test Mode Function** setting must be "Enabled" and the operand assigned to the **Test Mode Initiate** setting must be set to logic 1.

In particular, the test mode is initiated as follows.

- To initiate test mode through the C90^{Plus} settings, set the **Test Mode Initiate** to "ON". The test mode starts when the **Test Mode Function** setting is changed from "Disabled" to "Enabled".

- To initiate test mode through a user-programmable condition, such as FlexLogic™ operand, set the **Test Mode Function** setting to "Enabled" and the **Test Mode Initiate** to the desired operand. The test mode starts when the selected operand assumes a logic 1 state.

When in the test mode, the C90^{Plus} remains fully operational, allowing for various testing procedures. The only difference between the normal operation and the test mode is the behavior of the input and output contacts. The former can be forced to report as open or closed or remain fully operational; the latter can be forced to open, close, freeze, or remain fully operational. The response of the digital input and output contacts to the test mode is programmed individually for each input and output using the force contact inputs and force contact outputs test functions described in the following sections.

Force contact inputs

The force contact inputs feature provides a method of performing checks on the function of all contact inputs. Once enabled, the C90^{Plus} is placed into test mode, allowing this feature to override the normal function of contact inputs. All contact input operations return to normal when all settings for this feature are disabled.

Select the **Settings > Testing > Force Contact Inputs** menu item to open the force contact inputs configuration window.

Figure 372: Force contact inputs configuration settings

The following settings are available.

Test Mode Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disabled the test mode functionality.

Test Mode Initiate

Range: any FlexLogic™ operand

Default: ON

The test mode will initiate when the operand assigned to this setting is logic 1.

Cont Ip 1, Cont Ip 2, ..., Cont Ip 12

Range: Normal, Open, Closed

Default: Normal

These settings allow the C90^Plus^ contact inputs to respond to the test mode in the following ways.

– If set to "Normal", the input remains fully operational. It is controlled by the voltage across its input terminals and can be turned on and off by external circuitry. This value should be selected if a given input must be operational during the test. This includes, for example, an input initiating the test, or being a part of a user pre-programmed test sequence.

– If set to "Open", the input is forced to report as opened (logic 0) for the entire duration of the test mode regardless of the voltage across the input terminals.

– If set to "Closed", the input is forced to report as closed (logic 1) for the entire duration of the test mode regardless of the voltage across the input terminals.

These setting names will reflect the programmed contact input names.

Force contact outputs

The force contact output feature allows relay contact outputs to be pre-programmed to respond to the test mode. These settings are applied two ways. First, external circuits may be tested by energizing or de-energizing contacts. Second, by controlling the output contact state, relay logic may be tested and undesirable effects on external circuits avoided.

Select the **Settings > Testing > Force Contact Outputs** menu item to open the force contact outputs configuration window.

Figure 373: Force contact outputs configuration settings
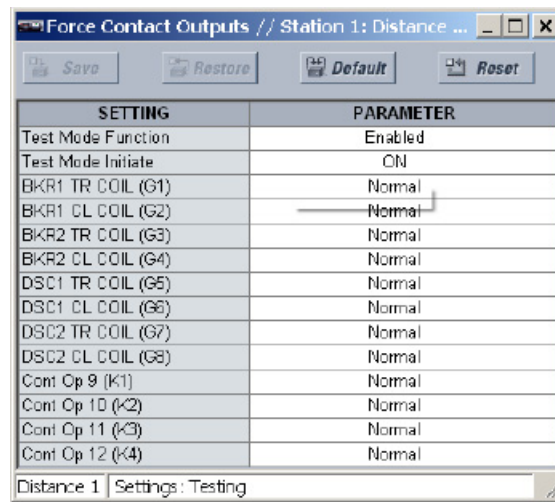
The following settings are available.

Test Mode Function
Range: Enabled, Disabled
Default: Disabled

This setting enables and disabled the test mode functionality.

Test Mode Initiate
Range: any FlexLogic™ operand
Default: ON

The test mode will initiate when the operand assigned to this setting is logic 1.

Cont Op 1, Cont Op 2, ..., Cont Op 12
Range: Normal, Energized, De-energized, Freeze
Default: Normal

These settings allow the C90^{Plus} contact outputs to respond to the test mode in the following ways.

–   If set to "Normal", the contact output remains fully operational. It operates when its control operand is logic 1 and resets when its control operand is logic 0.

–   If set to "Energized", the output will close and remain closed for the entire duration of the test mode, regardless of the status of the operand configured to control the output contact.

–   If set to "De-energized", the output will open and remain opened for the entire duration of the test mode regardless of the status of the operand configured to control the output contact.

–   If set to "Freeze", the output retains its position from before entering the test mode, regardless of the status of the operand configured to control the output contact.

These setting names will reflect the programmed contact output names.

Self-tests

The relay performs a number of self-test diagnostic checks to ensure device integrity. When a self-test error occurs, an item will be displayed in the self-test summary on the annunciator. All errors record an event in the event recorder.

Self-test error messages

The self-test error messages are displayed on the annunciator panel. Error messages can be accessed from the self-test tab. The self-test tab becomes illuminates when there are errors to report.

Figure 374: Typical self-test error page
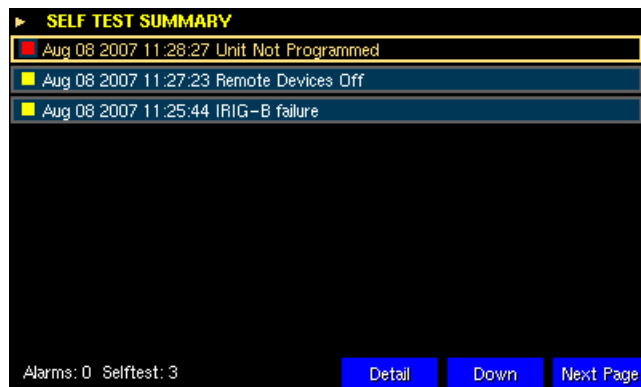
There are three soft-keys associated with the self-test summary page.

- The **Next Page** soft-key cycles through the pages of alarms and to the error messages page. If there are more errors present than can be displayed, scroll bars will appear to notify the user to scroll beyond the screen to view more error messages.

- The **Down** soft-key allows user to cycle through the self-test error messages from top to bottom. A white frame borders the selected self-test error message.

- The **Detail** soft-key displays additional details of the selected error message. A definition of problem, a graphical indication, and some possible solutions are displayed. The following figures shows the details about the IRIG-B FAILURE self-test error message.

Figure 375: IRIG-B failure message details
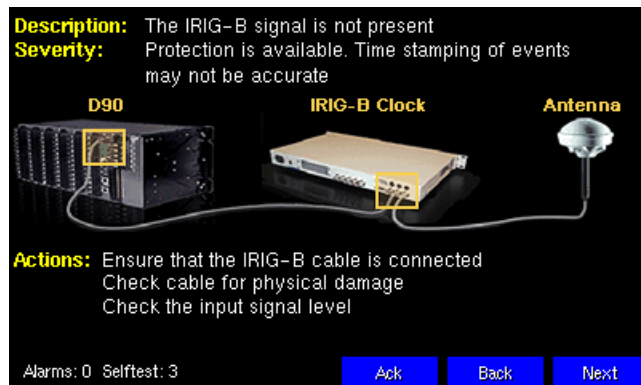
Self-test errors are classed as minor errors and major errors. The major self-test error messages are indicated in red on the annunciator display and are described below.

AC CARD FAILURE

Description: The AC module is not operational.
Severity: Protection is not available.

If this message appears, reset the alarm. If the alarm recurs, replace the AC module.

CPU CARD FAILURE

Description: The CPU module is not operational.
Severity: Protection is not available

If this message appears, reset the alarm. If the alarm recurs, replace the CPU module.

EQUIPMENT MISMATCH

Description: The configuration of modules does not match the order code stored in the CPU.
Severity: Protection is not available.

If this message appears, check all modules against the order code. Ensure they are inserted properly, and recycle the control power.

UNIT NOT PROGRAMMED

Description: The unit is configured as not programmed.
Severity: Protection is not available

If this message appears, confirm that the unit has the proper settings. Change the Relay Settings value to "Programmed".

The minor self-test error messages are indicated in yellow on the annunciator display and are described below.

AUTOMATION MATH ERROR

Description: A mathematical operation in the automation logic has produced an invalid result.
Severity: Protection is available. Automation logic may not produce expected results.

If this message appears, check the event record to determine the nature of the error. Review the automation logic to confirm correct programming.

CPU CARD TROUBLE

Description: There may be a problem with the CPU card.
Severity: Protection is available.

If this message appears, cycle the control power If the alarm recurs, contact GE Multilin.

DELAYED AUTOMATION EXECUTION

Description: Execution of the automation logic is longer than specified.
Severity: Protection is available. Automation logic may not produce expected results.

If this message appears, review the automation logic to confirm correct programming. Move less critical tasks to an automation block with a slower scan.

DIRECT DEVICE OFF

Description: The direct input/output settings are configured for a ring, but the connection is not in a ring.
Severity: Protection and direct input/output messaging is available. However, there is no redundant path available.

If this message appears, check the direct input/output configuration and/or wiring.

DIRECT RING BREAK

Description: A direct device is specified in the configuration but is not connected to the network.

Severity: Protection is available. Direct input/output messaging with the offline device is not available.

If this message appears, check that all devices that are connected to the direct input/output network are properly configured. Check direct input/output wiring.

IRIG-B FAILURE

Description: The IRIG-B input signal is not present.

Severity: Protection is available. Timestamping of events may not be accurate.

If this message appears, ensure that the IRIG-B receiver is operational and properly configured. Ensure that the IRIG-B cable is connected. Check cable integrity (that is, look for physical damage or perform a continuity test). Check the input signal level.

POWER SUPPLY CARD TROUBLE

Description: The power supply module has a problem.

Severity: Protection is available; however, power supply failure may occur. The 48 volt supply may also be impacted.

If this message appears, check that the voltage at the power supply input is within limits. If OK, check that the 48 volt supply is healthy. If not OK, replace the power supply module.

ETHERNET PORT 1 FAILURE, ETHERNET PORT 2 FAILURE, ETHERNET PORT 3 FAILURE

Description: The indicated Ethernet port is not connected to a LAN.

Severity: Protection is available. Remote communications may not be available.

If this message appears, ensure that the external Ethernet switch is operational and properly configured. Check for a link light at both ends of the Ethernet cable. If there is no link light, replace the Ethernet cable. If these steps do not solve the problem, replace the communications module.

REMOTE DEVICE OFF

Description: A remote device is specified in the configuration for GOOSE messaging but is not connected to the network.

Severity: Protection is available. GOOSE messaging with the offline device is not available.

If this message appears, check that all devices that are specified for GOOSE messaging are connected to the network, are functioning properly, and are correctly configured.

SNTP FAILURE

Description: The SNTP server is not responding.

Severity: Protection is available. Timestamping of events may not be accurate.

If this message appears, check that the SNTP server is operational and correctly configured. Check for Ethernet LAN problems.

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