GE Industrial Systems

L90 Line Differential Relay

UR Series Instruction Manual

L90 Revision: **2.9X**

Manual P/N: 1601-0081-**B8** (GEK-106382)

CE

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LISTED

MEASURING EQUIP.

36GN

Manufactured under an

ISO9000 Registered system.

ADDENDUM

This Addendum contains information that relates to the L90 relay, version 2.9X. This addendum lists a number of information items that appear in the instruction manual GEK-106382 (1601-0081-B8) but are not included in the current L90 operations.

The following functions/items are not yet available with the current version of the L90 relay:

- Signal Sources SRC 3 to SRC 6 (availability is pending for this release)

NOTE:

- The UCA2 specifications are not yet finalized. There will be changes to the object models described in Appendix C: UCA/MMS.

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Please read this chapter to help guide you through the initial setup of your new relay.

1.1.1 CAUTIONS AND WARNINGS

WARNING CAUTION

Before attempting to install or use the relay, it is imperative that all WARNINGS and CAUTIONS in this manual are reviewed to help prevent personal injury, equipment damage, and/or downtime.

1.1.2 INSPECTION CHECKLIST

- Open the relay packaging and inspect the unit for physical damage.
- Check that the battery tab is intact on the power supply module (for more details, see the section BATTERY TAB in this chapter).
- View the rear name-plate and verify that the correct model has been ordered.

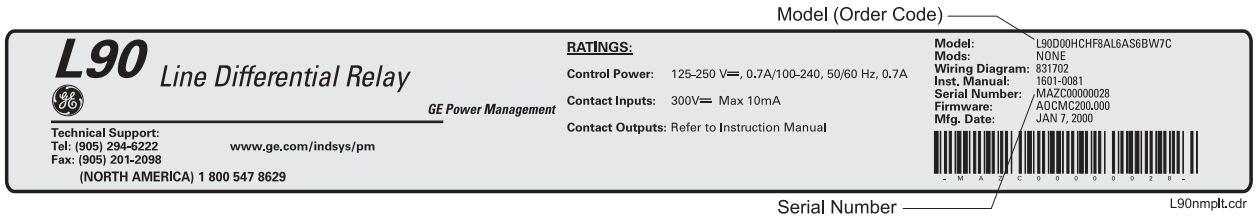

Figure 1–1: REAR NAME-PLATE (EXAMPLE)

- Ensure that the following items are included:
  - Instruction Manual
  - Products CD (includes URPC software and manuals in PDF format)
  - mounting screws
  - registration card (attached as the last page of the manual)
- Fill out the registration form and mail it back to GE Multilin (include the serial number located on the rear nameplate).
- For product information, instruction manual updates, and the latest software updates, please visit the GE Multilin Home Page at http://www.GEindustrial.com/multilin.

NOTE **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:**

GE Multilin
215 Anderson Avenue
Markham, Ontario
Canada L6E 1B3

TELEPHONE: (905) 294-6222, 1-800-547-8629 (North America only)
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1.2.1 INTRODUCTION TO THE UR RELAY

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 5 milliseconds. This has been established by the Electric Power Research Institute, a collective body of many American and Canadian power utilities, in their Utilities Communications Architecture 2 (MMS/UCA2) project. In late 1998, some European utilities began to show an interest in this ongoing initiative.

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 Universal Relay (UR) has been developed to meet these goals.

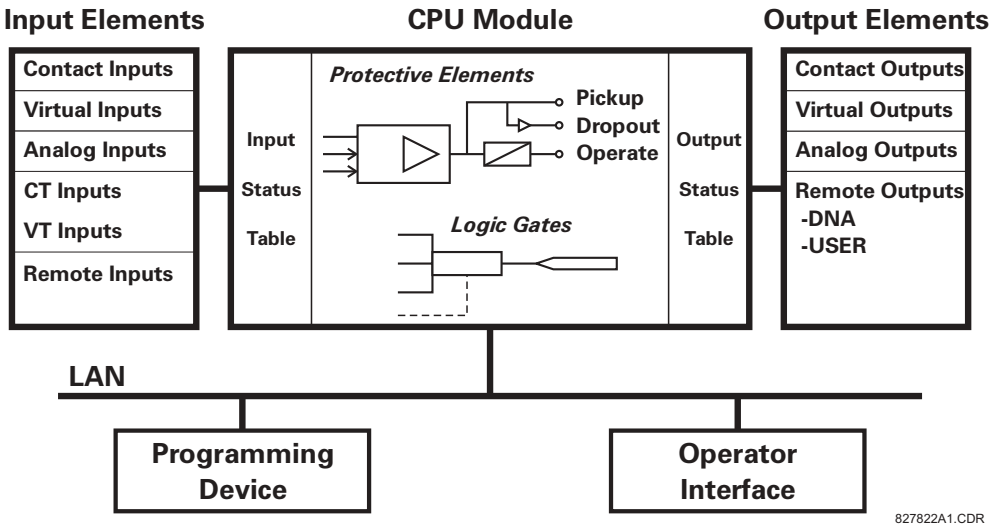


Figure 1–2: UR CONCEPT BLOCK DIAGRAM

a) UR BASIC DESIGN

The UR is a digital-based device containing a central processing unit (CPU) that handles multiple types of input and output signals. The UR can communicate over a local area network (LAN) with an operator interface, a programming device, or another UR device.

The **CPU module** contains firmware that provides protection elements in the form of logic algorithms, as well as programmable logic gates, timers, and latches for control features.

Input elements accept a variety of analog or digital signals from the field. The UR isolates and converts these signals into logic signals used by the relay.

Output elements convert and isolate the logic signals generated by the relay into digital or analog signals that can be used to control field devices.

b) UR SIGNAL TYPES

The **contact inputs and outputs** are digital signals associated with connections to hard-wired contacts. Both 'wet' and 'dry' contacts are supported.

The **virtual inputs and outputs** are digital signals associated with UR internal logic signals. Virtual inputs include signals generated by the local user interface. The virtual outputs are outputs of FlexLogic™ equations used to customize the UR device. Virtual outputs can also serve as virtual inputs to FlexLogic™ equations.

The **analog inputs and outputs** are signals that are associated with transducers, such as Resistance Temperature Detectors (RTDs).

The **CT and VT inputs** refer to analog current transformer and voltage transformer signals used to monitor AC power lines. The UR supports 1 A and 5 A CTs.

The **remote inputs and outputs** provide a means of sharing digital point state information between remote UR devices. The remote outputs interface to the remote inputs of other UR devices. Remote outputs are FlexLogic™ operands inserted into UCA2 GOOSE messages and are of two assignment types: DNA standard functions and USER defined functions.

1

c) UR SCAN OPERATION

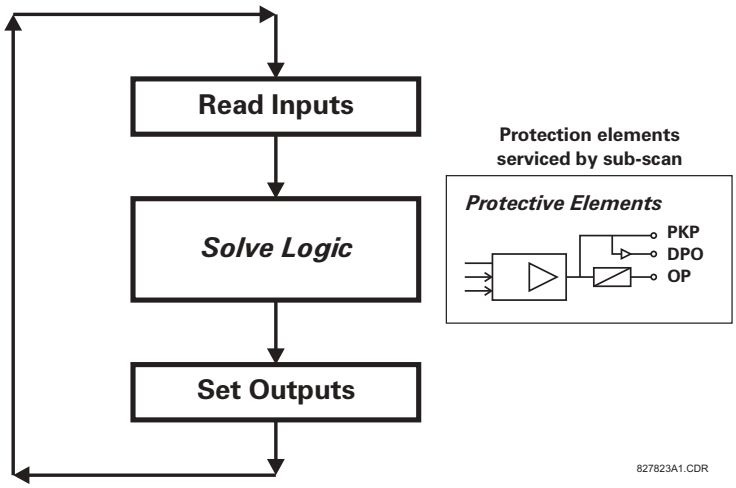


Figure 1–3: UR SCAN OPERATION

The UR device operates in a cyclic scan fashion. The UR reads the inputs into an input status table, solves the logic program (FlexLogic™ equation), and then sets each output to the appropriate state in an output status table. Any resulting task execution is priority interrupt-driven.

1.2.3 UR SOFTWARE ARCHITECTURE

The firmware (software embedded in the relay) is designed in functional modules which can be installed in any relay as required. This is achieved with Object-Oriented Design and Programming (OOD/OOP) techniques.

Object-Oriented techniques involve the use of ‘objects’ and ‘classes’. An ‘object’ is defined as “a logical entity that contains both data and code that manipulates that data”. A ‘class’ is the generalized form of similar objects. By using this concept, one can create a Protection Class with the Protection Elements as objects of the class such as Time Overcurrent, Instantaneous Overcurrent, Current Differential, Undervoltage, Overvoltage, Underfrequency, and Distance. These objects represent completely self-contained software modules. The same object-class concept can be used for Metering, I/O Control, HMI, Communications, or any functional entity in the system.

Employing OOD/OOP in the software architecture of the Universal Relay achieves the same features as the hardware architecture: modularity, scalability, and flexibility. The application software for any Universal Relay (e.g. Feeder Protection, Transformer Protection, Distance Protection) is constructed by combining objects from the various functionality classes. This results in a ’common look and feel’ across the entire family of UR platform-based applications.

1.2.4 IMPORTANT UR CONCEPTS

As described above, the architecture of the UR relay is different from previous devices. In order to achieve a general understanding of this device, some sections of Chapter 5 are quite helpful. The most important functions of the relay are contained in "Elements". A description of UR elements can be found in the INTRODUCTION TO ELEMENTS section. An example of a simple element, and some of the organization of this manual, can be found in the DIGITAL ELEMENTS MENU section. An explanation of the use of inputs from CTs and VTs is in the INTRODUCTION TO AC SOURCES section. A description of how digital signals are used and routed within the relay is contained in the INTRODUCTION TO FLEXLOGIC™ section.

1.3.1 PC REQUIREMENTS

The Faceplate keypad and display or the URPC software interface can be used to communicate with the relay.

The URPC 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 URPC software to properly operate on a PC.

Processor:	Intel® Pentium 300 or higher
RAM Memory:	64 MB minimum (128 MB recommended)
Hard Disk:	50 MB free space required before installation of URPC software
O/S:	Windows® NT 4.x or Windows® 9x/2000
Device:	CD-ROM drive
Port:	COM1(2) / Ethernet

1.3.2 SOFTWARE INSTALLATION

Refer to the following procedure to install the **URPC** software:

1. **Start** the Windows® operating system.
2. **Insert** the **URPC** software CD into the CD-ROM drive.
3. If the installation program does not start automatically, choose **Run** from the Windows® **Start** menu and type D:\SETUP.EXE. Press Enter to start the installation.
4. Follow the on-screen instructions to install the URPC software. When the **Welcome** window appears, click on **Next** to continue with the installation procedure.
5. When the **Choose Destination Location** window appears and if the software is not to be located in the default directory, click **Browse** and type in the complete path name including the new directory name.
6. Click **Next** to continue with the installation procedure.
7. The default program group where the application will be added to is shown in the **Select Program Folder** window. If it is desired that the application be added to an already existing program group, choose the group name from the list shown.
8. Click **Next** to begin the installation process.
9. To launch the URPC application, click Finish in the Setup Complete window.
10. Subsequently, double click on the URPC software icon to activate the application.

NOTE

Refer to the HUMAN INTERFACES chapter in this manual and the URPC Software Help program for more information about the URPC software interface.

1.3.3 CONNECTING URPC® WITH THE L90

This section is intended as a quick start guide to using the URPC software. Please refer to the URPC Help File and the HUMAN INTERFACES chapter for more information.

a) CONFIGURING AN ETHERNET CONNECTION

Before starting, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay.

1. Start the URPC software. Enter the password "URPC" at the login password box.
2. Select the **Help > Connection Wizard** menu item to open the Connection Wizard. Click "Next" to continue.
3. Click the "New Interface" button to open the Edit New Interface window.
   - Enter the desired interface name in the **Enter Interface Name** field.
   - Select the "Ethernet" interface from the drop down list and press "Next" to continue.
4. Click the "New Device" button to open the Edit New Device Window.
   - Enter the desired name in the **Enter Interface Name** field.
   - Enter the Modbus address of the relay (from **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ MODBUS PROTOCOL ⇨ MODBUS SLAVE ADDRESS**) in the **Enter Modbus Address** field.
   - Enter the IP address (from **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK ⇨ IP ADDRESS**) in the **Enter TCPIP Address** field.
5. Click the "4.1 Read Device Information" button then "OK" when the relay information has been received. Click "Next" to continue.
6. Click the "New Site" button to open the Edit Site Name window.
   - Enter the desired site name in the **Enter Site Name** field.
7. Click the "OK" button then click "Finish". The new Site List tree will be added to the Site List window (or Online window) located in the top left corner of the main URPC window.

The Site Device has now been configured for Ethernet communications. Proceed to Section c) CONNECTING TO THE RELAY below to begin communications.

b) CONFIGURING AN RS232 CONNECTION

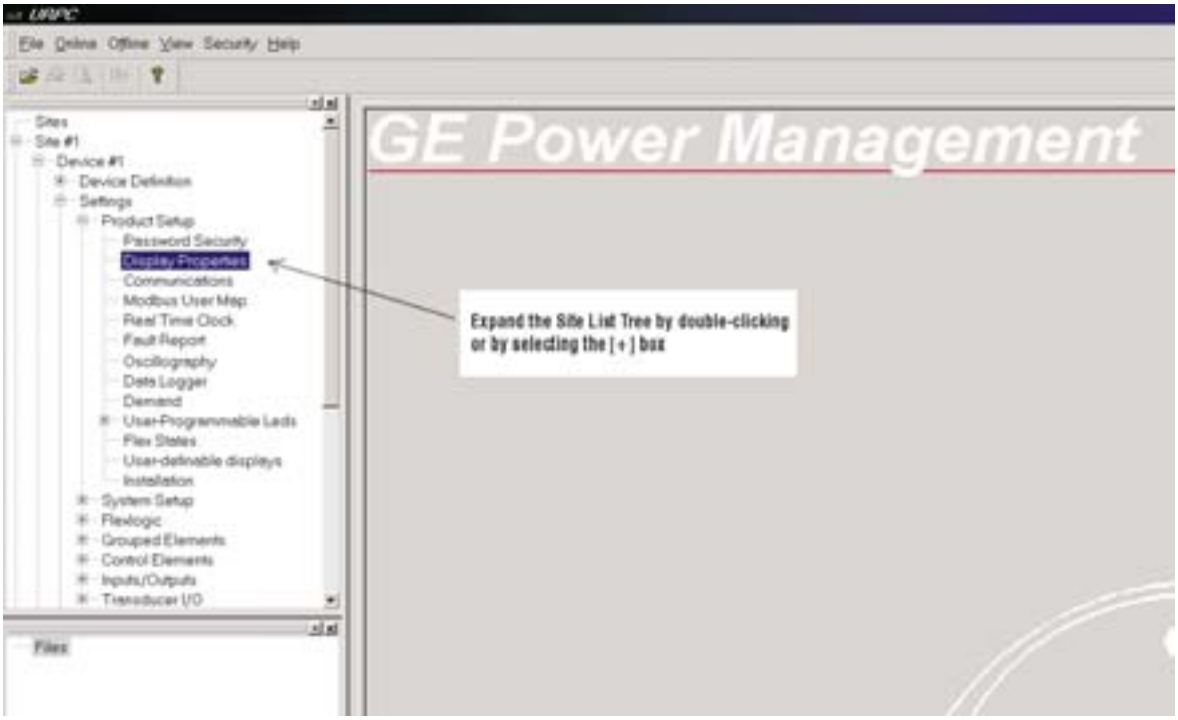
Before starting, verify that the RS232 serial cable is properly connected to the RS232 port on the front panel of the relay.

1. Start the URPC software. Enter the password "URPC" at the login password box.
2. Select the **Help > Connection Wizard** menu item to open the Connection Wizard. Click "Next" to continue.
3. Click the "New Interface" button to open the Edit New Interface window.
   - Enter the desired interface name in the **Enter Interface Name** field.
   - Select the "RS232" interface from the drop down list and press "Next" to continue.
4. Click the "New Device" button to open the Edit New Device Window.
   - Enter the desired name in the **Enter Interface Name** field.
   - Enter the PC COM port number in the **COM Port** field.
5. Click "OK" then click "Next" to continue.
6. Click the "New Site" button to open the Edit Site Name window.
   - Enter the desired site name in the **Enter Site Name** field.
7. Click the "OK" button then click "Finish". The new Site List tree will be added to the Site List window (or Online window) located in the top left corner of the main URPC window.

The Site Device has now been configured for RS232 communications. Proceed to Section c) CONNECTING TO THE RELAY below to begin communications.

c) CONNECTING TO THE RELAY

1. Select the Display Properties window through the Site List tree as shown below:



2. The Display Properties window will open with a flashing status indicator.
   - If the indicator is red, click the Connect button (lightning bolt) in the menu bar of the Displayed Properties window.
3. In a few moments, the flashing light should turn green, indicating that URPC is communicating with the relay.

NOTE

Refer to the HUMAN INTERFACES chapter in this manual and the URPC Software Help program for more information about the URPC software interface.

1.4.1 MOUNTING AND WIRING

Please refer to the HARDWARE chapter for detailed relay mounting and wiring instructions. Review all **WARNINGS and CAUTIONS**.

1.4.2 COMMUNICATIONS

The URPC software communicates to the relay via the faceplate RS232 port or the rear panel RS485 / Ethernet ports. To communicate via the faceplate RS232 port, a standard “straight-through” serial cable is used. The DB-9 male end is connected to the relay and the DB-9 or DB-25 female end is connected to the PC COM1 or COM2 port as described in the HARDWARE chapter.

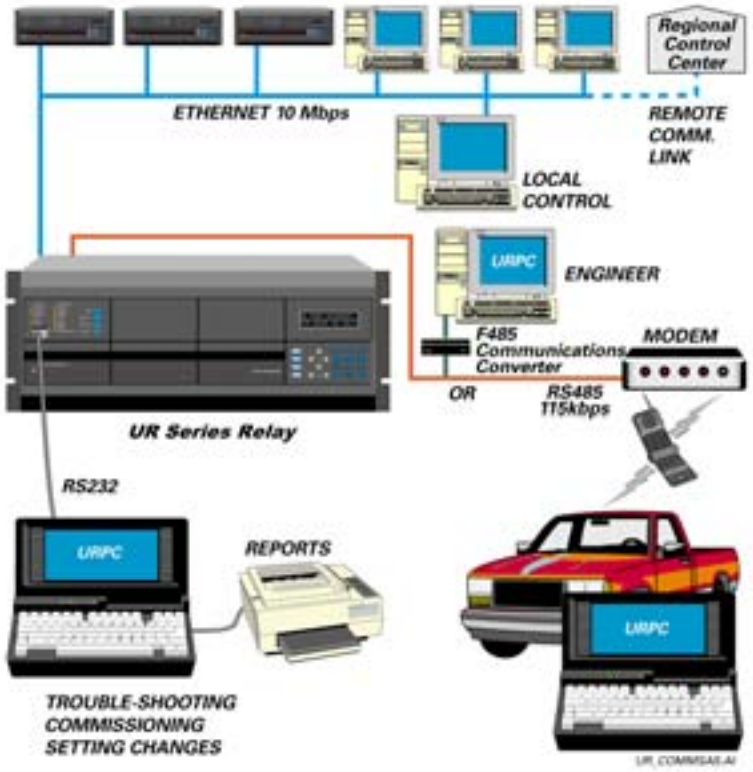


Figure 1–4: RELAY COMMUNICATIONS OPTIONS

To communicate through the L90 rear RS485 port from a PC RS232 port, the GE Power Management 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 L90 rear communications port. The converter terminals (+, –, GND) are connected to the L90 communication module (+, –, COM) terminals. Refer to the CPU COMMUNICATION PORTS section in the HARDWARE chapter for option details. The line should be terminated with an R-C network (i.e. 120 Ω, 1 nF) as described in the HARDWARE chapter.

1.4.3 FACEPLATE DISPLAY

All messages are displayed on a 2 × 20 character vacuum fluorescent display to make them visible under poor lighting conditions. Messages are displayed in English and do not require the aid of an instruction manual for deciphering. While the keypad and display are not actively being used, the display will default to defined messages. Any high priority event driven message will automatically override the default message and appear on the display.

1.5.1 FACEPLATE KEYPAD

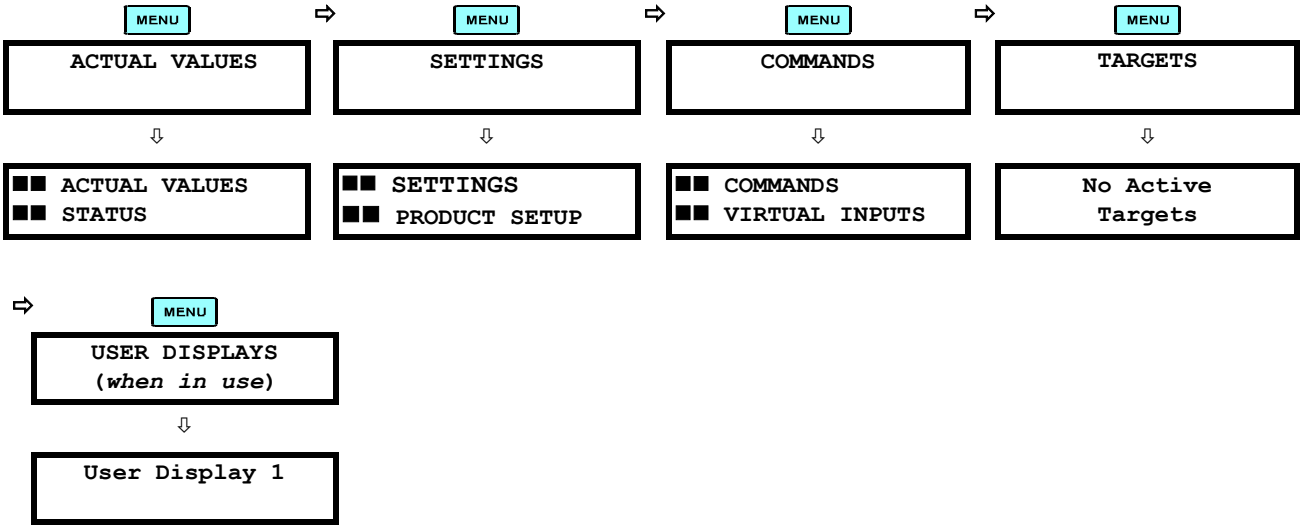
Display messages are organized into 'pages' under the following headings: Actual Values, Settings, Commands, and Targets. The MENU key navigates through these pages. Each heading page is broken down further into logical subgroups.

The MESSAGE keys navigate through the subgroups. The VALUE keys scroll increment or decrement numerical setting values when in programming mode. These keys also scroll through alphanumeric values in the text edit mode. Alternatively, values may also be entered with the numeric keypad.

The key initiates and advance to the next character in text edit mode or enters a decimal point. The HELP key may be pressed at any time for context sensitive help messages. The ENTER key stores altered setting values.

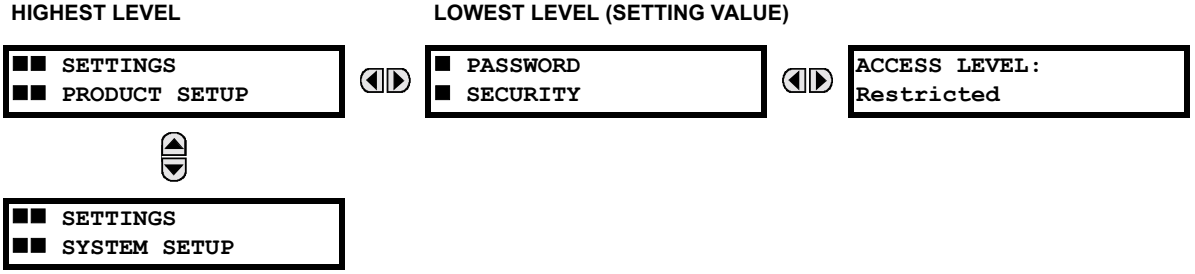
1.5.2 MENU NAVIGATION

Press the MENU key to select the desired header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the MENU key advances through the main heading pages as illustrated below.



1.5.3 MENU HIERARCHY

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bar characters (■■), while sub-header pages are indicated by single scroll bar characters (■). The header display pages represent the highest level of the hierarchy and the sub-header display pages fall below this level. The MESSAGE and keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the MESSAGE key from a header display displays specific information for the header category. Conversely, continually pressing the MESSAGE key from a setting value or actual value display returns to the header display.



1.5.4 RELAY ACTIVATION

The relay is defaulted to the "Not Programmed" state when it leaves the factory. This safeguards against the installation of a relay whose settings have not been entered. When powered up successfully, the TROUBLE indicator will be on and the IN SERVICE indicator off. The relay in the "Not Programmed" state will block signaling of any output relay. These conditions will remain until the relay is explicitly put in the "Programmed" state.

Select the menu message **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION ⇨ RELAY SETTINGS**

```
RELAY SETTINGS:
Not Programmed
```

To put the relay in the "Programmed" state, press either of the VALUE keys once and then press ENTER. The faceplate TROUBLE indicator will turn off and the IN SERVICE indicator will turn on. The settings for the relay can be programmed manually (refer to the SETTINGS chapter) via the faceplate keypad or remotely (refer to the URPC Help file) via the URPC software interface.

1.5.5 BATTERY TAB

The battery tab is installed in the power supply module before the L90 shipped from the factory. The battery tab prolongs battery life in the event the relay is powered down for long periods of time before installation. The battery is responsible for backing up event records, oscillography, data logger, and real-time clock information when the relay is powered off. The battery failure self-test error generated by the relay is a minor and should not affect the relay functionality. When the relay is installed and ready for commissioning, the tab should be removed. The battery tab should be re-inserted if the relay is powered off for an extended period of time. If required, contact the factory for a replacement battery or battery tab.

1.5.6 RELAY PASSWORDS

It is recommended that passwords be set up for each security level and assigned to specific personnel. There are two user password SECURITY access levels:

1. **COMMAND**

The COMMAND access level restricts the user from making any settings changes, but allows the user to perform the following operations:

- operate breakers via faceplate keypad
- change state of virtual inputs
- clear event records
- clear oscillography records

2. **SETTING**

The SETTING access level allows the user to make any changes to any of the setting values.

NOTE **Refer to the CHANGING SETTINGS section (in the HUMAN INTERFACES chapter) for complete instructions on setting up security level passwords.**

1.5.7 FLEXLOGIC™ CUSTOMIZATION

FlexLogic™ equation editing is required for setting up user-defined logic for customizing the relay operations. See section FLEXLOGIC™ in the SETTINGS chapter.

1.5.8 COMMISSIONING

Templated tables for charting all the required settings before entering them via the keypad are available in the COMMISSIONING chapter, which also includes instructions for commissioning tests.

2.1.1 OVERVIEW

The L90 relay is a digital current differential relay system with an integral communications channel interface.

The L90 is intended to provide complete protection for transmission lines of any voltage level. Both three phase and single phase tripping schemes are available. Models of the L90 are available for application on both two and three terminal lines. The L90 uses per phase differential at 64 kbps transmitting 2 phaselets per cycle. The current differential scheme is based on innovative patented techniques developed by GE. The L90 algorithms are based on the Fourier transform–phaselet approach and an adaptive statistical restraint. The restraint is similar to a traditional percentage differential scheme, but is adaptive based on relay measurements. When used with a 64 kbps channel, the innovative “phaselets” approach yields an operating time of 1.0 to 1.5 cycles typical. The adaptive statistical restraint approach provides both more sensitive and more accurate fault sensing. This allows the L90 to detect relatively higher impedance single line to ground faults that existing systems may not. The basic current differential element operates on current input only. Long lines with significant capacitance can benefit from charging current compensation if terminal voltage measurements are applied to the relay. The voltage input is also used for some protection and monitoring features such as directional elements, fault locator, metering, and distance backup.

The L90 is designed to operate over different communications links with various degrees of noise encountered in power systems and communications environments. Since correct operation of the relay is completely dependent on data received from the remote end, special attention must be paid to information validation. The L90 incorporates a high degree of security by using a 32-bit CRC (cyclic redundancy code) inter-relay communications packet.

In addition to current differential protection, the relay provides multiple backup protection for phase and ground faults. For overcurrent protection, the time overcurrent curves may be selected from a selection of standard curve shapes or a custom FlexCurve™ for optimum co-ordination. Additionally, one zone of phase and ground distance protection with power swing blocking, out-of-step tripping, line pickup, load encroachment, and POTT features is included.

The L90 incorporates charging current compensation for applications on very long transmission lines without loss of sensitivity. The line capacitive current is removed from the terminal phasors.

The relay uses a sampling rate of 64 samples per cycle to provide metering values and flexible oscillography.

Voltage and current metering is included as a standard feature. Additionally, currents are available as total RMS values. Power, power factor and frequency measurements are also provided.

Diagnostic features include a sequence of records of 1024 time-tagged events. The internal clock used for time-tagging can be synchronized with an IRIG-B signal. This precise time stamping allows the sequence of events to be determined throughout the system. Events can also be programmed (via FlexLogic™ equations) to trigger oscillography data capture which may be set to record the measured parameters before and after the event for viewing on a portable computer (PC). These tools will significantly reduce troubleshooting time and simplify report generation in the event of system faults.

A faceplate RS232 port may be used to connect a PC for programming settings and for monitoring actual values. A variety of communications modules are available. Two rear RS485 ports are standard to allow independent access by operating and engineering staff. All serial ports use the Modbus® RTU protocol. The RS485 ports may be connected to system computers with baud rates up to 115.2 kbps. The RS232 port has a fixed baud rate of 19.2 kbps. Optional communications modules include a 10BaseF Ethernet interface which can be used to provide fast, reliable communications in noisy environments. Another option provides two 10BaseF fiber optic ports for redundancy. The Ethernet port supports MMS/UCA2 protocol.

The relay uses flash memory technology which allows field upgrading as new features are added.

The testing features can be used to verify and test settings and operations.

2.1.2 FEATURES

LINE CURRENT DIFFERENTIAL:

- Phase segregated, high-speed digital current differential system
- Overhead and underground AC transmission lines, series compensated lines
- Two and three terminal line applications
- Zero-sequence removal for application on lines with tapped transformers connected in a grounded Wye on the line side
- GE phaselets approach based on Discrete Fourier Transform with 64 samples per cycle and transmitting 2 time-stamped phaselets per cycle
- Adaptive restraint approach improving sensitivity and accuracy of fault sensing
- Increased security for trip decision using Disturbance Detector and Trip Output logic
- Continuous clock synchronization via the distributed synchronization technique
- Increased transient stability through DC decaying offset removal
- Accommodates up to 5 times CT ratio differences
- Peer-to-Peer (Master-Master) architecture changing to Master-Slave via DTT (if channel fails) at 64 kbps
- Charging current compensation
- Interfaces direct fiber, multiplexed RS422 and G.703 connections with relay ID check
- Per phase line differential protection Direct Transfer Trip plus 8 user-assigned pilot signals via the communications channel
- Secure 32-bit CRC protection against communications errors

BACKUP PROTECTION:

- DTT provision for pilot schemes
- 1 zone distance protection with POTT scheme, power swing blocking/out-of-step tripping, line pickup, and load encroachment
- 2-element TOC and 2-element IOC directional phase overcurrent protection
- 2-element TOC and 2-element IOC directional zero sequence overcurrent protection
- 2-element TOC and 2-element IOC negative sequence overcurrent protection
- Undervoltage and overvoltage protection

ADDITIONAL PROTECTION:

- Breaker failure protection
- Stub bus protection
- VT and CT supervision
- GE "Sources" approach allowing grouping of different CTs and VTs from multiple input channels
- Open pole detection
- Breaker trip coil supervision and "seal-in" of trip command
- FlexLogic™ allowing creation of user-defined distributed protection and control logic

CONTROL:

- 1 and 2 breakers configuration for 1½ and ring bus schemes, pushbutton control from the relay
- Auto-reclosing and synchrochecking
- Breaker arcing current

MONITORING:

- Oscillography of current, voltage, FlexLogic™ operands, and digital signals (1 × 128 cycles to 31 × 8 cycles configurable)
- Events recorder - 1024 events
- Fault locator

METERING:

- Actual 87L remote phasors, differential current and channel delay at all line terminals of line current differential protection
- Line current, voltage, real power, reactive power, apparent power, power factor, and frequency

COMMUNICATIONS:

- RS232 front port - 19.2 kbps
- 1 or 2 RS485 rear ports - up to 115 kbps
- 10BaseF Ethernet port supporting MMS/UCA2.0 protocol

2.1.3 FUNCTIONALITY

The following SINGLE LINE DIAGRAM illustrates relay functionality using ANSI (American National Standards Institute) device numbers

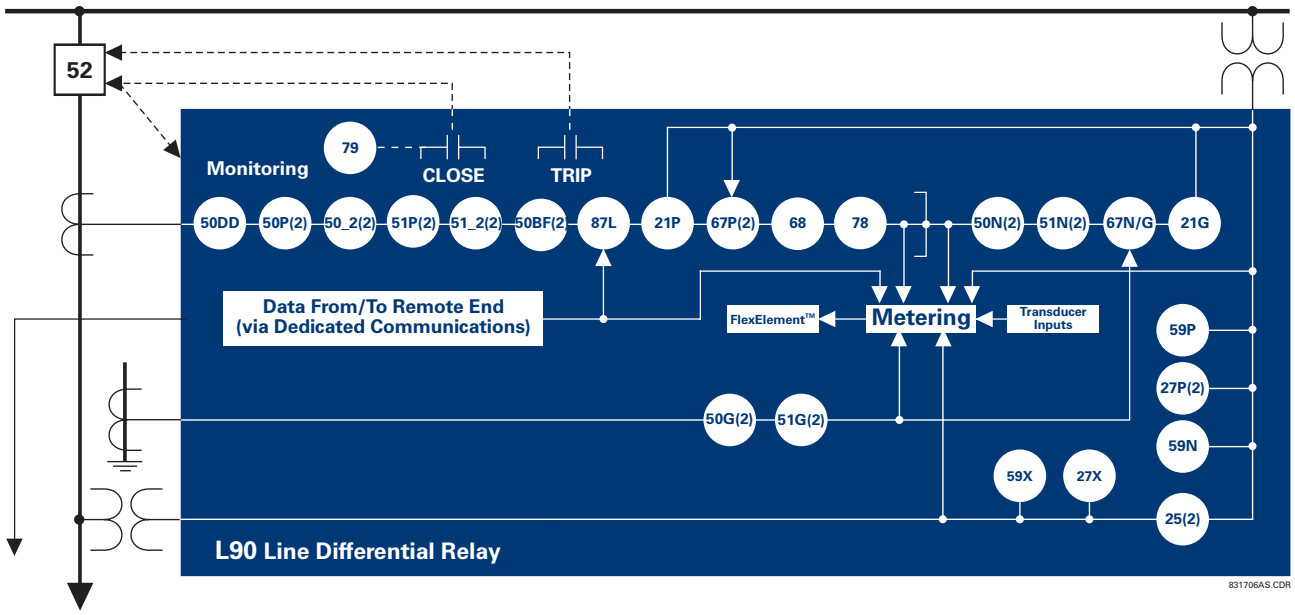


Figure 2–1: SINGLE LINE DIAGRAM

Table 2–1: DEVICE NUMBERS AND FUNCTIONS

DEVICE NUMBER	FUNCTION
21G	Ground Distance
21P	Phase Distance
25	Synchrocheck
27P	Phase Undervoltage
27X	Auxiliary Undervoltage
50BF	Breaker Failure
50DD	Adaptive Fault Detector (sensitive current disturbance detector)
50G	Ground Instantaneous Overcurrent
50N	Neutral Instantaneous Overcurrent
50P	Phase Instantaneous Overcurrent
50_2	Negative Sequence Instantaneous Overcurrent
51G	Ground Time Overcurrent

DEVICE NUMBER	FUNCTION
51N	Neutral Time Overcurrent
51P	Phase Time Overcurrent
51_2	Negative Sequence Time Overcurrent
52	AC Circuit Breaker
59N	Neutral Overvoltage
59P	Phase Overvoltage
59X	Auxiliary Overvoltage
67N	Neutral Directional Overcurrent
67P	Phase Directional Overcurrent
68	Power Swing Blocking
78	Out-of-step Tripping
79	Automatic Recloser
87L	Segregated Line Current Differential

Table 2–2: ADDITIONAL DEVICE FUNCTIONS

FUNCTION
Breaker Arcing Current (I^2T)
Breaker Control
Contact Inputs (up to 96)
Contact Outputs (up to 64)
CT Failure Detector
Data Logger
Digital Counters (8)
Digital Elements (16)
Direct Inputs (8 per L90 comms channel)
DNP 3.0
Event Recorder
Fault Locator
Fault Reporting

FUNCTION
FlexElements™
FlexLogic™ Equations
L90 Channel Tests
Line Pickup
Load Encroachment
Metering: Current, Voltage, Power, Energy, Frequency, Demand, Power Factor, 87L differential current, local & remote phasors
MMS/UCA Communications
MMS/UCA Remote I/O ("GOOSE")
ModBus Communications
ModBus User Map
Open Pole Detector

FUNCTION
Oscillography
Pilot Scheme (POTT)
Setting Groups (8)
Stub Bus
Transducer I/O
User Definable displays
User Programmable LEDs
Virtual Inputs (32)
Virtual Outputs (64)
VT Fuse Failure

2.1.4 ORDERING

The relay is available as a 19-inch rack horizontal mount unit or as a reduced size (¾) vertical mount unit, and consists of power supply, CPU, Digital Input/Output, Transducer I/O and L90 Communications modules. Each of these can be supplied in a number of configurations which must be specified at the time of ordering. The information required to completely specify the relay is provided in the following table.

Table 2–3: ORDER CODES

	L90	- *	00	- H C	*	- F **	- H **	- L **	- N **	- S **	- U **	- W **	For Full Sized Horizontal Mount
	L90	- *	00	- V F	*	- F **	- H **	- L **	- N **			- R **	For Reduced Size Vertical Mount
Base Unit	L90												Base Unit
CPU		A											RS485 + RS485 (ModBus RTU, DNP)
		C											RS485 + 10BaseF (MMS/UCA2, Modbus TCP/IP, DNP)
		D											RS485 + Redundant 10BaseF (MMS/UCA2, Modbus TCP/IP, DNP)
Software			00										No Software Options
Mount / Faceplate				H C									Horizontal (19” rack)
				V F									Vertical (3/4 size)
Power Supply					H								125 / 250 V AC/DC
					L								24 to 48 V (DC only)
CT/VT DSP						8A							Standard 4CT/4VT
						8C							Standard 8CT
Digital I/O								XX	XX	XX	XX		No Module
							6A	6A	6A	6A	6A		2 Form-A (Volt w/ opt Curr) & 2 Form-C outputs, 8 Digital Inputs
							6B	6B	6B	6B	6B		2 Form-A (Volt w/ opt Curr) & 4 Form-C Outputs, 4 Digital Inputs
							6C	6C	6C	6C	6C		8 Form-C Outputs
							6D	6D	6D	6D	6D		16 Digital Inputs
							6E	6E	6E	6E	6E		4 Form-C Outputs, 8 Digital Inputs
							6F	6F	6F	6F	6F		8 Fast Form-C Outputs
							6G	6G	6G	6G	6G		4 Form-A (Voltage w/ opt Current) Outputs, 8 Digital Inputs
							6H	6H	6H	6H	6H		6 Form-A (Voltage w/ opt Current) Outputs, 4 Digital Inputs
							6K	6K	6K	6K	6K		4 Form-C & 4 Fast Form-C Outputs
							6L	6L	6L	6L	6L		2 Form-A (Curr w/ opt Volt) & 2 Form-C Outputs, 8 Digital Inputs
							6M	6M	6M	6M	6M		2 Form-A (Curr w/ opt Volt) & 4 Form-C Outputs, 4 Digital Inputs
							6N	6N	6N	6N	6N		4 Form-A (Current w/ opt Voltage) Outputs, 8 Digital Inputs
							6P	6P	6P	6P	6P		6 Form-A (Current w/ opt Voltage) Outputs, 4 Digital Inputs
							6R	6R	6R	6R	6R		2 Form-A (No Monitoring) & 2 Form-C Outputs, 8 Digital Inputs
							6S	6S	6S	6S	6S		2 Form-A (No Monitoring) & 4 Form-C Outputs, 4 Digital Inputs
							6T	6T	6T	6T	6T		4 Form-A (No Monitoring) Outputs, 8 Digital Inputs
							6U	6U	6U	6U	6U		6 Form-A (No Monitoring) Outputs, 4 Digital Inputs
Transducer I/O (max of 3 per unit)							5C	5C	5C	5C	5C		8 RTD Inputs
							5E	5E	5E	5E	5E		4 RTD Inputs, 4 dcmA Inputs
							5F	5F	5F	5F	5F		8 dcmA Inputs
Inter-Relay Communications												7A	820 nm, multi-mode, LED, 1 Channel
												7B	1300 nm, multi-mode, LED, 1 Channel
												7C	1300 nm, single-mode, ELED, 1 Channel
												7D	1300 nm, single-mode, LASER, 1 Channel
												7E	Channel 1: G.703; Channel 2: 820 nm, multi-mode LED
												7F	Channel 1: G.703; Channel 2: 1300 nm, multi-mode LED
												7G	Channel 1: G.703; Channel 2: 1300 nm, single-mode ELED
												7Q	Channel 1: G.703; Channel 2: 1300 nm, single-mode LASER
												7H	820 nm, multi-mode, LED, 2 Channels
												7I	1300 nm, multi-mode, LED, 2 Channels
												7J	1300 nm, single-mode, ELED, 2 Channels
												7K	1300 nm, single-mode, LASER, 2 Channels
												7L	Channel 1 - RS422; Channel 2 - 820 nm, multi-mode, LED
												7M	Channel 1 - RS422; Channel 2 - 1300 nm, multi-mode, LED
												7N	Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED
												7P	Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, LASER
												7R	G.703, 1 Channel
												7T	RS422, 1 Channel
												7S	G.703, 2 Channels
												7W	RS422, 2 Channels
												72	1550 nm, single-mode, LASER, 1 Channel
												73	1550 nm, single-mode, LASER, 2 Channel
												74	Channel 1 - RS422; Channel 2 - 1550 nm, single-mode, LASER
												75	Channel 1 - G.703, Channel 2 - 1550 nm, single -mode, LASER

The order codes for replacement modules to be ordered separately are shown in the following table. **When ordering a replacement CPU module or Faceplate, please provide the serial number of your existing unit.**

Table 2–4: ORDER CODES FOR REPLACEMENT MODULES

	UR - ** -	
POWER SUPPLY	1H	125 / 250 V AC/DC
	1L	24 - 48 V (DC only)
CPU	9A	RS485 + RS485 (ModBus RTU, DNP 3.0)
	9C	RS485 + 10BaseF (MMS/UCA2, ModBus TCP/IP, DNP 3.0)
	9D	RS485 + Redundant 10BaseF (MMS/UCA2, ModBus TCP/IP, DNP 3.0)
FACEPLATE	3C	Horizontal Faceplate with Display & Keypad
	3F	Vertical Faceplate with Display & Keypad
DIGITAL I/O	6A	2 Form-A (Voltage w/ opt Current) & 2 Form-C Outputs, 8 Digital Inputs
	6B	2 Form-A (Voltage w/ opt Current) & 4 Form-C Outputs, 4 Digital Inputs
	6C	8 Form-C Outputs
	6D	16 Digital Inputs
	6E	4 Form-C Outputs, 8 Digital Inputs
	6F	8 Fast Form-C Outputs
	6G	4 Form-A (Voltage w/ opt Current) Outputs, 8 Digital Inputs
	6H	6 Form-A (Voltage w/ opt Current) Outputs, 4 Digital Inputs
	6K	4 Form-C & 4 Fast Form-C Outputs
	6L	2 Form-A (Current w/ opt Voltage) & 2 Form-C Outputs, 8 Digital Inputs
	6M	2 Form-A (Current w/ opt Voltage) & 4 Form-C Outputs, 4 Digital Inputs
	6N	4 Form-A (Current w/ opt Voltage) Outputs, 8 Digital Inputs
	6P	6 Form-A (Current w/ opt Voltage) Outputs, 4 Digital Inputs
	6R	2 Form-A (No Monitoring) & 2 Form-C Outputs, 8 Digital Inputs
	6S	2 Form-A (No Monitoring) & 4 Form-C Outputs, 4 Digital Inputs
	6T	4 Form-A (No Monitoring) Outputs, 8 Digital Inputs
	6U	6 Form-A (No Monitoring) Outputs, 4 Digital Inputs
CT/VT DSP	8A	Standard 4CT/4VT
	8B	Sensitive Ground 4CT/4VT
	8C	Standard 8CT
	8D	Sensitive Ground 8CT
	8Z	HI-Z 4CT
L60 INTER-RELAY COMMUNICATIONS	7U	110/125 V, 20 mA Input/Output Channel Interface
	7V	48/60 V, 20 mA Input/Output Channel Interface
	7Y	125 V Input, 5V Output, 20 mA Channel Interface
	7Z	5 V Input, 5V Output, 20 mA Channel Interface
L90 INTER-RELAY COMMUNICATIONS	7A	820 nm, multi-mode, LED, 1 Channel
	7B	1300 nm, multi-mode, LED, 1 Channel
	7C	1300 nm, single-mode, ELED, 1 Channel
	7D	1300 nm, single-mode, LASER, 1 Channel
	7E	Channel 1: G.703; Channel 2: 820 nm, multi-mode LED
	7F	Channel 1: G.703; Channel 2: 1300 nm, multi-mode LED
	7G	Channel 1: G.703; Channel 2: 1300 nm, single-mode ELED
	7Q	Channel 1: G.703; Channel 2: 820 nm, single-mode LASER
	7H	820 nm, multi-mode, LED, 2 Channels
	7I	1300 nm, multi-mode, LED, 2 Channels
	7J	1300 nm, single-mode, ELED, 2 Channels
	7K	1300 nm, single-mode, LASER, 2 Channels
	7L	Channel 1 - RS422; Channel 2 - 820 nm, multi-mode, LED
	7M	Channel 1 - RS422; Channel 2 - 1300 nm, multi-mode, LED
	7N	Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED
	7P	Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, LASER
	7R	G.703, 1 Channel
	7S	G.703, 2 Channels
	7T	RS422, 1 Channel
	7W	RS422, 2 Channels
	72	1550 nm, single-mode, LASER, 1 Channel
	73	1550 nm, single-mode, LASER, 2 Channel
	74	Channel 1 - RS422; Channel 2 - 1550 nm, single-mode, LASER
	75	Channel 1 - G.703, Channel 2 - 1550 nm, single -mode, LASER
TRANSDUCER I/O	5C	8 RTD Inputs
	5E	4 dcmA Inputs, 4 RTD Inputs
	5F	8 dcmA Inputs

2.2.1 INTER-RELAY COMMUNICATIONS

Dedicated inter-relay communications may operate over 64 kbps digital channels or dedicated fiber optic channels. Available interfaces include:

- RS422 at 64 kbps
- G.703 at 64 kbps
- Dedicated fiber optics at 64 kbps. The fiber optic options include:
  - 820 nm multi-mode fiber with an LED transmitter
  - 1300 nm multi-mode fiber with an LED transmitter
  - 1300 nm single-mode fiber with an ELED transmitter
  - 1300 nm single-mode fiber with a LASER transmitter
  - 1550 nm single-mode fiber with a LASER transmitter

All fiber optic options use an ST connector. L90 models are available for use on two or three terminal lines. A two terminal line application requires one bi-directional channel. However, in two terminal line applications, it is also possible to use an L90 relay with two bi-directional channels. The second bi-directional channel will provide a redundant backup channel with automatic switchover if the first channel fails.

The L90 current differential relay is designed to function in a Peer to Peer or Master–Master architecture. In the Peer to Peer architecture, all relays in the system are identical and perform identical functions in the current differential scheme. In order for every relay on the line to be a Peer, each relay must be able to communicate with all of the other relays. If there is a failure in communications among the relays, the relays will revert to a Master - Slave architecture, with the Master as the relay that has current phasors from all terminals. The use of two different operational modes is intended to increase the dependability of the current differential scheme by reducing reliance on the communications.

The main difference between a Master and a Slave L90 is that only a Master relay performs the actual current differential calculation, and only a Master relay communicates with the relays at all other terminals of the protected line.

At least one Master L90 relay must have live communications to all other terminals in the current differential scheme; the other L90 relays on that line may operate as Slave relays. All Master relays in the scheme will be equal, and each will perform all functions. Each L90 relay in the scheme will determine if it is a Master by comparing the number of terminals on the line to the number of active communication channels.

The Slave terminals only communicate with the Master; there is no Slave to Slave communications path. As a result, a Slave L90 relay cannot calculate the differential current. When a Master L90 relay issues a local trip signal, it also sends a Direct Transfer Trip signal to all of the other L90 relays on the protected line.

If a Slave L90 relay issues a trip from one of its backup functions, it can send a transfer trip signal to its Master and other Slave relays if such option is designated. Because a Slave cannot communicate with all the relays in the differential scheme, the Master will then “broadcast” the Direct Transfer Trip signal to all other terminals.

The Slave L90 Relay performs the following functions:

- Samples currents and voltages
- Removes DC offset from the current via the mimic algorithm
- Creates phaselets
- Calculates sum of squares data
- Transmits current data to all Master L90 relays
- Performs all local relaying functions
- Receives Current Differential DTT and Direct Input signals from all other L90 relays
- Transmits Direct Output signals to all communicating relays
- Sends synchronization information of local clock to all other L90 clocks

The Master L90 Relay performs the following functions:

- Performs all functions of a Slave L90
- Receives current phasor information from all relays
- Performs the Current Differential algorithm
- Sends a Current Differential DTT signal to all L90 relays on the protected line

In the Peer to Peer mode, all L90 relays act as Masters.

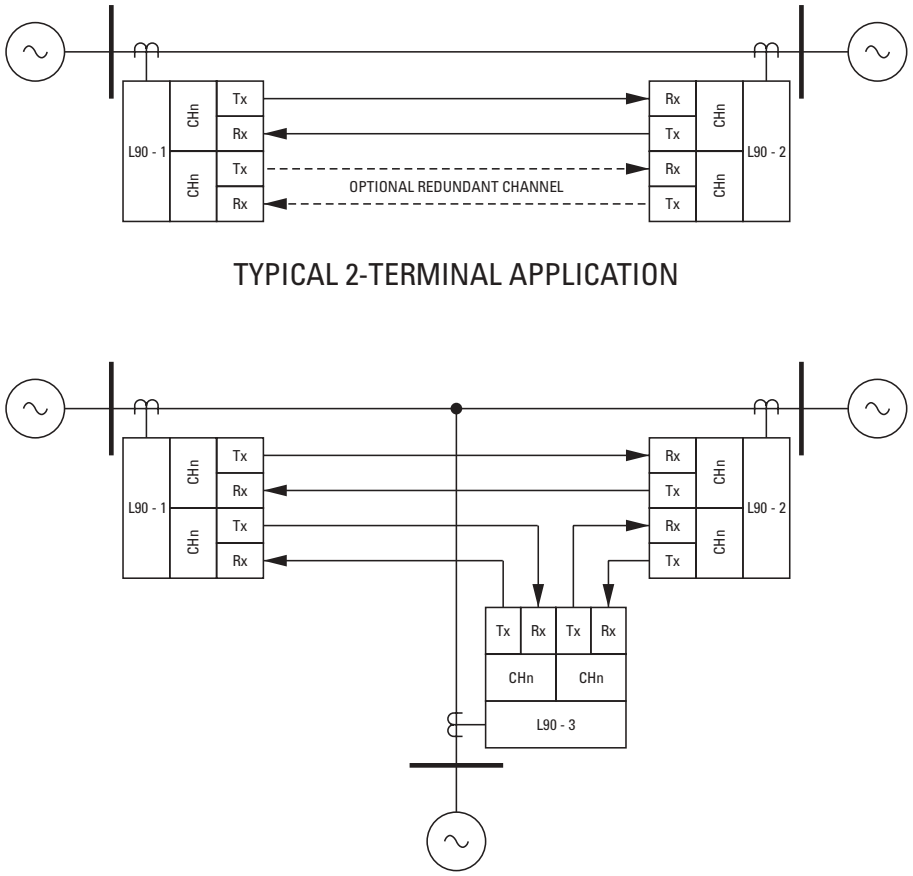


Figure 2–2: COMMUNICATION PATHS DIAGRAM

2.2.2 CHANNEL MONITOR

The L90 has logic to detect that the communications channel is deteriorating or has failed completely. This can provide an alarm indication and disable the current differential protection. Note that a failure of the communications from the Master to a Slave does not prevent the Master from performing the current differential algorithm; failure of the communications from a Slave to the Master will prevent the Master from performing the correct current differential logic. Channel propagation delay is being continuously measured and adjusted according to changes in the communications path. Every relay on the protection system can assigned an unique ID to prevent advertent loopbacks at multiplexed channels.

2.2.3 LOOPBACK TEST

This option allows the user to test the relay at one terminal of the line by “looping” the transmitter output to the receiver input; at the same time, the signal sent to the remote will not change. A local loopback feature is included in the relay to simplify single ended testing.

2.2.4 DIRECT TRANSFER TRIPPING

The L90 includes provision for sending and receiving a single-pole Direct Transfer Trip (DTT) signal from current differential protection between the L90 relays at the terminals of the line using the pilot communications channel. The user may also initiate an additional 8 pilot signals with an L90 communications channel to create trip/block/signaling logic. A FlexLogic™ operand, an external contact closure, or a signal over the LAN communication channels can be assigned for that logic.

2.3.1 CURRENT DIFFERENTIAL PROTECTION

The current differential algorithms used in the L90 Line Differential Relay are based on the Fourier transform “phaselet” approach and an adaptive statistical restraint. The L90 uses per phase differential at 64 kbps with 2 “phaselets” per cycle. A detailed description of the current differential algorithms is found in the THEORY OF OPERATION chapter. The current differential protection can be set in a percentage differential scheme with a single or dual slope.

2.3.2 BACKUP PROTECTION

In addition to the primary current differential protection, the L90 Line Differential Relay incorporates backup functions that operate on the local relay current only, such as directional phase overcurrent, directional neutral overcurrent, negative sequence overcurrent, undervoltage, overvoltage, and distance protection.

2.3.3 MULTIPLE SETTINGS GROUPS

The relay can store 8 sets of settings. They may be selected by user command, a configurable contact input or a FlexLogic™ equation to allow the relay to respond to changing conditions.

2.3.4 USER PROGRAMMABLE LOGIC

In addition to the built-in protection logic, the relay may be programmed by the user via FlexLogic™ equations.

2.3.5 CONFIGURABLE INPUTS AND OUTPUTS

All of the contact converter inputs (Digital Inputs) to the relay may be assigned by the user to directly block a protection element, operate an output relay or serve as an input to FlexLogic™ equations. All of the outputs, except for the self test critical alarm contacts, may also be assigned by the user.

2.4.1 METERING

The relay measures all input currents and calculates both phasors and symmetrical components. When AC potential is applied to the relay via the optional voltage inputs, metering data includes phase and neutral current, phase voltage, three phase and per phase W, VA, and var, and power factor. Frequency is measured on either current or voltage inputs. They may be called onto the local display or accessed via a computer. All terminal current phasors and differential currents are also displayed at all relays, allowing the user opportunity to analyze correct polarization of currents at all terminals.

2.4.2 EVENT RECORDS

The relay has a 'sequence of events' recorder which combines the recording of snapshot data and oscillography data. Events consist of a broad range of change of state occurrences, including input contact changes, measuring-element pickup and operation, FlexLogic™ equation changes, and self-test status. The relay stores up to 1024 events with the date and time stamped to the nearest microsecond. This provides the information needed to determine a sequence of events, which can reduce troubleshooting time and simplify report generation after system events.

2.4.3 OSCILLOGRAPHY

The relay stores oscillography data at a sampling rate of 64 times per cycle. The relay can store from 1 to 64 records. Each oscillography file includes a sampled data report consisting of:

- Instantaneous sample of the selected currents and voltages (if AC potential is used),
- The status of each selected contact input,
- The status of each selected contact output,
- The status of each selected measuring function,
- The status of various selected logic signals, including virtual inputs and outputs.

The captured oscillography data files can be accessed via the remote communications ports on the relay.

2.4.4 CT FAILURE / CURRENT UNBALANCE ALARM

The relay has current unbalance alarm logic. The unbalance alarm may be supervised by a zero sequence voltage detector. The user may block the relay from tripping when the current unbalance alarm operates.

2.4.5 TRIP CIRCUIT MONITOR

On those outputs designed for trip duty, a trip voltage monitor will continuously measure the DC voltage across output contacts to determine if the associated trip circuit is intact. If the voltage dips below the minimum voltage or the breaker fails to open or close after a trip command, an alarm can be activated.

2.4.6 SELF TEST

The most comprehensive self testing of the relay is performed during a power-up. Because the system is not performing any protection activities at power-up, tests that would be disruptive to protection processing may be performed.

The processors in the CPU and all DSP modules participate in startup self-testing. Self-testing checks approximately 85-90% of the hardware, and CRC/check-sum verification of all PROMs is performed. The processors communicate their results to each other so that if any failures are detected, they can be reported to the user. Each processor must successfully complete its self tests before the relay begins protection activities.

During both startup and normal operation, the CPU polls all plug-in modules and checks that every one answers the poll. The CPU compares the module types that identify themselves to the relay order code stored in memory and declares an alarm if a module is either non-responding or the wrong type for the specific slot.

When running under normal power system conditions, the relay processors will have "idle" time. During this time, each processor performs "background" self-tests that are not disruptive to the foreground processing.

2.5.1 ALARMS

The relay contains a dedicated alarm relay, the Critical Failure Alarm, housed in the Power Supply module. This output relay is not user programmable. This relay has Form-C contacts and is energized under normal operating conditions. The Critical Failure Alarm will become de-energized if the relay self test algorithms detect a failure that would prevent the relay from properly protecting the transmission line.

2.5.2 LOCAL USER INTERFACE

The relay's local user interface (on the faceplate) consists of a 2 × 20 vacuum florescent display (VFD) and a 22 button keypad. The keypad and display may be used to view data from the relay, to change settings in the relay, or to perform control actions. Also, the faceplate provides LED indications of status and events. The operation of the keypad is discussed in the HUMAN INTERFACES chapter.

2.5.3 TIME SYNCHRONIZATION

The relay includes a clock which can run freely from the internal oscillator or be synchronized from an external IRIG-B signal. With the external signal, all relays wired to the same synchronizing signal will be synchronized to within 0.1 millisecond.

2.5.4 FUNCTION DIAGRAMS

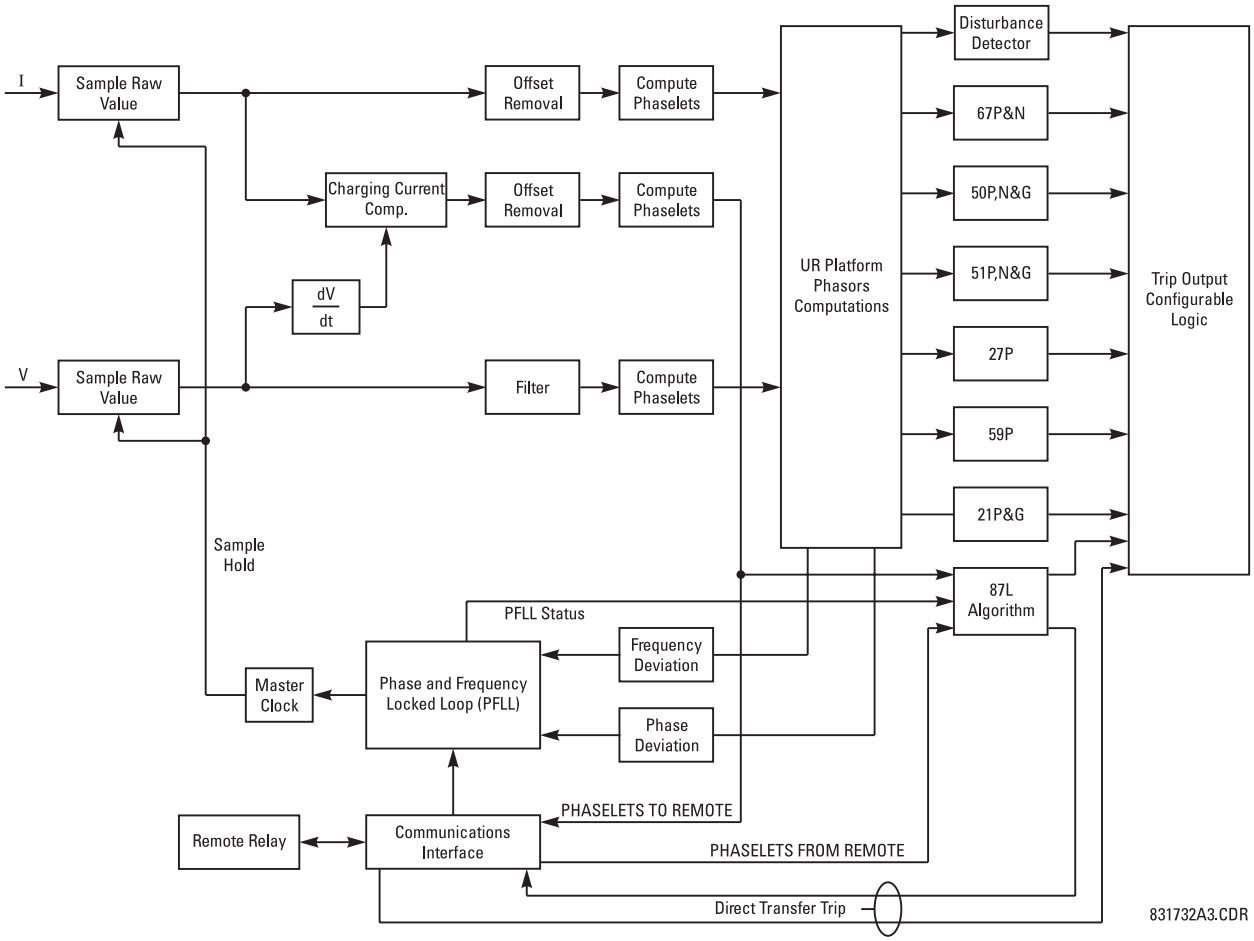


Figure 2–3: L90 BLOCK DIAGRAM

2

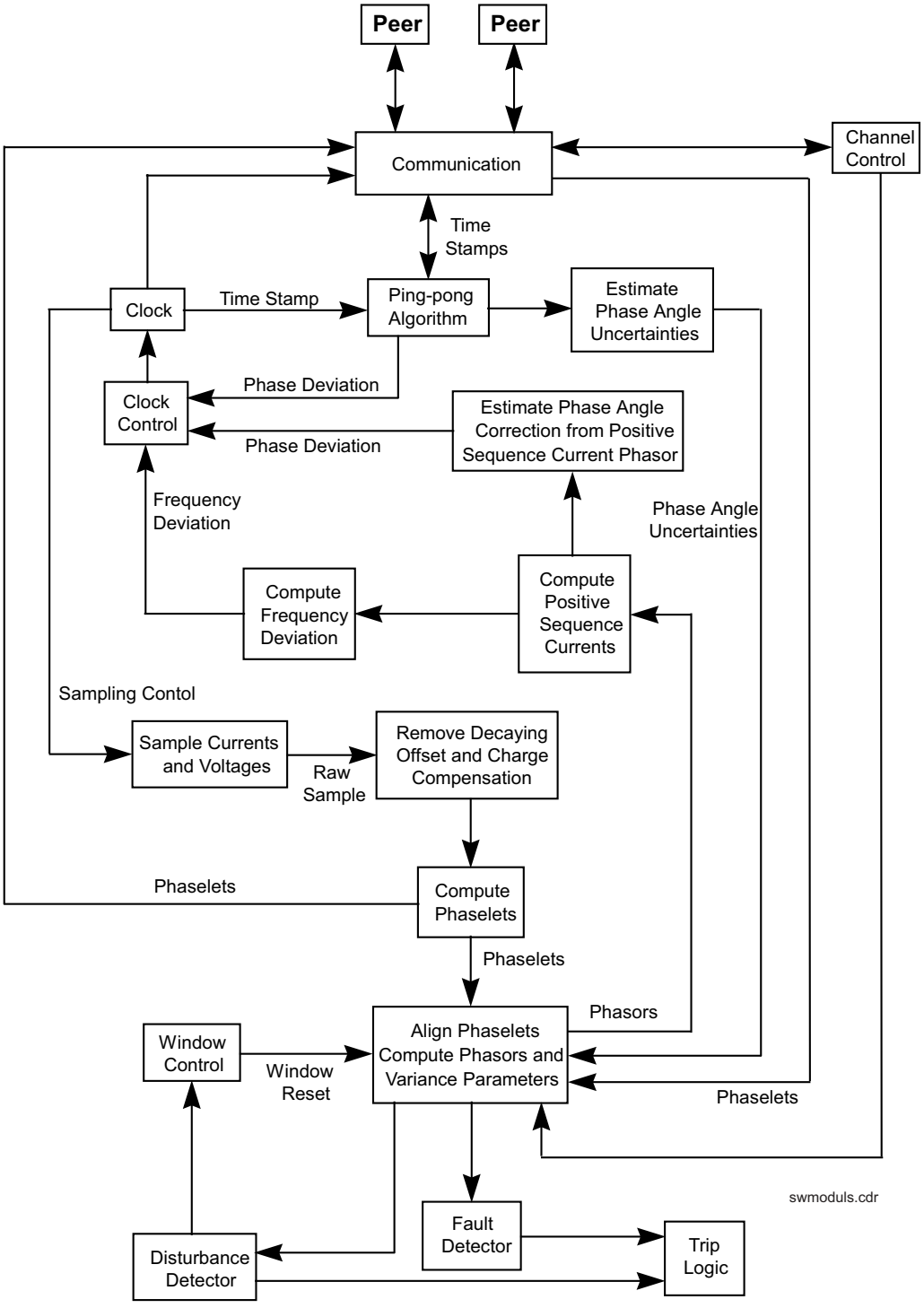


Figure 2–4: MAIN SOFTWARE MODULES

SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE

2.6.1 PROTECTION ELEMENTS

NOTE

The operating times below include the activation time of a trip rated Form-A output contact unless otherwise indicated. FlexLogic™ operands of a given element are 4 ms faster. This should be taken into account when using FlexLogic™ to interconnect with other protection or control elements of the relay, building FlexLogic™ equations, or interfacing with other IEDs or power system devices via communications or different output contacts.

LINE CURRENT DIFFERENTIAL (87L)

Application: 2 or 3 terminal line, series compensated line, tapped line, with charging current compensation

Pickup Current Level: 0.20 to 4.00 pu in steps of 0.01

CT Tap (CT mismatch factor): 0.20 to 5.00 in steps of 0.01

Slope # 1: 1 to 50%

Slope # 2: 1 to 70%

Breakpoint between Slopes: 0.0 to 20.0 pu in steps of 0.1

DTT: Direct Transfer Trip (1 and 3 pole) to remote L90

Operating Time: 1.0 to 1.5 power cycles duration

LINE CURRENT DIFFERENTIAL TRIP LOGIC

87L Trip: Adds security for trip decision; creates 1 & 3 pole trip logic

DTT: Engaged Direct Transfer Trip (1 and 3 pole) from remote L90

DD: Sensitive Disturbance Detector to detect fault occurrence

Stub Bus Protection: Security for ring bus and 1½ breaker configurations

Open Pole Detector: Security for sequential and evolving faults

PHASE DISTANCE

Characteristic: Dynamic (100% memory-polarized) MHO or QUAD

Number of Zones: 1

Directionality: reversible

Reach (secondary Ω): 0.02 to 250.00 Ω in steps of 0.01

Reach Accuracy: ±5% including the effect of CVT transients up to an SIR of 30

Distance Characteristic Angle: 30 to 90° in steps of 1

Distance Comparator Limit Angle: 30 to 90° in steps of 1

Directional Supervision:
- Characteristic Angle: 30 to 90° in steps of 1
- Limit Angle: 30 to 90° in steps of 1

Right Blinder (QUAD only):
- Reach: 0.02 to 250 Ω in steps of 0.01
- Characteristic Angle: 60 to 90° in steps of 1

Left Blinder (QUAD only):
- Reach: 0.02 to 250 Ω in steps of 0.01
- Characteristic Angle: 60 to 90° in steps of 1

Time Delay: 0.000 to 65.535 s in steps of 0.001

Timing Accuracy: ±3% or 4 ms, whichever is greater

Current Supervision:
- Level: line-to-line current
- Pickup: 0.050 to 30.000 pu in steps of 0.001
- Dropout: 97 to 98%

Memory Duration: 5 to 25 cycles in steps of 1

Voltage Supervision Pickup (series compensation applications): 0 to 5.000 pu in steps of 0.001

Operation Time: 1 to 1.5 cycles (typical)

Reset Time: 1 power cycle (typical)

GROUND DISTANCE

Characteristic: Dynamic (100% memory-polarized) MHO, or QUAD

Number of Zones: 1

Directionality: reversible

Reach (secondary Ω): 0.02 to 250.00 Ω in steps of 0.01

Reach Accuracy: ±5% including the effect of CVT transients up to an SIR of 30

Distance Characteristic Angle: 30 to 90° in steps of 1

Distance Comparator Limit Angle: 30 to 90° in steps of 1

Directional Supervision:
- Characteristic Angle: 30 to 90° in steps of 1
- Limit Angle: 30 to 90° in steps of 1

Zero-Sequence Compensation
- Z0/Z1 magnitude: 0.50 to 7.00 in steps of 0.01
- Z0/Z1 angle: –90 to 90° in steps of 1

Zero-Sequence Mutual Compensation
- Z0M/Z1 magnitude: 0.00 to 7.00 in steps of 0.01
- Z0M/Z1 angle: –90 to 90° in steps of 1

Right Blinder (QUAD only):
- Reach: 0.02 to 250 Ω in steps of 0.01
- Characteristic Angle: 60 to 90° in steps of 1

Left Blinder (QUAD only):
- Reach: 0.02 to 250 Ω in steps of 0.01
- Characteristic Angle: 60 to 90° in steps of 1

Time Delay: 0.000 to 65.535 s in steps of 0.001

Timing Accuracy: ±3% or 4 ms, whichever is greater

Current Supervision:
- Level: neutral current (3I_0)
- Pickup: 0.050 to 30.000 pu in steps of 0.001
- Dropout: 97 to 98%

Memory Duration: 5 to 25 cycles in steps of 1

Voltage Supervision Pickup (series compensation applications): 0 to 5.000 pu in steps of 0.001

Operation Time: 1 to 1.5 cycles (typical)

Reset Time: 1 power cycle (typical)

PHASE/NEUTRAL/GROUND TOC

Current: Phasor or RMS
Pickup Level: 0.000 to 30.000 pu in steps of 0.001
Dropout Level: 97% to 98% of Pickup
Level Accuracy:
for 0.1 to 2.0 × CT: ±0.5% of reading or ±1% of rated (whichever is greater)
for > 2.0 × CT: ±1.5% of reading > 2.0 × CT rating
Curve Shapes: IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/Extremely Inverse; I^2t; FlexCurve™ (programmable); Definite Time (0.01 s base curve)
Curve Multiplier: Time Dial = 0.00 to 600.00 in steps of 0.01
Reset Type: Instantaneous/Timed (per IEEE)
Timing Accuracy: Operate at > 1.03 × Actual Pickup ±3.5% of operate time or ±½ cycle (whichever is greater)

PHASE/NEUTRAL/GROUND IOC

Pickup Level: 0.000 to 30.000 pu in steps of 0.001
Dropout Level: 97 to 98% of Pickup
Level Accuracy:
0.1 to 2.0 × CT rating: ±0.5% of reading or ±1% of rated (whichever is greater)
> 2.0 × CT rating ±1.5% of reading
Overreach: <2%
Pickup Delay: 0.00 to 600.00 s in steps of 0.01
Reset Delay: 0.00 to 600.00 s in steps of 0.01
Operate Time: <20 ms at 3 × Pickup at 60 Hz
Timing Accuracy: Operate at 1.5 × Pickup ±3% or ±4 ms (whichever is greater)

NEGATIVE SEQUENCE TOC

Current: Phasor
Pickup Level: 0.000 to 30.000 pu in steps of 0.001
Dropout Level: 97% to 98% of Pickup
Level Accuracy: ±0.5% of reading or ±1% of rated (whichever is greater)
from 0.1 to 2.0 x CT rating
±1.5% of reading > 2.0 x CT rating
Curve Shapes: IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/Extremely Inverse; I^2t; FlexCurve™ (programmable); Definite Time (0.01 s base curve)
Curve Multiplier (Time Dial): 0.00 to 600.00 in steps of 0.01
Reset Type: Instantaneous/Timed (per IEEE) and Linear
Timing Accuracy: Operate at > 1.03 × Actual Pickup ±3.5% of operate time or ±½ cycle (whichever is greater)

NEGATIVE SEQUENCE IOC

Pickup Level: 0.000 to 30.000 pu in steps of 0.001
Dropout Level: 97 to 98% of Pickup
Level Accuracy:
0.1 to 2.0 × CT rating: ±0.5% of reading or ±1% of rated (whichever is greater)
> 2.0 × CT rating: ±1.5% of reading
Overreach: < 2 %
Pickup Delay: 0.00 to 600.00 s in steps of 0.01
Reset Delay: 0.00 to 600.00 s in steps of 0.01
Operate Time: < 20 ms at 3 × Pickup at 60 Hz
Timing Accuracy: Operate at 1.5 × Pickup ±3% or ± 4 ms (whichever is greater)

PHASE DIRECTIONAL OVERCURRENT

Relay Connection: 90° (quadrature)
Quadrature Voltage:
ABC Phase Seq.: phase A (V_{BC}), phase B (V_{CA}), phase C (V_{AB})
ACB Phase Seq.: phase A (V_{CB}), phase B (V_{AC}), phase C (V_{BA})
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°
Operation Time (FlexLogic™ Operands):
Tripping (reverse load, forward fault):< 12 ms, typically
Blocking (forward load, reverse fault):< 8 ms, typically

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: $3 \times (|I\_0| - K \times |I\_1|)$, $K = 0.0625$; IG
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 Ω in steps of 0.01
Pickup Level: 0.05 to 30.00 pu in steps of 0.01
Dropuot Level: 97 to 98%
Operation Time: < 16 ms at 3 × Pickup at 60 Hz

BREAKER FAILURE

Mode: 1-pole, 3-pole
Current Supv. Level: Phase, Neutral
Current Supv. Pickup: 0.001 to 30.000 pu in steps of 0.001
Current Supv. DPO: 97 to 98% of Pickup
Current Supv. Accuracy:
0.1 to 2.0 × CT rating: ±0.75% of reading or ±1% of rated (whichever is greater)
> 2 × CT rating: ±1.5% of reading

PHASE UNDERVOLTAGE

Voltage:	Phasor only
Pickup Level:	0.000 to 3.000 pu in steps of 0.001
Dropout Level:	102 to 103% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Curve Shapes:	GE IAV Inverse; Definite Time (0.1s base curve)
Curve Multiplier:	Time Dial = 0.00 to 600.00 in steps of 0.01
Timing Accuracy:	Operate at < 0.90 × Pickup ±3.5% of operate time or ±4 ms (whichever is greater)

PHASE OVERVOLTAGE

Voltage:	Phasor only
Pickup Level:	0.000 to 3.000 pu in steps of 0.001
Dropout Level:	97 to 98% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Pickup Delay:	0.00 to 600.00 in steps of 0.01 s
Operate Time:	< 30 ms at 1.10 × Pickup at 60 Hz
Timing Accuracy:	±3% or ±4 ms (whichever is greater)

NEUTRAL OVERVOLTAGE

Pickup Level:	0.000 to 1.250 pu in steps of 0.001
Dropout Level:	97 to 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
Reset Delay:	0.00 to 600.00 s in steps of 0.01
Timing Accuracy:	±3% or ±4 ms (whichever is greater)
Operate Time:	< 30 ms at 1.10 × Pickup at 60 Hz

AUXILIARY UNDERVOLTAGE

Pickup Level:	0.000 to 3.000 pu in steps of 0.001
Dropout Level:	102 to 103% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Curve Shapes:	GE IAV Inverse Definite Time
Curve Multiplier:	Time Dial = 0 to 600.00 in steps of 0.01
Timing Accuracy:	±3% of operate time or ±4 ms (whichever is greater)

AUXILIARY OVERVOLTAGE

Pickup Level:	0.000 to 3.000 pu in steps of 0.001
Dropout Level:	97 to 98% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Pickup Delay:	0 to 600.00 s in steps of 0.01
Reset Delay:	0 to 600.00 s in steps of 0.01
Timing Accuracy:	±3% of operate time or ±4 ms (whichever is greater)
Operate Time:	< 30 ms at 1.10 × pickup at 60 Hz

LINE PICKUP

Phase IOC:	0.000 to 30.000 pu
Positive Sequence UV:	0.000 to 3.000 pu
Positive Seq. OV Delay:	0.000 to 65.535 s

SYNCHROCHECK

Max Volt Difference:	0 to 100000 V in steps of 1
Max Angle Difference:	0 to 100° in steps of 1
Max Freq Difference:	0.00 to 2.00 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)

AUTORECLOSURE

Single breaker applications, 3-pole tripping schemes.

Up to 4 reclose attempts before lockout.

Independent dead time setting before each shot.

Possibility of changing protection settings after each shot with FlexLogic™.

POWER SWING DETECT

Functions:	Power swing block, Out-of-step trip
Measured Impedance:	Positive-sequence
Blocking & Tripping Modes:	2-step or 3-step
Tripping Mode:	Early or Delayed
Current Supervision:	
Pickup Level:	0.050 to 30.000 pu in steps of 0.001
Dropout Level:	97 to 98% of Pickup
Fwd / Reverse Reach (sec. Ω):	0.10 to 500.00 Ω in steps of 0.01
Impedance Accuracy:	±5%
Fwd / Reverse Angle Impedances:	40 to 90° in steps of 1
Angle Accuracy:	±2°
Characteristic Limit Angles:	40 to 140° in steps of 1
Timers:	0.000 to 65.535 s in steps of 0.001
Timing Accuracy:	±3% or 4 ms, whichever is greater

LOAD ENCROACHMENT

Measured Impedance:	Positive-sequence
Minumum Voltage:	0.000 to 3.000 pu in steps of 0.001
Reach (sec. Ω):	0.02 to 250.00 Ω in steps of 0.01
Impedance Accuracy:	±5%
Angle:	5 to 50° in steps of 1
Angle Accuracy:	±2°
Pickup Delay:	0 to 65.535 s in steps of 0.001
Reset Delay:	0 to 65.535 s in steps of 0.001
Time Accuracy:	±3% or ±4 ms, whichever is greater
Operate Time:	< 30 ms at 60 Hz

2.6.2 USER PROGRAMMABLE ELEMENTS

FLEXLOGIC™

Programming language: Reverse Polish Notation with graphical visualization (keypad programmable)
Lines of code: 512
Number of 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, sec., min.) in steps of 1
Dropout delay: 0 to 60000 (ms, sec., min.) in steps of 1

FLEXCURVES™

Number: 2 (A and B)
Number of reset points: 40 (0 through 1 of pickup)
Number of operate points: 80 (1 through 20 of pickup)
Time delay: 0 to 65535 ms in steps of 1

FLEXELEMENTS™

Number of elements: 8
Operating signal: any analog actual value, or two values in differential mode
Operating signal mode: Signed or Absolute Value
Operating mode: Level, Delta
Comparator direction: Over, Under
Pickup Level: –30.000 to 30.000 pu in steps of 0.001
Hysteresis: 0.1 to 50.0% in steps of 0.1
Delta dt: 20 ms to 60 days
Pickup and dropout delay: 0.000 to 65.535 in steps of 0.001

FLEX STATES

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

USER-PROGRAMMABLE LEDS

Number: 48 plus Trip and Alarm
Programmability: from any logical variable, contact, or virtual input
Reset mode: Self-reset or Latched

USER-DEFINABLE DISPLAYS

Number of displays: 8
Lines of display: 2 × 20 alphanumeric characters
Parameters up to 5, any Modbus register addresses

2.6.3 MONITORING

OSCILLOGRAPHY

Max. No. of Records: 64
Sampling Rate: 64 samples per power cycle
Triggers: Any element pickup, dropout or operate
Digital input change of state
Digital output change of state
FlexLogic™ equation
Data: AC input channels
Element state
Digital input state
Digital output state
Data Storage: In non-volatile memory

EVENT RECORDER

Capacity: 1024 events
Time-tag: to 1 microsecond
Triggers: Any element pickup, dropout or operate
Digital input change of state
Digital output change of state
Self-test events
Data Storage: In non-volatile memory

DATA LOGGER

Number of Channels: 1 to 16
Parameters: Any available analog Actual Value
Sampling Rate: 1 sec.; 1, 5, 10, 15, 20, 30, 60 min.
Storage Capacity: (NN is dependent on memory)
1-second rate: 01 channel for NN days
16 channels for NN days
↓ ↓
60-minute rate: 01 channel for NN days
16 channels for NN days

FAULT LOCATOR

Method: Single-ended

Maximum accuracy if: Fault resistance is zero or fault currents from all line terminals are in phase

Relay Accuracy: ±1.5% (V > 10 V, I > 0.1 pu)

Worst-case Accuracy:

$VT_{\%error}$ + (user data)
$CT_{\%error}$ + (user data)
$Z_{Line\%error}$ + (user data)
$METHOD_{\%error}$ +(Chapter 6)
$RELAY\ ACCURACY_{\%error}$ + (1.5%)

2.6.4 METERING

RMS CURRENT: PHASE, NEUTRAL, AND GROUND

Accuracy at
0.1 to 2.0 × CT rating: ±0.25% of reading or ±0.1% of rated (whichever is greater)
> 2.0 × CT rating: ±1.0% of reading

RMS VOLTAGE

Accuracy: ±0.5% of reading from 10 to 208 V

APPARENT POWER VA

Accuracy: ±1.0% of reading

REAL POWER WATT

Accuracy: ±1.0% of reading at –0.8 < PF ≤ –1.0 and 0.8 < PF ≤ 1.0

REACTIVE POWER VAR

Accuracy: ±1.0% of reading –0.2 ≤ PF ≤ 0.2

WATT-HOURS (POSITIVE & NEGATIVE)

Accuracy: ±2.0% of reading
Range: ±0 to 2×10^9 MWh
Parameters: 3-phase only
Update Rate: 50 ms

VAR-HOURS (POSITIVE & NEGATIVE)

Accuracy: ±2.0% of reading
Range: ±0 to 2×10^9 Mvarh
Parameters: 3-phase only
Update Rate: 50 ms

DEMAND

Measurements: Phases A, B, and C present and maximum measured currents
3-Phase Power (P, Q, and S) present and maximum measured currents
Accuracy: ±2.0%

FREQUENCY

Accuracy at
V = 0.8 to 1.2 pu: ±0.01 Hz (when voltage signal is used for frequency measurement)
I = 0.1 to 0.25 pu: ±0.05 Hz
I > 0.25 pu ±0.02 Hz (when current signal is used for frequency measurement)

2.6.5 INPUTS

AC CURRENT

CT Rated Primary: 1 to 50000 A
CT Rated Secondary: 1 A or 5 A by connection
Nominal Frequency: 20 to 65 Hz
Relay Burden: < 0.2 VA at rated secondary
Conversion Range:
Standard CT Module: 0.02 to 46 × CT rating RMS symmetrical
Sensitive Ground Module: 0.002 to 4.6 × CT rating RMS symmetrical
Current Withstand: 20 ms at 250 times rated
1 sec. at 100 times rated
Cont. at 3 times rated

AC VOLTAGE

VT Rated Secondary: 50.0 to 240.0 V
VT Ratio: 0.1 to 24000.0
Nominal Frequency: 20 to 65 Hz
Relay Burden: < 0.25 VA at 120 V
Conversion Range: 1 to 275 V
Voltage Withstand: cont. at 260 V to neutral
1 min./hr at 420 V to neutral

NOTE

FOR L90, THE NOMINAL SYSTEM FREQUENCY SHOULD BE SELECTED AS 50 HZ OR 60 HZ ONLY.

CONTACT INPUTS

Dry Contacts: 1000 Ω maximum
Wet Contacts: 300 V DC maximum
Selectable Thresholds: 17 V, 33 V, 84 V, 166 V
Recognition Time: < 1 ms
Debounce Timer: 0.0 to 16.0 ms in steps of 0.5

IRIG-B INPUT

Amplitude Modulation: 1 to 10 V pk-pk
DC Shift: TTL
Input Impedance: 22 kΩ

2.6.6 POWER SUPPLY

LOW RANGE

Nominal DC Voltage: 24 to 48 V at 3 A
Min./Max. DC Voltage: 20 / 60 V
NOTE: Low range is DC only.

HIGH RANGE

Nominal DC Voltage: 125 to 250 V at 0.7 A
Min./Max. DC Voltage: 88 / 300 V
Nominal AC Voltage: 100 to 240 V at 50/60 Hz, 0.7 A
Min./Max. AC Voltage: 88 / 265 V at 48 to 62 Hz

ALL RANGES

Volt Withstand: 2 × Highest Nominal Voltage for 10 ms
Voltage Loss Hold-Up: 50 ms duration at nominal
Power Consumption: Typical = 35 VA; Max. = 75 VA

INTERNAL FUSE

RATINGS

Low Range Power Supply: 7.5 A / 600 V
High Range Power Supply: 5 A / 600 V

INTERRUPTING CAPACITY

AC: 100 000 A RMS symmetrical
DC: 10 000 A

2.6.7 OUTPUTS

FORM-A RELAY

Make and Carry for 0.2 sec.: 30 A as per ANSI C37.90
Carry Continuous: 6 A
Break at L/R of 40 ms: 0.25 A DC max.
Operate Time: < 4 ms
Contact Material: Silver alloy

FORM-A VOLTAGE MONITOR

Applicable Voltage: approx. 15 to 250 V DC
Trickle Current: approx. 1 to 2.5 mA

FORM-A CURRENT MONITOR

Threshold Current: approx. 80 to 100 mA

FORM-C AND CRITICAL FAILURE RELAY

Make and Carry for 0.2 sec: 10 A
Carry Continuous: 6 A
Break at L/R of 40 ms: 0.1 A DC max.
Operate Time: < 8 ms
Contact Material: Silver alloy

FAST FORM-C RELAY

Make and Carry: 0.1 A max. (resistive load)
Minimum Load Impedance:

INPUT VOLTAGE	IMPEDANCE	
	2 W RESISTOR	1 W RESISTOR
250 V DC	20 KΩ	50 KΩ
120 V DC	5 KΩ	2 KΩ
48 V DC	2 KΩ	2 KΩ
24 V DC	2 KΩ	2 KΩ

Note: values for 24 V and 48 V are the same due to a required 95% voltage drop across the load impedance.

Operate Time: < 0.6 ms
INTERNAL LIMITING RESISTOR:
Power: 2 watts
Resistance: 100 ohms

CONTROL POWER EXTERNAL OUTPUT (FOR DRY CONTACT INPUT)

Capacity: 100 mA DC at 48 V DC
Isolation: ±300 Vpk

2.6.8 COMMUNICATIONS

RS232

Front Port: 19.2 kbps, Modbus® RTU

RS485

1 or 2 Rear Ports: Up to 115 kbps, Modbus® RTU, isolated together at 36 Vpk
Typical Distance: 1200 m

ETHERNET PORT

10BaseF: 820 nm, multi-mode, supports half-duplex/full-duplex fiber optic with ST connector
Redundant 10BaseF: 820 nm, multi-mode, half-duplex/full-duplex fiber optic with ST connector
Power Budget: 10 db
Max Optical Ip Power: –7.6 dBm
Typical Distance: 1.65 km

2.6.9 INTER-RELAY COMMUNICATIONS

SHIELDED TWISTED PAIR INTERFACE OPTIONS

INTERFACE TYPE	TYPICAL DISTANCE
RS422	1200 m
G.703	100 m

NOTE **RS422 distance is based on transmitter power and does not take into consideration the clock source provided by the user.**

LINK POWER BUDGET

EMITTER, FIBER TYPE	TRANSMIT POWER	RECEIVED SENSITIVITY	POWER BUDGET
820 nm LED, Multimode	–20 dBm	–30 dBm	10 dB
1300 nm LED, Multimode	–21 dBm	–30 dBm	9 dB
1300 nm ELED, Singlemode	–21 dBm	–30 dBm	9 dB
1300 nm Laser, Singlemode	–1 dBm	–30 dBm	29 dB
1550 nm Laser, Singlemode	+5 dBm	–30 dBm	35 dB

NOTE **These Power Budgets are calculated from the manufacturer's worst-case transmitter power and worst case receiver sensitivity.**

MAXIMUM OPTICAL INPUT POWER

EMITTER, FIBER TYPE	MAX. OPTICAL INPUT POWER
820 nm LED, Multimode	–7.6 dBm
1300 nm LED, Multimode	–11 dBm
1300 nm ELED, Singlemode	–14 dBm
1300 nm Laser, Singlemode	–14 dBm
1550 nm Laser, Singlemode	–14 dBm

TYPICAL LINK DISTANCE

EMITTER TYPE	FIBER TYPE	CONNECTOR TYPE	TYPICAL DISTANCE
820 nm LED	Multimode	ST	1.65 km
1300 nm LED	Multimode	ST	3.8 km
1300 nm ELED	Singlemode	ST	11.4 km
1300 nm Laser	Singlemode	ST	64 km
1550 nm Laser	Singlemode	ST	105 km

NOTE **Typical distances listed are based on the following assumptions for system loss. As actual losses will vary from one installation to another, the distance covered by your system may vary.**

CONNECTOR LOSSES (TOTAL OF BOTH ENDS):
ST Connector 2 dB

FIBER LOSSES:
820 nm Multimode 3 dB/km
1300 nm Multimode 1 dB/km
1300 nm Singlemode 0.35 dB/km
1550 nm Singlemode 0.25 dB/km
Splice losses: One splice every 2 km, at 0.05 dB loss per splice.

SYSTEM MARGIN:
3 dB additional loss added to calculations to compensate for all other losses.

2.6.10 ENVIRONMENTAL

Operating Temperatures:
Cold: IEC 60028-2-1, 16 h at –40°C
Dry Heat: IEC 60028-2-2, 16 h at 85°C

Humidity (noncondensing): IEC 60068-2-30, 95%, Variant 1, 6 days
Altitude: Up to 2000 m
Installation Category: II

2.6.11 TYPE TESTS

Electrical Fast Transient: ANSI/IEEE C37.90.1
IEC 61000-4-4
IEC 60255-22-4

Oscillatory Transient: ANSI/IEEE C37.90.1
IEC 61000-4-12

Insulation Resistance: IEC 60255-5

Dielectric Strength: IEC 60255-6
ANSI/IEEE C37.90

Electrostatic Discharge: EN 61000-4-2

Surge Immunity: EN 61000-4-5

RFI Susceptibility: ANSI/IEEE C37.90.2
IEC 61000-4-3
IEC 60255-22-3
Ontario Hydro C-5047-77

Conducted RFI: IEC 61000-4-6

Voltage Dips/Interruptions/Variations:
IEC 61000-4-11
IEC 60255-11

Power Frequency Magnetic Field Immunity:
IEC 61000-4-8

Vibration Test (sinusoidal): IEC 60255-21-1

Shock and Bump: IEC 60255-21-2

NOTE **Type test report available upon request.**

2.6.12 PRODUCTION TESTS

THERMAL

Products go through an environmental test based upon an Accepted Quality Level (AQL) sampling process.

2.6.13 APPROVALS

APPROVALS

UL Listed for the USA and Canada

CE:

LVD 73/23/EEC: IEC 1010-1

EMC 81/336/EEC: EN 50081-2
EN 50082-2

2.6.14 MAINTENANCE

Cleaning: Normally, cleaning is not required; but for situations where dust has accumulated on the faceplate display, a dry cloth can be used.

3.1.1 PANEL CUTOUT

The relay is available as a 19-inch rack horizontal mount unit or as a reduced size (¾) vertical mount unit, with a removable faceplate. 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, and is itself removable to allow mounting on doors with limited rear depth. There is also a removable dust cover that fits over the faceplate, which must be removed when attempting to access the keypad or RS232 communications port.

The vertical and horizontal case dimensions are shown below, along with panel 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 relay must be mounted such that the faceplate sits semi-flush with the panel or switchgear door, allowing the operator access to the keypad and the RS232 communications port. The relay is secured to the panel with the use of four screws supplied with the relay.

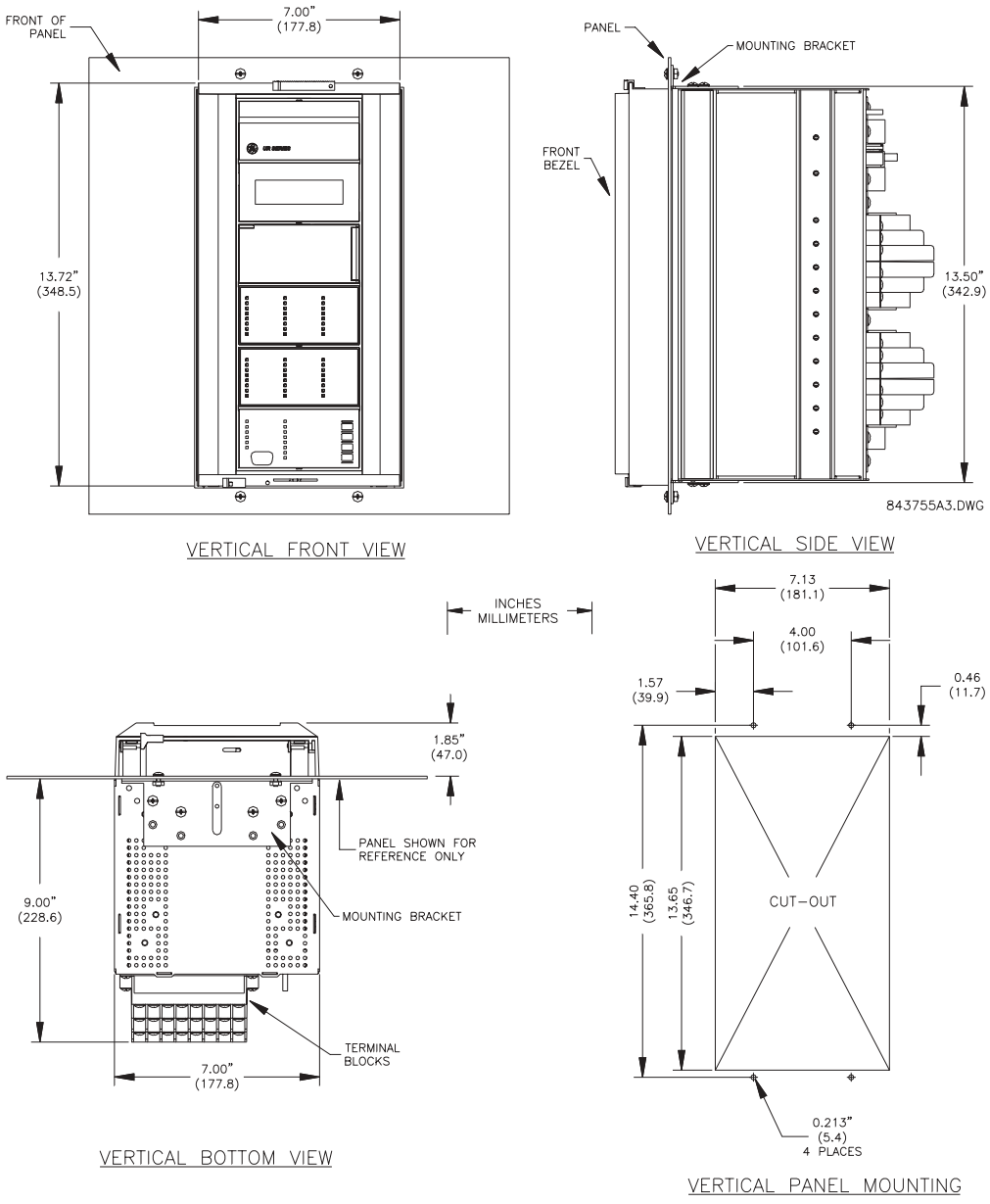


Figure 3–1: L90 VERTICAL MOUNTING AND DIMENSIONS

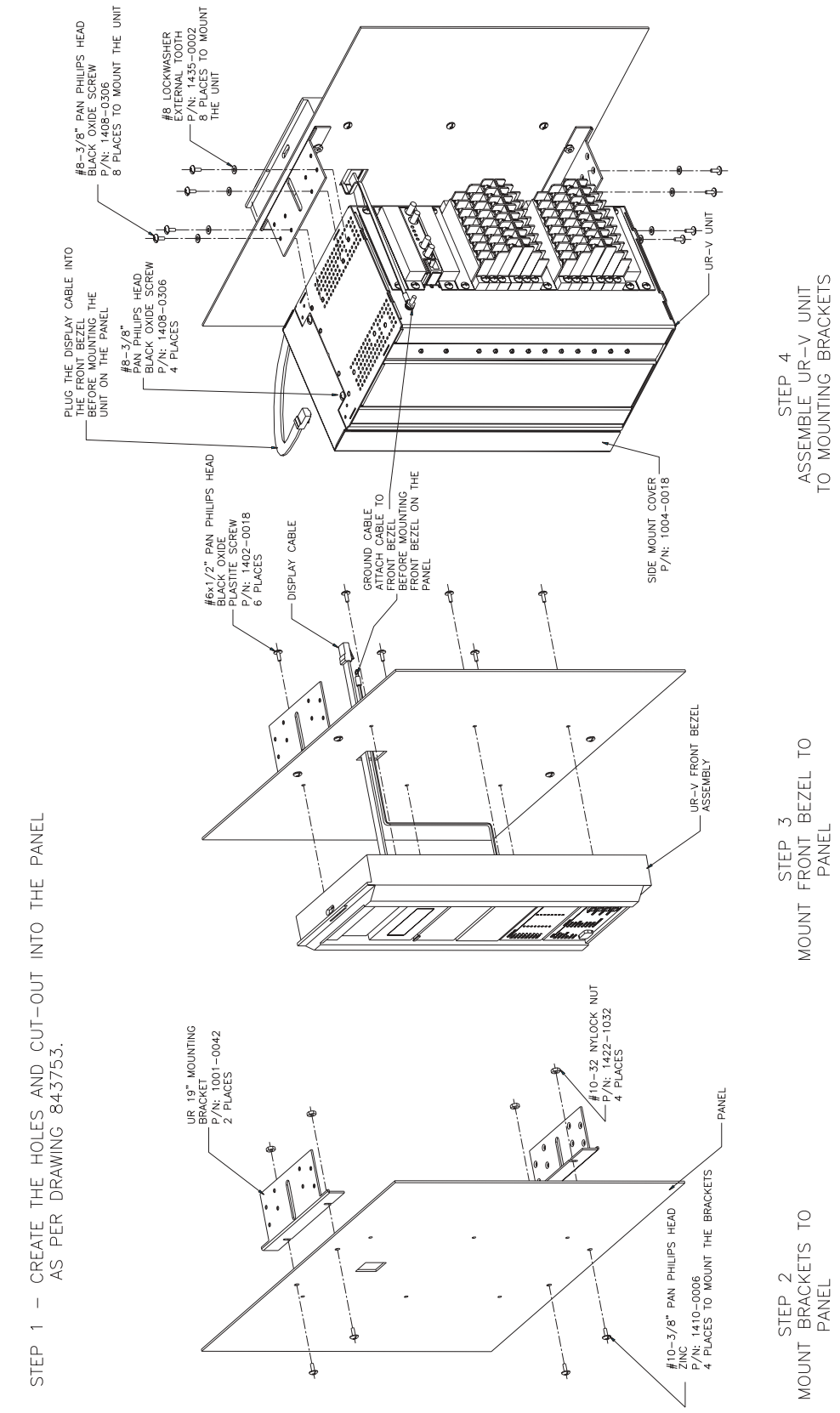


Figure 3–2: L90 VERTICAL SIDE MOUNTING INSTALLATION

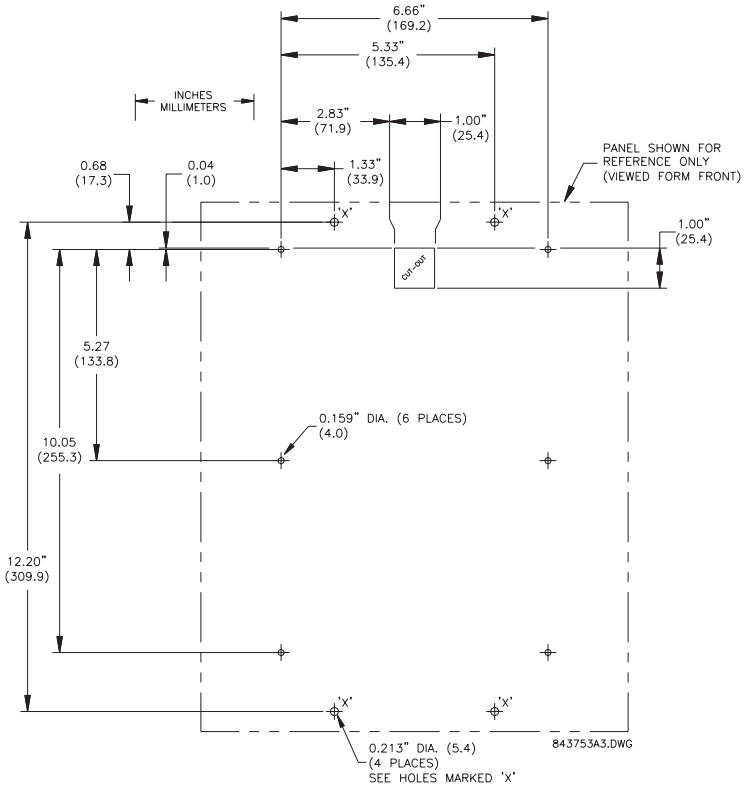


Figure 3–3: L90 VERTICAL SIDE MOUNTING REAR DIMENSIONS

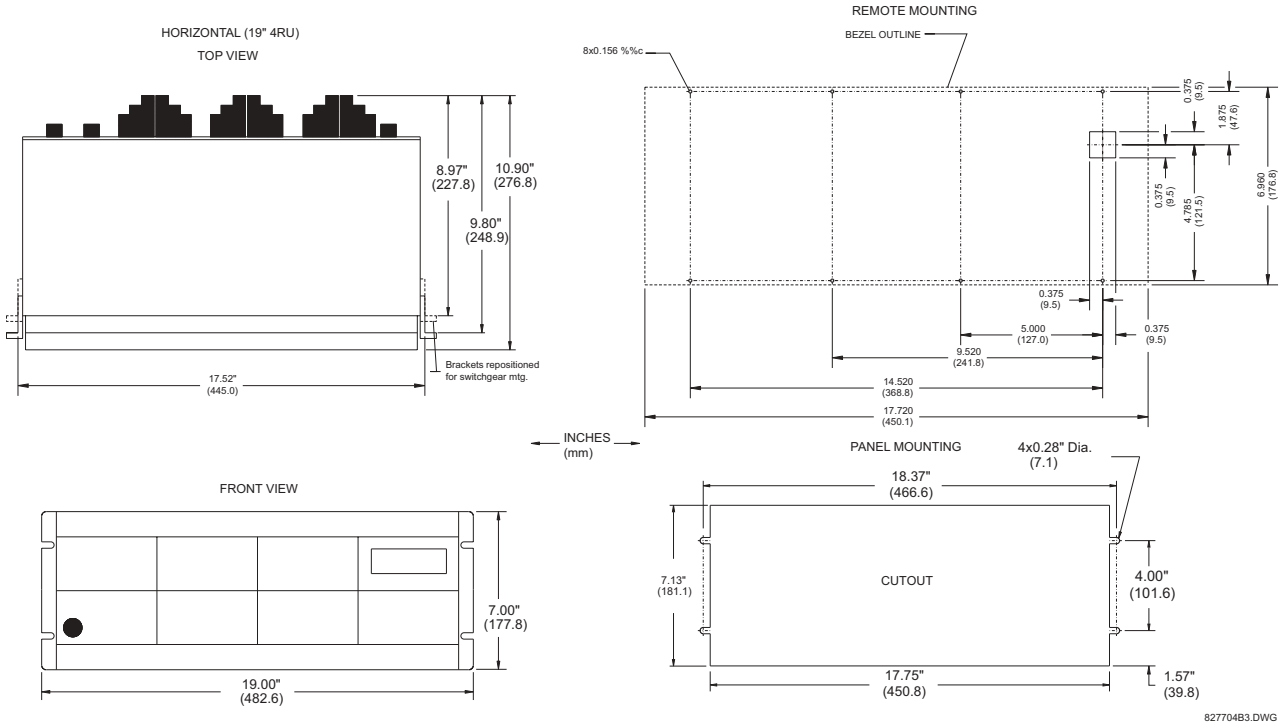


Figure 3–4: L90 HORIZONTAL MOUNTING AND DIMENSIONS

3.1.2 MODULE WITHDRAWAL / INSERTION

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!

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

The relay, being modular in design, allows for the withdrawal and insertion of modules. Modules must only be replaced with like modules 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 in the figure below. This allows for easy accessibility of the modules for withdrawal.

Figure 3–5: UR MODULE WITHDRAWAL/INSERTION

WITHDRAWAL: The ejector/inserter clips, located at the top and bottom of each module, must be pulled simultaneously to release the module for removal. Before performing this action, **control power must be 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.

INSERTION: Ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/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.

Type 9C and 9D CPU modules are equipped with 10BaseT and 10BaseF Ethernet connectors for communications. These connectors must be individually disconnected from the module before the it can be removed from the chassis.

3.1.3 REAR TERMINAL LAYOUT

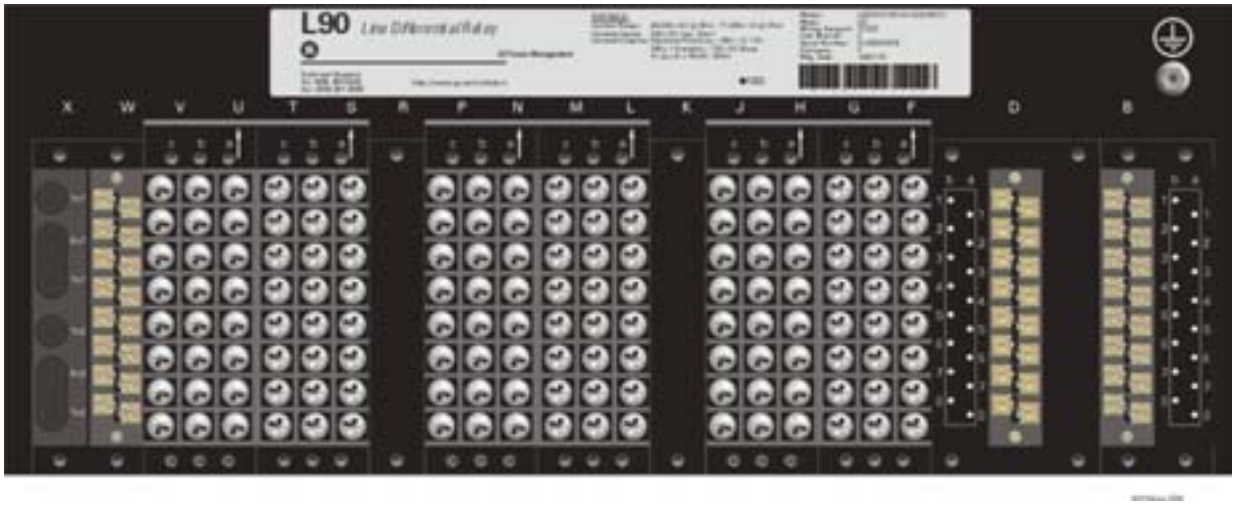


Figure 3–6: REAR TERMINAL VIEW

Do not touch any rear terminals while the relay is energized!

WARNING

3.1.4 REAR TERMINAL ASSIGNMENTS

The relay follows a convention with respect to terminal number assignments which are three characters long assigned in order by module slot position, row number, and column letter. Two-slot wide modules take their slot designation from the first slot position (nearest to CPU module) which is indicated by an arrow marker on the terminal block. See the following figure for an example of rear terminal assignments.

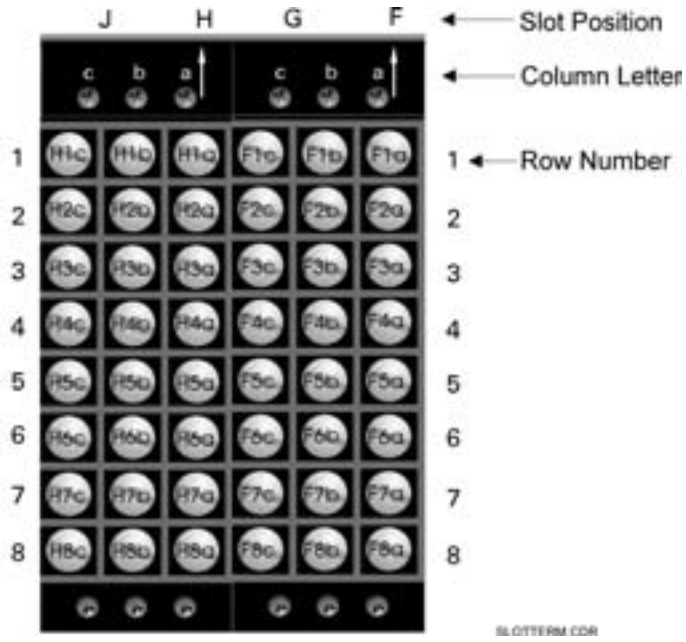


Figure 3–7: EXAMPLE OF MODULES IN F & H SLOTS

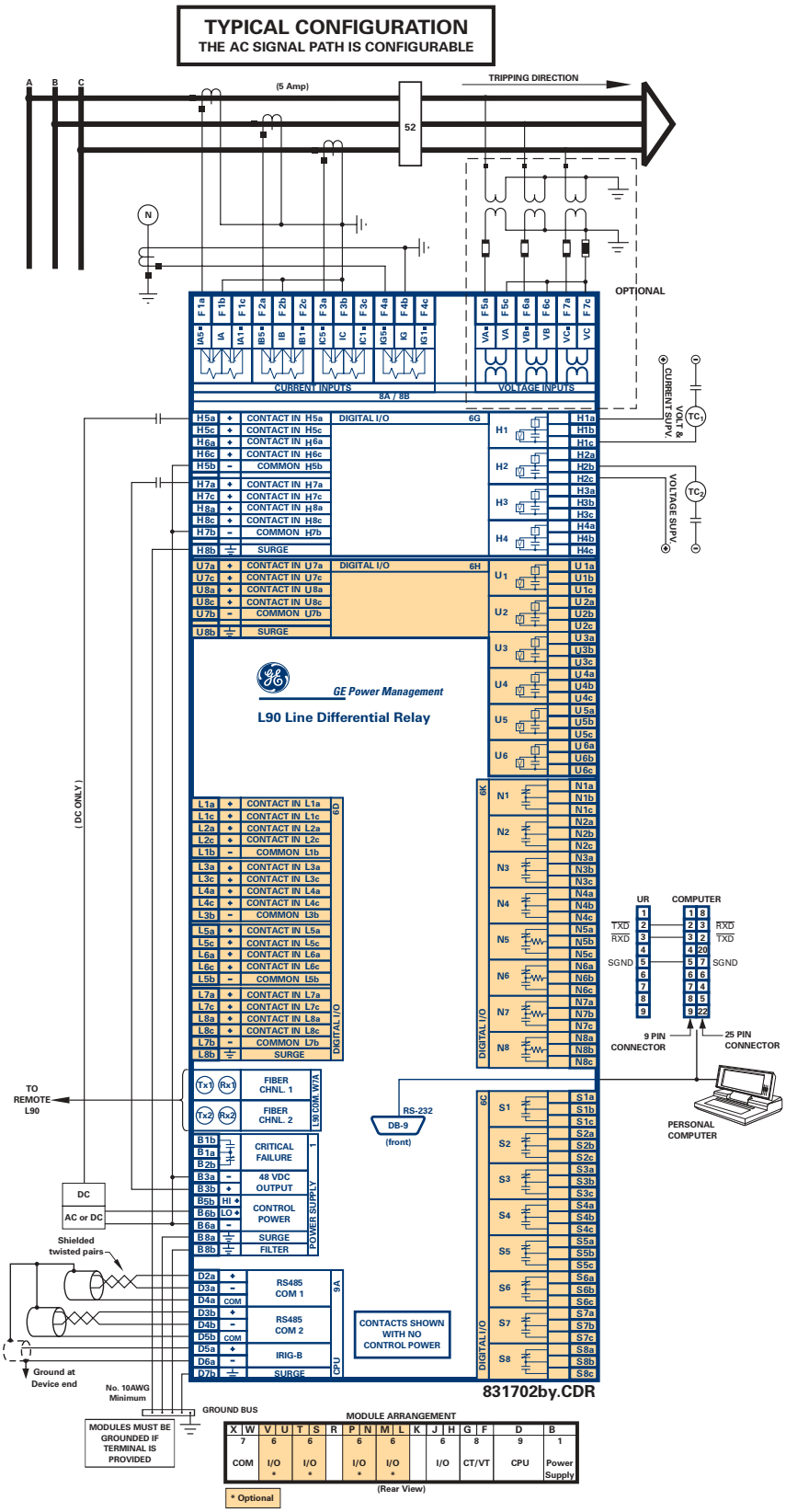


Figure 3–8: TYPICAL WIRING DIAGRAM

This diagram is based on the following order code: L90-A00-HCL-F8A-H6G-L6D-N6K-S6C-U6H-W7A.

The purpose of this diagram is to provide an example of how the relay is typically wired, not specifically how to wire your own relay. Please refer to the following pages for examples to help you wire your relay correctly based on your own relay configuration and order code.

CAUTION

3.2.2 DIELECTRIC STRENGTH RATINGS AND TESTING

a) RATINGS

The dielectric strength of UR module hardware is shown in the following table:

Table 3–1: DIELECTRIC STRENGTH OF UR MODULE HARDWARE

MODULE TYPE	MODULE FUNCTION	TERMINALS		DIELECTRIC STRENGTH (AC)
		FROM	TO	
1	Power Supply	High (+); Low (+); (–)	Chassis	2000 V AC for 1 min. (See Precaution 1)
1	Power Supply	48 V DC (+) and (–)	Chassis	2000 V AC for 1 min. (See Precaution 1)
1	Power Supply	Relay Terminals	Chassis	2000 V AC for 1 min. (See Precaution 1)
2	Reserved for Future	N/A	N/A	N/A
3	Reserved for Future	N/A	N/A	N/A
4	Reserved for Future	N/A	N/A	N/A
5	Analog I/O	All except 8b	Chassis	< 50 V DC
6	Digital I/O	All (See Precaution 2)	Chassis	2000 V AC for 1 min.
7R	L90 G.703	All except 2b, 3a, 7b, 8a	Chassis	2000 V AC for 1 min.
7T	L90 RS422	All except 6a, 7b, 8a	Chassis	< 50 V DC
8	CT/VT	All	Chassis	2000 V AC for 1 min.
9	CPU	All except 7b	Chassis	< 50 VDC

b) TESTING

Filter networks and transient protection clamps are used in module 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. For testing of dielectric strength where the test interval may exceed one minute, always observe the following precautions:

Test Precautions:

1. The connection from ground to the Filter Ground (Terminal 8b) and Surge Ground (Terminal 8a) must be removed before testing.
2. Some versions of the digital I/O module have a Surge Ground connection on Terminal 8b. On these module types, this connection must be removed before testing.

3.2.3 CONTROL POWER

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!

The power supply module can be ordered with either of two possible voltage ranges. Each range has a dedicated input connection for proper operation. The ranges are as shown below (see the Technical Specifications section for details).

Table 3–2: CONTROL POWER VOLTAGE RANGE

RANGE	NOMINAL VOLTAGE
LO	24 to 48 V (DC only)
HI	125 to 250 V

The power supply module provides power to the relay and supplies power for dry contact input connections.

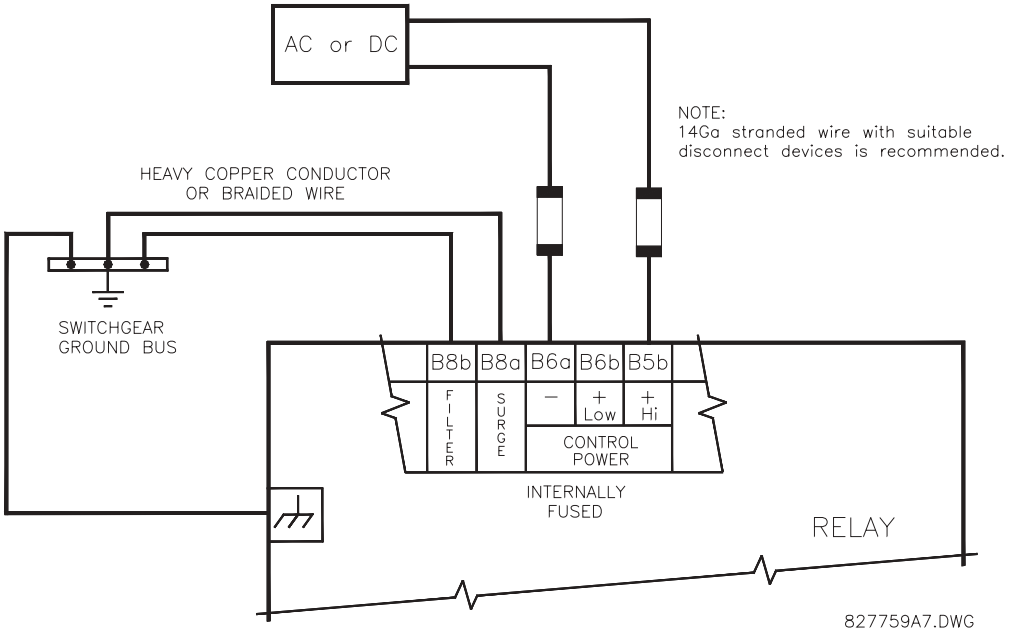


Figure 3–9: CONTROL POWER CONNECTION

The power supply module provides 48 V DC power for dry contact input connections and a critical failure relay (see TYPICAL WIRING DIAGRAM). 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 any of the on-going self-test features detect a critical failure or control power is lost, the relay will de-energize.

3.2.4 CT/VT MODULES

A CT/VT module may have voltage inputs on channels 1 through 4 inclusive, or channels 5 through 8 inclusive. Channels 1 and 5 are intended for connection to phase A, and are labeled as such in the relay. Channels 2 and 6 are intended for connection to phase B, and are labeled as such in the relay. Channels 3 and 7 are intended for connection to phase C and are labeled as such in the relay. Channels 4 and 8 are intended for connection to a single phase source. If voltage, this channel is labelled the auxiliary voltage (VX). If current, this channel is intended for connection to a CT between a system neutral and ground, and is labelled the ground current (IG).

a) AC CURRENT TRANSFORMER INPUTS

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.

The CT/VT module may be ordered with a standard ground current input that is the same as the phase current inputs (type 8A) or with a sensitive ground input (type 8B) which is 10 times more sensitive (see the Technical Specifications section for more details). Each AC current input has an isolating transformer and an automatic shorting mechanism that shorts the input when the module is withdrawn from the chassis. 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 CT so that ground fault current will be detected is shown below. Twisted pair cabling on the zero sequence CT is recommended.

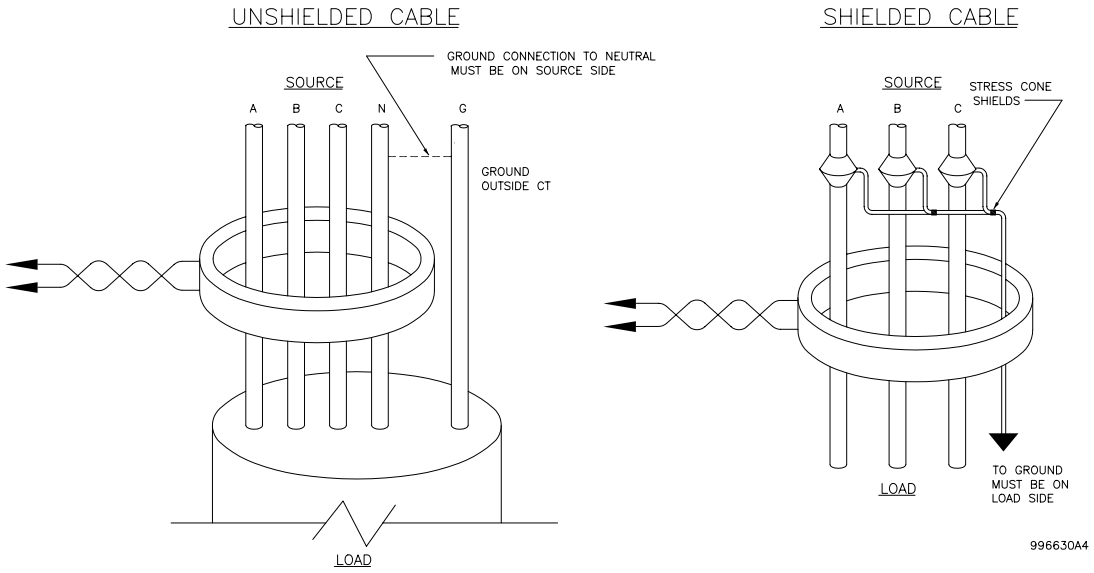


Figure 3–10: ZERO-SEQUENCE CORE BALANCE CT INSTALLATION

b) AC VOLTAGE TRANSFORMER INPUTS

The phase voltage channels are used for most metering and protection purposes. The auxiliary voltage channel is used as input for the Synchrocheck and Volts/Hertz features.

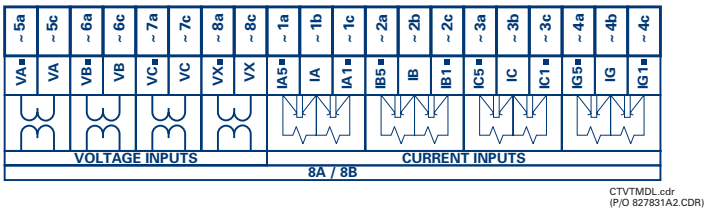


Figure 3–11: CT/VT MODULE WIRING

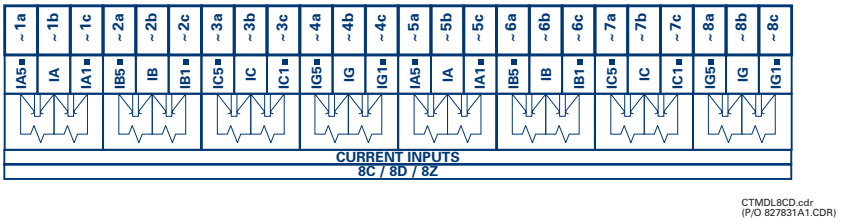


Figure 3–12: CT MODULE WIRING

NOTE

Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module.

Every digital input/output module has 24 terminal connections. They are arranged as 3 terminals per row, with 8 rows in total. A given row of three terminals may be used for the outputs of one relay. For example, for Form-C relay outputs, the terminals connect to the normally open (NO), normally closed (NC), and common contacts of the relay. For a Form-A output, there are options of using current or voltage detection for feature supervision, depending on the module ordered. The terminal configuration for contact inputs is different for the two applications. When a digital I/O module is ordered with contact inputs, they are arranged in groups of four and use two rows of three terminals. Ideally, each input would be totally isolated from any other input. However, this would require that every input have two dedicated terminals and limit the available number of contacts based on the available number of terminals. So, although each input is individually optically isolated, each group of four inputs uses a single common as a reasonable compromise. This allows each group of four outputs to be supplied by wet contacts from different voltage sources (if required) or a mix of wet and dry contacts.

The tables and diagrams on the following pages illustrate the module types (6A, etc.) and contact arrangements that may be ordered for the relay. Since an entire row is used for a single contact output, the name is assigned using the module slot position and row number. However, since there are two contact inputs per row, these names are assigned by module slot position, row number, and column position.

UR RELAY FORM-A OUTPUT CONTACTS

Some Form-A 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 "On = 1" when the current in the circuit is above the threshold setting. The voltage monitor is set to "On = 1" when the current is above about 1 to 2.5 mA, and the current monitor is set to "On = 1" when the current exceeds about 80 to 100 mA. 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. The block diagrams of the circuits are below above for the Form-A outputs with:

a) optional voltage monitor

b) optional current monitor

c) with no monitoring

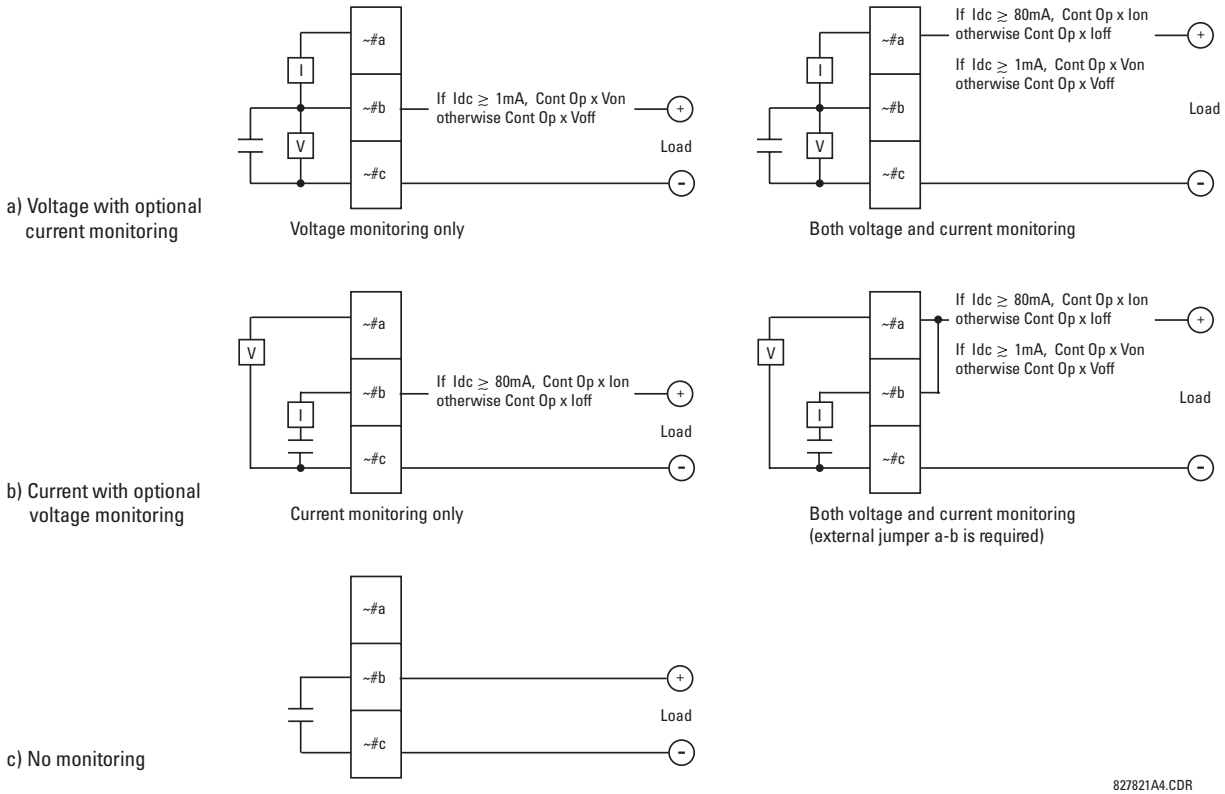


Figure 3–13: FORM-A CONTACT FUNCTIONS

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. Refer DIGITAL ELEMENTS section for an example of how Form A contacts can be applied for Breaker Trip Circuit Integrity Monitoring.

WARNING

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

USE OF FORM-A OUTPUTS IN HIGH IMPEDANCE CIRCUITS

For Form-A output contacts internally equipped with a voltage measuring cIrcuit across the contact, the circuit has an impedance that can cause a problem when used in conjunction with external high input impedance monitoring equipment such as modern relay test set trigger circuits. These monitoring circuits may continue to read the Form-A contact as being closed after it has closed and subsequently opened, when measured as an impedance.

The solution to this problem is to use the voltage measuring trigger input of the relay test set, and connect the Form-A contact through a voltage-dropping resistor to a DC voltage source. If the 48 V DC output of the power supply is used as a source, a 500 Ω, 10 W resistor is appropriate. In this configuration, the voltage across either the Form-A contact or the resistor can be used to monitor the state of the output.

NOTE

Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module; wherever a number sign "#" appears, substitute the contact number

NOTE

When current monitoring is used to seal-in the Form-A 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).

Table 3–3: DIGITAL I/O MODULE ASSIGNMENTS

~6A I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6B I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5	Form-C
~6	Form-C
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6C I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT
~1	Form-C
~2	Form-C
~3	Form-C
~4	Form-C
~5	Form-C
~6	Form-C
~7	Form-C
~8	Form-C

~6D I/O MODULE	
TERMINAL ASSIGNMENT	INPUT
~1a, ~1c	2 Inputs
~2a, ~2c	2 Inputs
~3a, ~3c	2 Inputs
~4a, ~4c	2 Inputs
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6E I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-C
~2	Form-C
~3	Form-C
~4	Form-C
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6F I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT
~1	Fast Form-C
~2	Fast Form-C
~3	Fast Form-C
~4	Fast Form-C
~5	Fast Form-C
~6	Fast Form-C
~7	Fast Form-C
~8	Fast Form-C

~6G I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6H I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5	Form-A
~6	Form-A
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6K I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT
~1	Form-C
~2	Form-C
~3	Form-C
~4	Form-C
~5	Fast Form-C
~6	Fast Form-C
~7	Fast Form-C
~8	Fast Form-C

~6L I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6M I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5	Form-C
~6	Form-C
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6N I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6P I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5	Form-A
~6	Form-A
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6R I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6S I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5	Form-C
~6	Form-C
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6T I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6U I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5	Form-A
~6	Form-A
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

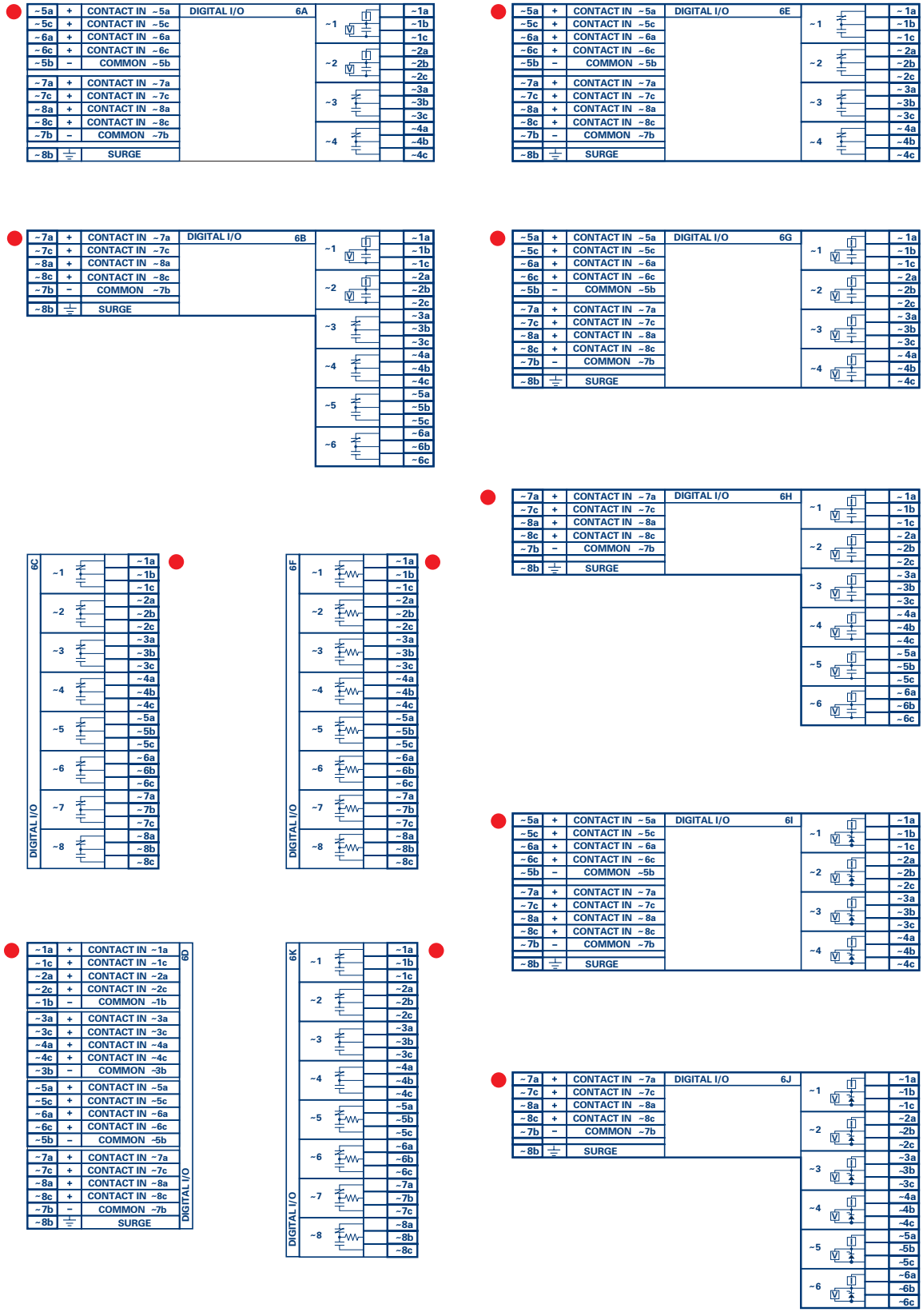


Figure 3–14: DIGITAL I/O MODULE WIRING (SHEET 1 OF 2)

827719AR.CDR
Sheet 2 of 2

Figure 3–15: DIGITAL I/O MODULE WIRING (SHEET 2 OF 2)

CAUTION

CORRECT POLARITY MUST BE OBSERVED FOR ALL CONTACT INPUT CONNECTIONS OR EQUIPMENT DAMAGE MAY RESULT.

A dry contact has one side connected to terminal B3b. 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 the required contact input terminal. Each contact input group has its own common (negative) terminal which must be connected to the DC negative terminal (B3a) of the power supply module. When a dry contact closes, a current of 1 to 3 mA will flow through the associated circuit.

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 required contact input terminal. In addition, the negative side of the external source must be connected to the relay common (negative) terminal of each contact input group. 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 17 V DC for 24 V sources, 33 V DC for 48 V sources, 84 V DC for 110 to 125 V sources, and 166 V DC for 250 V sources.

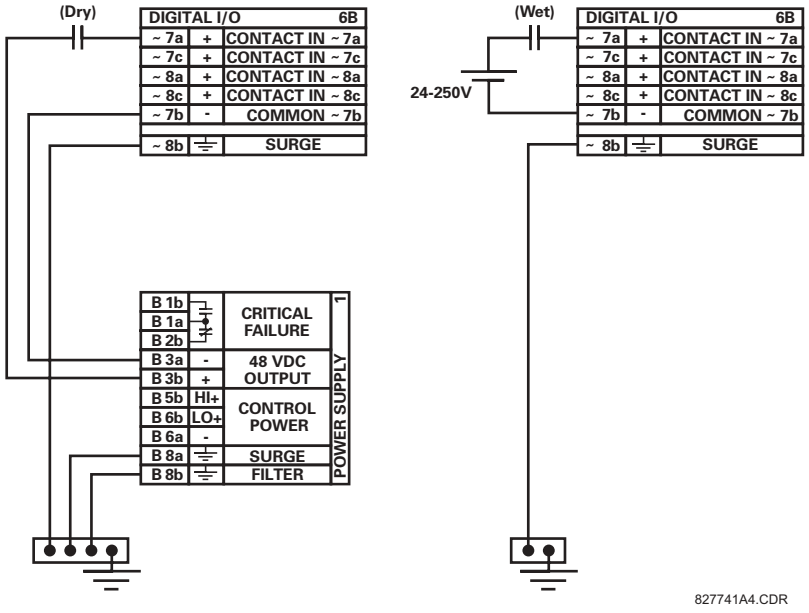


Figure 3–16: DRY AND WET CONTACT INPUT CONNECTIONS

NOTE

Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module.

Contact outputs may be ordered as Form-A or Form-C. The Form A 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.

3.2.6 TRANSDUCER INPUTS/OUTPUTS

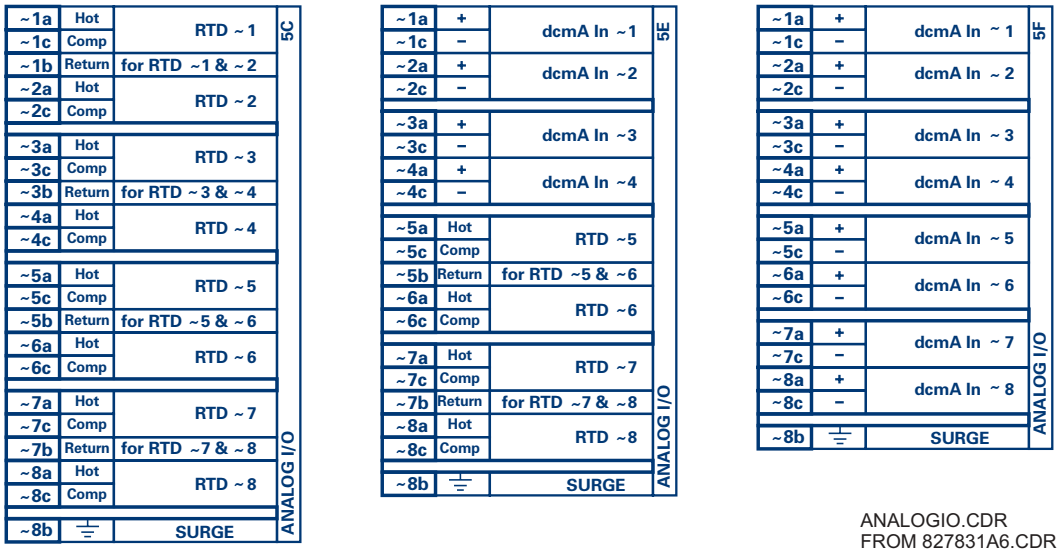
Transducer input/output modules can receive input signals from external dcmA output transducers (dcmA In) or resistance temperature detectors (RTD). Hardware and software is provided to receive signals from these external transducers and convert these signals into a digital format for use as required.

Every transducer input/output module has a total of 24 terminal connections. These connections are arranged as three terminals per row with a total of eight rows. A given row may be used for either inputs or outputs, with terminals in column "a" having positive polarity and terminals in column "c" having negative polarity. Since an entire row is used for a single input/output channel, the name of the channel is assigned using the module slot position and row number.

Each module also requires that a connection from an external ground bus be made to Terminal 8b. The figure below illustrates the transducer module types (5C, 5E, and 5F) and channel arrangements that may be ordered for the relay.

NOTE

Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module.



ANALOGIO.CDR
FROM 827831A6.CDR

Figure 3–17: TRANSDUCER I/O MODULE WIRING

3.2.7 RS232 FACEPLATE PROGRAM PORT

A 9 pin RS232C serial port is located on the relay's faceplate for programming with a portable (personal) computer. All that is required to use this interface is a personal computer running the URPC software provided with the relay. Cabling for the RS232 port is shown in the following figure for both 9 pin and 25 pin connectors.

Note that the baud rate for this port is fixed at **19200 bps**.

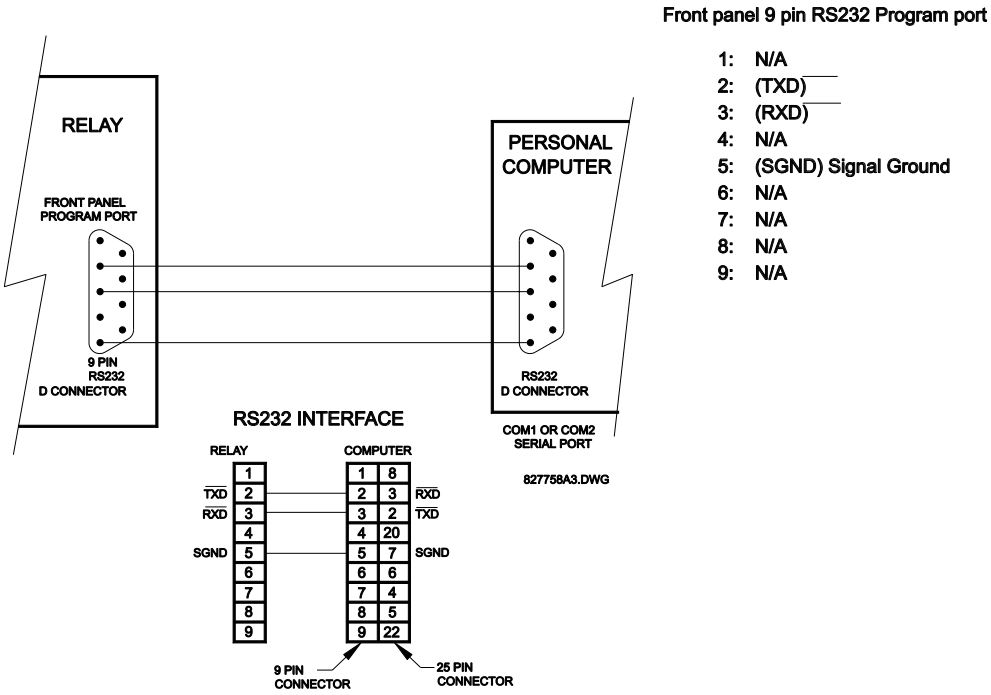


Figure 3–18: RS232 FACEPLATE PORT CONNECTION

3.2.8 CPU COMMUNICATION PORTS

In addition to the RS232 port on the faceplate, the relay provides the user with two additional communication port(s) depending on the CPU module installed.

Table 3–4: CPU COMMUNICATION PORT OPTIONS

CPU TYPE	COM 1	COM 2
9A	RS485	RS485
9C	10BASE-F	RS485
9D	Redundant 10BASE-F	RS485

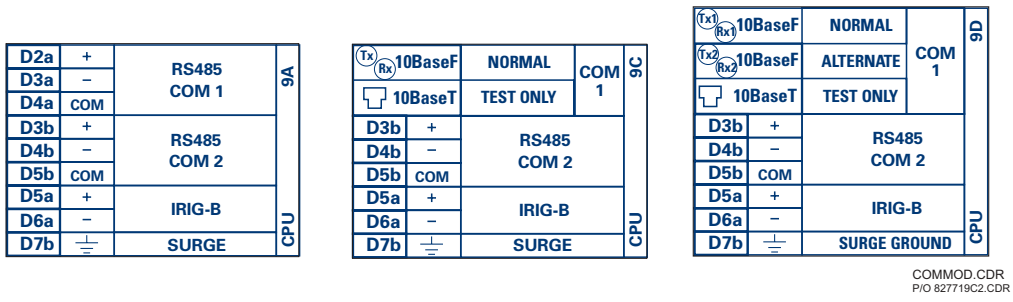


Figure 3–19: CPU MODULE COMMUNICATIONS WIRING

a) RS485 PORTS

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 these port(s), 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.

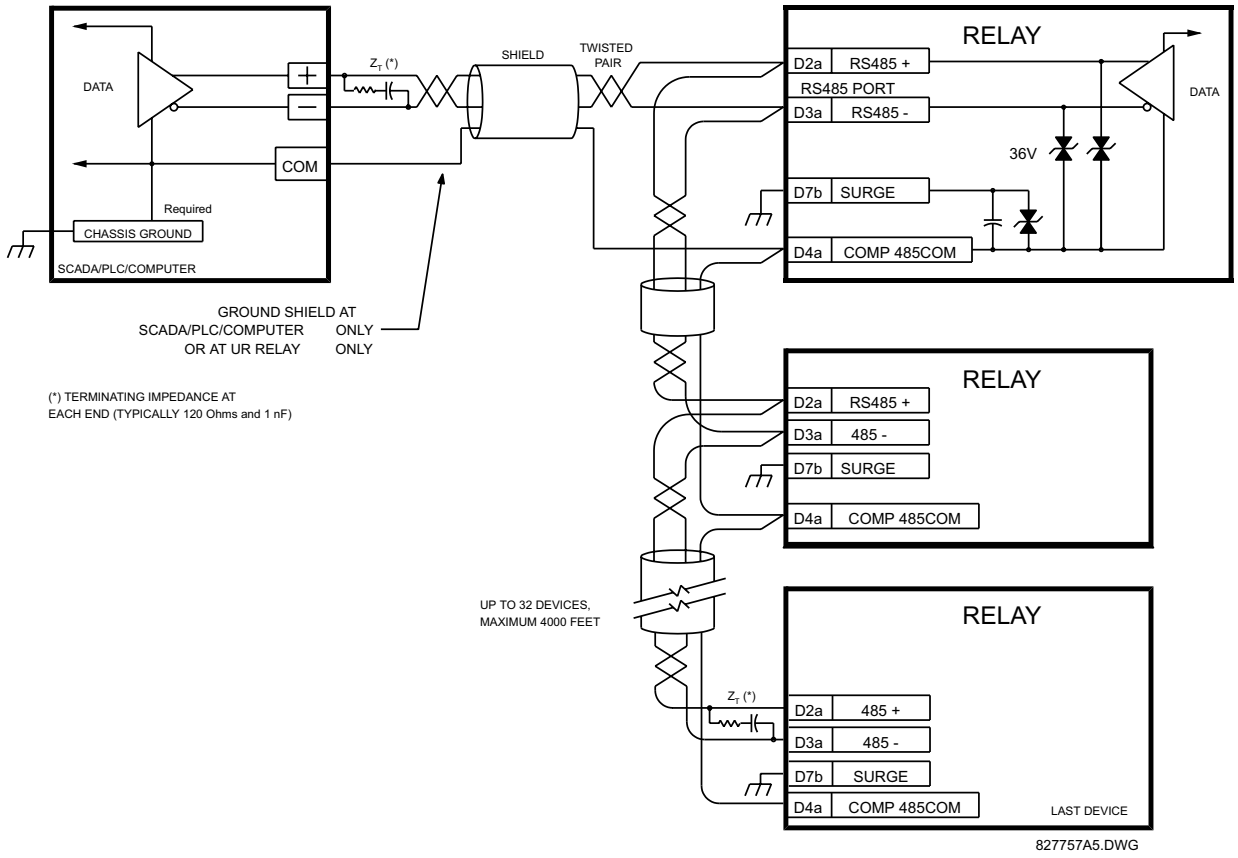


Figure 3–20: RS485 SERIAL CONNECTION

b) 10BASE-F FIBER OPTIC PORT

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.

OBSERVING ANY FIBER TRANSMITTER OUTPUT MAY CAUSE INJURY TO THE EYE.

The fiber optic communication ports allow for fast and efficient communications between relays at 10 Mbps. Optical fiber may be connected to the relay supporting a wavelength of 820 nanometers in multimode. Optical fiber is only available for CPU types 9C and 9D. The 9D CPU has a 10BaseF transmitter and receiver for optical fiber communications and a second pair of identical optical fiber transmitter and receiver for redundancy.

The optical fiber sizes supported include 50/125 µm, 62.5/125 µm and 100/140 µm. The fiber optic port is designed such that the response times will not vary for any core that is 100 µm or less in diameter. For optical power budgeting, splices are required every 1 km for the transmitter/receiver pair (the ST type connector contributes for a connector loss of 0.2 dB). 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.

3.2.9 IRIG-B

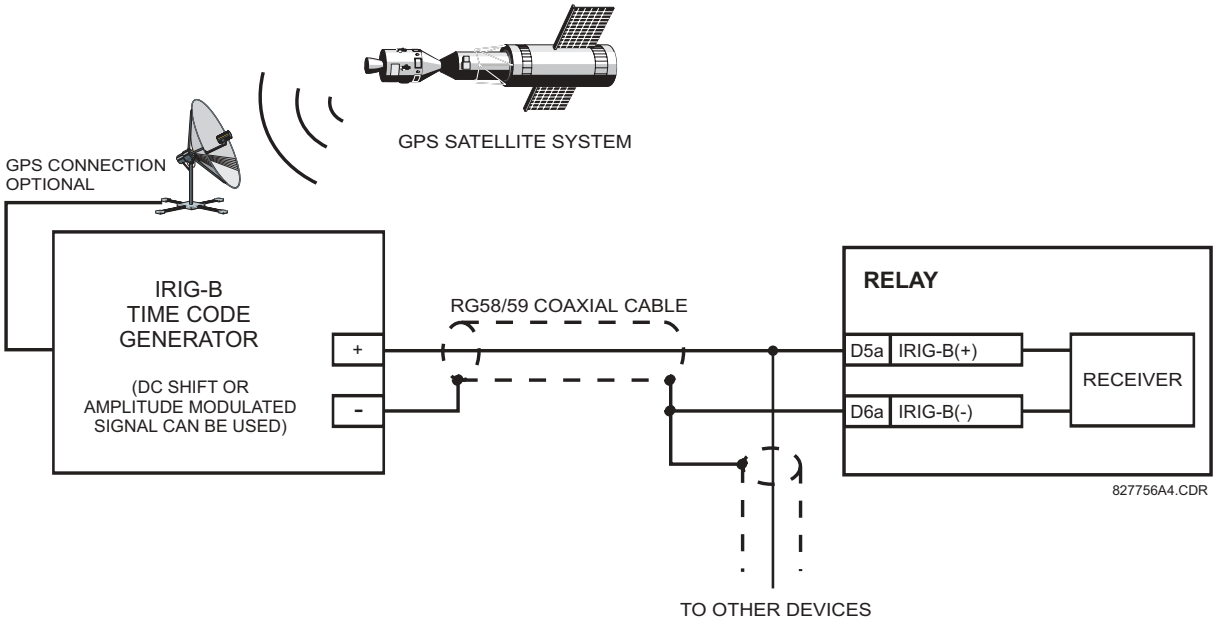


Figure 3–21: IRIG-B CONNECTION

IRIG-B is a standard time code format that allows stamping of events to be synchronized among connected devices within 1 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.

3.3.1 DESCRIPTION

The L90 relay requires a special communications module which is plugged into slot “W” for UR-Horizontal or slot “R” for UR-Vertical. This module is available in several varieties. Relay to relay channel communication is not the same as the 10Base-F interface (available as an option with the CPU module). Channel communication is used for sharing data among relays.

Table 3–5: CHANNEL COMMUNICATION OPTIONS

MODULE TYPE	SPECIFICATION
7A	820 nm, multi-mode, LED, 1 Channel
7B	1300 nm, multi-mode, LED, 1 Channel
7C	1300 nm, single-mode, ELED, 1 Channel
7D	1300 nm, single-mode, LASER, 1 Channel
7E	Channel 1: G.703; Channel 2: 820 nm, multi-mode, LED
7F	Channel 1: G.703; Channel 2: 1300 nm, multi-mode, LED
7G	Channel 1: G.703; Channel 2: 1300 nm, single-mode, ELED
7Q	Channel 1: G.703; Channel 2: 1300 nm, single-mode, LASER
7H	820 nm, multi-mode, LED, 2 Channels
7I	1300 nm, multi-mode, LED, 2 Channels
7J	1300 nm, single-mode, ELED, 2 Channels
7K	1300 nm, single-mode, LASER, 2 Channels
7L	Ch 1 - RS422, Ch 2 - 820 nm, multi-mode, LED
7M	Ch 1 - RS422, Ch 2 - 1300 nm, multi-mode, LED
7N	Ch 1 - RS422, Ch 2 - 1300 nm, single-mode, ELED
7P	Ch 1 - RS422, Ch 2 - 1300 nm, single-mode, LASER
7R	G.703, 1 Channel
7S	G.703, 2 Channels
7T	RS422, 1 Channel
7W	RS422, 2 Channels
72	1550 nm, single-mode, LASER, 1 Channel
73	1550 nm, single-mode, LASER, 2 Channel
74	Channel 1 - RS422; Channel 2 - 1550 nm, single-mode, LASER
75	Channel 1 - G.703; Channel 2 - 1550 nm, single-mode, LASER

The above table shows the various Channel Communication interfaces available for the L90 relay. All of the fiber modules use ST type connectors. For 2-Terminal applications, each L90 relay requires at least one communications channel.

NOTE

The L90 Current Differential Function must be “Enabled” for the Communications Module to work. Refer to SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ LINE DIFFERENTIAL ⇨ CURRENT DIFFERENTIAL menu.

CAUTION

OBSERVING ANY FIBER TRANSMITTER OUTPUT MAY CAUSE INJURY TO THE EYE.

3.3.2 FIBER: LED & ELED TRANSMITTERS

The following figure shows the configuration for the 7A, 7B, 7C, 7H, 7I, and 7J fiber-only modules.

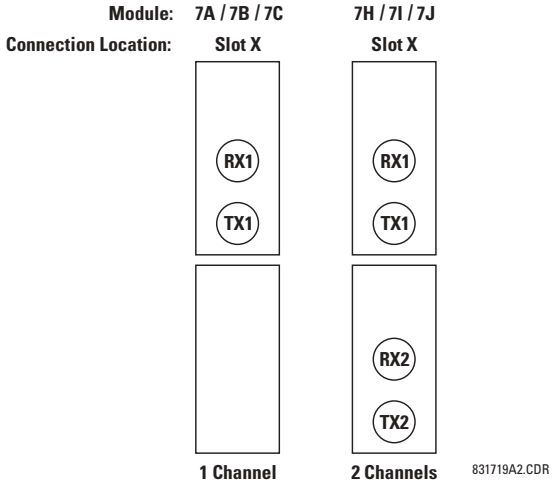


Figure 3–22: LED & ELED FIBER MODULES

3.3.3 FIBER-LASER TRANSMITTERS

The following figure shows the configuration for the 72, 73, 7D, and 7K fiber-laser module.

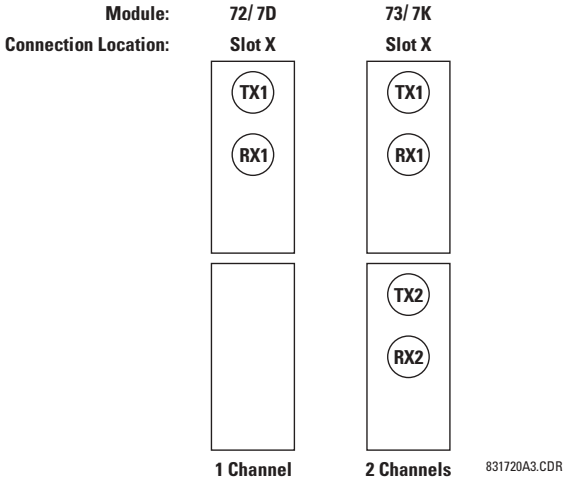


Figure 3–23: LASER FIBER MODULES

When using a LASER Interface, attenuators may be necessary to ensure that you do not exceed Maximum Optical Input Power to the receiver.

a) DESCRIPTION

The following figure shows the 64K ITU G.703 co-directional interface configuration. For 2-Terminal configurations, channel 2 is not used.

AWG 22 twisted shielded pair is recommended for external connections, with the shield grounded at only at one end. Connecting the shield to Pin # X1a or X6a grounds the shield since these pins are internally connected to ground. Thus, if Pin # X1a or X6a is used, do not ground at the other end.

This interface module is protected by surge suppression devices.

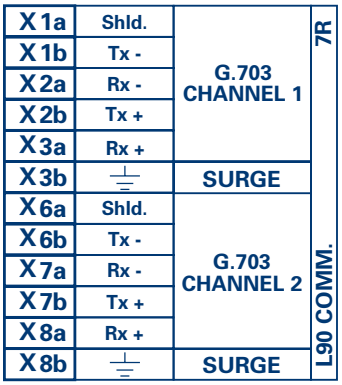


Figure 3–24: G.703 INTERFACE CONFIGURATION

The following figure shows the typical pin interconnection between two G.703 interfaces. For the actual physical arrangement of these pins, see the REAR TERMINAL ASSIGNMENTS section earlier in this chapter. All pin interconnections are to be maintained for a connection to a multiplexer.

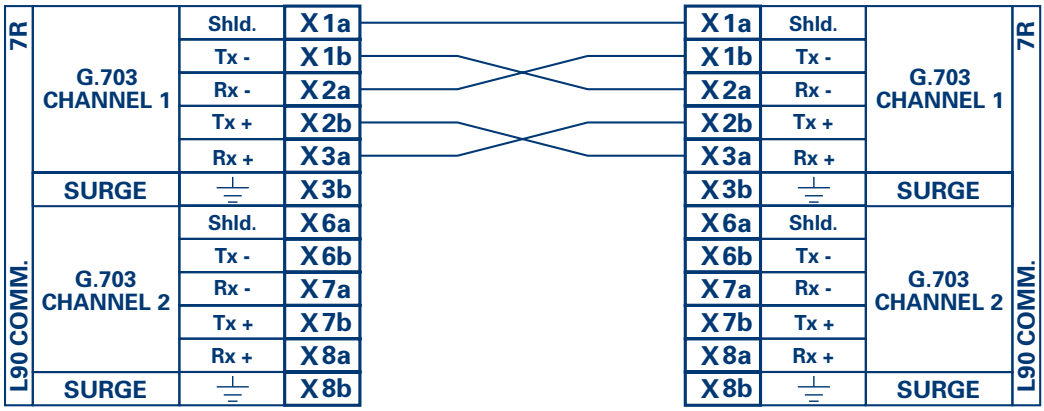


Figure 3–25: TYPICAL PIN INTERCONNECTION BETWEEN TWO G.703 INTERFACES

NOTE

Pin nomenclature may differ from one manufacturer to another. Therefore, it is not uncommon to see pinouts numbered TxA, TxB, RxA and RxB. In such cases, it can be assumed that "A" is equivalent to "+" and "B" is equivalent to "–".

b) G.703 SELECTION SWITCH PROCEDURE

Step 1: Remove the G.703 module (7R or 7S):

The ejector/inserter clips located at the top and at the bottom of each module, must be pulled simultaneously in order to release the module for removal. Before performing this action, **control power must be removed from the relay**. The original location of the module should be recorded to help ensure that the same or replacement module is inserted into the correct slot.

Step 2: Remove the module cover screw.

Step 3: Remove the top cover by sliding it towards the rear and then lift it upwards.

Step 4: Set the Timing Selection Switches (Channel 1, Channel 2) to the desired timing modes.

Step 5: Replace the top cover and the cover screw.

Step 6: Re-insert the G.703 module:

Take care to ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/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.

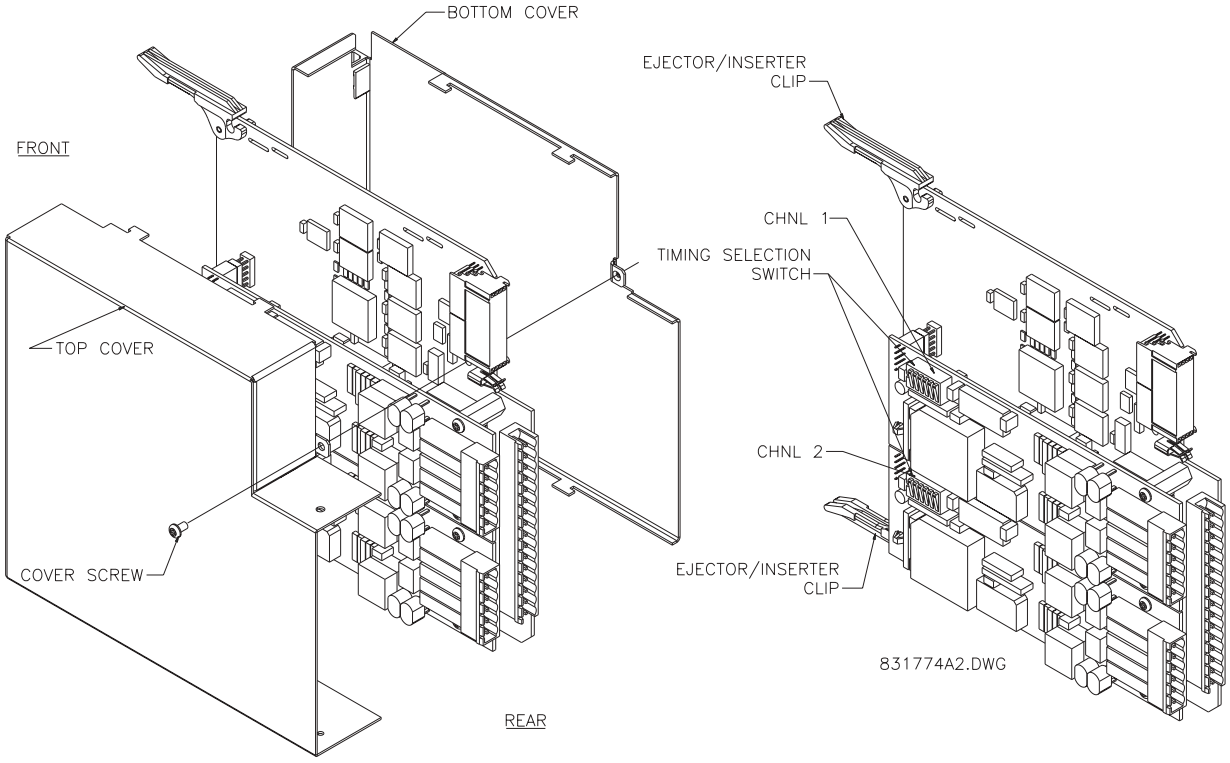


Figure 3–26: G.703 TIMING SELECTION SWITCH SETTING

Table 3–6: G.703 TIMING SELECTIONS

SWITCHES	FUNCTION
S1	OFF → Octet Timing Disabled ON → Octet Timing 8 kHz
S5 & S6	S5 = OFF & S6 = OFF → Loop Timing Mode S5 = ON & S6 = OFF → Internal Timing Mode S5 = OFF & S6 = ON → Minimum Remote Loopback Mode S5 = ON & S6 = ON → Dual Loopback Mode

c) OCTET TIMING (S1)

If Octet Timing is enabled (ON), this 8 kHz signal will be asserted during the violation of Bit 8 (LSB) necessary for connecting to higher order systems. When L90's are connected back to back, Octet Timing should be disabled (OFF).

d) TIMING MODES (S5 & S6)

Internal Timing Mode:

System clock generated internally; therefore, the G.703 timing selection should be in the Internal Timing Mode for back to back connections.

Figure 3–27: BACK TO BACK CONNECTION

For Back to Back Connections: Octet Timing (S1 = OFF); Timing Mode = Internal Timing (S5 = ON & S6 = OFF)

Loop Timing Mode:

System clock derived from the received line signal; therefore, the G.703 timing selection should be in Loop Timing Mode for connections to higher order systems.

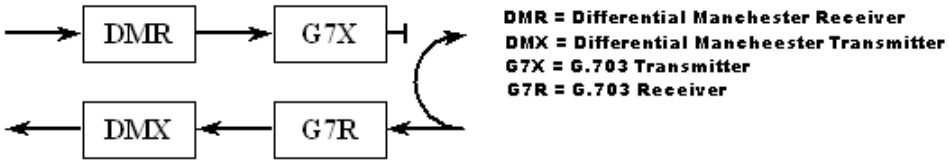
Figure 3–28: CONNECTION TO HIGHER ORDER SYSTEM

For connection to a higher order system (factory defaults): Octet Timing (S1 = ON);
Timing Mode = Loop Timing (S5 = OFF & S6 = OFF)

e) TEST MODES (S5 & S6)

Minimum Remote Loopback Mode:

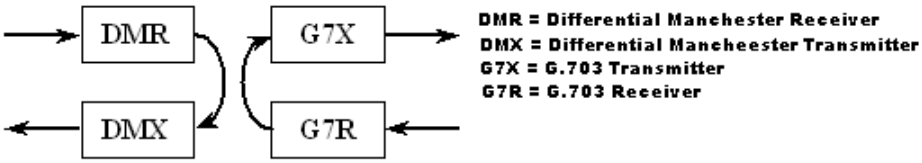
In Minimum Remote Loopback mode, the multiplexer is enabled to return the data from the external interface without any processing to assist in diagnosing G.703 Line Side problems irrespective of clock rate. Data enters from the G.703 inputs, passes through the data stabilization latch which also restores the proper signal polarity, passes through the multiplexer and then returns to the transmitter. The Differential Received Data is processed and passed to the G.703 Transmitter module after which point the data is discarded. The G.703 Receiver module is fully functional and continues to process data and passes it to the Differential Manchester Transmitter module. Since timing is returned as it is received, the timing source is expected to be from the G.703 line side of the interface.



Dual Loopback Mode:

In Dual Loopback Mode, the multiplexers are active and the functions of the circuit are divided into two with each Receiver/Transmitter pair linked together to deconstruct and then reconstruct their respective signals. Differential Manchester data enters the Differential Manchester Receiver module and then is returned to the Differential Manchester Transmitter module. Likewise, G.703 data enters the G.703 Receiver module and is passed through to the G.703 Transmitter module to be

returned as G.703 data. Because of the complete split in the communications path and because, in each case, the clocks are extracted and reconstructed with the outgoing data, in this mode there must be two independent sources of timing. One source lies on the G.703 line side of the interface while the other lies on the Differential Manchester side of the interface.



3.3.5 RS422 INTERFACE

a) DESCRIPTION

The following figure shows the RS422 2-Terminal interface configuration at 64K baud. For 2-Terminal configurations, channel 2 is not used. AWG 22 twisted shielded pair is recommended for external connections. This interface module is protected by surge suppression devices which optically isolated.

Shield Termination

The shield pins (6a and 7b) are internally connected to the ground pin (8a). Proper shield termination is as follows:

Site 1: Terminate shield to pins 6a and/or 7b.
Site 2: Terminate shield to 'COM' pin 2b.

NOTE

The clock terminating impedance should match the impedance of the line.

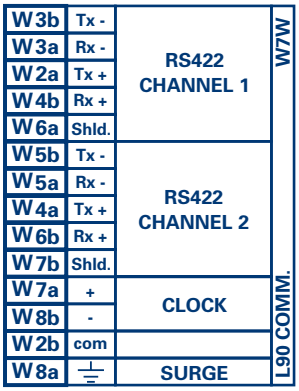


Figure 3–29: RS422 INTERFACE CONFIGURATION

The following figure shows the typical pin interconnection between two RS422 interfaces. All pin interconnections are to be maintained for a connection to a multiplexer.

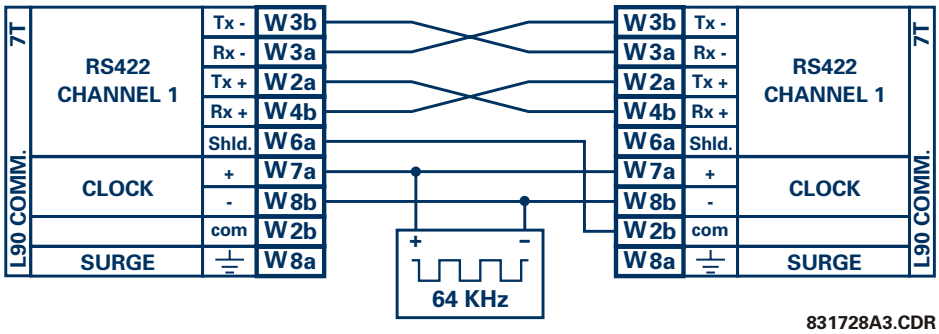


Figure 3–30: TYPICAL PIN INTERCONNECTION BETWEEN TWO RS422 INTERFACES

b) TWO CHANNEL APPLICATIONS VIA MULTIPLEXERS

The RS422 Interface may be used for '1 channel - 2 terminal' or '2 channel - 3 terminal' applications over SONET/SDH and/or Multiplexed systems. When used in 1 channel - 2 terminal applications, the RS422 interface links to higher order systems in a typical fashion observing Tx, Rx, and Send Timing connections. However, when used in 2 channel - 3 terminal applications, certain criteria have to be followed due to the fact that there is 1 clock input for the two RS422 channels. The system will function correctly if the following connections are observed and your Data Module has a feature called Terminal Timing. Terminal Timing is a common feature to most Synchronous Data Units that allows the module to accept timing from an external source. Using the Terminal Timing feature, 2 channel - 3 terminal applications can be achieved if these connections are followed: The Send Timing outputs from the Multiplexer - Data Module 1, will connect to the Clock inputs of the UR - RS422 interface in the usual fashion. In addition, the Send Timing outputs of Data Module 1 will also be paralleled to the Terminal Timing inputs of Data Module 2. By using this configuration the timing for both Data Modules and both UR - RS422 channels will be derived from a single clock source. As a result, data sampling for both of the UR - RS422 channels will be synchronized via the Send Timing leads on Data Module 1 as shown in the following figure. If the Terminal Timing feature is not available or this type of connection is not desired, the G.703 interface is a viable option that does not impose timing restrictions.

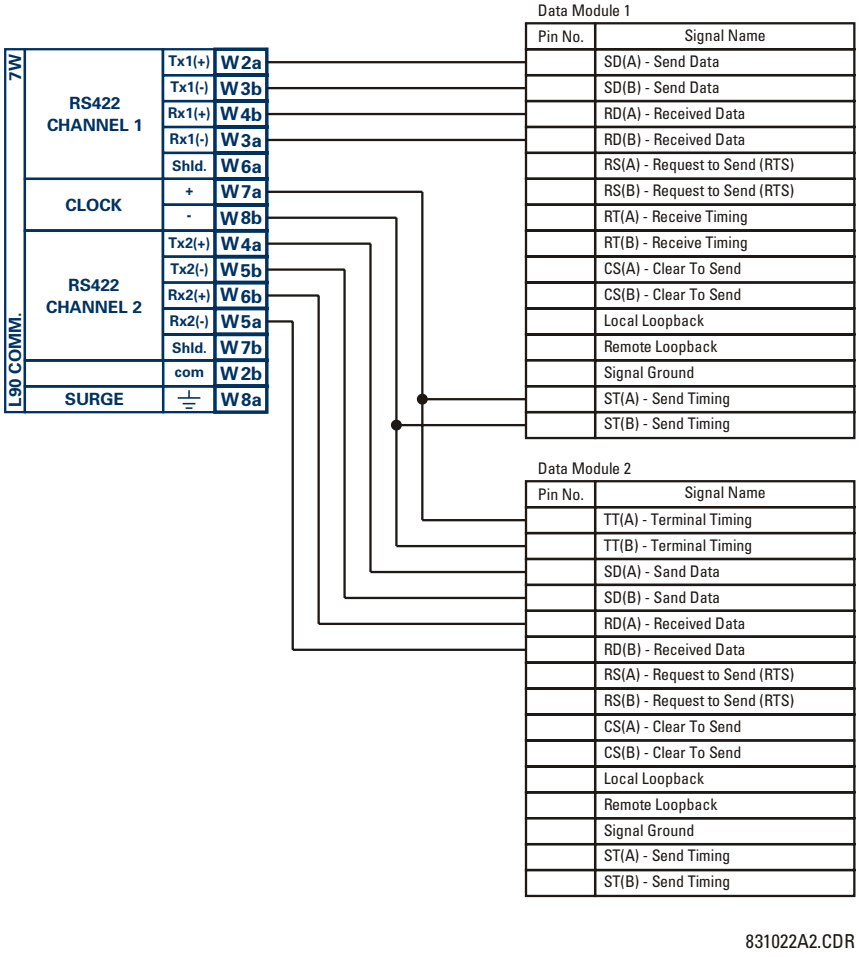


Figure 3–31: TIMING CONFIGURATION FOR RS422 2 CHANNEL - 3 TERMINAL APPLICATION

Data Module 1 provides timing to the L90 RS422 interface via the ST(A) and ST(B) outputs. Data Module 1 also provides timing to Data Module 2 TT(A) and TT(B) inputs via the ST(A) and AT(B) outputs.

NOTE

The Data Module Pin Numbers, in the figure above, have been omitted since they may vary depending on the manufacturer.

c) TRANSMIT TIMING

The RS422 Interface accepts one clock input for Transmit Timing. It is important that the rising edge of the 64 kHz Transmit Timing clock of the Multiplexer Interface is sampling the data in the center of the Transmit Data window. Therefore, it is important to confirm Clock and Data Transitions to ensure Proper System Operation. For example, the following figure shows the positive edge of the Tx Clock in the center of the Tx Data bit.

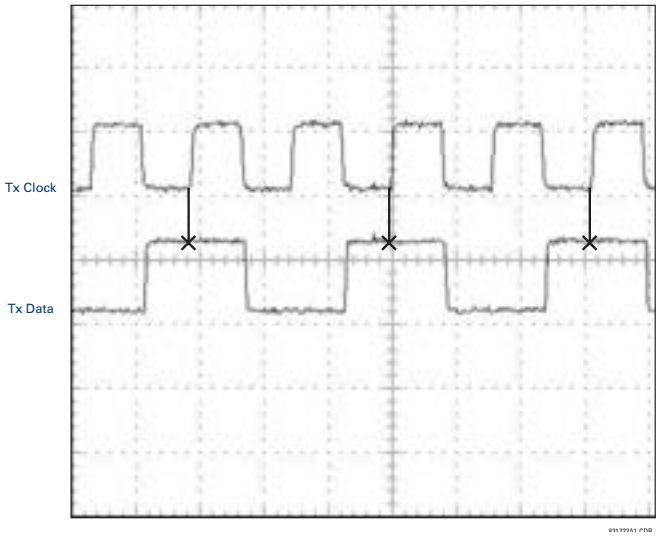


Figure 3–32: CLOCK AND DATA TRANSITIONS

d) RECEIVE TIMING

The RS422 Interface utilizes NRZI-MARK Modulation Code and; therefore, does not rely on an Rx Clock to recapture data. NRZI-MARK is an edge-type, invertible, self-clocking code.

To recover the Rx Clock from the data-stream, an integrated DPLL (Digital Phase Lock Loop) circuit is utilized. The DPLL is driven by an internal clock, which is over-sampled 16X, and uses this clock along with the data-stream to generate a data clock that can be used as the SCC (Serial Communication Controller) receive clock.

3.3.6 RS422 & FIBER INTERFACE

The following figure shows the combined RS422 plus Fiber interface configuration at 64K baud. The 7L, 7M, 7N, 7P, and 74 modules are used in 2-terminal with a redundant channel or 3-terminal configurations where Channel 1 is employed via the RS422 interface (possibly with a multiplexer) and Channel 2 via direct fiber.

AWG 22 twisted shielded pair is recommended for external RS422 connections and the shield should be grounded only at one end. For the direct fiber channel, power budget issues should be addressed properly.

WARNING

When using a LASER Interface, attenuators may be necessary to ensure that you do not exceed Maximum Optical Input Power to the receiver.

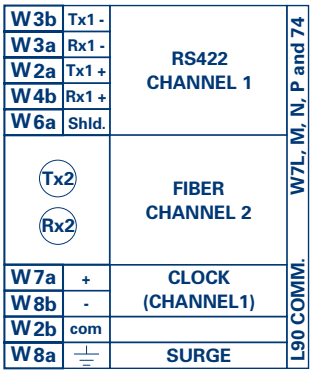


Figure 3–33: RS422 & FIBER INTERFACE CONFIGURATION

3.3.7 G.703 & FIBER INTERFACE

The following figure shows the combined G.703 plus Fiber interface configuration at 64K baud. The 7E, 7F, 7G, 7Q, and 75 modules are used in 2-terminal with a redundant channel or 3-terminal configurations where Channel 1 is employed via the G.703 interface (possibly with a multiplexer) and Channel 2 via direct fiber. AWG 22 twisted shielded pair is recommended for external G.703 connections connecting the shield to Pin # 1A at one end only. For the direct fiber channel, power budget issues should be addressed properly. See more details related to G.703 and fiber interfaces in previous sections of this chapter.

WARNING

When using a LASER Interface, attenuators may be necessary to ensure that you do not exceed Maximum Optical Input Power to the receiver.

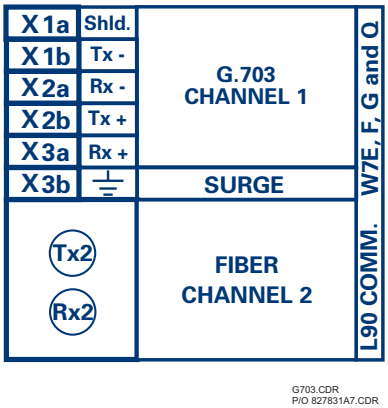


Figure 3–34: G.703 & FIBER INTERFACE CONFIGURATION

4.1.1 GRAPHICAL USER INTERFACE

The URPC software provides a graphical user interface (GUI) as one of two human interfaces to a UR device. The alternate human interface is implemented via the device's faceplate keypad and display (see FACEPLATE INTERFACE section in this chapter).

URPC provides a single facility to configure, monitor, maintain, and trouble-shoot the operation of relay functions, connected over local or wide area communication networks. It can be used while disconnected (i.e. off-line) or connected (i.e. on-line) to a UR device. In off-line mode, settings files can be created for eventual downloading to the device. In on-line mode, you can communicate with the device in real-time.

The URPC software, provided with every L90 relay, can be run from any computer supporting Microsoft Windows® 95, 98, or NT. This chapter provides a summary of the basic URPC software interface features. The URPC Help file provides details for getting started and using the URPC software interface.

4.1.2 CREATING A SITE LIST

To start using the URPC program, a Site List must first be created. See the instructions in the URPC Help program under the topic "Creating a Site List".

4.1.3 URPC® SOFTWARE OVERVIEW

a) ENGAGING A COMMUNICATING DEVICE

The URPC software may be used in on-line mode (relay connected) to directly communicate with a UR relay. Communicating relays are organized and grouped by communication interfaces and into sites. Sites may contain any number of relays selected from the UR product series.

b) USING SETTINGS FILES

The URPC software interface supports three ways of handling changes to relay settings:

- In off-line mode (relay disconnected) to create or edit relay settings files for later download to communicating relays.
- While connected to a communicating relay to directly modify any relay settings via relay data view windows, and then save the settings to the relay.
- You can create/edit settings files and then write them to the relay while the interface is connected to the relay.

Settings files are organized on the basis of file names assigned by the user. A settings file contains data pertaining to the following types of relay settings:

- Device Definition
- Product Setup
- System Setup
- FlexLogic™
- Grouped Elements
- Control Elements
- Inputs/Outputs
- Testing

Factory default values are supplied and can be restored after any changes.

c) CREATING / EDITING FLEXLOGIC™ EQUATIONS

You can create or edit a FlexLogic™ equation in order to customize the relay. You can subsequently view the automatically generated logic diagram.

d) VIEWING ACTUAL VALUES

You can view real-time relay data such as input/output status and measured parameters.

e) VIEWING TRIGGERED EVENTS

While the interface is in either on-line or off-line mode, you can view and analyze data generated by triggered specified parameters, via:

- **Event Recorder facility**

  The event recorder captures contextual data associated with the last 1024 events, listed in chronological order from most recent to oldest.

- **Oscillography facility**

  The oscillography waveform traces and digital states are used to provide a visual display of power system and relay operation data captured during specific triggered events.

f) CREATING INTERACTIVE SINGLE LINE DIAGRAMS

The URPC® software provides an icon-based interface facility for designing and monitoring electrical schematic diagrams of sites employing UR relays.

g) FILE SUPPORT

- **Execution**

  Any URPC file which is double clicked or opened will launch the application, or provide focus to the already opened application. If the file was a settings file (*.urs) which had been removed from the Settings List tree menu, it will be added back to the Settings List tree menu.

- **Drag and Drop**

  The Site List and Settings List control bar windows are each mutually a drag source and a drop target for device-order-code-compatible files or individual menu items. Also, the Settings List control bar window and any Windows Explorer directory folder are each mutually a file drag source and drop target.

  New files which are dropped into the Settings List window are added to the tree which is automatically sorted alphabetically with respect to settings file names. Files or individual menu items which are dropped in the selected device menu in the Site List window will automatically be sent to the on-line communicating device.

h) UR FIRMWARE UPGRADES

The firmware of a UR device can be upgraded, locally or remotely, via the URPC® software. The corresponding instructions are provided by the URPC® Help program under the topic “Upgrading Firmware”.

NOTE

Modbus addresses assigned to firmware modules, features, settings, and corresponding data items (i.e. default values, min/max values, data type, and item size) may change slightly from version to version of firmware. The addresses are rearranged when new features are added or existing features are enhanced or modified. The “EEPROM DATA ERROR” message displayed after upgrading/downgrading the firmware is a resettable, self-test message intended to inform users that the Modbus addresses have changed with the upgraded firmware. This message does not signal any problems when appearing after firmware upgrades.

The URPC software main window supports the following primary display components:

a. Title bar which shows the pathname of the active data view
b. Main window menu bar
c. Main window tool bar
d. Site List control bar window
e. Settings List control bar window
f. Device data view window(s), with common tool bar
g. Settings File data view window(s), with common tool bar
h. Workspace area with data view tabs
i. Status bar

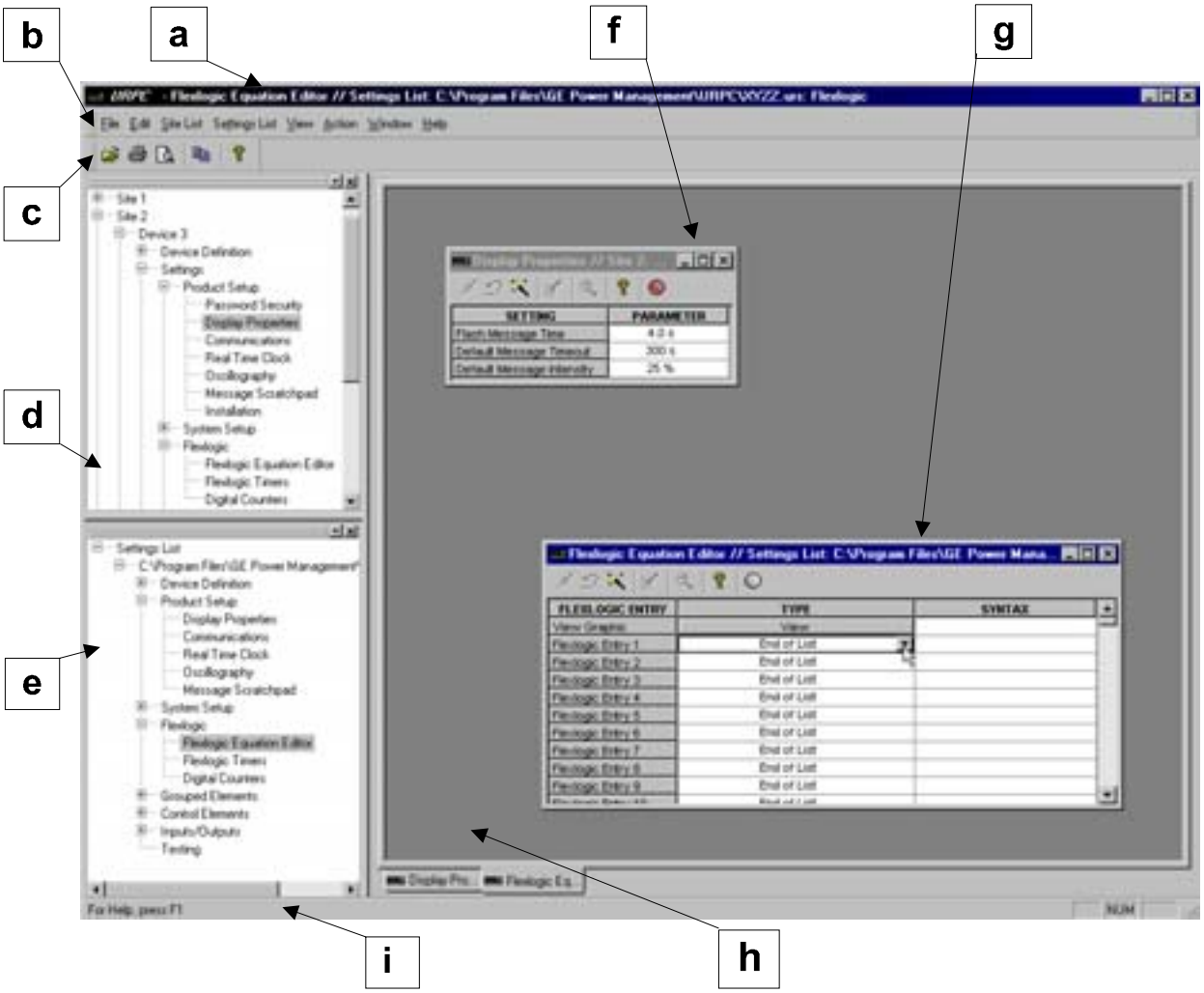


Figure 4–1: URPC SOFTWARE MAIN WINDOW

4.2.1 FACEPLATE

The keypad/display/LED interface is one of two alternate human interfaces supported. The other alternate human interface is implemented via the URPC software. The UR faceplate interface is available in two configurations: horizontal or vertical. The faceplate interface consists of several functional panels.

The faceplate is hinged to allow easy access to the removable modules. There is also a removable dust cover that fits over the faceplate which must be removed in order to access the keypad panel. The following two figures show the horizontal and vertical arrangement of faceplate panels.

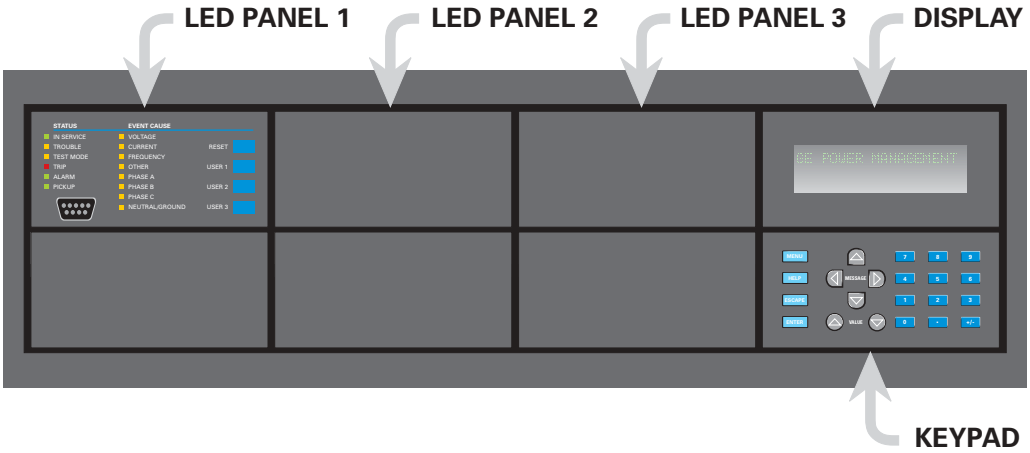


Figure 4–2: UR HORIZONTAL FACEPLATE PANELS

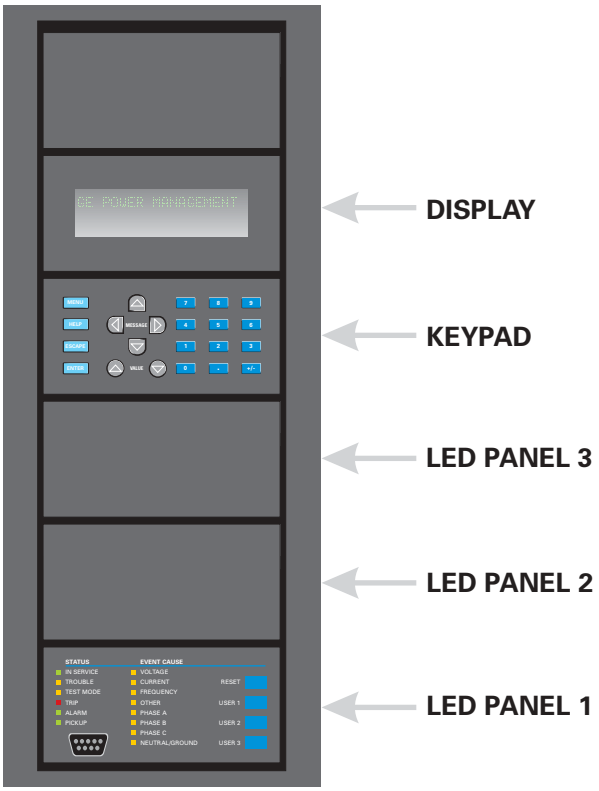


Figure 4–3: UR VERTICAL FACEPLATE PANELS

a) LED PANEL 1

This panel provides several LED indicators, several keys, and a communications port. The RESET key is used to reset any latched LED indicator or target message, once the condition has been cleared (these latched conditions can also be reset via the **SETTINGS** ⇨⇩ **INPUT/OUTPUTS** ⇨⇩ **RESETTING** menu). The USER keys are used by the Breaker Control feature. The RS232 port is intended for connection to a portable PC.

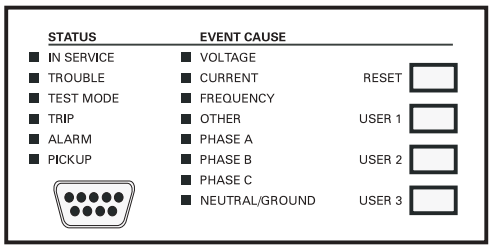


Figure 4–4: LED PANEL 1

STATUS INDICATORS:

- **IN SERVICE**: Indicates that control power is applied; all monitored I/O and internal systems are OK; the relay has been programmed.
- **TROUBLE**: Indicates that the relay has detected an internal problem.
- **TEST MODE**: Indicates that the relay is in test mode.
- **TRIP**: Indicates that the selected FlexLogic™ operand serving as a Trip switch has operated. This indicator always latches; the RESET command must be initiated to allow the latch to be reset.
- **ALARM**: Indicates that the selected FlexLogic™ operand serving as an Alarm switch has operated. This indicator is never latched.
- **PICKUP**: Indicates that an element is picked up. This indicator is never latched.

EVENT CAUSE INDICATORS:

These indicate the input type that was involved in a condition detected by an element that is operated or has a latched flag waiting to be reset.

- **VOLTAGE**: Indicates voltage was involved.
- **CURRENT**: Indicates current was involved.
- **FREQUENCY**: Indicates frequency was involved.
- **OTHER**: Indicates a composite function was involved.
- **PHASE A**: Indicates Phase A was involved.
- **PHASE B**: Indicates Phase B was involved.
- **PHASE C**: Indicates Phase C was involved.
- **NEUTRAL/GROUND**: Indicates neutral or ground was involved.

b) LED PANELS 2 & 3

These panels provide 48 amber LED indicators whose operation is controlled by the user. Support for applying a customized label beside every LED is provided.

User customization of LED operation is of maximum benefit in installations where languages other than English are used to communicate with operators. Refer to the USER-PROGRAMMABLE LEDs section in Chapter 5 for the settings used to program the operation of the LEDs on these panels.

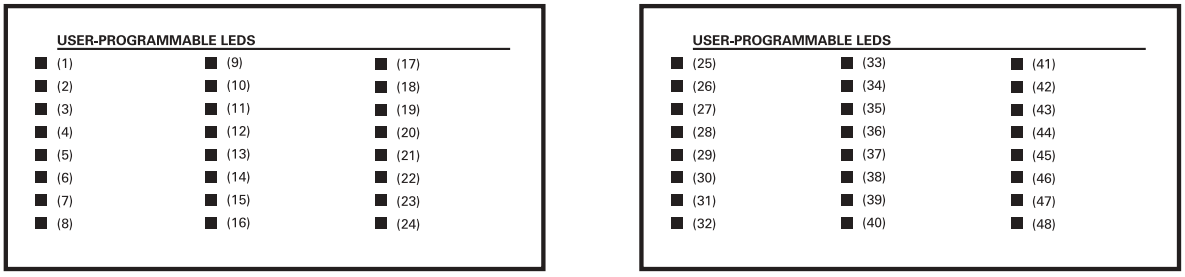


Figure 4–5: LED PANELS 2 AND 3 (INDEX TEMPLATE)

c) DEFAULT LABELS FOR LED PANEL 2

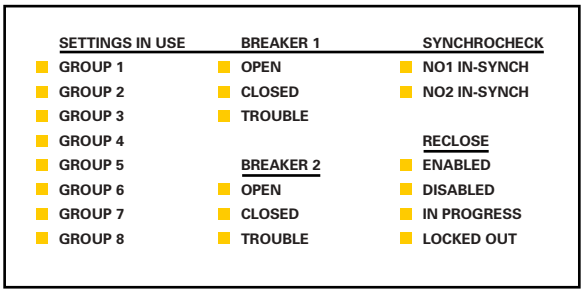


Figure 4–6: LED PANEL 2 (DEFAULT LABEL)

The default labels are meant to represent:

- **GROUP 1...8**: The illuminated GROUP is the active settings group.
- **BREAKER n OPEN**: The breaker is open.
- **BREAKER n CLOSED**: The breaker is closed.
- **BREAKER n TROUBLE**: A problem related to the breaker has been detected.
- **SYNCHROCHECK NO n IN-SYNCH**: Voltages have satisfied the synchrocheck element.
- **RECLOSE ENABLED**: The recloser is operational.
- **RECLOSE DISABLED**: The recloser is not operational.
- **RECLOSE IN PROGRESS**: A reclose operation is in progress.
- **RECLOSE LOCKED OUT**: The recloser is not operational and requires a reset.

The relay is shipped with the default label for the LED panel 2. The LEDs, however, are not pre-programmed. To match the pre-printed label, the LED settings must be entered as shown in the USER-PROGRAMMABLE LEDs section of the SETTINGS chapter in the D60 manual. The LEDs are fully user-programmable. The default labels can be replaced by user-printed labels for both LED panels 2 and 3 as explained in the next section.

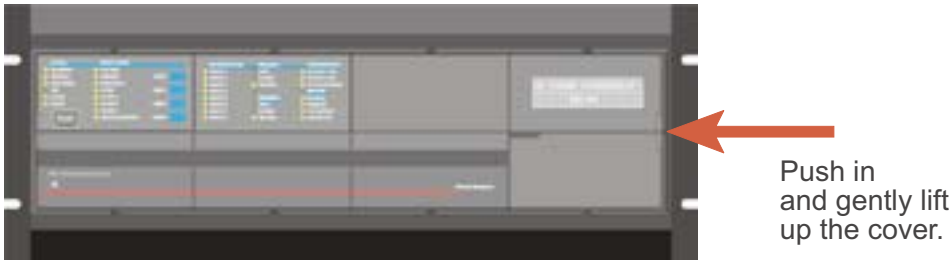
4.2.3 CUSTOM LABELING OF LEDs

Custom labeling of an LED-only panel is facilitated by downloading a 'zip' file from

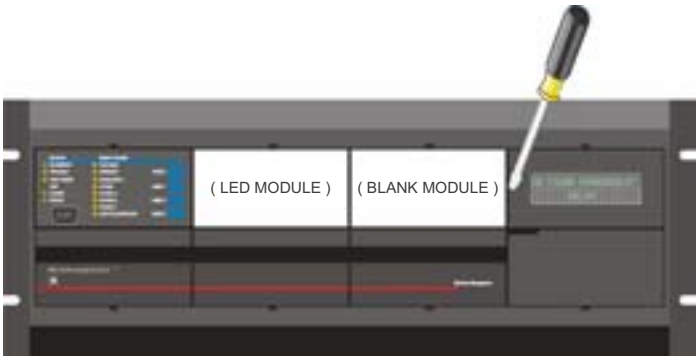
http://www.ge.com/indsys/pm/drawings/ur/custmod.zip.

This file provides templates and instructions for creating appropriate labeling for the LED panel. The following procedures are contained in the downloadable file. The CorelDRAW panel-templates provide relative LED locations and located example-text (x) edit boxes. The following procedure demonstrates how to install/uninstall the custom panel labeling.

1. Remove the clear LEXAN FRONT COVER (P/N: 1501-0014).



2. Pop out the LED MODULE and/or BLANK MODULE with a screwdriver as shown below. Be careful not to damage the plastic.



3. Place the left side of the customized module back to the front panel frame, then snap back the right side.
4. Put the clear LEXAN FRONT COVER back into place.

4.2.4 CUSTOMIZING THE DISPLAY MODULE

The following items are required to customize the UR display module:

- Black and white or color printer (color preferred)
- CorelDRAW version 5.0 or later software
- 1 each of: 8.5 x 11 white paper, exacto knife, ruler, custom display module (P/N: 1516-0069), custom module cover (P/N: 1502-0015)

1. Open the LED panel customization template in CorelDRAW. Add text in places of the Xs on the template(s) with the **Edit > Text** menu command. Delete the X place holders as required.Setup the print copy by selecting the **File > Print** menu command and pressing the "Properties" button.
2. On the **Page Setup** tab, choose **Paper Size**: "Letter" and **Orientation**: "Landscape" and press "OK".
3. Click the "Options" button and select the **Layout** tab.
4. For **Position and Size** enable the "Center image" and "Maintain aspect ratio" check boxes and press "OK", then "OK" once more to print.
5. From the printout, cut-out the BACKGROUND TEMPLATE from the three windows (use the cropmarks as a guide).

6. Put the BACKGROUND TEMPLATE on top of the custom display module (P/N: 1513-0069) and snap the clear cutome module cover (P/N: 1502-0015) over it and the templates.

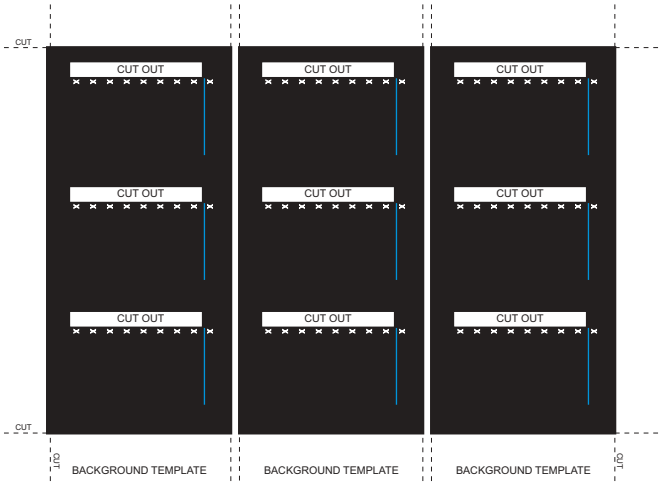


Figure 4–7: LED PANEL CUSTOMIZATION TEMPLATES (EXAMPLE)

4.2.5 DISPLAY

All messages are displayed on a 2 × 20 character vacuum fluorescent display to make them visible under poor lighting conditions. Messages are displayed in English and do not require the aid of an instruction manual for deciphering. While the keypad and display are not actively being used, the display will default to defined messages. Any high priority event driven message will automatically override the default message and appear on the display.

4.2.6 KEYPAD

Display messages are organized into 'pages' under the following headings: Actual Values, Settings, Commands, and Targets. The MENU key navigates through these pages. Each heading page is broken down further into logical subgroups.

The MESSAGE keys navigate through the subgroups. The VALUE keys scroll increment or decrement numerical setting values when in programming mode. These keys also scroll through alphanumeric values in the text edit mode. Alternatively, values may also be entered with the numeric keypad.

The . key initiates and advance to the next character in text edit mode or enters a decimal point. The HELP key may be pressed at any time for context sensitive help messages. The ENTER key stores altered setting values.

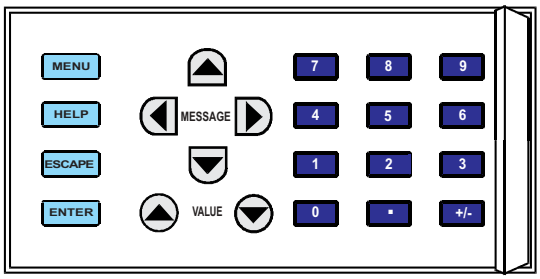


Figure 4–8: KEYPAD

4.2.7 BREAKER CONTROL

The L90 can interface with associated circuit breakers. In many cases the application monitors the state of the breaker, which can be presented on faceplate LEDs, along with a breaker trouble indication. Breaker operations can be manually initiated from faceplate keypad or automatically initiated from a FlexLogic™ operand. A setting is provided to assign names to each breaker; this user-assigned name is used for the display of related flash messages. These features are provided for two breakers; the user may use only those portions of the design relevant to a single breaker, which must be breaker No. 1.

For the following discussion it is assumed the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER n ⇨ BREAKER FUNCTION** setting is "Enabled" for each breaker.

a) CONTROL MODE SELECTION & MONITORING

Installations may require that a breaker is operated in the three-pole only mode (3-Pole), or in the one and three-pole (1-Pole) mode, selected by setting. If the mode is selected as 3-pole, a single input tracks the breaker open or closed position. If the mode is selected as 1-Pole, all three breaker pole states must be input to the relay. These inputs must be in agreement to indicate the position of the breaker.

For the following discussion it is assumed the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER n ⇨⇩ BREAKER PUSH BUTTON CONTROL** setting is "Enabled" for each breaker..

b) FACEPLATE PUSHBUTTON (USER KEY) CONTROL

After the 30 minute interval during which command functions are permitted after a correct command password, the user cannot open or close a breaker via the keypad. The following discussions begin from the not-permitted state.

c) CONTROL OF TWO BREAKERS

For the following example setup, the symbol "(Name)" represents the user-programmed variable name.

For this application (setup shown below), the relay is connected and programmed for both breaker No. 1 and breaker No. 2. The USER 1 key performs the selection of which breaker is to be operated by the USER 2 and USER 3 keys. The USER 2 key is used to manually close the breaker and the USER 3 key is used to manually open the breaker.

`ENTER COMMAND PASSWORD`	This message appears when the USER 1, USER 2, or USER 3 key is pressed and a **COMMAND PASSWORD** is required; i.e. if **COMMAND PASSWORD** is enabled and no commands have been issued within the last 30 minutes.
`Press USER 1 To Select Breaker`	This message appears if the correct password is entered or if none is required. This message will be maintained for 30 seconds or until the USER 1 key is pressed again.
`BKR1-(Name) SELECTED USER 2=CLS/USER 3=OP`	This message is displayed after the USER 1 key is pressed for the second time. Three possible actions can be performed from this state within 30 seconds as per items **(1)**, **(2)** and **(3)** below:
(1)	
`USER 2 OFF/ON To Close BKR1-(Name)`	If the USER 2 key is pressed, this message appears for 20 seconds. If the USER 2 key is pressed again within that time, a signal is created that can be programmed to operate an output relay to close breaker No. 1.
(2)	
`USER 3 OFF/ON To Open BKR1-(Name)`	If the USER 3 key is pressed, this message appears for 20 seconds. If the USER 3 key is pressed again within that time, a signal is created that can be programmed to operate an output relay to open breaker No. 1.
(3)	
`BKR2-(Name) SELECTED USER 2=CLS/USER 3=OP`	If the USER 1 key is pressed at this step, this message appears showing that a different breaker is selected. Three possible actions can be performed from this state as per **(1)**, **(2)** and **(3)**. Repeatedly pressing the USER 1 key alternates between available breakers. Pressing keys other than USER 1, 2 or 3 at any time aborts the breaker control function.

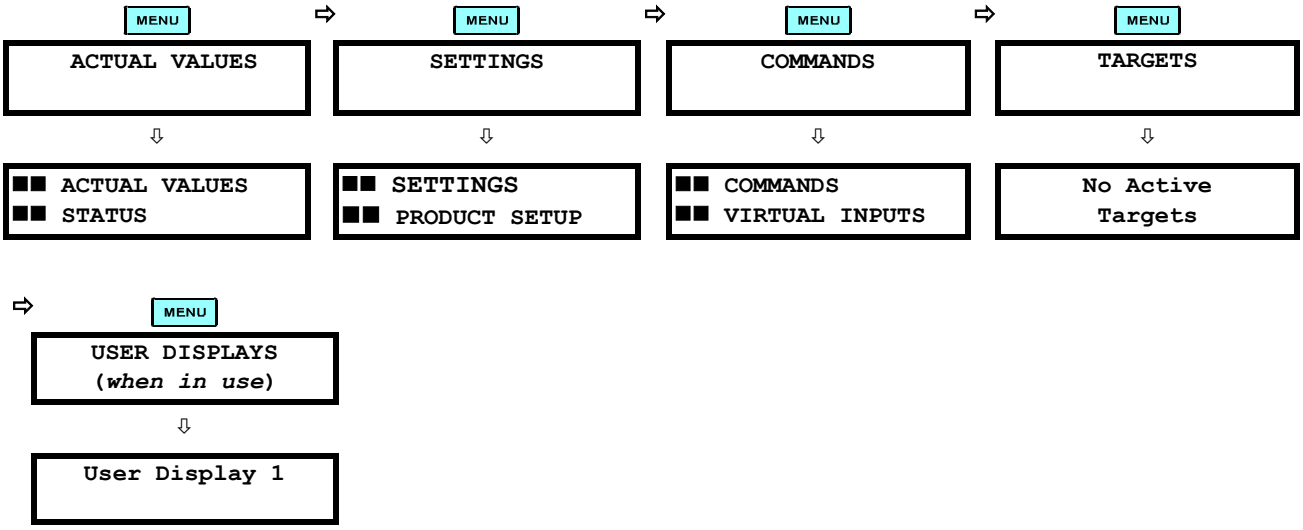
d) CONTROL OF ONE BREAKER

For this application the relay is connected and programmed for breaker No. 1 only. Operation for this application is identical to that described for two breakers.

4.2.8 MENUS

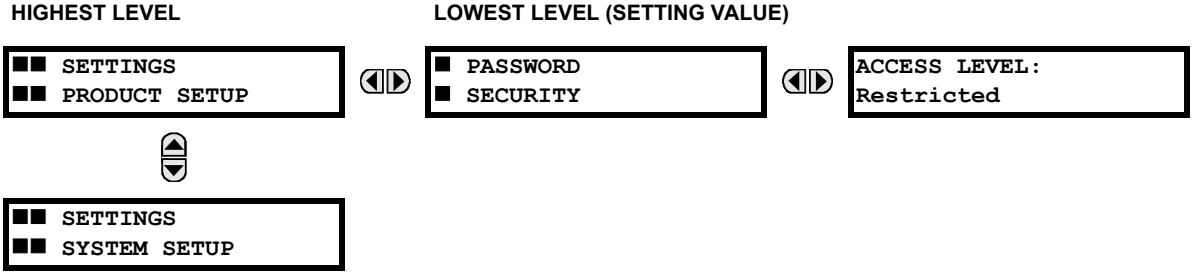
a) NAVIGATION

Press the MENU key to select the desired header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the MENU key advances through the main heading pages as illustrated below.



b) HIERARCHY

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bar characters (■■), while sub-header pages are indicated by single scroll bar characters (■). The header display pages represent the highest level of the hierarchy and the sub-header display pages fall below this level. The MESSAGE ▲ and ▼ keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the MESSAGE ► key from a header display displays specific information for the header category. Conversely, continually pressing the ◄ MESSAGE key from a setting value or actual value display returns to the header display.



c) EXAMPLE NAVIGATION

```
■■ ACTUAL VALUES
■■ STATUS
```

Press the MENU key until the header for the first Actual Values page appears. This page contains system and relay status information. Repeatedly press the ⏶ ⏴ MESSAGE ⏵ ⏷ keys to display the other actual value headers.

⇩

```
■■ SETTINGS
■■ PRODUCT SETUP
```

Press the MENU key until the header for the first page of Settings appears. This page contains settings to configure the relay.

⇩

```
■■ SETTINGS
■■ SYSTEM SETUP
```

Press the MESSAGE ⏷ key to move to the next Settings page. This page contains settings for system setup. Repeatedly press the ⏶ MESSAGE ⏷ keys to display the other setting headers and then back to the first Settings page header.

⇩

```
■ PASSWORD
■ SECURITY
```

From the Settings page one header (Product Setup), press the MESSAGE ⏵ key once to display the first sub-header (Password Security).

⇩

```
ACCESS LEVEL:
Restricted
```

Press the MESSAGE ⏵ key once more and this will display the first setting for Password Security. Pressing the MESSAGE ⏷ key repeatedly will display the remaining setting messages for this sub-header.

⇩

```
■ PASSWORD
■ SECURITY
```

Press the MESSAGE ⏴ key once to move back to the first sub-header message.

⇩

```
■ DISPLAY
■ PROPERTIES
```

Pressing the MESSAGE ⏷ key will display the second setting sub-header associated with the Product Setup header.

⇩

```
FLASH MESSAGE
TIME: 1.0 s
```

Press the MESSAGE ⏵ key once more and this will display the first setting for Display Properties.

⇩

```
DEFAULT MESSAGE
INTENSITY: 25%
```

To view the remaining settings associated with the Display Properties subheader, repeatedly press the MESSAGE ⏷ key. The last message appears as shown.

4.2.9 CHANGING SETTINGS

a) ENTERING NUMERICAL DATA

Each numerical setting has its own minimum, maximum, and increment value associated with it. These parameters define what values are acceptable for a setting.

```
FLASH MESSAGE
TIME:  1.0 s
```

For example, select the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨ FLASH MESSAGE TIME** setting.

⇩

```
MINIMUM:   0.5
MAXIMUM:  10.0
```

Press the HELP key to view the minimum and maximum values. Press the HELP key again to view the next context sensitive help message.

Two methods of editing and storing a numerical setting value are available.

- **0 to 9** and ▪ (decimal point): The relay numeric keypad works the same as that of any electronic calculator. A number is entered one digit at a time. The leftmost digit is entered first and the rightmost digit is entered last. Pressing the MESSAGE ⏴ key or pressing the ESCAPE key, returns the original value to the display.
- ⏶ **VALUE** ⏷: The VALUE ⏶ key increments the displayed value by the step value, up to the maximum value allowed. While at the maximum value, pressing the VALUE ⏶ key again will allow the setting selection to continue upward from the minimum value. The VALUE ⏷ key decrements the displayed value by the step value, down to the

minimum value. While at the minimum value, pressing the VALUE ⏷ key again will allow the setting selection to continue downward from the maximum value.

```
FLASH MESSAGE
TIME:  2.5 s
```

⇩

```
NEW SETTING
HAS BEEN STORED
```

As an example, set the flash message time setting to 2.5 seconds. Press the appropriate numeric keys in the sequence "2 . 5". The display message will change as the digits are being entered.

Until the ENTER key is pressed, editing changes are not registered by the relay. Therefore, press the ENTER key to store the new value in memory. This flash message will momentarily appear as confirmation of the storing process. Numerical values which contain decimal places will be rounded-off if more decimal place digits are entered than specified by the step value.

b) ENTERING ENUMERATION DATA

Enumeration settings have data values which are part of a set, whose members are explicitly defined by a name. A set is comprised of two or more members.


```
ACCESS LEVEL:
Restricted
```

For example, the selections available for **ACCESS LEVEL** are "Restricted", "Command", "Setting", and "Factory Service".

Enumeration type values are changed using the ⏶ VALUE ⏷ keys. The VALUE ⏶ key displays the next selection while the VALUE ⏷ key displays the previous selection.

```
ACCESS LEVEL:
Setting
```

If the **ACCESS LEVEL** needs to be "Setting", press the ⏶ VALUE ⏷ keys until the proper selection is displayed. Press the HELP key at any time for the context sensitive help messages.

⇩

```
NEW SETTING
HAS BEEN STORED
```

Changes are not registered by the relay until the ENTER key is pressed. Pressing ENTER stores the new value in memory. This flash message momentarily appears as confirmation of the storing process.

c) ENTERING ALPHANUMERIC TEXT

Text settings have data values which are fixed in length, but user-defined in character. They may be comprised of upper case letters, lower case letters, numerals, and a selection of special characters.

In order to allow the relay to be customized for specific applications, there are several places where text messages may be programmed. One example is the MESSAGE SCRATCHPAD. To enter alphanumeric text messages, the following procedure should be followed:

Example: to enter the text, “Breaker #1”

1. Press ▪ to enter text edit mode.
2. Press the VALUE ⏶ or VALUE ⏷ key until the character 'B' appears; press ▪ to advance the cursor to the next position.
3. Repeat step 2 for the remaining characters: r,e,a,k,e,r, ,#,1.
4. Press ENTER to store the text.
5. If you have any problem, press the HELP key to view the context sensitive help. Flash messages will sequentially appear for several seconds each. For the case of a text setting message, the HELP key displays how to edit and store a new value.

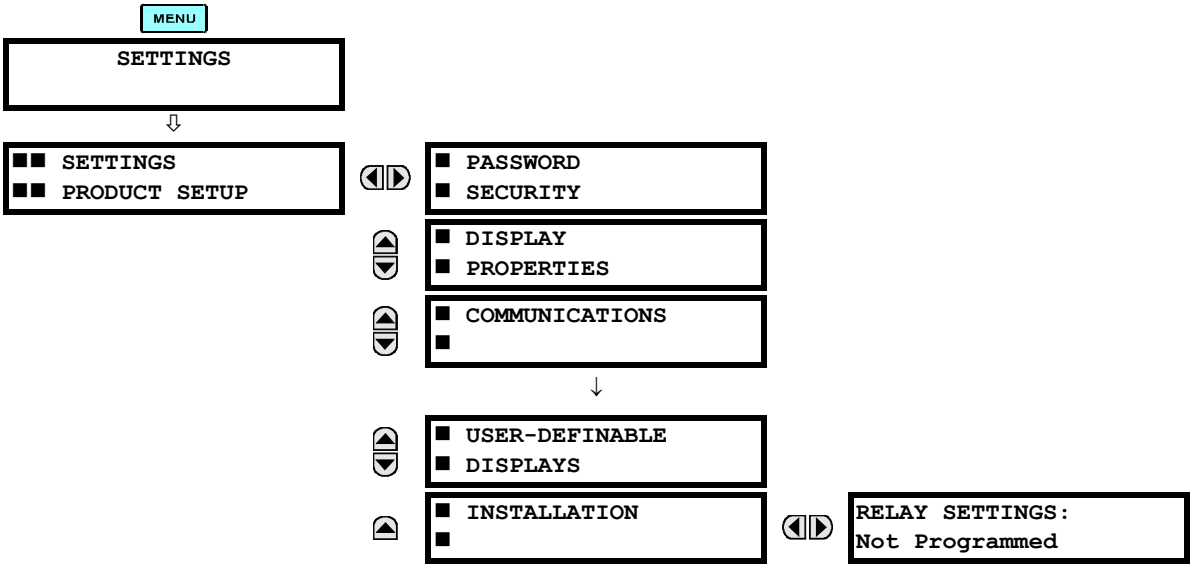
d) ACTIVATING THE RELAY

RELAY SETTINGS: Not Programmed

When the relay is powered up, the TROUBLE indicator will be on, the IN SERVICE indicator off, and this message displayed. This indicates that the relay is in the "Not Programmed" state and is safeguarding (output relays blocked) against the installation of a relay whose settings have not been entered. This message will remain until the relay is explicitly put in the "Programmed" state.

To change the **RELAY SETTINGS:** "Not Programmed" mode to "Programmed", proceed as follows:

1. Press the MENU key until the **SETTINGS** header flashes momentarily and the **SETTINGS PRODUCT SETUP** message appears on the display.
2. Press the MESSAGE ▶ key until the **PASSWORD SECURITY** message appears on the display.
3. Press the MESSAGE ▼ key until the **INSTALLATION** message appears on the display.
4. Press the MESSAGE ▶ key until the **RELAY SETTINGS: Not Programmed** message is displayed.



5. After the **RELAY SETTINGS: Not Programmed** message appears on the display, press the VALUE ▲ key or the VALUE ▼ key to change the selection to "Programmed".
6. Press the ENTER key.

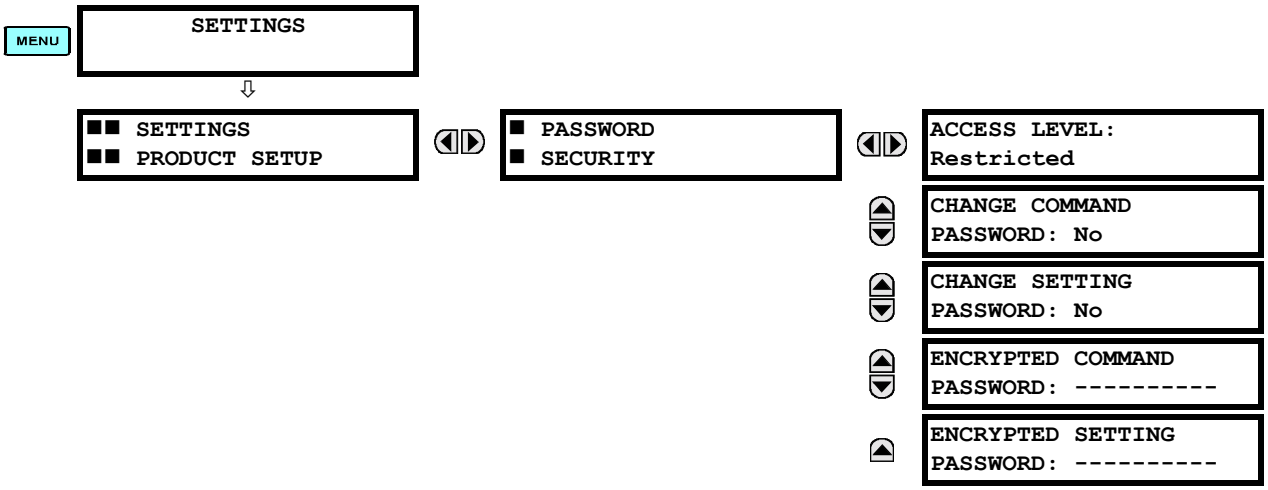
7. When the "NEW SETTING HAS BEEN STORED" message appears, the relay will be in "Programmed" state and the IN SERVICE indicator will turn on.

e) ENTERING INITIAL PASSWORDS

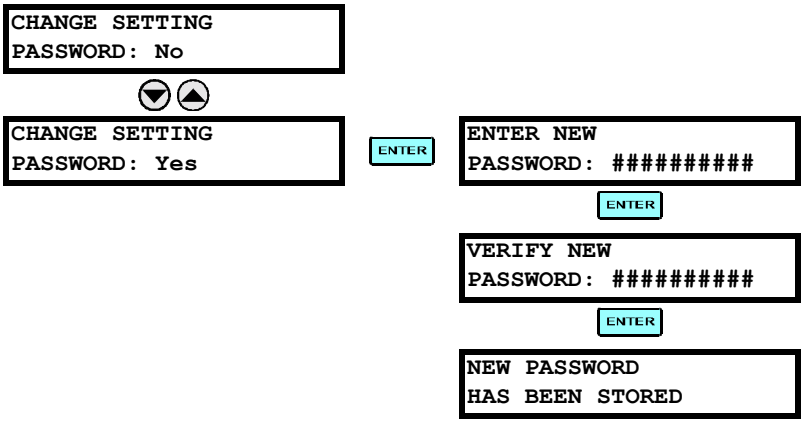
To enter the initial SETTING (or COMMAND) PASSWORD, proceed as follows:

1. Press the MENU key until the 'SETTINGS' header flashes momentarily and the 'SETTINGS PRODUCT SETUP' message appears on the display.
2. Press the MESSAGE ▶ key until the 'ACCESS LEVEL:' message appears on the display.

3. Press the MESSAGE key until the 'CHANGE SETTING (or COMMAND) PASSWORD:' message appears on the display.



4. After the 'CHANGE...PASSWORD' message appears on the display, press the VALUE key or the VALUE key to change the selection to Yes.
5. Press the ENTER key and the display will prompt you to 'ENTER NEW PASSWORD'.
6. Type in a numerical password (up to 10 characters) and press the ENTER key.
7. When the 'VERIFY NEW PASSWORD' is displayed, re-type in the same password and press ENTER.

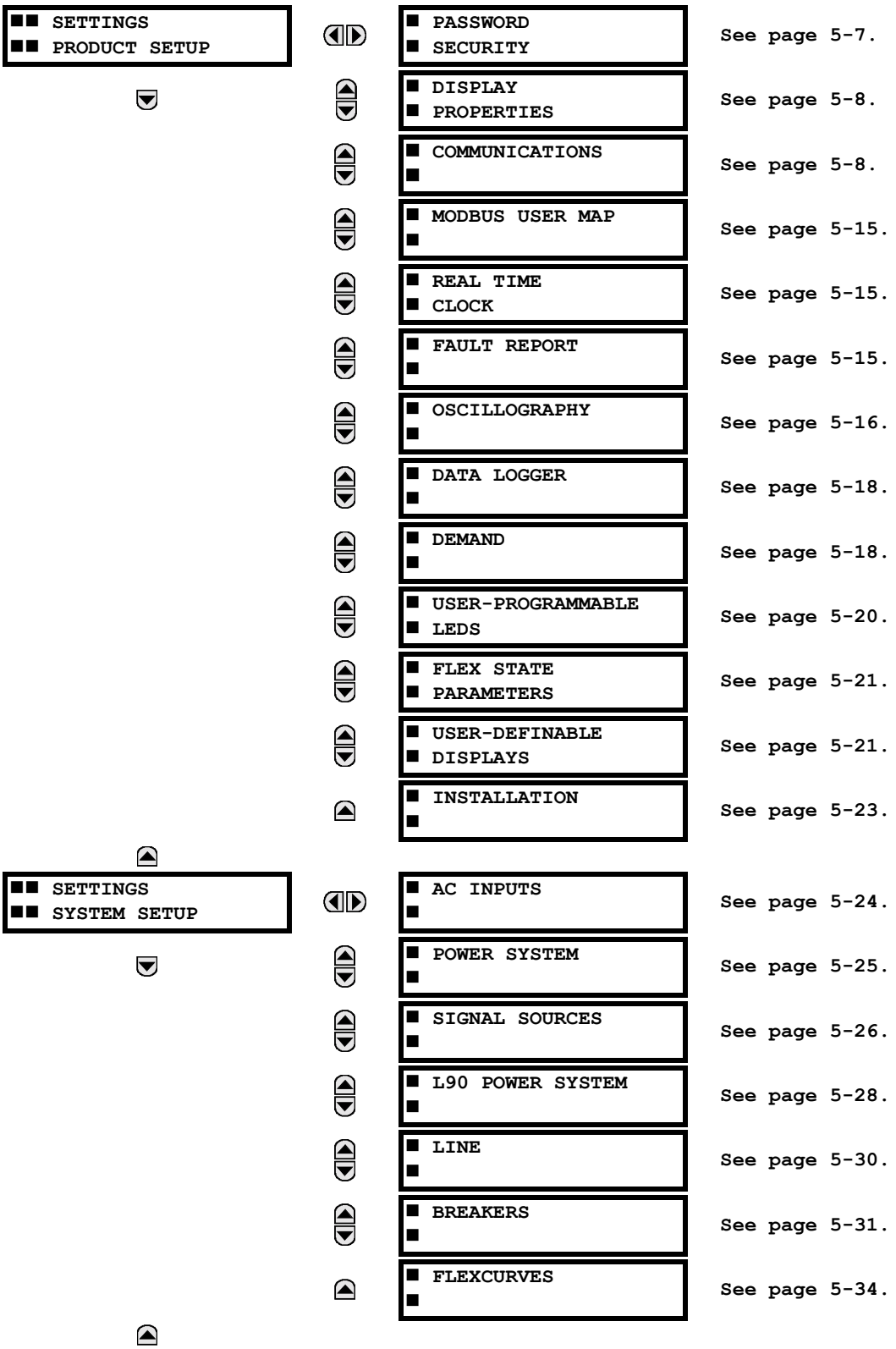


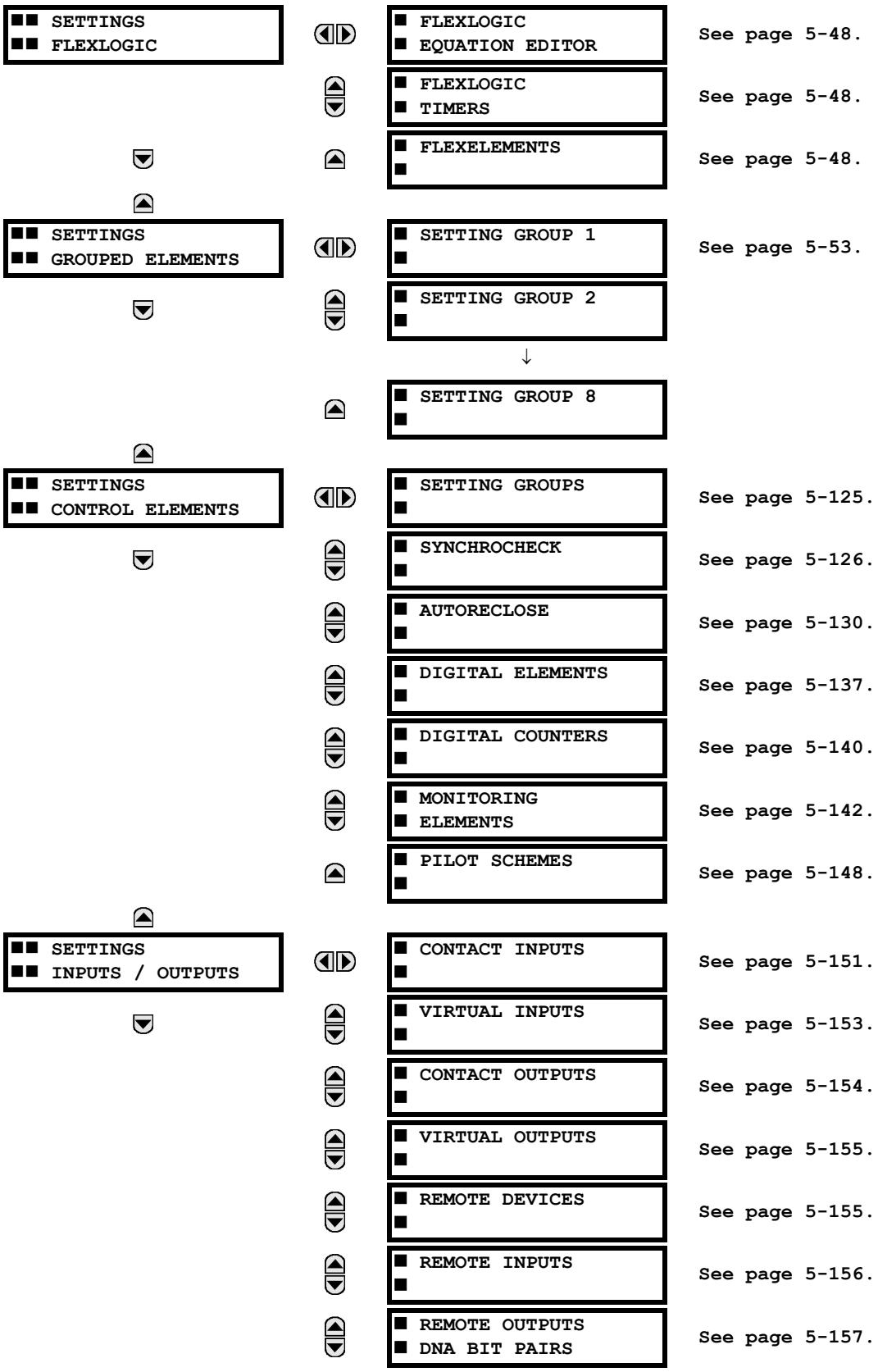
8. When the 'NEW PASSWORD HAS BEEN STORED' message appears, your new SETTING (or COMMAND) PASSWORD will be active.

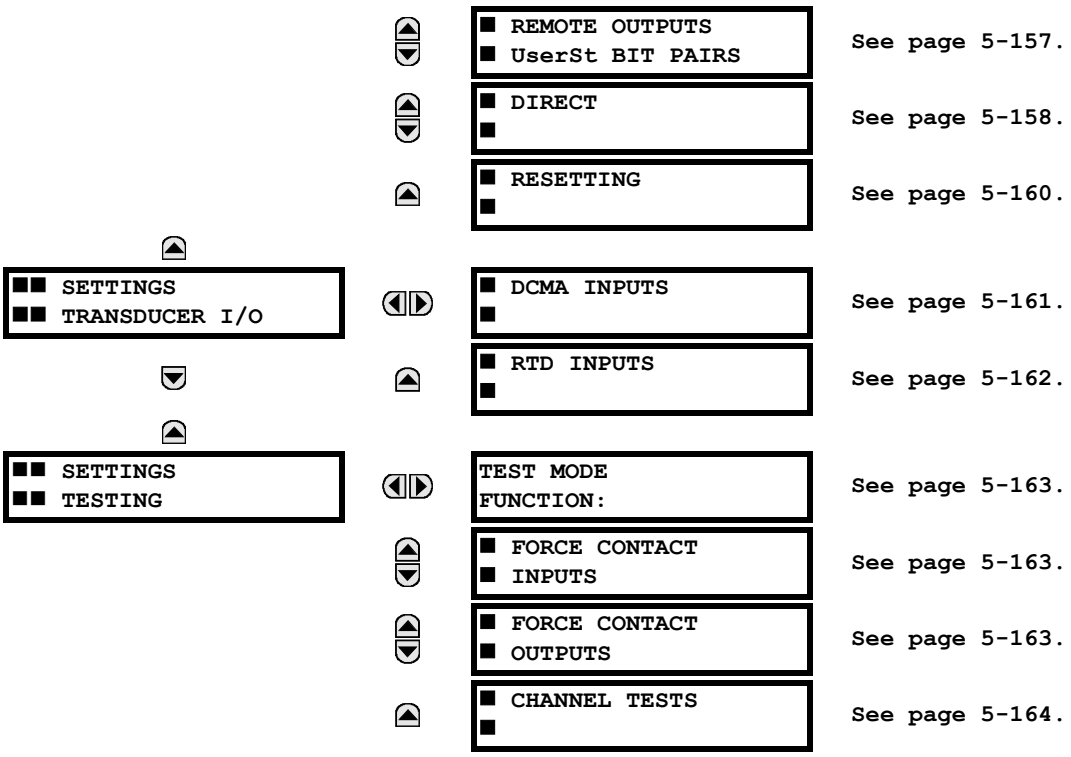
f) CHANGING EXISTING PASSWORD

To change an existing password, follow the instructions in the previous section with the following exception. A message will prompt you to type in the existing password (for each security level) before a new password can be entered.

In the event that a password has been lost (forgotten), submit the corresponding Encrypted Password from the PASSWORD SECURITY menu to the Factory for decoding.


SETTINGS
PRODUCT SETUP
PASSWORD SECURITY
See page 5-7.
DISPLAY PROPERTIES
See page 5-8.
COMMUNICATIONS
See page 5-8.
MODBUS USER MAP
See page 5-15.
REAL TIME CLOCK
See page 5-15.
FAULT REPORT
See page 5-15.
OSCILLOGRAPHY
See page 5-16.
DATA LOGGER
See page 5-18.
DEMAND
See page 5-18.
USER-PROGRAMMABLE LEDS
See page 5-20.
FLEX STATE PARAMETERS
See page 5-21.
USER-DEFINABLE DISPLAYS
See page 5-21.
INSTALLATION
See page 5-23.
SETTINGS
SYSTEM SETUP
AC INPUTS
See page 5-24.
POWER SYSTEM
See page 5-25.
SIGNAL SOURCES
See page 5-26.
L90 POWER SYSTEM
See page 5-28.
LINE
See page 5-30.
BREAKERS
See page 5-31.
FLEXCURVES
See page 5-34.


SETTINGS
FLEXLOGIC
FLEXLOGIC
EQUATION EDITOR
See page 5-48.
FLEXLOGIC
TIMERS
See page 5-48.
FLEXELEMENTS
See page 5-48.
SETTINGS
GROUPED ELEMENTS
SETTING GROUP 1
See page 5-53.
SETTING GROUP 2
SETTING GROUP 8
SETTINGS
CONTROL ELEMENTS
SETTING GROUPS
See page 5-125.
SYNCHROCHECK
See page 5-126.
AUTORECLOSE
See page 5-130.
DIGITAL ELEMENTS
See page 5-137.
DIGITAL COUNTERS
See page 5-140.
MONITORING
ELEMENTS
See page 5-142.
PILOT SCHEMES
See page 5-148.
SETTINGS
INPUTS / OUTPUTS
CONTACT INPUTS
See page 5-151.
VIRTUAL INPUTS
See page 5-153.
CONTACT OUTPUTS
See page 5-154.
VIRTUAL OUTPUTS
See page 5-155.
REMOTE DEVICES
See page 5-155.
REMOTE INPUTS
See page 5-156.
REMOTE OUTPUTS
DNA BIT PAIRS
See page 5-157.



5.1.2 INTRODUCTION TO ELEMENTS

In the design of UR relays, the term “element” is used to describe a feature that is 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.

Elements are arranged into two classes, GROUPED and CONTROL. Each element classed as a GROUPED element is provided with eight alternate sets of settings, in setting groups numbered 1 through 8. 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 scheme logic diagram. This includes the input(s), settings, fixed logic, and the output operands that are generated (abbreviations used on scheme logic diagrams are defined in Appendix F).

Some settings for current and voltage elements are specified in per-unit (pu) calculated quantities:

pu quantity = (actual quantity) / (base quantity)

- 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 (i.e. normalized to the larger of the 2 rated CT inputs). For example, if CT1 = 300 / 5 A and CT2 = 100 / 5 A, then in order to sum these, CT2 is scaled to the CT1 ratio. In this case, the ‘base quantity’ will be 5 A secondary or 300 A primary.
- For voltage elements, the ‘base quantity’ is the nominal secondary or primary voltage of the VT.

Some settings are common to most elements and are discussed below:

FUNCTION Setting

This setting programs 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 Setting

This setting is used to uniquely identify the element.

SOURCE Setting

This setting is used to select the parameter or set of parameters to be monitored.

PICKUP Setting

For simple elements, this setting is 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.

TARGET Setting

This setting is used to define the operation of an element target message. When set to Disabled, no target message or illumination of a faceplate LED indicator is issued upon operation of the element. When set to Self-Reset, the target message and LED indication follow the Operate state of the element, and self-resets once the operate element condition clears. When set to Latched, the target message and LED indication will remain visible after the element output returns to logic 0 - until a RESET command is received by the relay.

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, an event is created for:

- (Element) PKP (pickup)
- (Element) DPO (dropout)
- (Element) OP (operate)

The DPO 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 ‘0’.

5.1.3 INTRODUCTION TO AC SOURCES

a) BACKGROUND

The L90 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 required to calculate watts and vars for each of three windings, using voltage from different sets of VTs. All these requirements can be satisfied with a single UR relay, equipped with sufficient CT and VT input channels, by selecting the parameter to be measured. A mechanism is provided to specify the AC parameter (or group of parameters) used as the input to protection/control comparators and some metering elements.

Selection of the parameter(s) to be measured 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 be measured. The user completes the selection process by selecting the instrument transformer input channels to be used 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 currents of phase, 3I_0 and ground current, current from CTs with different ratios are adjusted to a single ratio before the summation.

A mechanism called a "Source" configures the routing of input CT and VT channels to measurement sub-systems. Sources, in the context of the UR family of relays, refer to the logical grouping of current and voltage signals such that one Source contains all of 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 as illustrated in the following figure. In this application, the current flows as shown by the labeled 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 winding 1 of the power transformer 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 same considerations apply to transformer winding 2. The protection elements need access to the net current for the protection of the transformer, but some elements may need access to the individual currents from CT1 and CT2.

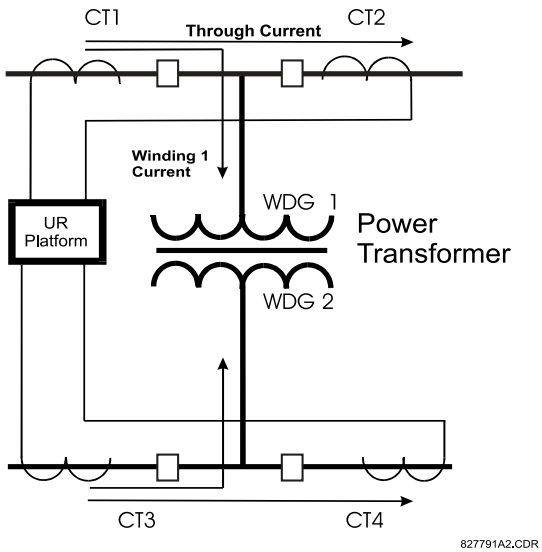


Figure 5–1: BREAKER-AND-A-HALF SCHEME

In conventional analog or electronic relays, the sum of the currents is obtained from an appropriate external connection of all the 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 UR platform, provisions have been included for all the current signals to be brought to the UR 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, as additional information to calculate a restraint current, for example, 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 elements in the UR platform. Individual names can be given to each Source to help identify them more clearly for later use. For example, in the scheme shown in the BREAKER-AND-A-HALF SCHEME above, the user would configure one Source to be the sum of CT1 and CT2 and could name this Source as 'Wdg 1 Current'.

Once the Sources have been configured, the user has them available as selections for the choice of input signal for the protection elements and as metered quantities.

b) CT/VT MODULE CONFIGURATIONS

CT and VT input channels are contained in CT/VT modules in UR products. The type of input channel can be phase/neutral/other voltage, phase/ground current, or sensitive ground current. The CT/VT modules calculate total waveform RMS levels, fundamental frequency phasors, symmetrical components and harmonics for voltage or current, as allowed by the hardware in each channel. These modules may calculate other parameters as directed by the CPU module.

A CT/VT module can contain up to eight input channels numbered 1 through 8. The numbering of channels in a CT/VT module corresponds to the module terminal numbering of 1 through 8 and is arranged as follows; channels 1, 2, 3 and 4 are always provided as a group, hereafter called a "bank," and all four are either current or voltage, as are channels 5, 6, 7 and 8. Channels 1, 2, 3 and 5, 6, 7 are arranged as phase A, B and C respectively. Channels 4 and 8 are either another current or voltage.

Banks are ordered sequentially from the block of lower-numbered channels to the block of higher-numbered channels, and from the CT/VT module with the lowest slot position letter to the module with the highest slot position letter, as follows:

INCREASING SLOT POSITION LETTER -->		
CT/VT MODULE 1	**CT/VT MODULE 2**	**CT/VT MODULE 3**
< bank 1 >	< bank 3 >	< bank 5 >
< bank 2 >	< bank 4 >	< bank 6 >

The UR platform allows for a maximum of three sets of three-phase voltages and six sets of three-phase currents. The result of these restrictions leads to the maximum number of CT/VT modules in a chassis to three. The maximum number of Sources is six. A summary of CT/VT module configurations is shown below.

ITEM	MAXIMUM NUMBER
CT/VT Module	3
CT Bank (3 phase channels, 1 ground channel)	6
VT Bank (3 phase channels, 1 auxiliary channel)	3

c) CT/VT INPUT CHANNEL CONFIGURATION SETTINGS

Upon startup of the relay, configuration settings for every bank of current or voltage input channels in the relay are automatically generated, as determined from the order code. Within each bank, a channel identification label is automatically assigned to each bank of channels in a given product. The ‘bank’ naming convention is based on the physical location of the channels, required by the user to know how to connect the relay to external circuits. Bank identification consists of the letter designation of the slot in which the CT/VT module is mounted as the first character, followed by numbers indicating the channel, either 1 or 5.

For three-phase channel sets, the number of the lowest numbered channel identifies the set. For example, F1 represents the three-phase channel set of F1/F2/F3, where F is the slot letter and 1 is the first channel of the set of three channels.

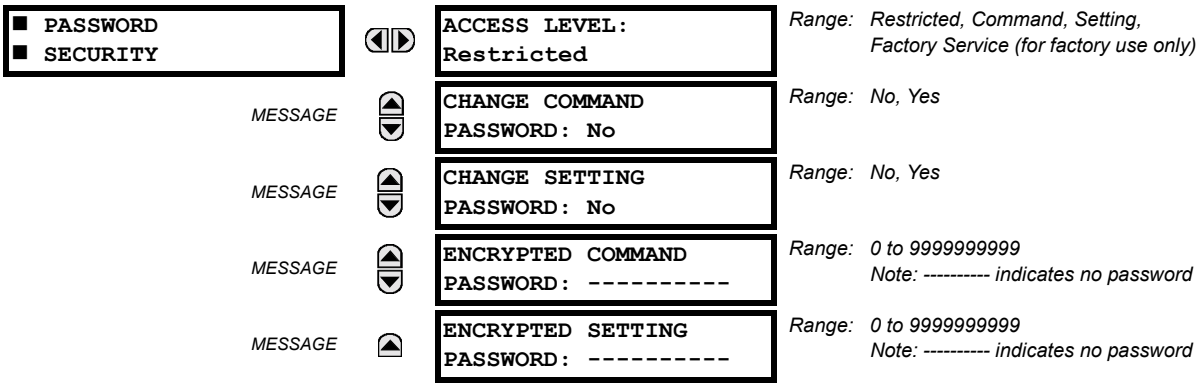
Upon startup, the CPU configures the settings required to characterize the current and voltage inputs, and will display them in the appropriate section in the sequence of the banks (as described above) as shown below for a maximum configuration:

F1, F5, L1, L5, S1, S5

The above 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 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.

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ PASSWORD SECURITY



The L90 provides two user levels of password security: Command and Setting. Operations under password supervision are as follows:

COMMAND:

- Operating the breakers via faceplate keypad
- Changing the state of virtual inputs
- Clearing the event records
- Clearing the oscillography records

SETTING:

- Changing any setting.

The Command and Setting passwords are defaulted to "Null" when the relay is shipped from the factory. When a password is set to "Null", the password security feature is disabled.

Programming a password code is required to enable each access level. A password consists of 1 to 10 numerical characters. When a **CHANGE ... PASSWORD** setting is set to "Yes", the following message sequence is invoked:

1. ENTER NEW PASSWORD: _____
2. VERIFY NEW PASSWORD: _____
3. NEW PASSWORD HAS BEEN STORED

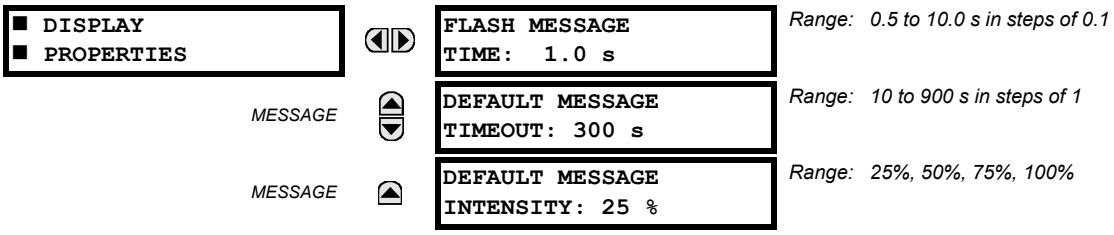
To gain write access to a "Restricted" setting, set **ACCESS LEVEL** to "Setting" and then change the setting, or attempt to change the setting and follow the prompt to enter the programmed password. If the password is correctly entered, access will be allowed. If no keys are pressed for longer than 30 minutes or control power is cycled, accessibility will automatically revert to the "Restricted" level.

If an entered password is lost (or forgotten), consult the factory service department with the corresponding **ENCRYPTED PASSWORD**.

NOTE **If the SETTING password and COMMAND password are set the same, the one password will allow access to commands and settings.**

5.2.2 DISPLAY PROPERTIES

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES



Some relay messaging characteristics can be modified to suit different situations using the display properties settings.

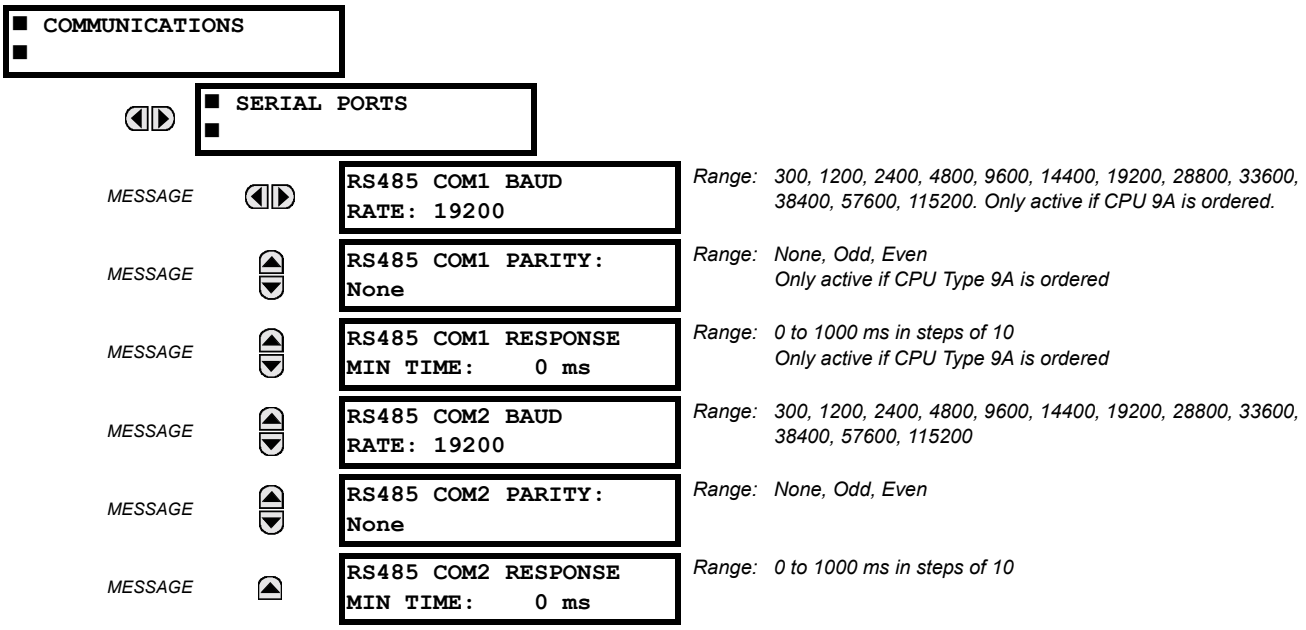
Flash messages are status, warning, error, or information messages displayed for several seconds in response to certain key presses during setting programming. These messages override any normal messages. The time a flash message remains on the display can be changed to accommodate different reading rates. If no keys are pressed for a period of time, the relay automatically displays a default message. This time can be modified to ensure messages remain on the screen long enough during programming or reading of actual values.

To extend the life of the phosphor in the vacuum fluorescent display, the brightness can be attenuated when displaying default messages. When interacting with the display using the keypad, the display always operates at full brightness.

5.2.3 COMMUNICATIONS

a) SERIAL PORTS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨ SERIAL PORTS



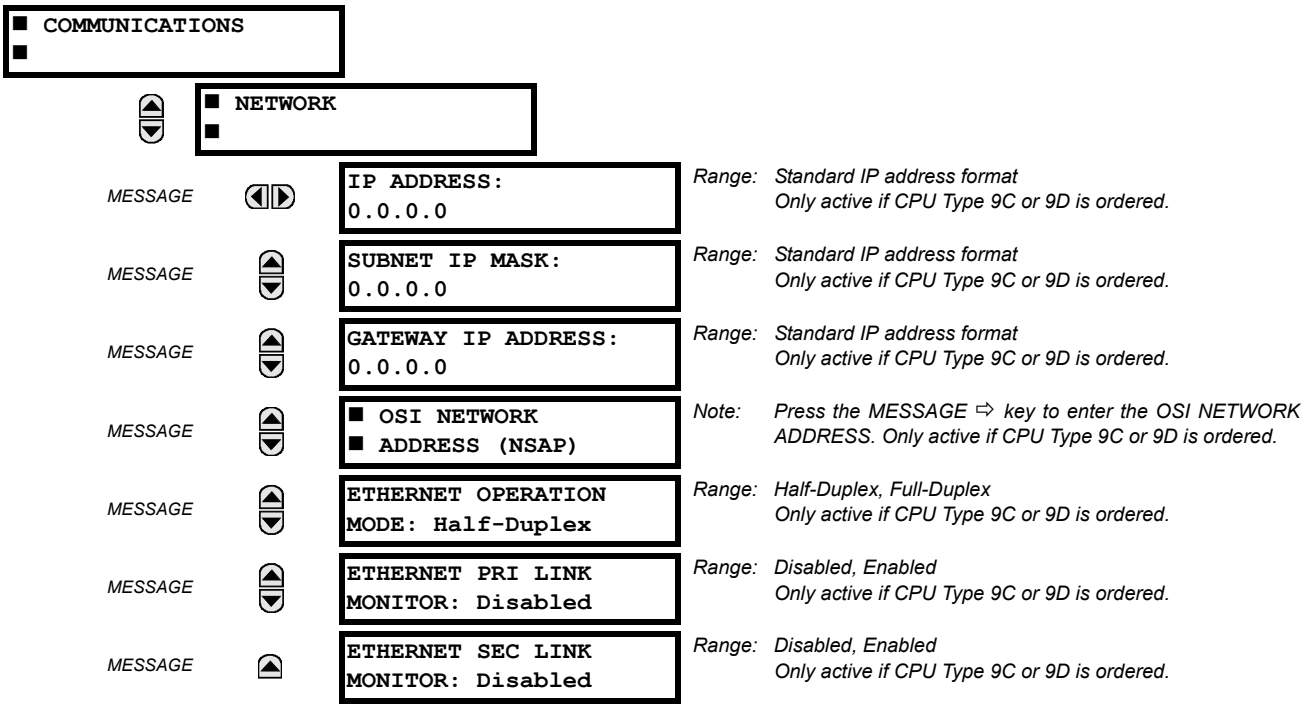
The L90 is equipped with up to 3 independent serial communication ports. The faceplate RS232 port is intended for local use and has fixed parameters of 19200 baud and no parity. The rear COM1 port type will depend on the CPU ordered: it may be either an Ethernet or an RS485 port. The rear COM2 port is RS485. The RS485 ports have 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. Any of these ports may be connected to a personal computer running URPC. This software is used for downloading or uploading setting files, viewing measured parameters, and upgrading the relay firmware to the latest version. A maximum of 32 relays can be daisy-chained and connected to a DCS, PLC or PC using the RS485 ports.

NOTE

For each RS485 port, the minimum time before the port will transmit after receiving data from a host can be set. This feature allows operation with hosts which hold the RS485 transmitter active for some time after each transmission.

b) NETWORK

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK



The Network setting messages will appear only if the UR is ordered with an Ethernet card. The Ethernet Primary and Secondary Link Monitor settings allow internal self test targets to be triggered when either the Primary or Secondary ethernet fibre link status indicates a connection loss. The IP addresses are used with DNP/Network, Modbus/TCP, MMS/UCA2, IEC 60870-5-104, TFTP, and HTTP (web server) protocols. The NSAP address is used with the MMS/UCA2 protocol over the OSI (CLNP/TP4) stack only. Each network protocol has a setting for the **TCP/UDP PORT NUMBER**. These settings are used only in advanced network configurations. They should normally be left at their default values, but may be changed if required; for example, to allow access to multiple URs behind a router. By setting a different TCP/UCP Port Number for a given protocol on each UR, the router can map the URs to the same external IP address. The client software (URPC, for example) must be configured to use the correct port number if these settings are used.

WARNING

Do not set more than one protocol to use the same TCP/UDP Port Number, as this will result in unreliable operation of those protocols.

NOTE

When the NSAP address, any TCP/UDP Port Number, 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/ON).

c) MODBUS PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ MODBUS PROTOCOL

```
■ COMMUNICATIONS
■
```

```
■ MODBUS PROTOCOL
■
```

MESSAGE

```
MODBUS SLAVE
ADDRESS: 254
```

Range: 1 to 254 in steps of 1

MESSAGE

```
MODBUS TCP PORT
NUMBER:   502
```

Range: 1 to 65535 in steps of 1

The serial communication ports utilize the Modbus protocol, unless configured for DNP operation (see DNP PROTOCOL below). This allows the URPC program to be used. UR relays operate as Modbus slave devices only. When using Modbus protocol on the RS232 port, the L90 will respond regardless of the **MODBUS SLAVE ADDRESS** programmed. For the RS485 ports each L90 must have a unique address from 1 to 254. Address 0 is the broadcast address which all Modbus slave devices listen to. 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. Refer to Appendix B for more information on the Modbus protocol.

d) DNP PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL


```
■ COMMUNICATIONS
■
```

```
■ DNP PROTOCOL
■
```

MESSAGE

```
DNP PORT:
NONE
```

Range: NONE, COM1 - RS485, COM2 - RS485, FRONT PANEL - RS232, NETWORK

MESSAGE

```
DNP ADDRESS:
  255
```

Range: 0 to 65519 in steps of 1

MESSAGE

```
■ DNP NETWORK
■ CLIENT ADDRESSES
```

Note: Press the MESSAGE ⇨ key to enter the DNP NETWORK CLIENT ADDRESSES

MESSAGE

```
DNP TCP/UDP PORT
NUMBER: 20000
```

Range: 1 to 65535 in steps of 1

MESSAGE

```
DNP UNSOL RESPONSE
FUNCTION: Disabled
```

Range: Enabled, Disabled

MESSAGE

```
DNP UNSOL RESPONSE
TIMEOUT: 5 s
```

Range: 0 to 60 s in steps of 1

MESSAGE

```
DNP UNSOL RESPONSE
MAX RETRIES: 10
```

Range: 1 to 255 in steps of 1

MESSAGE

```
DNP UNSOL RESPONSE
DEST ADDRESS: 1
```

Range: 0 to 65519 in steps of 1

MESSAGE

```
USER MAP FOR DNP
ANALOGS: Disabled
```

Range: Enabled, Disabled

MESSAGE

```
NUMBER OF SOURCES
IN ANALOG LIST: 1
```

Range: 1 to 6 in steps of 1

MESSAGE
DNP CURRENT SCALE FACTOR: 1
Range: 0.01. 0.1, 1, 10, 100, 1000

MESSAGE
DNP VOLTAGE SCALE FACTOR: 1
Range: 0.01. 0.1, 1, 10, 100, 1000

MESSAGE
DNP CURRENT SCALE FACTOR: 1
Range: 0.01. 0.1, 1, 10, 100, 1000

MESSAGE
DNP POWER SCALE FACTOR: 1
Range: 0.01. 0.1, 1, 10, 100, 1000

MESSAGE
DNP ENERGY SCALE FACTOR: 1
Range: 0.01. 0.1, 1, 10, 100, 1000

MESSAGE
DNP OTHER SCALE FACTOR: 1
Range: 0.01. 0.1, 1, 10, 100, 1000

MESSAGE
DNP CURRENT DEFAULT DEADBAND: 30000
Range: 0 to 65535 in steps of 1

MESSAGE
DNP VOLTAGE DEFAULT DEADBAND: 30000
Range: 0 to 65535 in steps of 1

MESSAGE
DNP POWER DEFAULT DEADBAND: 30000
Range: 0 to 65535 in steps of 1

MESSAGE
DNP ENERGY DEFAULT DEADBAND: 30000
Range: 0 to 65535 in steps of 1

MESSAGE
DNP OTHER DEFAULT DEADBAND: 30000
Range: 0 to 65535 in steps of 1

MESSAGE
DNP TIME SYNC IIN PERIOD: 1440 min
Range: 1 to 10080 min. in steps of 1

MESSAGE
DNP MESSAGE FRAGMENT SIZE: 240
Range: 30 to 2048 in steps of 1

MESSAGE
■ DNP BINARY INPUTS
■ USER MAP

The L90 supports the Distributed Network Protocol (DNP) version 3.0. The L90 can be used as a DNP slave device connected to a single DNP master (usually either an RTU or a SCADA master station). Since the L90 maintains one set of DNP data change buffers and connection information, only one DNP master should actively communicate with the L90 at one time. The DNP PORT setting is used to select the communications port assigned to the DNP protocol. DNP can be assigned to a single port only. Once DNP is assigned to a serial port, the Modbus protocol is disabled on that port. Note that COM1 can be used only in non-ethernet UR relays. When this setting is set to NETWORK, the DNP protocol can be used over either TCP/IP or UDP/IP. Refer to Appendix E for more information on the DNP protocol.

The **DNP ADDRESS** setting is the DNP slave address. This number identifies the L90 on a DNP communications link. Each DNP slave should be assigned a unique address.

The **DNP NETWORK CLIENT ADDRESS** settings can force the L90 to respond to a maximum of five specific DNP masters.

The **DNP UNSOL RESPONSE FUNCTION** should be set to "Disabled" for RS485 applications since there is no collision avoidance mechanism.

The **DNP UNSOL RESPONSE TIMEOUT** sets the time the L90 waits for a DNP master to confirm an unsolicited response.

The **DNP UNSOL RESPONSE MAX RETRIES** setting determines the number of times the L90 will retransmit an unsolicited response without receiving a confirmation from the master. A value of 255 allows infinite re-tries.

The **DNP UNSOL RESPONSE DEST ADDRESS** setting is the DNP address to which all unsolicited responses are sent. The IP address to which unsolicited responses are sent is determined by the L90 from either the current DNP TCP connection or the most recent UDP message.

The **USER MAP FOR DNP ANALOGS** setting allows the large pre-defined Analog Inputs points list to be replaced by the much smaller Modbus User Map. This can be useful for users wishing to read only selected Analog Input points from the L90. See Appendix E for more information

The **NUMBER OF SOURCES IN ANALOG LIST** setting allows the selection of the number of current/voltage source values that are included in the Analog Inputs points list. This allows the list to be customized to contain data for only the sources that are configured. This setting is relevant only when the User Map is not used.

The **DNP SCALE FACTOR** settings are numbers used to scale Analog Input point values. These settings group the L90 Analog Input data into types: current, voltage, power, energy, and other. Each setting represents the scale factor for all Analog Input points of that type. For example, if the **DNP VOLTAGE SCALE FACTOR** setting is set to a value of 1000, all DNP Analog Input points that are voltages will be returned with values 1000 times smaller (e.g. a value of 72000 V on the L90 will be returned as 72). These settings are useful when Analog Input values must be adjusted to fit within certain ranges in DNP masters. Note that a scale factor of 0.1 is equivalent to a multiplier of 10 (i.e. the value will be 10 times larger).

The **DNP DEFAULT DEADBAND** settings are the values used by the L90 to determine when to trigger unsolicited responses containing Analog Input data. These settings group the L90 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, in order to trigger unsolicited responses from the L90 when any current values change by 15 A, the **DNP CURRENT DEFAULT DEADBAND** setting should be set to 15. Note that these settings are the default values of the deadbands. 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 L90, the default deadbands will be in effect.

The **DNP TIME SYNC IIN PERIOD** setting determines how often the "Need Time" Internal Indication (IIN) bit is set by the L90. Changing this time allows the DNP master to send time synchronization commands more or less often, as required.

The **DNP MESSAGE FRAGMENT SIZE** 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.

The **DNP BINARY INPUTS USER MAP** setting allows for the creation of a custom DNP Binary Inputs points list. The default DNP Binary Inputs list on the L90 contains 928 points representing various binary states (contact inputs and outputs, virtual inputs and outputs, protection element states, etc.). If not all of these points are required in the DNP master, a custom Binary Inputs points list can be created by selecting up to 58 blocks of 16 points. Each block represents 16 Binary Input points. Block 1 represents Binary Input points 0 to 15, block 2 represents Binary Input points 16 to 31, block 3 represents Binary Input points 32 to 47, etc. The minimum number of Binary Input points that can be selected is 16 (1 block). If all of the **BIN INPUT BLOCK X** settings are set to "Not Used", the standard list of 928 points will be in effect. The L90 will form the Binary Inputs points list from the **BIN INPUT BLOCK X** settings up to the first occurrence of a setting value of "Not Used".

NOTE

When using either of the User Maps for DNP data points (Analog Inputs and/or Binary Inputs), for UR relays with the ethernet option installed, check the "DNP Points Lists" L90 web page to ensure the desired points lists have been created. This web page can be viewed using Internet Explorer or Netscape Navigator by entering the L90 IP address to access the L90 "Main Menu", then by selecting the "Device Information Menu", and then selecting the "DNP Points Lists".

e) UCA/MMS PROTCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ UCA/MMS PROTOCOL

```
■ COMMUNICATIONS
■
```

```
■ UCA/MMS PROTOCOL
■
```

MESSAGE

```
DEFAULT GOOSE UPDATE
TIME: 60 s
```

Range: 1 to 60 s in steps of 1
See UserSt BIT PAIRS in the REMOTE OUTPUTS section.

MESSAGE

```
UCA LOGICAL DEVICE:
UCADevice
```

Range: Up to 16 alphanumeric characters representing the name of the UCA logical device.

MESSAGE

```
UCA/MMS TCP PORT
NUMBER:   102
```

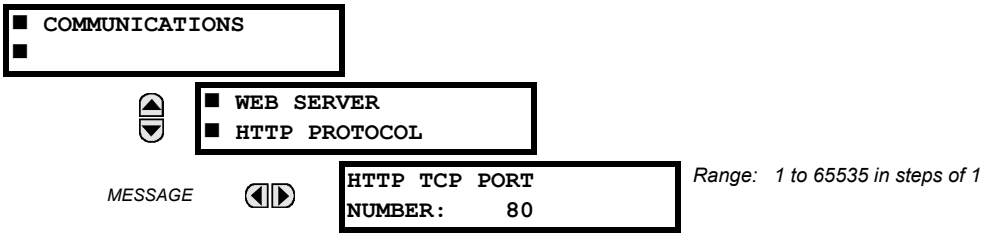
Range: 1 to 65535 in steps of 1

The L90 supports the Manufacturing Message Specification (MMS) protocol as specified by the Utility Communication Architecture (UCA). UCA/MMS is supported over two protocol stacks: TCP/IP over ethernet and TP4/CLNP (OSI) over ethernet. The L90 operates as a UCA/MMS server. Appendix C describes the UCA/MMS protocol implementation in more detail. The REMOTE INPUTS and REMOTE OUTPUT sections of Chapter 5: SETTINGS describes the peer-to-peer GOOSE message scheme.

The UCA LOGICAL DEVICE setting represents the name of the MMS domain (UCA logical device) in which all UCA objects are located.

f) WEB SERVER HTTP PROTOCOL

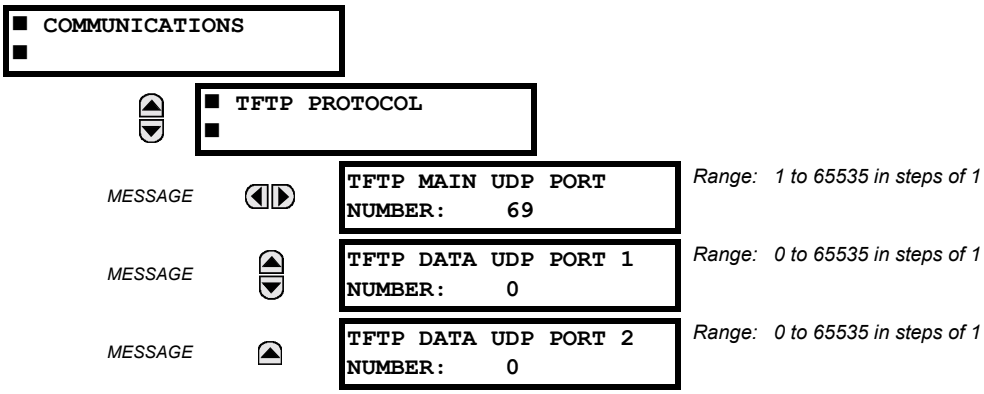
PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ WEB SERVER HTTP PROTOCOL



The L90 contains an embedded web server. That is, the L90 is capable of transferring web pages to a web browser such as Microsoft Internet Explorer or Netscape Navigator. This feature is available only if the L90 has the ethernet option installed. The web pages are organized as a series of menus that can be accessed starting at the L90 "Main Menu". Web pages are available showing DNP and IEC 60870-5-104 points lists, Modbus registers, Event Records, Fault Reports, etc. The web pages can be accessed by connecting the UR and a computer to an ethernet network. The Main Menu will be displayed in the web browser on the computer simply by entering the IP address of the L90 into the "Address" box on the web browser.

g) TFTP PROTOCOL

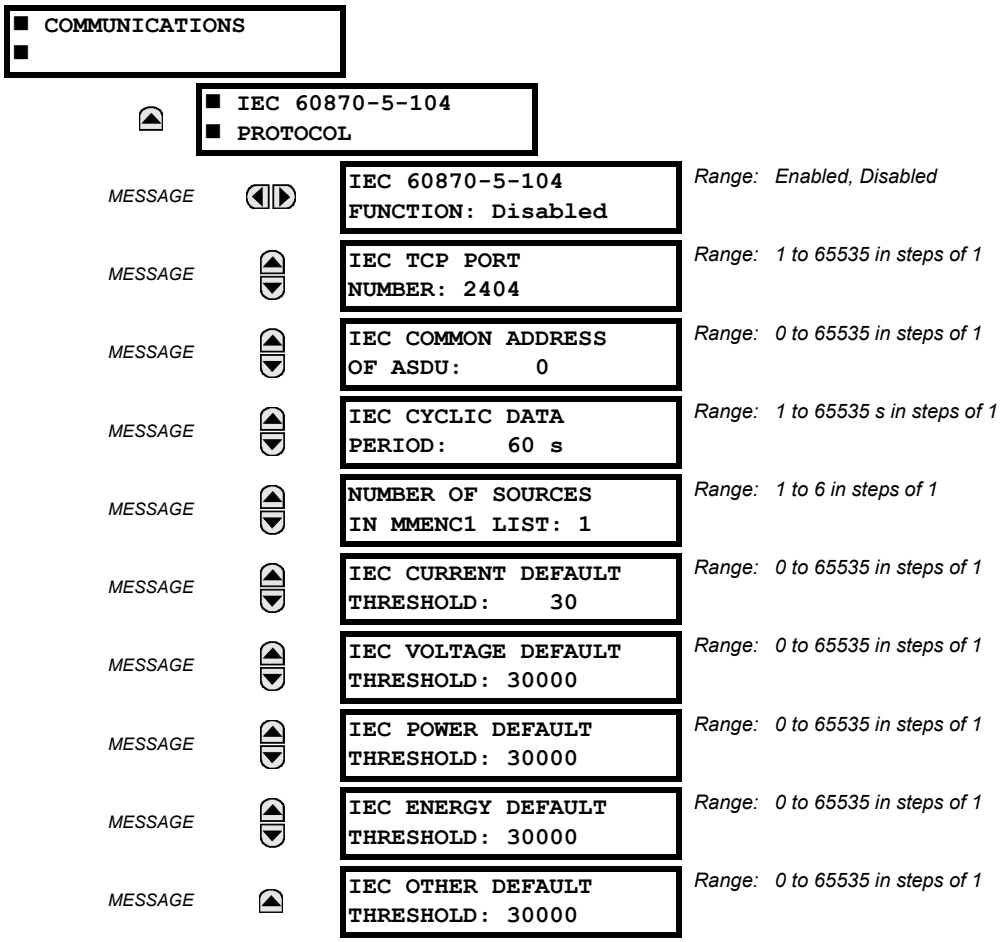
PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ TFTP PROTOCOL



The Trivial File Transfer Protocol (TFTP) can be used to transfer files from the UR over a network. The L90 operates as a TFTP server. TFTP client software is available from various sources, including Microsoft Windows NT. The file "dir.txt" is an ASCII text file that can be transferred from the L90. This file contains a list and description of all the files available from the UR (event records, oscillography, etc.).

h) IEC 60870-5-104 PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-104 PROTOCOL



The L90 supports the IEC 60870-5-104 protocol. The L90 can be used as an IEC 60870-5-104 slave device connected to a single master (usually either an RTU or a SCADA master station). Since the L90 maintains one set of IEC 60870-5-104 data change buffers, only one master should actively communicate with the L90 at one time. For situations where a second master is active in a "hot standby" configuration, the UR supports a second IEC 60870-5-104 connection providing the standby master sends only IEC 60870-5-104 Test Frame Activation messages for as long as the primary master is active.

The **NUMBER OF SOURCES IN MMENC1 LIST** setting allows the selection of the number of current/voltage source values that are included in the M_ME_NC_1 (Measured value, short floating point) Analog points list. This allows the list to be customized to contain data for only the sources that are configured.

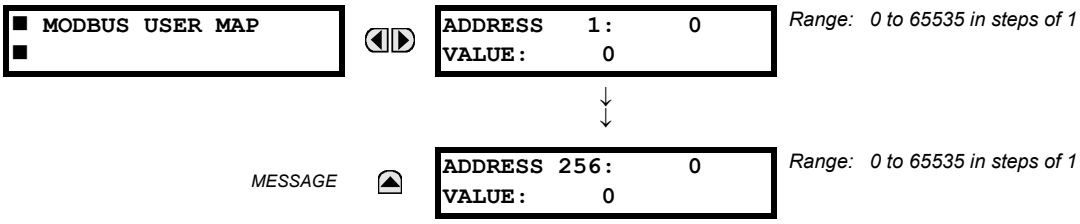
The **IEC ------- DEFAULT THRESHOLD** settings are the values used by the UR to determine when to trigger spontaneous responses containing M_ME_NC_1 analog data. These settings group the UR analog data into types: current, voltage, power, energy, and other. Each setting represents the default threshold value for all M_ME_NC_1 analog points of that type. For example, in order to trigger spontaneous responses from the UR when any current values change by 15 A, 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 UR, the default thresholds will be in effect.

NOTE

The IEC 60870-5-104 and DNP protocols can not be used at the same time. When the IEC 60870-5-104 FUNCTION setting is set to Enabled, the DNP protocol will not be operational. When this setting is changed it will not become active until power to the relay has been cycled (OFF/ON).

5.2.4 MODBUS® USER MAP

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ MODBUS USER MAP



The Modbus® User Map provides up to 256 registers with read only access. To obtain a value for a memory map address, enter the desired location in the **ADDRESS** line (the value must be converted from hex to decimal format). The corresponding value from the is displayed in the **VALUE** line. A value of "0" in subsequent register **ADDRESS** lines automatically return 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.

NOTE **These settings can also be used with the DNP protocol. See the DNP ANALOG INPUT POINTS section in Appendix E for details.**

5.2.5 REAL TIME CLOCK

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK

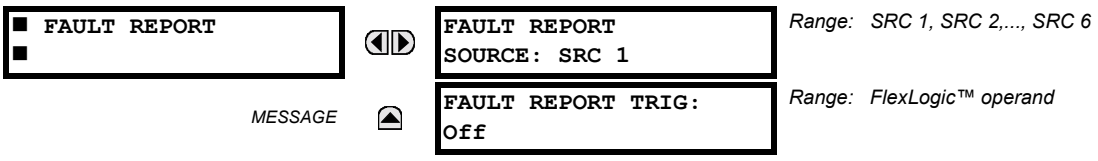
The date and time for the relay clock can be synchronized to other relays using an IRIG-B signal. It has the same accuracy as an electronic watch, approximately ±1 minute per month.

An IRIG-B signal may be connected to the relay to synchronize the clock to a known time base and to other relays. If an IRIG-B signal is used, only the current year needs to be entered.

See also the COMMANDS ⇩ SET DATE AND TIME menu for manually setting the relay clock.

5.2.6 FAULT REPORT

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FAULT REPORT



The fault report stores data, in non-volatile memory, pertinent to an event when triggered. The captured data will include:

- Name of the relay, programmed by the user
- Date and time of trigger
- Name of trigger (specific operand)
- Active setting group
- Pre-fault current and voltage phasors (one-quarter cycle before the trigger)
- Fault current and voltage phasors (three-quarter cycle after the trigger)
- Target Messages that are set at the time of triggering
- Events (9 before trigger and 7 after 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) The Fault Locator does not report fault type or location if the source VTs are connected in the Delta configuration.

The trigger can be any FlexLogic™ operand, but in most applications it is expected to be the same operand, usually a virtual output, that is used to drive an output relay to trip a breaker. To prevent the over-writing of fault events, the disturbance detector should not be used to trigger a fault report.

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. As the fault report must capture a usable amount of pre and post-fault data, it can not be triggered faster than every 20 ms.

Each fault report is stored as a file; the relay capacity is ten files. An eleventh trigger overwrites the oldest file. The operand selected as the fault report trigger automatically triggers an oscillography record which can also be triggered independently.

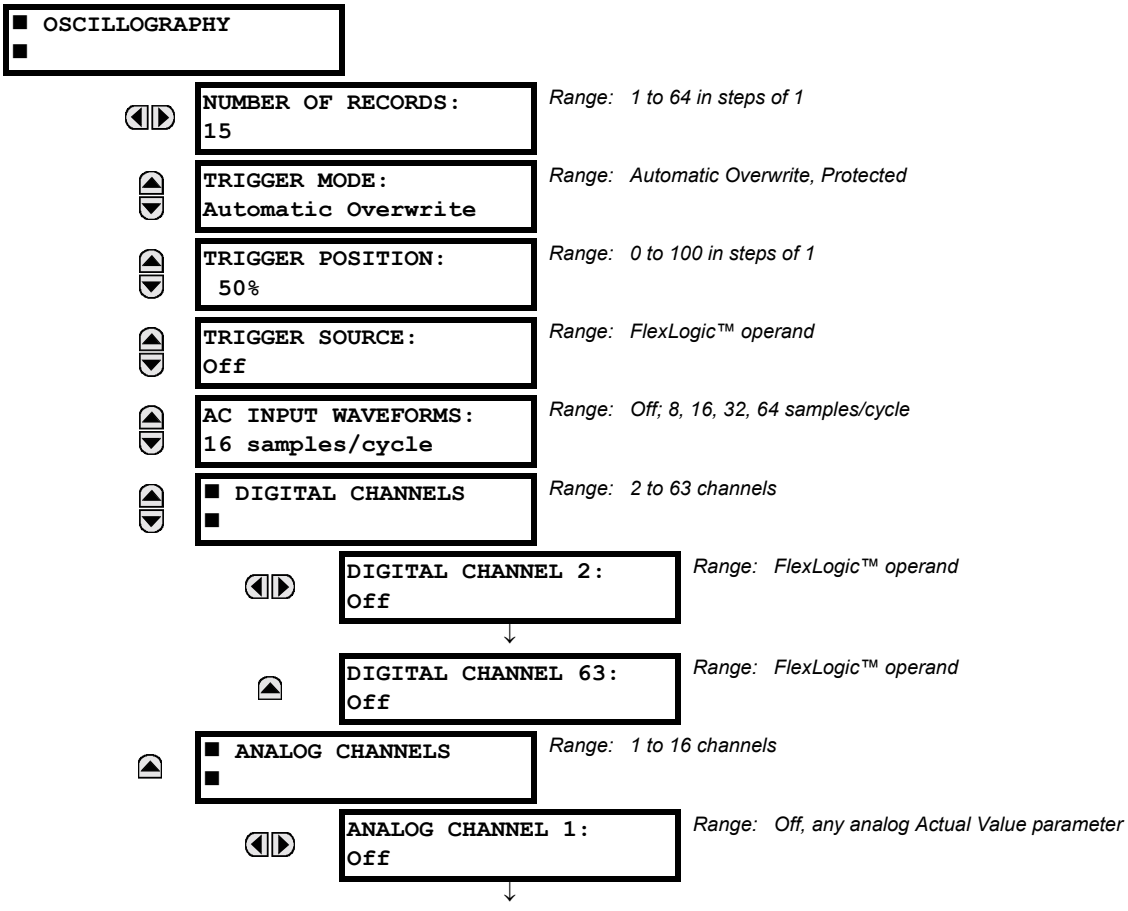
URPC is required to view all captured data. The relay faceplate display can be used to view the date and time of trigger, the fault type, the distance location of the fault, and the reclose shot number

The **FAULT REPORT SOURCE** setting selects the Source for input currents and voltages and disturbance detection. The **FAULT REPORT TRIG** setting assigns the FlexLogic™ operand representing the protection element/elements requiring operational fault location calculations. The distance to fault calculations are initiated by this signal.

See also **SETTINGS ⇩ SYSTEM SETUP ⇨⇩ LINE** menu for specifying line characteristics and the **ACTUAL VALUES ⇩ RECORDS ⇨ FAULT REPORTS** menu.

5.2.7 OSCILLOGRAPHY

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ OSCILLOGRAPHY



```
ANALOG CHANNEL 16:
Off
```

Range: Off, any analog Actual Value parameter

Oscillography records contain waveforms captured at the sampling rate as well as other relay data at the point of trigger. Oscillography records are triggered by a programmable FlexLogic™ operand. Multiple oscillography records may be captured simultaneously.

The **NUMBER OF RECORDS** is selectable, but the number of cycles captured in a single record varies considerably based on other factors such as sample rate and the number of operational CT/VT modules. There is a fixed amount of data storage for oscillography; the more data captured, the less the number of cycles captured per record. See the **ACTUAL VALUES** ⇨⇩ **RECORDS** ⇨⇩ **OSCILLOGRAPHY** menu to view the number of cycles captured per record. The following table provides sample configurations with corresponding cycles/record.

Table 5–1: OSCILLOGRAPHY CYCLES/RECORD EXAMPLE

# RECORDS	# CT/VTS	SAMPLE RATE	# DIGITALS	# ANALOGS	CYCLES/ RECORD
1	1	8	0	0	1872.0
1	1	16	16	0	1685.0
8	1	16	16	0	276.0
8	1	16	16	4	219.5
8	2	16	16	4	93.5
8	2	16	64	16	93.5
8	2	32	64	16	57.6
8	2	64	64	16	32.3
32	2	64	64	16	9.5

A new record may automatically overwrite an older record if **TRIGGER MODE** is set to "Automatic Overwrite".

The **TRIGGER POSITION** is programmable as a percent of the total buffer size (e.g. 10%, 50%, 75%, etc.). A trigger position of 25% consists of 25% pre- and 75% post-trigger data.

The **TRIGGER SOURCE** is always captured in oscillography and may be any FlexLogic™ parameter (element state, contact input, virtual output, etc.). The relay sampling rate is 64 samples per cycle.

The **AC INPUT WAVEFORMS** setting determines the sampling rate at which AC input signals (i.e. current and voltage) are stored. Reducing the sampling rate allows longer records to be stored. This setting has no effect on the internal sampling rate of the relay which is always 64 samples per cycle, i.e. it has no effect on the fundamental calculations of the device.

An **ANALOG CHANNEL** setting selects the metering actual value recorded in an oscillography trace. The length of each oscillography trace depends in part on the number of parameters selected here. Parameters set to 'Off' are ignored. The parameters available in a given relay are dependent on: (a) the type of relay, (b) the type and number of CT/VT hardware modules installed, and (c) the type and number of Analog Input hardware modules installed. Upon startup, the relay will automatically prepare the parameter list. Tables of all possible analog metering actual value parameters are presented in Appendix A: FLEXANALOG PARAMETERS. The parameter index number shown in any of the tables is used to expedite the selection of the parameter on the relay display. It can be quite time-consuming to scan through the list of parameters via the relay keypad/display - entering this number via the relay keypad will cause the corresponding parameter to be displayed.

All eight CT/VT module channels are stored in the oscillography file. The CT/VT module channels are named as follows:

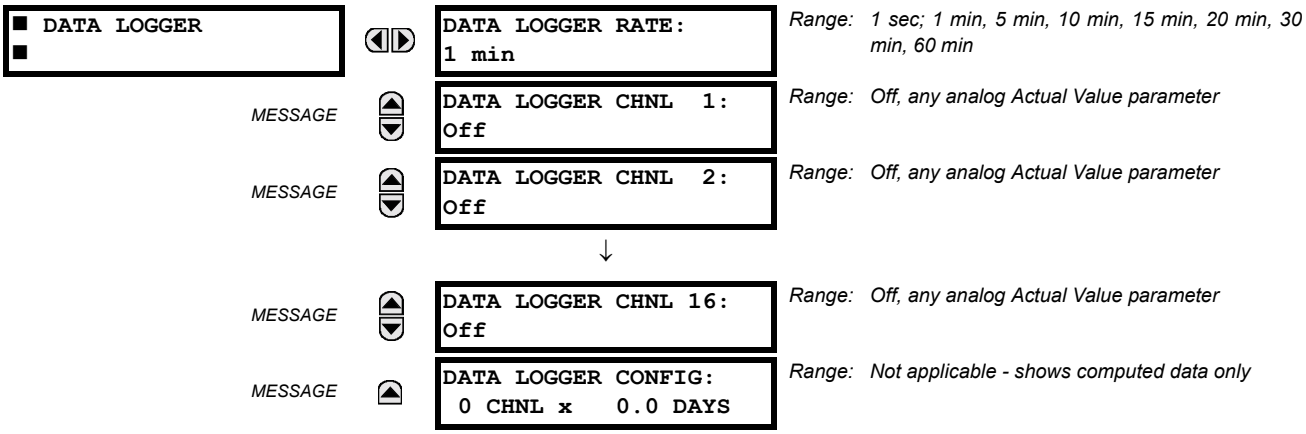
<slot_letter><terminal_number>—<I or V><phase A, B, or C, or 4th input>

The fourth current input in a bank is called IG, and the fourth voltage input in a bank is called VX. For example, F2-IB designates the IB signal on terminal 2 of the CT/VT module in slot F. If there are no CT/VT modules and Analog Input modules, no analog traces will appear in the file; only the digital traces will appear.

When changes are made to the oscillography settings, all existing oscillography records will be CLEARED.

5.2.8 DATA LOGGER

PATH: SETTINGS ⇨⇩ PRODUCT SETUP ⇨⇩ 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 URPC 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 between the channels in use.

NOTE

Changing any setting affecting Data Logger operation will clear any data that is currently in the log.

DATA LOGGER RATE:

This setting selects the time interval at which the actual value data will be recorded.

DATA LOGGER CHNL 1 (to 16):

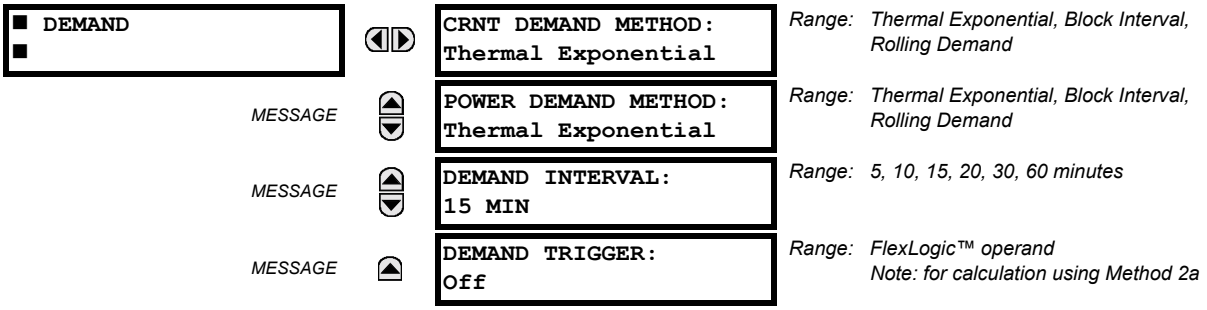
This setting selects the metering actual value that is to be recorded in Channel 1(16) of the data log. The parameters available in a given relay are dependent on: the type of relay, the type and number of CT/VT hardware modules installed, and the type and number of Analog Input hardware modules installed. Upon startup, the relay will automatically prepare the parameter list. Tables of all possible analog metering actual value parameters are presented in Appendix A: FLEXANALOG PARAMETERS. The parameter index number shown in any of the tables is used to expedite the selection of the parameter on the relay display. It can be quite time-consuming to scan through the list of parameters via the relay keypad/display – entering this number via the relay keypad will cause the corresponding parameter to be displayed.

DATA LOGGER CONFIG:

This display presents the total amount of time the Data Logger can record the channels not selected to "Off" without overwriting old data.

5.2.9 DEMAND

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DEMAND



The relay measures current demand on each phase, and three-phase demand for real, reactive, and apparent power. Current and Power methods can be chosen separately for the convenience of the user. Settings are provided to allow the user to emulate some common electrical utility demand measuring techniques, for statistical or control purposes. If the **CRNT DEMAND METHOD** is set to "Block Interval" and the **DEMAND TRIGGER** is set to “Off”, Method 2 is used (see below). If **DEMAND TRIGGER** is assigned to any other FlexLogic™ operand, Method 2a is used (see below).

The relay can be set to calculate demand by any of three methods as described below:

CALCULATION METHOD 1: THERMAL EXPONENTIAL

This method emulates the action of an analog peak recording thermal demand meter. The relay measures the quantity (RMS current, real power, reactive power, or apparent power) on each phase every second, and assumes the circuit quantity remains at this value until updated by the next measurement. It calculates the 'thermal demand equivalent' based on the following equation:

$d(t) = D(1 - e^{-kt})$

d = demand value after applying input quantity for time t (in minutes)
D = input quantity (constant)
k = 2.3 / thermal 90% response time.

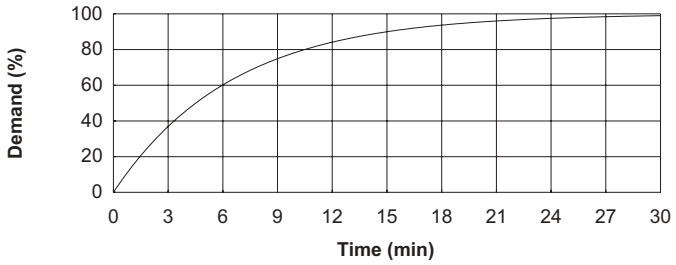


Figure 5–2: THERMAL DEMAND CHARACTERISTIC

See the 90% thermal response time characteristic of 15 minutes in the figure above. A setpoint establishes the time to reach 90% of a steady-state value, just as the response time of an analog instrument. A steady state value applied for twice the response time will indicate 99% of the value.

CALCULATION METHOD 2: BLOCK INTERVAL

This method calculates a linear average of the quantity (RMS current, real power, reactive power, or apparent power) over the programmed demand time interval, starting daily at 00:00:00 (i.e. 12:00 am). The 1440 minutes per day is divided into the number of blocks as set by the programmed time interval. Each new value of demand becomes available at the end of each time interval.

CALCULATION METHOD 2a: BLOCK INTERVAL (with Start Demand Interval Logic Trigger)

This method calculates a linear average of the quantity (RMS current, real power, reactive power, or apparent power) over the interval between successive Start Demand Interval logic input pulses. Each new value of demand becomes available at the end of each pulse. Assign a FlexLogic™ operand to the **DEMAND TRIGGER** setting to program the input for the new demand interval pulses.

NOTE

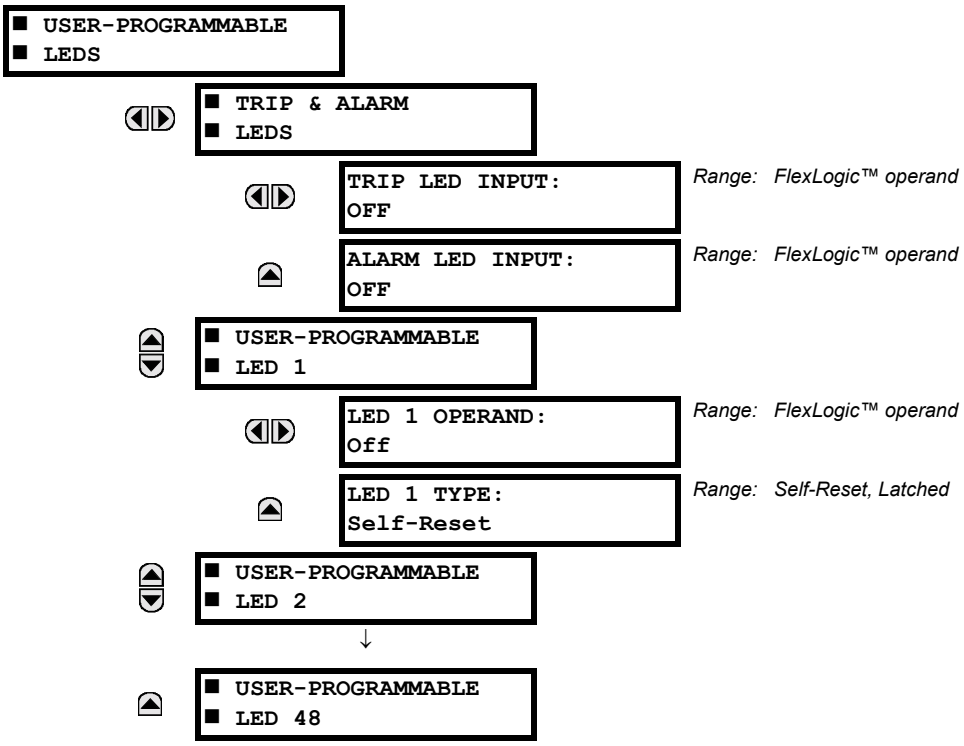
If no trigger is assigned in the **DEMAND TRIGGER** setting and the **CRNT DEMAND METHOD** is "Block Interval", use calculating method #2. If a trigger is assigned, the maximum allowed time between 2 trigger signals is 60 minutes. If no trigger signal appears within 60 minutes, demand calculations are performed and available and the algorithm resets and starts the new cycle of calculations. The minimum required time for trigger contact closure is 20 μs.

CALCULATION METHOD 3: ROLLING DEMAND

This method calculates a linear average of the quantity (RMS current, real power, reactive power, or apparent power) over the programmed demand time interval, in the same way as Block Interval. The value is updated every minute and indicates the demand over the time interval just preceding the time of update.

5.2.10 USER-PROGRAMMABLE LEDS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS



The TRIP and ALARM LEDs are on LED panel 1. Each indicator can be programmed to become illuminated when the selected FlexLogic™ operand is in the logic 1 state. There are 48 amber LEDs across the relay faceplate LED panels. Each of these indicators can be programmed to illuminate when the selected FlexLogic™ operand is in the logic 1 state.

- LEDs 1 through 24 inclusive are on LED panel 2; LEDs 25 through 48 inclusive are on LED panel 3.

Refer to the LED INDICATORS section in the HUMAN INTERFACES chapter for the locations of these indexed LEDs. This menu selects the operands to control these LEDs. Support for applying user-customized labels to these LEDs is provided. If the **LED X TYPE** setting is "Self-Reset" (default setting), the LED illumination will track the state of the selected LED operand. If the **LED X TYPE** setting is 'Latched', the LED, once lit, remains so until reset by the faceplate RESET button, from a remote device via a communications channel, or from any programmed operand, even if the LED operand state de-asserts.

Table 5–3: RECOMMENDED SETTINGS FOR LED PANEL 2 LABELS

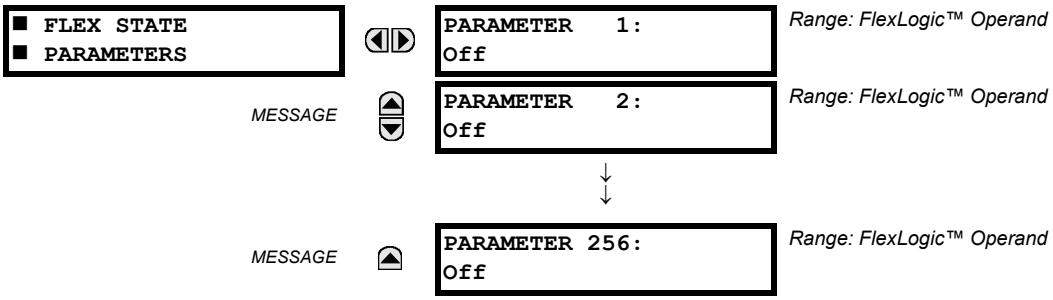
SETTING	PARAMETER
LED 1 Operand	SETTING GROUP ACT 1
LED 2 Operand	SETTING GROUP ACT 2
LED 3 Operand	SETTING GROUP ACT 3
LED 4 Operand	SETTING GROUP ACT 4
LED 5 Operand	SETTING GROUP ACT 5
LED 6 Operand	SETTING GROUP ACT 6
LED 7 Operand	SETTING GROUP ACT 7
LED 8 Operand	SETTING GROUP ACT 8
LED 9 Operand	BREAKER 1 OPEN
LED 10 Operand	BREAKER 1 CLOSED
LED 11 Operand	BREAKER 1 TROUBLE
LED 12 Operand	Off

SETTING	PARAMETER
LED 13 Operand	Off
LED 14 Operand	BREAKER 2 OPEN
LED 15 Operand	BREAKER 2 CLOSED
LED 16 Operand	BREAKER 2 TROUBLE
LED 17 Operand	SYNC 1 SYNC OP
LED 18 Operand	SYNC 2 SYNC OP
LED 19 Operand	Off
LED 20 Operand	Off
LED 21 Operand	AR ENABLED
LED 22 Operand	AR DISABLED
LED 23 Operand	AR RIP
LED 24 Operand	AR LO

Refer to the CONTROL OF SETTINGS GROUPS example in the CONTROL ELEMENTS section for group activation.

5.2.11 FLEX STATE PARAMETERS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FLEX STATE PARAMETERS

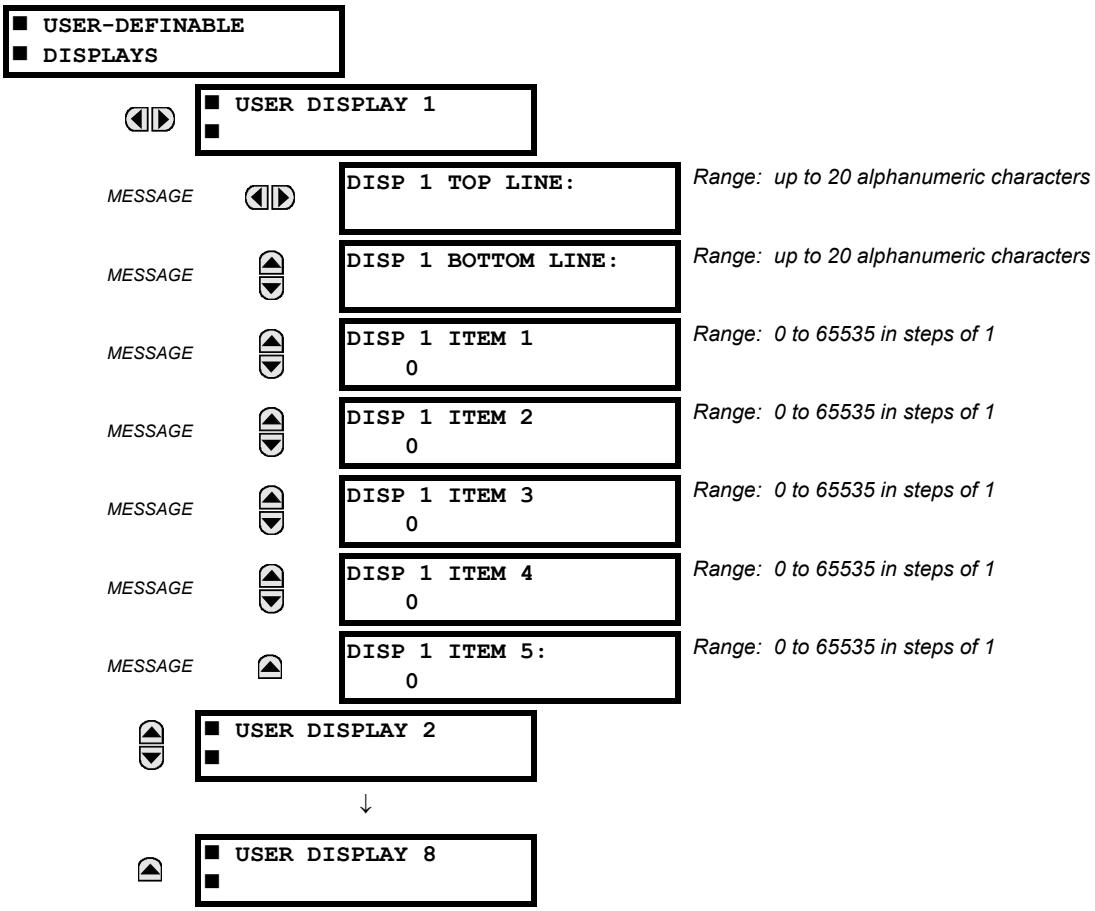


This feature provides a mechanism where any of 256 selected FlexLogic™ operand states can be used for efficient monitoring. The feature allows user-customized access to the FlexLogic™ operand states in the relay. The state bits are packed so that 16 states may be read out in a single Modbus register. 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 "Flex States" register array beginning at Modbus address 900 hex. 16 states are packed into each register, with the lowest-numbered state in the lowest-order bit. There are 16 registers in total to accommodate the 256 state bits.

5.2.12 USER-DEFINABLE DISPLAYS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-DEFINABLE DISPLAYS



This menu provides a mechanism for manually creating up to 8 user-defined information displays in a convenient viewing sequence in the USER DISPLAYS menu (between the TARGETS and ACTUAL VALUES top-level menus). The sub-menus facilitate text entry and Modbus Register data pointer options for defining the User Display content.

Also, any existing system display can be automatically copied into an available User Display by selecting the existing display and pressing the ENTER key. The display will then prompt "ADD TO USER DISPLAY LIST?". After selecting 'Yes', a message will indicate that the selected display has been added to the user display list. When this type of entry occurs, the sub-menus are automatically configured with the proper content - this content may subsequently be edited.

This menu is used **to enter** user-defined text and/or user-selected Modbus-registered data fields into the particular User Display. Each User Display consists of two 20-character lines (TOP & BOTTOM). The Tilde (~) character is used to mark the start of a data field - the length of the data field needs to be accounted for. Up to 5 separate data fields (ITEM 1...5) can be entered in a User Display - the nth Tilde (~) refers to the nth ITEM.

A User Display may be entered from the faceplate keypad or the URPC interface (preferred for convenience).

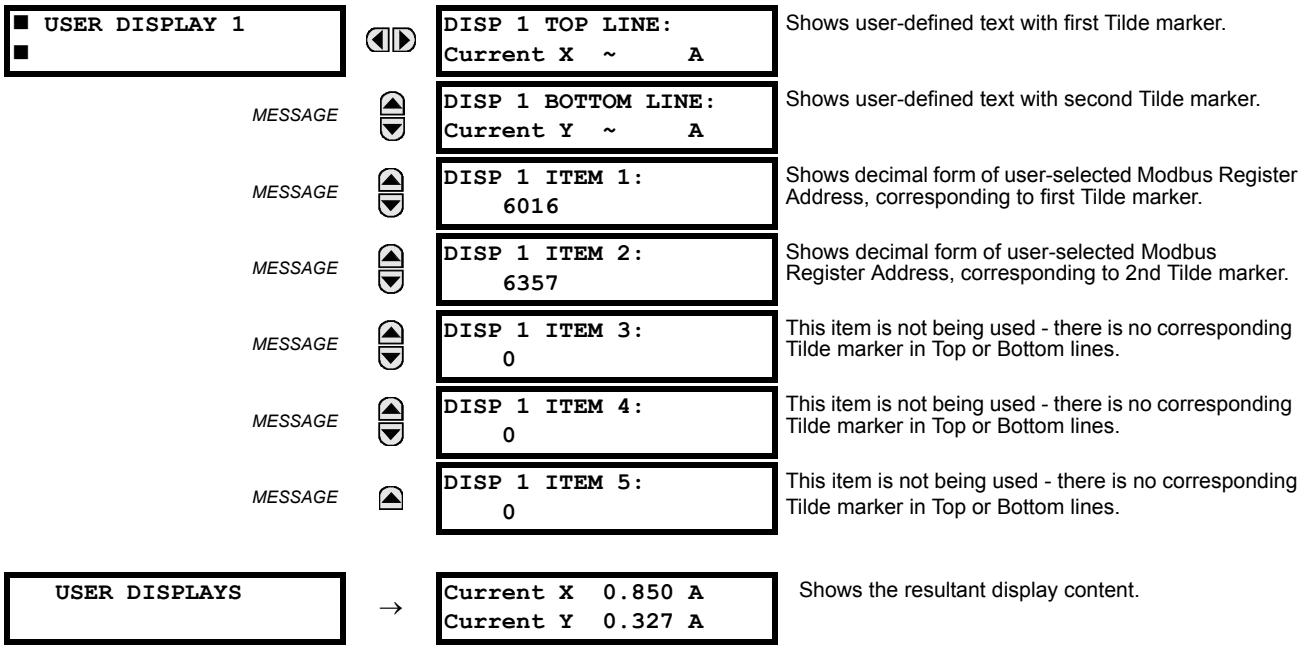
To enter text characters in the TOP LINE and BOTTOM LINE from the faceplate keypad:

1. Select the line to be edited.
2. Press the key to enter text edit mode.
3. Use either VALUE key to scroll through the characters. A space is selected like a character.
4. Press the key to advance the cursor to the next position.
5. Repeat step 3 and continue entering characters until the desired text is displayed.
6. The HELP key may be pressed at any time for context sensitive help information.
7. Press the ENTER key to store the new settings.

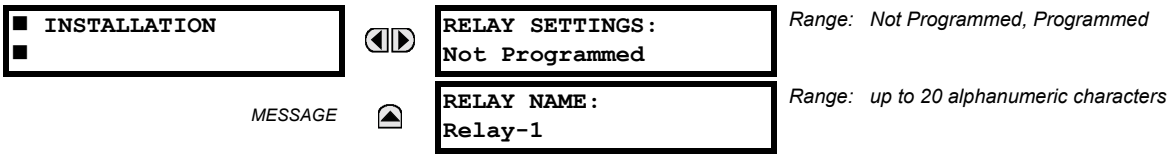
To enter a numerical value for any of the 5 ITEMs (the *decimal form* of the selected Modbus Register Address) from the faceplate keypad, use the number keypad. Use the value of '0' for any ITEMs not being used. Use the HELP key at any selected system display (Setting, Actual Value, or Command) which has a Modbus address, to view the *hexadecimal form* of the Modbus Register Address, then manually convert it to decimal form before entering it (URPC usage would conveniently facilitate this conversion).

Use the MENU key to go to the USER DISPLAYS menu **to view** the user-defined content. The current user displays will show in sequence, changing every 4 seconds. While viewing a User Display, press the ENTER key and then select the 'Yes" option **to remove** the display from the user display list. Use the MENU key again **to exit** the USER DISPLAYS menu.

EXAMPLE USER DISPLAY SETUP AND RESULT:



PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION

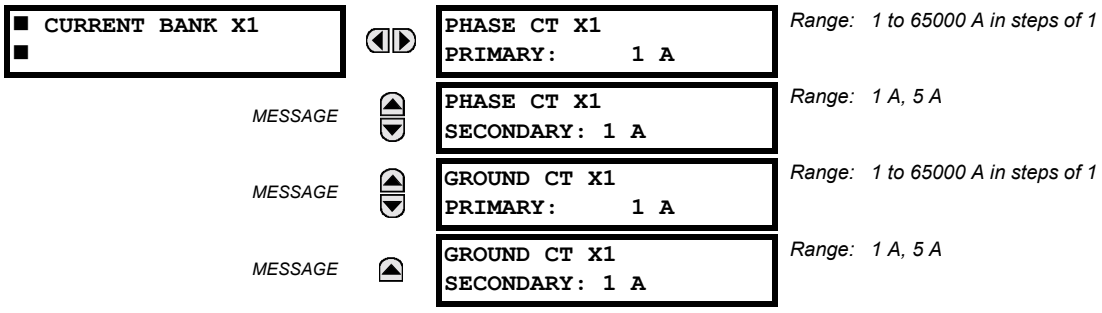


To safeguard against the installation of a relay whose settings have not been entered, the unit will not allow signaling of any output relay until **RELAY SETTINGS** is set to "Programmed". This setting is defaulted to "Not Programmed" when the relay leaves the factory. The UNIT NOT PROGRAMMED self-test error message is displayed automatically until the relay is put into the Programmed state.

The **RELAY NAME** setting allows the user to uniquely identify a relay. This name will appear on generated reports. This name is also used to identify specific devices which are engaged in automatically sending/receiving data over the Ethernet communications channel using the UCA2/MMS protocol.

a) CURRENT BANKS

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨ CURRENT BANK X1



'X' = F, M, or U. 'F', 'M', and 'U' are module slot position letters. See also the section INTRODUCTION TO AC SOURCES.

Up to 6 banks of phase/ground CTs can be set.

These settings are critical for all features that have settings dependent on current measurements. When the relay is ordered, the CT module must be specified to include a standard or sensitive ground input. As the phase CTs are connected in Wye (star), the calculated phasor sum of the three phase currents (IA + IB + IC = Neutral Current = 3Io) 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. For this configuration, the ground CT primary rating must be entered. To detect low level ground fault currents, the sensitive ground input may be used. In this case, the sensitive ground CT primary rating must be entered. For more details on CT connections, refer to the HARDWARE chapter.

Enter the rated CT primary current values. For both 1000:5 and 1000:1 CTs, the entry would be 1000. For correct operation, the CT secondary rating must match the setting (which must also correspond to the specific CT connections used).

If CT inputs (banks of current) are to be summed as one source current, the following rule applies:

EXAMPLE:

SRC1 = F1 + F5 + U1

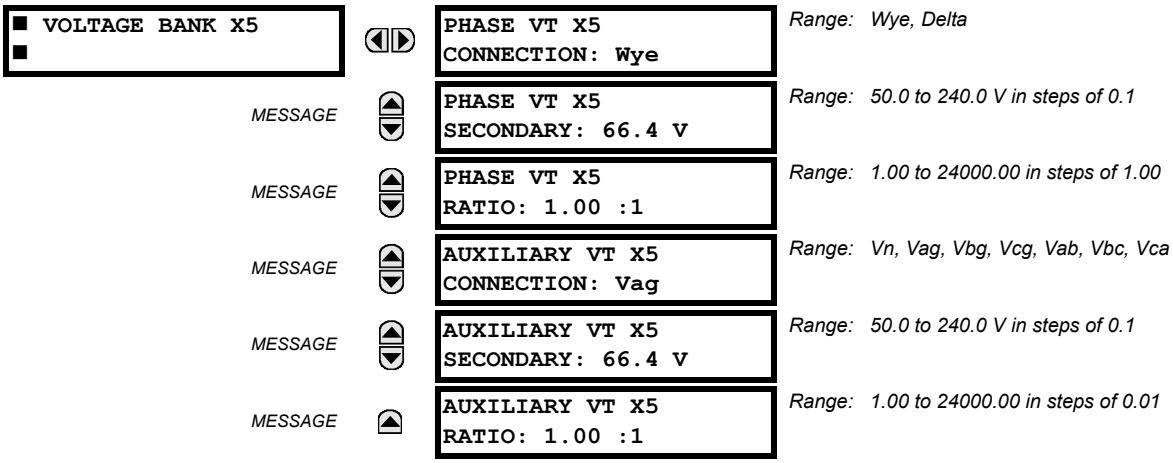
Where *F1*, *F5*, and *U1* are banks of CTs with ratios of 500:1, 1000:1 and 800:1 respectively.

1 pu is the highest primary current. In this case, 1000 is entered and the secondary current from the 500:1 and 800:1 ratio CTs will be adjusted to that which would be created by a 1000:1 CT before summation. If a protection element is set up to act on SRC1 currents, then PKP level of 1 pu will operate on 1000 A primary.

The same rule will apply for sums of currents from CTs with different secondary taps (5 A and 1 A).

b) VOLTAGE BANKS

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK X1



'X' = F, M, or U. 'F', 'M', and 'U' are module slot position letters. See also the INTRODUCTION TO AC SOURCES section.

Up to 3 banks of phase/auxiliary VTs can be set.

With VTs installed, the relay can be used to perform voltage measurements as well as power calculations. Enter the **PHASE VT xx CONNECTION** made to the system as "Wye" or "Delta". An open-delta source VT connection would be entered as "Delta". See the typical wiring diagram in the HARDWARE chapter for details.

NOTE

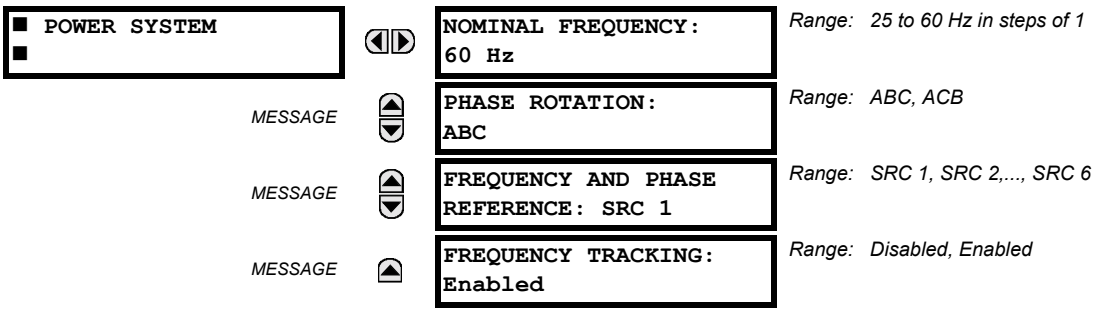
The nominal Phase VT Secondary Voltage setting is the voltage across the relay input terminals when nominal voltage is applied to the VT primary.

For example, on a system with a 13.8 kV nominal primary voltage and with a 14400:120 Volt VT in a Delta connection, the secondary voltage would be 115, i.e. (13800 / 14400) × 120. For a Wye connection, the voltage value entered must be the phase to neutral voltage which would be 115 / $\sqrt{3}$ = 66.4.

On a 14.4 kV system with a Delta connection and a VT primary to secondary turns ratio of 14400:120, the voltage value entered would be 120, i.e. 14400 / 120.

5.3.2 POWER SYSTEM

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM



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.

The phase sequence of the power system is required to properly calculate sequence components and power parameters. The **PHASE ROTATION** setting matches the power system phase sequence. Note that this setting informs the relay of the actual system phase sequence, either ABC or ACB. CT and VT inputs on the relay, labeled as A, B, and C, must be connected to system phases A, B, and C for correct operation.

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 AC inputs that are 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 ($V_{\text{ANGLE REF}} = V_A$), while Clarke transformation of the phase signals is used for frequency metering and tracking ($V_{\text{FREQUENCY}} = (2V_A - V_B - V_C)/3$) 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.

Phase angle of the reference signal will always display zero degrees and all other phase angles will be 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 relays if they have the same AC signal reference. These results in very precise correlation of time tagging in the event recorder between different UR relays provided the relays have an IRIG-B connection.

NOTE

FREQUENCY TRACKING should only be set to "Disabled" in very unusual circumstances; consult the factory for special variable-frequency applications.

NOTE

The nominal system frequency should be selected as 50 Hz or 60 Hz only. The **FREQUENCY AND PHASE REFERENCE** setting, used as a reference for calculating all angles, must be identical for all terminals. Whenever the 87L function is "Enabled", the UR Platform frequency tracking function is disabled, and frequency tracking is driven by the L90 algorithm (see the THEORY OF OPERATION chapter). Whenever the 87L function is "Disabled", the frequency tracking mechanism reverts to the UR Platform mechanism which uses the **FREQUENCY TRACKING** setting to provide frequency tracking for all other elements and functions.

5

5.3.3 SIGNAL SOURCES

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES ⇨ SOURCE 1(6)

■ SOURCE 1 ■		SOURCE 1 NAME: SRC 1	*Range: up to 6 alphanumeric characters*
	MESSAGE	SOURCE 1 PHASE CT: None	*Range: None, F1, F5, F1+F5,..., F1+F5+M1+M5+U1+U5 Only phase current inputs will be displayed.*
	MESSAGE	SOURCE 1 GROUND CT: None	*Range: None, F1, F5, F1+F5,..., F1+F5+M1+M5+U1+U5 Only ground current inputs will be displayed.*
	MESSAGE	SOURCE 1 PHASE VT: None	*Range: None, F1, F5, M1, M5, U1, U5 Only phase voltage inputs will be displayed.*
	MESSAGE	SOURCE 1 AUX VT: None	*Range: None, F1, F5, M1, M5, U1, U5 Only auxiliary voltage inputs will be displayed.*

There are up to 6 identical Source setting menus available, numbered from 1 to 6.

"SRC 1" can be replaced by whatever name is defined by the user for the associated source.

'F', 'U', and 'M' are module slot position letters. The number following the letter represents either the first bank of four channels (1, 2, 3, 4) called '1' or the second bank of four channels (5, 6, 7, 8) called '5' in a particular CT/VT module. Refer to the INTRODUCTION TO AC SOURCES section at the beginning of this chapter for additional details.

It is possible to select the sum of any combination of CTs. The first channel displayed is the CT to which all others will be referred. For example, the selection "F1+F5" indicates the sum of each phase from channels "F1" and "F5", scaled to whichever CT has the higher ratio. Selecting "None" hides the associated actual values.

The approach used to configure the AC Sources consists of several steps; first step is to specify the information about each CT and VT input. For CT inputs, this is the nominal primary and secondary current. For VTs, this is the connection type, ratio and nominal secondary voltage. Once the inputs have been specified, the configuration for each Source is entered, including specifying which CTs will be summed together.

USER SELECTION OF AC PARAMETERS FOR COMPARATOR ELEMENTS:

CT/VT modules automatically calculate all current and voltage parameters that can be calculated from the inputs available. Users will have to select the specific input parameters that are to be measured by every element, as selected in the element settings. The internal design of the element specifies which type of parameter to use and provides a setting for selection of the Source. In some elements where the parameter may be either fundamental or RMS magnitude, such as phase time overcurrent, two settings are provided. One setting specifies the Source, the second selects between fundamental phasor and RMS.

AC INPUT ACTUAL VALUES:

The calculated parameters associated with the configured voltage and current inputs are displayed in the current and voltage input sections of Actual Values. Only the phasor quantities associated with the actual AC physical input channels will be displayed here. All parameters contained within a configured Source are displayed in the Sources section of Actual Values.

DISTURBANCE DETECTORS (Internal):

The 50DD element is a sensitive current disturbance detector that is used to detect any disturbance on the protected system. 50DD 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 every Source.

The 50DD function responds to the changes in magnitude of the sequence currents.

The disturbance detector scheme logic is as follows:

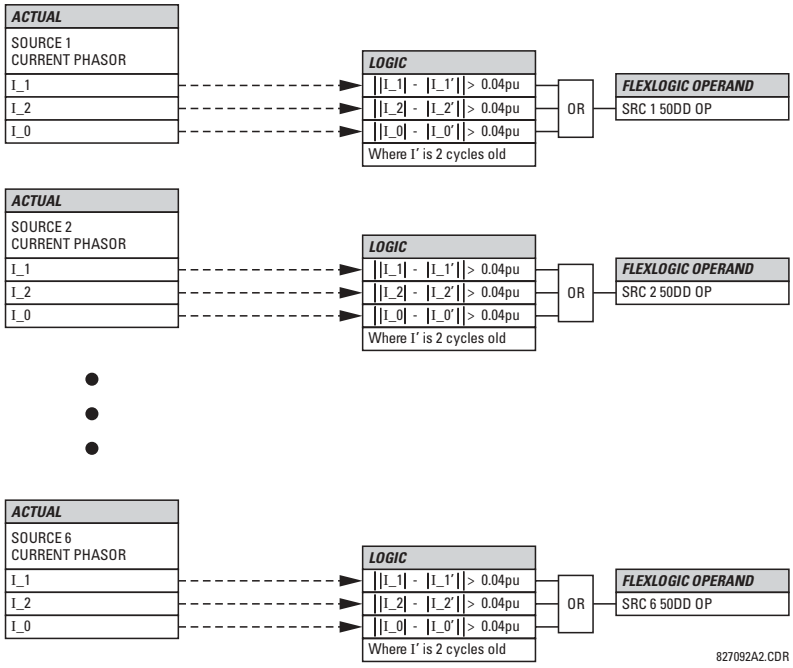


Figure 5–3: DISTURBANCE DETECTOR LOGIC DIAGRAM

EXAMPLE USE OF SOURCES:

An example of the use of Sources, with a relay with three CT/VT modules, is shown in the diagram below. A relay could have the following hardware configuration:

INCREASING SLOT POSITION LETTER -->		
CT/VT MODULE 1	**CT/VT MODULE 2**	**CT/VT MODULE 3**
CTs	CTs	VTs
CTs	VTs	---

This configuration could be used on a two winding transformer, with one winding 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 CT/VT inputs that are used to provide the data.

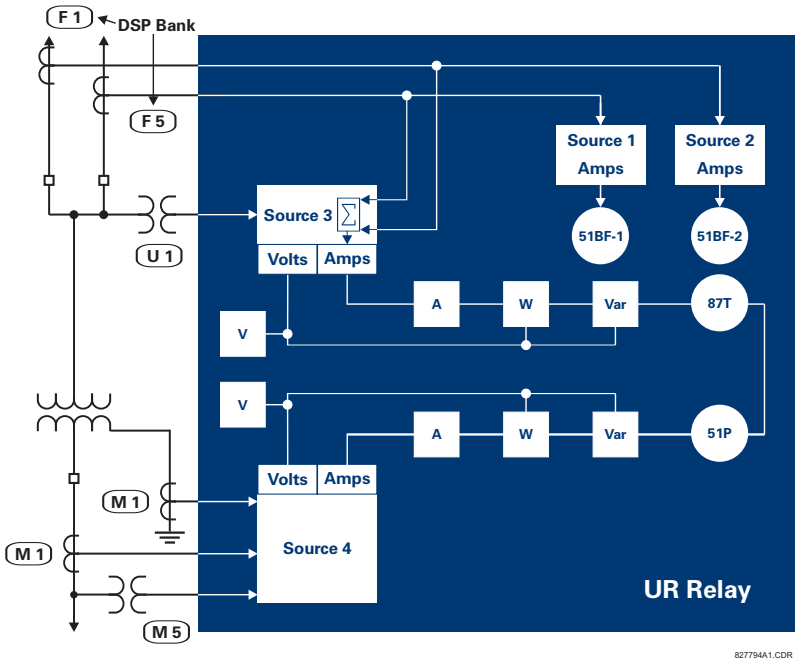


Figure 5–4: EXAMPLE USE OF SOURCES

5.3.4 L90 POWER SYSTEM

PATH: SETTINGS ⇨⇩ POWER SYSTEM ⇨⇩ L90 POWER SYSTEM

■ L90 POWER SYSTEM ■	◀▶	NUMBER OF TERMINALS: 2	*Range: 2, 3*
MESSAGE	▲▼	NUMBER OF CHANNELS: 1	*Range: 1, 2*
MESSAGE	▲▼	CHARGING CURRENT COMPENSATN: Disabled	*Range: Disabled, Enabled*
MESSAGE	▲▼	POS SEQ CAPACITIVE REACTANCE: 0.100 kΩ	*Range: 0.100 to 65.535 kΩ in steps of 0.001*
MESSAGE	▲▼	ZERO SEQ CAPACITIVE REACTANCE: 0.100 kΩ	*Range: 0.100 to 65.535 kΩ in steps of 0.001*
MESSAGE	▲▼	ZERO SEQ CURRENT REMOVAL: Disabled	*Range: Disabled, Enabled*
MESSAGE	▲▼	LOCAL RELAY ID NUMBER: 0	*Range: 0 to 255 in steps of 1*
MESSAGE	▲▼	TERMINAL 1 RELAY ID NUMBER: 0	*Range: 0 to 255 in steps of 1*
MESSAGE	▲	TERMINAL 2 RELAY ID NUMBER: 0	*Range: 0 to 255 in steps of 1*

NUMBER OF TERMINALS:

This setting is the number of the terminals of the associated protected line.

NUMBER OF CHANNELS:

This setting should correspond to the type of communications module installed. If the relay is applied on two terminal lines with a single communications channel, this setting should be selected as "1". For a two terminal line with a second redundant channel for increased dependability, or for three terminal line applications, this setting should be selected as "2".

CHARGING CURRENT COMPENSATION:

This setting enables/disables the charging current calculations and corrections of current phasors. The following diagram shows possible configurations.

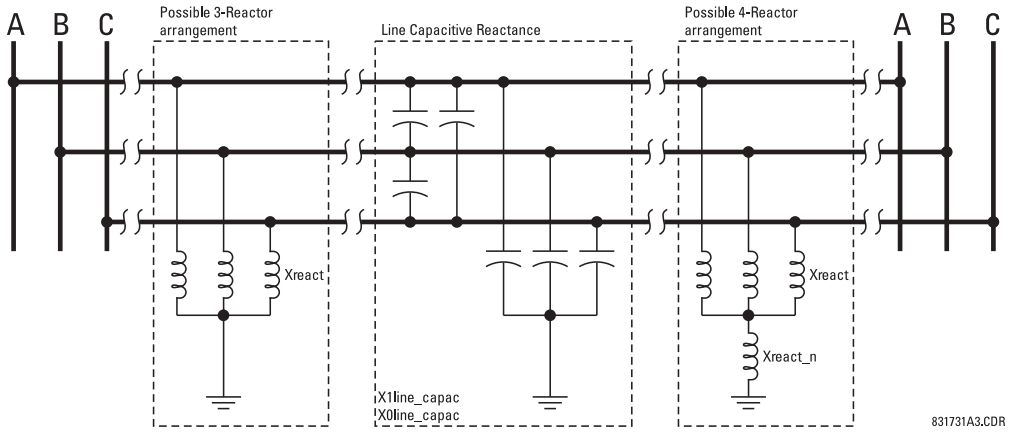


Figure 5–5: CHARGING CURRENT COMPENSATION CONFIGURATIONS

POSITIVE & ZERO SEQUENCE CAPACITIVE REACTANCE:

The values of positive and zero sequence capacitive reactance of the protected line are required for charging current compensation calculations. The line capacitive reactance values should be entered in *primary kOhms* for the total line length. Details of the charging current compensation algorithm can be found in the THEORY OF OPERATION chapter.

If shunt reactors are also installed on the line, the resulting value entered in the POSITIVE and ZERO SEQUENCE CAPACITIVE REACTANCE settings should be calculated as follows:

1. **3-reactor arrangement:** three identical line reactors (X_{react}) solidly connected phase to ground:

$$X_{C1} = \frac{X_{1line\_capac} \cdot X_{react}}{X_{react} - X_{1line\_capac}} \quad , X_{C0} = \frac{X_{0line\_capac} \cdot X_{react}}{X_{react} - X_{0line\_capac}}$$

2. **4-reactor arrangement:** three identical line reactors (X_{react}) wye-connected with the fourth reactor (X_{react_n}) connected between reactor-bank neutral and the ground.

$$X_{C1} = \frac{X_{1line\_capac} \cdot X_{react}}{X_{react} - X_{1line\_capac}} \quad , X_{C0} = \frac{X_{0line\_capac} \cdot (X_{react} + 3X_{react\_n})}{X_{react} + 3X_{react\_n} - X_{0line\_capac}} \quad \text{, where:}$$

X_{1line_capac} = the total line positive sequence capacitive reactance
X_{0line_capac} = the total line zero sequence capacitive reactance
X_{react} = the total reactor inductive reactance per phase. If reactors are installed at both ends of the line and are identical, the value of the inductive reactance is divided by 2 (or 3 for a 3-terminal line) before using in the above equations. If the reactors installed at both ends of the line are different, the following equations apply:

1. **For 2 terminal line:** $X_{react} = 1 \Big/ \left(\frac{1}{X_{react\_terminal1}} + \frac{1}{X_{react\_terminal2}} \right)$
2. **For 3 terminal line:** $X_{react} = 1 \Big/ \left(\frac{1}{X_{react\_terminal1}} + \frac{1}{X_{react\_terminal2}} + \frac{1}{X_{react\_terminal3}} \right)$

X_{react_n} = the total neutral reactor inductive reactance. If reactors are installed at both ends of the line and are identical, the value of the inductive reactance is divided by 2 (or 3 for a 3-terminal line) before using in the above equations. If the reactors installed at both ends of the line are different, the following equations apply:

1. **For 2 terminal line:** $X_{react} = 1 \Big/ \left(\frac{1}{X_{react\_n\_terminal1}} + \frac{1}{X_{react\_n\_terminal2}} \right)$

2. **For 3 terminal line:** $X_{react} = 1 \Big/ \left(\frac{1}{X_{react\_terminal1}} + \frac{1}{X_{react\_terminal2}} + \frac{1}{X_{react\_terminal3}} \right)$

NOTE

Charging current compensation calculations should be performed for an arrangement where the VTs are connected to the line side of the circuit; otherwise, opening the breaker at one end of the line will cause a calculation error.

NOTE

Differential current is significantly decreased when the **CHARGING CURRENT COMPENSATION** setting is "Enabled" and the proper reactance values are entered. The effect of charging current compensation can be viewed in the **METERING ⇨⇩ 87L DIFFERENTIAL CURRENT** actual values menu. This effect is very dependent on CT and VT accuracy.

ZERO-SEQUENCE CURRENT REMOVAL:

This setting facilitates application of the L90 to transmission lines with tapped transformer(s) without current measurement at the tap(s). If the tapped transformer is connected in a grounded wye on the line side, it becomes a source of the zero-sequence current for external ground faults. As the transformer current is not measured by the L90 protection system, the zero-sequence current would create a spurious differential signal and may cause a false trip.

This setting, if enabled, forces the L90 relays to remove the zero-sequence current from the phase currents prior to forming their differential signals. This ensures stability of the L90 protection on external ground faults. Removal of the zero-sequence current may, however, cause the relays to trip all three phases for internal ground faults. Consequently, a phase selective operation of the L90 system is not retained if the setting is enabled. This does not impose any limitation, as single-pole tripping is not recommended for lines with tapped transformers.

Refer to the APPLICATION OF SETTINGS chapter for more setting guidelines.

LOCAL (TERMINAL 1 and TERMINAL 2) ID NUMBER:

In installations using multiplexers or modems for communication, it is desirable to ensure the data used by the relays protecting a given line comes from the correct relays. The L90 performs this check by reading the ID number contained in the messages sent by transmitting relays and comparing this ID to the programmed correct ID numbers by the receiving relays. This check is used to block the differential element of a relay, if the channel is inadvertently set to Loopback mode, by recognizing its own ID on a received channel. If an incorrect ID is found on a either channel during normal operation, the FlexLogic™ operand 87 CH1(2) ID FAIL is set, driving the event with the same name. The result of channel identification is also available in **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ VALIDITY OF CHANNEL CONFIGURATION** for commissioning purposes. The default value "0" at local relay ID setting indicates that the channel ID number is not to be checked. Refer to the CURRENT DIFFERENTIAL section in this chapter for additional information.

5.3.5 LINE

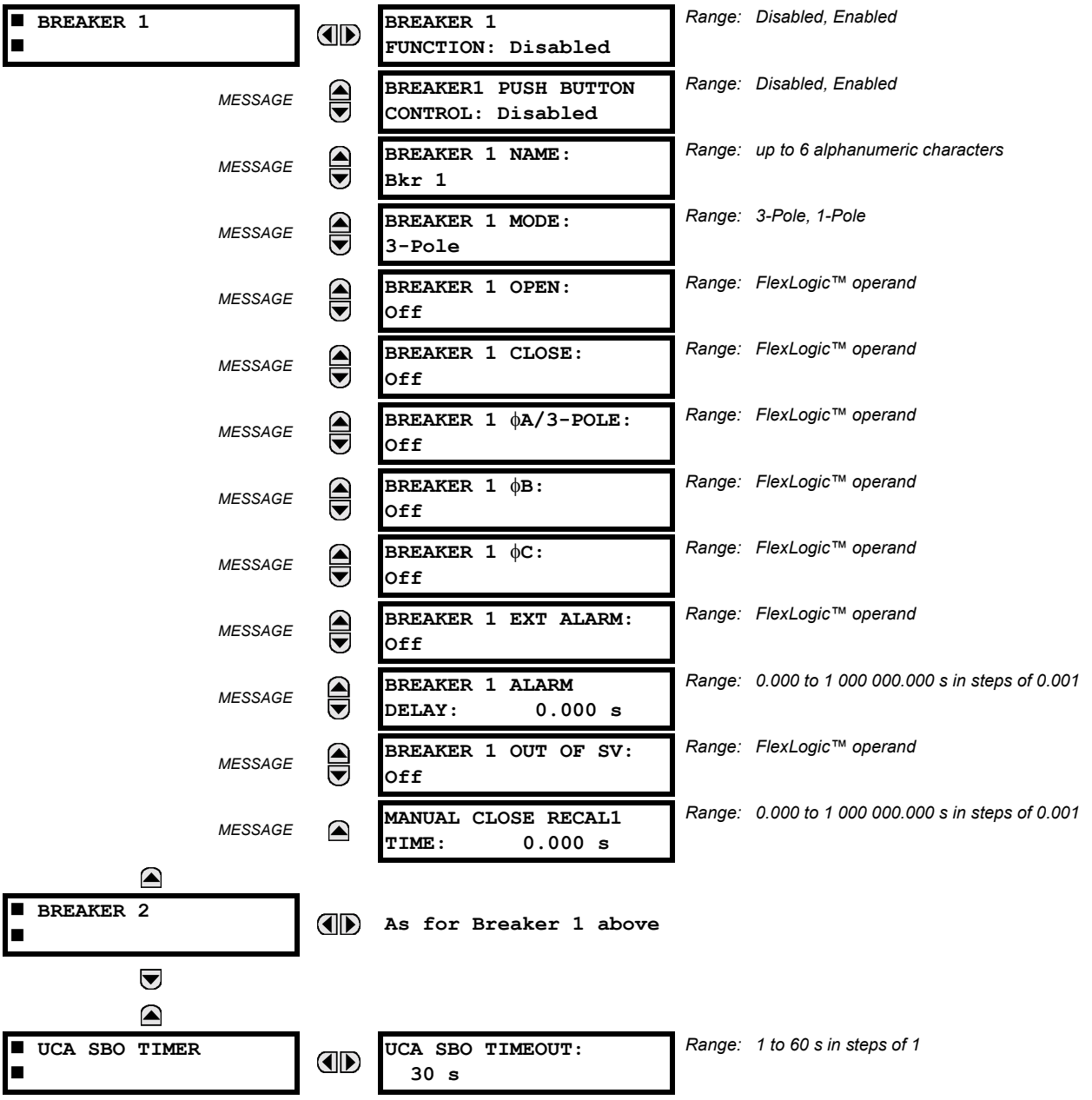
PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ LINE

■ LINE ■	◀▶	POS SEQ IMPEDANCE MAGNITUDE: 3.00 Ω	*Range: 0.01 to 250.00 Ω in steps of 0.01*
MESSAGE	▲▼	POS SEQ IMPEDANCE ANGLE: 75°	*Range: 25 to 90° in steps of 1*
MESSAGE	▲▼	ZERO SEQ IMPEDANCE MAGNITUDE: 9.00 Ω	*Range: 0.01 to 650.00 Ω in steps of 0.01*
MESSAGE	▲▼	ZERO SEQ IMPEDANCE ANGLE: 75°	*Range: 25 to 90° in steps of 1°*
MESSAGE	▲▼	LINE LENGTH UNITS: km	*Range: km, miles*
MESSAGE	▲	LINE LENGTH (km): 100.0	*Range: 0.0 to 2000.0 in steps of 0.1*

These settings specify the characteristics of the line. The line impedance value should be entered as secondary ohms.

This data is used for fault location calculations. See the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FAULT REPORT** menu for assigning the Source and Trigger for fault calculations.

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER 1(2)



A description of the operation of the breaker control and status monitoring features is provided in the HUMAN INTERFACES chapter. Only information concerning programming of the associated settings is covered here. These features are provided for two breakers; a user may use only those portions of the design relevant to a single breaker, which must be breaker No. 1.

BREAKER 1 FUNCTION:

Set to "Enable" to allow the operation of any breaker control feature.

BREAKER1 PUSH BUTTON CONTROL:

Set to "Enable" to allow faceplate push button operations.

BREAKER 1 NAME:

Assign a user-defined name (up to 6 characters) to the breaker. This name will be used in flash messages related to Breaker No. 1.

BREAKER 1 MODE:

Selects "3-pole" mode, where all breaker poles are operated simultaneously, or "1-pole" mode where all breaker poles are operated either independently or simultaneously.

BREAKER 1 OPEN:

Selects an operand that creates a programmable signal to operate an output relay to open Breaker No. 1.

BREAKER 1 CLOSE:

Selects an operand that creates a programmable signal to operate an output relay to close Breaker No. 1.

BREAKER 1 ΦA/3-POLE:

Selects an operand, usually a contact input connected to a breaker auxiliary position tracking mechanism. This input can be either a 52/a or 52/b contact, or a combination the 52/a and 52/b contacts, that must be programmed to create a logic 0 when the breaker is open. If **BREAKER 1 MODE** is selected as "3-Pole", this setting selects a single input as the operand used to track the breaker open or closed position. If the mode is selected as "1-Pole", the input mentioned above is used to track phase A and settings **BREAKER 1 ΦB** and **BREAKER 1 ΦC** select operands to track phases B and C, respectively.

BREAKER 1 ΦB:

If the mode is selected as 3-pole, this setting has no function. If the mode is selected as 1-pole, this input is used to track phase B as above for phase A.

BREAKER 1 ΦC:

If the mode is selected as 3-pole, this setting has no function. If the mode is selected as 1-pole, this input is used to track phase C as above for phase A.

BREAKER 1 EXT ALARM:

Selects an operand, usually an external contact input, connected to a breaker alarm reporting contact.

BREAKER 1 ALARM DELAY:

Sets the delay interval during which a disagreement of status among the three pole position tracking operands will not declare a pole disagreement, to allow for non-simultaneous operation of the poles.

BREAKER 1 OUT OF SV:

Selects an operand indicating that Breaker No. 1 is out-of-service.

MANUAL CLOSE RECAL1 TIME:

Sets the interval required to maintain setting changes in effect after an operator has initiated a manual close command to operate a circuit breaker.

UCA SBO TIMEOUT:

The Select-Before-Operate timer specifies an interval from the receipt of the Breaker Control Select signal (pushbutton USER 1 on the relay faceplate) until the automatic de-selection of the breaker, so that the breaker does not remain selected indefinitely. This setting is active only if **BREAKER PUSHBUTTON CONTROL** is "Enabled".

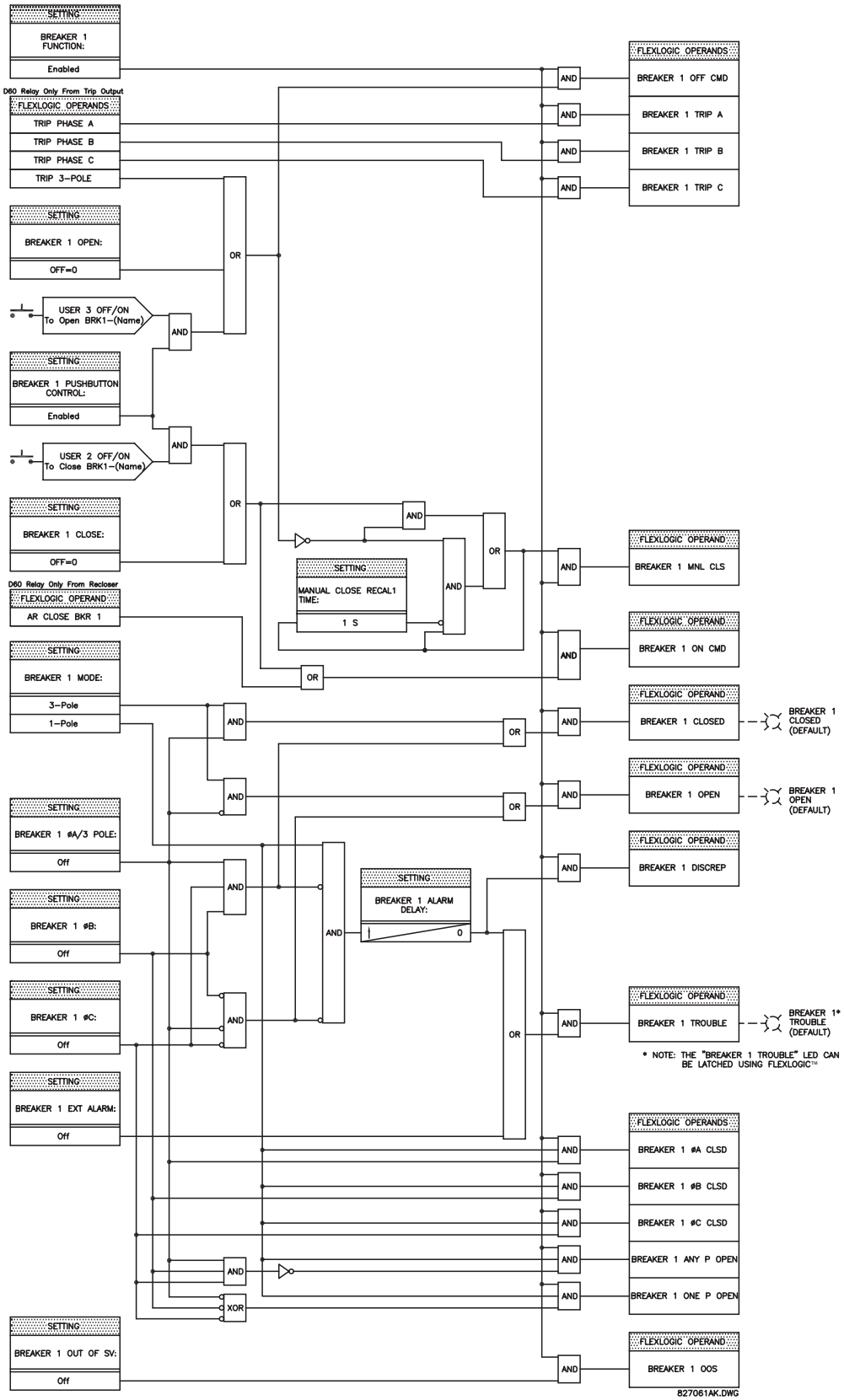


Figure 5–6: DUAL BREAKER CONTROL SCHEME LOGIC

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ FLEXCURVES ⇨ FLEXCURVE A

```
■ FLEXCURVE A
■
```

⇦⇨

```
FLEXCURVE A TIME AT
0.00 xPKP:     0 ms
```

Range: 0 to 65535 ms in steps of 1

FlexCurves™ A and B have settings for entering times to Reset/Operate at the following pickup levels: 0.00 to 0.98 / 1.03 to 20.00. This data is converted into 2 continuous curves by linear interpolation between data points. To enter a custom FlexCurve™, enter the Reset/Operate time (using the ⏶ VALUE ⏷ keys) for each selected pickup point (using the ⏶ MESSAGE ⏷ keys) for the desired protection curve (A or B).

Table 5–9: FLEXCURVE™ TABLE

RESET	TIME MS	RESET	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS
0.00		0.68		1.03		2.9		4.9		10.5	
0.05		0.70		1.05		3.0		5.0		11.0	
0.10		0.72		1.1		3.1		5.1		11.5	
0.15		0.74		1.2		3.2		5.2		12.0	
0.20		0.76		1.3		3.3		5.3		12.5	
0.25		0.78		1.4		3.4		5.4		13.0	
0.30		0.80		1.5		3.5		5.5		13.5	
0.35		0.82		1.6		3.6		5.6		14.0	
0.40		0.84		1.7		3.7		5.7		14.5	
0.45		0.86		1.8		3.8		5.8		15.0	
0.48		0.88		1.9		3.9		5.9		15.5	
0.50		0.90		2.0		4.0		6.0		16.0	
0.52		0.91		2.1		4.1		6.5		16.5	
0.54		0.92		2.2		4.2		7.0		17.0	
0.56		0.93		2.3		4.3		7.5		17.5	
0.58		0.94		2.4		4.4		8.0		18.0	
0.60		0.95		2.5		4.5		8.5		18.5	
0.62		0.96		2.6		4.6		9.0		19.0	
0.64		0.97		2.7		4.7		9.5		19.5	
0.66		0.98		2.8		4.8		10.0		20.0	

NOTE

The relay using a given FlexCurve™ applies linear approximation for times between the user-entered points. Special care must be applied when setting the two points that are close to the multiple of pickup of 1, i.e. 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 the is close to 1.00 pu.

5.4.1 INTRODUCTION TO FLEXLOGIC™

To provide maximum flexibility to the user, the arrangement of internal digital logic combines fixed and user-programmed parameters. 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 relay involved in this process are shown below.

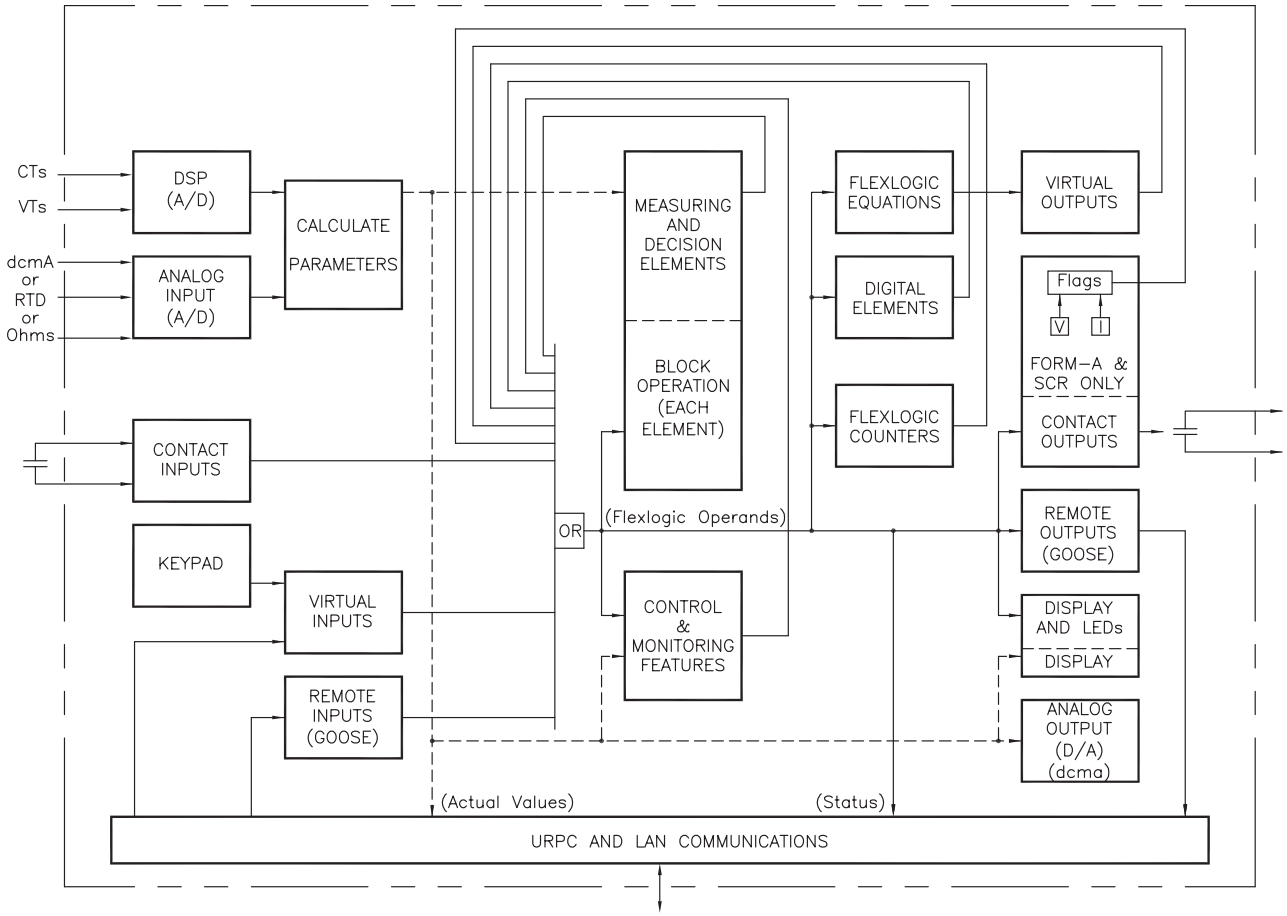


Figure 5–7: UR ARCHITECTURE OVERVIEW

The states of all digital signals used in the UR are represented by flags (or FlexLogic™ operands, which are described later in this section). A digital "1" 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 1 (= ON, i.e. flag set) or 0 (= OFF, i.e. flag not set). Each equation is evaluated at least 4 times every power system cycle.

Some types of operands are present in the relay in multiple instances; e.g. 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 listed in the table: FLEXLOGIC™ OPERAND TYPES.

Table 5–10: UR FLEXLOGIC™ OPERAND TYPES

OPERAND TYPE	STATE	EXAMPLE FORMAT	CHARACTERISTICS [INPUT IS '1' (= ON) IF...]
Contact Input	On	Cont Ip On	Voltage is presently applied to the input (external contact closed).
	Off	Cont Ip Off	Voltage is presently not applied to the input (external contact open).
Contact Output (type Form-A contact only)	Voltage On	Cont Op 1 VOn	Voltage exists across the contact.
	Voltage Off	Cont Op 1 VOff	Voltage does not exists across the contact.
	Current On	Cont Op 1 IOn	Current is flowing through the contact.
	Current Off	Cont Op 1 IOff	Current is not flowing through the contact.
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 above PKP 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	PH DIR1 BLK	The output of the comparator is set to the block function.
Element (Digital)	Pickup	Dig Element 1 PKP	The input operand is at logic 1.
	Dropout	Dig Element 1 DPO	This operand is the logical inverse of the above PKP operand.
	Operate	Dig Element 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.
Element (Digital Counter)	Higher 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.
	Lower than	Counter 1 LO	The number of pulses counted is below the set number.
Fixed	On	On	Logic 1
	Off	Off	Logic 0
Remote Input	On	REMOTE INPUT 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 set state (i.e. evaluation of the equation which produces this virtual output results in a "1").

The operands available for this relay are listed alphabetically by types in the following table.

Table 5–11: L90 FLEXLOGIC™ OPERANDS (Sheet 1 of 5)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: 50DD Supervision	50DD SV	Disturbance Detector is supervising
ELEMENT: 87L Current Differential	87L DIFF OP 87L DIFF OP A 87L DIFF OP B 87L DIFF OP C 87L DIFF RECVD DTT A 87L DIFF RECVD DTT B 87L DIFF RECVD DTT C 87L DIFF KEY DTT 87L DIFF PFLL FAIL 87L DIFF CH1 FAIL 87L DIFF CH2 FAIL 87L DIFF CH1 LOSTPKT 87L DIFF CH2 LOSTPKT 87L DIFF CH1 CRCFAIL 87L DIFF CH2 CRCFAIL 87L DIFF CH1 ID FAIL 87L DIFF CH2 ID FAIL 87L BLOCKED	At least one phase of Current Differential is operated Phase A of Current Differential has operated Phase B of Current Differential has operated Phase C of Current Differential has operated Direct Transfer Trip Phase A has received Direct Transfer Trip Phase B has received Direct Transfer Trip Phase C has received Direct Transfer Trip is keyed Phase & Frequency Lock Loop has failed Channel 1 has failed Channel 2 has failed Exceeded maximum lost packet threshold on channel 1 Exceeded maximum lost packet threshold on channel 2 Exceeded maximum CRC error threshold on channel 1 Exceeded maximum CRC error threshold on channel 2 The ID check for a peer L90 on channel 1 has failed. The ID check for a peer L90 on channel 2 has failed. The 87L function is blocked due to communication problems.
ELEMENT: 87L Differential Trip	87L TRIP OP 87L TRIP OP A 87L TRIP OP B 87L TRIP OP C	At least one phase of Trip Output has operated Phase A of Trip Output has operated Phase B of Trip Output has operated Phase C of Trip Output has operated
ELEMENT: Autoreclose (per CT bank)	AR 1 ENABLED AR 1 RIP AR 1 LO AR 1 BLK FROM MAN CL AR 1 CLOSE AR 1 SHOT CNT=0 ↓ AR 1 SHOT CNT=4 AR 1 DISABLED	Autoreclose 1 is enabled Autoreclose 1 is in progress Autoreclose 1 is locked out Autoreclose 1 is temporarily disabled Autoreclose 1 close command is issued Autoreclose 1 shot count is 0 Autoreclose 1 shot count is 4 Autoreclose 1 is disabled
ELEMENT: Auxiliary OV	AUX OV1 PKP AUX OV1 DPO AUX OV1 OP	Auxiliary Overvoltage element has picked up Auxiliary Overvoltage element has dropped out Auxiliary Overvoltage element has operated
ELEMENT: Auxiliary UV	AUX UV1 PKP AUX UV1 DPO AUX UV1 OP	Auxiliary Undervoltage element has picked up Auxiliary Undervoltage element has dropped out Auxiliary Undervoltage element has operated
ELEMENT: Breaker Arcing	BKR ARC 1 OP BKR ARC 2 OP	Breaker Arcing 1 is operated Breaker Arcing 2 is operated
ELEMENT (Breaker Failure)	BKR FAIL 1 RETRIPA BKR FAIL 1 RETRIPB BKR FAIL 1 RETRIPC BKR FAIL 1 RETRIP BKR FAIL 1 T1 OP BKR FAIL 1 T2 OP BKR FAIL 1 T3 OP BKR FAIL 1 TRIP OP	Breaker Failure 1 re-trip phase A (only for 1-pole schemes) Breaker Failure 1 re-trip phase B (only for 1-pole schemes) Breaker Failure 1 re-trip phase C (only for 1-pole schemes) Breaker Failure 1 re-trip 3-phase Breaker Failure 1 Timer 1 is operated Breaker Failure 1 Timer 2 is operated Breaker Failure 1 Timer 3 is operated Breaker Failure 1 trip is operated
	BKR FAIL 2...	Same set of operands as shown for BKR FAIL 1
ELEMENT: Breaker Control	BREAKER 1 OFF CMD BREAKER 1 ON CMD BREAKER 1 ϕA CLSD BREAKER 1 ϕB CLSD BREAKER 1 ϕC CLSD BREAKER 1 CLOSED BREAKER 1 OPEN BREAKER 1 DISCREP BREAKER 1 TROUBLE BREAKER 1 MNL CLS BREAKER 1 TRIP A BREAKER 1 TRIP B BREAKER 1 TRIP C BREAKER 1 ANY P OPEN BREAKER 1 ONE P OPEN BREAKER 1 OOS	Breaker 1 OFF command Breaker 1 ON command Breaker 1 phase A is closed Breaker 1 phase B is closed Breaker 1 phase C is closed Breaker 1 is closed Breaker 1 is open Breaker 1 has discrepancy Breaker 1 trouble alarm Breaker 1 manual close Breaker 1 trip phase A command Breaker 1 trip phase B command Breaker 1 trip phase C command At least one pole of Breaker 1 is open Only one pole of Breaker 1 is open Breaker 1 is out of service
	BREAKER 2	Same set of operands as shown for BREAKER 1

Table 5–11: L90 FLEXLOGIC™ OPERANDS (Sheet 2 of 5)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: Continuous Monitor	CONT MONITOR PKP CONT MONITOR OP	Continuous monitor has picked up Continuous monitor has operated
ELEMENT: CT Fail	CT FAIL PKP CT FAIL OP	CT Fail has picked up CT Fail has dropped out
ELEMENT: Digital Counter	Counter 1 HI Counter 1 EQL Counter 1 LO ↓ Counter 8 HI Counter 8 EQL Counter 8 LO	Digital Counter 1 output is 'more than' comparison value Digital Counter 1 output is 'equal to' comparison value Digital Counter 1 output is 'less than' comparison value ↓ Digital Counter 8 output is 'more than' comparison value Digital Counter 8 output is 'equal to' comparison value Digital Counter 8 output is 'less than' comparison value
ELEMENT: Digital Element	Dig Element 1 PKP Dig Element 1 OP Dig Element 1 DPO ↓ Dig Element 16 PKP Dig Element 16 OP Dig Element 16 DPO	Digital Element 1 is picked up Digital Element 1 is operated Digital Element 1 is dropped out ↓ Digital Element 16 is picked up Digital Element 16 is operated Digital Element 16 is dropped out
ELEMENT: Disturbance Detector	SRCx 50DD OP	Source x Disturbance Detector is operated
ELEMENT: FlexElements™	FLEXELEMENT 1 PKP FLEXELEMENT 1 OP FLEXELEMENT 1 DPO ↓ FLEXELEMENT 8 PKP FLEXELEMENT 8 OP FLEXELEMENT 8 DPO	FlexElement 1 has picked up FlexElement 1 has operated FlexElement 1 has dropped out ↓ FlexElement 8 has picked up FlexElement 8 has operated FlexElement 8 has dropped out
ELEMENT: Ground Distance	GND DIST Z2 PKP GND DIST Z2 OP GND DIST Z2 OP A GND DIST Z2 OP B GND DIST Z2 OP C GND DIST Z2 PKP A GND DIST Z2 PKP B GND DIST Z2 PKP C GND DIST Z2 SUPN IN GND DIST Z2 DIR SUPN GND DIST Z2 DPO A GND DIST Z2 DPO B GND DIST Z2 DPO C	Ground Distance Zone 2 has picked up Ground Distance Zone 2 has operated Ground Distance Zone 2 phase A has operated Ground Distance Zone 2 phase B has operated Ground Distance Zone 2 phase C has operated Ground Distance Zone 2 phase A has picked up Ground Distance Zone 2 phase B has picked up Ground Distance Zone 2 phase C has picked up Ground Distance Zone 2 neutral is supervising Ground Distance Zone 2 Directional is supervising Ground Distance Zone 2 phase A has dropped out Ground Distance Zone 2 phase B has dropped out Ground Distance Zone 2 phase C has dropped out
ELEMENT: Ground IOC	GROUND IOC1 PKP GROUND IOC1 OP GROUND IOC1 DPO	Ground Instantaneous Overcurrent 1 has picked up Ground Instantaneous Overcurrent 1 has operated Ground Instantaneous Overcurrent 1 has dropped out
	GROUND IOC2	Same set of operands as shown for GROUND IOC 1
ELEMENT: Ground TOC	GROUND TOC1 PKP GROUND TOC1 OP GROUND TOC1 DPO	Ground Time Overcurrent 1 has picked up Ground Time Overcurrent 1 has operated Ground Time Overcurrent 1 has dropped out
	GROUND TOC2	Same set of operands as shown for GROUND TOC1
ELEMENT: Line Pickup	LINE PICKUP OP LINE PICKUP PKP LINE PICKUP DPO LINE PICKUP UV PKP LINE PICKUP LEO PKP	Line Pickup has operated Line Pickup has picked up Line Pickup has dropped out Line Pickup Undervoltage has picked up Line Pickup Line End Open has picked up
ELEMENT: Load Encroachment	LOAD ENCRMNT PKP LOAD ENCRMNT OP LOAD ENCRMNT DPO	Load Encroachment has picked up Load Encroachment has operated Load Encroachment has dropped out
ELEMENT: Negative Sequence IOC	NEG SEQ IOC1 PKP NEG SEQ IOC1 OP NEG SEQ IOC1 DPO	Negative Sequence Instantaneous Overcurrent 1 has picked up Negative Sequence Instantaneous Overcurrent 1 has operated Negative Sequence Instantaneous Overcurrent 1 has dropped out
	NEG SEQ IOC2	Same set of operands as shown for NEG SEQ IOC1
ELEMENT: Negative Sequence TOC	NEG SEQ TOC1 PKP NEG SEQ TOC1 OP NEG SEQ TOC1 DPO	Negative Sequence Time Overcurrent 1 has picked up Negative Sequence Time Overcurrent 1 has operated Negative Sequence Time Overcurrent 1 has dropped out
	NEG SEQ TOC2	Same set of operands as shown for NEG SEQ TOC1

Table 5–11: L90 FLEXLOGIC™ OPERANDS (Sheet 3 of 5)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: Neutral IOC	NEUTRAL IOC1 PKP NEUTRAL IOC1 OP NEUTRAL IOC1 DPO	Neutral Instantaneous Overcurrent 1 has picked up Neutral Instantaneous Overcurrent 1 has operated Neutral Instantaneous Overcurrent 1 has dropped out
	NEUTRAL IOC2	Same set of operands as shown for NEUTRAL IOC1
ELEMENT: Neutral OV	NEUTRAL OV1 PKP NEUTRAL OV1 DPO NEUTRAL OV1 OP	Neutral Overvoltage element has picked up Neutral Overvoltage element has dropped out Neutral Overvoltage element has operated
ELEMENT: Neutral TOC	NEUTRAL TOC1 PKP NEUTRAL TOC1 OP NEUTRAL TOC1 DPO	Neutral Time Overcurrent 1 has picked up Neutral Time Overcurrent 1 has operated Neutral Time Overcurrent 1 has dropped out
	NEUTRAL TOC2	Same set of operands as shown for NEUTRAL TOC1
ELEMENT: Neutral Directional	NTRL DIR OC1 FWD NTRL DIR OC1 REV	Neutral Directional OC1 Forward has operated Neutral Directional OC1 Reverse has operated
	NTRL DIR OC2	Same set of operands as shown for NTRL DIR OC1
ELEMENT: Open Pole Detector	OPEN POLE OP ΦA OPEN POLE OP ΦB OPEN POLE OP ΦC OPEN POLE OP	Open pole condition is detected in phase A Open pole condition is detected in phase B Open pole condition is detected in phase C Open pole detector is operated
ELEMENT: Phase Directional	PH DIR1 BLK A PH DIR1 BLK B PH DIR1 BLK C PH DIR1 BLK	Phase A Directional 1 Block Phase B Directional 1 Block Phase C Directional 1 Block Phase Directional 1 Block
	PH DIR2	Same set of operands as shown for PH DIR1
ELEMENT: Phase Distance	PH DIST Z2 PKP PH DIST Z2 OP PH DIST Z2 OP AB PH DIST Z2 OP BC PH DIST Z2 OP CA PH DIST Z2 PKP AB PH DIST Z2 PKP BC PH DIST Z2 PKP CA PH DIST Z2 SUPN IAB PH DIST Z2 SUPN IBC PH DIST Z2 SUPN ICA PH DIST Z2 DPO AB PH DIST Z2 DPO BC PH DIST Z2 DPO CA	Phase Distance Zone 2 has picked up Phase Distance Zone 2 has operated Phase Distance Zone 2 phase AB has operated Phase Distance Zone 2 phase BC has operated Phase Distance Zone 2 phase CA has operated Phase Distance Zone 2 phase AB has picked up Phase Distance Zone 2 phase BC has picked up Phase Distance Zone 2 phase CA has picked up Phase Distance Zone 2 phase AB IOC is supervising Phase Distance Zone 2 phase BC IOC is supervising Phase Distance Zone 2 phase CA IOC is supervising Phase Distance Zone 2 phase AB has dropped out Phase Distance Zone 2 phase BC has dropped out Phase Distance Zone 2 phase CA has dropped out
ELEMENT: Phase IOC	PHASE IOC1 PKP PHASE IOC1 OP PHASE IOC1 DPO PHASE IOC1 PKP A PHASE IOC1 PKP B PHASE IOC1 PKP C PHASE IOC1 OP A PHASE IOC1 OP B PHASE IOC1 OP C PHASE IOC1 DPO A PHASE IOC1 DPO B PHASE IOC1 DPO C	At least one phase of PHASE IOC1 has picked up At least one phase of PHASE IOC1 has operated At least one phase of PHASE IOC1 has dropped out Phase A of PHASE IOC1 has picked up Phase B of PHASE IOC1 has picked up Phase C of PHASE IOC1 has picked up Phase A of PHASE IOC1 has operated Phase B of PHASE IOC1 has operated Phase C of PHASE IOC1 has operated Phase A of PHASE IOC1 has dropped out Phase B of PHASE IOC1 has dropped out Phase C of PHASE IOC1 has dropped out
	PHASE IOC2	Same set of operands as shown for PHASE IOC1
ELEMENT: Phase OV	PHASE OV1 PKP PHASE OV1 OP PHASE OV1 DPO PHASE OV1 PKP A PHASE OV1 PKP B PHASE OV1 PKP C PHASE OV1 OP A PHASE OV1 OP B PHASE OV1 OP C PHASE OV1 DPO A PHASE OV1 DPO B PHASE OV1 DPO C	At least one phase of OV1 has picked up At least one phase of OV1 has operated At least one phase of OV1 has dropped out Phase A of OV1 has picked up Phase B of OV1 has picked up Phase C of OV1 has picked up Phase A of OV1 has operated Phase B of OV1 has operated Phase C of OV1 has operated Phase A of OV1 has dropped out Phase B of OV1 has dropped out Phase C of OV1 has dropped out

Table 5–11: L90 FLEXLOGIC™ OPERANDS (Sheet 4 of 5)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: Phase TOC	PHASE TOC1 PKP PHASE TOC1 OP PHASE TOC1 DPO PHASE TOC1 PKP A PHASE TOC1 PKP B PHASE TOC1 PKP C PHASE TOC1 OP A PHASE TOC1 OP B PHASE TOC1 OP C PHASE TOC1 DPO A PHASE TOC1 DPO B PHASE TOC1 DPO C	At least one phase of PHASE TOC1 has picked up At least one phase of PHASE TOC1 has operated At least one phase of PHASE TOC1 has dropped out Phase A of PHASE TOC1 has picked up Phase B of PHASE TOC1 has picked up Phase C of PHASE TOC1 has picked up Phase A of PHASE TOC1 has operated Phase B of PHASE TOC1 has operated Phase C of PHASE TOC1 has operated Phase A of PHASE TOC1 has dropped out Phase B of PHASE TOC1 has dropped out Phase C of PHASE TOC1 has dropped out
	PHASE TOC2	Same set of operands as shown for PHASE TOC1
ELEMENT: Phase UV	PHASE UV1 PKP PHASE UV1 OP PHASE UV1 DPO PHASE UV1 PKP A PHASE UV1 PKP B PHASE UV1 PKP C PHASE UV1 OP A PHASE UV1 OP B PHASE UV1 OP C PHASE UV1 DPO A PHASE UV1 DPO B PHASE UV1 DPO C	At least one phase of UV1 has picked up At least one phase of UV1 has operated At least one phase of UV1 has dropped out Phase A of UV1 has picked up Phase B of UV1 has picked up Phase C of UV1 has picked up Phase A of UV1 has operated Phase B of UV1 has operated Phase C of UV1 has operated Phase A of UV1 has dropped out Phase B of UV1 has dropped out Phase C of UV1 has dropped out
	PHASE UV2	Same set of operands as shown for PHASE UV1
ELEMENT: POTT	POTT OP POTT TX	Permissive over-reaching transfer trip has operated Permissive signal sent
ELEMENT: Power Swing Detect	POWER SWING OUTER POWER SWING MIDDLE POWER SWING INNER POWER SWING BLOCK POWER SWING TMRX PKP POWER SWING TRIP	Positive Sequence impedance in outer characteristic Positive Sequence impedance in middle characteristic Positive Sequence impedance in inner characteristic Power Swing Blocking element operated Power Swing Timer X picked up Out-of-step Tripping operated
ELEMENT: Setting Group	SETTING GROUP ACT 1 ↓ SETTING GROUP ACT 8	Setting group 1 is active ↓ Setting group 8 is active
ELEMENT: Stub Bus	STUB BUS OP	Stub Bus is operated
ELEMENT: Synchrocheck	SYNC 1 DEAD S OP SYNC 1 DEAD S DPO SYNC 1 SYNC OP SYNC 1 SYNC DPO SYNC 1 CLS OP SYNC 1 CLS DPO	Synchrocheck 1 dead source has operated Synchrocheck 1 dead source has dropped out Synchrocheck 1 in synchronization has operated Synchrocheck 1 in synchronization has dropped out Synchrocheck 1 close has operated Synchrocheck 1 close has dropped out
	SYNC 2	Same set of operands as shown for SYNC 1
ELEMENT: VTFF	SRCx VT FUSE F OP SRCx VT FUSE F DPO	Source x VT Fuse Failure detector has operated Source x VT Fuse Failure detector has dropped out
FIXED OPERANDS	Off	Logic = 0. Does nothing and may be used as a delimiter in an equation list; used as 'Disable' by other features.
	On	Logic = 1. Can be used as a test setting.
INPUTS/OUTPUTS: Contact Inputs	Cont Ip 1 On Cont Ip 2 On ↓ Cont Ip 1 Off Cont Ip 2 Off ↓	(will not appear unless ordered) (will not appear unless ordered) ↓ (will not appear unless ordered) (will not appear unless ordered) ↓
INPUTS/OUTPUTS: Contact Outputs, Current (from detector on Form-A output only)	Cont Op 1 IOn Cont Op 2 IOn ↓	(will not appear unless ordered) (will not appear unless ordered) ↓
	Cont Op 1 IOff Cont Op 2 IOff ↓	(will not appear unless ordered) (will not appear unless ordered) ↓

Table 5–11: L90 FLEXLOGIC™ OPERANDS (Sheet 5 of 5)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
INPUTS/OUTPUTS: Contact Outputs, Voltage (from detector on Form-A output only)	Cont Op 1 VOn Cont Op 2 VOn ↓	(will not appear unless ordered) (will not appear unless ordered) ↓
	Cont Op 1 VOff Cont Op 2 VOff ↓	(will not appear unless ordered) (will not appear unless ordered) ↓
INPUTS/OUTPUTS: Direct Input	Direct I/P 1-1 On ↓ Direct I/P 1-8 On	(appears only when L90 Comm card is used) ↓ (appears only when L90 Comm card is used)
	Direct I/P 2-1 On ↓ Direct I/P 2-8 On	(appears only when L90 Comm card is used) ↓ (appears only when L90 Comm card is used)
INPUTS/OUTPUTS: Remote Inputs	REMOTE INPUT 1 On ↓ REMOTE INPUT 32 On	Flag is set, logic=1 ↓ Flag is set, logic=1
INPUTS/OUTPUTS: Virtual Inputs	Virt Ip 1 On ↓ Virt Ip 32 On	Flag is set, logic=1 ↓ Flag is set, logic=1
INPUTS/OUTPUTS: Virtual Outputs	Virt Op 1 On ↓ Virt Op 64 On	Flag is set, logic=1 ↓ Flag is set, logic=1
REMOTE DEVICES	REMOTE DEVICE 1 On ↓ REMOTE DEVICE 16 On	Flag is set, logic=1 ↓ Flag is set, logic=1
	REMOTE DEVICE 1 Off ↓ REMOTE DEVICE 16 Off	Flag is set, logic=1 ↓ Flag is set, logic=1
RESETTING	RESET OP RESET OP (COMMS) RESET OP (OPERAND) RESET OP (PUSHBUTTON)	Reset command is operated (set by all 3 operands below) Communications source of the reset command Operand source of the reset command Reset key (pushbutton) source of the reset command
SELF-DIAGNOSTICS	ANY MAJOR ERROR ANY MINOR ERROR ANY SELF-TEST LOW ON MEMORY WATCHDOG ERROR PROGRAM ERROR EEPROM DATA ERROR PRI ETHERNET FAIL SEC ETHERNET FAIL BATTERY FAIL SYSTEM EXCEPTION UNIT NOT PROGRAMMED EQUIPMENT MISMATCH FLEXLGC ERROR TOKEN PROTOTYPE FIRMWARE UNIT NOT CALIBRATED NO DSP INTERRUPTS DSP ERROR IRIG-B FAILURE REMOTE DEVICE OFFLINE	Any of the major self-test errors generated (major error) Any of the minor self-test errors generated (minor error) Any self-test errors generated (generic, any error) See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter.

Some operands can be re-named by the user. These are the names of the breakers in the breaker control feature, the ID (identification) of contact inputs, the ID of virtual inputs, and the ID of virtual outputs. If the user changes the default name/ ID of any of these operands, the assigned name will appear in the relay list of operands. The default names are shown in the FLEXLOGIC™ OPERANDS table above.

The characteristics of the logic gates are tabulated below, and the operators available in FlexLogic™ are listed in the FLEX-LOGIC™ OPERATORS table.

Table 5–12: FLEXLOGIC™ GATE CHARACTERISTICS

GATES	NUMBER OF INPUTS	OUTPUT IS '1' (= ON) IF...
NOT	1	input is '0'
OR	2 to 16	any input is '1'
AND	2 to 16	all inputs are '1'
NOR	2 to 16	all inputs are '0'
NAND	2 to 16	any input is '0'
XOR	2	only one input is '1'

Table 5–13: FLEXLOGIC™ OPERATORS

OPERATOR TYPE	OPERATOR SYNTAX	DESCRIPTION	NOTES
Editor	INSERT	Insert a parameter in an equation list.	
	DELETE	Delete a parameter from an equation list.	
End	END	The first END encountered signifies the last entry in the list of FlexLogic™ parameters that is processed.	
One Shot	POSITIVE ONE SHOT	One shot that responds 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 is a maximum of 32 'one shots'.
	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.	
Logic Gate	NOT	Logical Not	Operates on the previous parameter.
	OR(2) ↓ OR(16)	2 input OR gate ↓ 16 input OR gate	Operates on the 2 previous parameters. ↓ Operates on the 16 previous parameters.
	AND(2) ↓ AND(16)	2 input AND gate ↓ 16 input AND gate	Operates on the 2 previous parameters. ↓ Operates on the 16 previous parameters.
	NOR(2) ↓ NOR(16)	2 input NOR gate ↓ 16 input NOR gate	Operates on the 2 previous parameters. ↓ Operates on the 16 previous parameters.
	NAND(2) ↓ NAND(16)	2 input NAND gate ↓ 16 input NAND gate	Operates on the 2 previous parameters. ↓ Operates on the 16 previous parameters.
	XOR(2)	2 input Exclusive OR gate	Operates on the 2 previous parameters.
	LATCH (S,R)	Latch (Set, Reset) - reset-dominant	The parameter preceding LATCH(S,R) is the Reset input. The parameter preceding the Reset input is the Set input.
Timer	TIMER 1 ↓ TIMER 32	Timer as configured with FlexLogic™ Timer 1 settings. ↓ Timer as configured with FlexLogic™ Timer 32 settings.	The timer is started by the preceding parameter. The output of the timer is TIMER #.
Assign Virtual Output	= Virt Op 1 ↓ = Virt Op 64	Assigns previous FlexLogic™ parameter to Virtual Output 1. ↓ Assigns previous FlexLogic™ parameter to Virtual Output 64.	The virtual output is set by the preceding parameter

5.4.2 FLEXLOGIC™ RULES

When forming a FlexLogic™ equation, the sequence in the linear array of parameters must follow these general rules:

1. Operands must precede the operator which uses the operands as inputs.
2. 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 an operator to a Virtual Output terminates the equation.
4. A timer operator (e.g. "TIMER 1") or virtual output assignment (e.g. " = Virt Op 1") may only be used once. If this rule is broken, a syntax error will be declared.

5.4.3 FLEXLOGIC™ EVALUATION

Each equation is evaluated in the order in which the parameters have been entered.

CAUTION

FLEXLOGIC™ PROVIDES LATCHES WHICH BY DEFINITION HAVE A MEMORY ACTION, REMAINING IN THE SET STATE AFTER THE SET INPUT HAS BEEN ASSERTED. HOWEVER, THEY ARE VOLATILE; I.E. THEY RESET ON THE RE-APPLICATION OF CONTROL POWER.

WHEN MAKING CHANGES TO PROGRAMMING, ALL FLEXLOGIC™ EQUATIONS ARE RE-COMPILED WHEN ANY NEW SETTING IS ENTERED, SO ALL LATCHES ARE AUTOMATICALLY RESET. IF IT IS REQUIRED TO RE-INITIALIZE FLEXLOGIC™ DURING TESTING, FOR EXAMPLE, IT IS SUGGESTED TO POWER THE UNIT DOWN AND THEN BACK UP.

5.4.4 FLEXLOGIC™ PROCEDURE EXAMPLE

This section provides an example of implementing logic for a typical application. The sequence of the steps is quite important as it should minimize the work necessary to develop the relay settings. Note that the example presented in the figure below is intended to demonstrate the procedure, not to solve a specific application situation.

In the example below, it is assumed that logic has already been programmed to produce Virtual Outputs 1 and 2, and is only a part of the full set of equations used. When using FlexLogic™, it is important to make a note of each Virtual Output used – a Virtual Output designation (1 to 64) can only be properly assigned once.

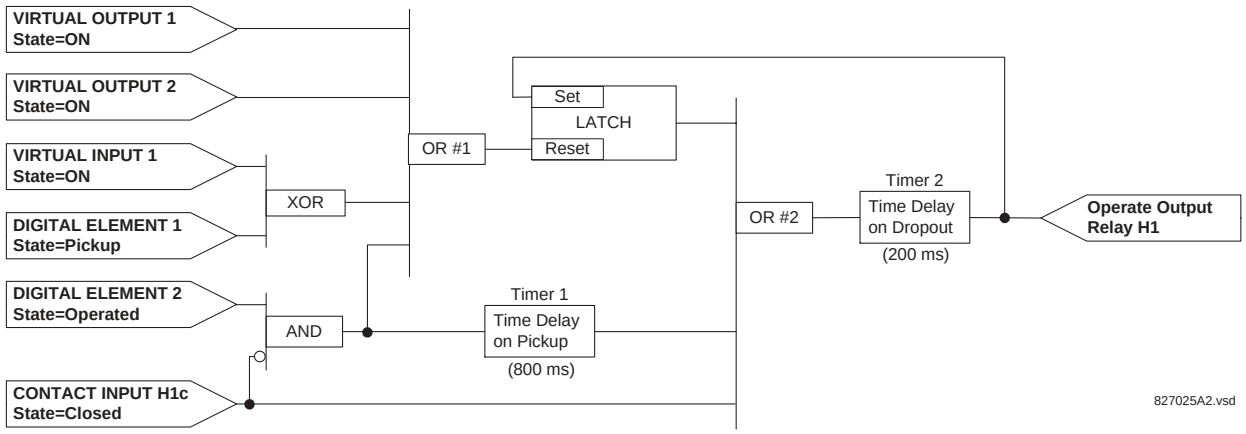


Figure 5–8: EXAMPLE LOGIC SCHEME

1. Inspect the example logic diagram to determine if the required logic can be implemented with the FlexLogic™ operators. If this is not possible, the logic must be altered until this condition is satisfied. Once this is done, count the inputs to each gate to verify that the number of inputs does not exceed the FlexLogic™ limits, which is unlikely but possible. If the number of inputs is too high, subdivide the inputs into multiple gates to produce an equivalent. For example, if 25 inputs to an AND gate are required, connect inputs 1 through 16 to one AND(16), 17 through 25 to another AND(9), and the outputs from these two gates to a third AND(2).

Inspect each operator between the initial operands and final virtual outputs to determine if the output from the operator is used as an input to more than one following operator. If so, the operator output must be assigned as a Virtual Output.

For the example shown above, the output of the AND gate is used as an input to both OR#1 and Timer 1, and must therefore be made a Virtual Output and assigned the next available number (i.e. Virtual Output 3). The final output must also be assigned to a Virtual Output as Virtual Output 4, which will be programmed in the contact output section to operate relay H1 (i.e. Output Contact H1).

Therefore, the required logic can be implemented with two FlexLogic™ equations with outputs of Virtual Output 3 and Virtual Output 4 as shown below.

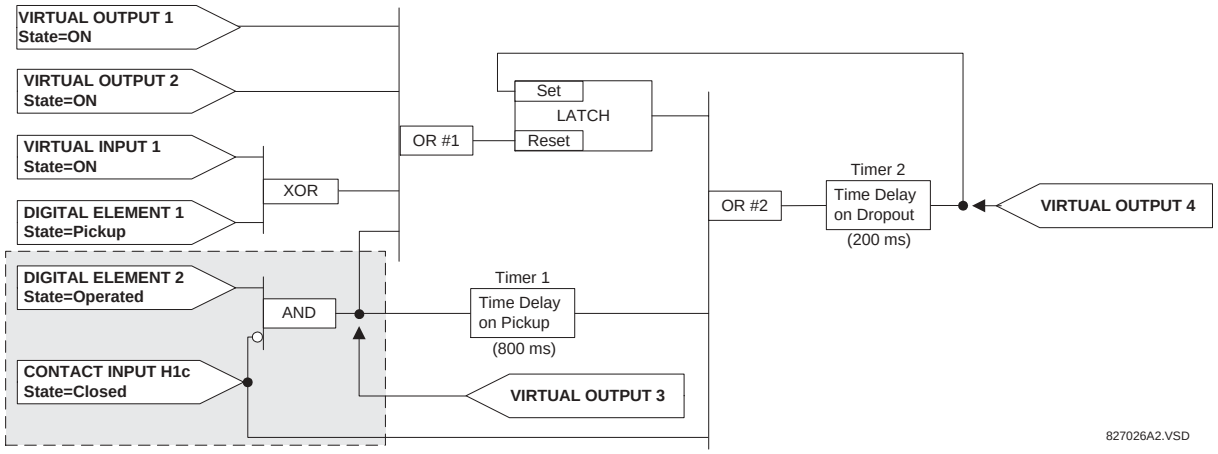


Figure 5–9: LOGIC EXAMPLE WITH VIRTUAL OUTPUTS

2. Prepare a logic diagram for the equation to produce Virtual Output 3, as this output will be used as an operand in the Virtual Output 4 equation (create the equation for every output that will be used as an operand first, so that when these operands are required they will already have been evaluated and assigned to a specific Virtual Output). The logic for Virtual Output 3 is shown below with the final output assigned.

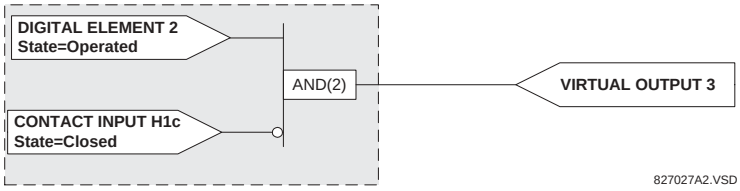


Figure 5–10: LOGIC FOR VIRTUAL OUTPUT 3

3. Prepare a logic diagram for Virtual Output 4, replacing the logic ahead of Virtual Output 3 with a symbol identified as Virtual Output 3, as shown below.

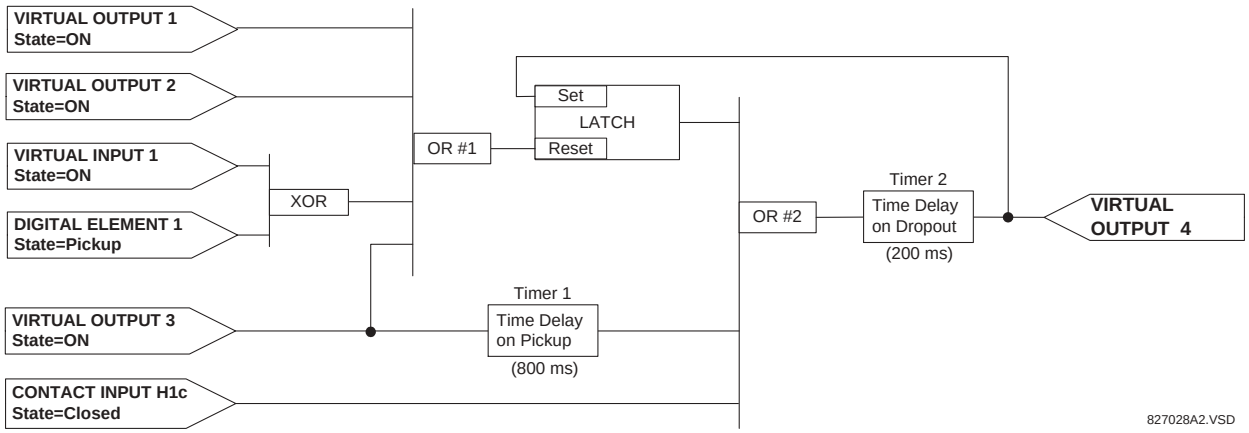


Figure 5–11: LOGIC FOR VIRTUAL OUTPUT 4

4. Program the FlexLogic™ equation for Virtual Output 3 by translating the logic into available FlexLogic™ parameters. The equation is formed one parameter at a time until the required logic is complete. It is generally easier to start at the output end of the equation and work back towards the input, as shown in the following steps. It is also recommended to list operator inputs from bottom to top. For demonstration, the final output will be arbitrarily identified as parameter 99, and each preceding parameter decremented by one in turn. Until accustomed to using FlexLogic™, it is suggested that a worksheet with a series of cells marked with the arbitrary parameter numbers be prepared, as shown below.

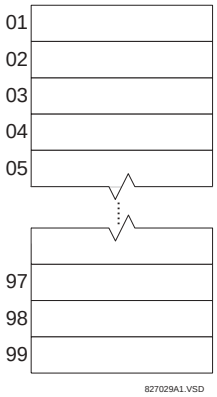


Figure 5–12: FLEXLOGIC™ WORKSHEET

5. Following the procedure outlined, start with parameter 99, as follows:

   99: The final output of the equation is Virtual Output 3, which is created by the operator "= Virt Op n". This parameter is therefore "= Virt Op 3."

   98: The gate preceding the output is an AND, which in this case requires two inputs. The operator for this gate is a 2-input AND so the parameter is “AND(2)”. Note that FlexLogic™ rules require that the number of inputs to most types of operators must be specified to identify the operands for the gate. As the 2-input AND will operate on the two operands preceding it, these inputs must be specified, starting with the lower.

   97: This lower input to the AND gate must be passed through an inverter (the NOT operator) so the next parameter is “NOT”. The NOT operator acts upon the operand immediately preceding it, so specify the inverter input next.

   96: The input to the NOT gate is to be contact input H1c. The ON state of a contact input can be programmed to be set when the contact is either open or closed. Assume for this example the state is to be ON for a closed contact. The operand is therefore "Cont Ip H1c On".

   95: The last step in the procedure is to specify the upper input to the AND gate, the operated state of digital element 2. This operand is "DIG ELEM 2 OP".

   Writing the parameters in numerical order can now form the equation for VIRTUAL OUTPUT 3:

```
[95] DIG ELEM 2 OP
[96] Cont Ip H1c On
[97] NOT
[98] AND(2)
[99] = Virt Op 3
```

It is now possible to check that this selection of parameters will produce the required logic by converting the set of parameters into a logic diagram. The result of this process is shown below, which is compared to figure: LOGIC FOR VIRTUAL OUTPUT 3 as a check.

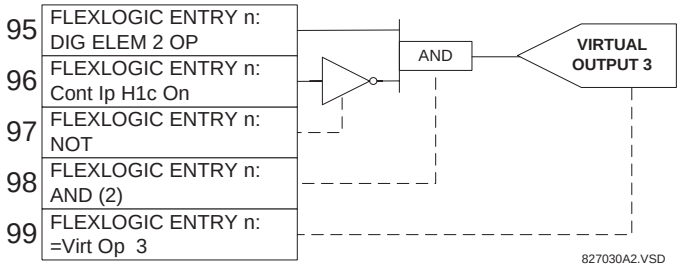


Figure 5–13: FLEXLOGIC™ EQUATION & LOGIC FOR VIRTUAL OUTPUT 3

6. Repeating the process described for VIRTUAL OUTPUT 3, select the FlexLogic™ parameters for Virtual Output 4.

   99: The final output of the equation is VIRTUAL OUTPUT 4 which is parameter “= Virt Op 4".

   98: The operator preceding the output is Timer 2, which is operand “TIMER 2". Note that the settings required for the timer are established in the timer programming section.

   97: The operator preceding Timer 2 is OR #2, a 3-input OR, which is parameter “OR(3)”.

   96: The lowest input to OR #2 is operand “Cont Ip H1c On”.

   95: The center input to OR #2 is operand “TIMER 1".

   94: The input to Timer 1 is operand “Virt Op 3 On".

   93: The upper input to OR #2 is operand “LATCH (S,R)”.

   92: There are two inputs to a latch, and the input immediately preceding the latch reset is OR #1, a 4-input OR, which is parameter “OR(4)”.

   91: The lowest input to OR #1 is operand “Virt Op 3 On".

   90: The input just above the lowest input to OR #1 is operand “XOR(2)”.

   89: The lower input to the XOR is operand “DIG ELEM 1 PKP”.

   88: The upper input to the XOR is operand “Virt Ip 1 On".

   87: The input just below the upper input to OR #1 is operand “Virt Op 2 On".

   86: The upper input to OR #1 is operand “Virt Op 1 On".

   85: The last parameter is used to set the latch, and is operand “Virt Op 4 On".

   The equation for VIRTUAL OUTPUT 4 is:

```
[85] Virt Op 4 On
[86] Virt Op 1 On
[87] Virt Op 2 On
[88] Virt Ip 1 On
[89] DIG ELEM 1 PKP
[90] XOR(2)
[91] Virt Op 3 On
[92] OR(4)
[93] LATCH (S,R)
[94] Virt Op 3 On
```

```
[95] TIMER 1
[96] Cont Ip H1c On
[97] OR(3)
[98] TIMER 2
[99] = Virt Op 4
```

It is now possible to check that the selection of parameters will produce the required logic by converting the set of parameters into a logic diagram. The result of this process is shown below, which is compared to figure: LOGIC FOR VIRTUAL OUTPUT 4, as a check.

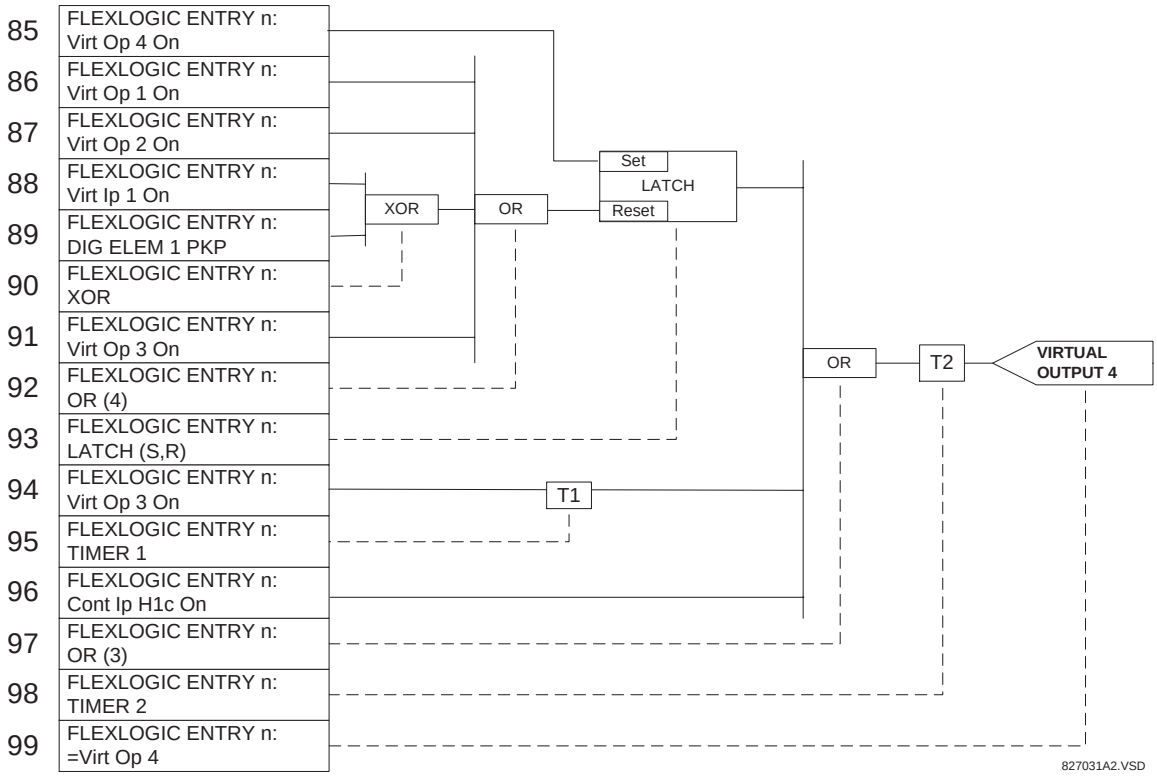


Figure 5–14: FLEXLOGIC™ EQUATION & LOGIC FOR VIRTUAL OUTPUT 4

7. Now write the complete FlexLogic™ expression required to implement the required logic, making an effort to assemble the equation in an order where Virtual Outputs that will be used as inputs to operators are created before needed. In cases where a lot of processing is required to perform considerable logic, this may be difficult to achieve, but in most cases will not cause problems because all of the logic is calculated at least 4 times per power frequency cycle. The possibility of a problem caused by sequential processing emphasizes the necessity to test the performance of FlexLogic™ before it is placed in service.

   In the following equation, Virtual Output 3 is used as an input to both Latch 1 and Timer 1 as arranged in the order shown below:

```
DIG ELEM 2 OP
Cont Ip H1c On
NOT
AND(2)
= Virt Op 3
Virt Op 4 On
Virt Op 1 On
Virt Op 2 On
Virt Ip 1 On
DIG ELEM 1 PKP
XOR(2)
```

```
Virt Op 3 On
OR(4)
LATCH (S,R)
Virt Op 3 On
TIMER 1
Cont Ip H1c On
OR(3)
TIMER 2
= Virt Op 4
END
```

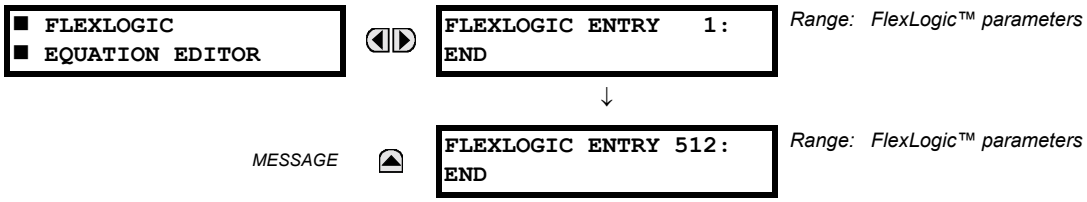
In the expression above, the Virtual Output 4 input to the 4-input OR is listed before it is created. This is typical of a form of feedback, in this case, used to create a seal-in effect with the latch, and is correct.

8. The logic should always be tested after it is loaded into the relay, in the same fashion as has been used in the past. Testing can be simplified by placing an "END" operator within the overall set of FlexLogic™ equations. The equations will then only be evaluated up to the first "END" operator.

   The "On" and "Off" operands can be placed in an equation to establish a known set of conditions for test purposes, and the "INSERT" and "DELETE" commands can be used to modify equations.

5.4.5 FLEXLOGIC™ EQUATION EDITOR

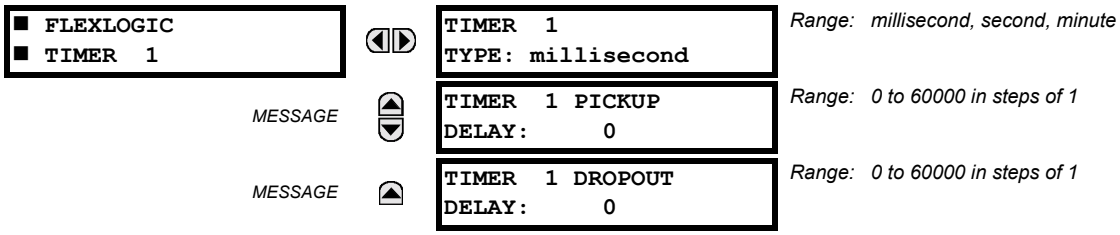
PATH: SETTINGS ⇨⇩ FLEXLOGIC ⇨ FLEXLOGIC EQUATION EDITOR



There are 512 FlexLogic™ entries available, numbered from 1 to 512, with default 'END' entry settings. If a "Disabled" Element is selected as a FlexLogic™ entry, the associated state flag will never be set to '1'. The '+/–' key may be used when editing FlexLogic™ equations from the keypad to quickly scan through the major parameter types.

5.4.6 FLEXLOGIC™ TIMERS

PATH: SETTINGS ⇨⇩ FLEXLOGIC ⇨⇩ FLEXLOGIC TIMERS ⇨ FLEXLOGIC TIMER 1(32)



There are 32 identical FlexLogic™ timers available, numbered from 1 to 32. These timers can be used as operators for FlexLogic™ equations.

TIMER 1 TYPE:

This setting is used to select the time measuring unit.

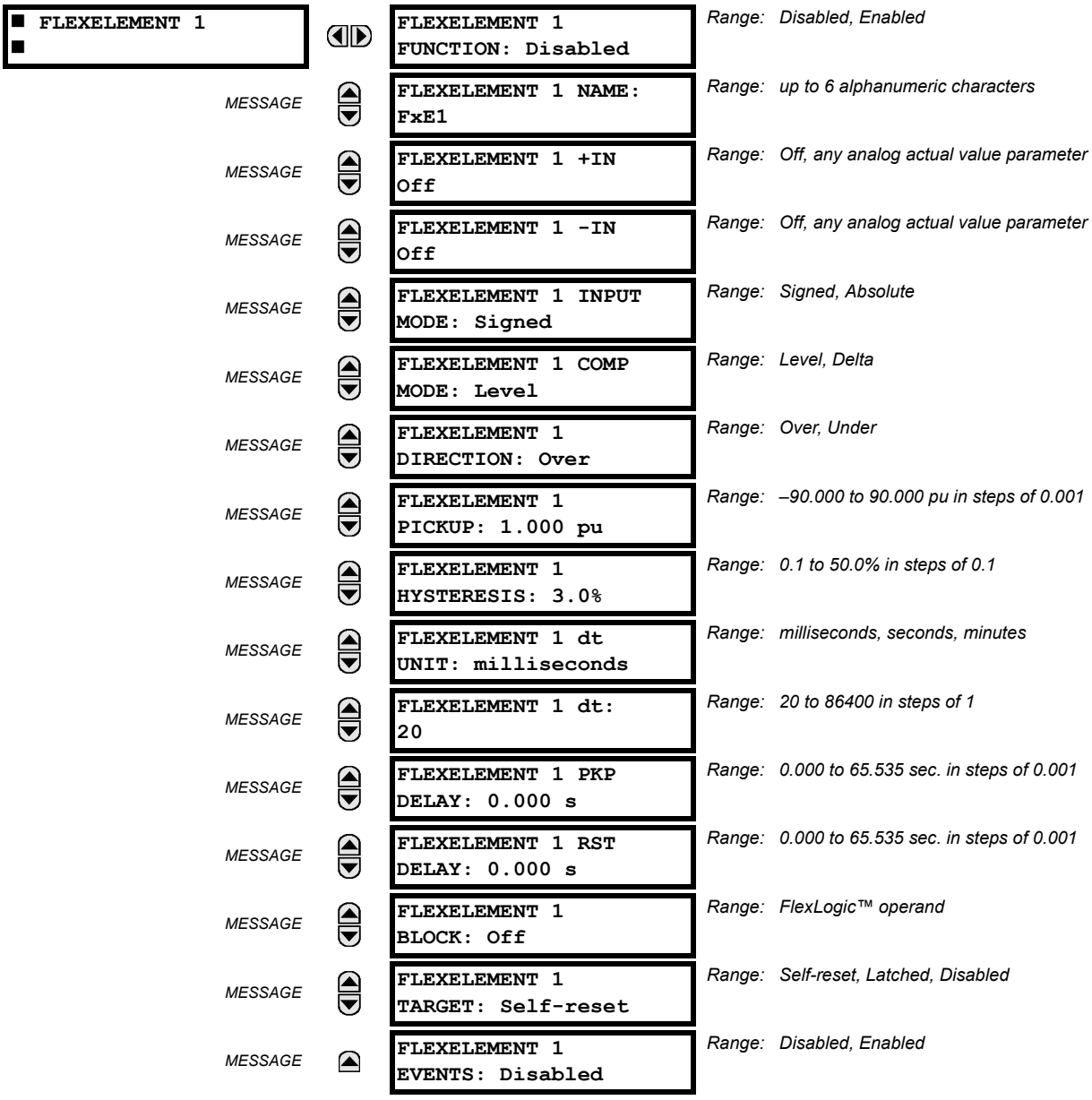
TIMER 1 PICKUP DELAY:

This setting is used to set the time delay to pickup. If a pickup delay is not required, set this function to "0".

TIMER 1 DROPOUT DELAY:

This setting is used to set the time delay to dropout. If a dropout delay is not required, set this function to "0".

PATH: SETTING ⇨⇩ FLEXLOGIC ⇨⇩ FLEXELEMENTS ⇨ FLEXELEMENT 1(8)



A FlexElement™ is a universal comparator that can be used to monitor any analog actual value calculated by the relay or a net difference of any two analog actual values of the same type. The effective operating signal could be treated as a signed number or its absolute value could be used as per user's choice.

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 threshold as per user's choice.

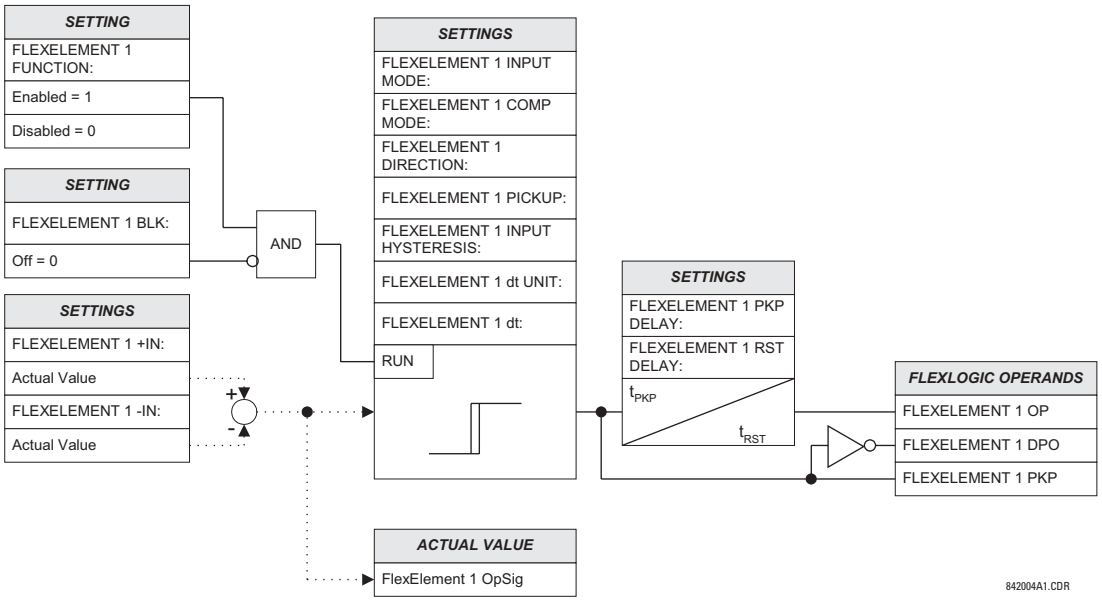


Figure 5–15: FLEXELEMENT™ SCHEME LOGIC

The **FLEXELEMENT 1 +IN** setting specifies the first (non-inverted) input to the FlexElement™. 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 **FLEXELEMENT 1 –IN** setting specifies the second (inverted) input to the FlexElement™. 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.

The element responds directly to the differential signal if the **FLEXELEMENT 1 INPUT MODE** setting is set to "Signed". The element responds to the absolute value of the differential signal if this setting is set to "Absolute". Sample applications for the "Absolute" setting 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.

The element responds directly to its operating signal – as defined by the **FLEXELEMENT 1 +IN**, **FLEXELEMENT 1 –IN** and **FLEXELEMENT 1 INPUT MODE** settings – if the **FLEXELEMENT 1 COMP MODE** setting is set to "Threshold". The element responds to the rate of change of its operating signal if the **FLEXELEMENT 1 COMP MODE** setting is set to "Delta". In this case the **FLEXELEMENT 1 dt UNIT** and **FLEXELEMENT 1 dt** settings specify how the rate of change is derived.

The **FLEXELEMENT 1 DIRECTION** setting enables the relay to respond to either high or low values of the operating signal. The following figure explains the application of the **FLEXELEMENT 1 DIRECTION**, **FLEXELEMENT 1 PICKUP** and **FLEXELEMENT 1 HYSTERESIS** settings.

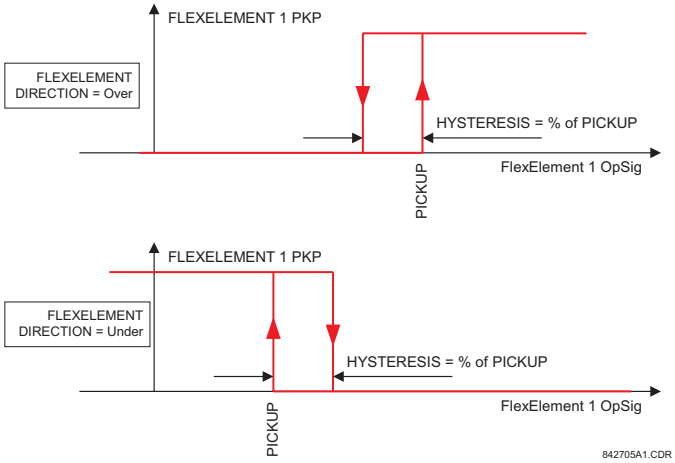


Figure 5–16: FLEXELEMENT™ DIRECTION, PICKUP, AND HYSTERESIS

In conjunction with the **FLEXELEMENT 1 INPUT MODE** setting the element could be programmed to provide two extra characteristics as shown in the figure below.

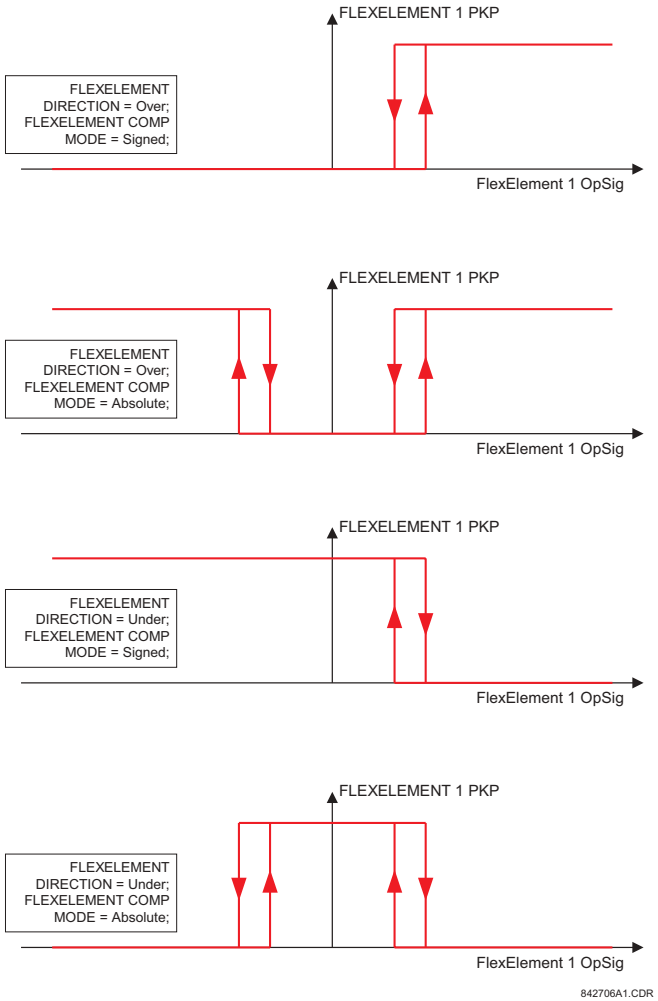


Figure 5–17: FLEXELEMENT™ INPUT MODE SETTING

The **FLEXELEMENT 1 PICKUP** setting specifies the operating threshold for the effective operating signal of the element. If set to "Over", the element picks up when the operating signal exceeds the **FLEXELEMENT 1 PICKUP** value. If set to "Under", the element picks up when the operating signal falls below the **FLEXELEMENT 1 PICKUP** value.

The **FLEXELEMENT 1 HYSTERESIS** setting controls the element dropout. 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. The **FLEXELEMENT 1 PICKUP** setting is entered in pu values using the following definitions of the base units:

Table 5–14: FLEXELEMENT™ BASE UNITS

87L SIGNALS (Local IA Mag, IB, and IC) (Diff Curr IA Mag, IB, and IC) (Terminal 1 IA Mag, IB, and IC) (Terminal 2 IA Mag, IB and IC)	I_{BASE} = maximum primary RMS value of the +IN and –IN inputs (CT primary for source currents, and 87L source primary current for line differential currents)
87L SIGNALS (Op Square Curr IA, IB, and IC) (Rest Square Curr IA, IB, and IC)	BASE = Squared CT secondary of the 87L source
BREAKER ARCING AMPS (Brk X Arc Amp A, B, and C)	BASE = 2000 $kA^2 \times$ cycle
dcmA	BASE = maximum value of the **DCMA INPUT MAX** setting for the two transducers configured under the +IN and –IN inputs.
FREQUENCY	f_{BASE} = 1 Hz
PHASE ANGLE	φ_{BASE} = 360 degrees (see the UR angle referencing convention)
POWER FACTOR	PF_{BASE} = 1.00
RTDs	BASE = 100°C
SOURCE CURRENT	I_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs
SOURCE POWER	P_{BASE} = maximum value of $V_{BASE} \times I_{BASE}$ for the +IN and –IN inputs
SOURCE VOLTAGE	V_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs
SYNCHROCHECK (Max Delta Volts)	V_{BASE} = maximum primary RMS value of all the sources related to the +IN and –IN inputs

The **FLEXELEMENT 1 HYSTERESIS** setting defines the pickup–dropout relation of the element by specifying the width of the hysteresis loop as a percentage of the pickup value as shown in the FLEXELEMENT DIRECTION, PICKUP, AND HYSTERESIS diagram.

The **FLEXELEMENT 1 DT UNIT** setting specifies the time unit for the setting **FLEXELEMENT 1 dt**. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to "Delta". The **FLEXELEMENT 1 DT** setting specifies duration of the time interval for the rate of change mode of operation. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to "Delta".

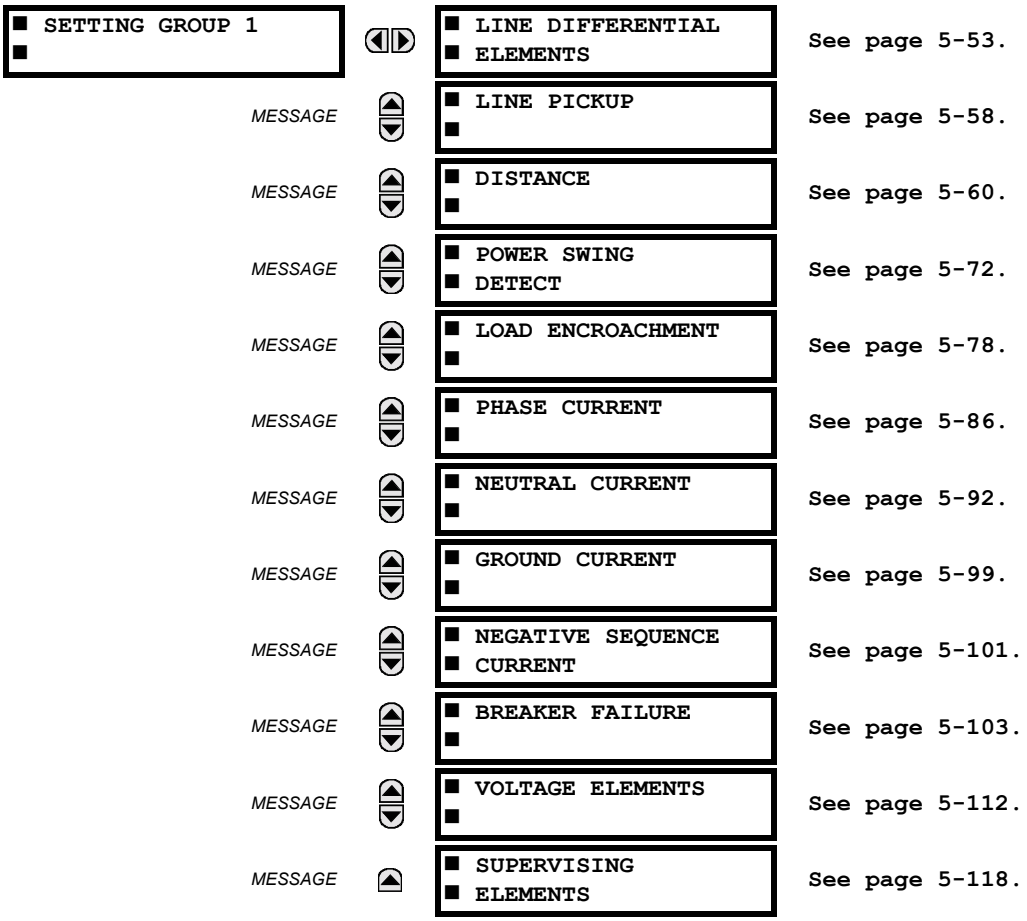
This **FLEXELEMENT 1 PKP DELAY** setting specifies the pickup delay of the element. The **FLEXELEMENT 1 RST DELAY** setting specifies the reset delay of the element.

5.5.1 OVERVIEW

Each protection element can be assigned up to 8 different sets of settings according to SETTING GROUP designations 1 to 8. 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 (e.g. altered power system configuration, season of the year). The active setting group can be preset or selected via the SETTING GROUPS menu (see the CONTROL ELEMENTS section). See also the INTRODUCTION TO ELEMENTS section at the front of this chapter.

5.5.2 SETTING GROUP

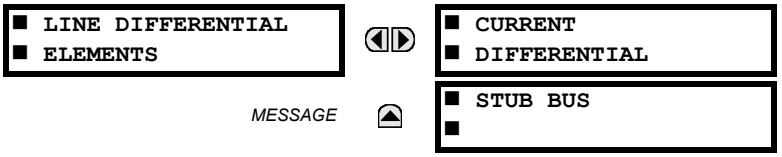
PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8)



Each of the 8 SETTING GROUP menus is identical. SETTING GROUP 1 (the default active group) automatically becomes active if no other group is active (see the CONTROL ELEMENTS section for additional details).

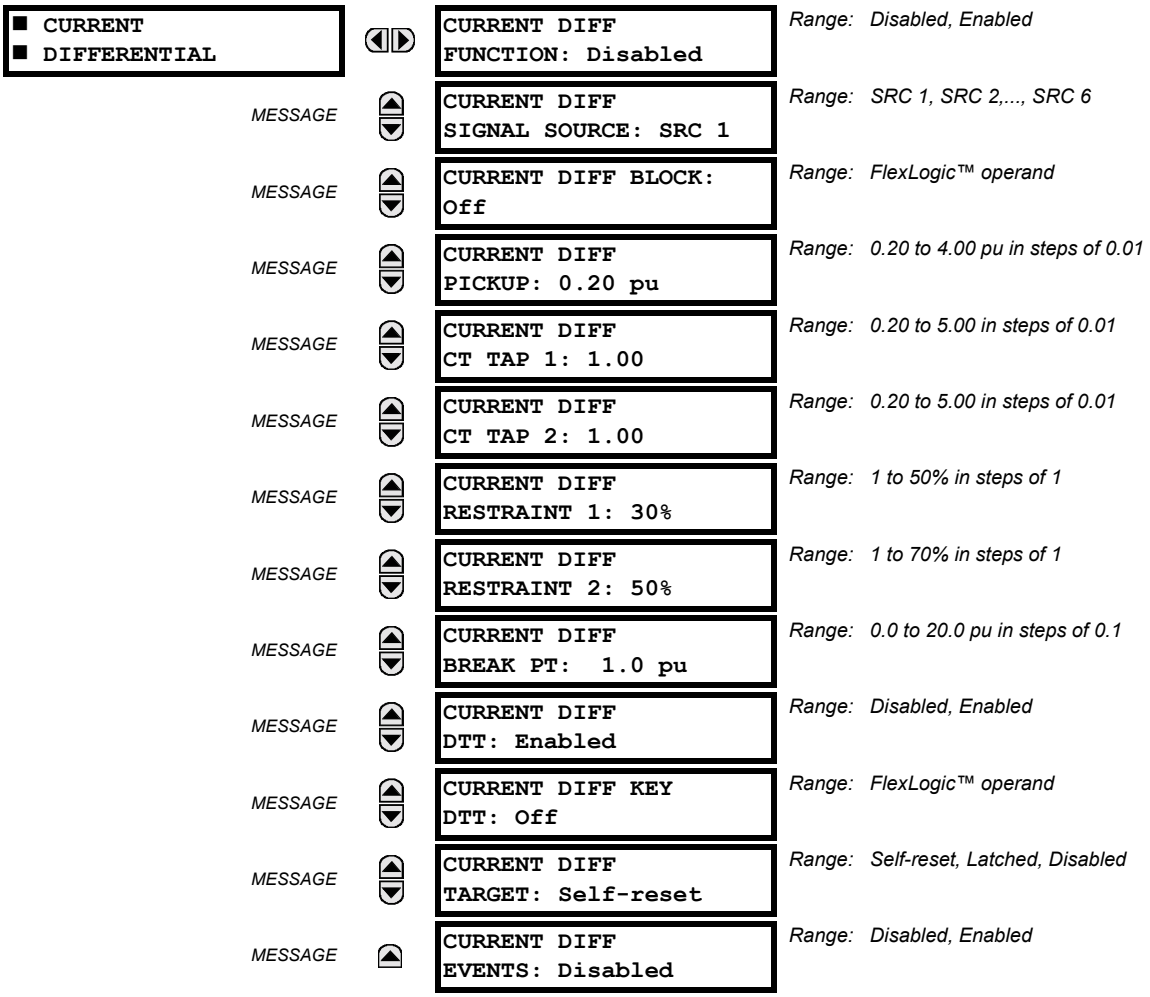
5.5.3 LINE DIFFERENTIAL ELEMENTS

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ LINE DIFFERENTIAL ELEMENTS



5.5.4 CURRENT DIFFERENTIAL

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ LINE DIFFERENTIAL... ⇨ CURRENT DIFFERENTIAL



CURRENT DIFF FUNCTION:

This setting is used to Enable/Disable operation of current differential element.

CURRENT DIFF SIGNAL SOURCE:

This setting is used to select the source for the local operating current of the current differential element.

CURRENT DIFF BLOCK:

This setting is used to select a FlexLogic™ Operand to block the operation of the current differential element.

CURRENT DIFF PICKUP:

This setting is used to select current differential pickup value.

CURRENT DIFF CT TAP 1:

This setting is used to adapt remote terminal 1 (communication channel 1) CT ratio to the local one if CT ratios for local and remote 1 terminals are different. Value of TAP 1 setting is determined as CTprim_rem / CTprim_loc for local and remote terminal CTs (where CTprim_rem / CTprim_loc is referred to as CT primary rated current). See the CURRENT DIFFERENTIAL SETTINGS application example in Chapter 9.

CURRENT DIFF CT TAP 2:

As above for remote terminal 2 (communication channel 2)

CURRENT DIFF RESTRAINT 1:

This setting is used to select bias characteristics for the first slope.

CURRENT DIFF RESTRAINT 2:

This setting is used to select bias characteristics for the second slope.

CURRENT DIFF BREAK PT:

This setting is used to select an intersection point between the two slopes.

CURRENT DIFF DTT:

This setting is used to Enable/Disable the sending of DTT by current differential element on per single-phase basis to remote relays. To allow the L90 protection system to restart from Master-Master to Master-Slave mode (very important on three-terminal applications), **CURR DIFF DTT** must be set to "Enabled".

CURRENT DIFF KEY DTT:

This setting is used to select additional protection element (i.e distance element or breaker failure), which key the DTT besides the current differential element on per three-phase basis.

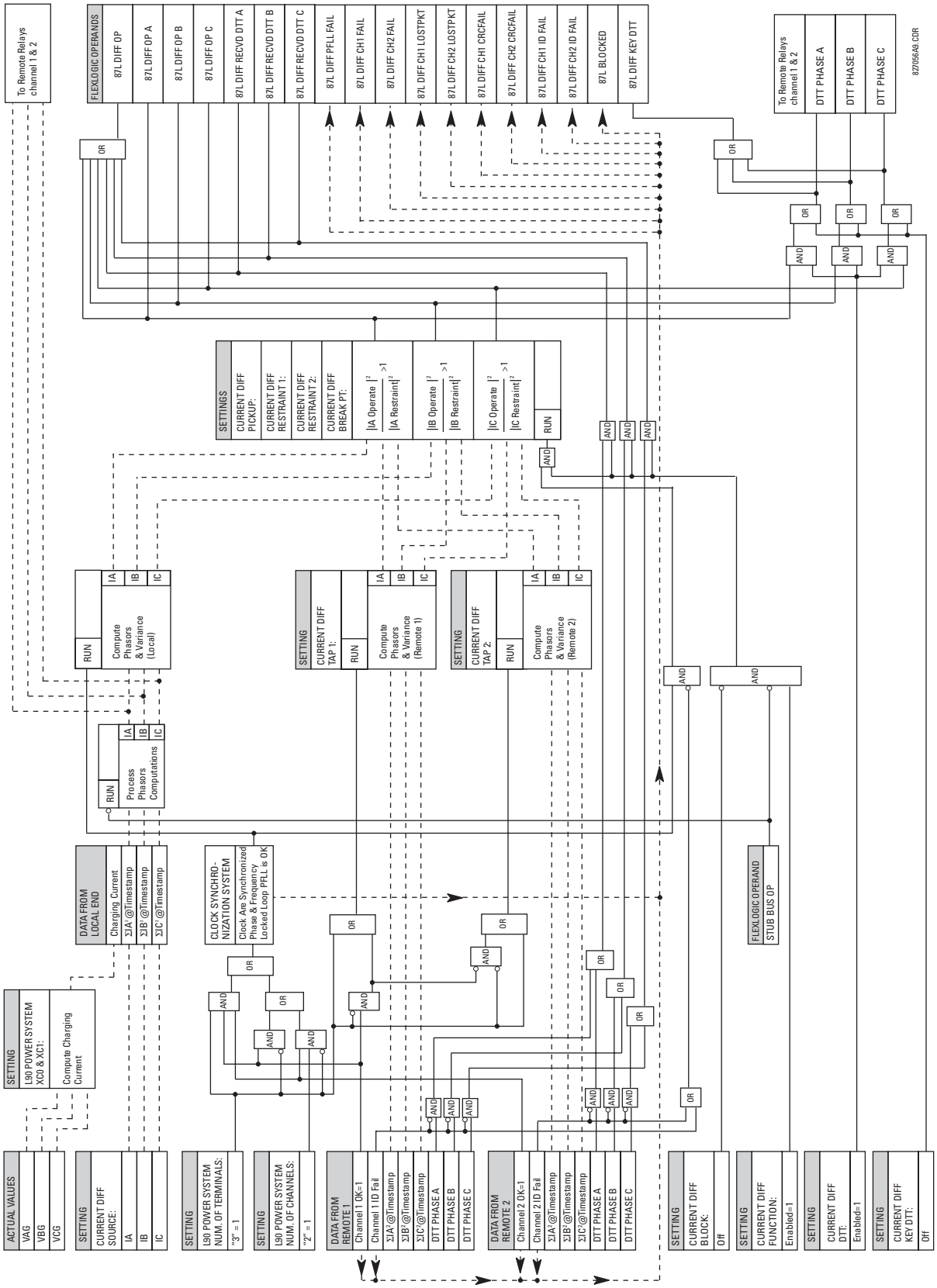
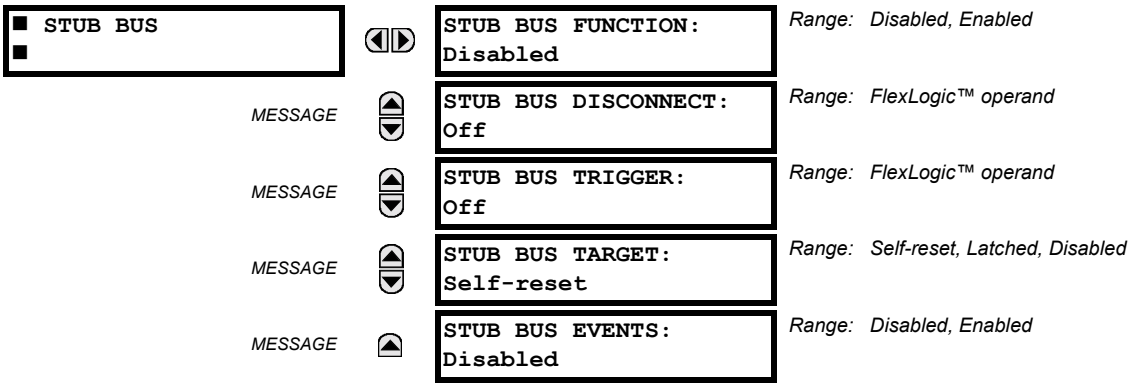


Figure 5–18: CURRENT DIFFERENTIAL SCHEME LOGIC

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ LINE DIFFERENTIAL ELEMENTS ⇨⇩ STUB BUS



The Stub Bus protects for faults between 2 breakers in a breaker-and-a-half or ring bus configuration when the line disconnect switch is open. At the same time, if the line is still energized through the remote terminal(s), differential protection is still required (the line may still need to be energized because there is a tapped load on a two terminal line or because the line is a three terminal line with two of the terminals still connected). Correct operation for this condition is achieved by the local relay sending zero current values to the remote end(s) so that a local bus fault does not result in tripping the line. At the local end, the differential element is disabled and stub bus protection is provided by a user-selected overcurrent element. If there is a line fault, the remote end(s) will trip on differential but local differential function and DTT signal (if enabled) to the local end, will be blocked by the stub bus logic allowing the local breakers to remain closed.

There are three requirements for Stub Bus operation: the element be enabled, an indication that the line disconnect is open, and the **STUB BUS TRIGGER** setting is set as indicated below. There are two ways of setting the stub bus trigger and thus setting up Stub Bus operation:

1. If **STUB BUS TRIGGER** is set to "On", the STUB BUS OPERATE operand picks up as soon as the disconnect switch opens, causing zero currents to be transmitted to remote end(s) and DTT receipt from remote end(s) to be permanently blocked. An overcurrent element, blocked by disconnect switch closed, provides protection for the local bus.
2. An alternate method is to set **STUB BUS TRIGGER** to be the pickup of an assigned instantaneous overcurrent element. The IOC element must operate quickly enough to pick up the "STUB BUS OPERATE" operand, disable the local differential, and send zero currents to the other terminal(s). If the bus minimum fault current is above 5 times the IOC pickup setting, tests have confirmed that the "STUB BUS OPERATE" operand will always pick up correctly for a stub bus fault and prevent tripping of the remote terminal. If minimum stub bus fault current is below this value, then Method 1 should be used. Note also that correct testing of stub bus operation, when this method is used, requires sudden injection of a fault currents above 5 times IOC pickup. The assigned current element should be mapped to appropriate output contact(s) to trip the stub bus breakers. It should be blocked unless disconnect is open.

STUB BUS DISCONNECT:

This setting selects a FlexLogic™ operand to represent the open state of auxiliary contact of line disconnect switch (logic “1” when line disconnect switch is open). If necessary, simple logic representing not only line disconnect switch but also the closed state of the breakers can be created with FlexLogic™ and assigned to this setting.

STUB BUS TRIGGER:

Selects a FlexLogic™ operand that causes the "STUB BUS OPERATE" operand to pick up if the line disconnect is open. As described above, it can be set either to "On" or to an IOC element. If the IOC to be used for the stub bus protection is set with a time delay, then **STUB BUS TRIGGER** should use the IOC PKP (pickup) operand. The source assigned for the current of this element must cover the stub between current transformers of the associated breakers and disconnect switch.

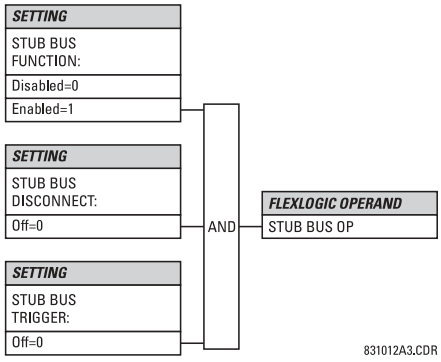


Figure 5–19: STUB BUS SCHEME LOGIC

5.5.6 LINE PICKUP

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ LINE PICKUP

■ LINE PICKUP ■		LINE PICKUP FUNCTION: Disabled	*Range: Disabled, Enabled*
	MESSAGE	LINE PICKUP SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
	MESSAGE	PHASE IOC LINE PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
	MESSAGE	POS SEQ UV PICKUP: 0.700 pu	*Range: 0.000 to 3.000 pu in steps of 0.001*
	MESSAGE	LINE END OPEN PICKUP DELAY: 0.150 s	*Range: 0.000 to 65.535 s in steps of 0.001*
	MESSAGE	LINE END OPEN RESET DELAY: 0.090 s	*Range: 0.000 to 65.535 s in steps of 0.001*
	MESSAGE	POS SEQ OV PICKUP DELAY: 0.040 s	*Range: 0.000 to 65.535 s in steps of 0.001*
	MESSAGE	AR CO-ORD BYPASS: Enabled	*Range: Disabled, Enabled*
	MESSAGE	AR CO-ORD PICKUP DELAY: 0.045 s	*Range: 0.000 to 65.535 s in steps of 0.001*
	MESSAGE	AR CO-ORD RESET DELAY: 0.005 s	*Range: 0.000 to 65.535 s in steps of 0.001*
	MESSAGE	LINE PICKUP BLOCK: Off	*Range: FlexLogic™ operand*
	MESSAGE	LINE PICKUP TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
	MESSAGE	LINE PICKUP EVENTS: Disabled	*Range: Disabled, Enabled*

The line pickup feature uses a combination of undercurrent and undervoltage to identify a line that has been de-energized (line end open). Three instantaneous overcurrent elements are used to identify a previously de-energized line that has been closed onto a fault which could be due to maintenance grounds that have not been removed. Faults other than close-in faults can be identified satisfactorily by the distance elements which initially will be self or faulted phase polarized and then become memory polarized when a satisfactory memory signal is available.

Co-ordination features are included to ensure satisfactory operation when high speed 'automatic reclosure (AR)' is employed. The **AR CO-ORD DELAY** setting allows the overcurrent setting to be below the expected load current seen after reclose. Co-ordination is achieved by the POS SEQ OV element picking up and blocking the trip path, before the **AR CO-ORD DELAY** times out. The **AR CO-ORD BYPASS** setting is normally enabled. It is disabled if high speed AR is implemented.

The positive sequence undervoltage pickup setting is based on phase to neutral quantities. If Delta VTs are used, then this per unit pickup is based on the (**VT SECONDARY** setting) / $\sqrt{3}$.

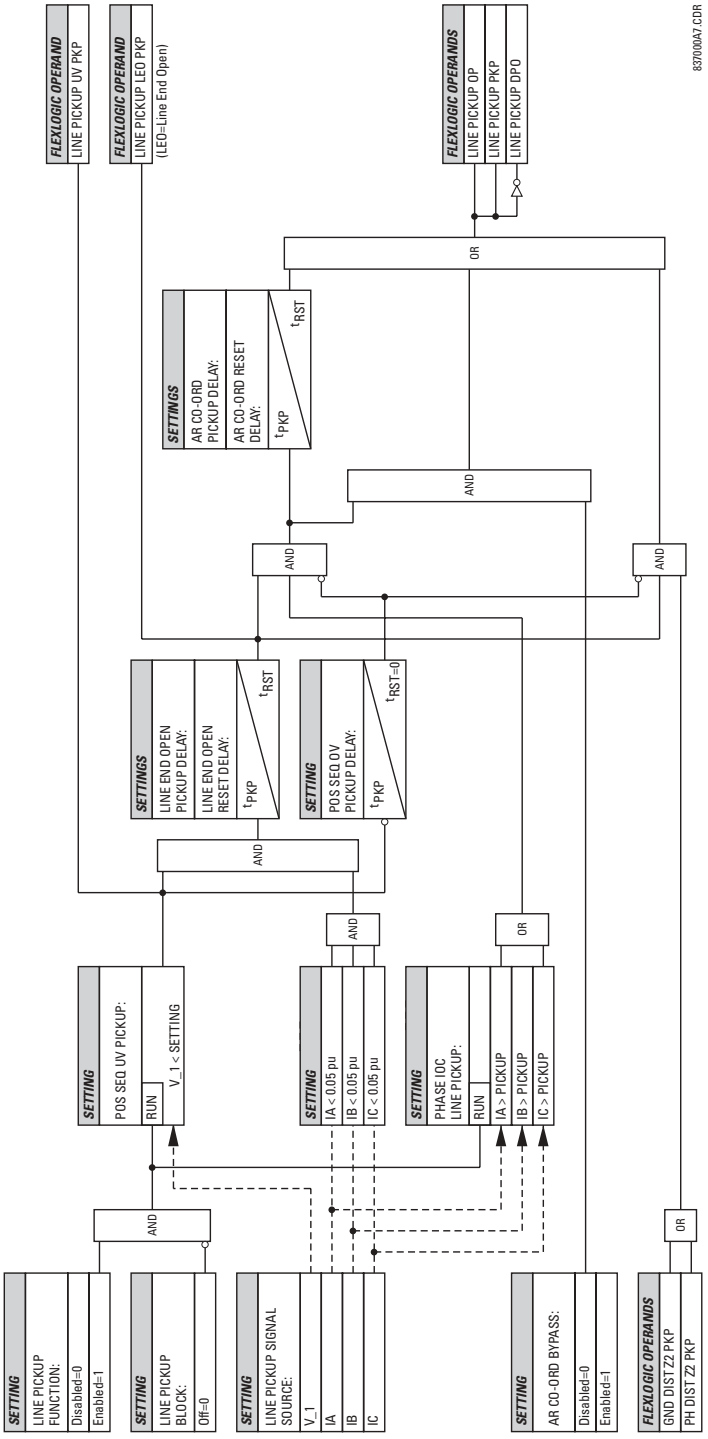
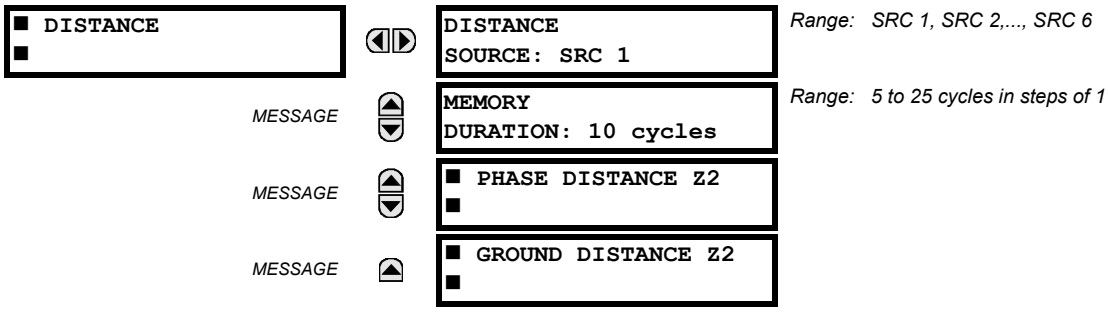


Figure 5–20: LINE PICKUP LOGIC

5.5.7 DISTANCE

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE



Two common settings (**DISTANCE SOURCE** and **MEMORY DURATION**) and two menus for one zone of phase and ground distance protection are available. The **DISTANCE SOURCE** identifies the Signal Source for all distance functions.

The MHO distance functions use a dynamic characteristic: the positive-sequence voltage – either memorized or actual – is used as a polarizing signal. The memory voltage is also used by the built-in directional supervising functions applied for both the MHO and QUAD characteristics.

The **MEMORY DURATION** setting specifies the length of time a memorized positive-sequence voltage should be used in the distance calculations. After this interval expires, the relay checks the magnitude of the actual positive-sequence voltage. If it is higher than 10% of the nominal, the actual voltage is used, if lower – the memory voltage continues to be used.

The memory is established when the positive-sequence voltage stays above 80% of its nominal value for five power system cycles. For this reason it is important to ensure that the nominal secondary voltage of the VT is entered correctly under the SETTINGS ⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK menu.

Set **MEMORY DURATION** long enough to ensure stability on close-in reverse three-phase faults. For this purpose, the maximum fault clearing time (breaker fail time) in the substation should be considered. On the other hand, the **MEMORY DURATION** cannot be too long as the power system may experience power swing conditions rotating the voltage and current phasors slowly while the memory voltage is static, as frozen at the beginning of the fault. Keeping the memory in effect for too long may eventually cause maloperation of the distance functions.

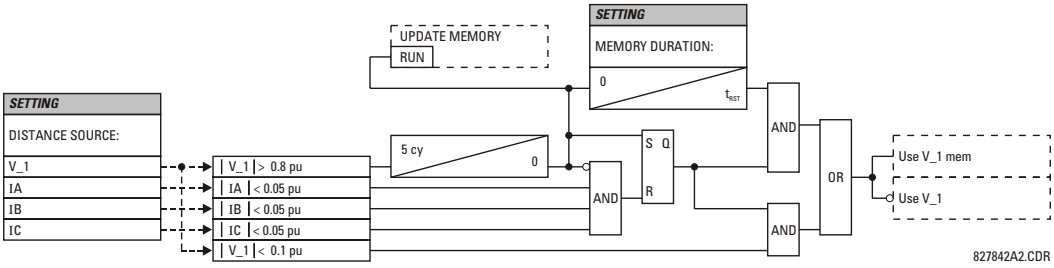
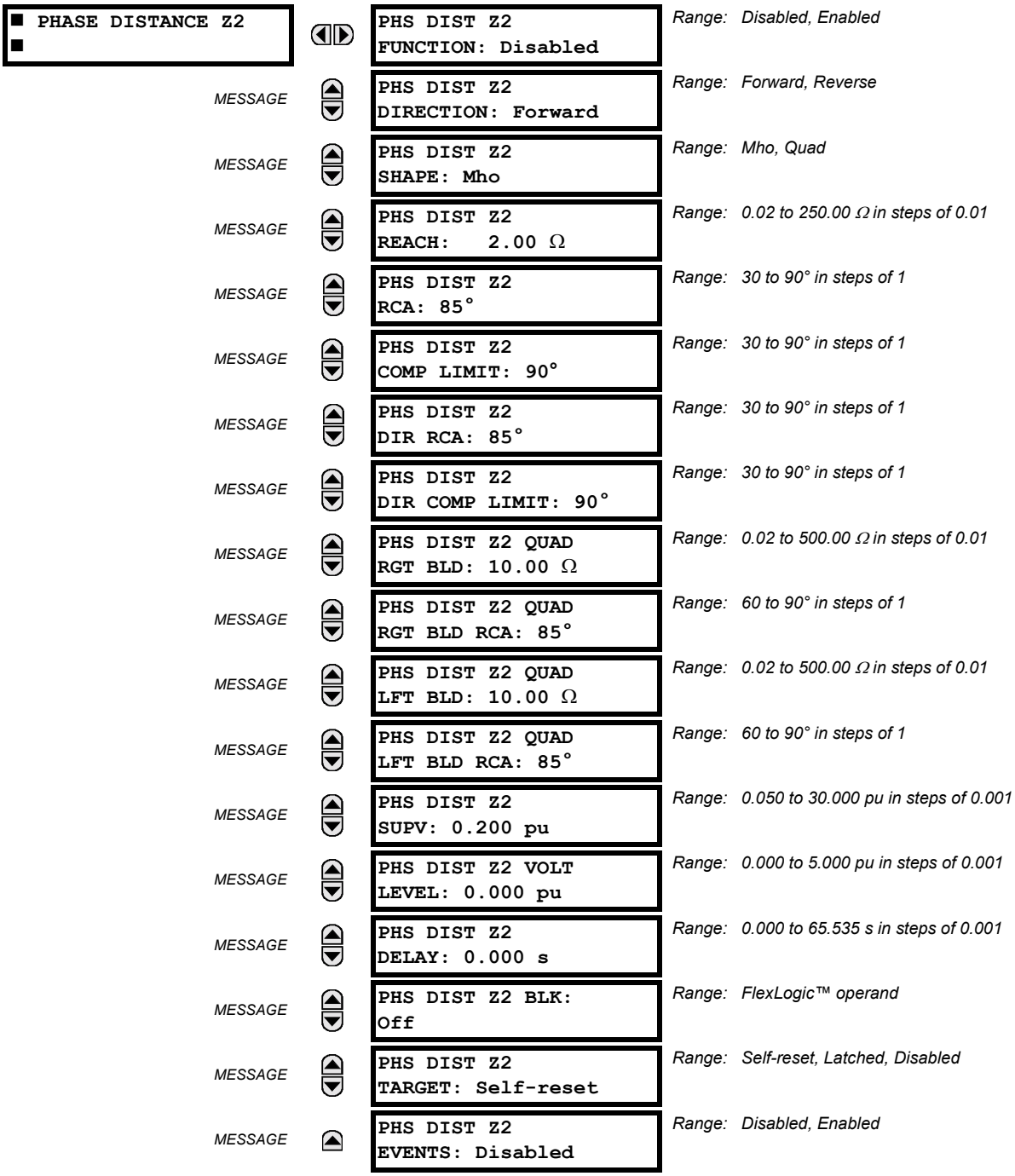


Figure 5–21: MEMORY VOLTAGE LOGIC

a) PHASE DISTANCE (ANSI 21P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE ⇨⇩ PHASE DISTANCE Z2



The phase MHO distance function uses a dynamic 100% memory-polarized mho characteristic with additional reactance, directional, and overcurrent supervising characteristics. The phase quad distance function is comprised of a reactance characteristic, right and left blinders, and 100% memory-polarized directional and current supervising characteristics.

The zone is configured through its own setting menu. All of the settings can be independently modified except:

- Signal Source (common for both phase and ground elements of all four zones as entered under SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE).
- Memory duration (common for both phase and ground elements of all four zones as entered under SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE).

The COMMON DISTANCE SETTINGS described earlier must be properly chosen for correct operation of the phase distance elements.

WARNING

Ensure that the PHASE VT SECONDARY VOLTAGE setting (see the SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK menu) is set correctly to prevent improper operation of associated memory action.

PHS DIST Z2 DIRECTION:

Zone2 is reversible. The forward direction by the **PHS DIST Z2 RCA** setting, whereas the reverse direction is shifted 180° from that angle.

PHS DIST Z2 SHAPE:

This setting selects the shape of the phase distance function between the mho and quad characteristics. The two characteristics and their possible variations are shown in the following figures.

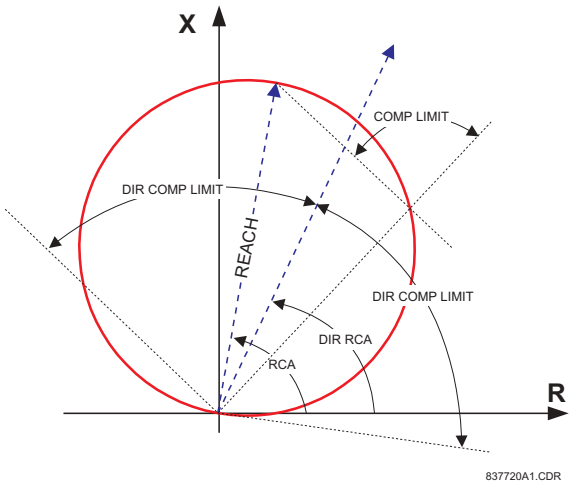


Figure 5–22: MHO DISTANCE CHARACTERISTIC

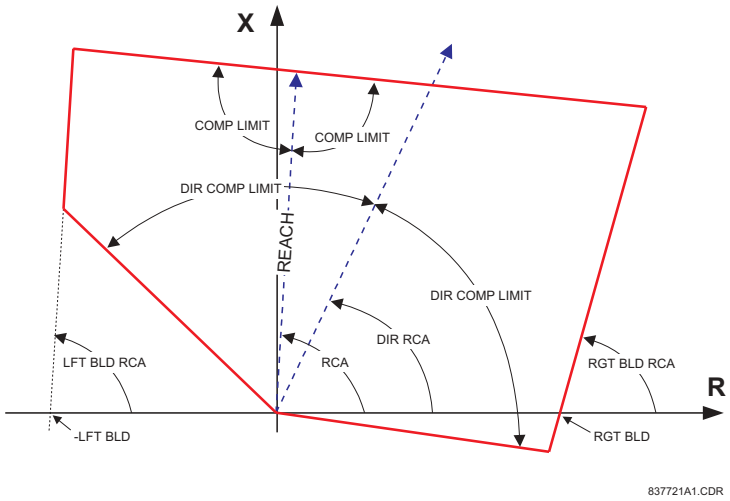


Figure 5–23: QUAD DISTANCE CHARACTERISTIC

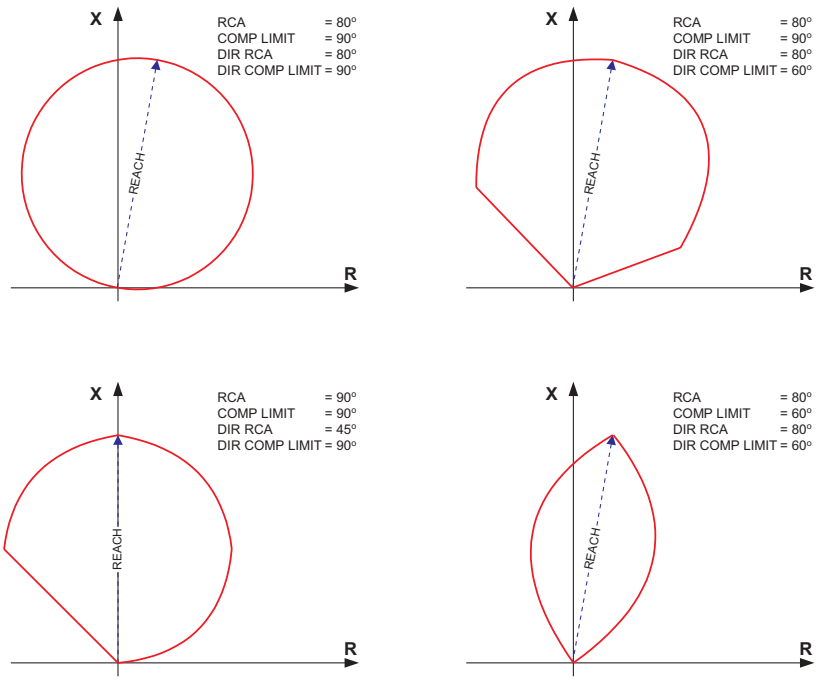


Figure 5–24: MHO DISTANCE CHARACTERISTIC SAMPLE SHAPES

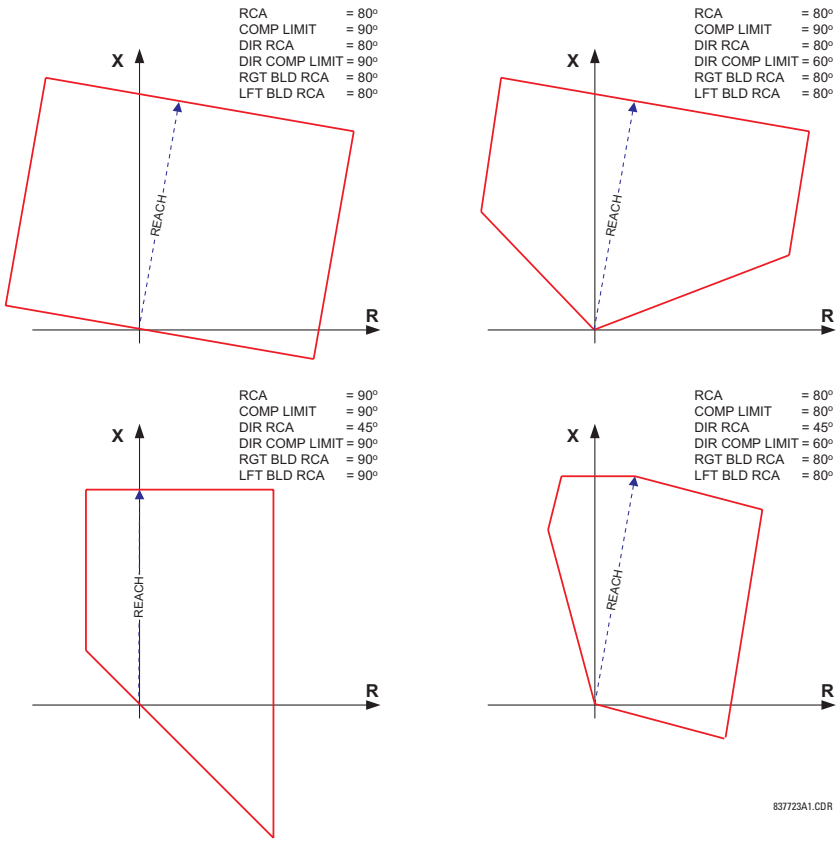


Figure 5–25: QUAD DISTANCE CHARACTERISTIC SAMPLE SHAPES

PHS DIST Z2 REACH:

This setting defines the zone reach. The reach impedance is entered in secondary ohms. The reach impedance angle is entered as the **PHS DIST Z2 RCA** setting.

PHS DIST Z2 RCA:

This setting specifies the characteristic angle (similar to the "maximum torque angle" in previous technologies) of the phase distance characteristic. The setting is an angle of reach impedance as shown in MHO DISTANCE CHARACTERISTIC and QUAD DISTANCE CHARACTERISTIC figures.

This setting is independent from **PHS DIST Z2 DIR RCA**, the characteristic angle of an extra directional supervising function.

PHS DIST Z2 COMP LIMIT:

This setting shapes the operating characteristic. In particular, it produces the lens-type characteristic of the MHO function and a tent-shaped characteristic of the reactance boundary of the quad function.

If the mho shape is selected, the same limit angle applies to both the mho and supervising reactance comparators. In conjunction with the mho shape selection, the setting improves loadability of the protected line. In conjunction with the quad characteristic, this setting improves security for faults close to the reach point by adjusting the reactance boundary into a tent-shape.

PHS DIST Z2 DIR RCA:

This setting select the characteristic angle (or "maximum torque angle") of the directional supervising function. If the mho shape is applied, the directional function is an extra supervising function as the dynamic mho characteristic itself is a directional one. In conjunction with the quad shape selection, this setting defines the only directional function built into the phase distance element. The directional function uses the memory voltage for polarization.

This setting typically equals the distance characteristic angle **PHS DIST Z2 RCA**.

PHS DIST Z2 DIR COMP LIMIT:

This setting selects the comparator limit angle for the directional supervising function.

PHS DIST Z2 QUAD RGT BLD:

This setting defines the right blinder position of the quad characteristic along the resistive axis of the impedance plane (see the QUAD DISTANCE CHARACTERISTIC figure). The angular position of the blinder is adjustable with the use of the **PHS DIST Z2 QUAD RGT BLD RCA** setting.

This setting applies only to the quad characteristic and should be set giving consideration to the maximum load current and required resistive coverage.

PHS DIST Z2 QUAD RGT BLD RCA:

This setting defines the angular position of the right blinder of the quad characteristic (see the QUAD DISTANCE CHARACTERISTIC figure). This setting applies only to the quad characteristic.

PHS DIST Z2 QUAD LFT BLD:

This setting defines the left blinder position of the quad characteristic along the resistive axis of the impedance plane (see the QUAD DISTANCE CHARACTERISTIC figure). The angular position of the blinder is adjustable with the use of the **PHS DIST Z2 QUAD LFT BLD RCA** setting. This setting applies only to the quad characteristic and should be set with consideration to the maximum load current.

PHS DIST Z2 QUAD LFT BLD RCA:

This setting defines the angular position of the left blinder of the quad characteristic (see the QUAD DISTANCE CHARACTERISTIC figure). This setting applies only to the quad characteristic.

PHS DIST Z2 SUPV:

The phase distance elements are supervised by the magnitude of the line-to-line current (fault loop current used for the distance calculations). For convenience, $\sqrt{3}$ is accommodated by the pickup (i.e., before being used, the entered value of the threshold setting is multiplied by $\sqrt{3}$).

If the minimum fault current level is sufficient, the current supervision pickup should be set above maximum full load current preventing maloperation under VT fuse fail conditions. This requirement may be difficult to meet for remote faults at the end of Zone 2. If this is the case, the current supervision pickup would be set below the full load current, but this may result in maloperation during fuse fail conditions.

PHS DIST Z2 VOLT LEVEL:

This setting is relevant for applications on series-compensated lines, or in general, if series capacitors are located between the relaying point and a point for which the zone shall not overreach. For plain (non-compensated) lines, this setting shall be set to zero. Otherwise, the setting is entered in per unit of the phase VT bank configured under the **DISTANCE SOURCE**. See the THEORY OF OPERATION chapter for more details, and the APPLICATION OF SETTINGS chapter for information on how to calculate this setting for applications on series compensated lines.

PHS DIST Z2 DELAY:

This setting enables the user to delay operation of the distance elements and implement a stepped distance protection. The distance element timer applies a short dropout delay to cope with faults located close to the zone boundary when small oscillations in the voltages and/or currents could inadvertently reset the timer.

PHS DIST Z2 BLK:

This setting enables the user to select a FlexLogic™ operand to block a given distance element. VT fuse fail detection is one of the applications for this setting.

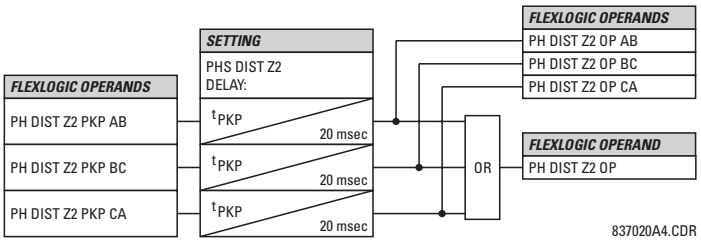


Figure 5–26: PHASE DISTANCE Z2 OP SCHEME

5

NOTE

In the L60 and L90 relay, all settings and operands are labeled as Z2

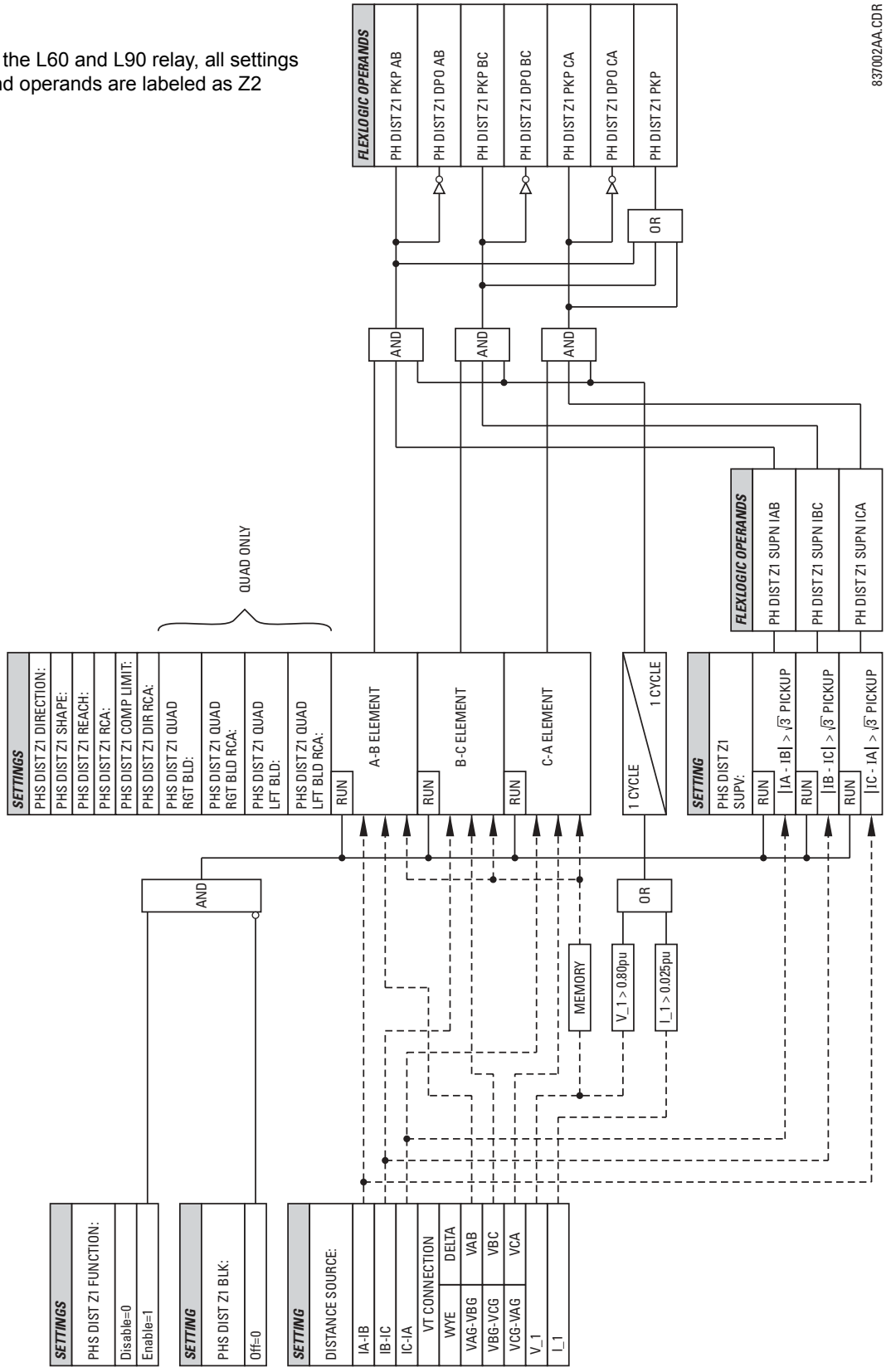
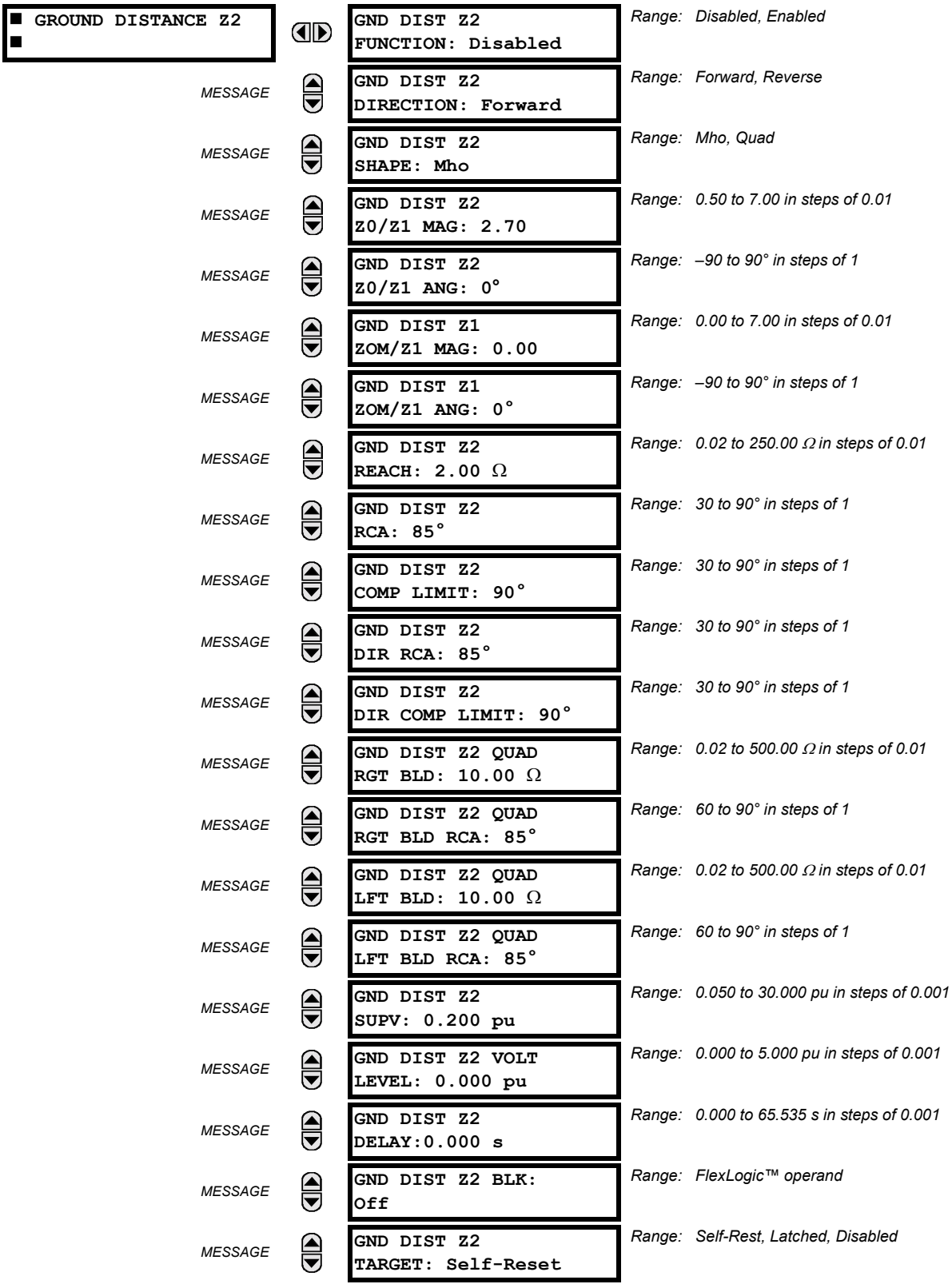


Figure 5–27: PHASE DISTANCE Z2 SCHEME LOGIC

b) GROUND DISTANCE (ANSI 21G)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE ⇨⇩ GROUND DISTANCE Z2



MESSAGE

```
GND DIST Z2
EVENTS: Disabled
```

Range: Disabled, Enabled

The ground MHO distance function uses a dynamic 100% memory-polarized mho characteristic with additional reactance, directional, current, and phase selection supervising characteristics. The ground quadrilateral distance function is composed of a reactance characteristic, right and left blinders, and 100% memory-polarized directional, overcurrent, and phase selection supervising characteristics.

The reactance supervision uses zero-sequence current as a polarizing quantity making the characteristic adaptable to the pre-fault power flow. The directional supervision uses memory voltage as polarizing quantity and both zero- and negative-sequence currents as operating quantities.

The phase selection supervision restrains the ground elements during double-line-to-ground faults as they – by principles of distance relaying – may be inaccurate in such conditions. The ground distance element applies additional zero-sequence directional supervision.

The setting menu configures the basic distance settings except for:

- Signal Source (common for both phase and ground elements as entered under the **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE** menu).
- Memory duration (common for both phase and ground elements as entered under the **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE** menu).

The common distance settings noted at the start of the DISTANCE section must be properly chosen for correct operation of the ground distance elements.

WARNING

Ensure that the PHASE VT SECONDARY VOLTAGE (see the SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK menu) is set correctly to prevent improper operation of associated memory action.

5

GND DIST Z2 DIRECTION:

The zone is reversible. The forward direction is defined by the **GND DIST Z2 RCA** setting and the reverse direction is shifted by 180° from that angle.

GND DIST Z2 SHAPE:

This setting selects the shape of the ground distance characteristic between the mho and quad characteristics.

GND DIST Z2 Z0/Z1 MAG:

This setting specifies the ratio between the zero-sequence and positive-sequence impedance required for zero-sequence compensation of the ground distance elements. This setting enables precise settings for tapped, non-homogeneous, and series compensated lines.

GND DIST Z2 Z0/Z1 ANG:

This setting specifies the angle difference between the zero-sequence and positive-sequence impedance required for zero-sequence compensation of the ground distance elements. The entered value is the zero-sequence impedance angle minus the positive-sequence impedance angle.

This setting enables precise values for tapped, non-homologous, and series-compensated lines.

GND DIST Z2 ZOM/Z1 MAG:

The ground distance elements can be programmed to apply compensation for the zero-sequence mutual coupling between parallel lines. If the compensation is required, the ground current from the parallel line (3I_0) measured in the direction of zone being compensated must be connected to the ground input CT of the CT bank configured under the **DISTANCE SOURCE**. This setting specifies the ratio between the magnitudes of the mutual zero-sequence impedance between the lines and the positive-sequence impedance of the protected line. It is imperative to set this setting to zero if the compensation is not to be performed.

GND DIST Z2 ZOM/Z1 ANG:

This setting specifies the angle difference between the mutual zero-sequence impedance between the lines and the positive-sequence impedance of the protected line.

GND DIST Z2 REACH:

This setting defines the reach of the zone. The angle of the reach impedance is entered as the **GND DIST Z2 RCA** setting. The reach impedance is entered in secondary ohms.

GND DIST Z2 RCA:

The characteristic angle (similar to the "maximum torque angle" in previous technologies) of the ground distance characteristic is specified by this setting. It is set as an angle of reach impedance as shown in the MHO DISTANCE CHARACTERISTIC and QUAD DISTANCE CHARACTERISTIC figures. This setting is independent from the **GND DIST Z2 DIR RCA** setting (the characteristic angle of an extra directional supervising function).

GND DIST Z2 COMP LIMIT:

This setting shapes the operating characteristic. In particular, it enables a lens-shaped characteristic of the mho function and a tent-shaped characteristic of the reactance boundary of the quad function.

If the mho shape is selected, the same limit angle applies to mho and supervising reactance comparators. In conjunction with the mho shape selection, this setting improves loadability of the protected line. In conjunction with the quad characteristic, this setting improves security for faults close to the reach point by adjusting the reactance boundary into a tent-shape.

GND DIST Z2 DIR RCA:

The characteristic angle (or "maximum torque angle") of the directional supervising function is selected by this setting. If the MHO shape is applied, the directional function is an extra supervising function, as the dynamic mho characteristic itself is a directional one. In conjunction with the quad shape selection, this setting defines the only directional function built into the ground distance element. The directional function uses memory voltage for polarization.

GND DIST Z2 DIR COMP LIMIT:

This setting selects the comparator limit angle for the directional supervising function.

GND DIST Z2 QUAD RGT BLD:

This setting defines the right blinder position of the quad characteristic along the resistive axis of the impedance plane (see the QUAD DISTANCE CHARACTERISTIC figure). The angular position of the blinder is adjustable with the use of the **GND DIST Z2 QUAD RGT BLD RCA** setting.

This setting applies only to the quad characteristic and should be set giving consideration to the maximum load current and required resistive coverage.

GND DIST Z2 QUAD RGT BLD RCA:

This setting defines the angular position of the right blinder of the quad characteristic (see the QUAD DISTANCE CHARACTERISTIC figure). This setting applies only to the quad characteristic.

GND DIST Z2 QUAD LFT BLD:

This setting defines the left blinder position of the quad characteristic along the resistive axis of the impedance plane (see the QUAD DISTANCE CHARACTERISTIC figure). The angular position of the blinder is adjustable with the use of the **GND DIST Z2 QUAD LFT BLD RCA** setting. This setting applies only to the quad characteristic and should be set with consideration to the maximum load current.

GND DIST Z2 QUAD LFT BLD RCA:

This setting defines the angular position of the left blinder of the quad characteristic (see the QUAD DISTANCE CHARACTERISTIC figure). This setting applies only to the quad characteristic.

GND DIST Z2 SUPV:

The ground distance elements are supervised by the magnitude of the neutral (3I_0) current. The current supervision pickup should be set above the maximum unbalance current under maximum load conditions preventing maloperation due to VT fuse failure.

GND DIST Z2 VOLT LEVEL:

This setting is relevant for applications on series-compensated lines, or in general, if series capacitors are located between the relaying point and a point for which the zone shall not overreach. For plain (non-compensated) lines, this setting shall be set to zero. Otherwise, the setting is entered in per unit of the VT bank configured under the **DISTANCE SOURCE**. See the THEORY OF OPERATION chapter for more details, and the APPLICATION OF SETTINGS chapter for information on how to calculate this setting for applications on series compensated lines.

GND DIST Z2 DELAY:

This setting enables the user to delay operation of the distance elements and implement a stepped distance backup protection. The distance element timer applies a short drop out delay to cope with faults located close to the boundary of the zone when small oscillations in the voltages and/or currents could inadvertently reset the timer.

GND DIST Z2 BLK:

This setting enables the user to select a FlexLogic™ operand to block the given distance element. VT fuse fail detection is one of the applications for this setting.

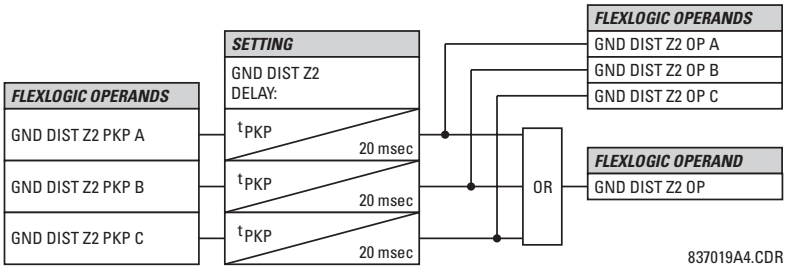


Figure 5–28: GROUND DISTANCE Z2 OP SCHEME

GROUND DIRECTIONAL SUPERVISION:

A dual (zero- and negative-sequence) memory-polarized directional supervision applied to the ground distance protection elements has been shown to give good directional integrity. However, a reverse double-line-to-ground fault can lead to a maloperation of the ground element in a sound phase if the zone reach setting is increased to cover high resistance faults.

Ground distance Zone 2 uses an additional ground directional supervision to enhance directional integrity. The element's directional characteristic angle is used as a "maximum torque angle" together with a 90° limit angle.

The supervision is biased toward operation in order to avoid compromising the sensitivity of ground distance elements at low signal levels. Otherwise, the reverse fault condition that generates concern will have high polarizing levels so that a correct reverse fault decision can be reliably made.

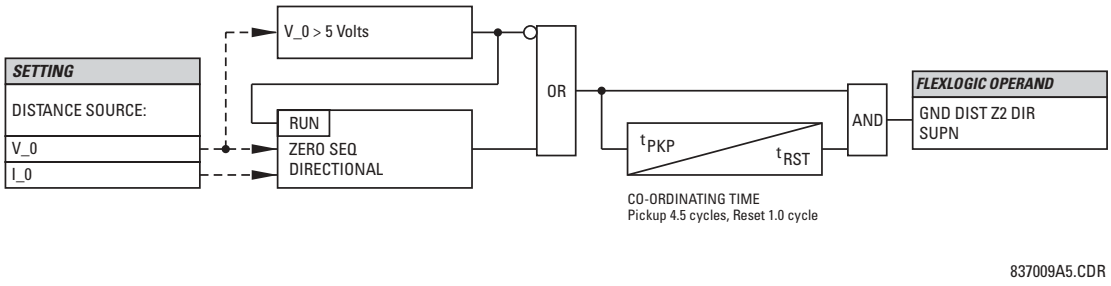


Figure 5–29: GROUND DIRECTIONAL SUPERVISION SCHEME LOGIC – Z2

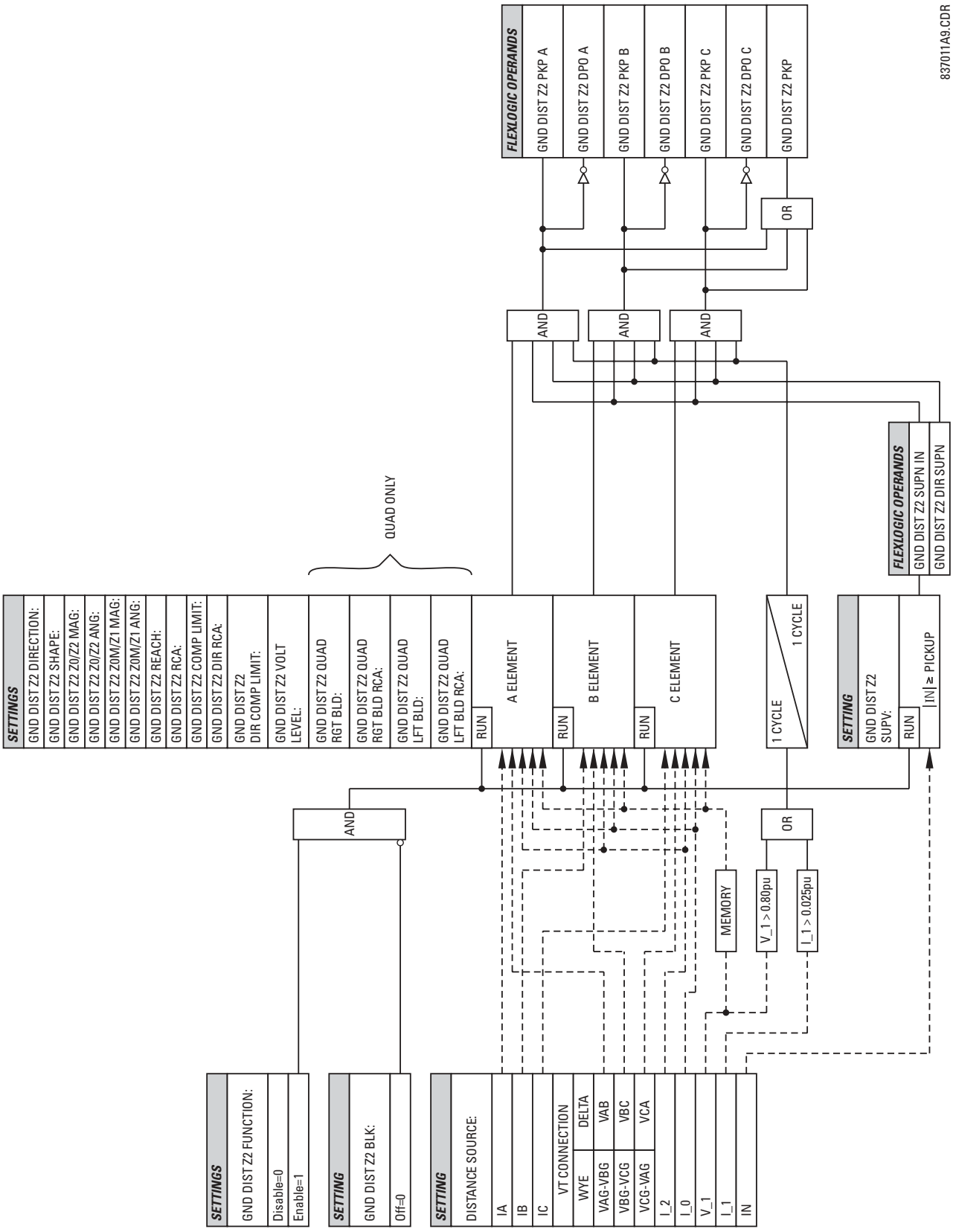
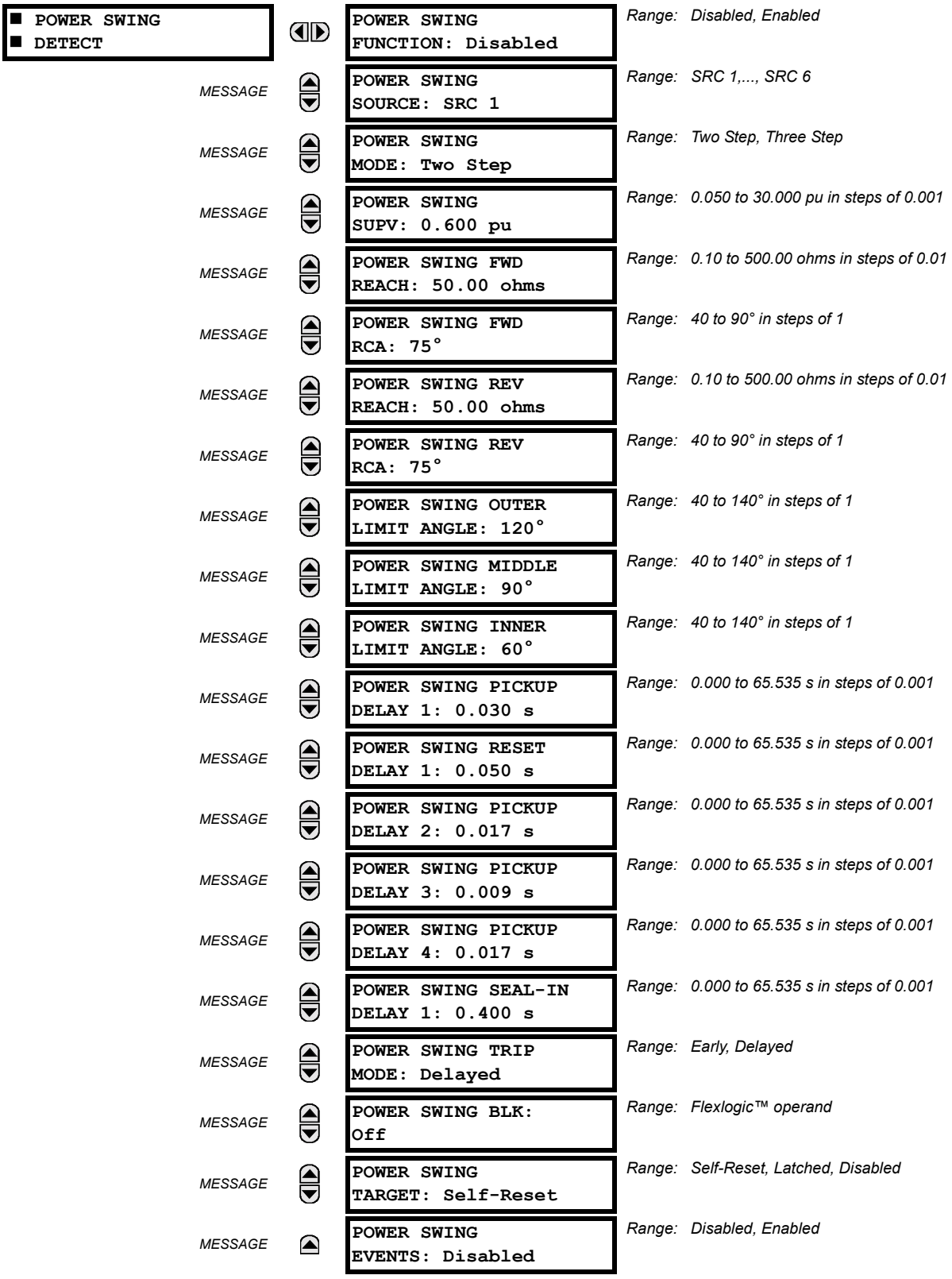


Figure 5–30: GROUND DISTANCE Z2 SCHEME LOGIC

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ POWER SWING DETECT



The Power Swing Detect element provides both power swing blocking and out-of-step tripping functions. The element measures the positive-sequence apparent impedance and traces its locus with respect to either two or three user-selectable operating characteristic boundaries as per user choice. Upon detecting appropriate timing relations, the blocking and/or tripping indication is given through FlexLogic™ operands. The POWER SWING OPERATING CHARACTERISTICS and POWER SWING LOGIC figures should be viewed along with the following discussion to develop an understanding of the operation of the element.

a) POWER SWING BLOCKING

Three-step operation:

The power swing blocking sequence essentially times the passage of the locus of the positive-sequence impedance between the outer and the middle characteristic boundaries. If the locus enters the outer characteristic (as indicated by setting of the POWER SWING OUTER FlexLogic™ operand) but stays outside the middle characteristic (as indicated by setting of the POWER SWING MIDDLE FlexLogic™ operand) for an interval longer than **POWER SWING PICKUP DELAY 1** the power swing blocking signal (POWER SWING BLOCK FlexLogic™ operand) is established and sealed-in. The blocking signal resets when the locus leaves the outer characteristic, but not sooner than after **POWER SWING RESET DELAY 1** time.

Two-step operation:

If the 2-step mode is selected, the sequence is identical, but it is the outer and inner characteristics that are used to time the power swing locus.

b) OUT-OF-STEP TRIPPING

Three-step operation:

The out-of-step trip sequence identifies unstable power swings by determining if the impedance locus spends a finite time between the outer and middle characteristics and then a finite time between the middle and inner characteristics.

The first step is similar to the power swing blocking sequence. After timer **POWER SWING PICKUP DELAY 1** times out, Latch 1 is set as long as the impedance stays within the outer characteristic.

If afterwards, at any time (given the impedance stays within the outer characteristic), the locus enters the middle characteristic but stays outside the inner characteristic for a period of time defined as **POWER SWING PICKUP DELAY 2**, Latch 2 is set as long as the impedance stays inside the outer characteristic.

If afterwards, at any time (given the impedance stays within the outer characteristic), the locus enters the inner characteristic and stays there for a period of time defined as **POWER SWING PICKUP DELAY 3**, Latch 2 is set as long as the impedance stays inside the outer characteristic - the element is now ready to trip.

If the "Early" trip mode is selected, operand POWER SWING TRIP is set immediately and is sealed-in for the interval established by setting **POWER SWING SEAL-IN DELAY**.

If the "Delayed" trip mode is selected, the element waits until the impedance locus leaves the inner characteristic, then times out the **POWER SWING PICKUP DELAY 2** delay, and sets Latch 4 - the element is now ready to trip. The trip operand will be set later, when the impedance locus leaves the outer characteristic.

Two-step operation:

The 2-step mode of operation is similar to the 3-step mode with two exceptions. First, the initial stage monitors the time spent by the impedance locus between the outer and inner characteristics. Second, the stage involving timer POWER SWING PICKUP DELAY 2 is bypassed.

It is up to the user to integrate the blocking (POWER SWING BLOCK) and tripping (POWER SWING TRIP) FlexLogic™ operands with other protection functions and output contacts in order to make this element fully operational.

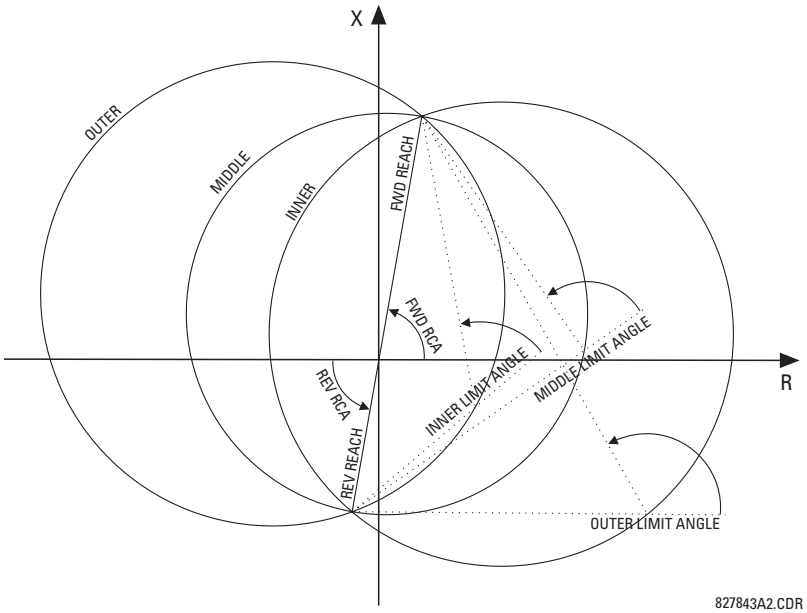


Figure 5–31: POWER SWING DETECT ELEMENT OPERATING CHARACTERISTICS

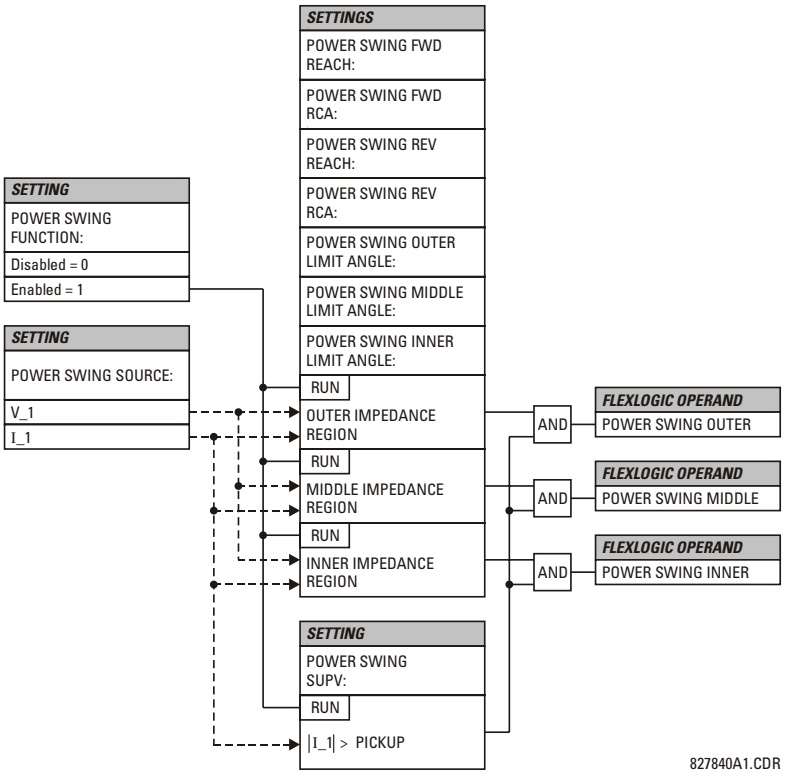


Figure 5–32: POWER SWING DETECT LOGIC (1 of 2)

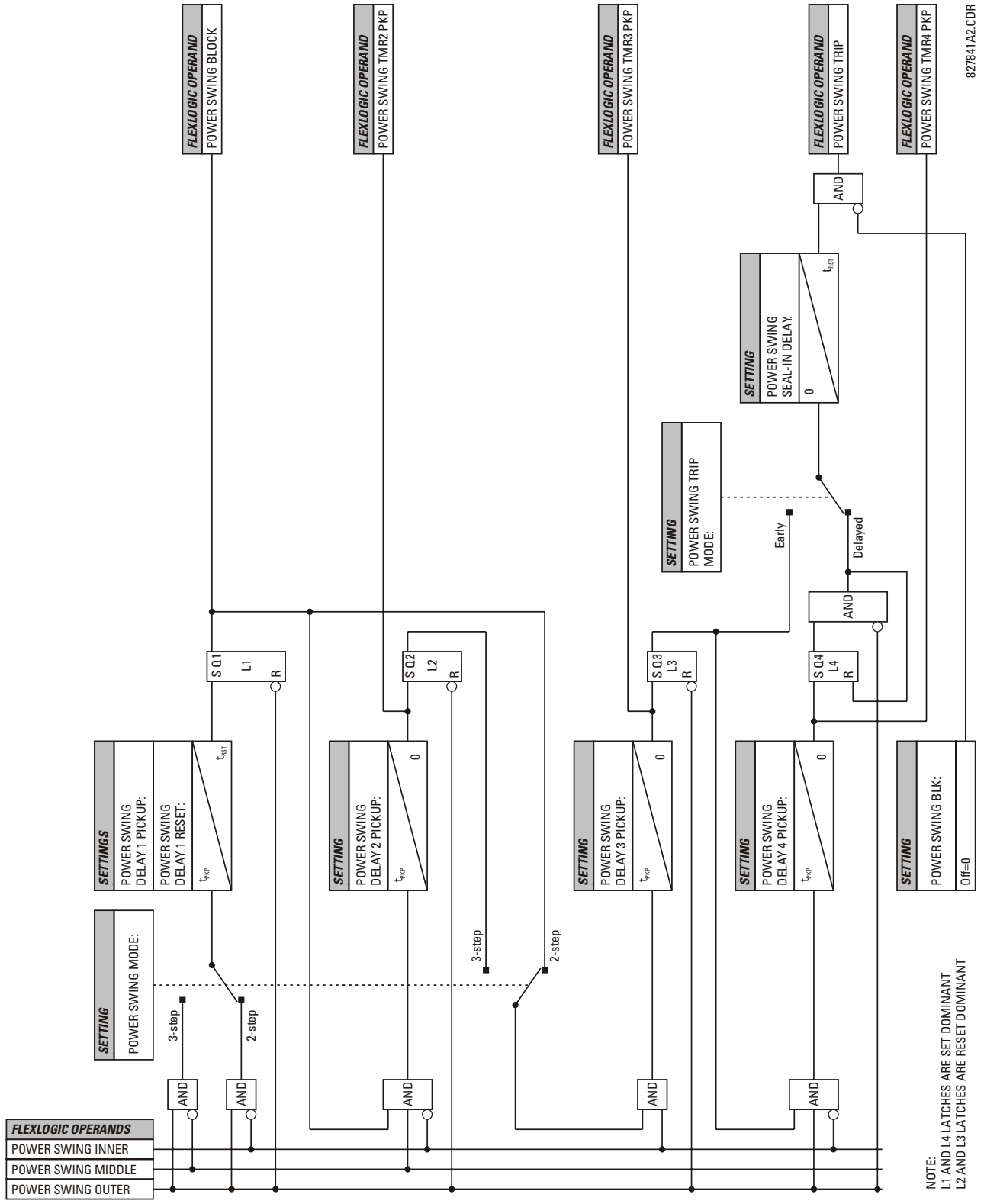


Figure 5–33: POWER SWING DETECT LOGIC (2 of 2)

c) SETTINGS

POWER SWING FUNCTION:

This setting enables/disables the entire POWER SWING DETECT protection element. The setting applies to both power swing blocking and out-of-step tripping functions.

POWER SWING SOURCE:

The source setting identifies the Signal Source for both blocking and tripping functions.

POWER SWING MODE:

This setting selects between the 2-step and 3-step operating modes and applies to both power swing blocking and out-of-step tripping functions.

The 3-step mode applies if there is enough space between the maximum load impedances and distance characteristics of the relay that all three (outer, middle, and inner) characteristics can be placed between the load and the distance characteristics. Whether the spans between the outer and middle as well as the middle and inner characteristics are sufficient should be determined by analysis of the fastest power swings expected in correlation with settings of the power swing timers.

The 2-step mode uses only the outer and inner characteristics for both blocking and tripping functions. This leaves more space in heavily loaded systems to place two power swing characteristics between the distance characteristics and the maximum load, but allows for only one determination of the impedance trajectory.

POWER SWING SUPV:

A common overcurrent pickup level supervises all three power swing characteristics. The supervision responds to the positive sequence current.

POWER SWING FWD REACH:

This setting specifies the forward reach of all three characteristics. For a simple system consisting of a line and two equivalent sources, this reach should be higher than the sum of the line and remote source positive-sequence impedances. Detailed transient stability studies may be needed for complex systems in order to determine this setting.

POWER SWING FWD RCA:

This setting specifies the angle of the forward reach impedance. The angle is measured as shown in the POWER SWING DETECT ELEMENT OPERATING CHARACTERISTICS diagram.

POWER SWING REV REACH:

This setting specifies the reverse reach of all three power detect characteristics. For a simple system consisting of a line and two equivalent sources, this reach should be higher than the positive-sequence impedance of the local source. Detailed transient stability studies may be needed for complex systems in order to determine this setting.

POWER SWING REV RCA:

This setting specifies the angle of the reverse reach impedance. The angle is measured as shown in the POWER SWING DETECT ELEMENT OPERATING CHARACTERISTICS diagram.

POWER SWING OUTER LIMIT ANGLE:

This setting defines the outer power swing detect characteristic. The convention depicted in the POWER SWING DETECT ELEMENT OPERATING CHARACTERISTICS diagram should be observed: values greater than 90° result in an "apple" shaped characteristic, values lower than 90° result in a lens shaped characteristic. This angle must be selected in consideration of to the maximum expected load. If the "maximum load angle" is known, the outer limit angle should be coordinated with some 20° security margin. Detailed studies may be needed for complex systems in order to determine this setting.

POWER SWING MIDDLE LIMIT ANGLE:

This setting defines the middle power swing detect characteristic. This setting is relevant only if the 3-step mode is selected. A typical value would be close to the average of the outer and inner limit angles.

POWER SWING INNER LIMIT ANGLE:

This setting defines the inner power swing detect characteristic.

The inner characteristic is used by the out-of-step tripping function: beyond the inner characteristic out-of-step trip action is definite (the actual trip may be delayed as per the **TRIP MODE** setting). Therefore, this angle must be selected in consideration to the power swing angle beyond which the system becomes unstable and cannot recover.

The inner characteristic is also used by the power swing blocking function in the 2-step mode. Therefore, this angle must be set large enough so that the characteristics of the distance elements are safely enclosed by the inner characteristic.

POWER SWING PICKUP DELAY 1:

All the coordinating timers are related to each other and should be set to detect the fastest expected power swing and produce out-of-step tripping in a secure manner. The timers should be set in consideration to the power swing detect characteristics, mode of power swing detect operation and mode of out-of-step tripping.

This timer defines the interval that the impedance locus must spend between the outer and inner characteristics (2-step operating mode), or between the outer and middle characteristics (3-step operating mode) before the power swing blocking signal is established. This time delay must be set shorter than the time required for the impedance locus to travel between the two selected characteristics during the fastest expected power swing.

This setting is relevant for both power swing blocking and out-of-step tripping.

POWER SWING RESET DELAY 1:

This setting defines the dropout delay for the power swing blocking signal. Detection of a condition requiring a Block output sets Latch 1 after **PICKUP DELAY 1** time. When the impedance locus leaves the outer characteristic, timer **POWER SWING RESET DELAY 1** is started. When the timer times-out the latch is reset.

This setting should be selected to give extra security for the power swing blocking action.

POWER SWING PICKUP DELAY 2:

This setting controls the out-of-step tripping function in the 3-step mode only. This timer defines the interval the impedance locus must spend between the middle and inner characteristics before the second step of the out-of-step tripping sequence is completed. This time delay must be set shorter than the time required for the impedance locus to travel between the two characteristics during the fastest expected power swing.

POWER SWING PICKUP DELAY 3:

This setting controls the out-of-step tripping function only. This timer defines the interval the impedance locus must spend within the inner characteristic before the last step of the out-of-step tripping sequence is completed and the element is armed to trip. The actual moment of tripping is controlled by the **TRIP MODE** setting.

This time delay is provided for extra security before the out-of-step trip action is executed.

POWER SWING PICKUP DELAY 4:

This setting controls the out-of-step tripping function in the Delayed trip mode only. This timer defines the interval the impedance locus must spend outside the inner characteristic but within the outer characteristic before the element gets armed for the Delayed trip. The delayed trip will take place when the impedance leaves the outer characteristic.

This time delay is provided for extra security and should be set considering the fastest expected power swing.

POWER SWING SEAL-IN DELAY:

The out-of-step trip FlexLogic™ operand (POWER SWING TRIP) is sealed-in for the specified period of time. The sealing-in is crucial in the delayed trip mode, as the original trip signal is a very short pulse occurring when the impedance locus leaves the outer characteristic after the out-of-step sequence is completed.

POWER SWING TRIP MODE:

Selection of the "Early" trip mode results in an instantaneous trip after the last step in the out-of-step tripping sequence is completed. The Early trip mode will stress the circuit breakers as the currents at that moment are high (the electromotive forces of the two equivalent systems are approximately 180° apart).

Selection of the "Delayed" trip mode results in a trip at the moment when the impedance locus leaves the outer characteristic. Delayed trip mode will relax the operating conditions for the breakers as the currents at that moment are low.

The selection should be made considering the capability of the breakers in the system.

POWER SWING BLK:

This setting specifies the FlexLogic™ operand used for blocking the out-of-step function only. The power swing blocking function is operational all the time as long as the element is enabled.

The blocking signal resets the output POWER SWING TRIP operand but does not stop the out-of-step tripping sequence.

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ LOAD ENCROACHMENT

■ LOAD ENCROACHMENT ■	LOAD ENCROACHMENT FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	LOAD ENCROACHMENT SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	LOAD ENCROACHMENT MIN VOLT: 0.250 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	LOAD ENCROACHMENT REACH: 1.00 Ω	Range: 0.02 to 250.00 ohms in steps of 0.01
MESSAGE	LOAD ENCROACHMENT ANGLE: 30°	Range: 5 to 50° in steps of 1
MESSAGE	LOAD ENCROACHMENT PKP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	LOAD ENCROACHMENT RST DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	LOAD ENCRMNT BLK: Off	Range: Flexlogic™ operand
MESSAGE	LOAD ENCROACHMENT TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	LOAD ENCROACHMENT EVENTS: Disabled	Range: Disabled, Enabled

The Load Encroachment element responds to the positive-sequence impedance and applies a characteristic shown in the figure below.

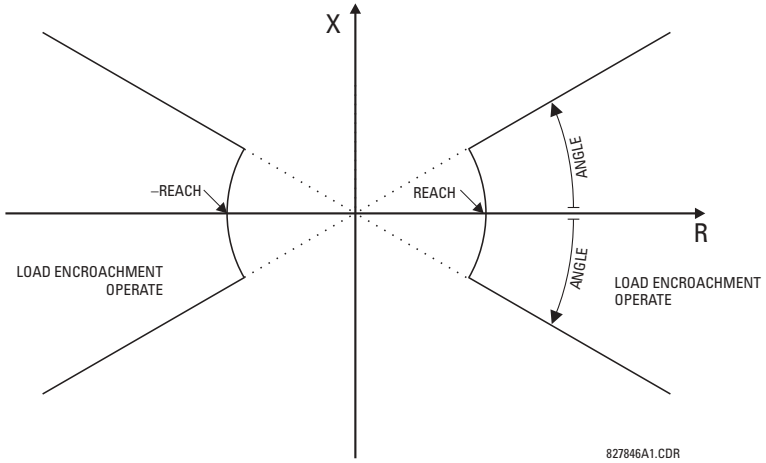


Figure 5–34: LOAD ENCROACHMENT CHARACTERISTIC

The element operates if the positive-sequence voltage is above a settable level and asserts its output signal that can be used to block selected protection elements such as distance or phase overcurrent. The following figure shows an effect of the Load Encroachment characteristics used to block the QUAD distance element.

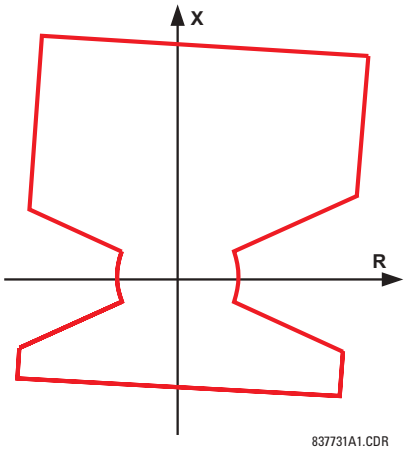


Figure 5–35: LOAD ENCROACHMENT APPLIED TO DISTANCE ELEMENT

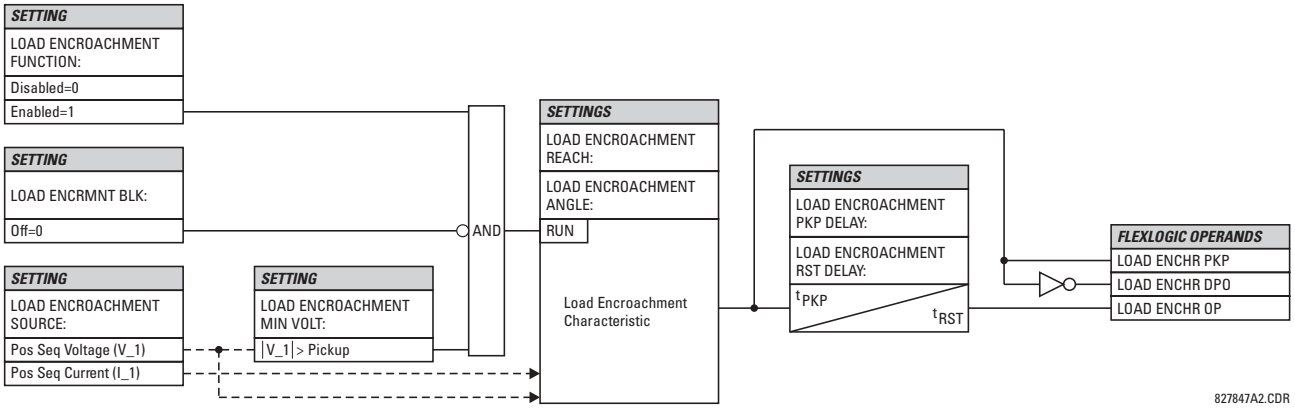


Figure 5–36: LOAD ENCROACHMENT SCHEME LOGIC

LOAD ENCROACHMENT MIN VOLT:

This setting specifies the minimum positive-sequence voltage required for operation of the element. If the voltage is below this threshold a blocking signal will not be asserted by the element. When selecting this setting one must remember that the UR measures the phase-to-ground sequence voltages regardless of the VT connection.

The nominal VT secondary voltage as specified under **PATH: SYSTEM SETUP ⇨⇩ AC INPUTS ⇨ VOLTAGE BANK X1 ⇨⇩ PHASE VT SECONDARY** is the p.u. base for this setting.

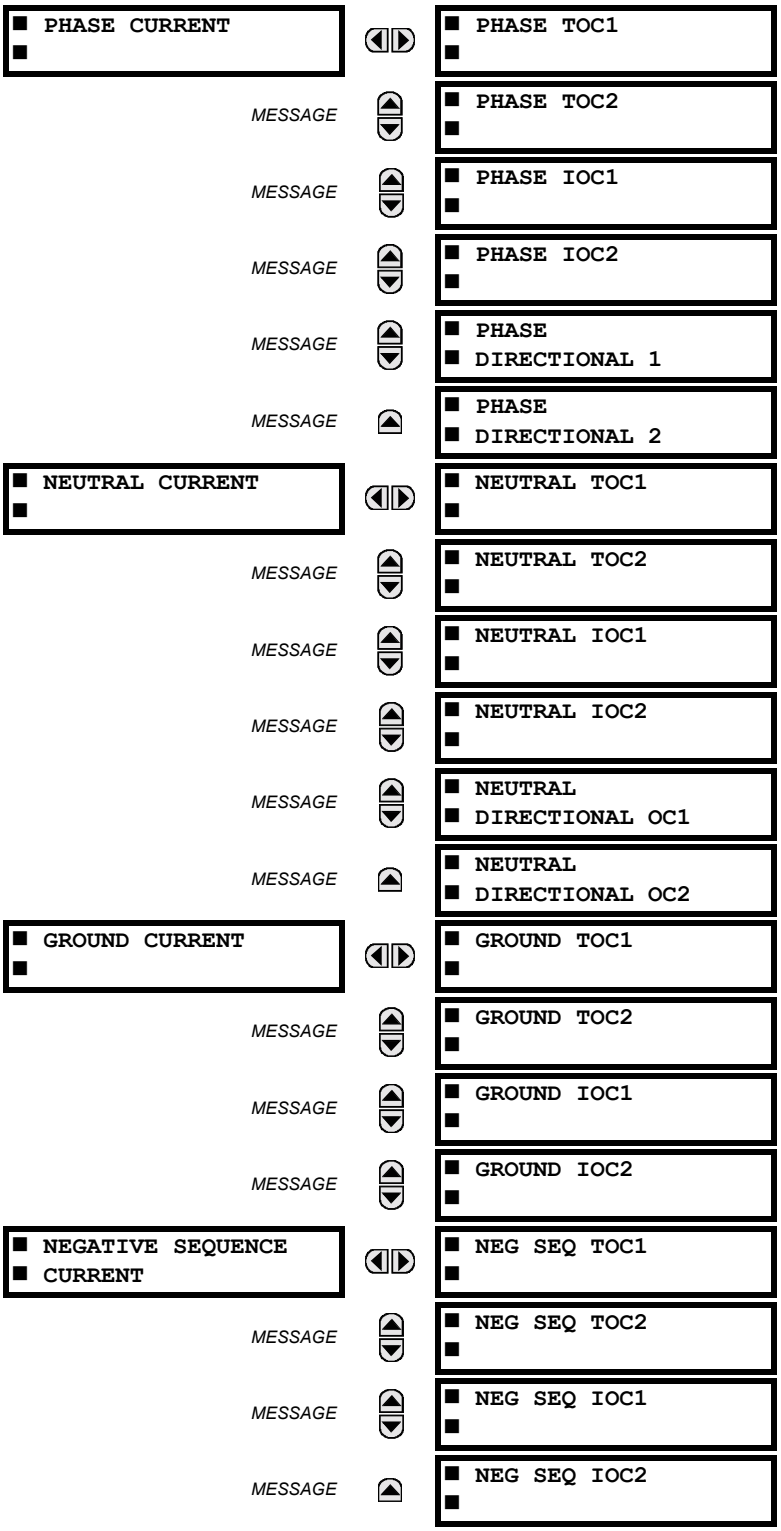
LOAD ENCROACHMENT REACH:

This setting specifies the resistive reach of the element as shown in the LOAD ENCROACHMENT CHARACTERISTIC diagram. This setting applies to the positive sequence impedance and should be entered in secondary ohms and should be calculated as the positive-sequence resistance seen by the relay under maximum load conditions and unity power factor.

LOAD ENCROACHMENT ANGLE:

This setting specifies the size of the blocking region as shown on the LOAD ENCROACHMENT CHARACTERISTIC and applies to the positive sequence impedance.

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨



The relay current elements menu consists of time overcurrent (TOC) , instantaneous overcurrent (IOC), and directional current elements. These elements can be used for tripping, alarming, or other functions.

5.5.11 INVERSE TIME OVERCURRENT CURVE CHARACTERISTICS

The inverse time overcurrent curves used by the TOC (time overcurrent) Current 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, the FlexCurve™ 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.

Table 5–15: OVERCURRENT CURVE TYPES

IEEE	IEC	GE TYPE IAC	OTHER
IEEE Extremely Inv.	IEC Curve A (BS142)	IAC Extremely Inv.	I^2t
IEEE Very Inverse	IEC Curve B (BS142)	IAC Very Inverse	FlexCurve A
IEEE Moderately Inv.	IEC Curve C (BS142)	IAC Inverse	FlexCurve B
	IEC Short Inverse	IAC Short Inverse	Definite Time

A time dial multiplier setting allows selection of a multiple of the base curve shape (where the time dial multiplier = 1) with the curve shape (**CURVE**) setting. Unlike the electromechanical time dial equivalent, operate times are directly proportional to the time multiplier (**TD 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 selection 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 selection can be used where the relay must coordinate with electromechanical relays.

Graphs of standard time-current curves on 11” × 17” log-log graph paper are available upon request from the GE Power Management literature department. The original files are also available in PDF format on the UR Software Installation CD and the GE Power Management Web Page.

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. The IEEE curves are derived from the formulae:

$$T = TDM \times \left[\frac{A}{\left(\frac{I}{I_{pickup}} \right)^{p} - 1} + B \right] \qquad T_{RESET} = TDM \times \left[\frac{t_r}{\left(\frac{I}{I_{pickup}} \right)^{2} - 1} \right]$$

where: T = Operate Time (sec.)
TDM = Multiplier Setting
I = Input Current
I_{pickup} = Pickup Current Setting
A, B, p = Constants
T_{RESET} = reset time in sec. (assuming energy capacity is 100% and RESET: Timed)
t_r = characteristic constant

Table 5–16: IEEE INVERSE TIME CURVE CONSTANTS

IEEE CURVE SHAPE	A	B	P	T_R
IEEE EXTREMELY INVERSE	28.2	0.1217	2.0000	29.1
IEEE VERY INVERSE	19.61	0.491	2.0000	21.6
IEEE MODERATELY INVERSE	0.0515	0.1140	0.02000	4.85

Table 5–17: 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 relay offers three standard curves defined in IEC 255-4 and British standard BS142. These are defined as IEC Curve A, IEC Curve B, and IEC Curve C. The formulae for these curves are:

$$T = TDM \times \left[\frac{K}{\left(\frac{I}{I_{pickup}} \right)^{E} - 1} \right] \qquad T_{RESET} = TDM \times \left[\frac{t_r}{\left(\frac{I}{I_{pickup}} \right)^{2} - 1} \right]$$

where: T = Operate Time (sec.) TDM = Multiplier Setting I = Input Current
I_{pickup} = Pickup Current Setting K, E = Constants t_r = Characteristic Constant
T_{RESET} = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

Table 5–18: IEC (BS) INVERSE TIME CURVE CONSTANTS

IEC (BS) 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 5–19: IEC 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 from the formulae:

$$T = \text{TDM} \times \left[A + \frac{B}{\left(\frac{I}{I_{pickup}} - C\right)} + \frac{D}{\left(\frac{I}{I_{pickup}} - C\right)^2} + \frac{E}{\left(\frac{I}{I_{pickup}} - C\right)^3} \right] \qquad T_{RESET} = TDM \times \left[\frac{t_r}{\left(\frac{I}{I_{pickup}}\right)^2 - 1} \right]$$

where: T = Operate Time (sec.) TDM = Multiplier Setting I = Input Current
I_{pickup} = Pickup Current Setting A to E = Constants t_r = Characteristic Constant
T_{RESET} = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

Table 5–20: 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

Table 5–21: IAC CURVE TRIP TIMES

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

I2t CURVES:

The curves for the I^2t are derived from the formulae:

$$T = \text{TDM} \times \left[\frac{100}{\left(\frac{I}{I_{pickup}} \right)^2} \right] \qquad T_{RESET} = \text{TDM} \times \left[\frac{100}{\left(\frac{I}{I_{pickup}} \right)^{-2}} \right]$$

where: T = Operate Time (sec.)
TDM = Multiplier Setting
I = Input Current
I_{pickup} = Pickup Current Setting
T_{RESET} = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

Table 5–22: I^2t CURVE TRIP TIMES

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

FLEXCURVE™:

The custom FlexCurve™ is described in detail in the FLEXCURVE™ section of this chapter. The curve shapes for the FlexCurves™ are derived from the formulae:

$$T = \text{TDM} \times \left[\text{FlexcurveTime@} \left(\frac{I}{I_{pickup}} \right) \right] \qquad \text{When } \left(\frac{I}{I_{pickup}} \right) \geq 1.00$$

$$T_{RESET} = \text{TDM} \times \left[\text{FlexcurveTime@} \left(\frac{I}{I_{pickup}} \right) \right] \qquad \text{When } \left(\frac{I}{I_{pickup}} \right) \leq 0.98$$

where: T = Operate Time (sec.)
TDM = Multiplier Setting
I = Input Current
I_{pickup} = Pickup Current Setting
T_{RESET} = Reset Time in seconds (assuming energy capacity is 100% and RESET: 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.

T = TDM in seconds, when $I > I_{pickup}$

T_{RESET} = –TDM in seconds

where: T = Operate Time (sec.)
TDM = Multiplier Setting
I = Input Current
I_{pickup} = Pickup Current Setting
T_{RESET} = Reset Time in seconds (assuming energy capacity is 100% and RESET: Timed)

a) PHASE TOC1 / TOC2 (PHASE TIME OVERCURRENT: ANSI 51P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ PHASE CURRENT ⇨ PHASE TOC1

PHASE TOC1	PHASE TOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	PHASE TOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	PHASE TOC1 INPUT: Phasor	*Range: Phasor, RMS*
MESSAGE	PHASE TOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
MESSAGE	PHASE TOC1 CURVE: IEEE Mod Inv	*Range: See OVERCURRENT CURVE TYPES table*
MESSAGE	PHASE TOC1 TD MULTIPLIER: 1.00	*Range: 0.00 to 600.00 in steps of 0.01*
MESSAGE	PHASE TOC1 RESET: Instantaneous	*Range: Instantaneous, Timed*
MESSAGE	PHASE TOC1 VOLTAGE RESTRAINT: Disabled	*Range: Disabled, Enabled*
MESSAGE	PHASE TOC1 BLOCK A: Off	*Range: FlexLogic™ operand*
MESSAGE	PHASE TOC1 BLOCK B: Off	*Range: FlexLogic™ operand*
MESSAGE	PHASE TOC1 BLOCK C: Off	*Range: FlexLogic™ operand*
MESSAGE	PHASE TOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	PHASE TOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

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” (refer to the INVERSE TOC CURVE CHARACTERISTICS section for details on curve setup, trip times and reset operation). 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.

The **PHASE TOC1 PICKUP** setting can be dynamically reduced by a voltage restraint feature (when enabled). This is accomplished via the multipliers (Mvr) corresponding to the phase-phase voltages of the voltage restraint characteristic curve (see the figure below); the pickup level is calculated as ‘Mvr’ times the PICKUP setting. If the voltage restraint feature is disabled, the pickup level always remains at the setting value.

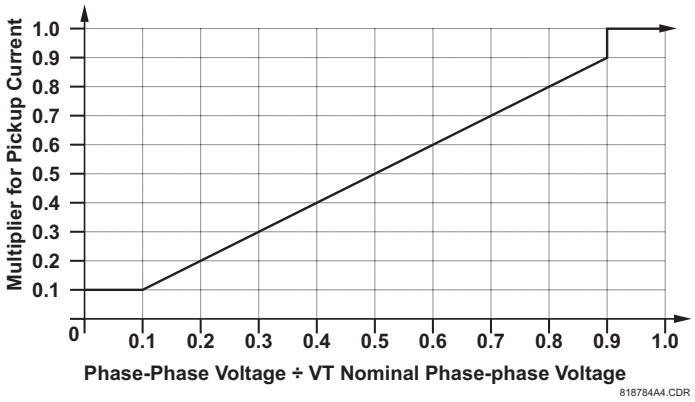


Figure 5–37: VOLTAGE RESTRAINT CHARACTERISTIC FOR PHASE TOC

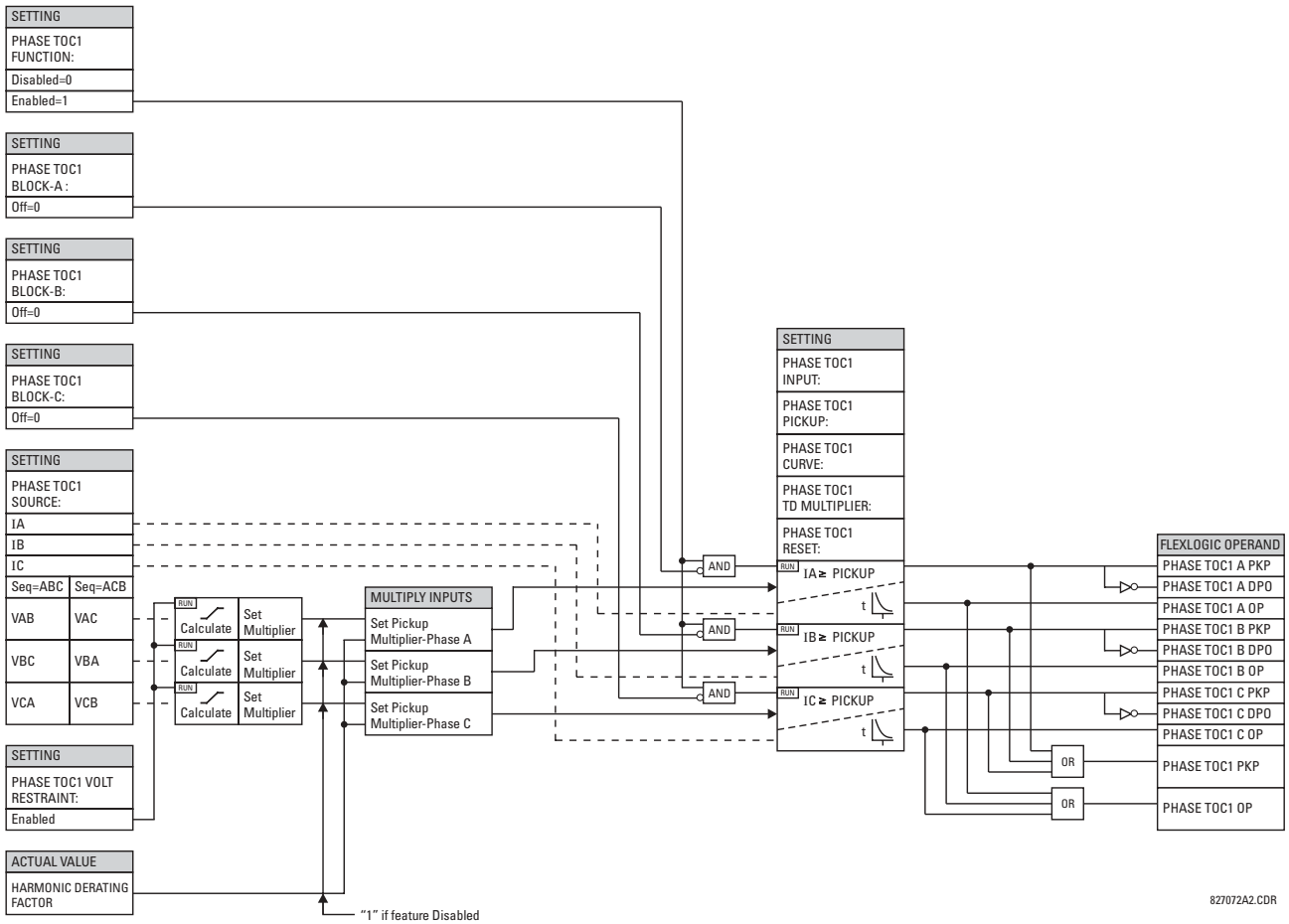


Figure 5–38: PHASE TOC1 SCHEME LOGIC

b) PHASE IOC1 / IOC2 (PHASE INSTANTANEOUS OVERCURRENT: ANSI 50P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ PHASE CURRENT ⇨ PHASE IOC 1

■ PHASE IOC1 ■	PHASE IOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	PHASE IOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	PHASE IOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
MESSAGE	PHASE IOC1 PICKUP DELAY: 0.00 s	*Range: 0.00 to 600.00 in steps of 0.01*
MESSAGE	PHASE IOC1 RESET DELAY: 0.00 s	*Range: 0.00 to 600.00 in steps of 0.01*
MESSAGE	PHASE IOC1 BLOCK A: Off	*Range: FlexLogic™ operand*
MESSAGE	PHASE IOC1 BLOCK B: Off	*Range: FlexLogic™ operand*
MESSAGE	PHASE IOC1 BLOCK C: Off	*Range: FlexLogic™ operand*
MESSAGE	PHASE IOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	PHASE IOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

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.

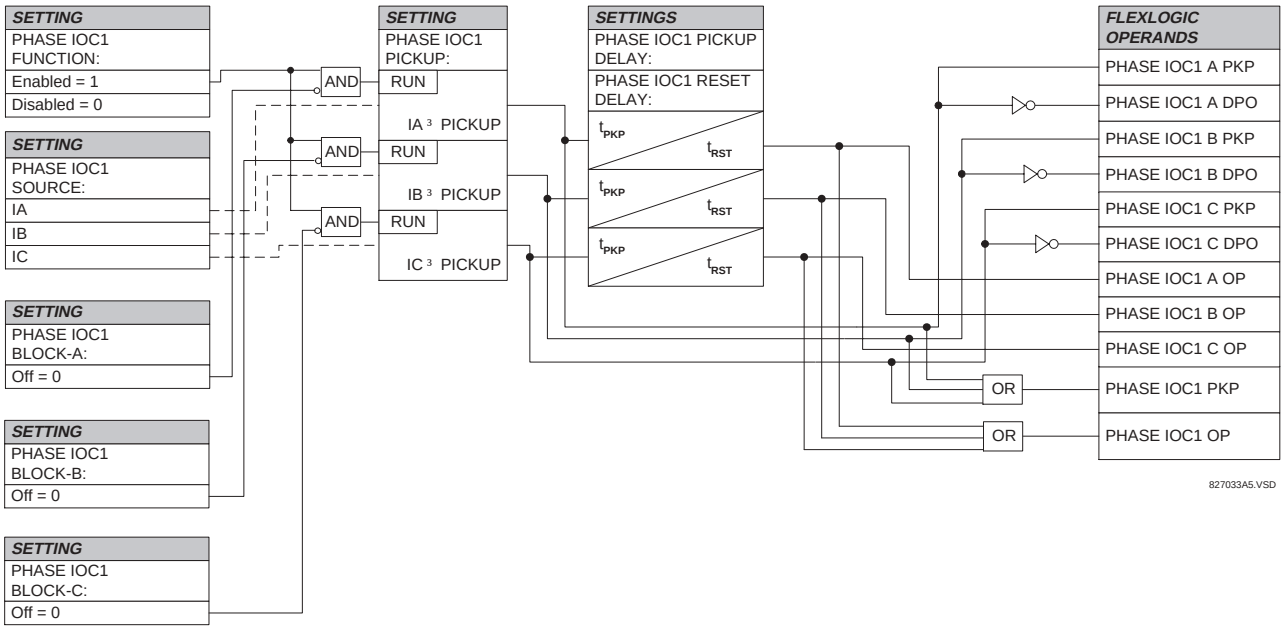


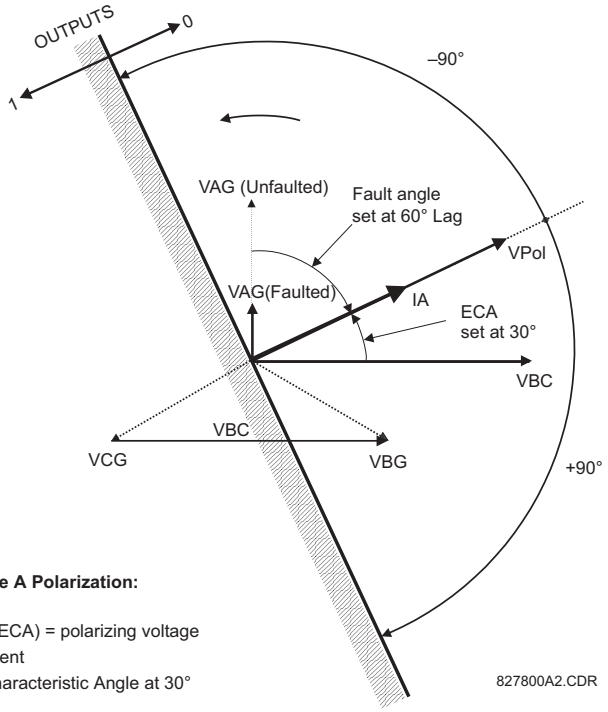
Figure 5–39: PHASE IOC1 SCHEME LOGIC

c) PHASE DIRECTIONAL 1(2) (PHASE DIRECTIONAL OVERCURRENT: ANSI 67P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ PHASE CURRENT ⇨ PHASE DIRECTIONAL 1

■ PHASE ■ DIRECTIONAL 1	PHASE DIR 1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	PHASE DIR 1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	PHASE DIR 1 BLOCK: Off	*Range: FlexLogic™ operand*
MESSAGE	PHASE DIR 1 ECA: 30	*Range: 0 to 359° in steps of 1*
MESSAGE	PHASE DIR POL V1 THRESHOLD:0.050 pu	*Range: 0.000 to 3.000 pu in steps of 0.001*
MESSAGE	PHASE DIR 1 BLOCK WHEN V MEM EXP: No	*Range: No, Yes*
MESSAGE	PHASE DIR 1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	PHASE DIR 1 EVENTS: Disabled	*Range: Disabled, Enabled*

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.



Phasors for Phase A Polarization:

VPol = VBC × (1/_ECA) = polarizing voltage
IA = operating current
ECA = Element Characteristic Angle at 30°

Figure 5–40: PHASE A DIRECTIONAL POLARIZATION

This 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 ECA settings.

To increase security for three phase faults very close to the location of the VTs used to measure the polarizing voltage, a 'voltage memory' feature is incorporated. This feature remembers the measurement of 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:

PHASE	OPERATING SIGNAL	POLARIZING SIGNAL VPOL	
		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)

MODE OF OPERATION:

- When the Phase Directional function is "Disabled", or the operating current is below 5% × CT Nominal, the element output is "0".
- When the Phase Directional function is "Enabled", the operating current is above 5% × CT Nominal and the polarizing voltage is above the set threshold, the element output depends on the phase angle between the operating and polarizing signals as follows:
  - 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 as follows:
  - When **BLOCK WHEN V MEM EXP** is set to "Yes", the directional element will block 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 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".

SETTINGS:

PHASE DIR 1 SIGNAL SOURCE:

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).

PHASE DIR 1 ECA:

This setting is used to select the Element Characteristic Angle, i.e. the angle by which the polarizing voltage is shifted in the leading direction to achieve dependable operation. In the design of UR elements, a block is applied to an element by asserting logic 1 at the blocking input. This element should be programmed via the ECA setting so that the output is **logic 1 for current in the non-tripping direction**.

PHASE DIR 1 POL V THRESHOLD:

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. The default value is 0.05 pu.

PHASE DIR 1 BLOCK WHEN V MEM EXP:

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.

NOTE

The Phase Directional element would respond to the forward load current. In the case of a following reverse fault, the element needs some time – in the order of 8 msec – 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 msec 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 msec – may be needed.

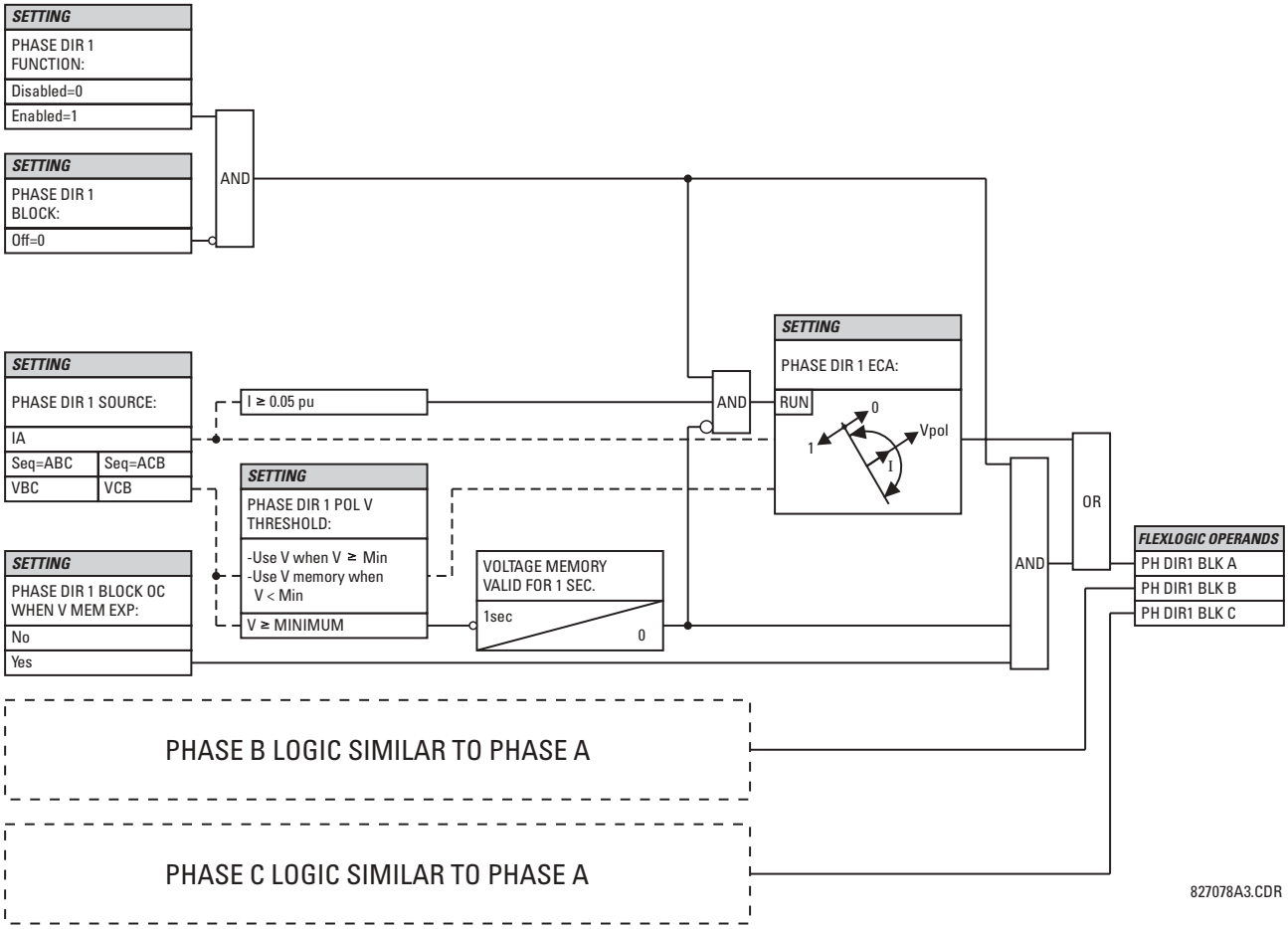


Figure 5–41: PHASE DIRECTIONAL SCHEME LOGIC

a) NEUTRAL TOC1 / TOC2 (NEUTRAL TIME OVERCURRENT: ANSI 51N)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ NEUTRAL CURRENT ⇨ NEUTRAL TOC1

NEUTRAL TOC1		NEUTRAL TOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
	MESSAGE	NEUTRAL TOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
	MESSAGE	NEUTRAL TOC1 INPUT: Phasor	*Range: Phasor, RMS*
	MESSAGE	NEUTRAL TOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
	MESSAGE	NEUTRAL TOC1 CURVE: IEEE Mod Inv	*Range: See OVERCURRENT CURE TYPES table*
	MESSAGE	NEUTRAL TOC1 TD MULTIPLIER: 1.00	*Range: 0.00 to 600.00 in steps of 0.01*
	MESSAGE	NEUTRAL TOC1 RESET: Instantaneous	*Range: Instantaneous, Timed*
	MESSAGE	NEUTRAL TOC1 BLOCK: Off	*Range: FlexLogic™ operand*
	MESSAGE	NEUTRAL TOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
	MESSAGE	NEUTRAL TOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

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 3Io 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” (refer to the INVERSE TOC CURVE CHARACTERISTICS section for details on curve setup, trip times and reset operation). 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.

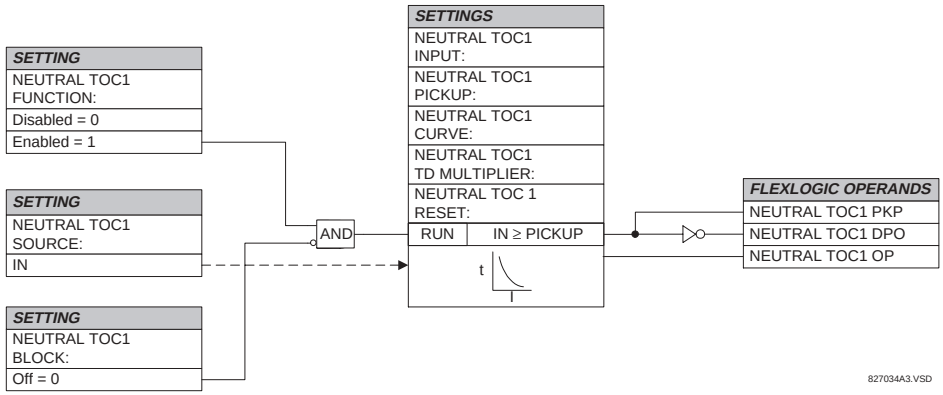


Figure 5–42: NEUTRAL TOC1 SCHEME LOGIC

NOTE

Once picked up, the NEUTRAL TOCx PKP output operand remains picked up until the thermal memory of the element resets completely. The PKP operand will not reset immediately after the operating current drops below the pickup threshold unless NEUTRL TOCx RESET is set to "Instantaneous".

b) NEUTRAL IOC1 / IOC2 (NEUTRAL INSTANTANEOUS OVERCURRENT: ANSI 50N)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL IOC1

■ NEUTRAL IOC1 ■		NEUTRAL IOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
	MESSAGE	NEUTRAL IOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
	MESSAGE	NEUTRAL IOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
	MESSAGE	NEUTRAL IOC1 PICKUP DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	MESSAGE	NEUTRAL IOC1 RESET DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	MESSAGE	NEUTRAL IOC1 BLOCK: Off	*Range: FlexLogic™ operand*
	MESSAGE	NEUTRAL IOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
	MESSAGE	NEUTRAL IOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

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:

$$I_{op} = 3 \times (|I\_0| - K \cdot |I\_1|) \quad , \text{ where } K = 1/16.$$

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 (single-phase injection: $I_{op} = 0.9375 \cdot I_{injected}$; three-phase pure zero-sequence injection: $I_{op} = 3 \times I_{injected}$).

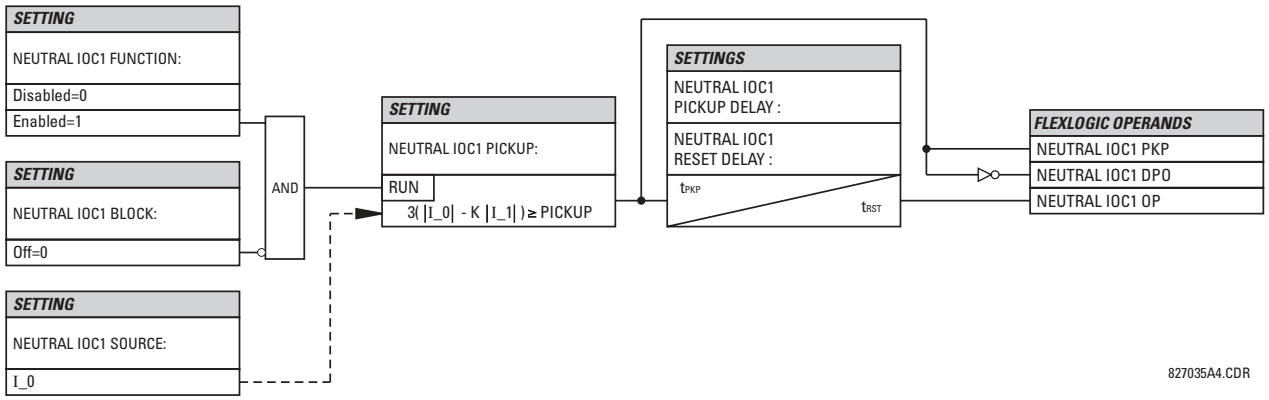
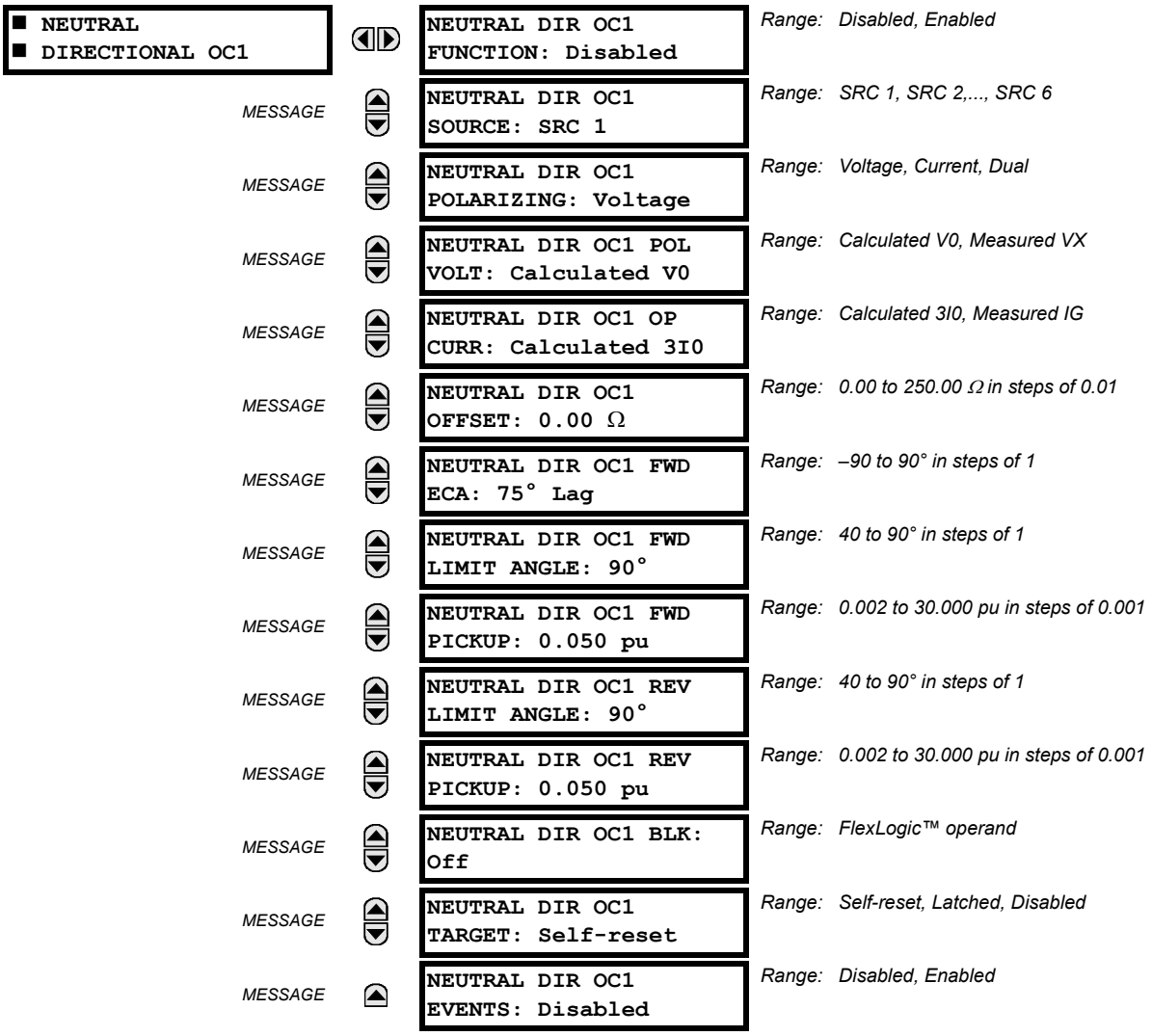


Figure 5–43: NEUTRAL IOC1 SCHEME LOGIC

c) NEUTRAL DIRECTIONAL OC1 / OC2 (NEUTRAL DIRECTIONAL OVERCURRENT: ANSI 67N)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ NEUTRAL CURRENT ⇨⇩ NEUTRAL DIRECTIONAL OC1



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 portion (6.25%) of the positive–sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity.

$$I_{op} = 3 \times (|I\_0| - K \times |I\_1|)$$, where K is 1/16.

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 (single-phase injection: $I_{op} = 0.9375 \times I_{injected}$; three-phase pure zero-sequence injection: $I_{op} = 3 \times I_{injected}$).

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 following tables define the Neutral Directional Overcurrent element.

Table 5–23: QUANTITIES FOR "CALCULATED 3I0" CONFIGURATION

DIRECTIONAL UNIT				OVERCURRENT UNIT
POLARIZING MODE	DIRECTION	COMPARED PHASORS		
Voltage	Forward	–V_0 + Z_offset × I_0	I_0 × 1∠ECA	$I_{op} = 3 \times (\|I\_0\| - K \times \|I\_1\|)$
	Reverse	–V_0 + Z_offset × I_0	–I_0 × 1∠ECA	
Current	Forward	IG	I_0	
	Reverse	IG	–I_0	
Dual	Forward	–V_0 + Z_offset × I_0	I_0 × 1∠ECA	
		or		
		IG	I_0	
	Reverse	–V_0 + Z_offset × I_0	–I_0 × 1∠ECA	
		or		
		IG	–I_0	

Table 5–24: QUANTITIES FOR "MEASURED IG" CONFIGURATION

DIRECTIONAL UNIT				OVERCURRENT UNIT
POLARIZING MODE	DIRECTION	COMPARED PHASORS		
Voltage	Forward	–V_0 + Z_offset × IG/3	IG × 1∠ECA	$I_{op} = \|IG\|$
	Reverse	–V_0 + Z_offset × IG/3	–IG × 1∠ECA	

where: $V\_0 = \frac{1}{3}(VAG + VBG + VCG)$ = zero sequence voltage

$I\_0 = \frac{1}{3}IN = \frac{1}{3}(IA + IB + IC)$ = zero sequence current

ECA = element characteristic angle

IG = ground current

When **NEUTRAL DIR OC1 POL VOLT** is set to "Measured VX", one-third of this voltage is used in place of V_0.

The following figure explains the usage of the voltage polarized directional unit of the element.

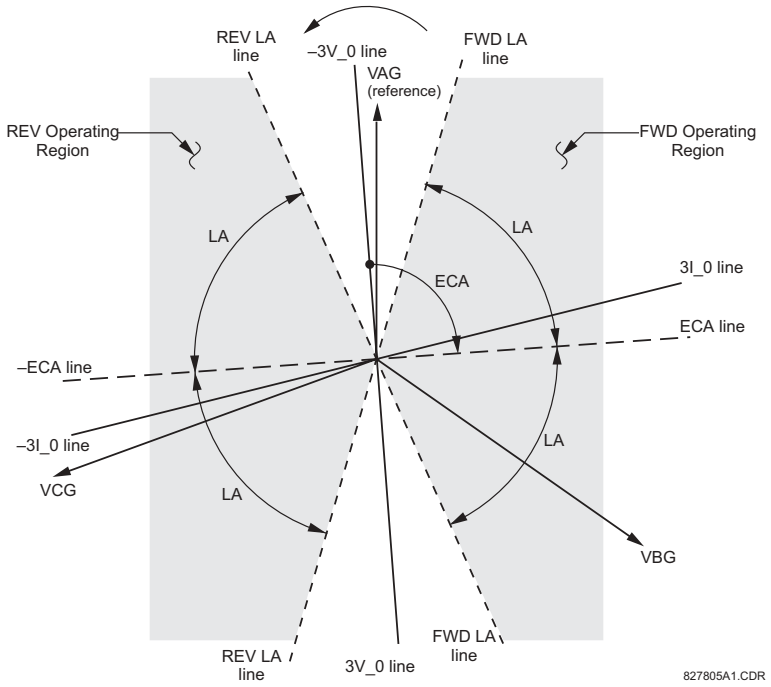


Figure 5–44: NEUTRAL DIRECTIONAL VOLTAGE-POLARIZED CHARACTERISTICS

The above figure shows the voltage-polarized phase angle comparator characteristics for a phase-A to ground fault, with:

ECA = 90° (Element Characteristic Angle = centerline of operating characteristic)
FWD LA = 80° (Forward Limit Angle = the ± angular limit with the ECA for operation)
REV LA = 80° (Reverse Limit Angle = the ± angular limit with the ECA for operation)

The 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.

NEUTRAL DIR OC1 POLARIZING:

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 DIR OC1 SOURCE**.

  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 **SYSTEM SETUP** ⇨ **AC INPUTS** ⇨⇩ **VOLTAGE BANK** ⇨⇩ **AUXILIARY VT CONNECTION** is set to "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 0.02 pu nominal voltage to be validated 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 **NEUTRAL OC1 SOURCE** for polarization. The ground current transformer 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 for use 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.

NEUTRAL DIR OC1 POL VOLT:

Selects the polarizing voltage used by the directional unit when "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").

NEUTRAL DIR OC1 OP CURR:

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 (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 **NEUTRAL DIR OC1 SOURCE**. Naturally, it is not possible to use the ground current as an operating and polarizing signal simultaneously. Therefore, "Voltage" is the only applicable selection for the polarizing mode under the "Measured IG" selection of this setting.

NEUTRAL DIR OC1 OFFSET:

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. See the APPLICATION OF SETTINGS chapter for information on how to calculate this setting.

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. See the THEORY OF OPERATION chapter for more details. The offset impedance shall be entered in secondary ohms.

NEUTRAL DIR OC1 FWD ECA:

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°.

NEUTRAL DIR OC1 FWD LIMIT ANGLE:

This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.

NEUTRAL DIR OC1 FWD PICKUP:

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.

NEUTRAL DIR OC1 REV LIMIT ANGLE:

This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.

NEUTRAL DIR OC1 REV PICKUP:

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.

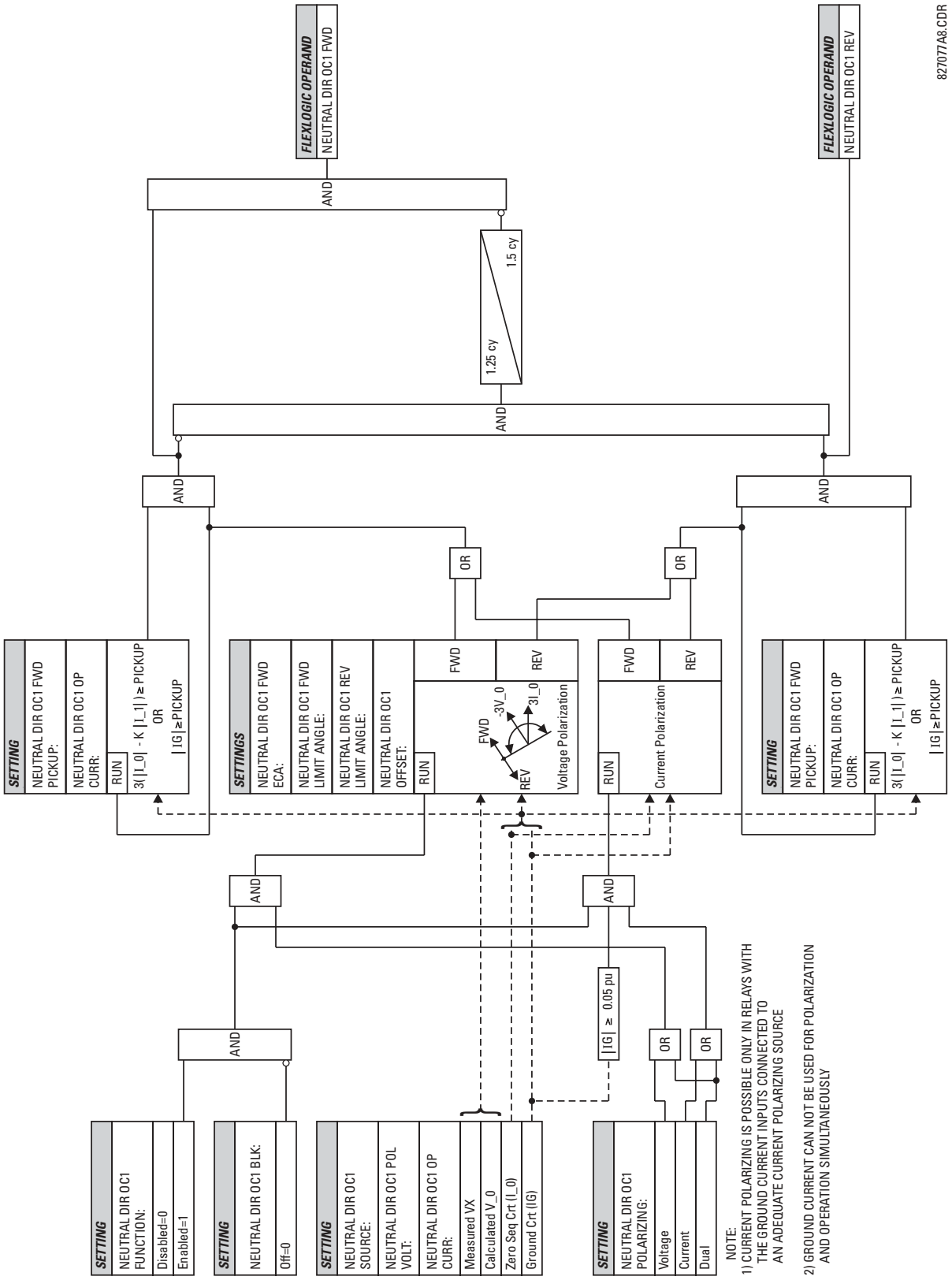


Figure 5–45: NEUTRAL DIRECTIONAL OC1 SCHEME LOGIC

a) GROUND TOC1 / TOC2 (GROUND TIME OVERCURRENT: ANSI 51G)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ GROUND CURRENT ⇨ GROUND TOC1

■ GROUND TOC1 ■		GROUND TOC1 FUNCTION: Disabled	Range: Disabled, Enabled
	MESSAGE	GROUND TOC1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
	MESSAGE	GROUND TOC1 INPUT: Phasor	Range: Phasor, RMS
	MESSAGE	GROUND TOC1 PICKUP: 1.000 pu	Range: 0.000 to 30.000 pu in steps of 0.001
	MESSAGE	GROUND TOC1 CURVE: IEEE Mod Inv	Range: see OVERCURRENT CURVE TYPES table
	MESSAGE	GROUND TOC1 TD MULTIPLIER: 1.00	Range: 0.00 to 600.00 in steps of 0.01
	MESSAGE	GROUND TOC1 RESET: Instantaneous	Range: Instantaneous, Timed
	MESSAGE	GROUND TOC1 BLOCK: Off	Range: FlexLogic™ operand
	MESSAGE	GROUND TOC1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
	MESSAGE	GROUND TOC1 EVENTS: Disabled	Range: Disabled, Enabled

This 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” (refer to the INVERSE TIME OVERCURRENT CURVE CHARACTERISTICS section for details). 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.

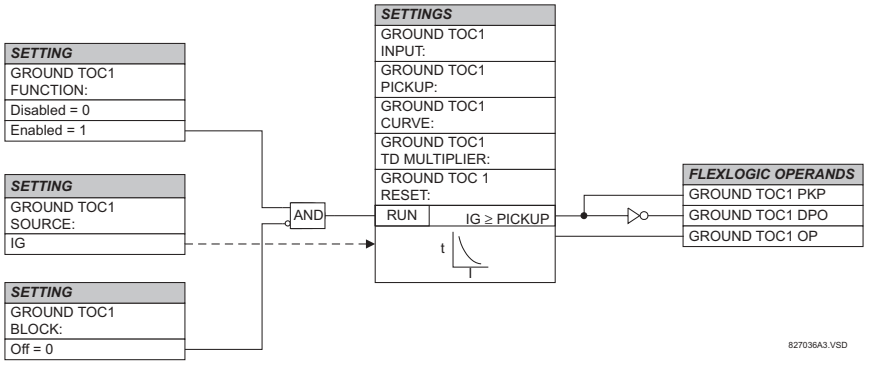


Figure 5–46: GROUND TOC1 SCHEME LOGIC

NOTE These elements measure the current that is connected to the ground channel of a CT/VT 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.

NOTE **Once picked up, the GROUND TOCx PKP output operand remains picked up until the thermal memory of the element resets completely. The PKP operand will not reset immediately after the operating current drops below the pickup threshold unless GROUND TOCx RESET is set to "Instantaneous".**

b) GROUND IOC1 / IOC2 (GROUND INSTANTANEOUS OVERCURRENT: ANSI 50G)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ GROUND CURRENT ⇨⇩ GROUND IOC1

GROUND IOC1	GROUND IOC1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	GROUND IOC1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	GROUND IOC1 PICKUP: 1.000 pu	Range: 0.000 to 30.000 pu in steps of 0.001
MESSAGE	GROUND IOC1 PICKUP DELAY: 0.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	GROUND IOC1 RESET DELAY: 0.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	GROUND IOC1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	GROUND IOC1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	GROUND IOC1 EVENTS: Disabled	Range: Disabled, Enabled

5

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 value is the quantity measured by the ground input CT and is the fundamental phasor magnitude.

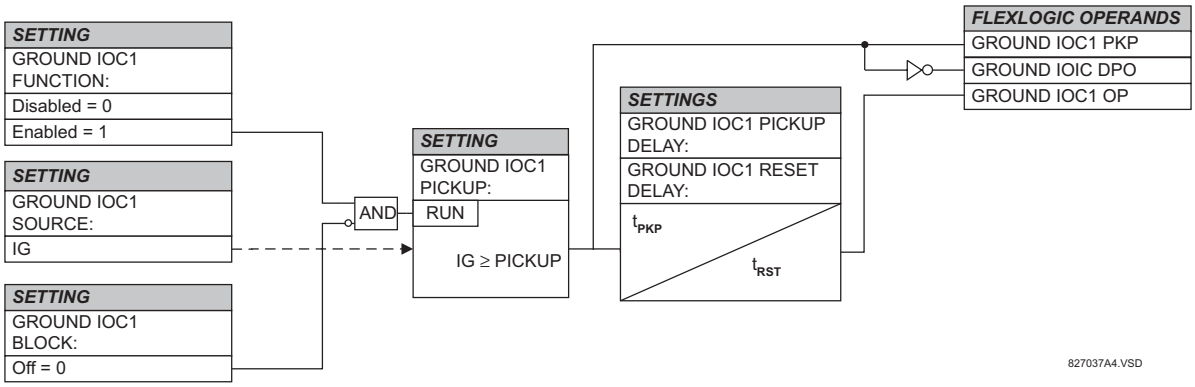


Figure 5–47: GROUND IOC1 SCHEME LOGIC

NOTE

These elements measure the current that is connected to the ground channel of a CT/VT 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.

a) NEGATIVE SEQUENCE TOC1 / TOC2 (NEGATIVE SEQUENCE TIME OVERCURRENT: ANSI 51_2)

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(8) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨ NEG SEQ TOC1

■ NEG SEQ TOC1 ■		
	NEG SEQ TOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	NEG SEQ TOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	NEG SEQ TOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
MESSAGE	NEG SEQ TOC1 CURVE: IEEE Mod Inv	*Range: see OVERCURRENT CURVE TYPES table*
MESSAGE	NEG SEQ TOC1 TD MULTIPLIER: 1.00	*Range: 0.00 to 600.00 in steps of 0.01*
MESSAGE	NEG SEQ TOC1 RESET: Instantaneous	*Range: Instantaneous, Timed*
MESSAGE	NEG SEQ TOC1 BLOCK: Off	*Range: FlexLogic™ operand*
MESSAGE	NEG SEQ TOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	NEG SEQ TOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

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” (refer to the INVERSE TIME OVERCURRENT CURVE CHARACTERISTICS section for details on curve setup, trip times and reset operation). 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.

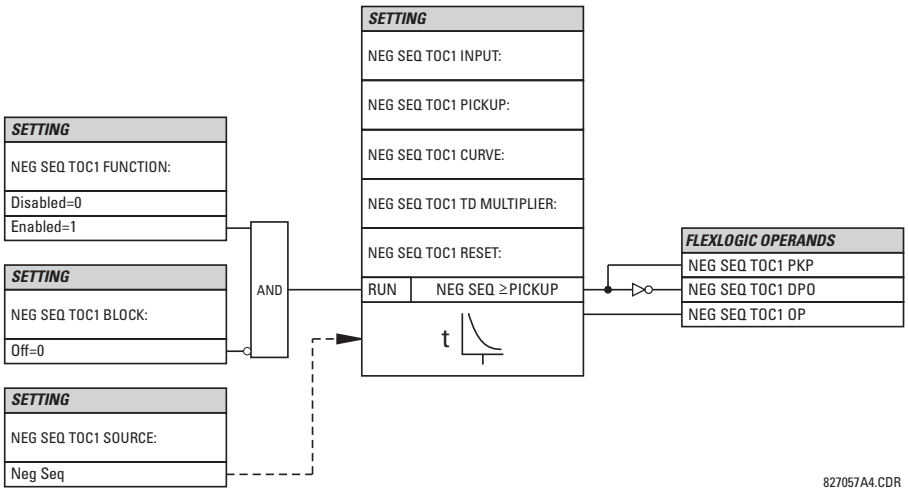


Figure 5–48: NEGATIVE SEQUENCE TOC1 SCHEME LOGIC

NOTE

Once picked up, the NEG SEQ TOCx PKP output operand remains picked up until the thermal memory of the element resets completely. The PKP operand will not reset immediately after the operating current drops below the pickup threshold unless NEG SEQ TOCx RESET is set to "Instantaneous".

b) NEGATIVE SEQUENCE IOC1 / IOC2 (NEGATIVE SEQUENCE INSTANTANEOUS O/C: ANSI 50_2)

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨⇩ NEG SEQ OC1

■ NEG SEQ IOC1 ■	NEG SEQ IOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	NEG SEQ IOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	NEG SEQ IOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
MESSAGE	NEG SEQ IOC1 PICKUP DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
MESSAGE	NEG SEQ IOC1 RESET DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
MESSAGE	NEG SEQ IOC1 BLOCK: Off	*Range: FlexLogic™ operand*
MESSAGE	NEG SEQ IOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	NEG SEQ IOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

5

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:

$$I_{op} = |I\_2| - K \cdot |I\_1| \quad , \text{ where } K = 1/8.$$

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 the way the test currents are injected into the relay (single phase injection: $I_{op} = 0.2917 \cdot I_{injected}$; three phase injection, opposite rotation: $I_{op} = I_{injected}$).

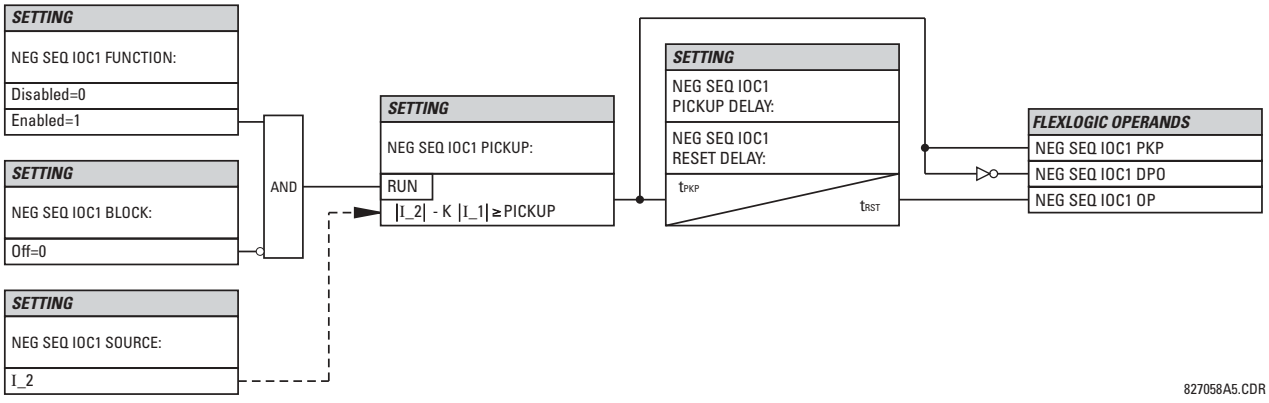


Figure 5–49: NEGATIVE SEQUENCE IOC1 SCHEME LOGIC

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ BREAKER FAILURE ⇨ BREAKER FAILURE 1

■ BREAKER FAILURE 1 ■		BF1 FUNCTION: Disabled	Range: Disabled, Enabled
	MESSAGE	BF1 MODE: 3-Pole	Range: 3-Pole, 1-Pole
	MESSAGE	BF1 SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
	MESSAGE	BF1 USE AMP SUPV: Yes	Range: Yes, No
	MESSAGE	BF1 USE SEAL-IN: Yes	Range: Yes, No
	MESSAGE	BF1 3-POLE INITIATE: Off	Range: FlexLogic™ operand
	MESSAGE	BF1 BLOCK: Off	Range: FlexLogic™ operand
	MESSAGE	BF1 PH AMP SUPV PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
	MESSAGE	BF1 N AMP SUPV PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
	MESSAGE	BF1 USE TIMER 1: Yes	Range: Yes, No
	MESSAGE	BF1 TIMER 1 PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
	MESSAGE	BF1 USE TIMER 2: Yes	Range: Yes, No
	MESSAGE	BF1 TIMER 2 PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
	MESSAGE	BF1 USE TIMER 3: Yes	Range: Yes, No
	MESSAGE	BF1 TIMER 3 PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
	MESSAGE	BF1 BKR POS1 ϕA/3P: Off	Range: FlexLogic™ operand
	MESSAGE	BF1 BKR POS2 ϕA/3P: Off	Range: FlexLogic™ operand
	MESSAGE	BF1 BREAKER TEST ON: Off	Range: FlexLogic™ operand
	MESSAGE	BF1 PH AMP HISET PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
	MESSAGE	BF1 N AMP HISET PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
	MESSAGE	BF1 PH AMP LOSET PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001

MESSAGE
BF1 N AMP LOSET PICKUP: 1.050 pu
Range: 0.001 to 30.000 pu in steps of 0.001

MESSAGE
BF1 LOSET TIME DELAY: 0.000 s
Range: 0.000 to 65.535 s in steps of 0.001

MESSAGE
BF1 TRIP DROPOUT DELAY: 0.000 s
Range: 0.000 to 65.535 s in steps of 0.001

MESSAGE
BF1 TARGET Self-Reset
Range: Self-reset, Latched, Disabled

MESSAGE
BF1 EVENTS Disabled
Range: Disabled, Enabled

MESSAGE
BF1 PH A INITIATE: Off
Range: FlexLogic™ operand
Valid only for 1-Pole breaker failure schemes.

MESSAGE
BF1 PH B INITIATE: Off
Range: FlexLogic™ operand
Valid only for 1-Pole breaker failure schemes.

MESSAGE
BF1 PH C INITIATE: Off
Range: FlexLogic™ operand
Valid only for 1-Pole breaker failure schemes.

MESSAGE
BF1 BKR POS1 ϕB Off
Range: FlexLogic™ operand
Valid only for 1-Pole breaker failure schemes.

MESSAGE
BF1 BKR POS1 ϕC Off
Range: FlexLogic™ operand
Valid only for 1-Pole breaker failure schemes.

MESSAGE
BF1 BKR POS2 ϕB Off
Range: FlexLogic™ operand
Valid only for 1-Pole breaker failure schemes.

MESSAGE
BF1 BKR POS2 ϕC Off
Range: FlexLogic™ operand
Valid only for 1-Pole breaker failure schemes.

There are 2 identical Breaker Failure menus available, numbered 1 and 2.

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 (identified by the name "3BF") and one for three pole plus single-pole operation (identified by the name "1BF"). 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.

INITIATION STAGE:

A FlexLogic™ operand representing the protection trip signal initially sent to the breaker must be selected to initiate the scheme. 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 **BF1 PH AMP SUPV PICKUP** or the **BF1 N AMP 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, Hiset and Loset, so that the supervision level can be changed from a current which flows before a breaker inserts an opening resistor into the faulted circuit to a lower level after resistor insertion. The Hiset detector is enabled after timeout of Timer 1 or 2, along with a timer that will enable the Loset detector after its delay interval. The delay interval between Hiset and Loset is the expected breaker opening time. Both current detectors provide a fast operating time for currents at small multiples of the pickup value. The O/C detectors are required to operate after the breaker failure delay interval to eliminate the need for very fast resetting O/C 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.

3. OUTPUT:

The outputs from the schemes are:

- FlexLogic™ operands that report on the operation of portions of the scheme
- 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.
- Target message indicating a failed breaker has been declared
- Illumination of the faceplate TRIP LED (and the PHASE A, B or C LED, if applicable)

MAIN PATH SEQUENCE:

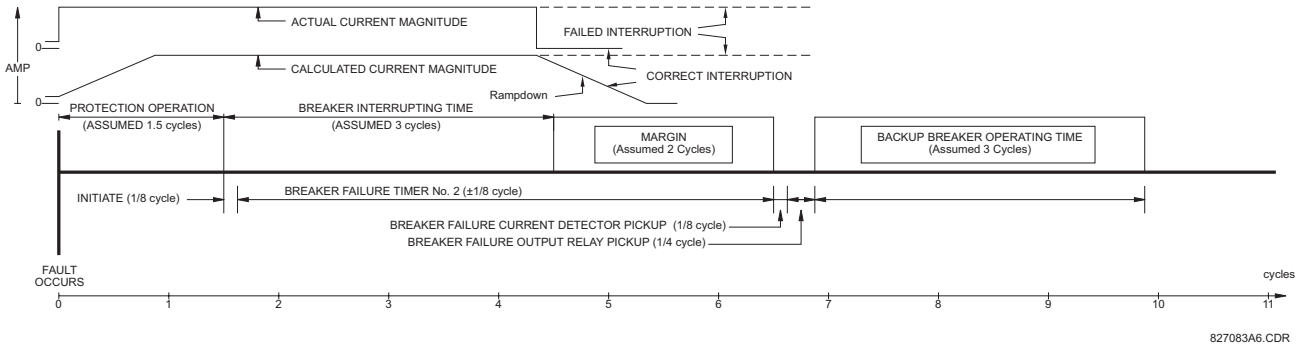


Figure 5–50: BREAKER FAILURE MAIN PATH SEQUENCE

BF1 MODE:

This setting is used to select the breaker failure operating mode: single or three pole.

BF1 USE AMP SUPV:

If set to Yes, the element will only be initiated if current flowing through the breaker is above the supervision pickup level.

BF1 USE SEAL-IN:

If set to Yes, the element will only be sealed-in if current flowing through the breaker is above the supervision pickup level.

BF1 3-POLE INITIATE:

This setting is used to select the FlexLogic™ operand that will initiate 3-pole tripping of the breaker.

BF1 PH AMP SUPV PICKUP:

This setting is used to set 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) - Hiset and Loset current supervision will guarantee correct operation.

BF1 N AMP SUPV PICKUP (valid only for 3-pole breaker failure schemes):

This setting is used to set 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.

BF1 USE TIMER 1:

If set to Yes, the Early Path is operational.

BF1 TIMER 1 PICKUP DELAY:

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.

BF1 USE TIMER 2:

If set to Yes, the Main Path is operational.

5

BF1 TIMER 2 PICKUP DELAY:

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 UR relays, 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.

Note that 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.

BF1 USE TIMER 3:

If set to Yes, the Slow Path is operational.

BF1 TIMER 3 PICKUP DELAY:

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.

BF1 BKR POS1 ϕA/3P:

This setting selects the FlexLogic™ operand that represents the protected breaker early-type auxiliary switch contact (52/a). When using 1-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.

BF1 BKR POS2 ϕA/3P:

This setting selects the FlexLogic™ operand that represents the breaker normal-type auxiliary switch contact (52/a). When using 1-Pole breaker failure scheme, this operand represents the protected breaker auxiliary switch contact on pole A. This may be a multiplied contact.

BF1 BREAKER TEST ON:

This setting is used to select the FlexLogic™ operand that represents the breaker In-Service/Out-of-Service switch set to the Out-of-Service position.

BF1 PH AMP HISET PICKUP:

This setting is used to set 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.

BF1 N AMP HISET PICKUP (valid only for 3-pole breaker failure schemes):

This setting sets 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.

BF1 PH AMP LOSET PICKUP:

This setting sets 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).

BF1 N AMP LOSET PICKUP (valid only for 3-pole breaker failure schemes):

This setting sets 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).

BF1 LOSET TIME DELAY:

This setting is used to set the pickup delay for current detection after opening resistor insertion.

BF1 TRIP DROPOUT DELAY:

This setting is used to set the period of 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.

BF1 PH A INITIATE / BF1 PH B INITIATE / BF 1 PH C INITIATE: (only valid for 1-pole breaker failure schemes)

These settings select the FlexLogic™ operand to initiate phase A, B, or C single-pole tripping of the breaker and the phase A, B, or C portion of the scheme, accordingly.

BF1 BKR POS1 ϕB / BF1 BKR POS 1 ϕC (valid only for 1-pole breaker failure schemes):

These settings select the FlexLogic™ operand to represents the protected breaker early-type auxiliary switch contact on poles B or C, accordingly. This contact is normally a non-multiplied Form-A contact. The contact may even be adjusted to have the shortest possible operating time.

BF1 BKR POS2 ϕB (valid only for 1-pole breaker failure schemes):

Selects the FlexLogic™ operand that represents the protected breaker normal-type auxiliary switch contact on pole B (52/a). This may be a multiplied contact.

BF1 BKR POS2 ϕC (valid only for 1-pole breaker failure schemes):

This setting selects the FlexLogic™ 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.

Upon operation of the breaker failure element for a single pole trip command, a 3-pole trip command should be given via output operand BKR FAIL 1 TRIP OP.

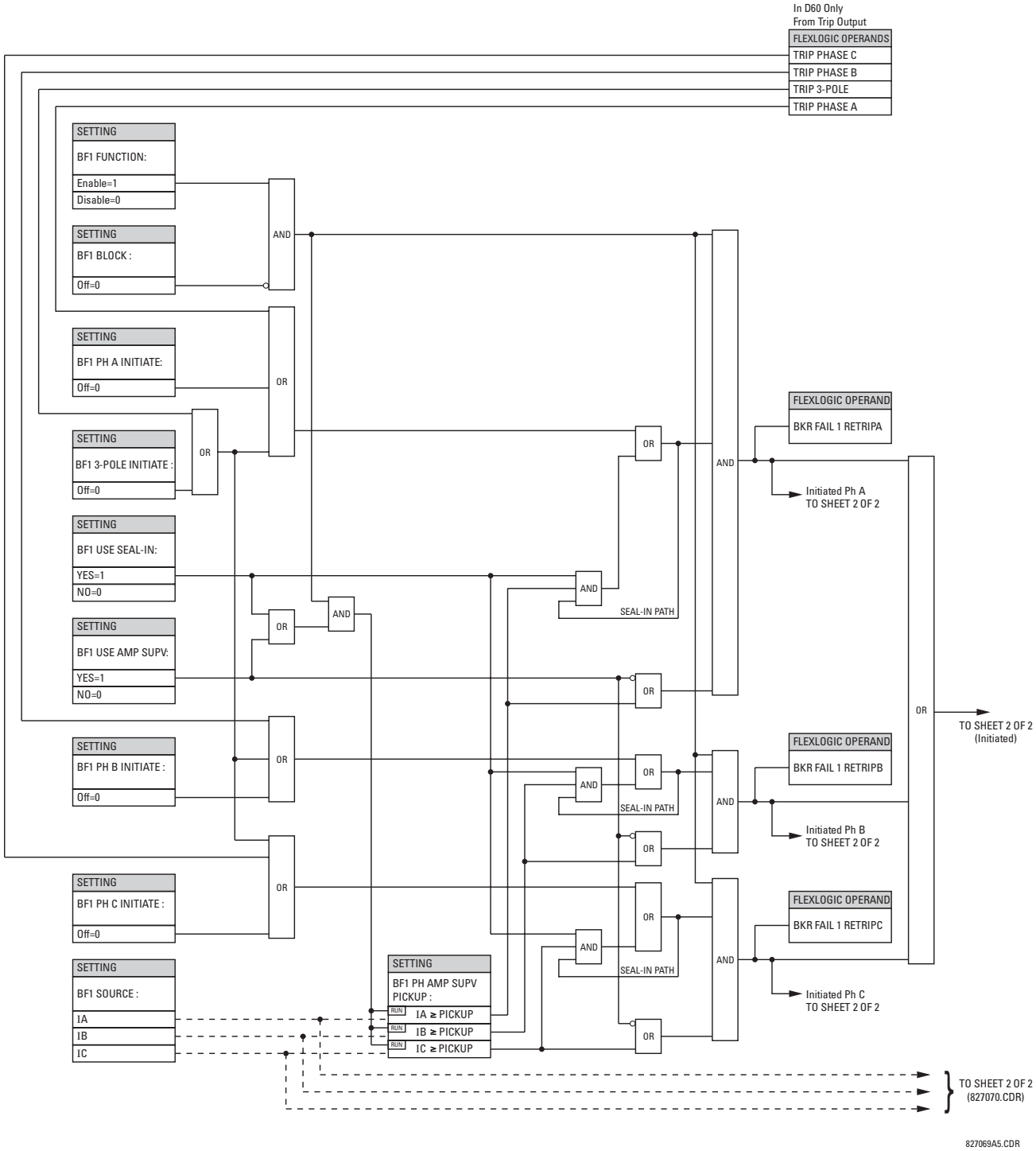


Figure 5–51: BREAKER FAILURE 1-POLE [INITIATE] (Sheet 1 of 2)

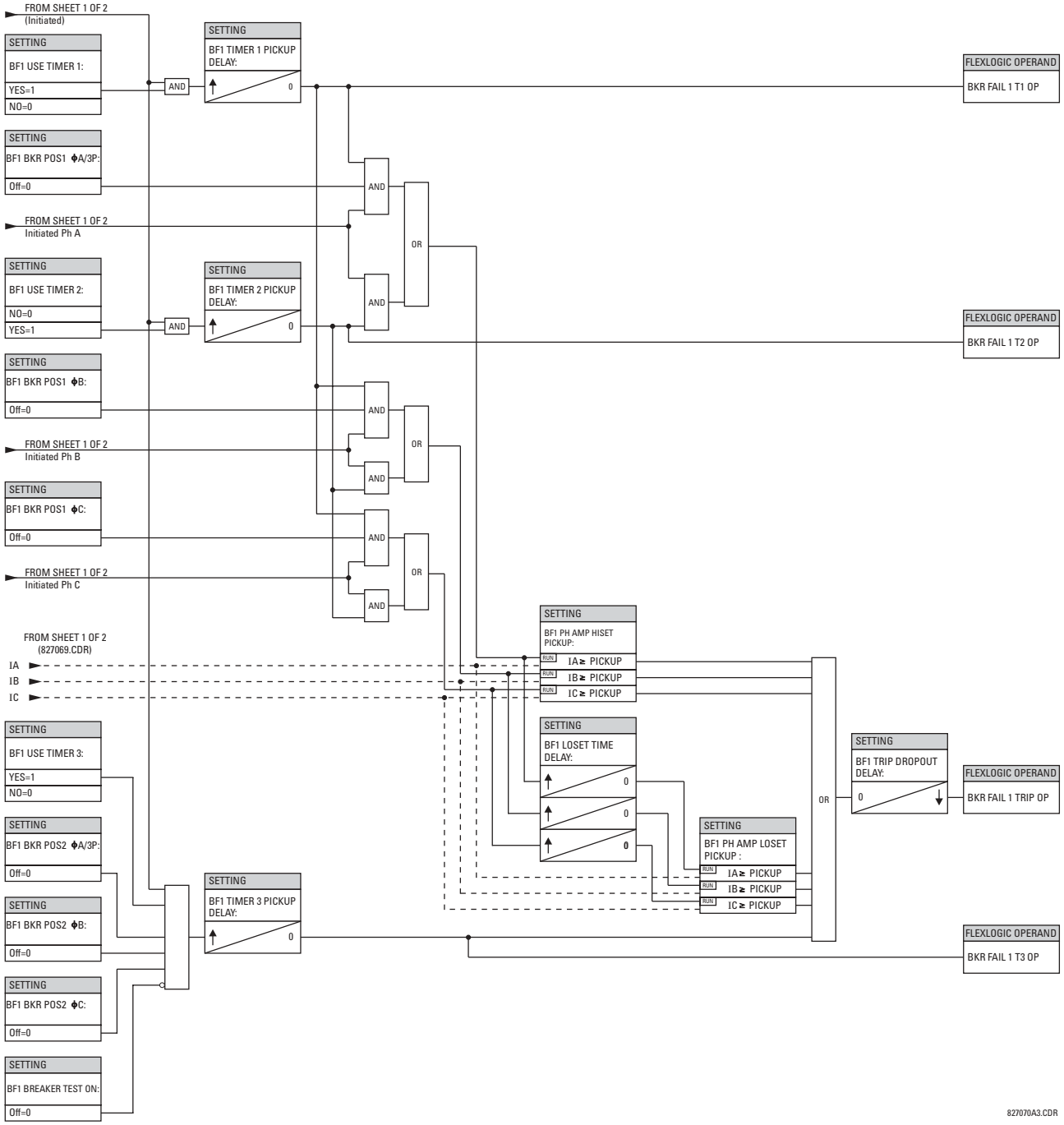


Figure 5–52: BREAKER FAILURE 1-POLE (TIMERS) [Sheet 2 of 2]

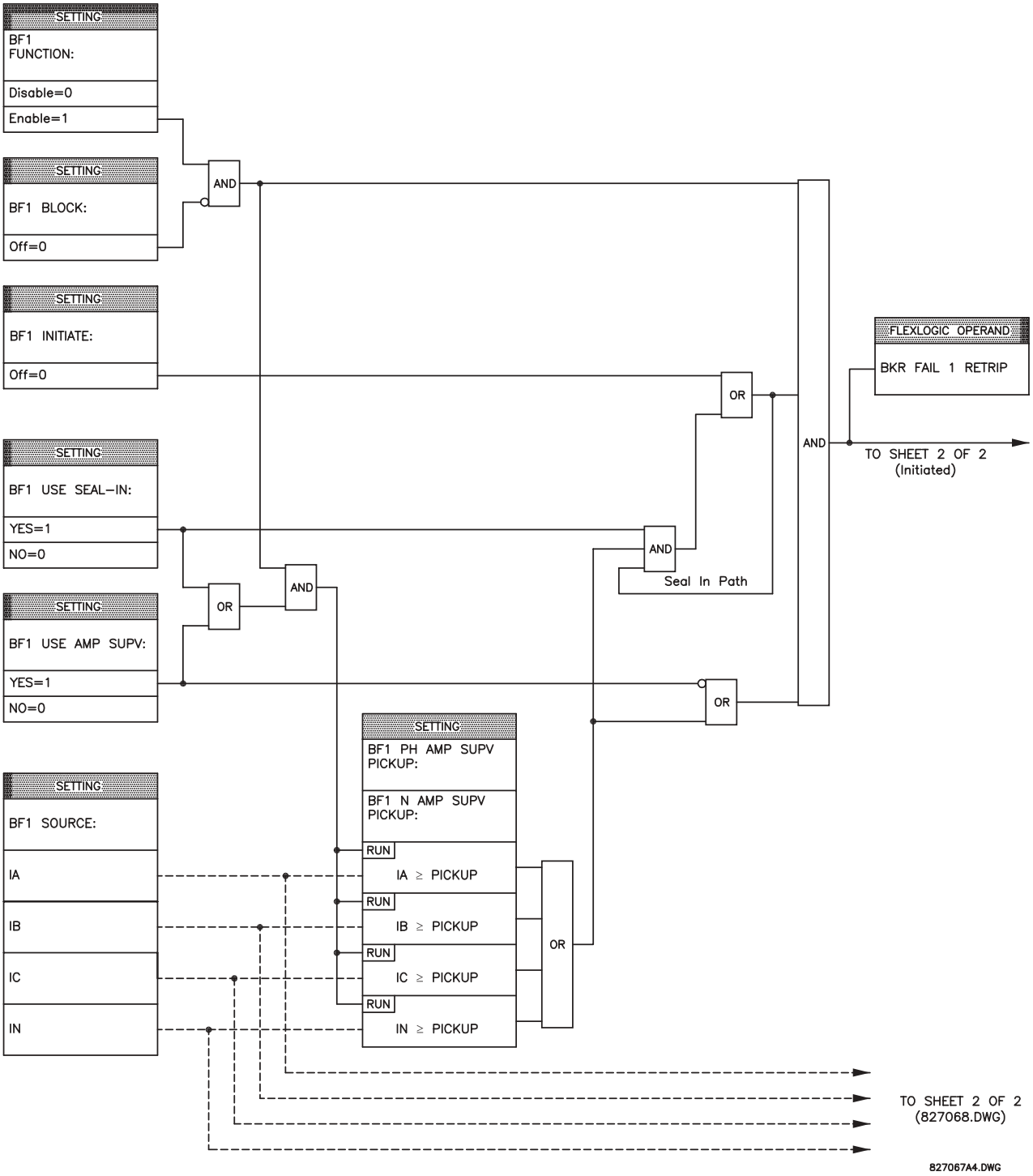


Figure 5–53: BREAKER FAILURE 3-POLE [INITIATE] (Sheet 1 of 2)

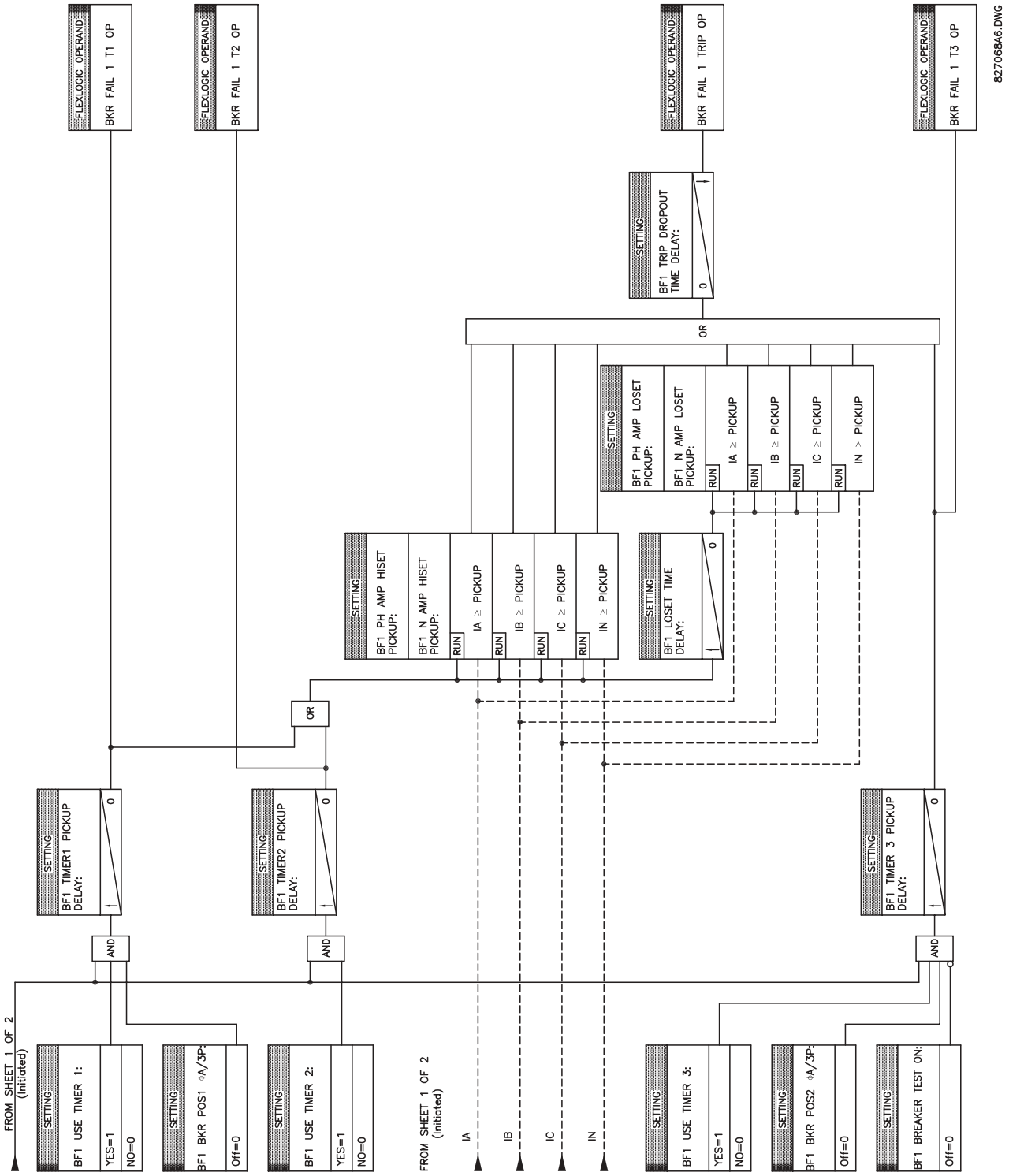
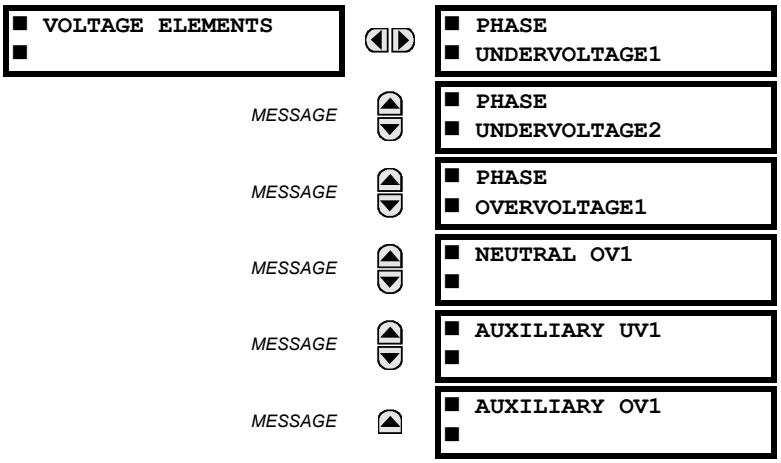


Figure 5–54: BREAKER FAILURE 3-POLE [TIMERS] (Sheet 2 of 2)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS



These protection elements can be used for a variety of applications such as:

Undervoltage Protection: 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.

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.

Source Transfer Schemes: In the event of an undervoltage, a transfer signal may be generated to transfer a load from its normal source to a standby or emergency power source.

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 10 ms. 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.

$$T = \frac{D}{\left(1 - \frac{V}{V_{pickup}}\right)}$$

where: T = Operating Time
D = Undervoltage Delay Setting
(D = 0.00 operates instantaneously)
V = Secondary Voltage applied to the relay
V_{pickup} = Pickup Level

NOTE

At 0% of pickup, the operating time equals the UNDERVOLTAGE DELAY setting.

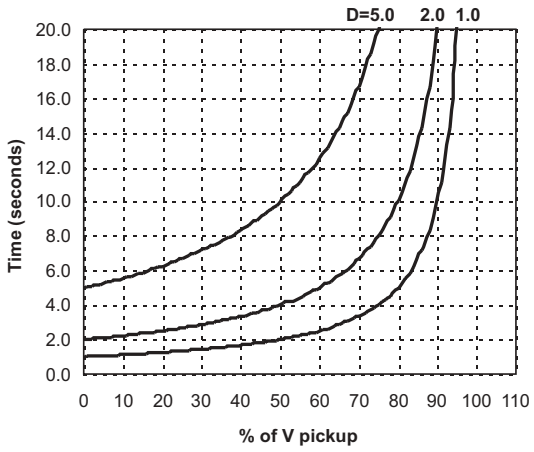


Figure 5–55: INVERSE TIME UNDERVOLTAGE CURVES

a) PHASE UV1 / UV2 (PHASE UNDERVOLTAGE: ANSI 27P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨ PHASE UNDERVOLTAGE1

■ PHASE ■ UNDERVOLTAGE1		
	PHASE UV1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	PHASE UV1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	PHASE UV1 MODE: Phase to Ground	*Range: Phase to Ground, Phase to Phase*
MESSAGE	PHASE UV1 PICKUP: 1.000 pu	*Range: 0.000 to 3.000 pu in steps of 0.001*
MESSAGE	PHASE UV1 CURVE: Definite Time	*Range: Definite Time, Inverse Time*
MESSAGE	PHASE UV1 DELAY: 1.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
MESSAGE	PHASE UV1 MINIMUM VOLTAGE: 0.100 pu	*Range: 0.000 to 3.000 pu in steps of 0.001*
MESSAGE	PHASE UV1 BLOCK: Off	*Range: FlexLogic™ operand*
MESSAGE	PHASE UV1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	PHASE UV1 EVENTS: Disabled	*Range: Disabled, Enabled*

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 connection, or phase to phase only for Delta VT connection) or as a simple Definite Time element. The element resets instantaneously if the applied voltage exceeds the dropout voltage. The delay setting selects the minimum operating time of the phase undervoltage element. The minimum voltage setting selects the operating voltage below which the element is blocked (a setting of '0' will allow a dead source to be considered a fault condition).

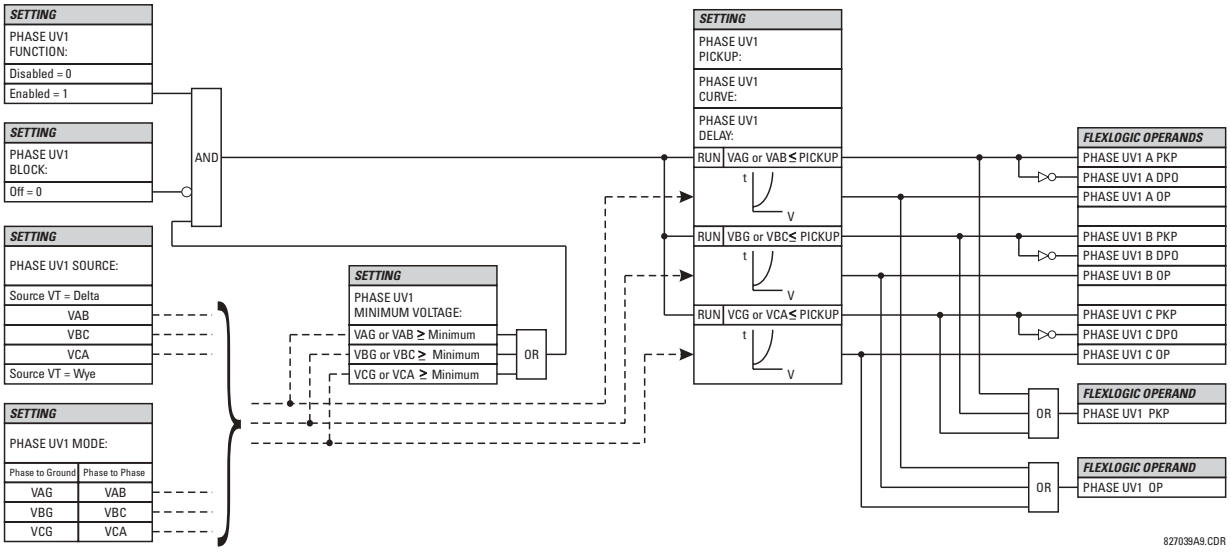


Figure 5–56: PHASE UV1 SCHEME LOGIC

b) PHASE OV1 (PHASE OVERVOLTAGE: ANSI 59P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ PHASE OVERVOLTAGE1

■ PHASE ■ OVERVOLTAGE1		PHASE OV1 FUNCTION: Disabled	*Range: Disabled, Enabled*
	MESSAGE	PHASE OV1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
	MESSAGE	PHASE OV1 PICKUP: 1.000 pu	*Range: 0.000 to 3.000 pu in steps of 0.001*
	MESSAGE	PHASE OV1 PICKUP DELAY: 1.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	MESSAGE	PHASE OV1 RESET DELAY: 1.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	MESSAGE	PHASE OV1 BLOCK: Off	*Range: FlexLogic™ Operand*
	MESSAGE	PHASE OV1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
	MESSAGE	PHASE OV1 EVENTS: Disabled	*Range: Disabled, Enabled*

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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 on the logic diagram.

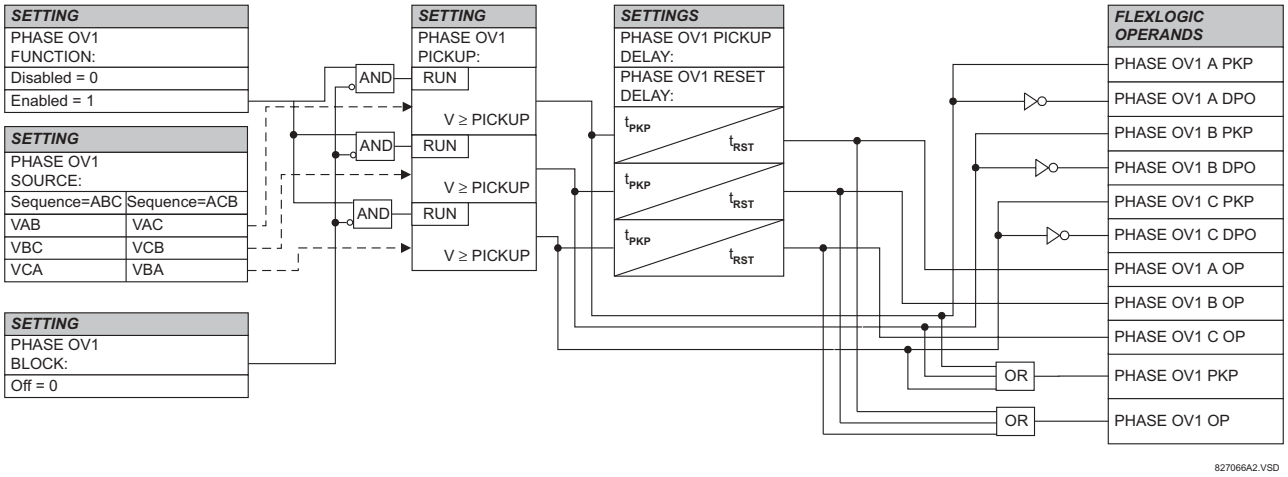


Figure 5–57: PHASE OV1 SCHEME LOGIC

a) NEUTRAL OV1 (NEUTRAL OVERVOLTAGE: ANSI 59N)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ NEUTRAL OV1

■ NEUTRAL OV1 ■		NEUTRAL OV1 FUNCTION: Disabled	*Range: Disabled, Enabled*
	MESSAGE	NEUTRAL OV1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
	MESSAGE	NEUTRAL OV1 PICKUP: 0.300 pu	*Range: 0.000 to 1.250 pu in steps of 0.001*
	MESSAGE	NEUTRAL OV1 PICKUP: DELAY: 1.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	MESSAGE	NEUTRAL OV1 RESET: DELAY: 1.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	MESSAGE	NEUTRAL OV1 BLOCK: Off	*Range: FlexLogic™ operand*
	MESSAGE	NEUTRAL OV1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
	MESSAGE	NEUTRAL OV1 EVENTS: Disabled	*Range: Disabled, Enabled*

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 under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK ⇨ PHASE VT SECONDARY** is the p.u. base used when setting the pickup level.

VT errors and normal voltage unbalance must be considered when setting this element. This function requires the VTs to be Wye connected.

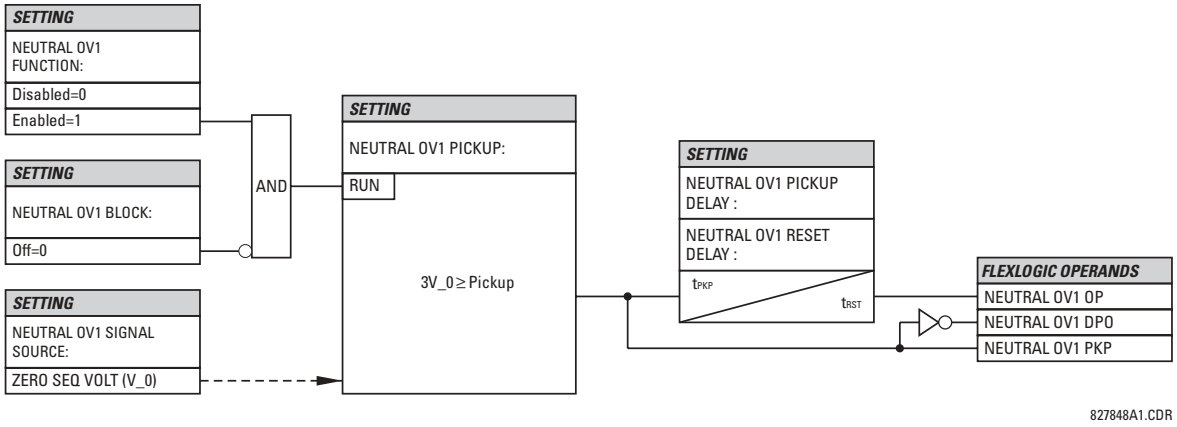


Figure 5–58: NEUTRAL OVERVOLTAGE SCHEME LOGIC

a) AUXILIARY UV1 (AUXILIARY UNDERVOLTAGE: ANSI 27X)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ AUXILIARY UV1

AUXILIARY UV1	AUX UV1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	AUX UV1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	AUX UV1 PICKUP: 0.700 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	AUX UV1 CURVE: Definite Time	Range: Definite Time, Inverse Time
MESSAGE	AUX UV1 DELAY: 1.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	AUX UV1 MINIMUM: VOLTAGE: 0.100 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	AUX UV1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	AUX UV1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	AUX UV1 EVENTS: Disabled	Range: Disabled, Enabled

This element is intended for monitoring undervoltage conditions of the auxiliary voltage. The **PICKUP** selects the voltage level at which the time undervoltage element starts timing. The nominal secondary voltage of the auxiliary voltage channel entered under SETTINGS ⇩ SYSTEM SETUP ⇨ AC INPUTS ⇩⇨ VOLTAGE BANK X5 / AUXILIARY VT X5 SECONDARY is the p.u. base used when setting the pickup level.

The **DELAY** setting selects the minimum operating time of the phase undervoltage element. Both **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 operating characteristics and equations for both Definite and Inverse Time Delay are as for the Phase Undervoltage Element.

The element resets instantaneously. The minimum voltage setting selects the operating voltage below which the element is blocked.

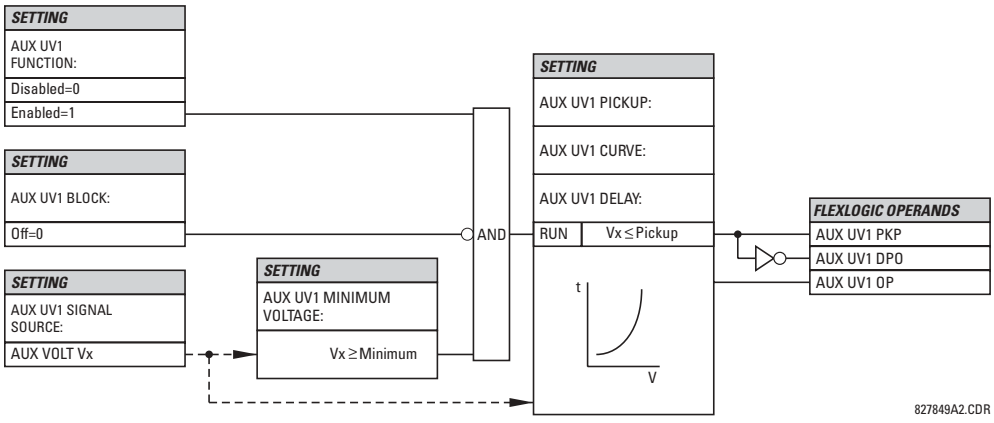


Figure 5–59: AUXILIARY UNDERVOLTAGE SCHEME LOGIC

b) AUXILIARY OV1 (AUXILIARY OVERVOLTAGE: ANSI 59X)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ AUXILIARY OV1

■ AUXILIARY OV1 ■		AUX OV1 FUNCTION: Disabled	*Range: Disabled, Enabled*
	MESSAGE	AUX OV1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
	MESSAGE	AUX OV1 PICKUP: 0.300 pu	*Range: 0.000 to 3.000 pu in steps of 0.001*
	MESSAGE	AUX OV1 PICKUP DELAY: 1.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	MESSAGE	AUX OV1 RESET DELAY: 1.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	MESSAGE	AUX OV1 BLOCK: Off	*Range: FlexLogic™ operand*
	MESSAGE	AUX OV1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
	MESSAGE	AUX OV1 EVENTS: Disabled	*Range: Disabled, Enabled*

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 under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇩⇨ VOLTAGE BANK X5 ⇩⇨ AUXILIARY VT X5 SECONDARY** is the p.u. base used when setting the pickup level.

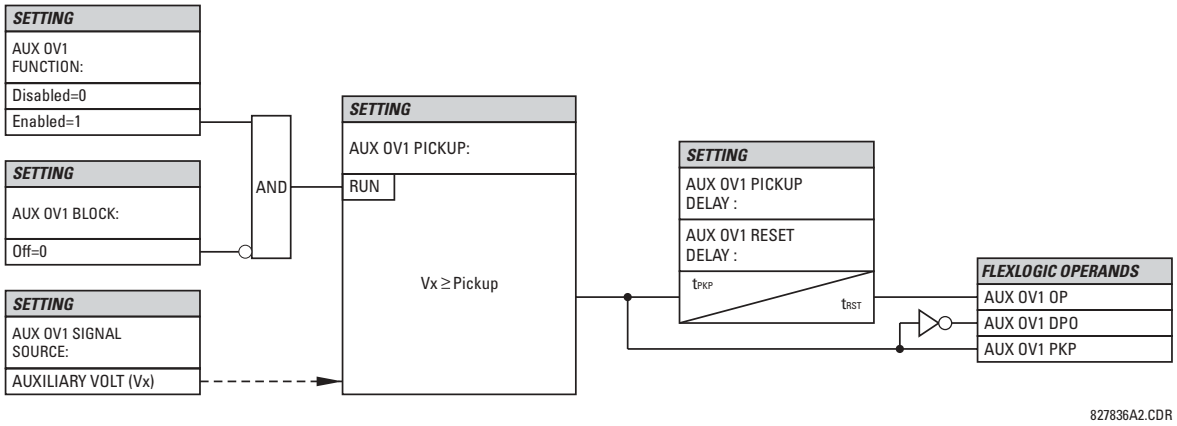
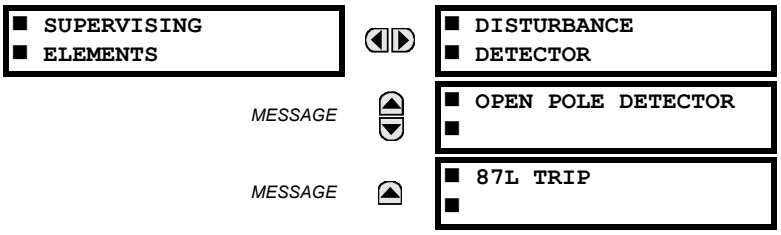


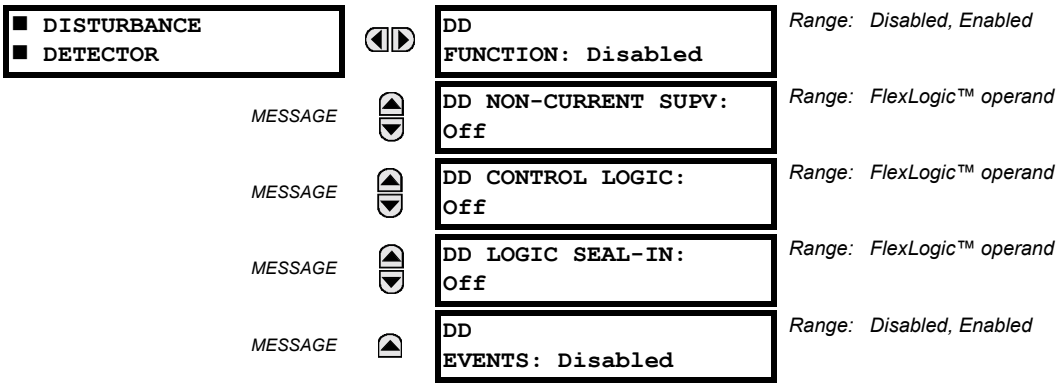
Figure 5–60: AUXILIARY OVERVOLTAGE SCHEME LOGIC

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨⇩ SUPERVISING ELEMENTS



a) DISTURBANCE DETECTOR

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ SUPERVISING ELEMENTS ⇨ DISTURBANCE DETECTOR



The DD element is an 87L-dedicated sensitive current disturbance detector that is used to detect any disturbance on the protected system. This detector is intended for such functions as; trip output supervision, VT and CT failure supervision, starting oscillography data capture, and providing a continuous monitor feature to the relays.

If the disturbance detector is used to supervise the operation of the 87L function, it is recommended that the 87L TRIP logic element be used. The 50DD SV disturbance detector FlexLogic™ output operand must then be assigned to an **87L TRIP SUPV** setting.

The DD function measures the magnitude of the negative sequence current (I_2), the magnitude of the zero sequence current (I_0), the change in negative sequence current (ΔI_2), the change in zero sequence current (ΔI_0), and the change in positive sequence current (ΔI_1).

The DD element uses the same source of computing currents as that for the current differential scheme 87L.

The Adaptive Level Detector operates as follows:

- When the absolute level increases above 0.12 pu for I_0 or I_2, the Adaptive Level Detector output is active and the next highest threshold level is increased 8 cycles later from 0.12 to 0.24 pu in steps of 0.02 pu. If the level exceeds 0.24 pu, the current Adaptive Level Detector setting remains at 0.24 pu and the output remains active (as well as the DD output) when the measured value remains above the current setting.
- When the absolute level is decreasing from in range from 0.24 to 0.12 pu, the lower level is set every 8 cycles without the Adaptive Level Detector active. Note that the 50DD output remains inactive during this change as long as the delta change is less than 0.04 pu.

The Delta Level Detectors (ΔI) detectors are designed to pickup for the 0.04 pu change in I_1, I_2, and I_0 currents. The ΔI is measured by comparing the present value to the value calculated 4 cycles earlier.

DD FUNCTION:

This setting is used to Enable/Disable the operation of the Disturbance Detector.

DD NON-CURRENT SUPV:

This setting is used to select a FlexLogic™ operand which will activate the output of the Disturbance Detector upon events (such as frequency or voltage change) not accompanied by a current change.

DD CONTROL LOGIC:

This setting is used to prevent operation of I_0 and I_2 logic of Disturbance Detector during conditions such as single breaker pole being open which leads to unbalanced load current in single pole tripping schemes. Breaker auxiliary contact can be used for such scheme.

DD LOGIC SEAL-IN:

This setting is used to maintain Disturbance Detector output for such conditions as balanced 3-phase fault, low level TOC fault, etc. whenever the Disturbance Detector might reset. Output of the Disturbance Detector will be maintained until the chosen FlexLogic™ Operand resets.

NOTE

The user may disable the **DD EVENTS** setting as the DD element will respond to any current disturbance on the system which may result in filling the Events buffer and thus cause the possible loss of any more valuable data.

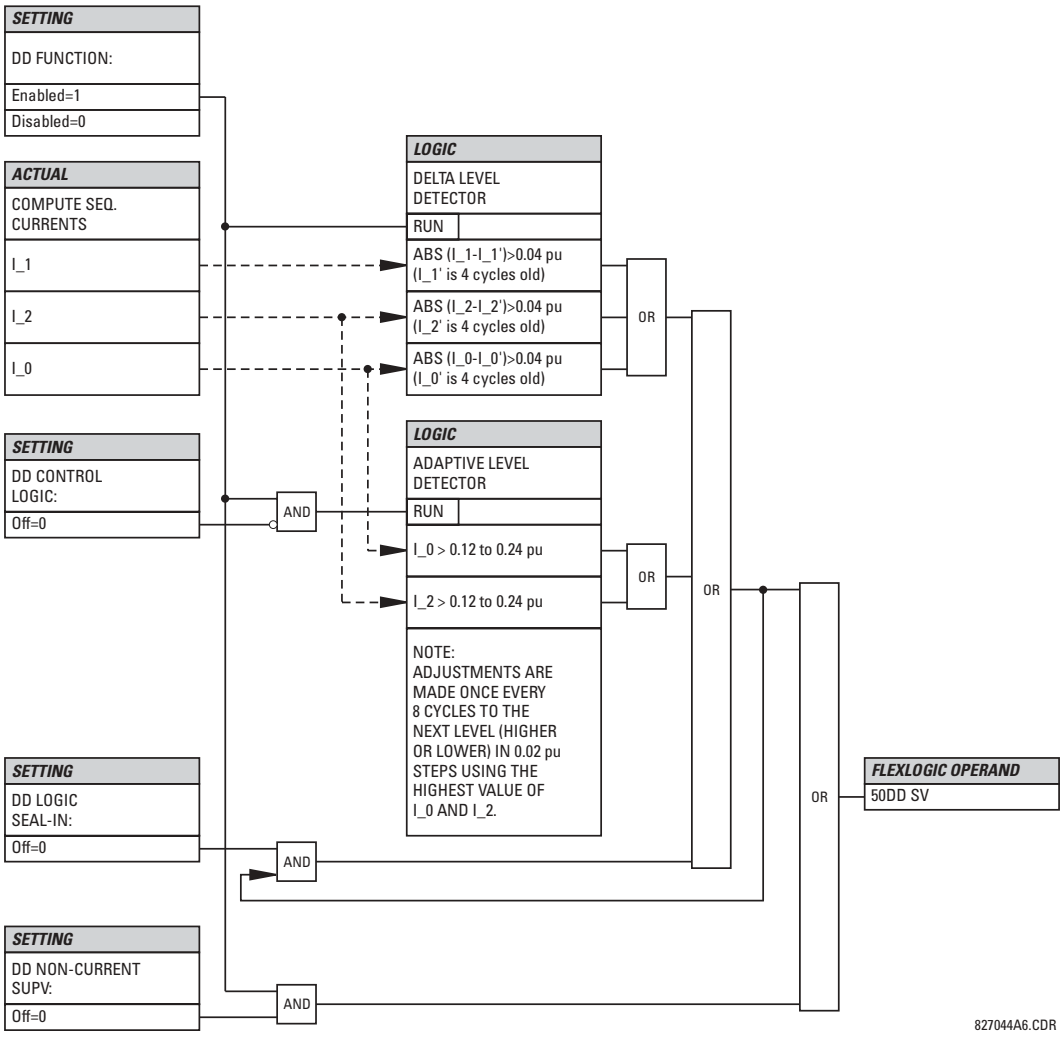
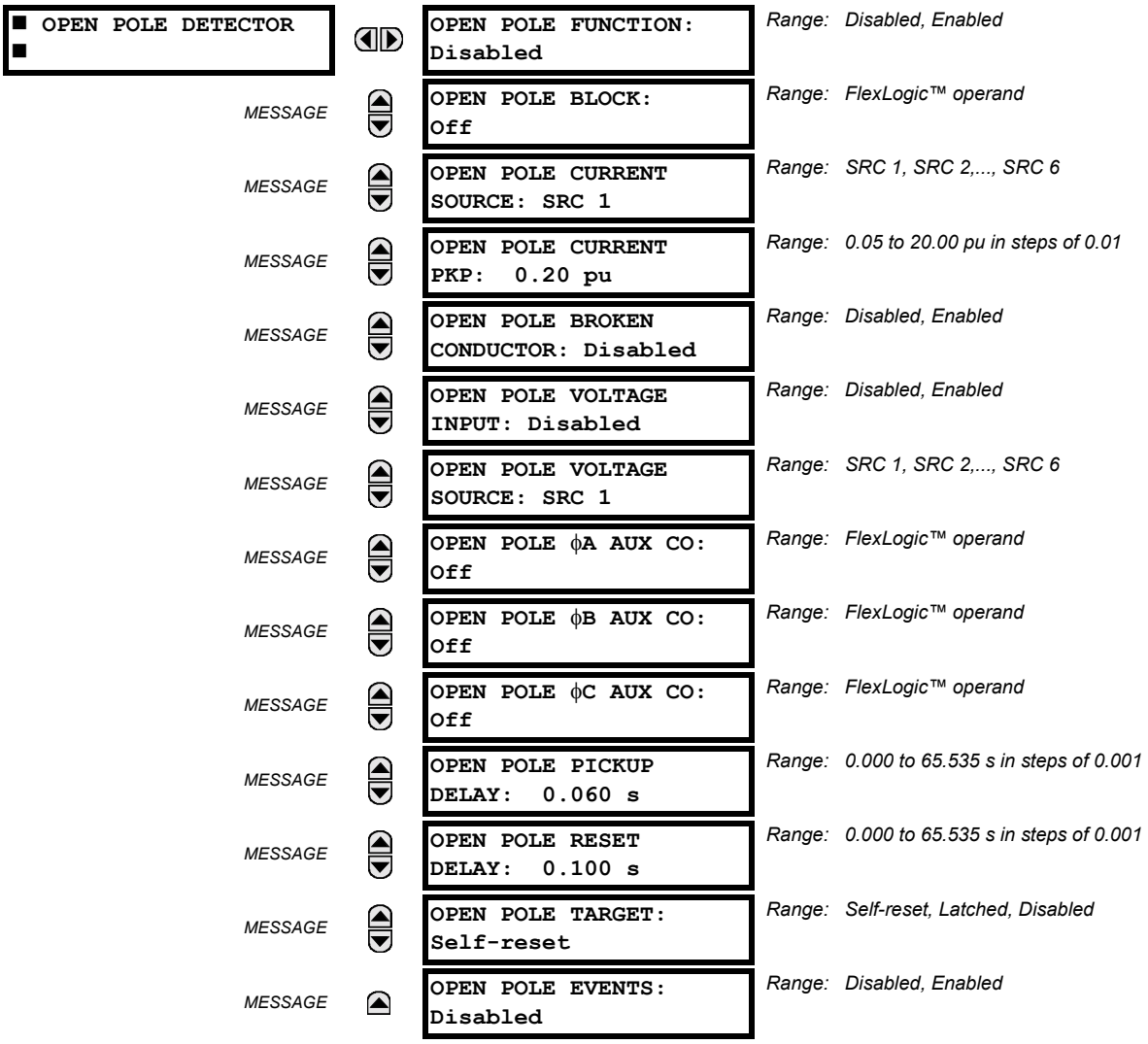


Figure 5–61: DISTURBANCE DETECTOR SCHEME LOGIC

b) OPEN POLE DETECTOR

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨⇩ SUPERVISING ELEMENTS ⇨⇩ OPEN POLE DETECTOR



The Open Pole Detector logic is designed to detect if any pole of the associated circuit breaker is opened or the conductor is broken on the protected power line and cable. The output FlexLogic™ operands can be used in three phase and single phase tripping schemes, in reclosing schemes, in blocking some elements (like CT failure) and in signaling or indication schemes. In single-pole tripping schemes, if OPEN POLE flag is set, any other subsequent fault should cause a three-phase trip regardless of fault type.

This element's logic is built on detecting absence of current in one phase during presence of current in other phases. Phases A, B and C breaker auxiliary contacts (if available) are used in addition to make a logic decision for single-pole tripping applications. If voltage input is available, Low Voltage function is used to detect absence of the monitoring voltage in the associated pole of the breaker.

OPEN POLE FUNCTION:

This setting is used to Enable/Disable operation of the element.

OPEN POLE BLOCK:

This setting is used to select a FlexLogic™ operand that blocks operation of the element.

OPEN POLE CURRENT SOURCE:

This setting is used to select the source for the current for the element.

OPEN POLE CURRENT PICKUP:

This setting is used to select the pickup value of the phase current. Pickup setting is the minimum of the range and likely to be somewhat above of the charging current of the line.

OPEN POLE BROKEN CONDUCTOR:

This setting enables or disables detection of Broken Conductor or Remote Pole Open conditions.

OPEN POLE VOLTAGE INPUT:

This setting is used to Enable/Disable voltage input in making a logical decision. If line VT (not bus VT) is available, voltage input can be set to "Enable".

OPEN POLE VOLTAGE SOURCE:

This setting is used to select the source for the voltage for the element.

OPEN POLE ϕA AUX CONTACT:

This setting is used to select a FlexLogic™ operand reflecting the state of phase A circuit breaker auxiliary contact 52b type (closed when main breaker contact is open) for single-pole tripping applications. If 2 breakers per line are being employed, both breaker auxiliary contacts feeding into the AND gate (representing auxiliary contacts connected in series) are to be assigned.

OPEN POLE ϕB AUX CONTACT:

As above for phase B for single-pole tripping applications.

OPEN POLE ϕC AUX CONTACT:

As above for phase C for single-pole tripping applications.

OPEN POLE PICKUP DELAY:

This setting is used to select the pickup delay of the element.

OPEN POLE RESET DELAY:

This setting is used to select the reset delay of the element. Depending on the particular application and whether 1-pole or 3-pole tripping mode is used, this setting should be thoroughly considered. It should comprise the reset time of the operating elements it used in conjunction with the breaker opening time and breaker auxiliary contacts discrepancy with the main contacts.

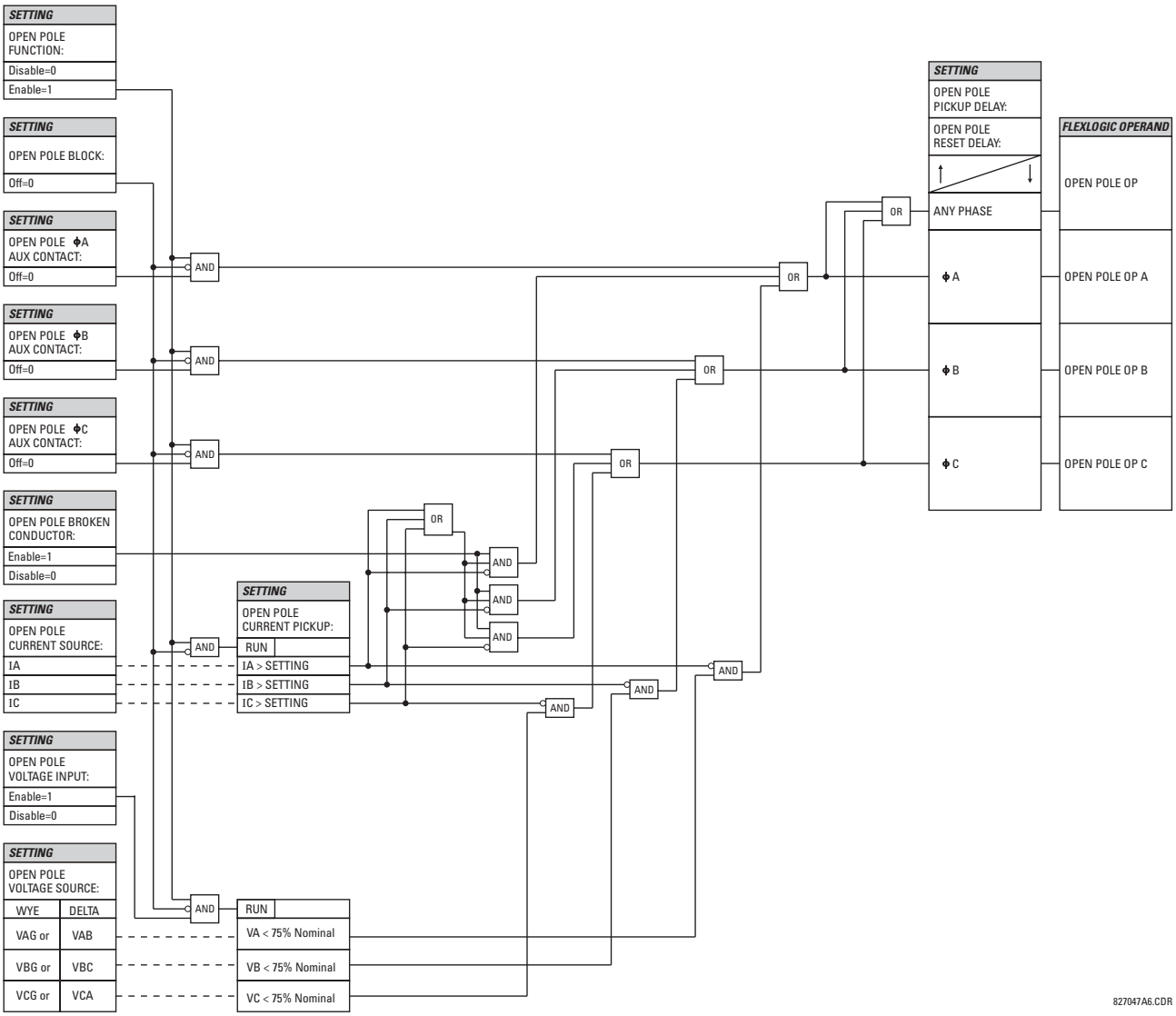
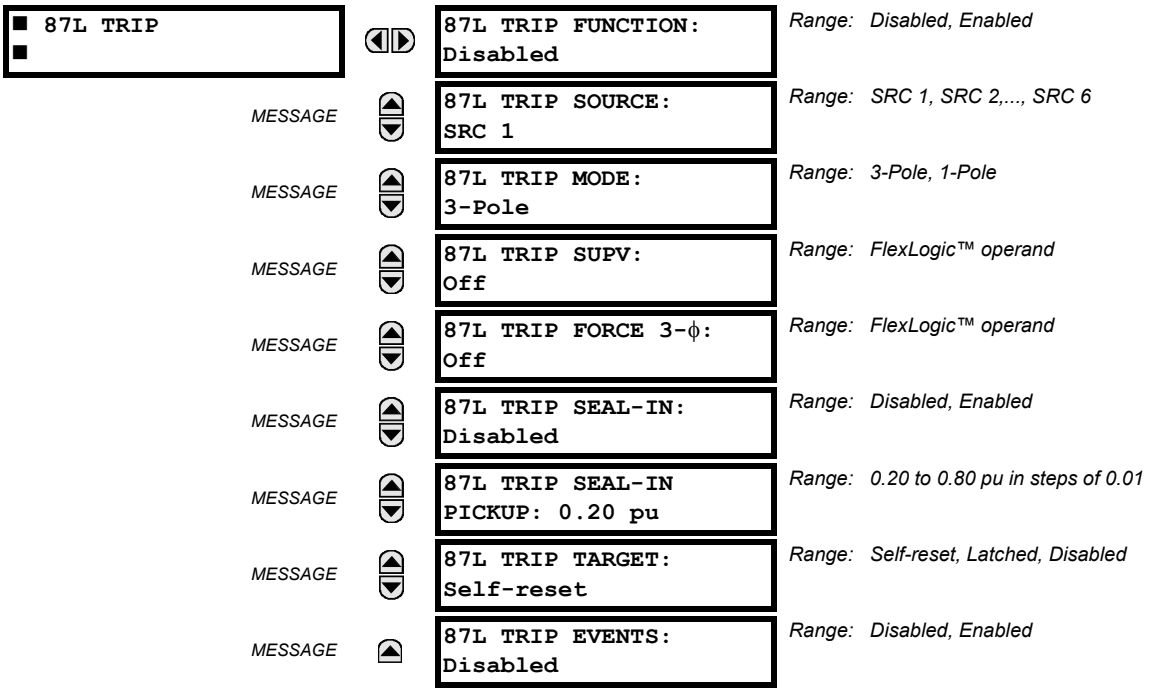


Figure 5–62: OPEN POLE DETECTOR SCHEME LOGIC

c) 87L TRIP

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ SUPERVISING ELEMENTS ⇨⇩ 87L TRIP



The 87L Trip element must be used to secure the generation of tripping outputs. It is especially recommended for use in all single-pole tripping applications. It provides the user with the capability of maintaining the trip signal while the fault current is still flowing, to choose single-pole or three-pole tripping, to employ the received Direct Transfer Trip signals, to assign supervising trip elements like 50DD, etc. The logic is used to ensure that the relay will:

- trip the faulted phase for a single line to ground fault, as detected by the line differential element
- trip all three phases for any internal multiphase fault
- trip all three phases for a second single line to ground fault during or following a single pole trip cycle

For maximum security, it is recommended the Disturbance Detector (plus other elements if required) be assigned to see a change in system status before a trip output is permitted. This ensures the relay will not issue a trip signal as a result of incorrect settings, incorrect manipulations with a relay, or inter-relay communications problems (for example, extremely noisy channels). The Open Pole Detector provides forcing of three-pole tripping for Sequential faults and Close onto Fault if desired. The Open Pole Detector feature must be employed and adequately programmed for proper operation of this feature.

NOTE

If DTT is not required to cause the 87L Trip scheme to operate, it should be disabled at the remote relay via the CURRENT DIFFERENTIAL menu (see SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ LINE DIFFERENTIAL ELEMENTS).

87L TRIP FUNCTION:

This setting is used to enable/disable the element.

87L TRIP SOURCE:

This setting is used to assign a source for seal-in function.

87L TRIP MODE:

This setting is used to select either three-pole or single-pole mode of operation.

87L TRIP SUPV:

This setting is used to assign a trip supervising element. FlexLogic™ operand 50DD SV is recommended (the element has to be enabled); otherwise elements like IOC, Distance, etc. can be used.

87L TRIP FORCE 3-ϕ:

This setting is used to select an element forcing 3-pole tripping if any type fault occurs when this element is active. Autoreclosure Disabled can be utilized, or Autoreclosure Counter if second trip for example is required to be a 3-pole signal, or element representing change in the power system configuration, etc. can be considered to be applied.

87L TRIP SEAL-IN:

This setting is used to enable/disable seal-in of the trip signal by measurement of the current flowing.

87L TRIP SEAL-IN PICKUP:

This setting is used to select a pickup setting of the current seal-in function.

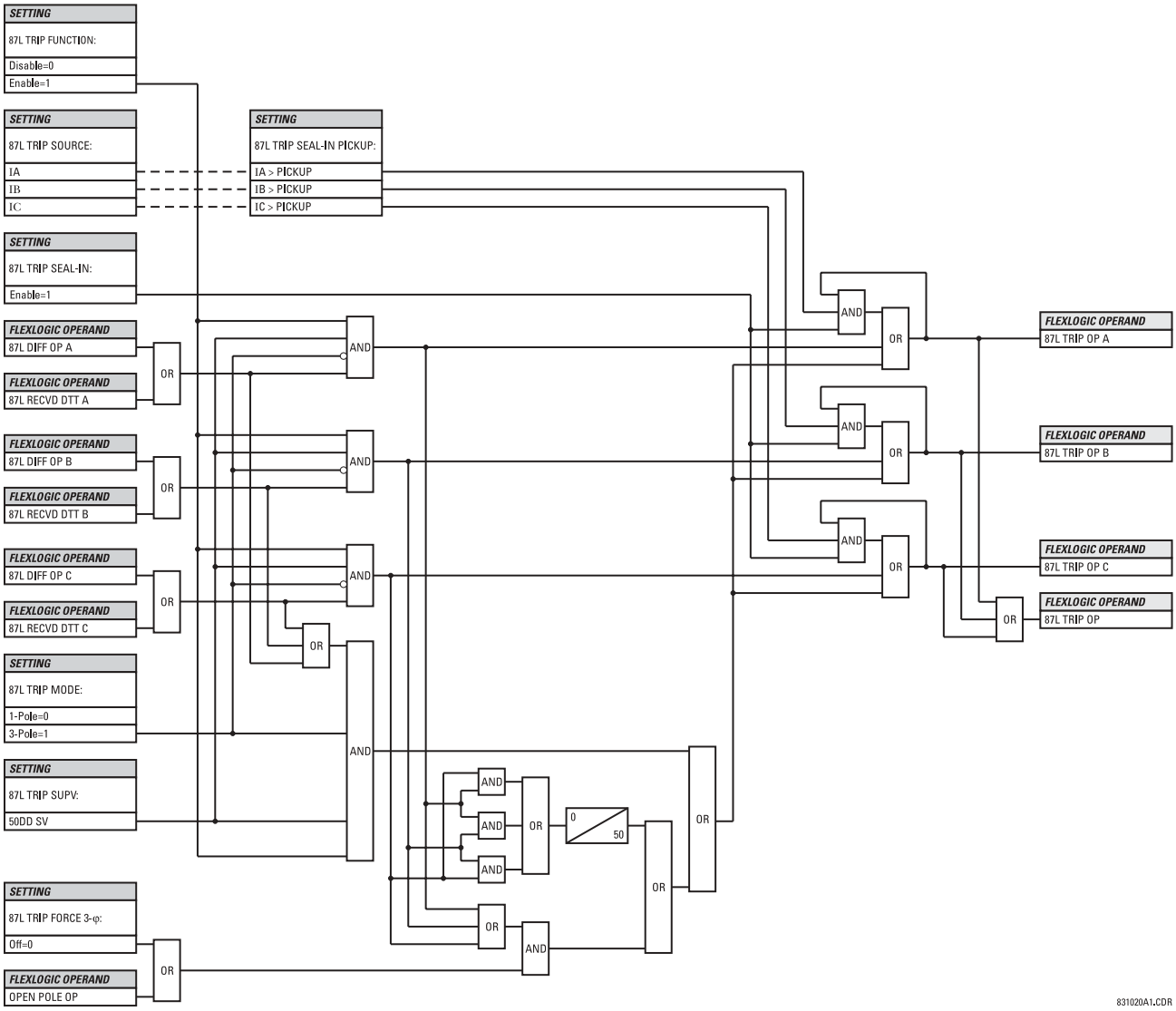


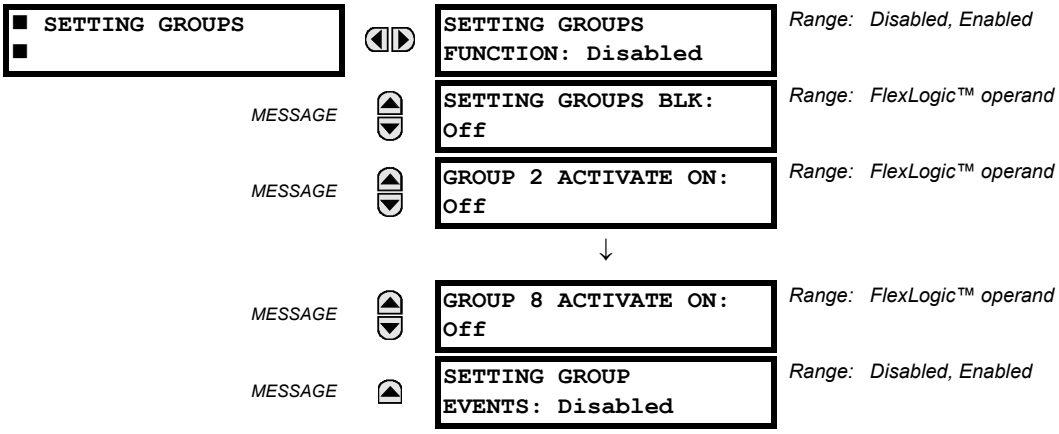
Figure 5–63: 87L TRIP SCHEME LOGIC

5.6.1 OVERVIEW

CONTROL elements are generally used for control rather than protection. See the INTRODUCTION TO ELEMENTS section at the front of this chapter for further information.

5.6.2 SETTING GROUPS

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ SETTINGS GROUPS



The Setting Groups menu controls the activation/deactivation of up to eight possible groups of settings in the **GROUPED ELEMENTS** settings menu. The faceplate 'SETTINGS IN USE' LEDs indicate which active group (with a non-flashing energized LED) is in service.

The **SETTING GROUPS BLK** setting prevents the active setting group from changing when the FlexLogic™ parameter is set to "On". This can be useful in applications where it is undesirable to change the settings under certain conditions, such as the breaker being open.

Each **GROUP ~ ACTIVATE ON** setting selects a FlexLogic™ operand which, when set, will make the particular setting group active for use by any grouped element. A priority scheme ensures that only one group is active at a given time – the highest-numbered group which is activated by its ACTIVATE ON parameter takes priority over the lower-numbered groups. There is no "activate on" setting for group 1 (the default active group), because group 1 automatically becomes active if no other group is active.

The relay can be set up via a FlexLogic™ equation to receive requests to activate or de-activate a particular non-default settings group. The following FlexLogic™ equation (see the figure below) illustrates requests via remote communications (e.g. VIRTUAL INPUT 1) or from a local contact input (e.g. H7a) 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.

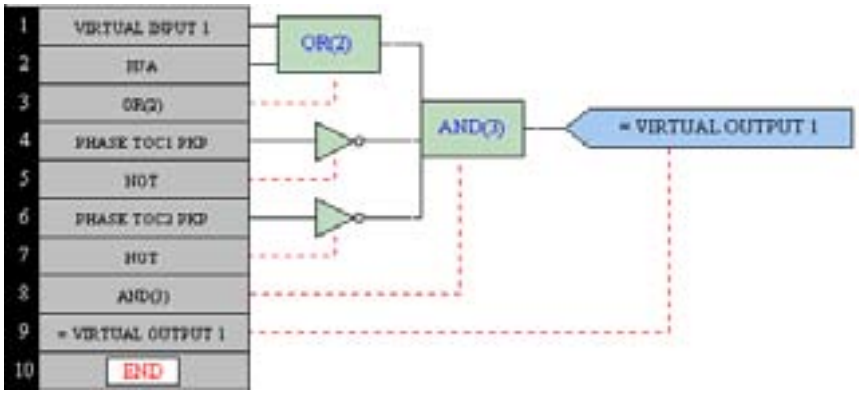
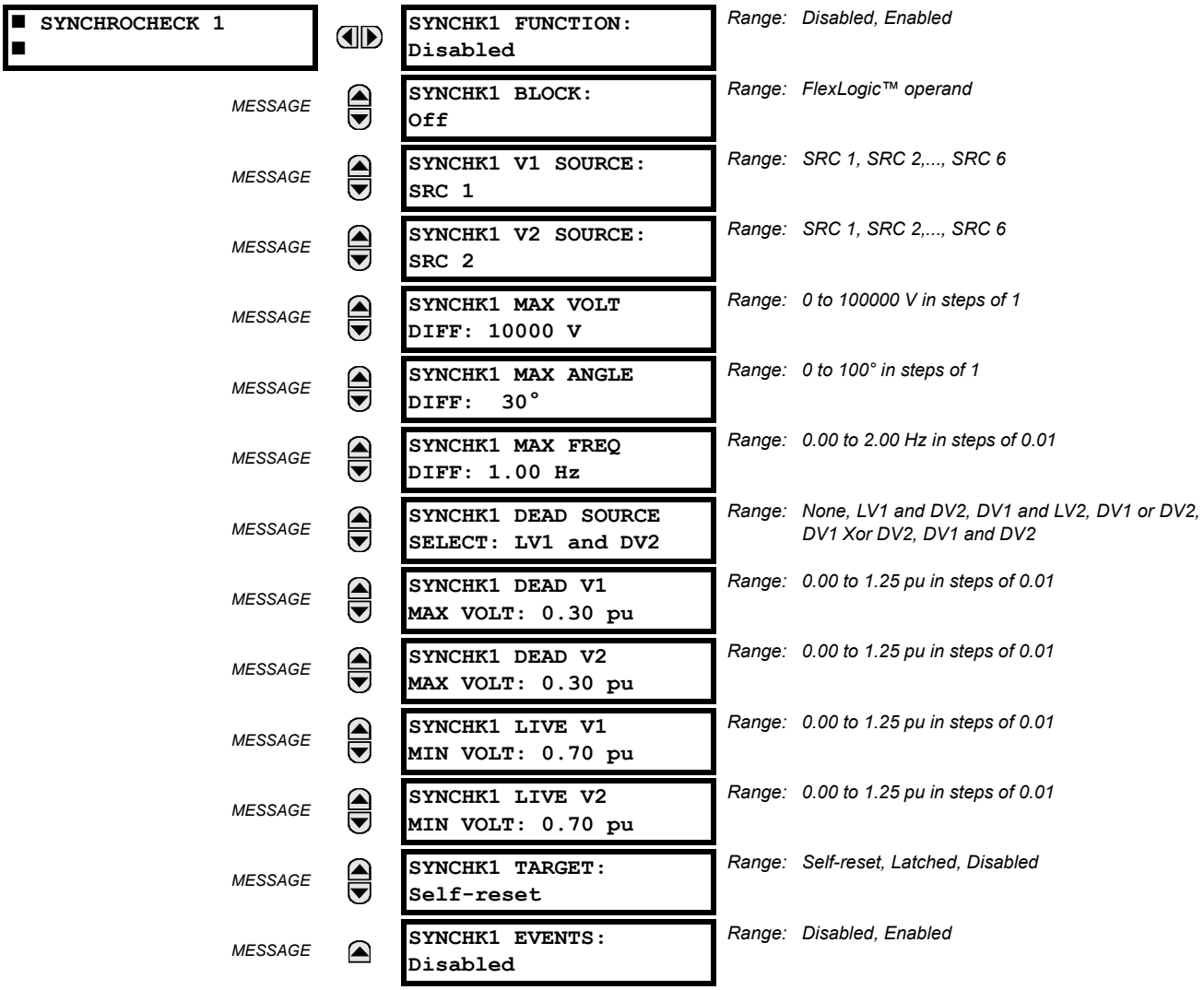


Figure 5–64: EXAMPLE FLEXLOGIC™ CONTROL OF A SETTINGS GROUP

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ SYNCHROCHECK ⇨ SYNCHROCHECK 1(2)



SYNCHK1 V1 SOURCE:

This setting selects the source for voltage V1 (see **NOTES** below).

SYNCHK1 V2 SOURCE:

This setting selects the source for voltage V2, which must not be the same as used for the V1 (see **NOTES** below).

SYNCHK1 MAX VOLT DIFF:

This setting selects the maximum voltage difference in 'kV' between the two sources. A voltage magnitude difference between the two input voltages below this value is within the permissible limit for synchronism.

SYNCHK1 MAX ANGLE DIFF:

This setting selects the maximum angular difference in degrees between the two sources. An angular difference between the two input voltage phasors below this value is within the permissible limit for synchronism.

SYNCHK1 MAX FREQ DIFF:

This setting selects the maximum frequency difference in 'Hz' between the two sources. A frequency difference between the two input voltage systems below this value is within the permissible limit for synchronism.

SYNCHK1 DEAD SOURCE SELECT:

This setting selects the combination of dead and live sources that will by-pass synchronism check function and permit the breaker to be closed when one or both of the two voltages (V1 or/and V2) are below the maximum voltage threshold. A dead or live source is declared by monitoring the voltage level.

Six options are available:

None: Dead Source function is disabled
LV1 and DV2: Live V1 and Dead V2
DV1 and LV2: Dead V1 and Live V2
DV1 or DV2: Dead V1 or Dead V2
DV1 Xor DV2: Dead V1 exclusive-or Dead V2 (one source is Dead and the other is Live)
DV1 and DV2: Dead V1 and Dead V2

SYNCHK1 DEAD V1 MAX VOLT:

This setting establishes a maximum voltage magnitude for V1 in 'pu'. Below this magnitude, the V1 voltage input used for synchrocheck will be considered "Dead" or de-energized.

SYNCHK1 DEAD V2 MAX VOLT:

This setting establishes a maximum voltage magnitude for V2 in 'pu'. Below this magnitude, the V2 voltage input used for synchrocheck will be considered "Dead" or de-energized.

SYNCHK1 LIVE V1 MIN VOLT:

This setting establishes a minimum voltage magnitude for V1 in 'pu'. Above this magnitude, the V1 voltage input used for synchrocheck will be considered "Live" or energized.

SYNCHK1 LIVE V2 MIN VOLT:

This setting establishes a minimum voltage magnitude for V2 in 'pu'. Above this magnitude, the V2 voltage input used for synchrocheck will be considered "Live" or energized.

NOTES:

1. The selected Sources for synchrocheck inputs V1 and V2 (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.

NO.	V1 OR V2 (SOURCE Y)	V2 OR V1 (SOURCE Z)	AUTO-SELECTED COMBINATION		AUTO-SELECTED VOLTAGE
			SOURCE Y	SOURCE Z	
1	Phase VTs and Auxiliary VT	Phase VTs and Auxiliary VT	Phase	Phase	VAB
2	Phase VTs and Auxiliary VT	Phase VT	Phase	Phase	VAB
3	Phase VT	Phase VT	Phase	Phase	VAB
4	Phase VT and Auxiliary VT	Auxiliary VT	Phase	Auxiliary	V auxiliary (as set for Source z)
5	Auxiliary VT	Auxiliary VT	Auxiliary	Auxiliary	V auxiliary (as set for selected sources)

The voltages V1 and V2 will be matched automatically so that the corresponding voltages from the two Sources will be used to measure conditions. A phase to phase voltage will be used if available in both sources; if one or both of the Sources have only an auxiliary voltage, this voltage will be used. For example, if an auxiliary voltage is programmed to VAG, the synchrocheck element will automatically select VAG 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 to be used for synchrocheck.

Exception: **Synchronism cannot be checked between Delta connected phase VTs and a Wye connected auxiliary voltage.**

2. The relay measures frequency and Volts/Hz 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.

The are two identical synchrocheck elements available, numbered 1 and 2.

The 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 (V1 and V2) on the two sides of the supervised circuit breaker are within set limits of magnitude, angle and frequency differences.

The time while 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 V1 or V2 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:

$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta\Phi} \times \Delta F}$$

where: $\Delta\Phi$ = phase angle difference in degrees; ΔF = frequency difference in Hz.

As an example; for the default values ($\Delta\Phi$ = 30°, ΔF = 0.1 Hz), the time while the angle between the two voltages will be less than the set value is:

$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta\Phi} \times \Delta F} = \frac{1}{\frac{360^\circ}{2 \times 30^\circ} \times 0.1 \text{ Hz}} = 1.66 \text{ sec.}$$

If one or both sources are de-energized, the synchrocheck programming can allow for closing of the circuit breaker using undervoltage control to by-pass the synchrocheck measurements (Dead Source function).

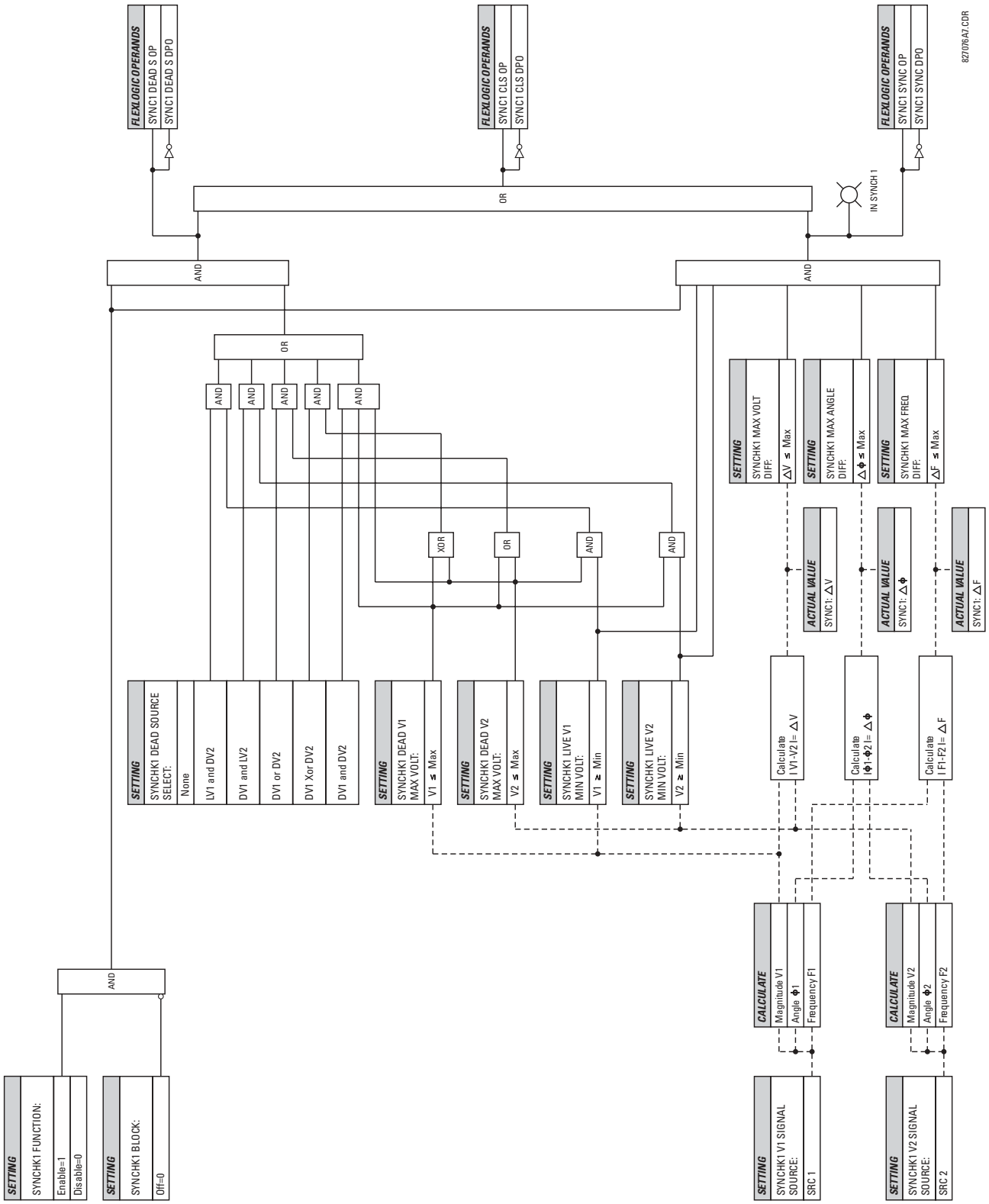


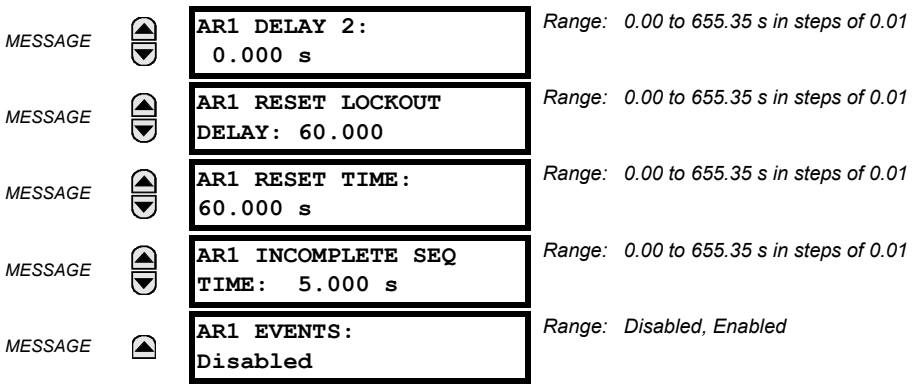
Figure 5–65: SYNCHROCHECK SCHEME LOGIC

5.6.4 AUTORECLOSE

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ AUTORECLOSE ⇨ AUTORECLOSE 1

■ AUTORECLOSE 1 ■	AR1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	AR1 INITIATE: Off	Range: FlexLogic™ operand
MESSAGE	AR1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	AR1 MAX NUMBER OF SHOTS: 1	Range: 1, 2, 3, 4
MESSAGE	AR1 REDUCE MAX TO 1: Off	Range: FlexLogic™ operand
MESSAGE	AR1 REDUCE MAX TO 2: Off	Range: FlexLogic™ operand
MESSAGE	AR1 REDUCE MAX TO 3: Off	Range: FlexLogic™ operand
MESSAGE	AR1 MANUAL CLOSE: Off	Range: FlexLogic™ operand
MESSAGE	AR1 MNL RST FRM LO: Off	Range: FlexLogic™ operand
MESSAGE	AR1 RESET LOCKOUT IF BREAKER CLOSED: Off	Range: Off, On
MESSAGE	AR1 RESET LOCKOUT ON MANUAL CLOSE: Off	Range: Off, On
MESSAGE	AR1 BKR CLOSED: Off	Range: FlexLogic™ operand
MESSAGE	AR1 BKR OPEN: Off	Range: FlexLogic™ operand
MESSAGE	AR1 BLK TIME UPON MNL CLS: 10.000 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR1 DEAD TIME 1: 1.000 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR1 DEAD TIME 2: 2.000 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR1 DEAD TIME 3: 3.000 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR1 DEAD TIME 4: 4.000 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR1 ADD DELAY 1: Off	Range: FlexLogic™ operand
MESSAGE	AR1 DELAY 1: 0.000 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR1 ADD DELAY 2: Off	Range: FlexLogic™ operand

5



a) FUNCTION

The autoreclosure feature is intended for use with transmission and distribution lines, in three-pole tripping schemes for single breaker applications. Up to four selectable reclosures "shots" are possible prior to locking out. Each shot has an independently settable dead time. The protection settings can be changed between shots if so desired, using FlexLogic™. Logic inputs are available for disabling or blocking the scheme.

Faceplate panel LEDs indicate the state of the autoreclose scheme as follows:

- RECLOSE ENABLED: The scheme is enabled and may reclose if initiated.
- RECLOSE DISABLED: The scheme is disabled.
- RECLOSE IN PROGRESS: An autoreclosure has been initiated but the breaker has not yet been signaled to close.
- RECLOSE LOCKED OUT: The scheme has generated the maximum number of breaker closures allowed and, as the fault persists, will not close the breaker again; known as "Lockout". The scheme may also be sent in "Lockout" when the incomplete sequence timer times out or when a block signal occurs while in "Reclose in Progress". The scheme must be reset from Lockout in order to perform reclose for further faults.

RECLOSE ENABLED:

The reclosure scheme is considered enabled when all of the following conditions are true:

- The "AR Function" is set to Enabled.
- The scheme is not in the "Lockout" state.
- The "Block" input is not asserted.
- The "AR Block Time Upon Manual Close" timer is not active.

RECLOSE INITIATION:

The autoreclose scheme is initiated by a trip signal from any selected protection feature operand. The scheme is initiated provided the circuit breaker is in the closed state before protection operation.

RECLOSE IN PROGRESS (RIP):

RIP is set when a reclosing cycle begins following a reclose initiate signal. Once the cycle is successfully initiated, the RIP signal will seal-in and the scheme will continue through its sequence until one of the following conditions is satisfied:

- The close signal is issued when the dead timer times out.
- The scheme goes to lockout.

While RIP is active, the scheme checks that the breaker is open and the shot number is below the limit, and then begins measuring the dead time.

DEAD TIME:

Each of the four possible shots has an independently settable dead time. Two additional timers can be used to increase the initial set dead times 1 to 4 by a delay equal to **AR1 DELAY 1** or **AR1 DELAY 2** or the sum of these two delays depending on the selected settings. This offers enhanced setting flexibility using FlexLogic™ operands to turn the two additional timers "on" and "off". These operands may possibly include "AR x SHOT CNT =n", "SETTING GROUP ACT x", etc.

The autoreclose provides up to maximum 4 selectable shots. Maximum number of shots can be dynamically modified through the settings **AR1 REDUCE MAX TO 1 (2, 3)**, using the appropriate FlexLogic™ operand.

LOCKOUT:

Scheme lockout will block all phases of the reclosing cycle, preventing automatic reclosure, if any of the following conditions occurs:

- The maximum shot number was reached.
- A "Block" input is in effect (for instance; Breaker Failure, bus differential protection operated, etc.).
- The "Incomplete Sequence" timer times out.

The recloser will be latched in the Lockout state until a "Reset from lockout" signal is asserted, either from a manual close of the breaker or from a manual reset command (local or remote). The reset from lockout can be accomplished:

- by operator command
- by manually closing the breaker
- whenever the breaker has been closed and stays closed for a preset time.

CLOSE:

After the dead time elapses, the scheme issues the close signal. The close signal is latched until the breaker closes or the scheme goes to Lockout.

RESET TIME:

A reset timer output resets the recloser following a successful reclosure sequence. The reset time is based on the breaker "reclaim time" which is the minimum time required between successive reclose sequences.

b) SETTINGS

AR1 INITIATE:

Selects the FlexLogic™ Operand that initiates the scheme, typically the trip signal from protection.

AR1 BLOCK:

Selects the FlexLogic™ Operand that blocks the Autoreclosure initiate (it could be from the Breaker Failure, Bus differential protection, etc.).

AR1 MAX NUMBER OF SHOTS:

Specifies the number of reclosures that can be attempted before reclosure goes to "Lockout" because the fault is permanent.

AR1 REDUCE MAX TO 1:

Selects the FlexLogic™ operand that changes the maximum number of shots from the initial setting to 1.

AR1 REDUCE MAX TO 2:

Selects the FlexLogic™ operand that changes the maximum number of shots from the initial setting to 2.

AR1 REDUCE MAX TO 3:

Selects the FlexLogic™ operand that changes the maximum number of shots from the initial setting to 3.

AR1 MANUAL CLOSE:

Selects the logic input set when the breaker is manually closed.

AR1 MNL RST FRM LO:

Selects the FlexLogic™ Operand that resets the autoreclosure from Lockout condition. Typically this is a manual reset from lockout, local or remote.

AR1 RESET LOCKOUT IF BREAKER CLOSED:

This setting allows the autoreclose scheme to reset from Lockout if the breaker has been manually closed and stays closed for a preset time. In order for this setting to be effective, the next setting (**AR1 RESET LOCKOUT ON MANUAL CLOSE**) should be disabled.

AR 1 RESET LOCKOUT ON MANUAL CLOSE:

This setting allows the autoreclose scheme to reset from Lockout when the breaker is manually closed regardless if the breaker remains closed or not. This setting overrides the previous setting (**AR1 RESET LOCKOUT IF BREAKER CLOSED**).

AR1 BLK TIME UPON MNL CLS:

The autoreclose scheme can be disabled for a programmable time delay after the associated circuit breaker is manually closed. This prevents reclosing onto a fault after a manual close. This delay must be longer than the slowest expected trip from any protection not blocked after manual closing. If no overcurrent trips occur after a manual close and this time expires, the autoreclose scheme is enabled.

AR1 DEAD TIME 1:

This is the intentional delay before first breaker automatic reclosure (1st shot) and should be set longer than the estimated deionizing time following a three pole trip.

AR1 DEAD TIME 2:

This is the intentional delay before second breaker automatic reclosure (2nd shot) and should be set longer than the estimated deionizing time following a three pole trip.

AR1 DEAD TIME 3:

This is the intentional delay before third breaker automatic reclosure (3rd shot) and should be set longer than the estimated deionizing time following a three pole trip.

AR1 DEAD TIME 4:

This is the intentional delay before fourth breaker automatic reclosure (4th shot) and should be set longer than the estimated deionizing time following a three pole trip.

AR1 ADD DELAY 1:

This setting selects the FlexLogic™ operand that introduces an additional delay (DELAY 1) to the initial set Dead Time (1 to 4). When this setting is "Off", DELAY 1 is by-passed.

AR1 DELAY 1:

This setting establishes the extent of the additional dead time DELAY 1.

AR1 ADD DELAY 2:

This setting selects the FlexLogic™ operand that introduces an additional delay (DELAY 2) to the initial set Dead Time (1 to 4). When this setting is "Off", DELAY 2 is by-passed.

AR1 DELAY 2:

This setting establishes the extent of the additional dead time DELAY 2.

AR1 RESET LOCKOUT DELAY:

This setting establishes how long the breaker should stay closed after a manual close command, in order for the autocloser to reset from Lockout.

AR1 RESET TIME:

A reset timer output resets the recloser following a successful reclosure sequence. The setting is based on the breaker "reclaim time" which is the minimum time required between successive reclose sequences.

AR1 INCOMPLETE SEQ TIME:

This timer 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 when the scheme is in the "RECLOSE IN PROGRESS" state. If all conditions allowing a breaker closure are not satisfied when this time expires, the scheme goes to "Lockout".

NOTE

This timer must be set to a delay less than the reset timer.

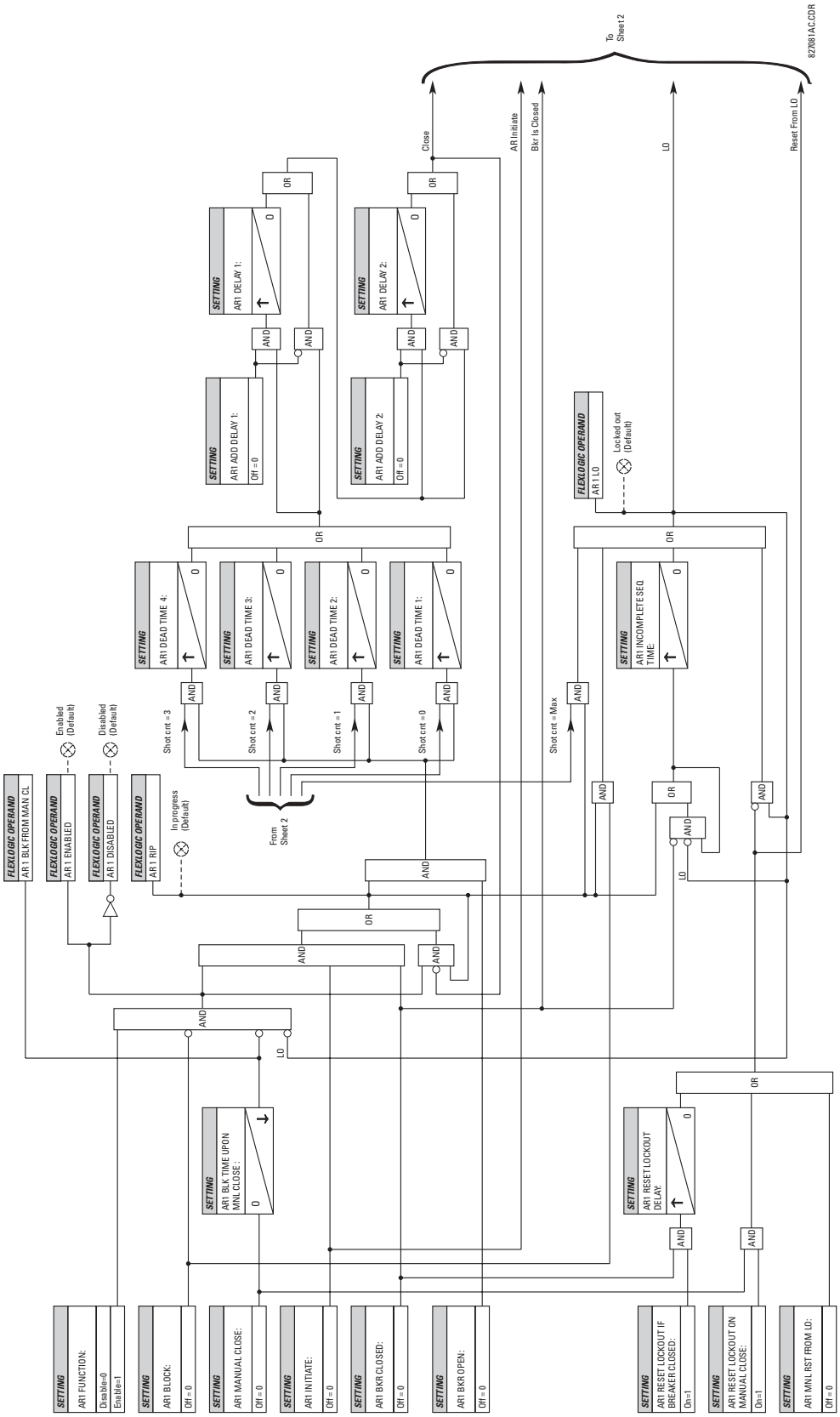


Figure 5–66: AUTORECLOSURE SCHEME LOGIC (Sheet 1 of 2)

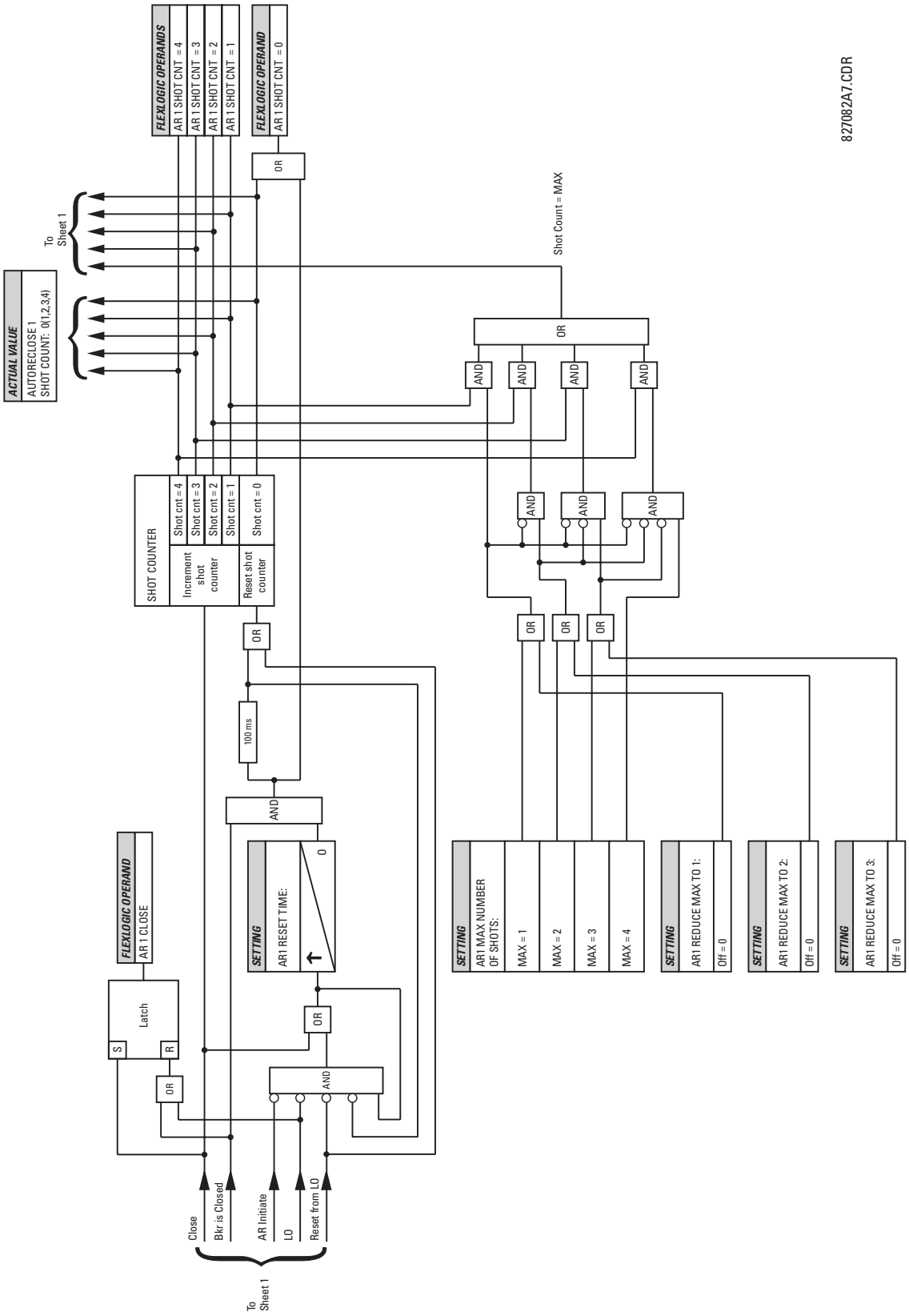


Figure 5–67: AUTORECLOSURE SCHEME LOGIC (Sheet 2 of 2)

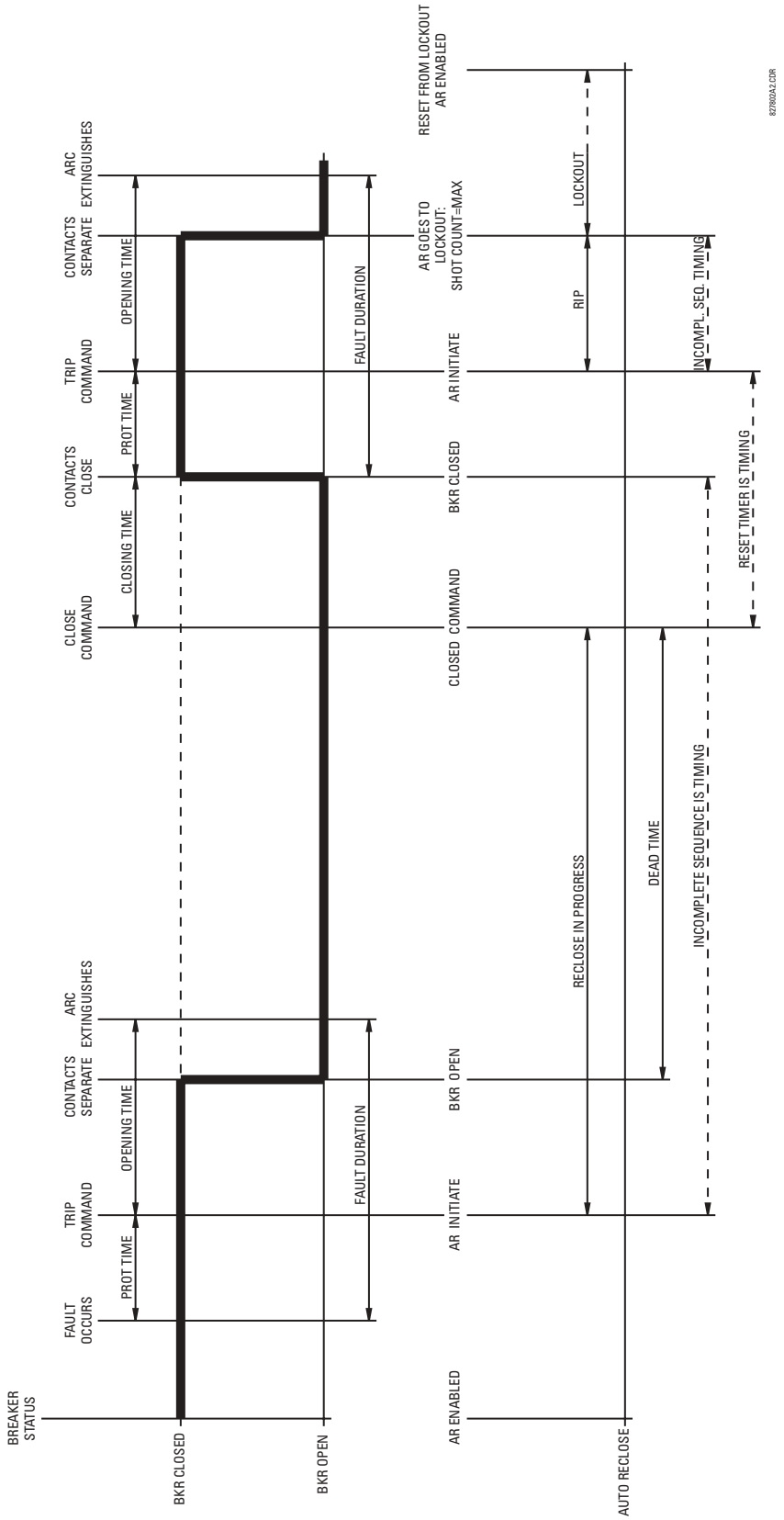
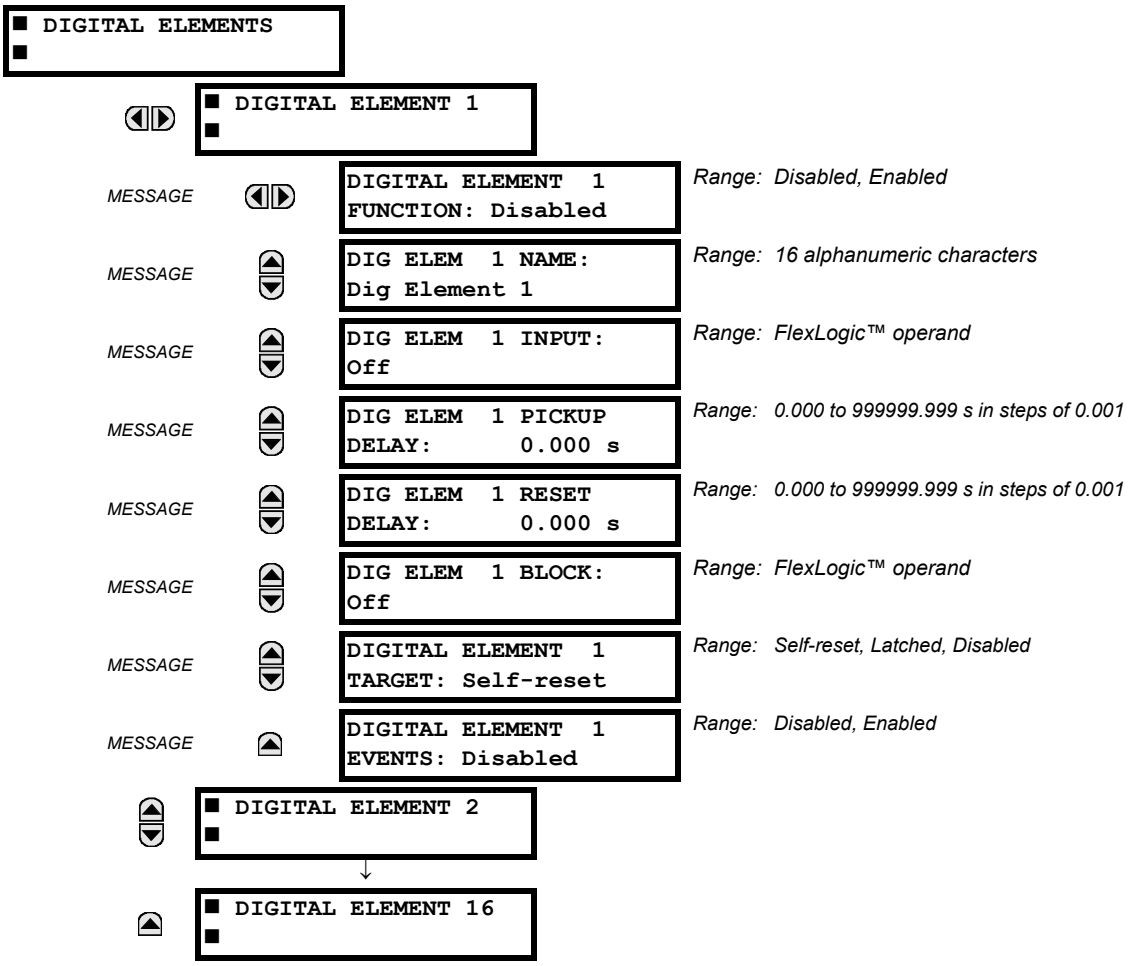


Figure 5–68: SINGLE SHOT AUTORECLOSING SEQUENCE - PERMANENT FAULT

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ DIGITAL ELEMENTS



There are 16 identical Digital Elements available, numbered 1 to 16. A Digital Element can monitor any FlexLogic™ operand and present a target message and/or enable events recording depending on the output operand state. The digital element settings include a 'name' which will be referenced in any target message, a blocking input from any selected FlexLogic™ operand, and a timer for pickup and reset delays for the output operand.

DIGITAL ELEMENT 1 INPUT: Selects a FlexLogic™ operand to be monitored by the Digital Element.

DIGITAL ELEMENT 1 PICKUP DELAY: Sets the time delay to pickup. If a pickup delay is not required, set to "0".

DIGITAL ELEMENT 1 RESET DELAY: Sets the time delay to reset. If a reset delay is not required, set to "0".

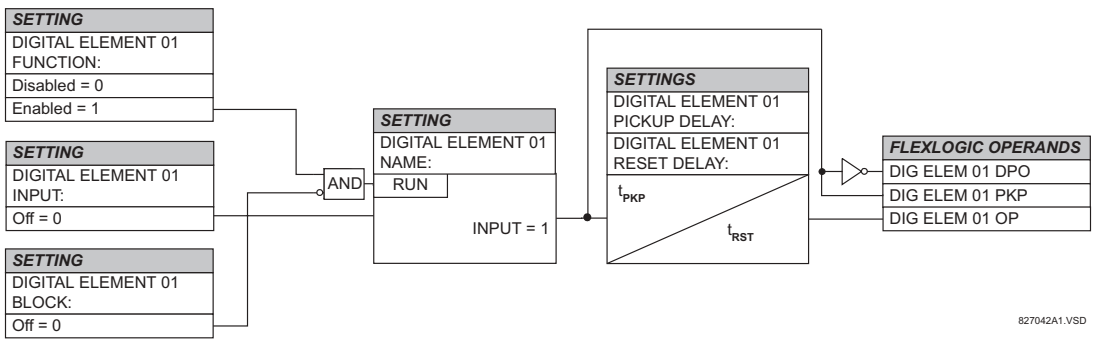


Figure 5–69: DIGITAL ELEMENT SCHEME LOGIC

a) CIRCUIT MONITORING APPLICATIONS

Some versions of the digital input modules include an active Voltage Monitor circuit connected across Form-A contacts. The Voltage Monitor circuit limits the trickle current through the output circuit (see Technical Specifications for Form-A).

As long as the current through the Voltage Monitor is above a threshold (see Technical Specifications for Form-A), the FlexLogic™ operand "Cont Op # VOn" will be set. (# represents the output contact number). If the output circuit has a high resistance or the DC current is interrupted, the trickle current will drop below the threshold and the FlexLogic™ operand "Cont Op # VOff" will be set. Consequently, the state of these operands can be used as indicators of the integrity of the circuits in which Form-A contacts are inserted.

b) BREAKER TRIP CIRCUIT INTEGRITY MONITORING – EXAMPLE 1

In many applications it is desired to monitor the breaker trip circuit integrity so problems can be detected before a trip operation is required. The circuit is considered to be healthy when the Voltage Monitor connected across the trip output contact detects a low level of current, well below the operating current of the breaker trip coil. If the circuit presents a high resistance, the trickle current will fall below the monitor threshold and an alarm would be declared.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact which is open when the breaker is open (see diagram below). To prevent unwanted alarms in this situation, the trip circuit monitoring logic must include the breaker position.

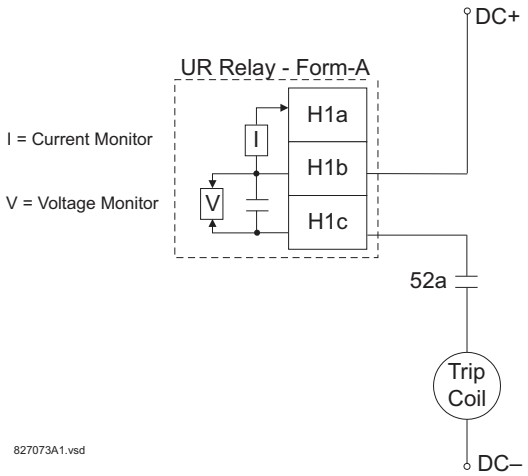
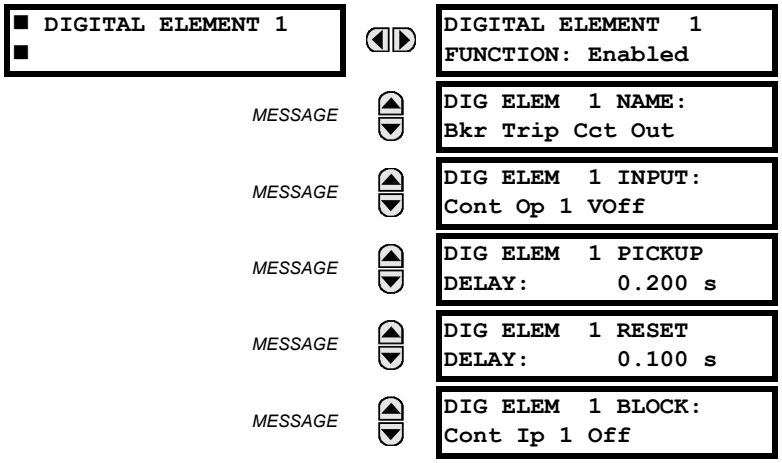


Figure 5–70: TRIP CIRCUIT EXAMPLE 1

Assume the output contact H1 is a trip contact. Using the contact output settings, this output will be given an ID name, e.g. "Cont Op 1". Assume a 52a breaker auxiliary contact is connected to contact input H7a to monitor breaker status. Using the contact input settings, this input will be given an ID name, e.g. "Cont Ip 1" and will be set "ON" when the breaker is closed. Using Digital Element 1 to monitor the breaker trip circuit, the settings will be:



MESSAGE
DIGITAL ELEMENT 1
TARGET: Self-reset

MESSAGE
DIGITAL ELEMENT 1
EVENTS: Enabled

NOTE: The PICKUP DELAY setting should be greater than the operating time of the breaker to avoid nuisance alarms.

c) BREAKER TRIP CIRCUIT INTEGRITY MONITORING – EXAMPLE 2

If it is required to monitor the trip circuit continuously, independent of the breaker position (open or closed), a method to maintain the monitoring current flow through the trip circuit when the breaker is open must be provided (as shown in Figure: TRIP CIRCUIT - EXAMPLE 2). This can be achieved by connecting a suitable resistor (as listed in the VALUES OF RESISTOR 'R' table) across the auxiliary contact in the trip circuit. In this case, it is not required to supervise the monitoring circuit with the breaker position - the BLOCK setting is selected to Off. In this case, the settings will be:

■ DIGITAL ELEMENT 1
■

DIGITAL ELEMENT 1
FUNCTION: Enabled

MESSAGE
DIG ELEM 1 NAME:
Bkr Trip Cct Out

MESSAGE
DIG ELEM 1 INPUT:
Cont Op 1 VOff

MESSAGE
DIG ELEM 1 PICKUP
DELAY: 0.200 s

MESSAGE
DIG ELEM 1 RESET
DELAY: 0.100 s

MESSAGE
DIG ELEM 1 BLOCK:
Off

MESSAGE
DIGITAL ELEMENT 1
TARGET: Self-reset

MESSAGE
DIGITAL ELEMENT 1
EVENTS: Enabled

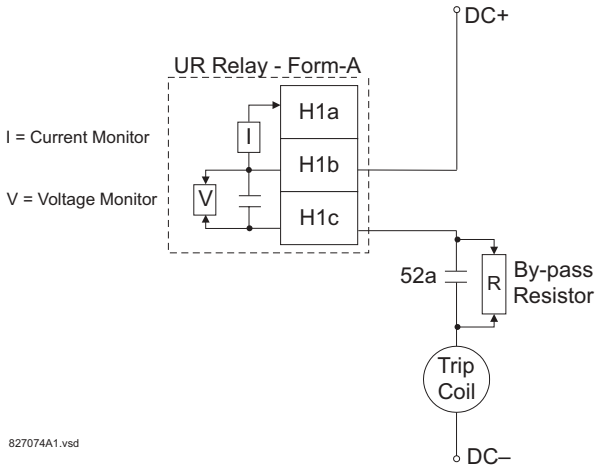
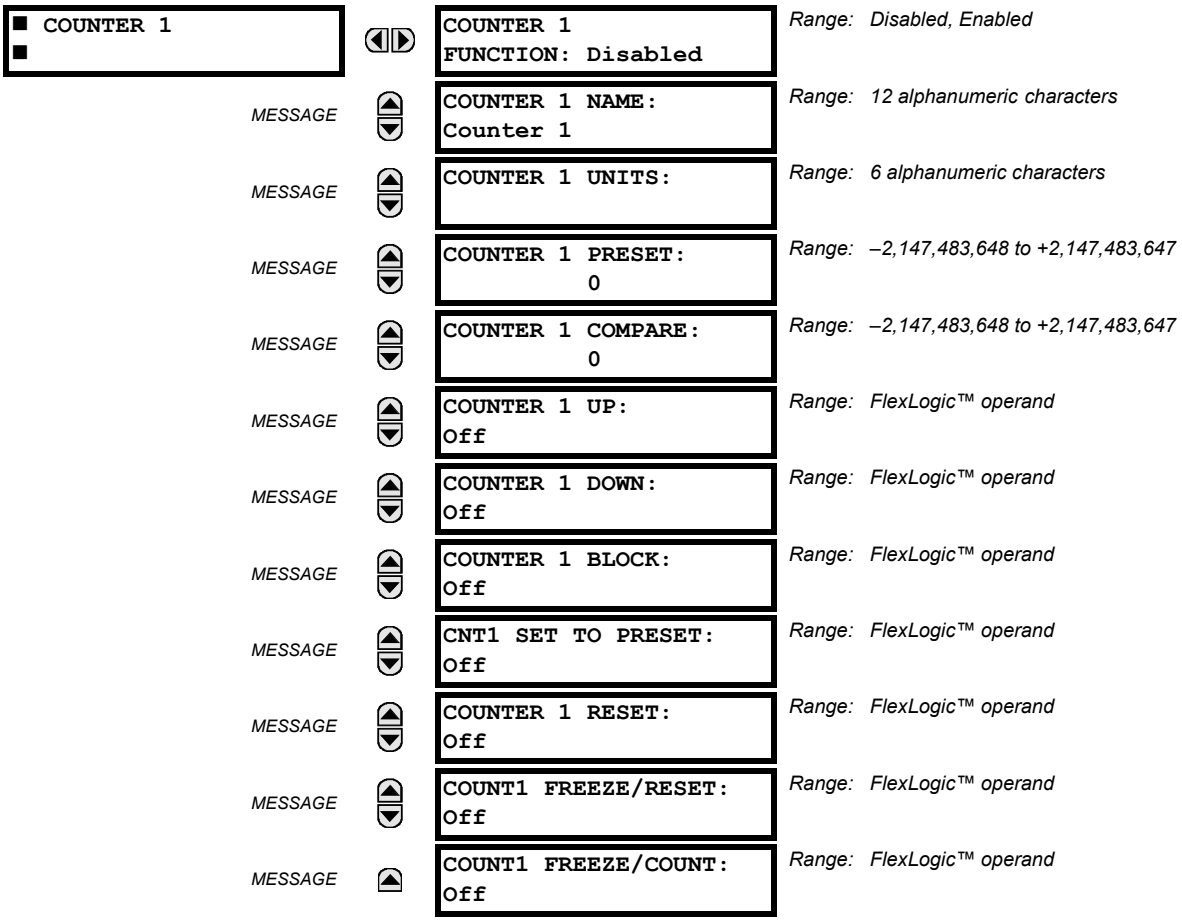


Figure 5–71: TRIP CIRCUIT EXAMPLE 2

Table 5–25: VALUES OF RESISTOR 'R'

POWER SUPPLY (V DC)	RESISTANCE (OHMS)	POWER (WATTS)
24	1000	2
30	5000	2
48	10000	2
110	25000	5
125	25000	5
250	50000	5

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ DIGITAL COUNTERS ⇨ COUNTER 1(8)



There are 8 identical digital counters, numbered from 1 to 8. A digital counter counts the number of state transitions from Logic 0 to Logic 1. The counter is used to count operations such as the pickups of an element, the changes of state of an external contact (e.g. breaker auxiliary switch), or pulses from a watt-hour meter.

COUNTER 1 UNITS:

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.

COUNTER 1 PRESET:

Sets 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.

COUNTER 1 COMPARE:

Sets the value to which the accumulated count value is compared. Three FlexLogic™ output operands are provided to indicate if the present value is 'more than (HI)', 'equal to (EQL)', or 'less than (LO)' the set value.

COUNTER 1 UP:

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.

COUNTER 1 DOWN:

Selects the FlexLogic™ 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.

COUNTER 1 BLOCK:

Selects the FlexLogic™ operand for blocking the counting operation. All counter operands are blocked.

CNT1 SET TO PRESET:

Selects the FlexLogic™ operand used to set the count to the preset value. The counter will be set to the preset value in the following situations:

1. When the counter is enabled and the **CNT1 SET TO PRESET** operand has the value 1 (when the counter is enabled and **CNT1 SET TO PRESET** is 0, the counter will be set to 0.)
2. When the counter is running and the **CNT1 SET TO PRESET** operand changes the state from 0 to 1 (**CNT1 SET TO PRESET** changing from 1 to 0 while the counter is running has no effect on the count).
3. When a reset or reset/freeze command is sent to the counter and the **CNT1 SET TO PRESET** operand has the value 1 (when a reset or reset/freeze command is sent to the counter and the **CNT1 SET TO PRESET** operand has the value 0, the counter will be set to 0).

COUNTER 1 RESET:

Selects the FlexLogic™ operand for setting the count to either "0" or the preset value depending on the state of the **CNT1 SET TO PRESET** operand.

COUNTER 1 FREEZE/RESET:

Selects the FlexLogic™ 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".

COUNTER 1 FREEZE/COUNT:

Selects the FlexLogic™ 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/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.

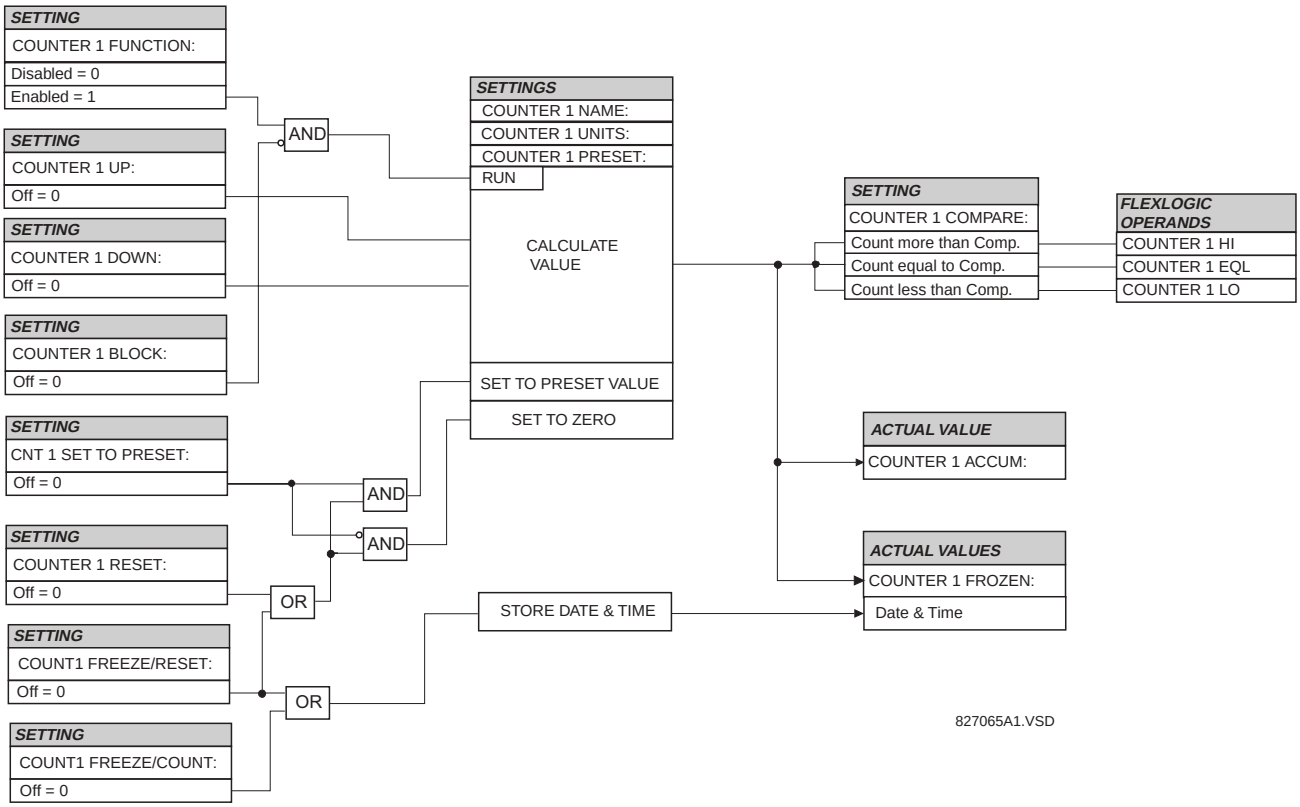
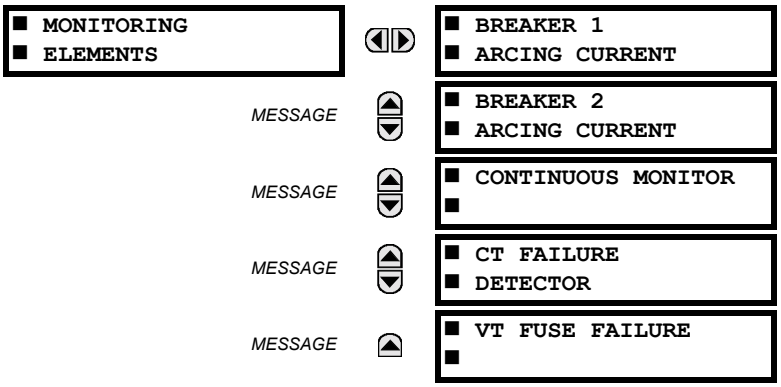


Figure 5–72: DIGITAL COUNTER SCHEME LOGIC

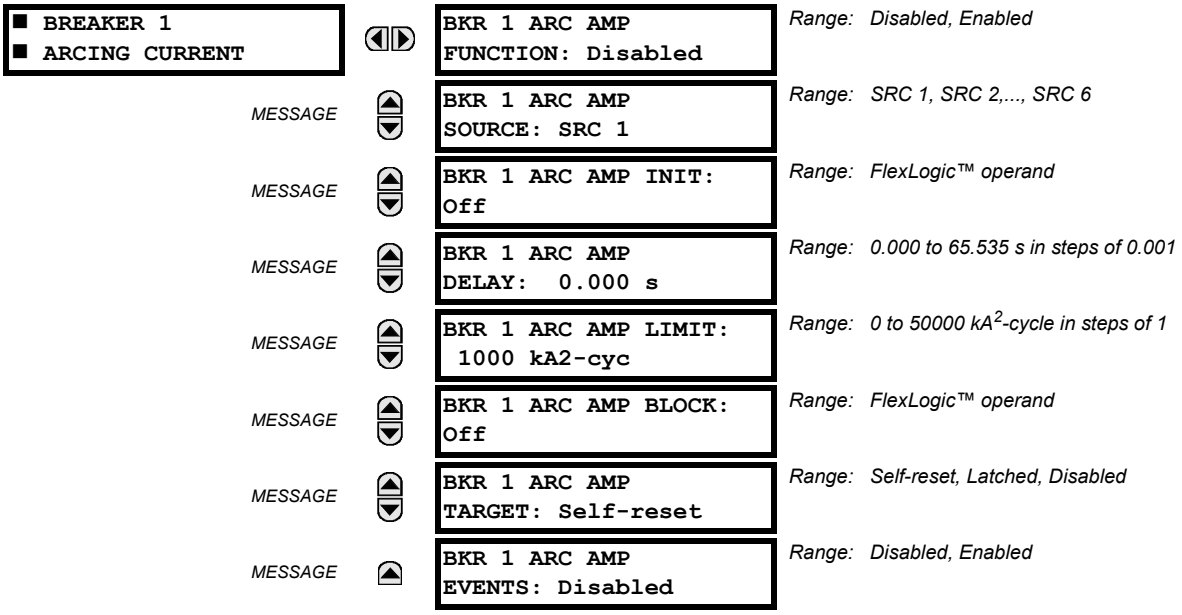
5.6.7 MONITORING ELEMENTS

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS



5.6.8 BREAKER ARCING CURRENT

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨ BREAKER 1 ARCING CURRENT



There are 2 identical Breaker Arcing Current features available for Breakers 1 and 2. This element calculates an estimate of the per-phase wear on the breaker contacts by measuring and integrating the current squared passing through the breaker contacts as an arc. These per-phase values are added to accumulated totals for each phase and compared to a programmed threshold value. When the threshold is exceeded in any phase, the relay can set an output operand to "1". The accumulated value for each phase can be displayed as an actual value.

The operation of the scheme is shown in the following logic diagram. The same output operand that is selected to operate the output relay used to trip the breaker, indicating a tripping sequence has begun, is used to initiate this feature. A time delay is introduced between initiation and the starting of integration to prevent integration of current flow through the breaker before the contacts have parted. This interval includes the operating time of the output relay, any other auxiliary relays and the breaker mechanism. For maximum measurement accuracy, the interval between change-of-state of the operand (from 0 to 1) and contact separation should be measured for the specific installation. Integration of the measured current continues for 100 milliseconds, which is expected to include the total arcing period.

BKR 1 ARC AMP INIT:

Selects the same output operand that is selected to operate the output relay used to trip the breaker.

BKR 1 ARC AMP DELAY:

This setting is used to program the delay interval between the time the tripping sequence is initiated and the time the breaker contacts are expected to part, starting the integration of the measured current.

BKR 1 ARC AMP LIMIT:

Selects the threshold value above which the output operand is set.

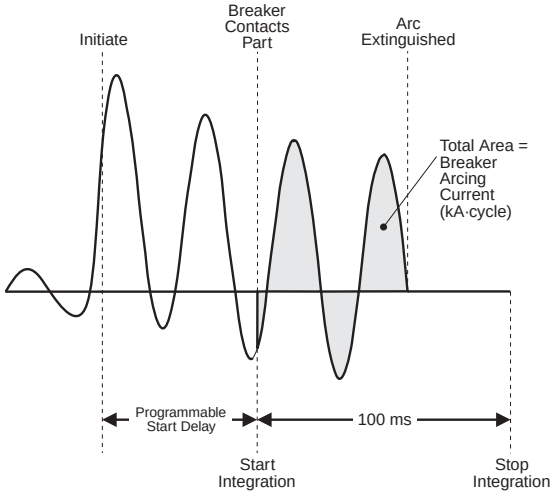


Figure 5–73: ARCING CURRENT MEASUREMENT

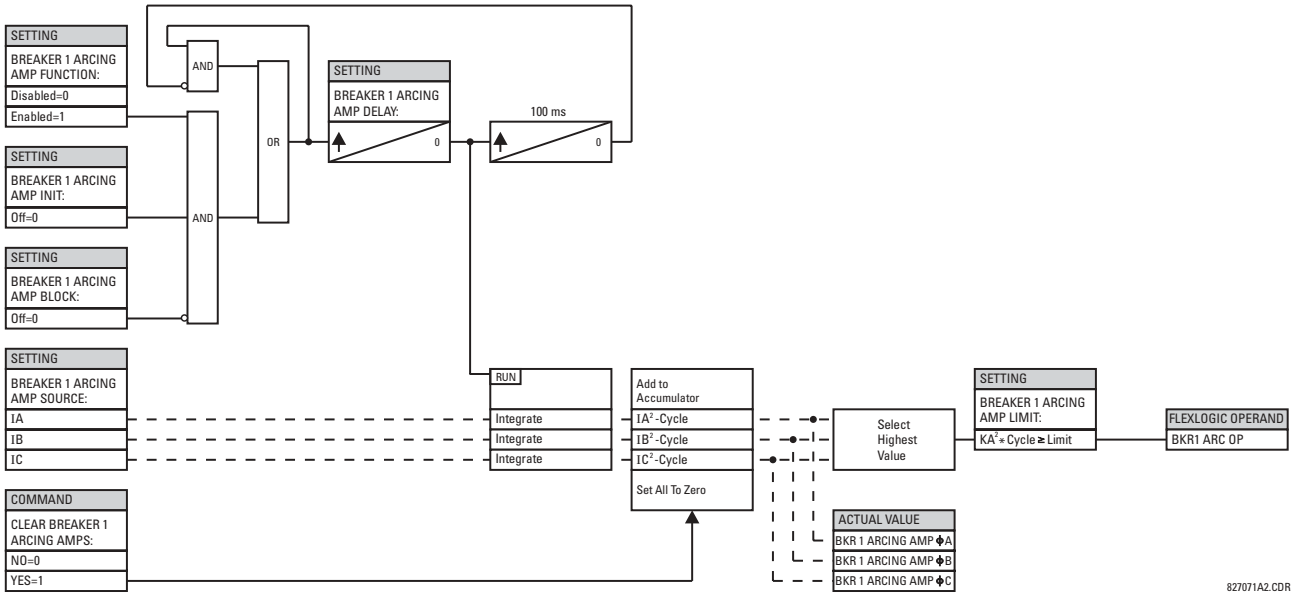


Figure 5–74: BREAKER ARCING CURRENT SCHEME LOGIC

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ CONTINUOUS MONITOR

■ CONTINUOUS MONITOR ■	CONT MONITOR FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	CONT MONITOR I-OP: Off	Range: FlexLogic™ operand Any Current Element(s) OP
MESSAGE	CONT MONITOR I-SUPV: Off	Range: FlexLogic™ operand To supervise current logic, use 50DD OP
MESSAGE	CONT MONITOR V-OP: Off	Range: FlexLogic™ operand Any Voltage Element(s) OP
MESSAGE	CONT MONITOR V-SUPV: Off	Range: FlexLogic™ operand. To supervise voltage logic, use VT FUSE FAIL OP
MESSAGE	CONT MONITOR TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	CONT MONITOR EVENTS: Disabled	Range: Disabled, Enabled

The Continuous Monitor logic is intended to detect the operation of any tripping element that has operated under normal load conditions; that is, when the DD disturbance detector has not operated. Because all tripping is supervised by the DD function, no trip will be issued under these conditions. This could occur when an element is incorrectly set so that it may misoperate under load. The Continuous Monitor can detect this state and issue an alarm and/or block the tripping of the relay.

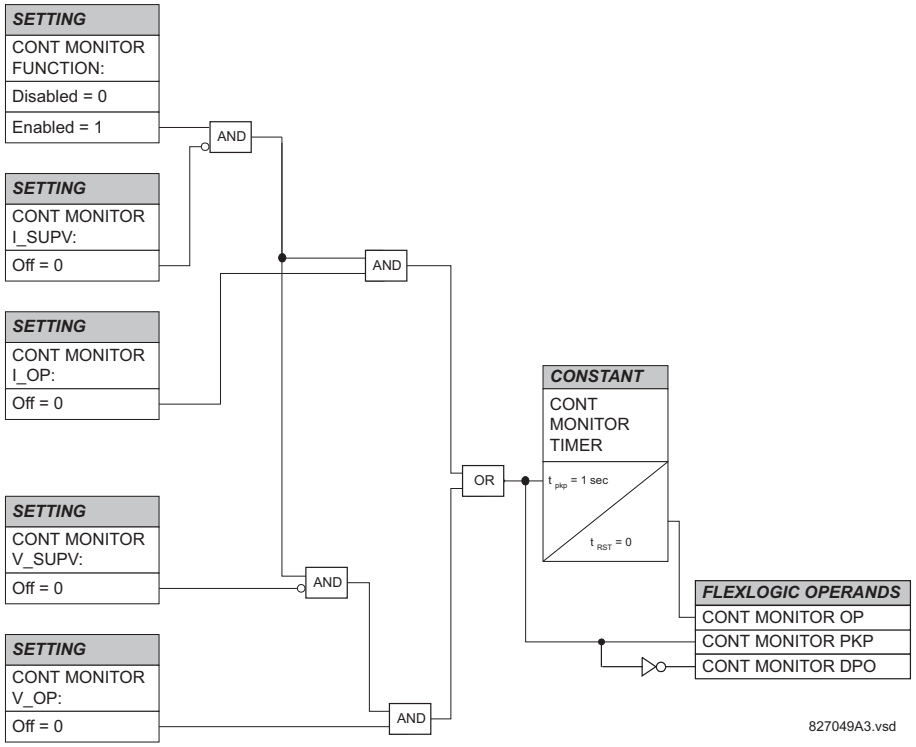
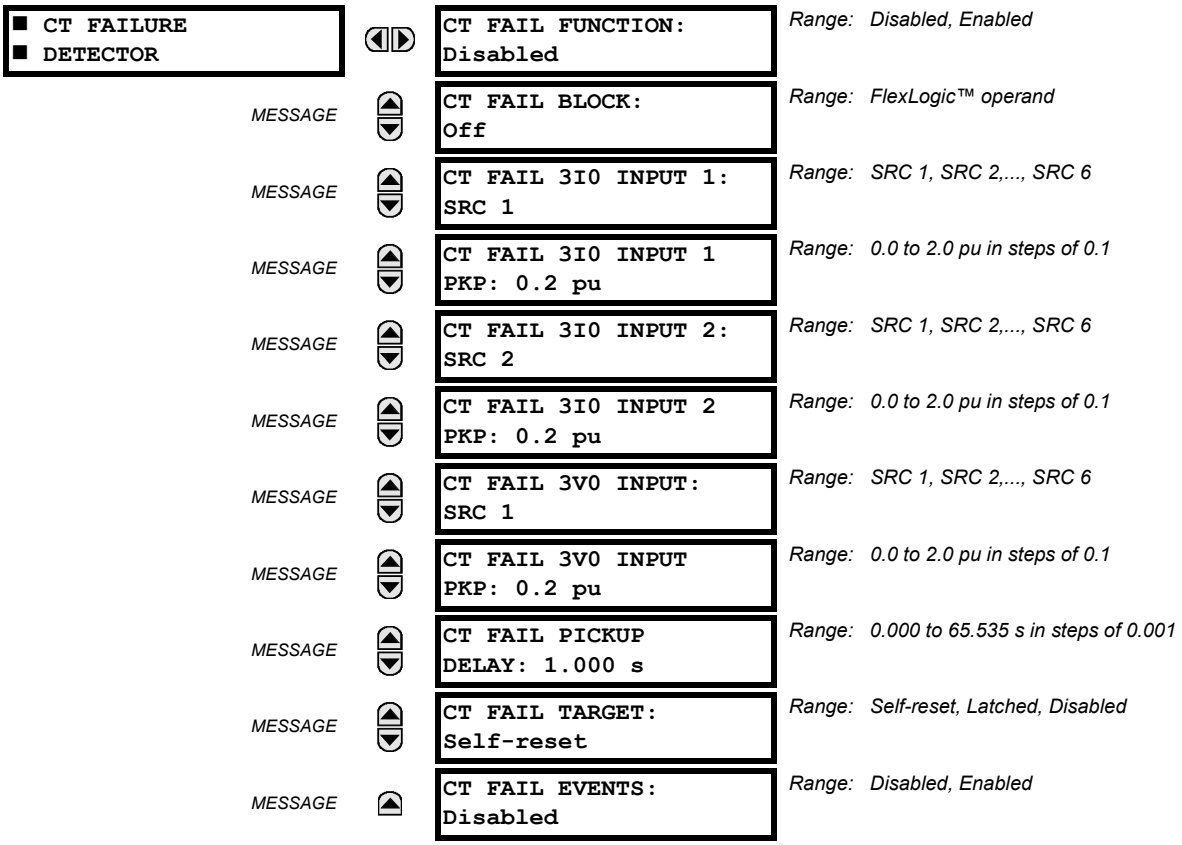


Figure 5–75: CONTINUOUS MONITOR SCHEME LOGIC

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ CT FAILURE DETECTOR



The CT FAIL logic is designed to detect problems with the system current transformers used to supply current to the relay. This logic detects the presence of a zero sequence current at the supervised source of current without a simultaneous zero sequence current at another source, zero sequence voltage or some protection element condition.

CT FAIL logic (see figure below) is based on the presence of the zero sequence current in the supervised CT source and absence of one of three or all three conditions as follows:

- zero sequence current at different source current (may be different set of CTs or different CT core of the same CT)
- zero sequence voltage at the assigned source
- appropriate protection element or remote signal

CT FAIL FUNCTION:

This setting is used to Enable/Disable operation of the element.

CT FAIL BLOCK:

This setting is used to select a FlexLogic™ operand that blocks operation of the element during some conditions (i.e. open pole in process of the single pole tripping-reclosing) when CT Fail should be blocked. Remote signals representing operation of some remote current protection elements via communication channel or local ones can be chosen as well.

CT FAIL 3I0 INPUT 1:

This setting is used to select the source for the current for input 1. Most important protection element of the relay should be assigned to the same source.

CT FAIL 3I0 INPUT 1 PICKUP:

This setting is used to select the pickup value for 3I_0 for the input 1 (main supervised CT source) of the relay.

CT FAIL 3I0 INPUT 2:

This setting is used to select the source for the current for input 2. Input 2 should use different set of CTs or different CT core of the same CT. Against absence at input 2 CT source (if exists), 3I_0 current logic is built.

CT FAIL 3I0 INPUT 2 PICKUP:

This setting is used to select the pickup value for 3I_0 for the input 2 (different CT input) of the relay.

CT FAIL 3V0 INPUT:

This setting is used to select the source for the voltage.

CT FAIL 3V0 INPUT PICKUP:

This setting is used to select the pickup value for 3V_0 source.

CT FAIL PICKUP DELAY:

This setting is used to select the pickup delay of the element.

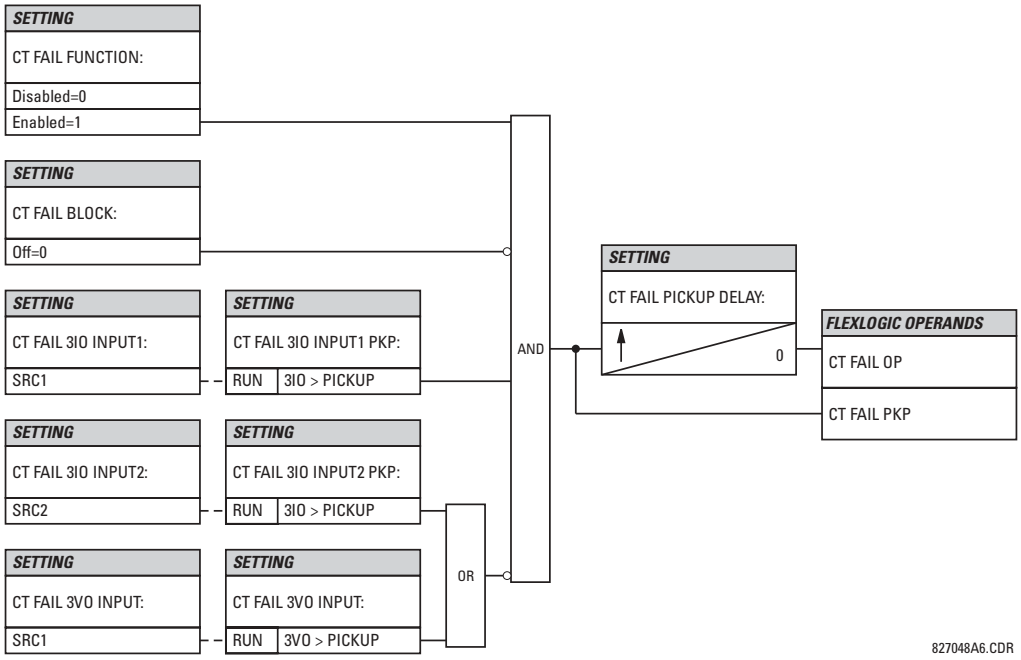


Figure 5–76: CT FAILURE DETECTOR SCHEME LOGIC

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ VT FUSE FAILURE

```
■ VT FUSE FAILURE
■
```

⇔

```
VT FUSE FAILURE
FUNCTION: Disabled
```

Range: Disabled, Enabled

Every signal source includes a fuse failure scheme.

The VT fuse failure detector can be used to raise an alarm and/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 input) are distance, voltage restrained overcurrent, and directional current.

There are two classes of fuse failure that may occur: (A) loss of one or two phases, and (B) loss of all three phases. A different means of detection is 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.

The common FUNCTION setting will Enable/Disable the fuse failure feature for all 6 sources.

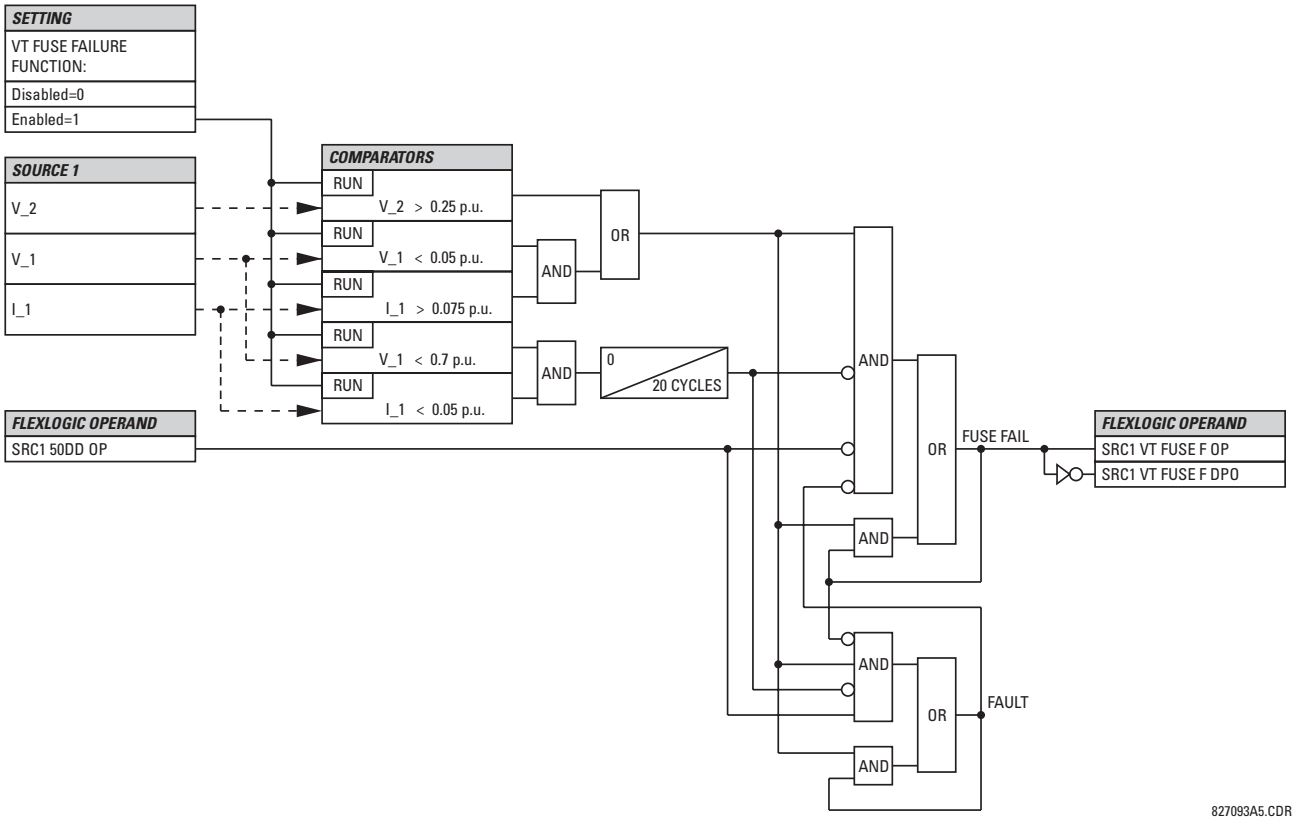
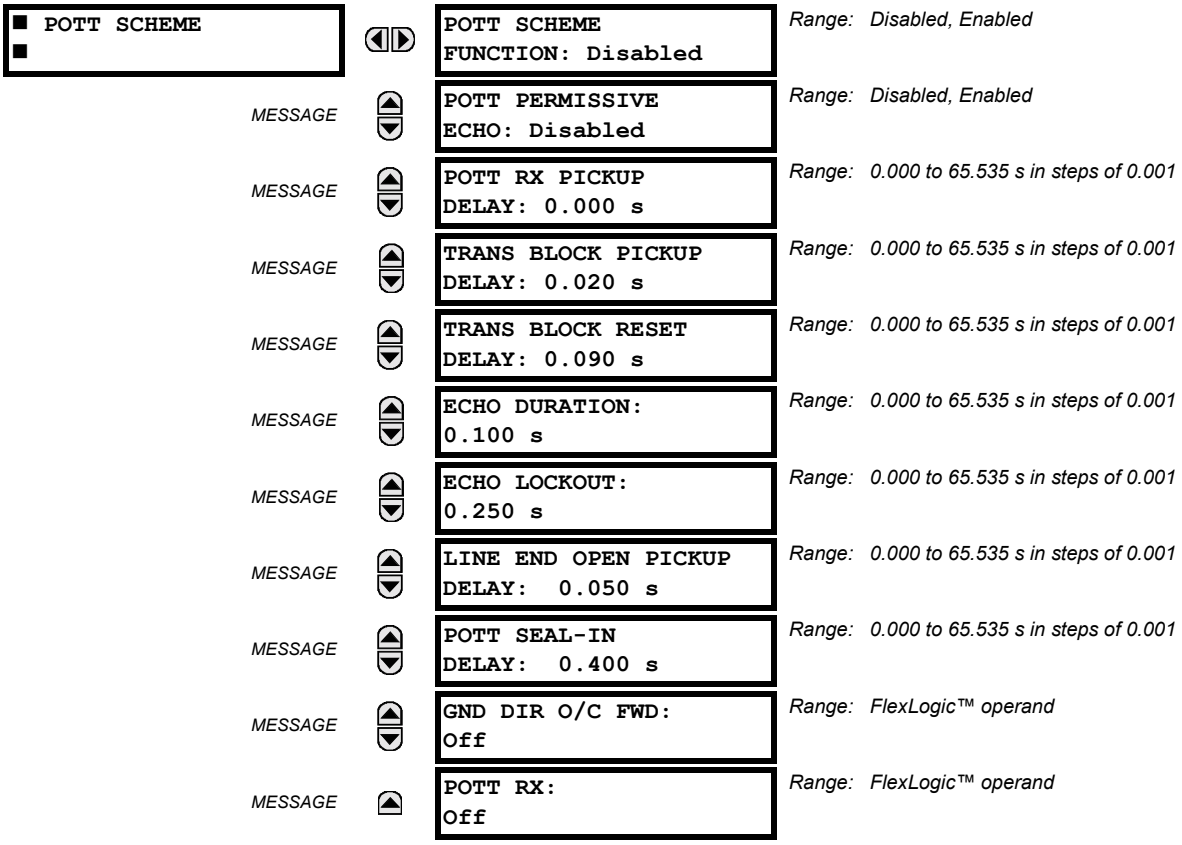


Figure 5–77: VT FUSE FAIL SCHEME LOGIC

a) PERMISSIVE OVER-REACHING TRANSFER TRIP (POTT)

PATH: SETTINGS ⇩ CONTROL ELEMENTS ⇨⇩ PILOT SCHEMES ⇨⇩ POTT SCHEME



This scheme is intended for two-terminal line applications only. It uses an over-reaching Zone 2 distance element to essentially compare the direction to a fault at both the ends of the line. Ground directional overcurrent functions available in the relay can be used in conjunction with the Zone 2 distance element to key the scheme and initiate its operation. This provides increased coverage for high-resistance faults.

For proper scheme operation, the Zone 2 phase and ground distance elements must be enabled, configured, and set per the rules of distance relaying. The Line Pickup element should be enabled, configured and set properly to detect line-end-open/weak-infeed conditions. If used by this scheme, the selected ground directional overcurrent function(s) must be enabled, configured, and set accordingly.

POTT PERMISSIVE ECHO:

If set to "Enabled" this setting will result in sending a permissive echo signal to the remote end. The permissive signal is echoed back upon receiving a reliable POTT RX signal from the remote end while the line-end-open condition is identified by the Line Pickup logic. The Permissive Echo is programmed as a one-shot logic. The echo is sent only once and then the echo logic locks out for a settable period of time (**ECHO LOCKOUT** setting). The duration of the echo pulse does not depend on the duration or shape of the received POTT RX signal but is settable as **ECHO DURATION**.

POTT RX PICKUP DELAY:

This setting enables the relay to cope with spurious receive signals. The delay should be set longer than the longest spurious TX signal that can occur simultaneously with the zone 2 pickup. The selected delay will increase the response time of the scheme.

TRANS BLOCK PICKUP DELAY:

This setting defines a transient blocking mechanism embedded in the POTT scheme for coping with the exposure of a ground directional overcurrent function (if used) to current reversal conditions. The transient blocking mechanism applies to the ground overcurrent path only as the reach settings for the zone 2 distance functions is not expected to be long for two-terminal applications, and the security of the distance functions is not endangered by the current reversal conditions.

Upon receiving the POTT RX signal, the transient blocking mechanism allows the RX signal to be passed and aligned with the **GND DIR O/C FWD** indication only for a period of time defined as **TRANS BLOCK PICKUP DELAY**. After that the ground directional overcurrent path will be virtually disabled for a period of time specified as **TRANS BLOCK RESET DELAY**.

The **TRANS BLOCK PICKUP DELAY** should be long enough to give the selected ground directional overcurrent function time to operate, but not longer than the fastest possible operation time of the protection system that can create current reversal conditions within the reach of the selected ground directional overcurrent function. This setting should take into account the **POTT RX PICKUP DELAY**. The POTT RX signal is shaped for aligning with the ground directional indication as follows: The original RX signal is delayed by the **POTT RX PICKUP DELAY**, then terminated at **TRANS BLOCK PICKUP DELAY** after the pickup of the original POTT TX signal, and eventually, locked-out for **TRANS BLOCK RESET DELAY**.

TRANS BLOCK RESET DELAY:

This setting defines a transient blocking mechanism embedded in the POTT scheme for coping with the exposure of a ground directional overcurrent function (if used) to current reversal conditions (see also the **TRANS BLOCK PICKUP DELAY**).

This delay should be selected long enough to cope with transient conditions including not only current reversals but also spurious negative- and zero-sequence currents occurring during breaker operations. The breaker failure time of the surrounding protection systems within the reach of the ground directional function used by the POTT scheme may be considered to make sure that the ground directional function is not jeopardized during delayed breaker operations.

ECHO DURATION:

This setting defines the guaranteed and exact duration of the echo pulse. The duration does not depend on the duration and shape of the received POTT RX signal. This setting enables the relay to avoid a permanent lock-up of the transmit/receive loop.

ECHO LOCKOUT:

This setting defines the lockout period for the echo logic after sending the echo pulse.

LINE END OPEN PICKUP DELAY:

This setting defines the pickup setting for validation of the line end open conditions as detected by the Line Pickup logic through the LINE PICKUP LEO PKP FlexLogic™ operand. The validated line end open condition is a requirement for the POTT scheme to return a received echo signal (if the ECHO feature is enabled).

The value of this setting should take into account the principle of operation and settings of the LINE PICKUP element.

POTT SEAL-IN DELAY:

The output FlexLogic™ operand (POTT OP) is produced according to the POTT scheme logic. A seal-in time delay is applied to this operand for coping with noisy communication channels. The POTT SEAL-IN DELAY defines a minimum guaranteed duration of the POTT OP pulse.

GND DIR O/C FWD:

This setting defines the FlexLogic™ operand (if any) of a protection element used in addition to Zone 2 for identifying faults on the protected line, and thus, for keying the communication channel and initiating operation of the scheme. Good directional integrity is the key requirement for an over-reaching forward-looking protection element used as **GND DIR O/C FWD**.

Even though any FlexLogic™ operand could be used as **GND DIR O/C FWD** allowing the user to combine responses of various protection elements, or to apply extra conditions through FlexLogic™ equations, this extra signal is primarily meant to be the output operand from either the Negative-Sequence Directional IOC or Neutral Directional IOC. Both of these elements have separate forward (FWD) and reverse (REV) output operands. The forward indication should be used (**NEG SEQ DIR OC1 FWD** or **NEUTRAL DIR OC1 FWD**).

POTT RX:

This setting enables the user to select the FlexLogic™ operand that represents the receive signal (RX) for the scheme. Typically an input contact interfacing with a signaling system is used. Other choices include Remote Inputs and FlexLogic™ equations. The POTT transmit signal (TX) should be appropriately interfaced with the signaling system by assigning the output FlexLogic™ operand (POTT TX) to an output contact. The Remote Output mechanism is another choice.

The output operand from the scheme (POTT OP) must be configured to interface with other relay functions, output contacts in particular, in order to make the scheme fully operational. Typically, the output operand should be programmed to initiate a trip, breaker fail, and autoreclose, and drive a user-programmable LED as per user application.

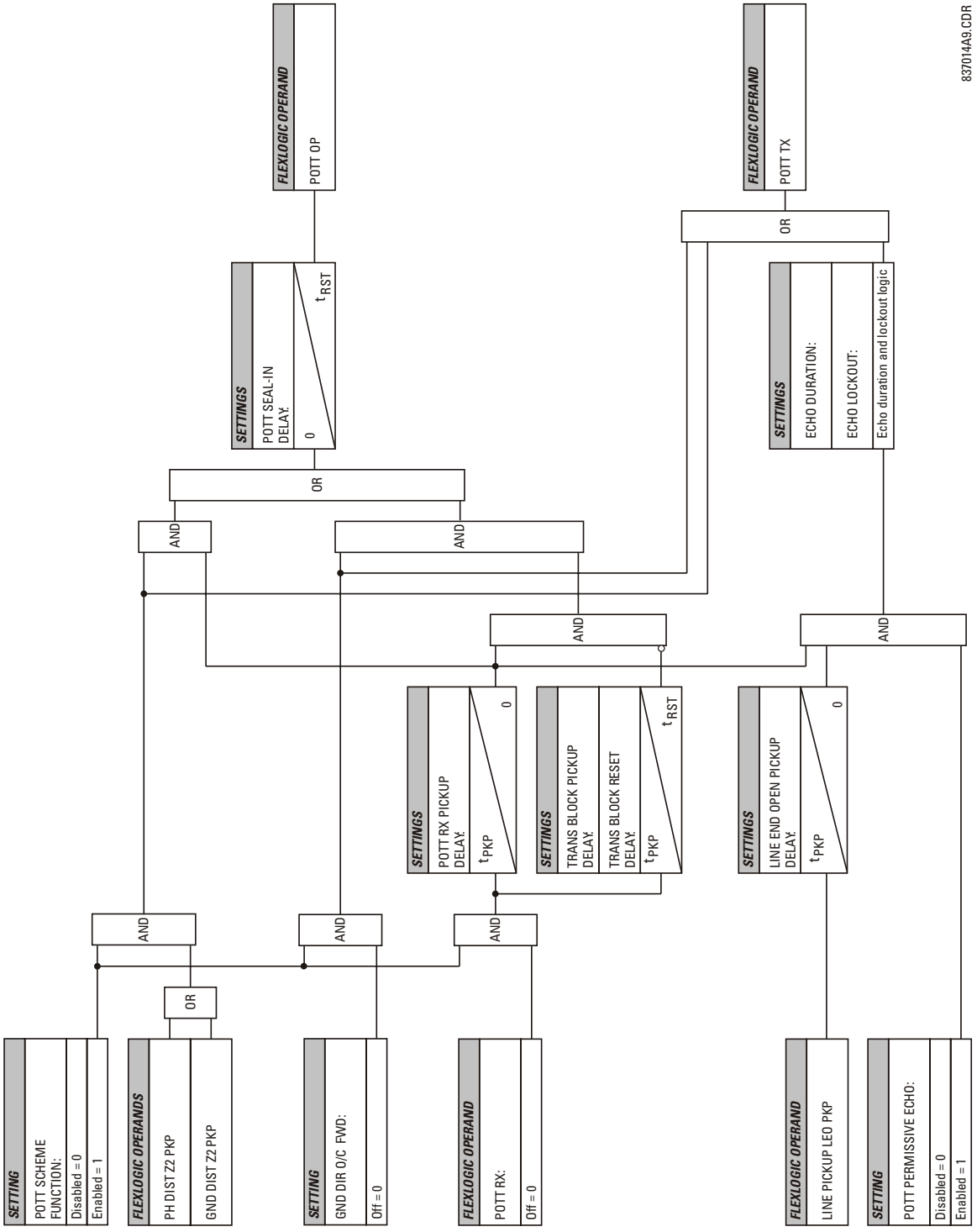
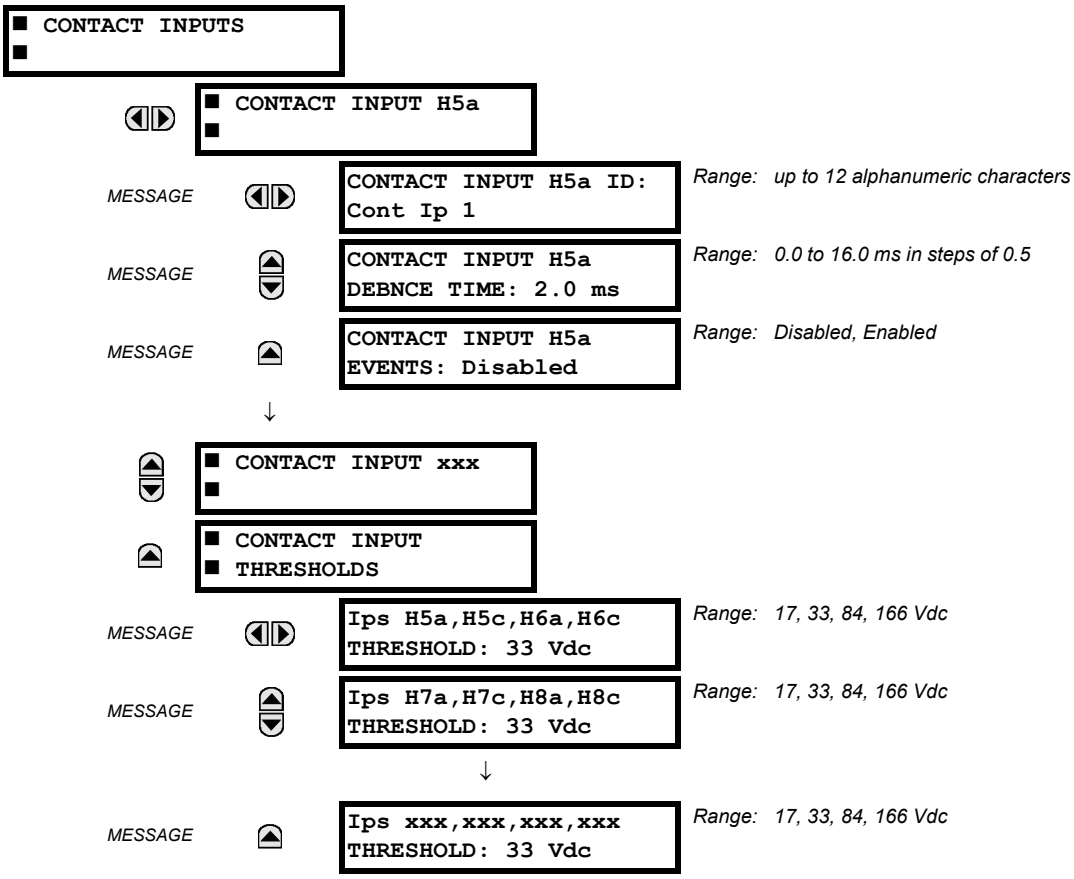


Figure 5–78: POTT SCHEME LOGIC

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨ CONTACT INPUTS



The contact inputs menu contains configuration settings for each contact input as well as voltage thresholds for each group of four contact inputs. Upon startup, the relay processor determines (from an assessment of the installed modules) which contact inputs are available and then display settings for only those inputs.

An alphanumeric ID may be assigned to a contact input for diagnostic, setting, and event recording purposes. The "Contact Ip X On" (Logic 1) FlexLogic™ operand corresponds to contact input "X" being closed, while "Contact Input X Off" corresponds to contact input "X" being open. The **CONTACT INPUT DEBNCE TIME** defines the time required for the contact to overcome 'contact bouncing' conditions. As this time differs for different contact types and manufacturers, set it as a maximum contact debounce time (per manufacturer specifications) plus some margin to ensure proper operation. If **CONTACT INPUT EVENTS** is set to "Enabled", every change in the contact input state will trigger an event.

A raw status is scanned for all Contact Inputs synchronously at the constant rate of 0.5 ms as shown in the figure below. The DC input voltage is compared to a user-settable threshold. A new contact input state must be maintained for a user-settable debounce time in order for the L90 to validate the new contact state. In the figure below, the debounce time is set at 2.5 ms; thus the 6th sample in a row validates the change of state (mark no.1 in the diagram). Once validated (debounced), the contact input asserts a corresponding FlexLogic™ operand and logs an event as per user setting.

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 no. 2 in the diagram).

Protection and control elements, as well as FlexLogic™ equations and timers, are executed eight 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 (marks no. 3 and 4 on the figure below). The update is performed at the beginning of the protection pass so all protection and control functions, as well as 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 up to one protection pass (variable and depending on system frequency if frequency tracking 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 0.5 ms scan rate, the time resolution for the input contact is below 1msec.

For example, 8 protection passes per cycle on a 60 Hz system correspond to a protection pass every 2.1 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 + 2.1 = 5.1 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 μs accuracy using the time of the first scan corresponding to the new state (mark no. 2 below). 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 LOW-HIGH (marks no.1, 2, 3, and 4 in the figure below) and HIGH-LOW (marks no.5, 6, 7, and 8 below) transitions.

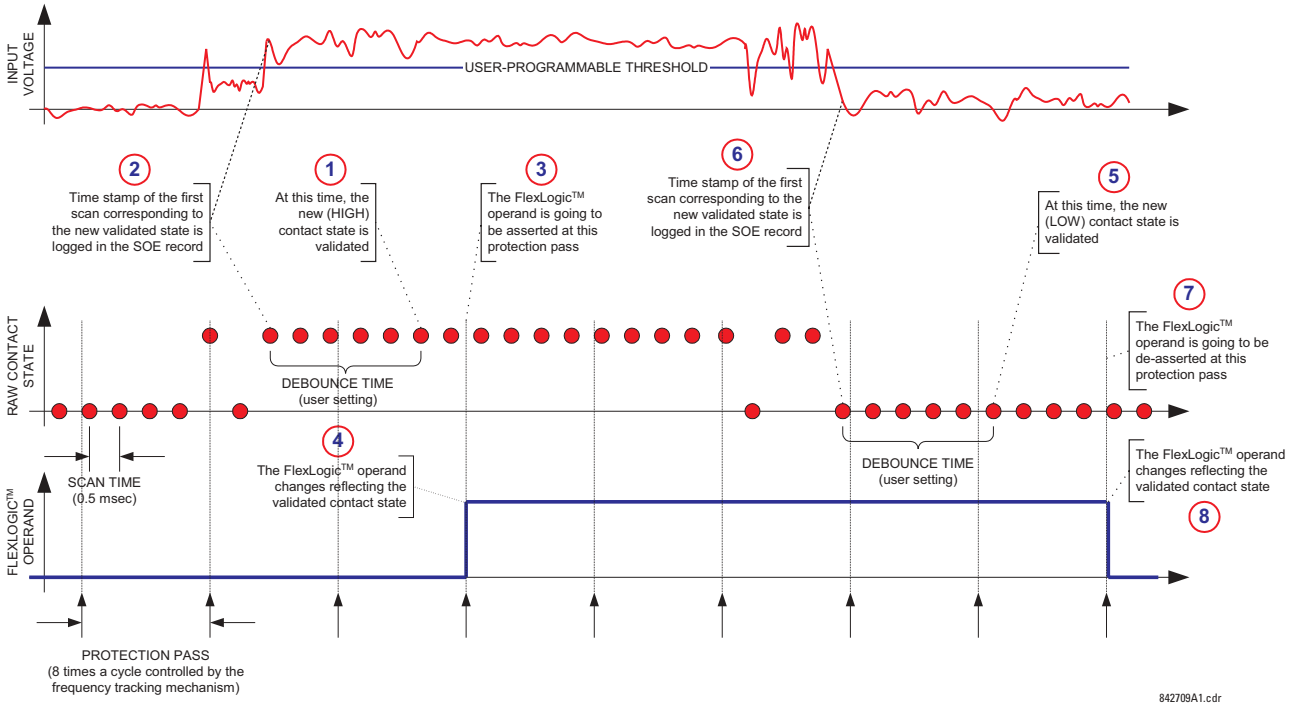


Figure 5–79: INPUT CONTACT DEBOUNCING MECHANISM AND TIME-STAMPING SAMPLE TIMING

Contact inputs are isolated in groups of four to allow connection of wet contacts from different voltage sources for each group. The **CONTACT INPUT THRESHOLDS** determine the minimum voltage required to detect a closed contact input. This value should be selected according to the following criteria: 17 for 24 V sources, 33 for 48 V sources, 84 for 110 to 125 V sources and 166 for 250 V sources.

For example, to use contact input H5a as a status input from the breaker 52b contact to seal-in the trip relay and record it in the Event Records menu, make the following settings changes:

CONTACT INPUT H5A ID: "Breaker Closed (52b)"
CONTACT INPUT H5A EVENTS: "Enabled"

Note that the 52b contact is closed when the breaker is open and open when the breaker is closed.

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL INPUTS ⇨ VIRTUAL INPUT 1(32)

```
■ VIRTUAL INPUT  1
■
```

```
VIRTUAL INPUT  1
FUNCTION: Disabled
```

Range: Disabled, Enabled

MESSAGE

```
VIRTUAL INPUT  1 ID:
Virt Ip 1
```

Range: Up to 12 alphanumeric characters

MESSAGE

```
VIRTUAL INPUT  1
TYPE: Latched
```

Range: Self-Reset, Latched

MESSAGE

```
VIRTUAL INPUT  1
EVENTS: Disabled
```

Range: Disabled, Enabled

There are 32 virtual inputs that can be individually programmed to respond to input signals from the keypad (COMMANDS menu) and non-UCA2 communications protocols only. All virtual input operands are defaulted to OFF = 0 unless the appropriate input signal is received. **Virtual input states are preserved through a control power loss**.

VIRTUAL INPUT 1 FUNCTION:

If set to Disabled, the input will be forced to 'OFF' (Logic 0) regardless of any attempt to alter the input. If set to Enabled, the input will operate as shown on the scheme logic diagram, and generate output FlexLogic™ operands in response to received input signals and the applied settings.

VIRTUAL INPUT 1 TYPE:

There are two types of operation, Self-Reset and Latched. If set to Self-Reset, when the input signal transits from OFF = 0 to ON = 1, the output operand will be set to ON = 1 for only one evaluation of the FlexLogic™ equations and then return to OFF = 0. If set to Latched, the virtual input sets the state of the output operand to the same state as the most recent received input, ON =1 or OFF = 0.

NOTE

Virtual Input operating mode Self-Reset generates the output operand for a single evaluation of the FlexLogic™ equations. If the operand is to be used anywhere other than internally in a FlexLogic™ equation, it will most probably have to be lengthened in time. A FlexLogic™ Timer with a delayed reset can perform this function.

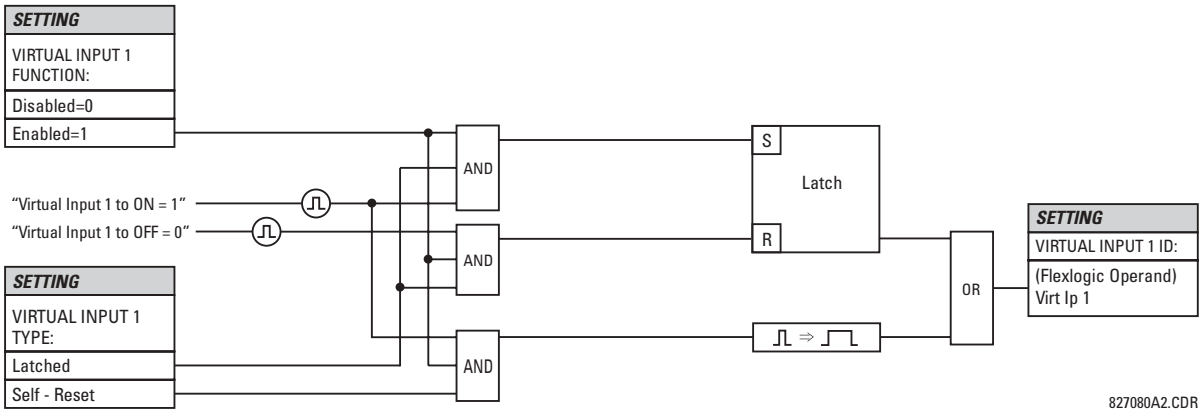
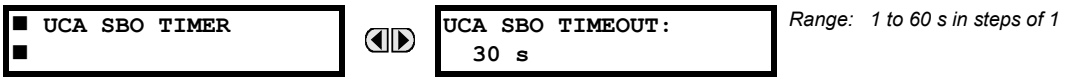


Figure 5–80: VIRTUAL INPUTS SCHEME LOGIC

5.7.3 UCA SBO TIMER

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL INPUTS ⇨⇩ UCA SBO TIMER

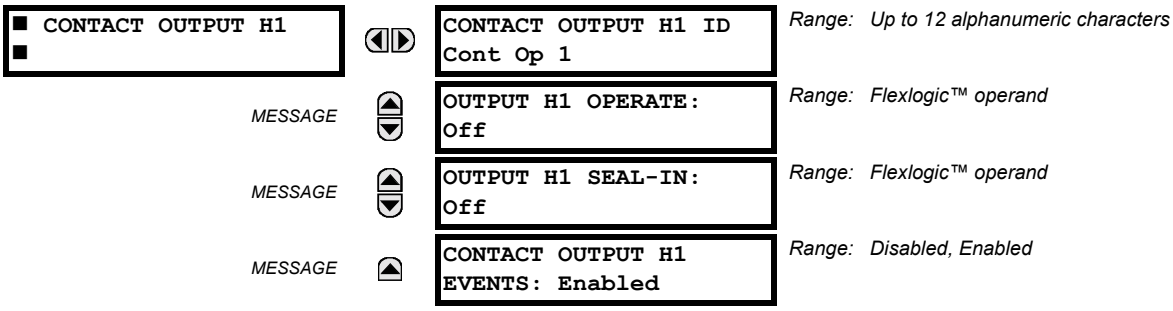


Range: 1 to 60 s in steps of 1

The Select-Before-Operate timer sets the interval from the receipt of an Operate signal to the automatic de-selection of the virtual input, so that an input does not remain selected indefinitely (this is used only with the UCA Select-Before-Operate feature).

5.7.4 CONTACT OUTPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1



Range: Up to 12 alphanumeric characters

Range: Flexlogic™ operand

Range: Flexlogic™ operand

Range: Disabled, Enabled

5

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.

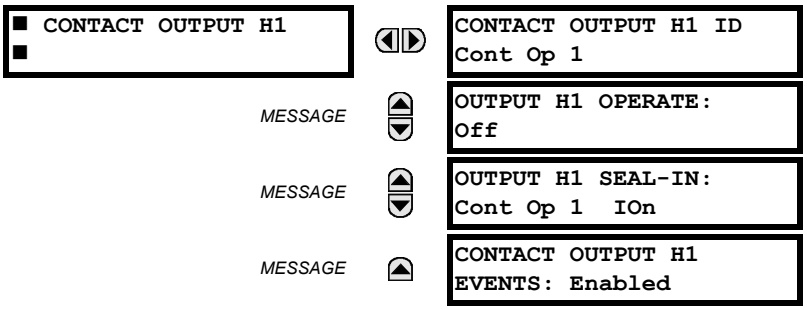
An ID may be assigned to each contact output. The signal that can OPERATE a contact output may be any FlexLogic™ operand (virtual output, element state, contact input, or virtual input). An additional FlexLogic™ operand may be used to SEAL-IN the relay. Any change of state of a contact output can be logged as an Event if programmed to do so.

EXAMPLE:

The trip circuit current is monitored by providing a current threshold detector in series with some Form-A contacts (see the TRIP CIRCUIT EXAMPLE in the DIGITAL ELEMENTS section). The monitor will set a flag (see Technical Specifications for Form-A). The name of the FlexLogic™ operand set by the monitor, consists of the output relay designation, followed by the name of the flag; e.g. 'Cont Op 1 IOn' or 'Cont Op 1 IOff'.

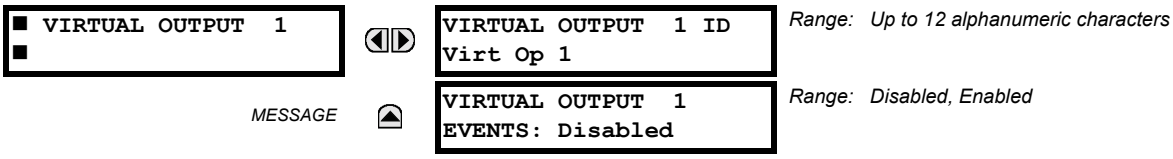
In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact used to interrupt current flow after the breaker has tripped, to prevent damage to the less robust initiating contact. This can be done by monitoring an auxiliary contact on the breaker which opens when the breaker has tripped, but 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 called "trip seal-in".

This can be realized in the UR using the 'Cont Op 1 IOn' FlexLogic™ operand to seal-in the Contact Output. For example,



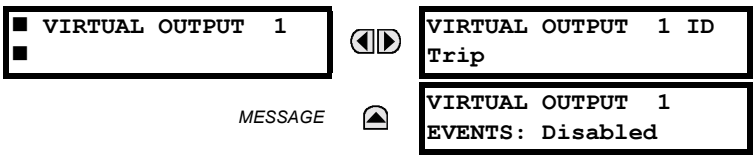
5.7.5 VIRTUAL OUTPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL OUTPUTS ⇨ VIRTUAL OUTPUT 1



There are 64 virtual outputs that may be assigned via FlexLogic™. If not assigned, the output will be forced to 'OFF' (Logic 0). An ID may be assigned to each virtual output. Virtual outputs are resolved in each pass through the evaluation of the FlexLogic™ equations. Any change of state of a virtual output can be logged as an event if programmed to do so.

For example, if Virtual Output 1 is the trip signal from FlexLogic™ and the trip relay is used to signal events, the settings would be programmed as follows:



5.7.6 REMOTE DEVICES

a) REMOTE INPUTS/OUTPUTS OVERVIEW

Remote inputs and outputs, which are a means of exchanging information regarding the state of digital points between remote devices, are provided in accordance with the Electric Power Research Institute's (EPRI) UCA2 "Generic Object Oriented Substation Event (GOOSE)" specifications.

NOTE

The UCA2 specification requires that communications between devices be implemented on Ethernet communications facilities. For UR relays, Ethernet communications is provided only on the type 9C and 9D versions of the CPU module.

The sharing of digital point state information between GOOSE equipped relays is essentially an extension to FlexLogic™ to allow distributed FlexLogic™ by making operands available to/from devices on a common communications network. In addition to digital point states, 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 from only those messages that have originated in selected devices.

GOOSE messages are designed to be short, high priority and with a high level of reliability. The GOOSE message structure contains space for 128 bit pairs representing digital point state information. The UCA specification provides 32 "DNA" bit pairs, which are status bits representing pre-defined events. All remaining bit pairs are "UserSt" bit pairs, which are status bits representing user-definable events. The UR implementation provides 32 of the 96 available UserSt bit pairs.

The UCA2 specification includes features that are used to cope with the loss of communication between transmitting and receiving devices. Each transmitting device will send a 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 to three times the programmed default time, which is 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 "hold" time for the device. The receiving relay sets a timer assigned to the originating device to the "hold" 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. This mechanism allows a receiving device to fail to detect a single transmission from a remote device which is sending messages at the slowest possible rate, as set by its "default update" timer, without reverting to use of the programmed default states. If a message is received from a remote device before the "hold" time 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 GOOSE facility provides for 64 remote inputs and 32 remote outputs.

The L90 provides an additional method of sharing digital point state information among different relays: Direct messages. Direct messages are only used between UR relays inter-connected via dedicated type 7X communications modules, usually between substations. The digital state data conveyed by direct messages are 'Direct Inputs' and 'Direct Outputs'.

b) DIRECT MESSAGES

Direct messages are only used between UR relays containing the 7X UR communications module (for example, the L90). These messages are transmitted every one-half of the power frequency cycle (10 ms for 50 Hz and 8.33 ms for 60 Hz) This facility is of particular value for pilot schemes and transfer tripping. Direct messaging is available on both single channel and dual channel communications modules. The inputs and outputs on communications channel No. 1 are numbered 1-1 through 1-8, and the inputs and outputs on communications channel No. 2 are numbered 2-1 through 2-8.

NOTE

Settings associated with Direct Messages are automatically presented in accordance with the number of channels provided in the communications module in a specific relay.

c) LOCAL DEVICES: DEVICE ID FOR TRANSMITTING GOOSE MESSAGES

In a UR relay, the device ID that identifies the originator of the message is programmed in the SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION ⇨⇩ RELAY NAME setting.

d) REMOTE DEVICES: DEVICE ID FOR RECEIVING GOOSE MESSAGES

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE DEVICES ⇨ REMOTE DEVICE 1(16)

```
■ REMOTE DEVICE  1
■
```

⇔

```
REMOTE DEVICE  1 ID:
Remote Device 1
```

Range: up to 20 alphanumeric characters

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 (bottom row) the exact identification (ID) assigned to those devices.

5.7.7 REMOTE INPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE INPUTS ⇨ REMOTE INPUT 1(32)

```
■ REMOTE INPUT 1
■
```

⇔

```
REMOTE IN  1 DEVICE:
Remote Device  1
```

Range: 1 to 16 inclusive

MESSAGE ⇕

```
REMOTE IN  1 BIT
PAIR: None
```

Range: None, DNA-1 to DNA-32, UserSt-1 to UserSt-32

MESSAGE ⇕

```
REMOTE IN  1 DEFAULT
STATE: Off
```

Range: On, Off

MESSAGE ⇧

```
REMOTE IN  1
EVENTS: Disabled
```

Range: Disabled, Enabled

Remote Inputs which create FlexLogic™ operands at the receiving relay, are extracted from 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 UCA2 specifications and is presented in the UCA2 DNA ASSIGNMENTS table in the Remote Outputs section. The function of UserSt inputs is defined by the user selection of the FlexLogic™ operand whose state is represented in the GOOSE message. A user must program a DNA point from the appropriate operand.

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 shown above.

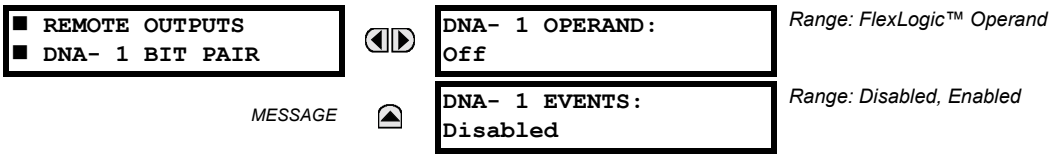
REMOTE IN 1 DEVICE selects the number (1 to 16) of the Remote Device which originates the required signal, as previously assigned to the remote device via the setting **REMOTE DEVICE NN ID** (see REMOTE DEVICES section). **REMOTE IN 1 BIT PAIR** selects the specific bits of the GOOSE message required. **REMOTE IN 1 DEFAULT STATE** 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.

NOTE

For more information on GOOSE specifications, see REMOTE INPUTS/OUTPUTS OVERVIEW in the REMOTE DEVICES section.

5.7.8 REMOTE OUTPUTS: DNA BIT PAIRS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE OUTPUTS DNA BIT PAIRS ⇨ REMOTE OUPUTS DNA- 1 BIT PAIR



Remote Outputs (1 to 32) are FlexLogic™ operands inserted into 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.

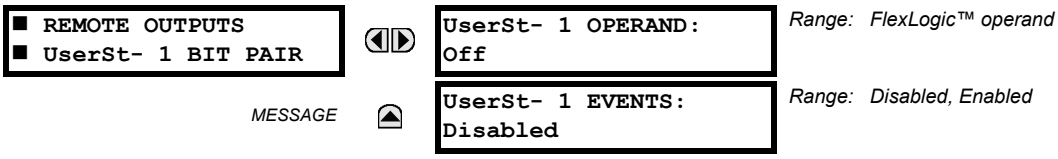
Table 5–26: UCA DNA2 ASSIGNMENTS

DNA	DEFINITION	INTENDED FUNCTION	LOGIC 0	LOGIC 1
1	OperDev		Trip	Close
2	Lock Out		LockoutOff	LockoutOn
3	Initiate Reclosing	Initiate remote reclose sequence	InitRecloseOff	InitRecloseOn
4	Block Reclosing	Prevent/cancel remote reclose sequence	BlockOff	BlockOn
5	Breaker Failure Initiate	Initiate remote breaker failure scheme	BFIOff	BFIOn
6	Send Transfer Trip	Initiate remote trip operation	TxXfrTripOff	TxXfrTripOn
7	Receive Transfer Trip	Report receipt of remote transfer trip command	RxXfrTripOff	RxXfrTripOn
8	Send Perm	Report permissive affirmative	TxPermOff	TxPermOn
9	Receive Perm	Report receipt of permissive affirmative	RxPermOff	RxPermOn
10	Stop Perm	Override permissive affirmative	StopPermOff	StopPermOn
11	Send Block	Report block affirmative	TxBlockOff	TxBlockOn
12	Receive Block	Report receipt of block affirmative	RxBlockOff	RxBlockOn
13	Stop Block	Override block affirmative	StopBlockOff	StopBlockOn
14	BkrDS	Report breaker disconnect 3-phase state	Open	Closed
15	BkrPhsADS	Report breaker disconnect phase A state	Open	Closed
16	BkrPhsBDS	Report breaker disconnect phase B state	Open	Closed
17	BkrPhsCDS	Report breaker disconnect phase C state	Open	Closed
18	DiscSwDS		Open	Closed
19	Interlock DS		DSLockOff	DSLockOn
20	LineEndOpen	Report line open at local end	Open	Closed
21	Status	Report operating status of local GOOSE device	Offline	Available
22	Event		EventOff	EventOn
23	Fault Present		FaultOff	FaultOn
24	Sustained Arc	Report sustained arc	SustArcOff	SustArcOn
25	Downed Conductor	Report downed conductor	DownedOff	DownedOn
26	Sync Closing		SyncClsOff	SyncClsOn
27	Mode	Report mode status of local GOOSE device	Normal	Test
28→32	Reserved			

NOTE **For more information on GOOSE specifications, see REMOTE INPUTS/OUTPUTS OVERVIEW in the REMOTE DEVICES section.**

5.7.9 REMOTE OUTPUTS: UserSt BIT PAIRS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE OUTPUTS UserSt BIT PAIRS ⇨ REMOTE OUTPUTS UserSt- 1 BIT PAIR



Remote Outputs 1 to 32 originate as 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.

The following setting represents the time between sending GOOSE messages when there has been no change of state of any selected digital point. This setting is located in the PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ UCA/MMS PROTOCOL settings menu.

NOTE **For more information on GOOSE specifications, see REMOTE INPUTS/OUTPUTS – OVERVIEW in the REMOTE DEVICES section.**

5.7.10 DIRECT INPUTS/OUTPUTS

5

The relay provides eight Direct Inputs that are conveyed on communications channel No. 1, numbered 1-1 through 1-8 and eight Direct Inputs that are conveyed on communications channel No. 2, numbered 2-1 through 2-8. A user must program the remote relay connected to channels 1 and 2 of the local relay by assigning the desired FlexLogic™ operand to be sent via the selected communications channel.

This relay allows the user to create distributed protection and control schemes via dedicated communications channels. Some examples are directional comparison pilot schemes and transfer tripping.

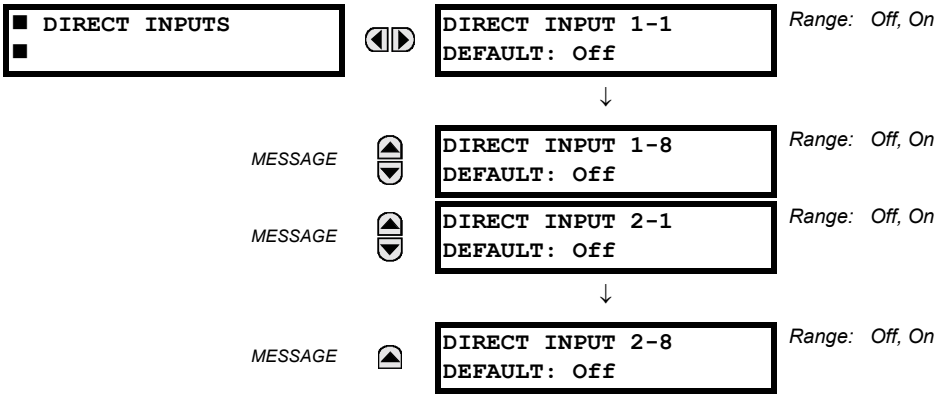
It should be noted that failures of communications channels will affect Direct I/O functionality. The 87L function must be enabled to utilize the direct inputs.

Direct I/O FlexLogic™ operands to be used at the local relay are assigned as follows:

- Direct I/O 1-1 through Direct I/O 1-8 for communications channel 1
- Direct I/O 2-1 through Direct I/O 2-8 for communications channel 2

a) DIRECT INPUTS

PATH: SETTINGS ⇩ INPUTS/OUTPUTS ⇨⇩ DIRECT ⇨ DIRECT INPUTS

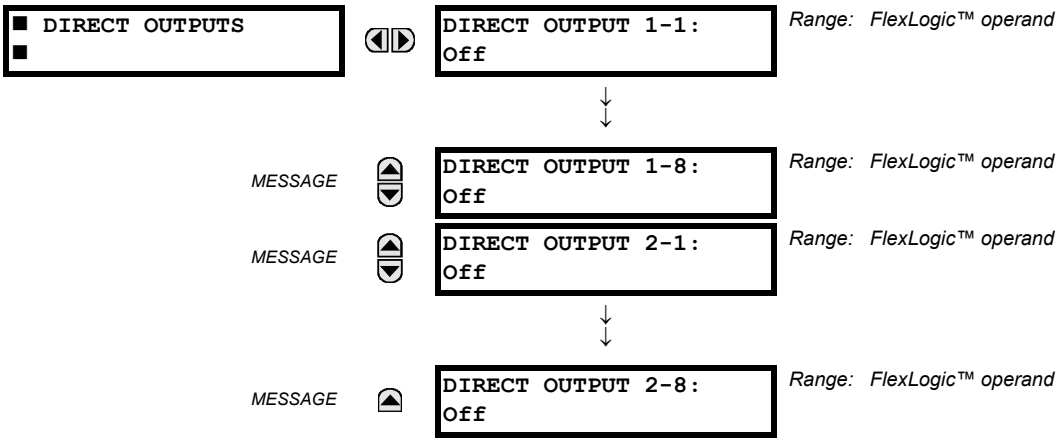


The **DIRECT INPUT 1-1 DEFAULT** setting selects the logic state of this particular bit used for this point if the local relay has just completed startup or the local communications channel is declared to have failed.

Setting **DIRECT INPUT 1-X DEFAULT** to "On" means that the corresponding local FlexLogic™ operand (DIRECT I/P 1-x) will have logic state "1" on relay startup or during communications channel failure. When the channel is restored, the operand logic state reflects the actual state of the corresponding remote direct output. The Direct Input/Ouput logic is shown in the DIRECT INPUTS/OUTPUTS LOGIC diagram.

b) DIRECT OUTPUTS

PATH: SETTINGS ⇩ INPUTS/OUTPUTS ⇨⇩ DIRECT ⇨⇩ DIRECT OUTPUTS



The relay provides eight Direct Outputs that are conveyed on communications channel No. 1, numbered 1-1 through 1-8 and eight Direct Outputs that are conveyed on communications channel No. 2, numbered 2-1 through 2-8. 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 function (as selected by the user) to be transmitted.

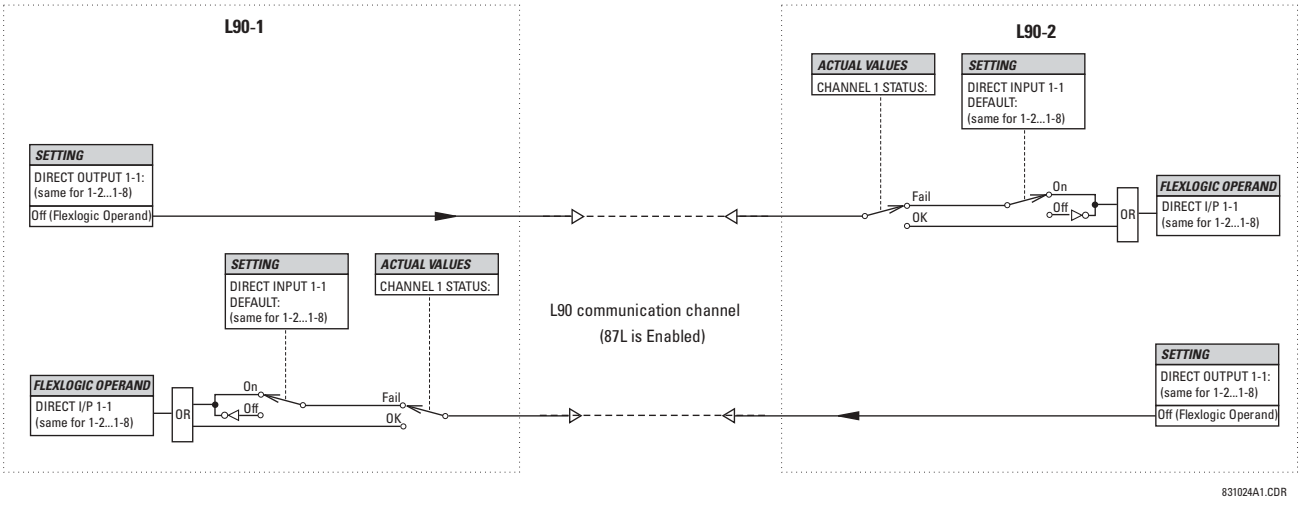


Figure 5–81: DIRECT INPUTS/OUTPUTS LOGIC

5.7.11 RESETTING

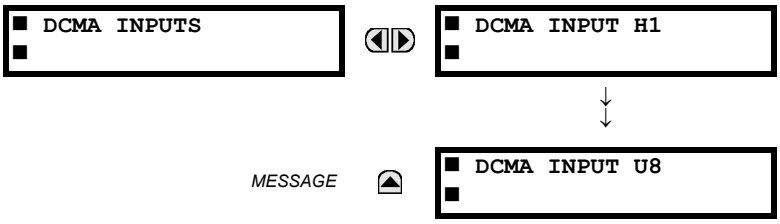
PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ RESETTING

Range: FlexLogic™ operand

Some events can be programmed to latch the faceplate LED event indicators and the target message on the display. Once set, the latching mechanism will hold all of the latched indicators or messages in the set state after the initiating condition has cleared until a RESET command is received to return these latches (not including FlexLogic™ latches) to the reset state. The RESET command can be sent from the faceplate RESET button, a remote device via a communications channel, or any programmed operand.

When the RESET command is received by the relay, two FlexLogic™ operands are created. These operands, which are stored as events, reset the latches if the initiating condition has cleared. The three sources of RESET commands each create the FlexLogic™ operand "RESET OP". Each individual source of a RESET command also creates its individual operand RESET OP (PUSHBUTTON), RESET OP (COMMS) or RESET OP (OPERAND) to identify the source of the command. The setting shown above selects the operand that will create the RESET OP (OPERAND) operand.

PATH: SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ DCMA INPUTS



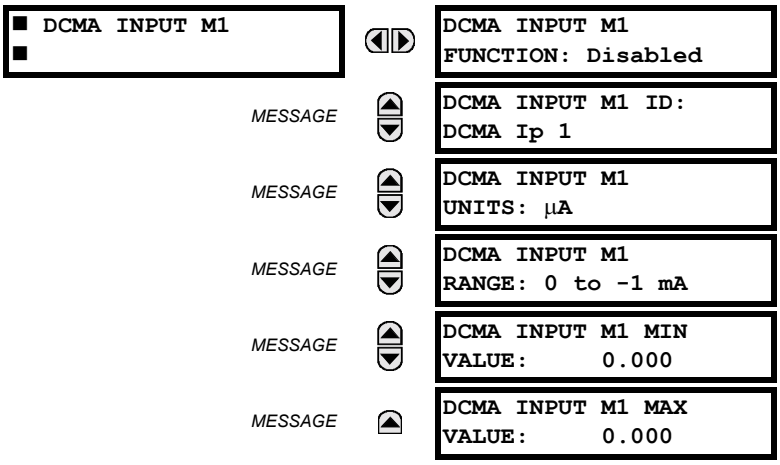
Hardware and software is provided to receive signals from external transducers and convert these signals into a digital format for use as required. The relay will accept inputs in the range of –1 to +20 mA DC, suitable for use with most common transducer output ranges; all inputs are assumed to be linear over the complete range. Specific hardware details are contained in the HARDWARE chapter.

Before the DCMA input signal can be used, the value of the signal measured by the relay must be converted to the range and quantity of the external transducer primary input parameter, such as DC voltage or temperature. The relay simplifies this process by internally scaling the output from the external transducer and displaying the actual primary parameter.

DCMA input channels are arranged in a manner similar to CT and VT channels. The user configures individual channels with the settings shown here.

The channels are arranged in sub-modules of two channels, numbered from 1 through 8 from top to bottom. On power-up, the relay will automatically generate configuration settings for every channel, based on the order code, in the same general manner that is used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number. The relay generates an actual value for each available input channel.

Settings are automatically generated for every channel available in the specific relay as shown below for the first channel of a type 5F transducer module installed in slot M.

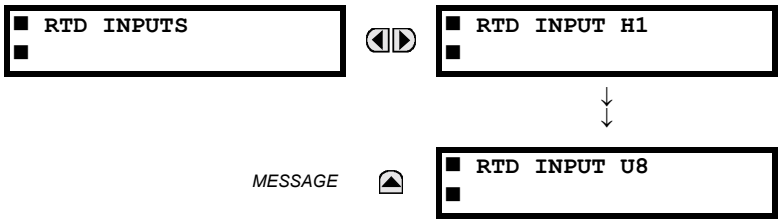


The function of the channel may be either "Enabled" or "Disabled." If Disabled, there will not be an actual value created for the channel. An alphanumeric "ID" is assigned to the channel - this ID will be included in the display of the channel actual value, along with the programmed "UNITS" associated with the parameter measured by the transducer, such as Volt, °C, MegaWatts, etc. This ID is also used to reference the channel as the input parameter to features designed to measure this type of parameter. The RANGE setting is used to select the specific mA DC range of the transducer connected to the input channel.

The MIN VALUE and MAX VALUE settings are used to program the span of the transducer in primary units. For example, a temperature transducer might have a span from 0 to 250°C; in this case the MIN value would be 0 and the MAX value 250. Another example would be a Watt transducer with a span from –20 to +180 MW; in this case the MIN value would be –20 and the MAX value 180. Intermediate values between the MIN and MAX are scaled linearly.

5.8.2 RTD INPUTS

PATH: SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ RTD INPUTS

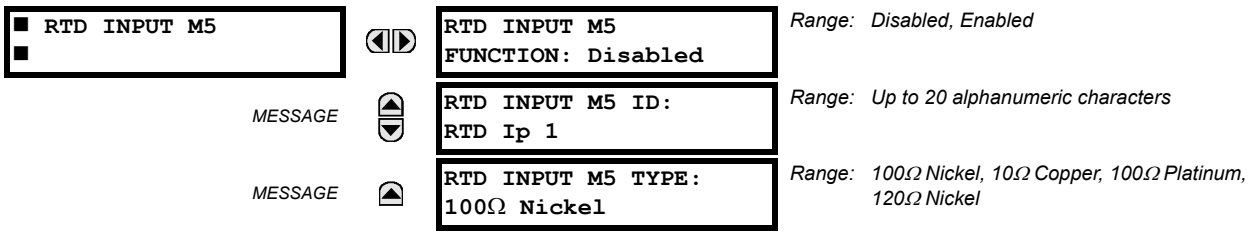


Hardware and software is provided to receive signals from external Resistance Temperature Detectors and convert these signals into a digital format for use as required. These channels are intended to be connected to any of the RTD types in common use. Specific hardware details are contained in the HARDWARE chapter.

RTD input channels are arranged in a manner similar to CT and VT channels. The user configures individual channels with the settings shown here.

The channels are arranged in sub-modules of two channels, numbered from 1 through 8 from top to bottom. On power-up, the relay will automatically generate configuration settings for every channel, based on the order code, in the same general manner that is used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number. The relay generates an actual value for each available input channel.

Settings are automatically generated for every channel available in the specific relay as shown below for the first channel of a type 5C transducer module installed in slot M.



The function of the channel may be either "Enabled" or "Disabled." If Disabled, there will not be an actual value created for the channel. An alphanumeric "ID" is assigned to the channel - this ID will be included in the display of the channel actual value. This ID is also used to reference the channel as the input parameter to features designed to measure this type of parameter. Selecting the type of RTD connected to the channel configures the channel.

5.9.1 TEST MODE

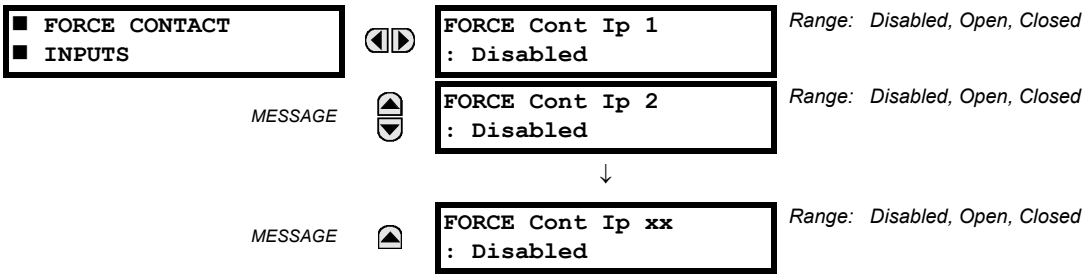
PATH: SETTINGS ⇨⇩ TESTING ⇨ TEST MODE

Range: Disabled, Enabled

The relay provides test settings to verify that the relay is functional using simulated conditions to test all contact inputs and outputs. While the relay is in Test Mode (**TEST MODE FUNCTION:** "Enabled"), the feature being tested overrides normal functioning of the relay. During this time the Test Mode LED will remain on. Once out of Test Mode (**TEST MODE FUNCTION:** "Disabled"), the normal functioning of the relay will be restored.

5.9.2 FORCE CONTACT INPUTS

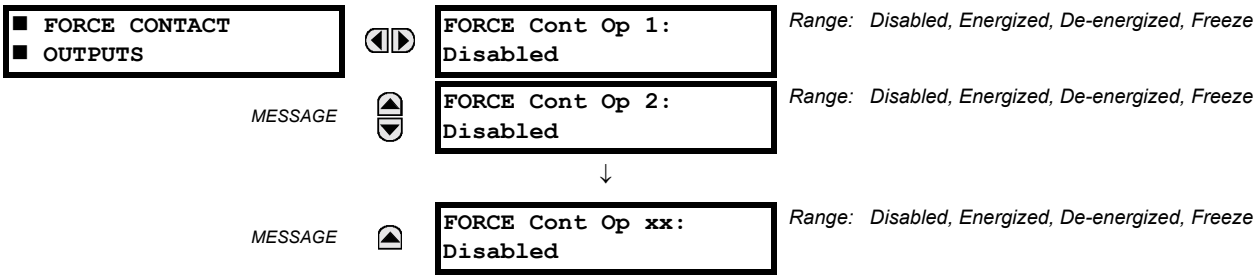
PATH: SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT INPUTS



The Force Contact Inputs feature provides a method of performing checks on the function of all contact inputs. Once enabled, the relay is placed into Test Mode, allowing this feature to override the normal function of contact inputs. The Test Mode LED will be ON indicating that the relay is in test mode. The state of each contact input may be programmed as Disabled, Open, or Closed. All contact input operations return to normal when all settings for this feature are disabled.

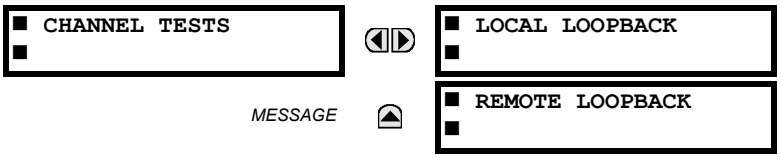
5.9.3 FORCE CONTACT OUTPUTS

PATH: SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT OUTPUTS

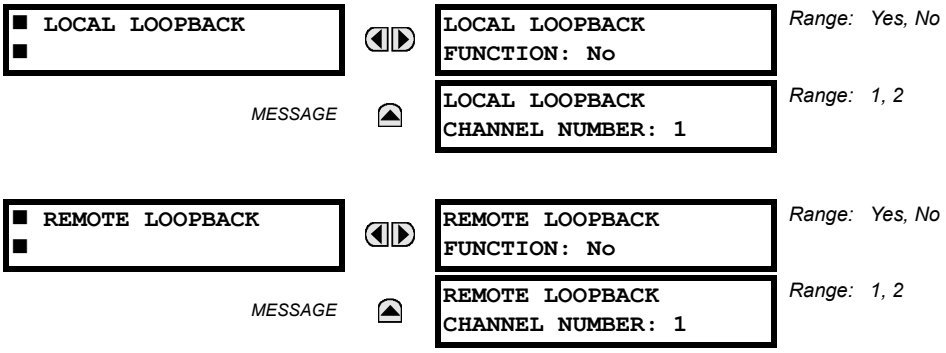


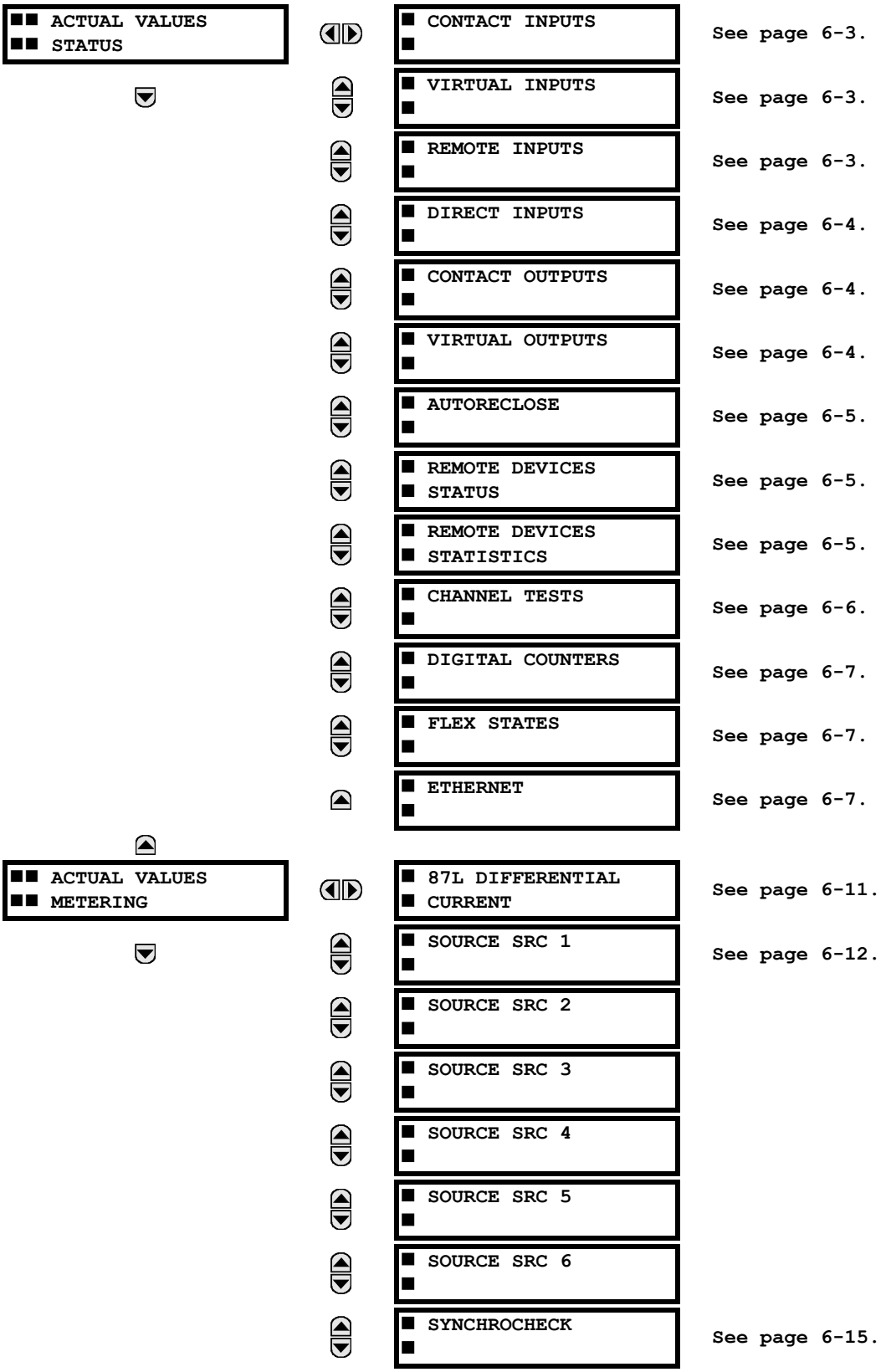
The Force Contact Output feature provides a method of performing checks on all contact outputs. Once enabled, the relay is placed into Test Mode, allowing this feature to override the normal contact outputs functions. The TEST MODE LED will be ON. The state of each contact output may be programmed as Disabled, Energized, De-energized, or Freeze. The Freeze option maintains the output contact in the state at which it was frozen. All contact output operations return to normal when all the settings for this feature are disabled.

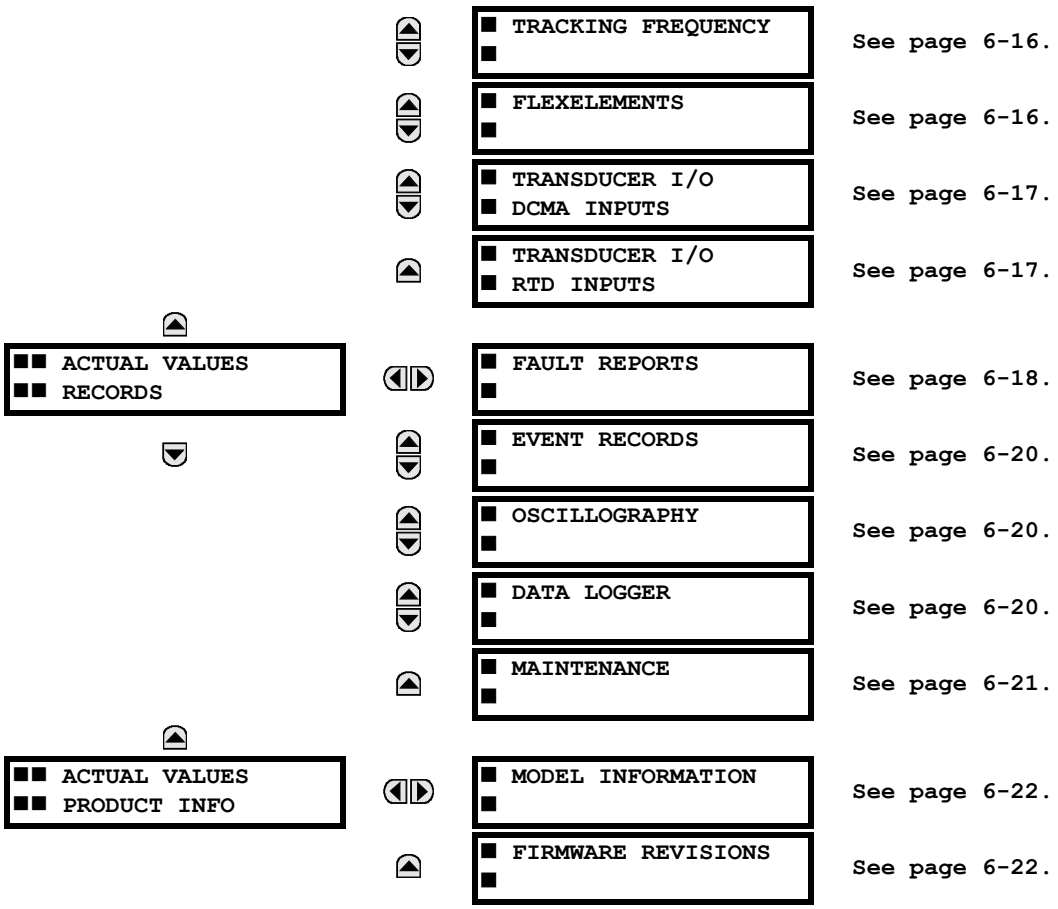
PATH: SETTINGS ⇩ TESTING ⇨⇩ CHANNEL TESTS



This function performs checking of the communications established by both relays.




ACTUAL VALUES
STATUS
CONTACT INPUTS
See page 6-3.
VIRTUAL INPUTS
See page 6-3.
REMOTE INPUTS
See page 6-3.
DIRECT INPUTS
See page 6-4.
CONTACT OUTPUTS
See page 6-4.
VIRTUAL OUTPUTS
See page 6-4.
AUTORECLOSE
See page 6-5.
REMOTE DEVICES STATUS
See page 6-5.
REMOTE DEVICES STATISTICS
See page 6-5.
CHANNEL TESTS
See page 6-6.
DIGITAL COUNTERS
See page 6-7.
FLEX STATES
See page 6-7.
ETHERNET
See page 6-7.
ACTUAL VALUES
METERING
87L DIFFERENTIAL CURRENT
See page 6-11.
SOURCE SRC 1
See page 6-12.
SOURCE SRC 2
SOURCE SRC 3
SOURCE SRC 4
SOURCE SRC 5
SOURCE SRC 6
SYNCHROCHECK
See page 6-15.

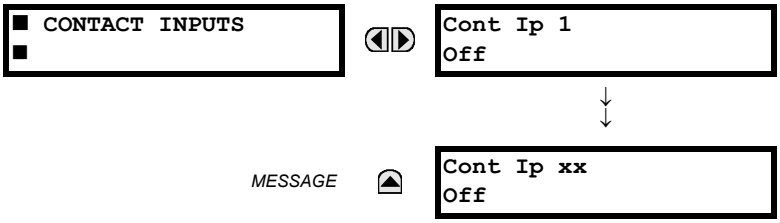

ACTUAL VALUES
RECORDS
TRACKING FREQUENCY
See page 6-16.
FLEXELEMENTS
See page 6-16.
TRANSDUCER I/O
DCMA INPUTS
See page 6-17.
TRANSDUCER I/O
RTD INPUTS
See page 6-17.
FAULT REPORTS
See page 6-18.
EVENT RECORDS
See page 6-20.
OSCILLOGRAPHY
See page 6-20.
DATA LOGGER
See page 6-20.
MAINTENANCE
See page 6-21.
ACTUAL VALUES
PRODUCT INFO
MODEL INFORMATION
See page 6-22.
FIRMWARE REVISIONS
See page 6-22.

NOTE

For status reporting, 'On' represents Logic 1 and 'Off' represents Logic 0.

6.2.1 CONTACT INPUTS

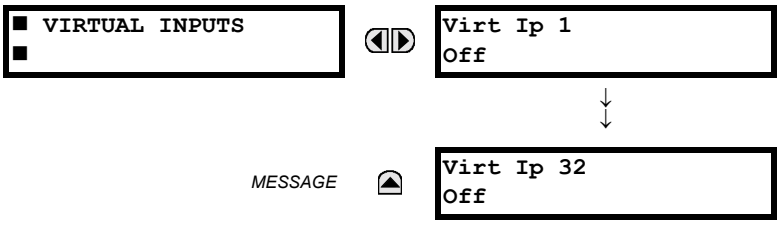
PATH: ACTUAL VALUES ⇨ STATUS ⇨ CONTACT INPUTS



The present status of the contact inputs is shown here. The first line of a message display indicates the ID of the contact input. For example, 'Cont Ip 1' refers to the contact input in terms of the default name-array index. The second line of the display indicates the logic state of the contact input.

6.2.2 VIRTUAL INPUTS

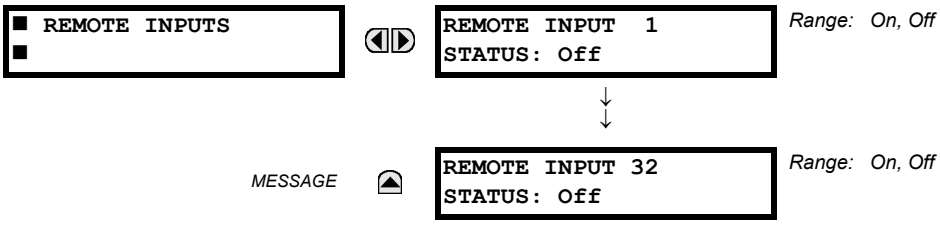
PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ VIRTUAL INPUTS



The present status of the 32 virtual inputs is shown here. The first line of a message display indicates the ID of the virtual input. For example, 'Virt Ip 1' refers to the virtual input in terms of the default name-array index. The second line of the display indicates the logic state of the virtual input.

6.2.3 REMOTE INPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE INPUTS

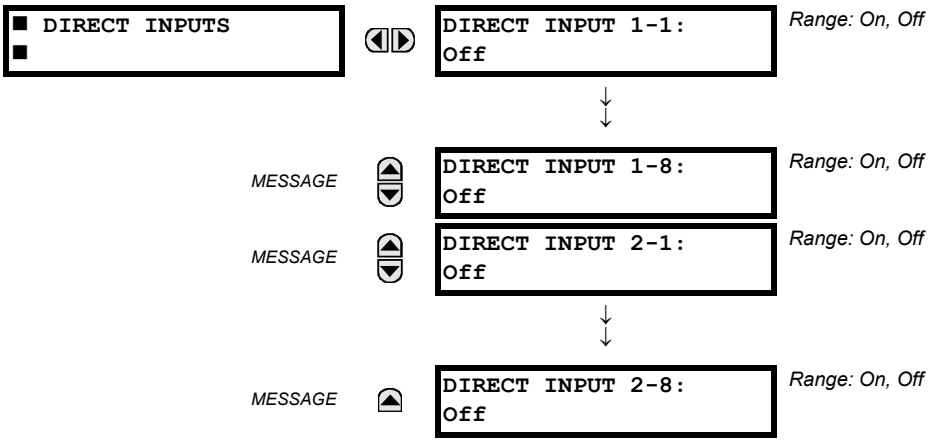


The present state of the 32 remote inputs is shown here.

The state displayed will be that of the remote point unless the remote device has been established to be "Offline" in which case the value shown is the programmed default state for the remote input.

6.2.4 DIRECT INPUTS

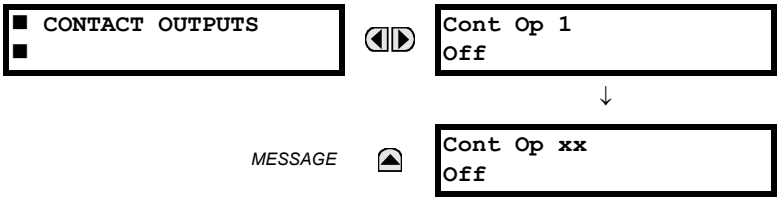
PATH: ACTUAL VALUES ⇩ STATUS ⇨⇩ DIRECT INPUTS



The present state of the Direct Inputs from communications channels 1 and 2 are shown here. The state displayed will be that of the remote point unless channel 1 or 2 has been declared to have "failed", in which case the value shown is the programmed default state defined in the SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ DIRECT ⇨ DIRECT INPUTS menu.

6.2.5 CONTACT OUTPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ CONTACT OUTPUTS



The present state of the contact outputs is shown here.

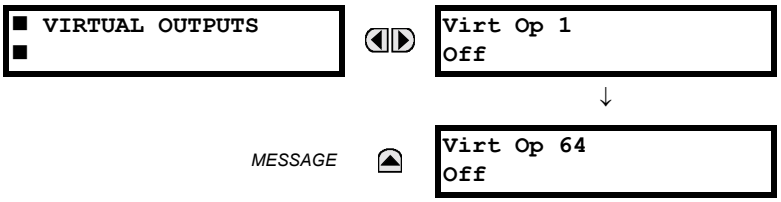
The first line of a message display indicates the ID of the contact output. For example, 'Cont Op 1' refers to the contact output in terms of the default name-array index. The second line of the display indicates the logic state of the contact output.

NOTE

For Form-A outputs, the state of the voltage(V) and/or current(I) detectors will show as: Off, VOff, IOff, On, VOn, and/or IOn. For Form-C outputs, the state will show as Off or On.

6.2.6 VIRTUAL OUTPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ VIRTUAL OUTPUTS



The present state of up to 64 virtual outputs is shown here. The first line of a message display indicates the ID of the virtual output. For example, 'Virt Op 1' refers to the virtual output in terms of the default name-array index. The second line of the display indicates the logic state of the virtual output, as calculated by the FlexLogic™ equation for that output.

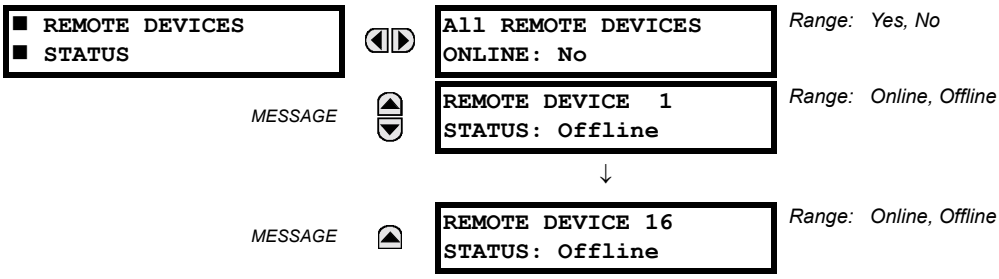
6.2.7 AUTORECLOSE

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ AUTORECLOSE ⇨ AUTORECLOSE 1

The automatic reclosure shot count is shown here.

6.2.8 REMOTE DEVICES STATUS

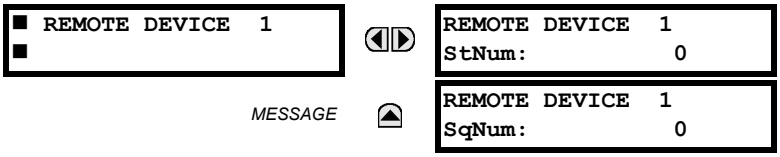
PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE DEVICES STATUS



The present state of up to 16 programmed Remote Devices is shown here. The **ALL REMOTE DEVICES ONLINE** message indicates whether or not all programmed Remote Devices are online. If the corresponding state is "No", then at least one required Remote Device is not online.

6.2.9 REMOTE DEVICES STATISTICS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE DEVICES STATISTICS ⇨ REMOTE DEVICE 1(16)

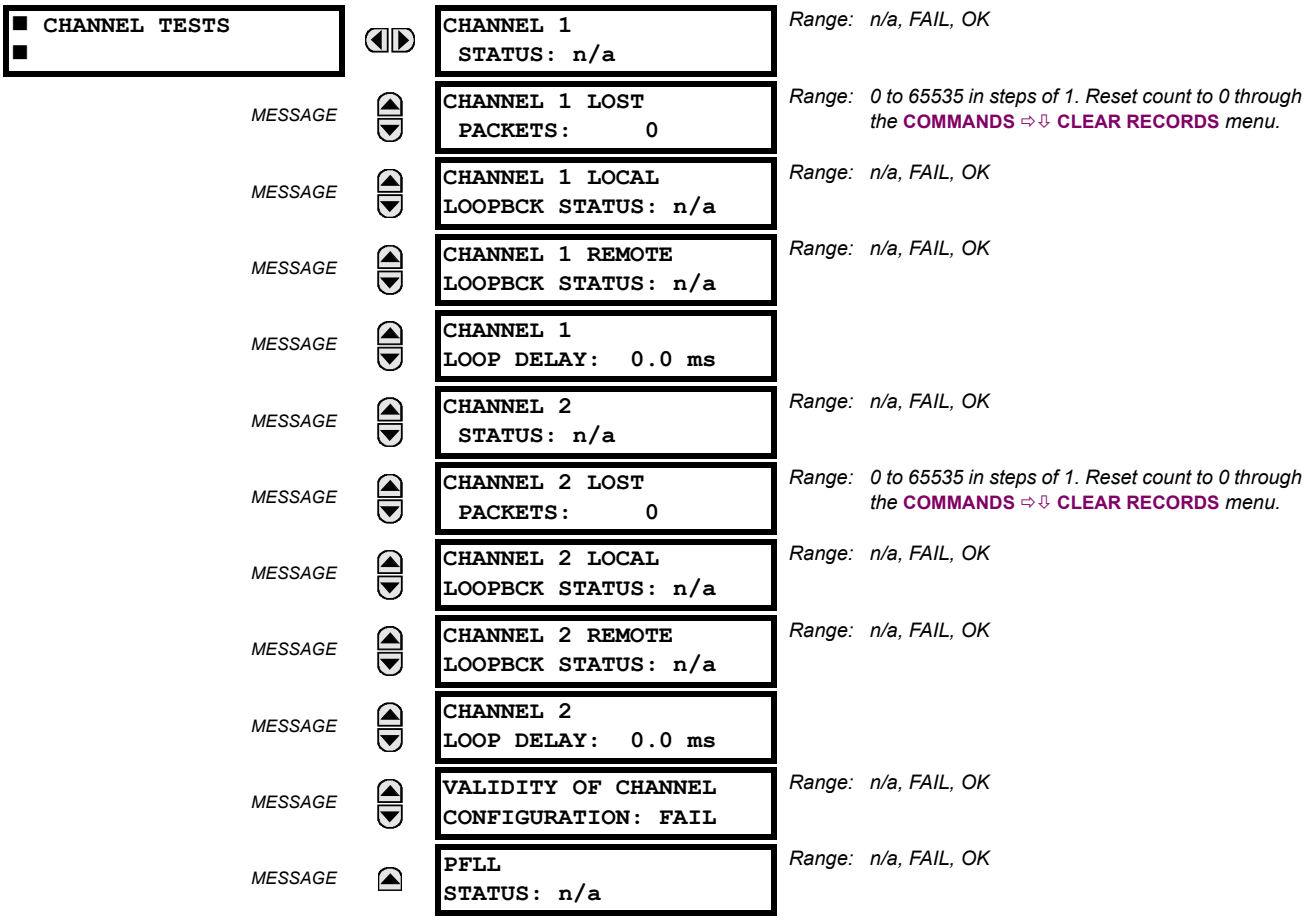


Statistical data (2 types) for up to 16 programmed Remote Devices is shown here.

- The **StNum** number is obtained from the indicated Remote Device and is incremented whenever a change of state of at least one DNA or UserSt bit occurs.
- The **SqNum** number is obtained from the indicated Remote Device and is incremented whenever a GOOSE message is sent. This number will rollover to zero when a count of 4,294,967,295 is incremented.

6.2.10 CHANNEL TESTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS



Status information for 2 channels is shown here. The following is a brief description of each actual value:

CHANNEL 1/2 STATUS:

This represents the receiver status of each channel. If the value is “OK”, the 87L Differential element is enabled and data is being received from the remote terminal; If the value is “FAIL”, the 87L element is enabled and data is not being received from the remote terminal. If “n/a”, the 87L element is disabled.

CHANNEL 1/2 LOST PACKETS:

Current, timing and control data is transmitted to the remote terminals in data packets at a rate of 2 packets/cycle. The number of lost packets represents data packets lost in transmission; this count can be reset through the COMMANDS ⇨⇩ CLEAR RECORDS menu.

CHANNEL 1/2 LOCAL LOOPBACK STATUS:

The result of the local loopback test is displayed here.

CHANNEL 1/2 REMOTE LOOPBACK STATUS:

The result of the remote loopback test is displayed here.

CHANNEL 1/2 LOOP DELAY:

Displays the round trip channel delay (including loopback processing time of the remote relay) computed during a remote loopback test under normal relay operation, in milliseconds (ms).

VALIDITY OF CHANNEL CONFIGURATION:

The current state of the communications channel identification check, and hence validity, is displayed here. If a remote relay ID number does not match the programmed number at the local relay, the "FAIL" value will be displayed. The "n/a" value appears if the Local relay ID is set to a default value of "0" or if the 87L element is disabled. Refer to **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ L90 POWER SYSTEM** section for more information

PFLL STATUS:

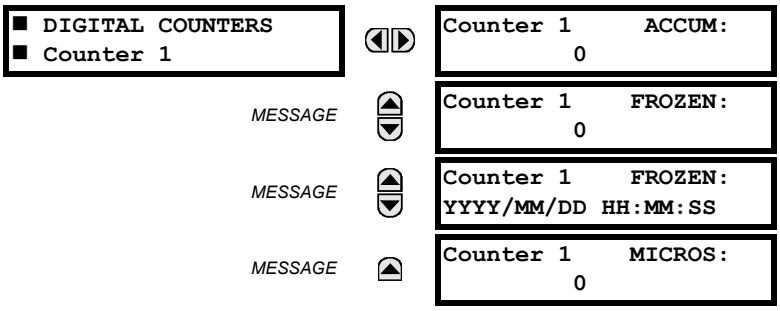
This value represents the status of the Phase & Frequency Locked Loop Filter which uses timing information from local & remote terminals to synchronize the clocks of all terminals. If **PFLL STATUS** is “OK”, the clocks of all terminals are synchronized and 87L protection is enabled. If it is “FAIL”, the clocks of all terminals are not synchronized and 87L protection is disabled. If “n/a”, then PFLL is disabled.

NOTE

At startup, the clocks of all terminals are not synchronized and the PFLL status displayed is FAIL. It takes approximately 1 to 2 minutes after startup for the value displayed to change from FAIL to OK.

6.2.11 DIGITAL COUNTERS

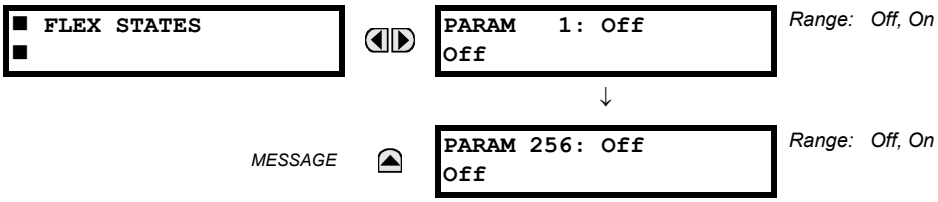
PATH: ACTUAL VALUES ⇨ DIGITAL COUNTERS ⇨⇩ DIGITAL COUNTERS ⇨ DIGITAL COUNTERS Counter 1(8)



The present status of the 8 digital counters is shown here. The status of each counter, with the user-defined counter name, includes the accumulated and frozen counts (the count units label will also appear). Also included, is the date/time stamp for the frozen count. The **Counter n MICROS** value refers to the microsecond portion of the time stamp.

6.2.12 FLEX STATES

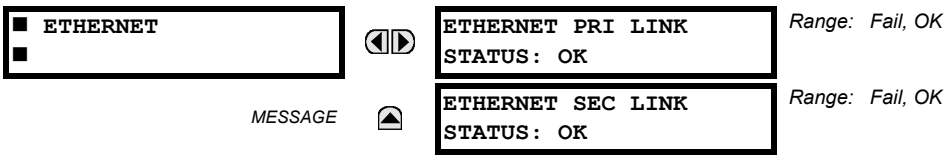
PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ FLEX STATES



There are 256 FlexState bits available. The second line value indicates the state of the given FlexState bit.

6.2.13 ETHERNET

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ ETHERNET



a) UR CONVENTION FOR MEASURING POWER AND ENERGY

The following figure illustrates the conventions established for use in UR relays.

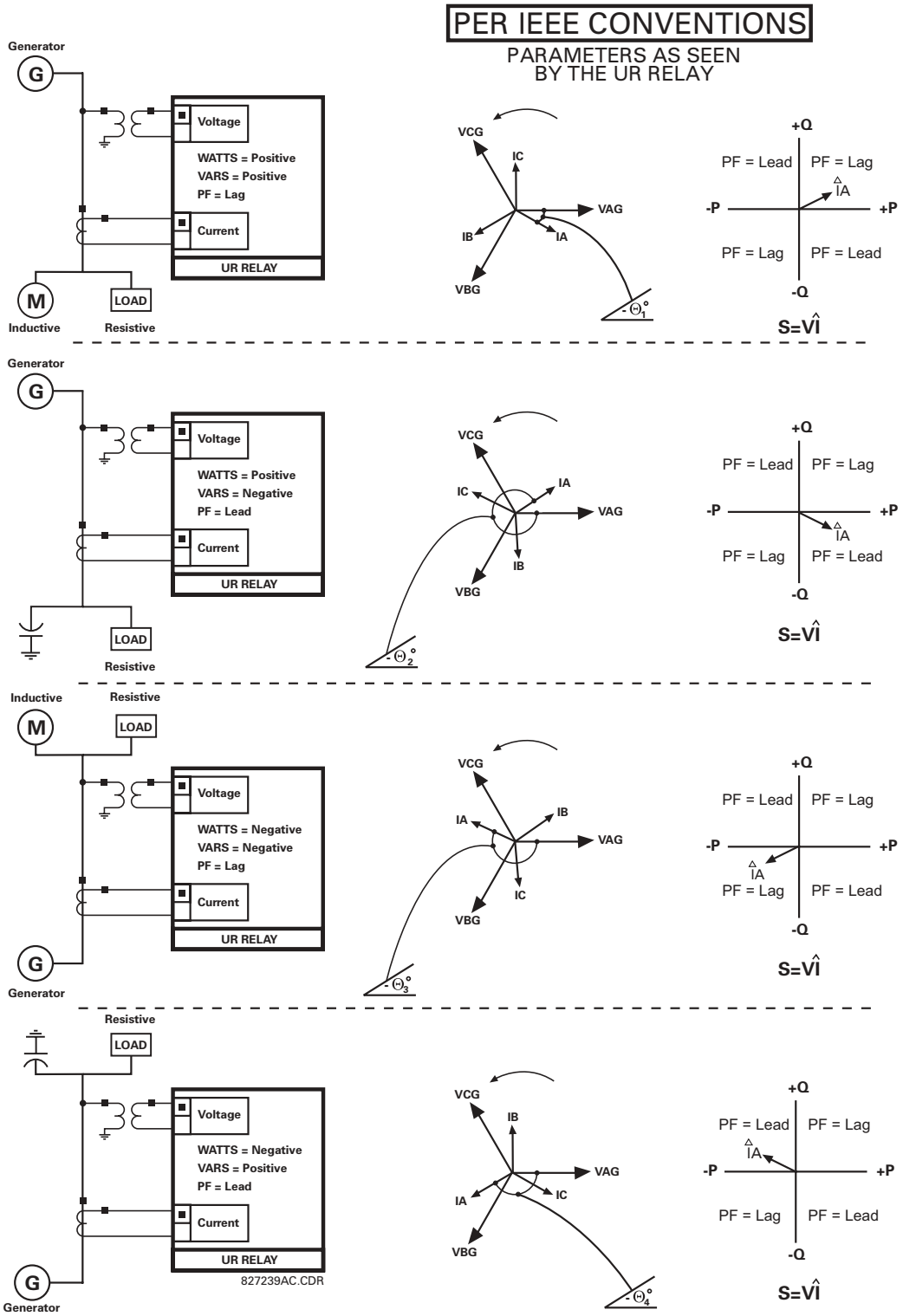


Figure 6–1: FLOW DIRECTION OF SIGNED VALUES FOR WATTS AND VARS

b) UR CONVENTION FOR MEASURING PHASE ANGLES

All phasors calculated by UR relays and used for protection, control and metering functions are rotating phasors that maintain the correct phase angle relationships with each other at all times.

For display and oscillography purposes, all phasor angles in a given relay are referred to an AC input channel pre-selected by the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM ⇨⇩ FREQUENCY AND PHASE REFERENCE** setting. This setting defines a particular Source to be used as the reference.

The relay will first determine if any "Phase VT" bank is indicated in the Source. If it is, voltage channel VA of that bank is used as the angle reference. Otherwise, the relay determines if any "Aux VT" bank is indicated; if it is, the auxiliary voltage channel of that bank is used as the angle reference. If neither of the two conditions is satisfied, then two more steps of this hierarchical procedure to determine the reference signal include "Phase CT" bank and "Ground CT" bank.

If the AC signal pre-selected by the relay upon configuration is not measurable, the phase angles are not referenced. The phase angles are assigned as positive in the leading direction, and are presented as negative in the lagging direction, to more closely align with power system metering conventions. This is illustrated below.

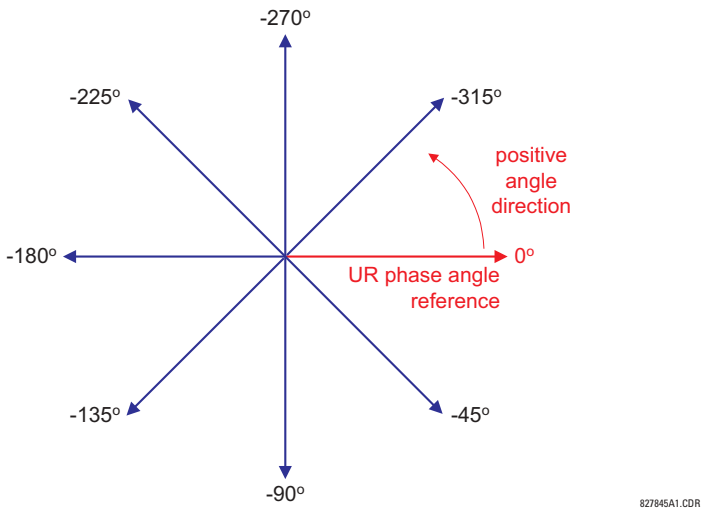


Figure 6–2: UR PHASE ANGLE MEASUREMENT CONVENTION

c) UR CONVENTION FOR SYMMETRICAL COMPONENTS

UR relays calculate voltage symmetrical components for the power system phase A line-to-neutral voltage, and symmetrical components of the currents for the power system phase A current. Owing to the above definition, phase angle relations between the symmetrical currents and voltages stay the same irrespective of the connection of instrument transformers. This is important for setting directional protection elements that use symmetrical voltages.

For display and oscillography purposes the phase angles of symmetrical components are referenced to a common reference as described in the previous sub-section.

WYE-Connected Instrument Transformers:

- ABC phase rotation:

$$V\_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$

$$V\_1 = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})$$

$$V\_2 = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})$$

- ACB phase rotation:

$$V\_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$

$$V\_1 = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})$$

$$V\_2 = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})$$

The above equations apply to currents as well.

DELTA-Connected Instrument Transformers:

- ABC phase rotation:

$$V\_0 = \text{N/A}$$

$$V\_1 = \frac{1\angle -30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$

$$V\_2 = \frac{1\angle 30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$

- ACB phase rotation:

$$V\_0 = \text{N/A}$$

$$V\_1 = \frac{1\angle 30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$

$$V\_2 = \frac{1\angle -30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$

The zero-sequence voltage is not measurable under the DELTA connection of instrument transformers and is defaulted to zero. The table below shows an example of symmetrical components calculations for the ABC phase rotation.

Table 6–1: CALCULATING VOLTAGE SYMMETRICAL COMPONENTS EXAMPLE

SYSTEM VOLTAGES, SEC. V *						VT CONN.	UR INPUTS, SEC. V			SYMM. COMP, SEC. V		
V_{AG}	V_{BG}	V_{CG}	V_{AB}	V_{BC}	V_{CA}		F5AC	F6AC	F7AC	V_0	V_1	V_2
13.9 ∠0°	76.2 ∠–125°	79.7 ∠–250°	84.9 ∠–313°	138.3 ∠–97°	85.4 ∠–241°	WYE	13.9 ∠0°	76.2 ∠–125°	79.7 ∠–250°	19.5 ∠–192°	56.5 ∠–7°	23.3 ∠–187°
UNKNOWN (only V_1 and V_2 can be determined)			84.9 ∠0°	138.3 ∠–144°	85.4 ∠–288°	DELTA	84.9 ∠0°	138.3 ∠–144°	85.4 ∠–288°	N/A	56.5 ∠–54°	23.3 ∠–234°

* The power system voltages are phase-referenced – for simplicity – to *VAG* and *VAB*, respectively. This, however, is a relative matter. It is important to remember that the UR displays are always referenced as specified under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM ⇨⇩ FREQUENCY AND PHASE REFERENCE**.

The example above is illustrated in the following figure.

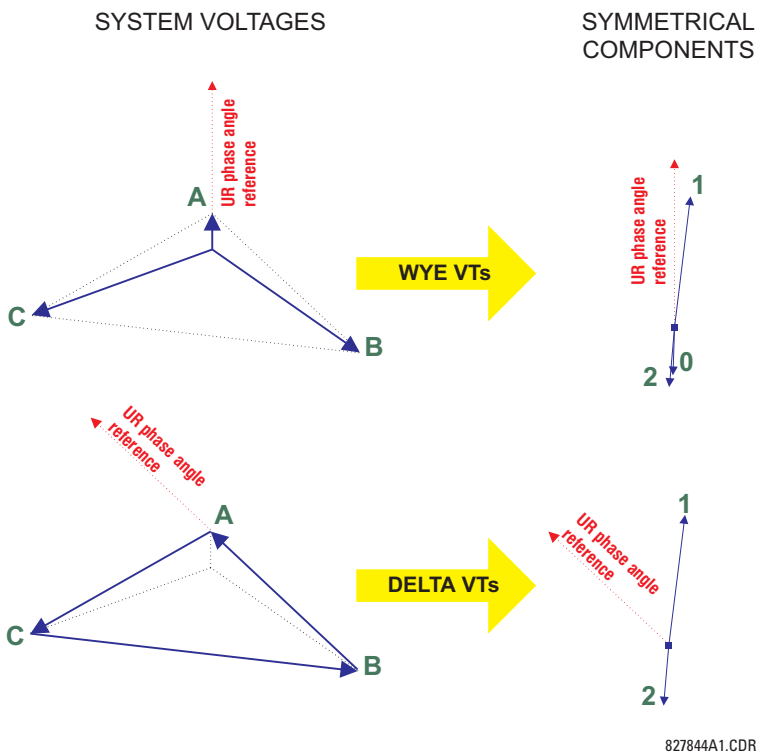
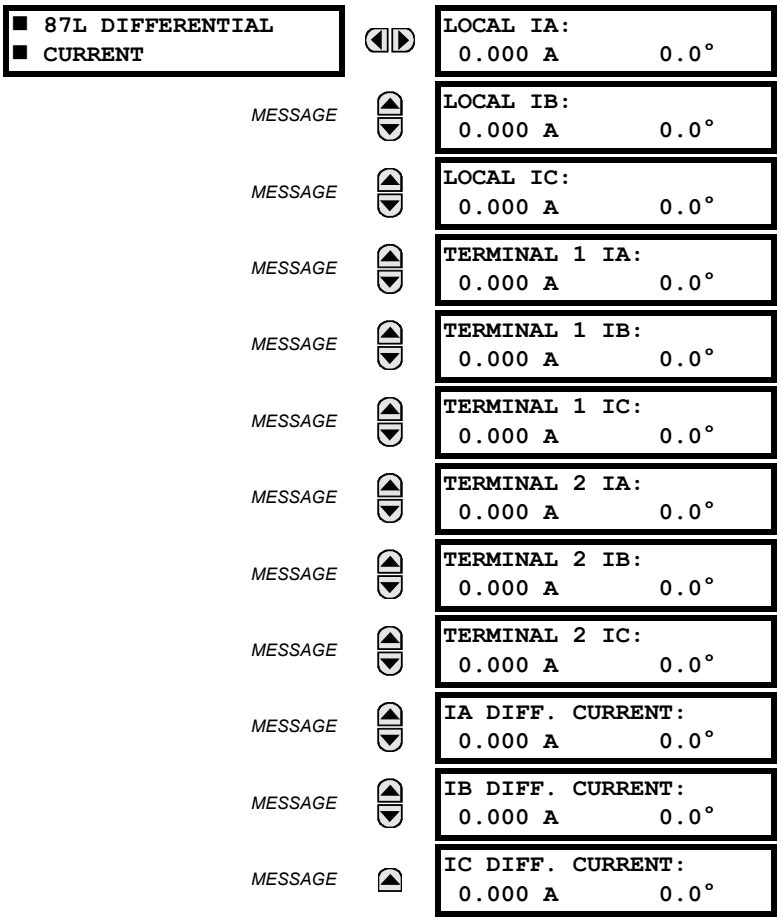


Figure 6–3: ILLUSTRATION OF THE UR CONVENTION FOR SYMMETRICAL COMPONENTS

PATH: ACTUAL VALUES ⇩ METERING ⇨⇩ 87L DIFFERENTIAL CURRENT



Primary real current values measured are displayed here for all line terminals in fundamental phasor form. All angles are shown with respect to the reference common for all UR relays, i.e. frequency, Source currents and voltages chosen. Real measured primary differential current is displayed for the local relay.

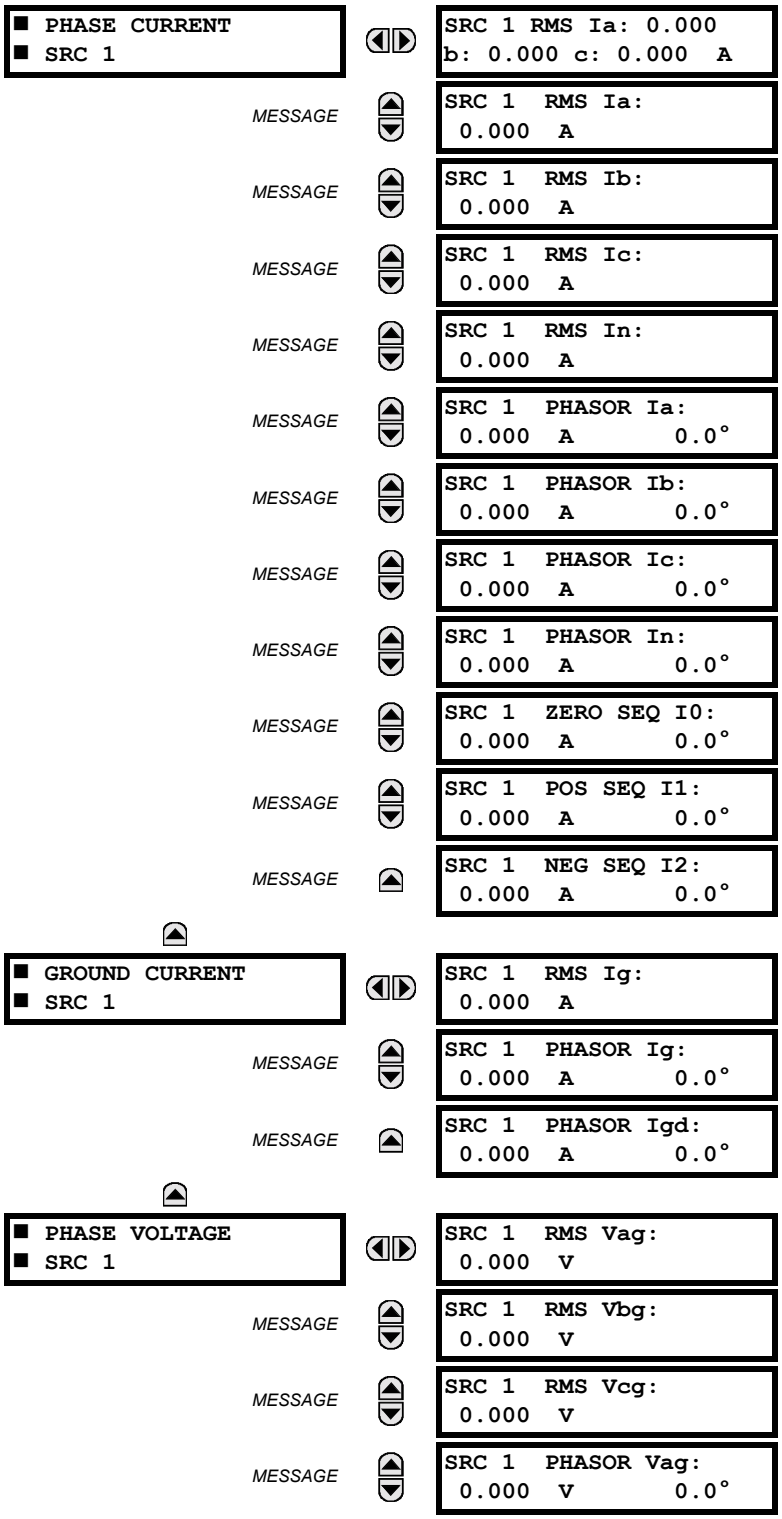
NOTE

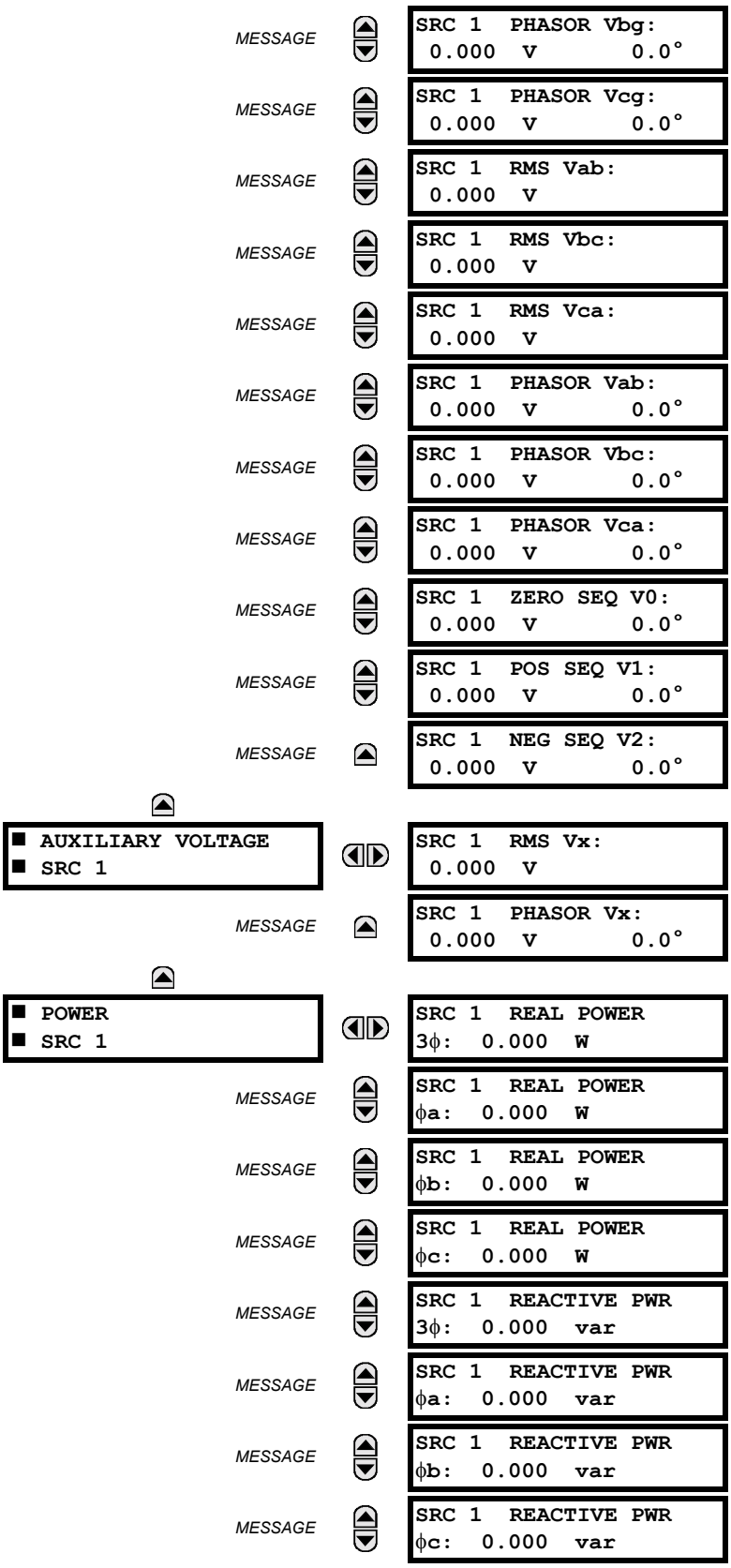
Terminal 1 refers to the communication channel 1 interface to a remote L90 at terminal 1. Terminal 2 refers to the communication channel 2 interface to a remote L90 at terminal 2.

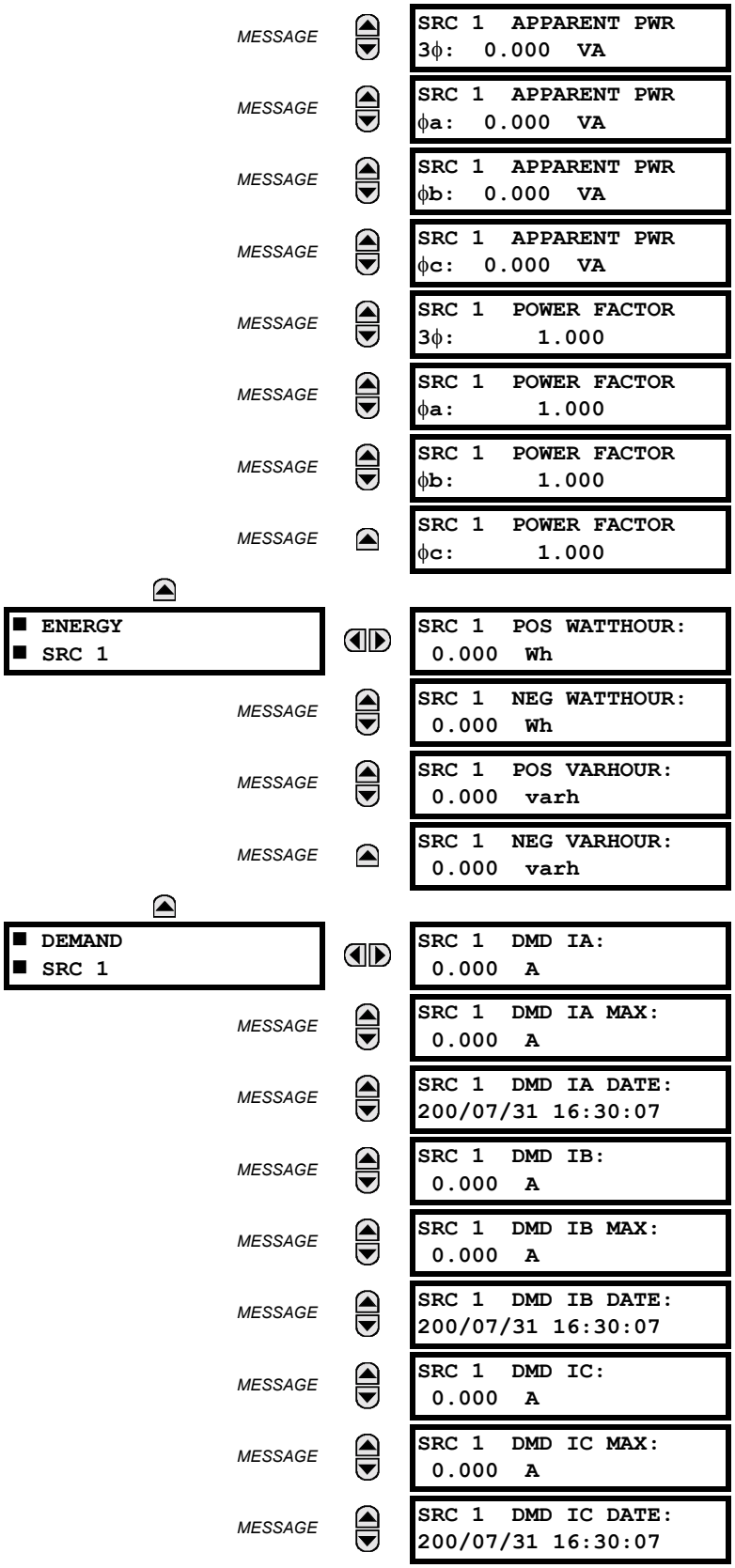
PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨

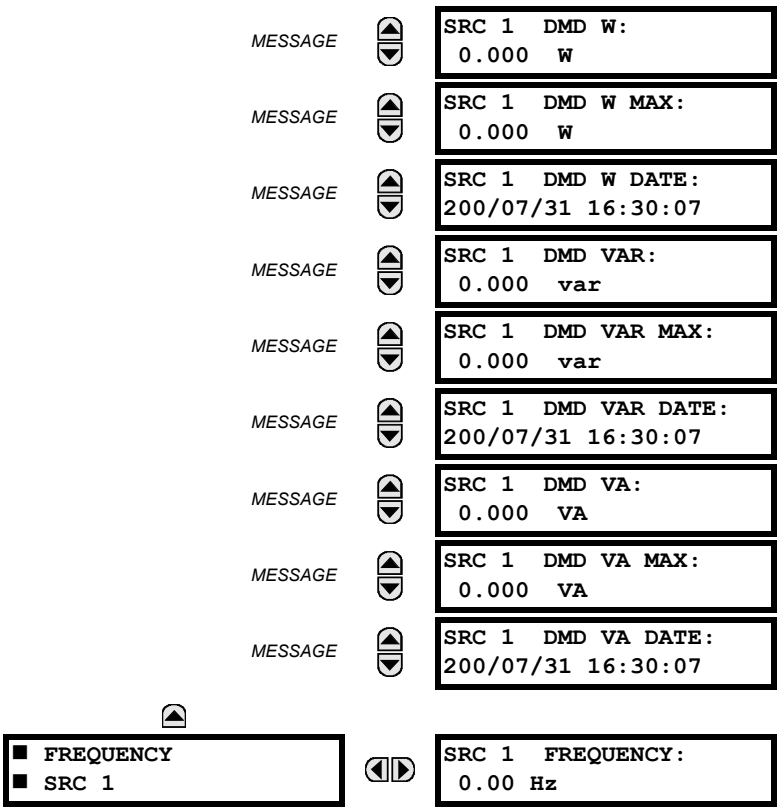
NOTE

Because energy values are accumulated, these values should be recorded and then reset immediately prior to changing CT or VT characteristics.




MESSAGE
SRC 1 PHASOR Vbg:
0.000 V 0.0°
MESSAGE
SRC 1 PHASOR Vcg:
0.000 V 0.0°
MESSAGE
SRC 1 RMS Vab:
0.000 V
MESSAGE
SRC 1 RMS Vbc:
0.000 V
MESSAGE
SRC 1 RMS Vca:
0.000 V
MESSAGE
SRC 1 PHASOR Vab:
0.000 V 0.0°
MESSAGE
SRC 1 PHASOR Vbc:
0.000 V 0.0°
MESSAGE
SRC 1 PHASOR Vca:
0.000 V 0.0°
MESSAGE
SRC 1 ZERO SEQ V0:
0.000 V 0.0°
MESSAGE
SRC 1 POS SEQ V1:
0.000 V 0.0°
MESSAGE
SRC 1 NEG SEQ V2:
0.000 V 0.0°
AUXILIARY VOLTAGE
SRC 1
SRC 1 RMS Vx:
0.000 V
MESSAGE
SRC 1 PHASOR Vx:
0.000 V 0.0°
POWER
SRC 1
SRC 1 REAL POWER
3ϕ: 0.000 W
MESSAGE
SRC 1 REAL POWER
ϕa: 0.000 W
MESSAGE
SRC 1 REAL POWER
ϕb: 0.000 W
MESSAGE
SRC 1 REAL POWER
ϕc: 0.000 W
MESSAGE
SRC 1 REACTIVE PWR
3ϕ: 0.000 var
MESSAGE
SRC 1 REACTIVE PWR
ϕa: 0.000 var
MESSAGE
SRC 1 REACTIVE PWR
ϕb: 0.000 var
MESSAGE
SRC 1 REACTIVE PWR
ϕc: 0.000 var


MESSAGE
SRC 1 APPARENT PWR
3ϕ: 0.000 VA
MESSAGE
SRC 1 APPARENT PWR
ϕa: 0.000 VA
MESSAGE
SRC 1 APPARENT PWR
ϕb: 0.000 VA
MESSAGE
SRC 1 APPARENT PWR
ϕc: 0.000 VA
MESSAGE
SRC 1 POWER FACTOR
3ϕ: 1.000
MESSAGE
SRC 1 POWER FACTOR
ϕa: 1.000
MESSAGE
SRC 1 POWER FACTOR
ϕb: 1.000
MESSAGE
SRC 1 POWER FACTOR
ϕc: 1.000
ENERGY
SRC 1
SRC 1 POS WATTHOUR:
0.000 Wh
MESSAGE
SRC 1 NEG WATTHOUR:
0.000 Wh
MESSAGE
SRC 1 POS VARHOUR:
0.000 varh
MESSAGE
SRC 1 NEG VARHOUR:
0.000 varh
DEMAND
SRC 1
SRC 1 DMD IA:
0.000 A
MESSAGE
SRC 1 DMD IA MAX:
0.000 A
MESSAGE
SRC 1 DMD IA DATE:
200/07/31 16:30:07
MESSAGE
SRC 1 DMD IB:
0.000 A
MESSAGE
SRC 1 DMD IB MAX:
0.000 A
MESSAGE
SRC 1 DMD IB DATE:
200/07/31 16:30:07
MESSAGE
SRC 1 DMD IC:
0.000 A
MESSAGE
SRC 1 DMD IC MAX:
0.000 A
MESSAGE
SRC 1 DMD IC DATE:
200/07/31 16:30:07



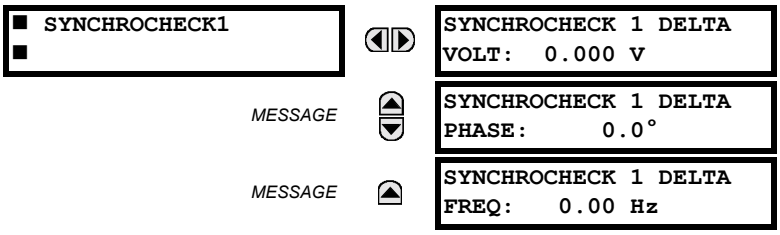
A maximum of 6 identical Source menus are available, numbered from SRC 1 to SRC 6. "SRC 1" will be replaced by whatever name was programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

The relay measures (absolute values only) **SOURCE DEMAND** on each phase and average three phase demand for real, reactive, and apparent power. These parameters can be monitored to reduce supplier demand penalties or for statistical metering purposes. Demand calculations are based on the measurement type selected in the **SETTINGS ⇩ PRODUCT SETUP ⇨⇩ DEMAND** menu. For each quantity, the relay displays the demand over the most recent demand time interval, the maximum demand since the last maximum demand reset, and the time and date stamp of this maximum demand value. Maximum demand quantities can be reset to zero with the **COMMANDS ⇩ CLEAR RECORDS ⇨⇩ CLEAR DEMAND RECORDS** command.

SOURCE FREQUENCY is measured via software-implemented zero-crossing detection of an AC signal. The signal is either a Clarke transformation of three-phase voltages or currents, auxiliary voltage, or ground current as per source configuration (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM**). The signal used for frequency estimation is low-pass filtered. The final frequency measurement is passed through a validation filter that eliminates false readings due to signal distortions and transients.

6.3.4 SYNCHROCHECK

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ SYNCHROCHECK ⇨ SYNCHROCHECK 1



The Actual Values menu for SYNCHROCHECK2 is identical to that of SYNCHROCHECK1. If a Synchrocheck Function setting is set to "Disabled", the corresponding Actual Values menu item will not be displayed.

6.3.5 TRACKING FREQUENCY

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRACKING FREQUENCY

The tracking frequency is displayed here. The frequency is tracked based on configuration of the reference source. See SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM for more details on frequency metering and tracking. With three-phase inputs configured the frequency is measured digitally using a Clarke combination of all three-phase signals for optimized performance during faults, open pole, and VT fuse fail conditions.

6.3.6 FLEXELEMENTS™

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ FLEXELEMENTS ⇨ FLEXELEMENT 1(8)

The operating signals for the FlexElements are displayed in pu values using the following definitions of the base units.

Table 6–2: FLEXELEMENT™ BASE UNITS

87L SIGNALS (Local IA Mag, IB, and IC) (Diff Curr IA Mag, IB, and IC) (Terminal 1 IA Mag, IB, and IC) (Terminal 2 IA Mag, IB and IC)	I_{BASE} = maximum primary RMS value of the +IN and –IN inputs (CT primary for source currents, and 87L source primary current for line differential currents)
87L SIGNALS (Op Square Curr IA, IB, and IC) (Rest Square Curr IA, IB, and IC)	BASE = Squared CT secondary of the 87L source
BREAKER ARCING AMPS (Brk X Arc Amp A, B, and C)	BASE = 2000 $kA^2 \times$ cycle
dcmA	BASE = maximum value of the **DCMA INPUT MAX** setting for the two transducers configured under the +IN and –IN inputs.
FREQUENCY	f_{BASE} = 1 Hz
PHASE ANGLE	φ_{BASE} = 360 degrees (see the UR angle referencing convention)
POWER FACTOR	PF_{BASE} = 1.00
RTDs	BASE = 100°C
SOURCE CURRENT	I_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs
SOURCE POWER	P_{BASE} = maximum value of $V_{BASE} \times I_{BASE}$ for the +IN and –IN inputs
SOURCE VOLTAGE	V_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs
SYNCHROCHECK (Max Delta Volts)	V_{BASE} = maximum primary RMS value of all the sources related to the +IN and –IN inputs

6.3.7 TRANSDUCER I/O

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRANSDUCER I/O DCMA INPUTS ⇨ DCMA INPUT xx

Actual values for each DCMA input channel that is Enabled are displayed with the top line as the programmed channel "ID" and the bottom line as the value followed by the programmed units.

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRANSDUCER I/O RTD INPUTS ⇨ RTD INPUT xx

Actual values for each RTD input channel that is Enabled are displayed with the top line as the programmed channel "ID" and the bottom line as the value.

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨ FAULT REPORTS ⇨

```
NO FAULTS TO REPORT
```

or

```
■ FAULT REPORT #
■
```

		Range:
	FAULT # DATE: 2000/08/11	YYYY/MM/DD
MESSAGE	FAULT # TIME: 00:00:00.000000	HH:MM:SS.ssssss
MESSAGE	FAULT # TYPE: ABG	where applicable; not seen if the source VTs are in the "Delta" configuration
MESSAGE	FAULT # LOCATION 00.0 km	where applicable; not seen if the source VTs are in the "Delta" configuration
MESSAGE	FAULT # RECLOSE SHOT: 0	where applicable

The latest 10 fault reports can be stored. The most recent fault location calculation (when applicable) is displayed in this menu, along with the date and time stamp of the event which triggered the calculation. See the SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FAULT REPORT menu for assigning the Source and Trigger for fault calculations. Refer to the COMMANDS ⇨⇩ CLEAR RECORDS menu for clearing fault reports.

a) FAULT LOCATOR OPERATION

Fault Type determination is required for calculation of Fault Location – the algorithm uses the angle between the negative and positive sequence components of the relay currents. To improve accuracy and speed of operation, the fault components of the currents are used, i.e., 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 and zero sequence currents.

The single-ended fault location method assumes that the fault components of the currents supplied from the local (A) and remote (B) systems are in phase. The figure below shows an equivalent system for fault location.

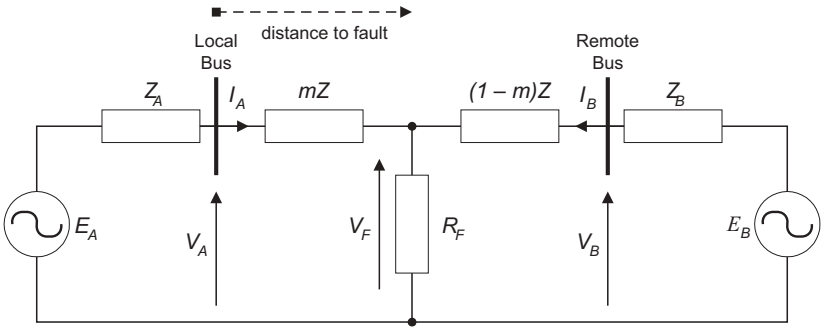


Figure 6–4: EQUIVALENT SYSTEM FOR FAULT LOCATION

The following equations hold true for this equivalent system.

$$V_A = m \cdot Z \cdot I_A + R_F \cdot (I_A + I_B) \quad \text{eqn. 1}$$

where: m = sought pu distance to fault, Z = positive sequence impedance of the line.

The currents from the local and remote systems can be parted between their fault (F) and pre-fault load (pre) components:

$$I_A = I_{AF} + I_{Apre} \quad \text{eqn. 2}$$

and neglecting shunt parameters of the line:

$$I_B = I_{BF} - I_{Apre} \quad \text{eqn. 3}$$

Inserting equations 2 and 3 into equation 1 and solving for the fault resistance yields:

$$R_F = \frac{V_A - m \cdot Z \cdot I_A}{I_{AF} \cdot \left(1 + \frac{I_{BF}}{I_{AF}}\right)} \quad \text{eqn. 4}$$

Assuming the fault components of the currents, I_{AF} and I_{BF} are in phase, and observing that the fault resistance, as impedance, does not have any imaginary part gives:

$$\text{Im}\left(\frac{V_A - m \cdot Z \cdot I_A}{I_{AF}}\right) \quad \text{eqn. 5}$$

where: Im() represents the imaginary part of a complex number. Equation 5 solved for the unknown m creates the following fault location algorithm:

$$m = \frac{\text{Im}(V_A \cdot I_{AF}^*)}{\text{Im}(Z \cdot I_A \cdot I_{AF}^*)} \quad \text{eqn. 6}$$

where: * denotes the complex conjugate and: $I_{AF} = I_A - I_{Apre}$ eqn. 7

Depending on the fault type, appropriate voltage and current signals are selected from the phase quantities before applying equations 6 and 7 (the superscripts denote phases, the subscripts denote stations):

- For AG faults: $V_A = V_A^A$, $I_A = I_A^A + K_0 \cdot I_{0A}$ eqn. 8a
- For BG faults: $V_A = V_A^B$, $I_A = I_A^B + K_0 \cdot I_{0A}$ eqn. 8b
- For CG faults: $V_A = V_A^C$, $I_A = I_A^{BC} + K_0 \cdot I_{0A}$ eqn. 8c
- For AB and ABG faults: $V_A = V_A^A - V_A^B$, $I_A = I_A^A - I_A^B$ eqn. 8d
- For BC and BCG faults: $V_A = V_A^B - V_A^C$, $I_A = I_A^B - I_A^C$ eqn. 8e
- For CA and CAG faults: $V_A = V_A^C - V_A^A$, $I_A = I_A^C - I_A^A$ eqn. 8f
  where K_0 is the zero sequence compensation factor (for equations 8a to 8f)
- For ABC faults, all three AB, BC, and CA loops are analyzed and the final result is selected based upon consistency of the results

The element calculates the distance to the fault (with m in miles or kilometers) and the phases involved in the fault.

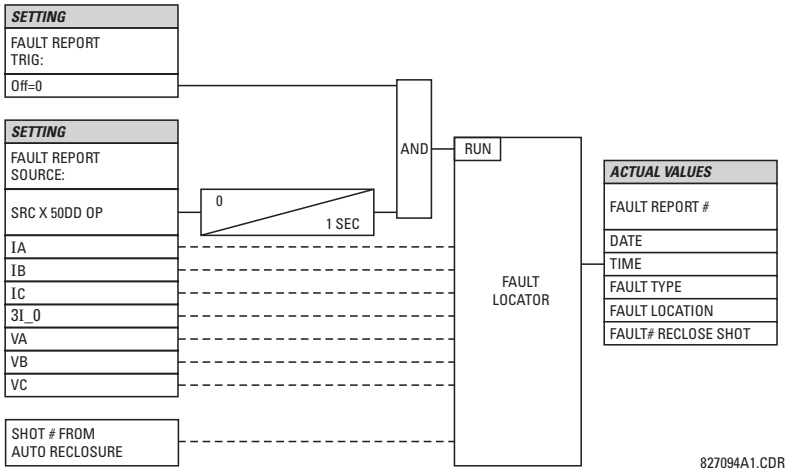


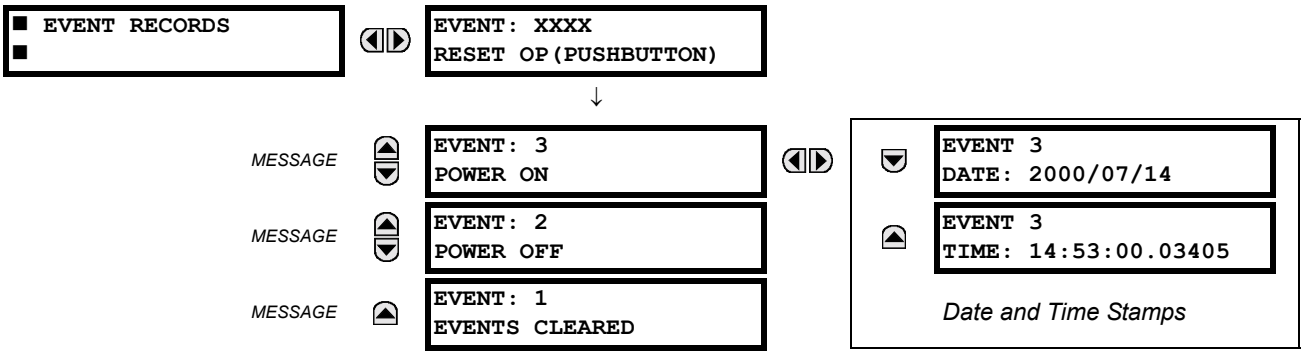
Figure 6–5: FAULT LOCATOR SCHEME

NOTE

As fault locator algorithm is based on the single-end measurement method, in 3-terminal configuration the estimation of fault location may not be correct at all 3 terminals especially if fault occurs behind the line's tap respective to the given relay.

6.4.2 EVENT RECORDS

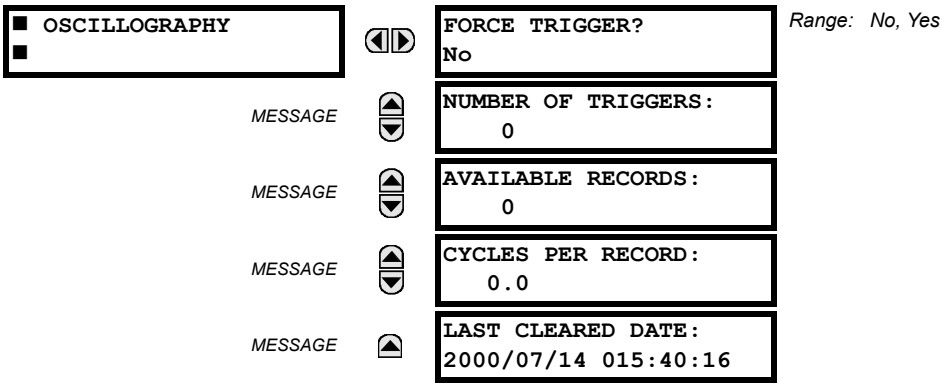
PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ EVENT RECORDS



The Event Records menu shows the contextual data associated with up to the last 1024 events, listed in chronological order from most recent to oldest. If all 1024 event records have been filled, the oldest record will be removed as a new record is added. Each event record shows the event identifier/sequence number, cause, and date/time stamp associated with the event trigger. Refer to the COMMANDS CLEAR RECORDS menu for clearing event records.

6.4.3 OSCILLOGRAPHY

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ OSCILLOGRAPHY

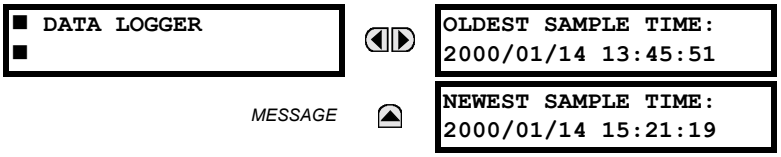


This menu allows the user to view the number of triggers involved and number of oscillography traces available. The 'cycles per record' value is calculated to account for the fixed amount of data storage for oscillography. See the OSCILLOGRAPHY section of Chapter 5.

A trigger can be forced here at any time by setting "Yes" to the **FORCE TRIGGER?** command. Refer to the **COMMANDS** ⇨⇩ **CLEAR RECORDS** menu for clearing the oscillography records.

6.4.4 DATA LOGGER

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ DATA LOGGER

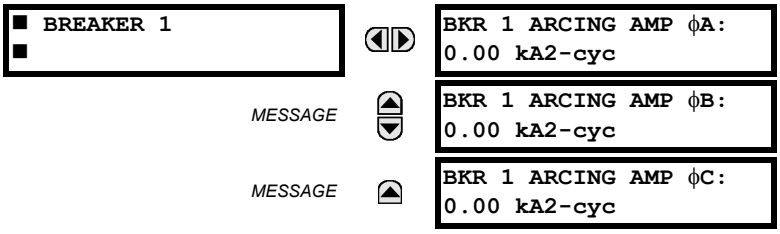


The **OLDEST SAMPLE TIME** is the time at which the oldest available samples were taken. It will be static until the log gets full, at which time it will start counting at the defined sampling rate. The **NEWEST SAMPLE TIME** is the time the most recent samples were taken. It counts up at the defined sampling rate. If Data Logger channels are defined, then both values are static.

Refer to the **COMMANDS** ⇨⇩ **CLEAR RECORDS** menu for clearing data logger records.

a) BREAKER 1(2)

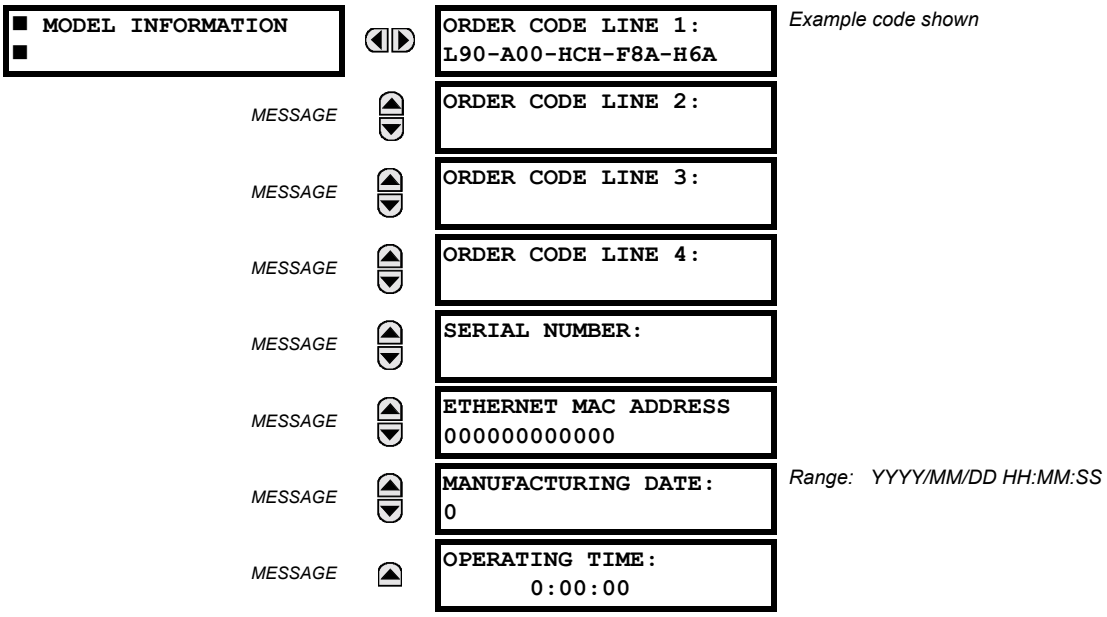
PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ MAINTENANCE ⇨ BREAKER 1



There is an identical Actual Value menu for each of the 2 Breakers. The **BKR 1 ARCING AMP** values are in units of kA^2-cycles. Refer to the **COMMANDS** ⇨⇩ **CLEAR RECORDS** menu for clearing breaker arcing current records.

6.5.1 MODEL INFORMATION

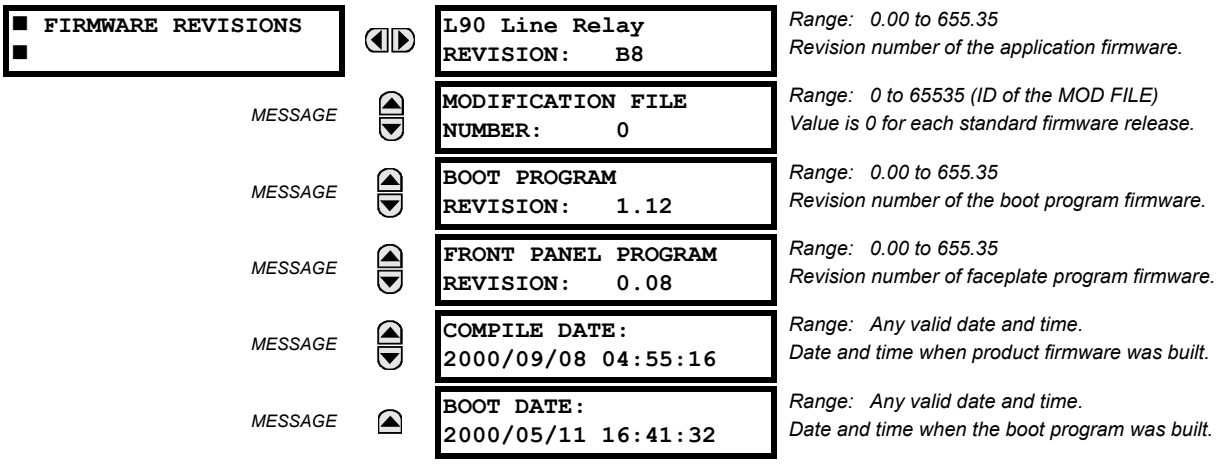
PATH: ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨ MODEL INFORMATION



The product order code, serial number, Ethernet MAC address, date/time of manufacture, and operating time are shown here.

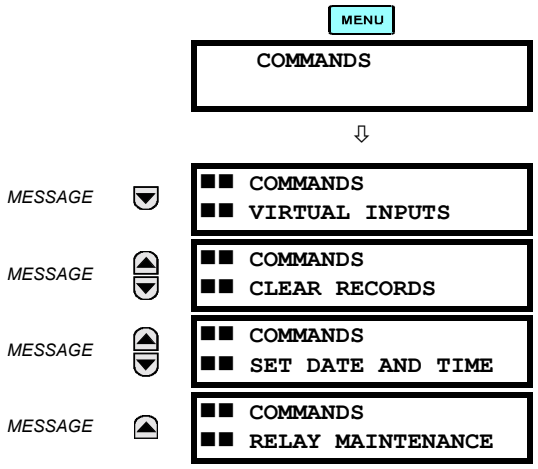
6.5.2 FIRMWARE REVISIONS

PATH: ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨⇩ FIRMWARE REVISIONS



The shown data is illustrative only. A modification file number of 0 indicates that, currently, no modifications have been installed.

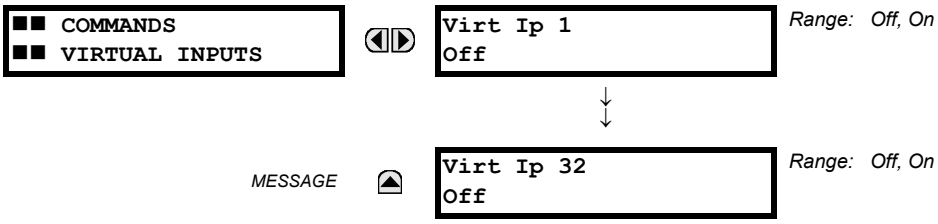
7.1.1 COMMANDS MENU



The COMMANDS menu contains relay directives intended for operations personnel. All commands can be protected from unauthorized access via the Command Password; see the PASSWORD SECURITY menu description in the PRODUCT SETUP section of Chapter 5. The following flash message appears after successfully command entry:

7.1.2 VIRTUAL INPUTS

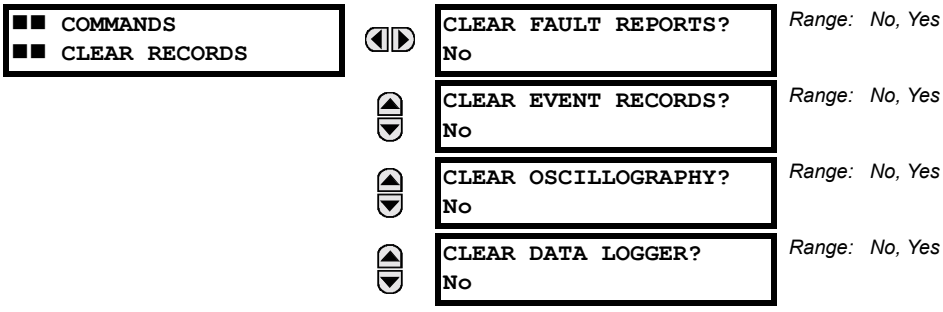
PATH: COMMANDS ⇩ COMMANDS VIRTUAL INPUTS

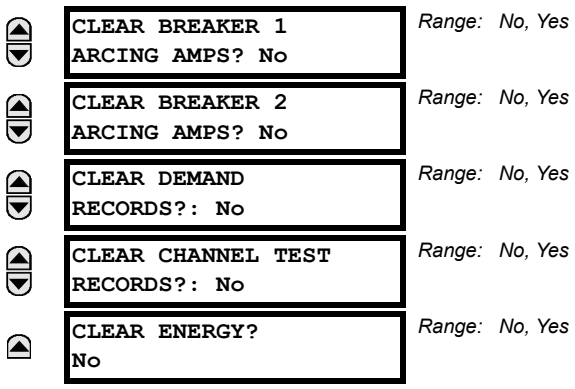


The states of up to 32 virtual inputs are changed here. The first line of the display indicates the ID of the virtual input. The second line indicates the current or selected status of the virtual input. This status will be a logical state 'Off' (0) or 'On' (1).

7.1.3 CLEAR RECORDS

PATH: COMMANDS ⇩ COMMANDS CLEAR RECORDS

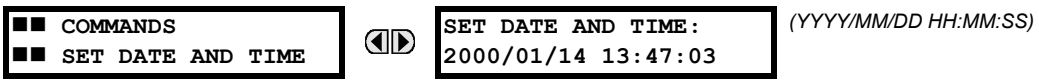




This menu contains commands for clearing historical data such as the Event Records. Data is cleard by changing a command setting to "Yes" and pressing the ENTER key. After clearing data, the command setting automatically reverts to "No".

7.1.4 SET DATE AND TIME

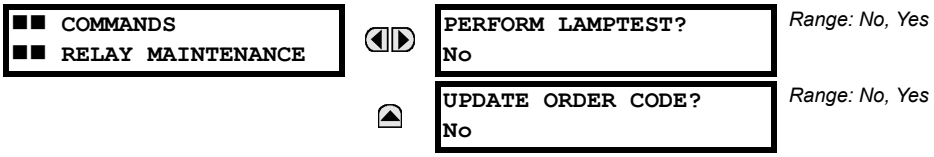
PATH: COMMANDS ⇩ SET DATE AND TIME



The date and time can be entered here via the faceplate keypad, provided that the IRIG-B signal is not being used. The time setting is based on the 24-hour clock. The complete date, as a minimum, must be entered to allow execution of this command. The new time will take effect at the moment the ENTER key is clicked.

7.1.5 RELAY MAINTENANCE

PATH: COMMANDS ⇩ RELAY MAINTENANCE

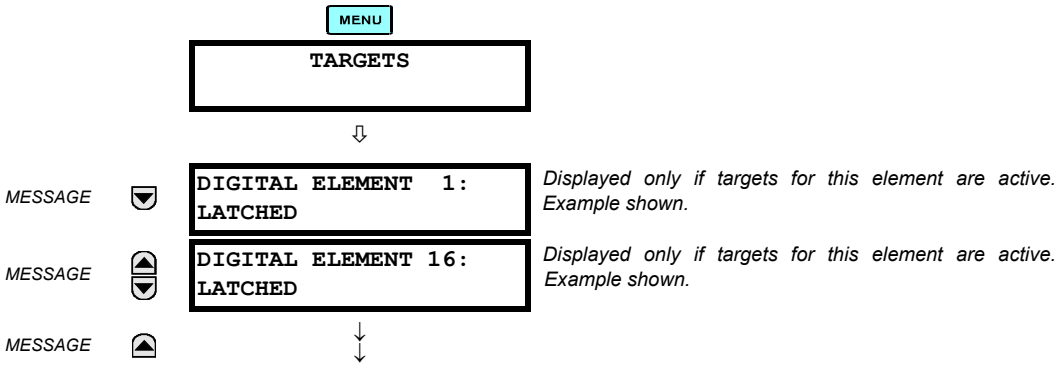


This menu contains commands for relay maintenance purposes. Commands are activated by changing a command setting to "Yes" and pressing the ENTER key. The command setting will then automatically revert to "No".

The **PERFORM LAMPTEST** command turns on all faceplate LEDs and display pixels for a short duration. The **UPDATE ORDER CODE** command causes the relay to scan the backplane for the hardware modules and update the order code to match. If an update occurs, the following message is shown.

There is no impact if there have been no changes to the hardware modules. When an update does not occur, the following message will be shown.

7.2.1 TARGETS MENU



The status of any active targets will be displayed in the TARGETS menu. If no targets are active, the display will read:

```
No Active
Targets
```

a) TARGET MESSAGES

When there are no active targets, the first target to become active will cause the display to immediately default to that message. If there are active targets and the user is navigating through other messages, and when the default message timer times out (i.e. the keypad has not been used for a determined period of time), the display will again default back to the target message.

The range of variables for the target messages is described below. Phase information will be included if applicable. If a target message status changes, the status with the highest priority will be displayed.

Table 7–1: TARGET MESSAGE PRIORITY STATUS

PRIORITY	ACTIVE STATUS	DESCRIPTION
1	OP	element operated and still picked up
2	PKP	element picked up and timed out
3	LATCHED	element had operated but has dropped out

If a self test error is detected, a message appears indicating the cause of the error. For example:

```
UNIT NOT PROGRAMMED
:Self Test Error
```

7.2.2 RELAY SELF-TESTS

The relay performs a number of self-test diagnostic checks to ensure device integrity. The two types of self-tests (major and minor) are listed in the tables below. When either type of self-test error occurs, the TROUBLE indicator will turn on and a target message displayed. All errors record an event in the event recorder. Latched errors can be cleared by pressing the RESET key, providing the condition is no longer present.

Major self-test errors also result in the following:

- the critical fail relay on the power supply module is de-energized
- all other output relays are de-energized and are prevented from further operation
- the faceplate IN SERVICE indicator is turned off
- a RELAY OUT OF SERVICE event is recorded

Table 7–2: MAJOR SELF-TEST ERROR MESSAGES

SELF-TEST ERROR MESSAGE	LATCHED TARGET MSG?	DESCRIPTION OF PROBLEM	HOW OFTEN THE TEST IS PERFORMED	WHAT TO DO
UNIT NOT PROGRAMMED	No	**PRODUCT SETUP** ⇨⇩ **INSTALLATION** setting indicates relay is not in a programmed state.	On power up and whenever the **RELAY PROGRAMMED** setting is altered.	Program all settings (especially those under **PRODUCT SETUP** ⇨⇩ **INSTALLATION**).
EQUIPMENT MISMATCH with 2nd-line detail message	No	Configuration of modules does not match the order code stored in the CPU.	On power up; thereafter, the backplane is checked for missing cards every 5 seconds.	Check all module types against the order code, ensure they are inserted properly, and cycle control power (if problem persists, contact the factory).
UNIT NOT CALIBRATED	No	Settings indicate the unit is not calibrated.	On power up.	Contact the factory.
FLEXLOGIC ERR TOKEN with 2nd-line detail message	No	FlexLogic equations do not compile properly.	Event driven; whenever FlexLogic equations are modified.	Finish all equation editing and use self test to debug any errors.
DSP ERRORS: A/D RESET FAILURE A/D CAL FAILURE A/D INT. MISSING A/D VOLT REF. FAIL NO DSP INTERRUPTS DSP CHECKSUM FAILED DSP FAILED	Yes	CT/VT module with digital signal processor may have a problem.	Every 1/8th of a cycle.	Cycle the control power (if the problem recurs, contact the factory).
PROGRAM MEMORY Test Failed	Yes	Error was found while checking Flash memory.	Once flash is uploaded with new firmware.	Contact the factory.

Table 7–3: MINOR SELF-TEST ERROR MESSAGES

SELF-TEST ERROR MESSAGE	LATCHED TARGET MSG?	DESCRIPTION OF PROBLEM	HOW OFTEN THE TEST IS PERFORMED	WHAT TO DO
EEPROM CORRUPTED	Yes	The non-volatile memory has been corrupted.	On power up only.	Contact the factory.
IRIG-B FAILURE	No	Bad IRIG-B input signal.	Monitored whenever an IRIG-B signal is received.	• Ensure the IRIG-B cable is connected to the relay. • Check functionality of the cable (i.e. look for physical damage or perform a continuity test). • Ensure the IRIG-B receiver is functioning properly. • Check the input signal level; it may be lower than specification. If none of the above items apply, contact the factory.
PRIM ETHERNET FAIL	No	Primary Ethernet connection failed	Monitored every 2 seconds	Check connections.
SEC ETHERNET FAIL	No	Secondary Ethernet connection failed	Monitored every 2 seconds	Check connections.
BATTERY FAIL	No	Battery is not functioning.	Monitored every 5 seconds. Reported after 1 minute if problem persists.	Replace the battery located in the power supply module (1H or 1L).
PROTOTYPE FIRMWARE	Yes	A prototype version of the firmware is loaded.	On power up only.	Contact the factory.
SYSTEM EXCEPTION or ABNORMAL RESTART	Yes	Abnormal restart due to modules being removed/inserted when powered-up, abnormal DC supply, or internal relay failure.	Event driven.	Contact the factory.
LOW ON MEMORY	Yes	Memory is close to 100% capacity	Monitored every 5 seconds.	Contact the factory.
WATCHDOG ERROR	No	Some tasks are behind schedule	Event driven.	Contact the factory.
REMOTE DEVICE OFFLINE	Yes	One or more GOOSE devices are not responding	Event driven. Occurs when a device programmed to receive GOOSE messages stops receiving message. Time is 1 to 60 sec. depending on GOOSE protocol packets.	Check GOOSE setup

8.1.1 INTRODUCTION

All differential techniques rely on the fact that under normal conditions, the sum of the currents entering each phase of a transmission line from all connected terminals is equal to the charging current for that phase. Beyond the fundamental differential principle, the three most important technical considerations are; data consolidation, restraint characteristic, and sampling synchronization. The L90 uses new and unique concepts in these areas.

Data consolidation refers to the extraction of appropriate parameters to be transmitted from raw samples of transmission line phase currents. By employing data consolidation, a balance is achieved between transient response and bandwidth requirements. Consolidation is possible along two dimensions: time and phases. Time consolidation consists of combining a time sequence of samples to reduce the required bandwidth. Phase consolidation consists of combining information from three phases and neutral. Although phase consolidation is possible, it is generally not employed in digital schemes, because it is desired to detect which phase is faulted. The L90 relay transmits data for all three phases.

Time consolidation reduces communications bandwidth requirements. Time consolidation also improves security by eliminating the possibility of falsely interpreting a single corrupted data sample as a fault.

The L90 relay system uses a new consolidation technique called “phaselets”. Phaselets are partial sums of the terms involved in a complete phasor computation. The use of phaselets in the L90 design improves the transient response performance without increasing the bandwidth requirements.

Phaselets themselves are not the same as phasors, but they can be combined into phasors over any time window that is aligned with an integral number of phaselets (see PHASELET COMPUTATION section for details). The number of phaselets that must be transmitted per cycle per phase is the number of samples per cycle divided by the number of samples per phaselet. The L90 design uses 64 samples per cycle and 32 samples per phaselet, leading to a phaselet communication bandwidth requirement of 2 phaselets per cycle. Two phaselets per cycle fits comfortably within a communications bandwidth of 64 Kbaud, and can be used to detect faults within a half cycle plus channel delay.

The second major technical consideration is the restraint characteristic, which is the decision boundary between situations that are declared to be a fault and those that are not. The L90 uses an innovative new adaptive decision process based on an on-line computation of the sources of measurement error. In this adaptive approach, the restraint region is an ellipse with variable major axis, minor axis, and orientation. Parameters of the ellipse vary with time to make best use of the accuracy of current measurements.

The third major element of L90 design is sampling synchronization. In order for a differential scheme to work, the data being compared must be taken at the same time. This creates a challenge when data is taken at remote locations.

The GE approach to clock synchronization relies upon distributed synchronization. Distributed synchronization is accomplished by synchronizing the clocks to each other rather than to a master clock. Clocks are phase synchronized to each other and frequency synchronized to the power system frequency. Each relay compares the phase of its clock to the phase of the other clocks and compares the frequency of its clock to the power system frequency and makes appropriate adjustments. As long as there are enough channels operating to provide protection, the clocks will be synchronized.

8.1.2 ARCHITECTURE

The L90 system uses a peer to peer architecture in which the relays at every terminal are identical. Each relay computes differential current and clocks are synchronized to each other in a distributed fashion. The peer to peer architecture is based on two main concepts that reduce the dependence of the system on the communication channels: replication of protection and distributed synchronization.

Replication of protection means that each relay is designed to be able to provide protection for the entire system, and does so whenever it has enough information. Thus a relay provides protection whenever it is able to communicate directly with all other relays. For a multi-terminal system, the degree of replication is determined by the extent of communication interconnection. If there is a channel between every pair of relays, every relay provides protection. If channels are not provided between every pair of relays, only those relays that are connected to all other relays provide protection.

Each L90 relay measures three phase currents 64 times per cycle. Ground current is derived from phase currents at each relay. Synchronization in sampling is maintained throughout the system via the distributed synchronization technique.

The next step in the process is the removal of any decaying offset from each phase current measurement. This is done using a digital simulation of the so-called “mimic circuit”, which is based on the differential equation of the inductive circuit which generates the offset. Next, phaselets are computed by each L90 relay for each phase from the outputs of the mimic calculation, and transmitted to the other relay terminals. Also, the sum of the squares of the raw data samples is computed for each phase, and transmitted with the phaselets.

At the receiving relay, the received phaselets are combined into phasors. Also, ground current is reconstructed from phase information. An elliptical restraint region is computed by combining sources of measurement error. In addition to the restraint region, a separate disturbance detector is used to enhance security.

The possibility of a fault is indicated by the detection of a disturbance as well as the sum of the current phasors falling outside of the elliptical restraint region. The statistical distance from the phasor to the restraint region is an indication of the severity of the fault. To provide speed of response that is commensurate with fault severity, the distance is filtered. For mild faults, filtering improves measurement precision at the expense of a slight delay, on the order of one cycle. Severe faults are detected within a single phaselet.

Whenever the sum of phasors falls within the elliptical restraint region, the system assumes there is no fault, and uses whatever information is available for fine adjustment of the clocks.

8.1.3 REMOVAL OF DECAYING OFFSET

The inductive behavior of power system transmission lines gives rise to decaying exponential offsets during transient conditions, which could lead to errors and interfere with the determination of how well measured current fits a sinewave.

The current signals are pre-filtered using an improved digital MIMIC filter. The filter removes effectively the DC component(s) guaranteeing transient overshoot below 2% regardless of the initial magnitude and time constant of the dc component(s). The filter has significantly better filtering properties for higher frequencies as compared with a classical MIMIC filter. This was possible without introducing any significant phase delay thanks to the high sampling rate used by the relay. The output of the MIMIC calculation is the input for the phaselet computation. The MIMIC computation is applied to the data samples for each phase at each terminal. The equation shown is for one phase at one terminal.

8.1.4 PHASELET COMPUTATION

Phaselets are partial sums in the computation for fitting a sine function to measured samples. Each slave computes phaselets for each phase current and transmits phaselet information to the master for conversion into phasors. Phaselets enable the efficient computation of phasors over sample windows that are not restricted to an integer multiple of a half cycle at the power system frequency. Determining the fundamental power system frequency component of current data samples by minimizing the sum of the squares of the errors gives rise to the first frequency component of the Discrete Fourier Transform (DFT). In the case of a data window that is a multiple of a half cycle, the computation is simply sine and cosine weighted sums of the data samples. In the case of a window that is not a multiple of a half-cycle, there is an additional correction that results from the sine and cosine functions not being orthogonal over such a window. However, the computation can be expressed as a two by two matrix multiplication of the sine and cosine weighted sums.

Phaselets and sum of squares are computed for each phase at each terminal from the output of the mimic computations as follows:

$$\mathrm{Re}(\mathrm{Phaselet}_p) = \sum_{\substack{k = p \cdot P - P + 1 \\ p \cdot P}} \cos\left(\frac{2\pi}{N} \cdot \left(k - \frac{1}{2}\right)\right) \cdot Imimic_k$$

$$\mathrm{Im}(\mathrm{Phaselet}_p) = \sum_{\substack{k = p \cdot P - P + 1 \\ p \cdot P}} -\sin\frac{2\pi}{N} \cdot k - \frac{1}{2} \cdot Imimic_k$$

$$\mathrm{PartialSumOfSquares}_p = \sum Imimic_k^{\,2}$$

where: $\mathrm{Re}(\mathrm{Phaselet}_p)$ = real component of the pth phaselet
$\mathrm{Im}(\mathrm{Phaselet}_p)$ = imaginary component of the pth phaselet
$\mathrm{PartialSumOfSquares}_p$ = the pth partial sum of squares
p = phaselet index: there are N / P phaselets per cycle
P = number of phaselets per cycle
$Imimic_k$ = kth sample of the mimic output, taken N samples per cycle

The computation of phaselets and sum of squares is basically a consolidation process. The phaselet sums are converted into stationary phasors by multiplying by a precomputed matrix. Phaselets and partial sums of squares are computed and time stamped at each relay and communicated to the remote relay terminals, where they are added and the matrix multiplication is performed. Since the sampling clocks are synchronized, the time stamp is simply a sequence number.

8.1.5 ADAPTIVE STRATEGY

The L90 uses an adaptive restraint in which the system uses measured statistical parameters to improve performance. In particular, the system is able to adjust the restraint boundary dynamically to reflect measurement error. Also, in the peer to peer architecture, fine adjustments are made to the sampling clocks to compensate for residual timing errors. Finally, the data sampling frequency tracks the power system frequency to improve the accuracy of the phasors.

Adjustment of the restraint boundary is based on computing and adding all sources of current measurement error. (See section on On-Line Estimate of Measurement Errors for sources and details of this calculation.) Each relay performs this calculation from phaselets and sum of squares each time new information is available from remote terminals. The L90 relay computes current phasor covariance parameters for all sources of measurement error for each phase of each terminal:

CRR = expected value of the square of the error in the real part of a phasor

CRI = CIR = expected value of the product of the errors in the real and imaginary parts

CII = expected value of the square of the error in the imaginary part of a phasor

Covariance parameters for each terminal are added together for each phase, and are used to establish an elliptical restraint boundary for each phase.

Each L90 relay digital clock is phase synchronized to every other L90 relay clock and frequency synchronized to the power system. Phase synchronization controls the uncertainty in phase angle measurements and frequency synchronization eliminates errors in phasor measurement when samples do not span one exact cycle.

8.1.6 DISTURBANCE DETECTION

A disturbance detection algorithm is used to enhance security and to improve transient response. Conditions for a disturbance include the magnitude of zero sequence current, the magnitude of negative sequence current, and changes in positive, negative, or zero sequence current. When a disturbance is detected, the phaselet computation is reset and fault detection is enabled.

8.1.7 FAULT DETECTION

Normally, the sum of the current phasors from all terminals is zero for each phase at every terminal. A fault is detected for a phase when the sum of the current phasors from each terminal for that phase falls outside of a dynamic elliptical restraint boundary for that phase, based on a statistical analysis. The severity of the fault is computed from covariance parameters and the sum of the current phasor for each phase as follows.

$$\text{Severity} = \text{Re}(\text{Phasor})^2 - \text{Re}(\text{Phasor}) \cdot \text{Im}(\text{Phasor}) \cdot 2 \cdot \frac{C_{R1}}{\min(C_{RR}, C_{11})} + \text{Im}(\text{Phasor})^2 - 18 \cdot \text{Restraint}^2 \cdot \max C_{RR}, C_{II}$$

This equation is based on the covariance matrix and yields an elliptical restraint characteristic, as shown in Figure 8–3. The elliptical area is the restraint region. When the covariance of the current measurements is small, the restraint region shrinks.

When the covariance increases, the restraint region grows to reflect the uncertainty of the measurement. The computed severity increases with the probability that the sum of the measured currents indicates a fault. With the exception of “Restraint”, all quantities are defined in previous sections. “Restraint” is a restraint multiplier, analogous to the slope setting of traditional differential approaches, for adjusting the sensitivity of the relay. For most applications, a value of 1 is recommended. Raising the restraint multiplier corresponds statistically to demanding a greater confidence interval, and has the effect of decreasing sensitivity while lowering it is equivalent to relaxing the confidence interval and increases sensitivity. Thus, the restraint multiplier is an application adjustment that is used to achieve the desired balance between sensitivity and security.

The sum of the first and the third term of the severity equation is analogous to the operate quantity of a conventional approach, and the last term is analogous to the restraint quantity of a conventional approach. The second term arises from the orientation of the ellipse. The equation yields an adaptive elliptical restraint characteristic. The size, shape, and orientation of the ellipse adapt to power system conditions. The computed severity is zero when the operate phasor is on the elliptical boundary, is negative inside the boundary, and positive outside the boundary. Outside of the restraint boundary, the computed severity grows as the square of the fault current. The restraint area grows as the square of the error in the measurements.

It is interesting to compare the severity equation with conventional approaches that are based on operate and restraint terms. For example, one typical operating characteristic based on restraint and operating quantities is shown in Figure 8–1. The restraint current in the conventional approach is derived from the sum of the magnitudes of the terminal currents, and is analogous to the last term in the elliptical severity equation. The operating current for the conventional scheme is derived from the sum of the currents, and is analogous to the first and third term of the elliptical severity equation.

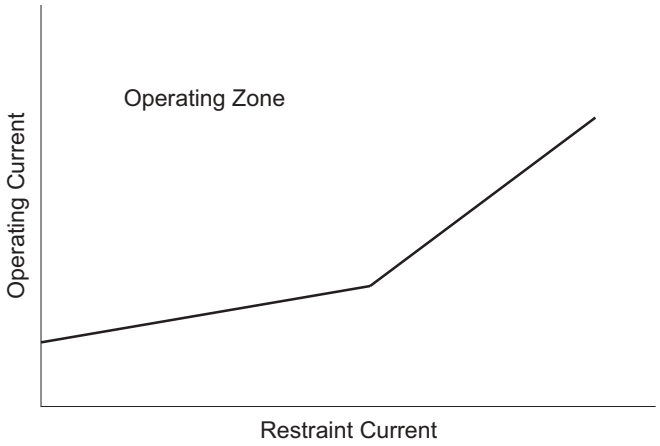


Figure 8–1: CONVENTIONAL RESTRAINT CHARACTERISTIC

Another way of plotting the conventional restraint curve as a region in the complex plane is shown in Figure 8–2. The restraint region is the area inside the circle. Whenever the sum of the current phasors falls within the circle, the conventional approach is restrained. The diameter of the circle depends on the restraint current.

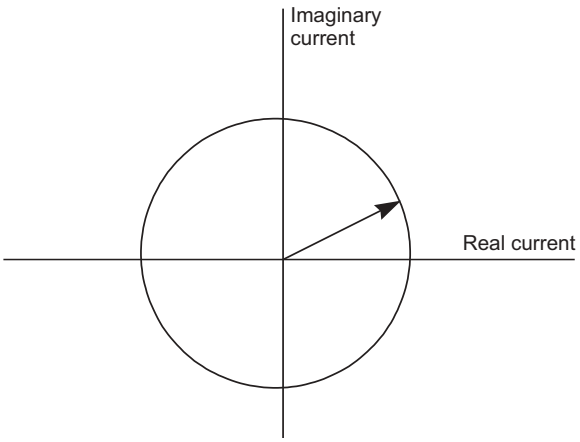


Figure 8–2: CONVENTIONAL RESTRAINT CHARACTERISTIC IN TERMS OF PHASORS

The adaptive elliptical restraint has several advantages over the conventional approach. Although both the adaptive approach and the conventional approach have a restraint region that changes size, the adaptive elliptical restraint region more accurately reflects the sources of measurement error. For example, the conventional approach does not take into account the effects of traveling waves and switching surges on the accuracy of measurements. The adaptive elliptical restraint region provides the best statistical confidence and is more sensitive and more secure than the conventional approach.

The conventional approach does not take into account the elliptical shape of the distribution of uncertainty that arises from separate uncertainty parameters in the magnitude and the phase angle of a current measurement, but rather assumes a circular distribution. In order to be secure, the diameter of the circle in the conventional approach must be at least as large as the major axis of the adaptive ellipse. This means that with the conventional restraint characteristic, the power system is unprotected for fault current phasors that fall within the region between the circle and the ellipse shown in Figure 8–3.

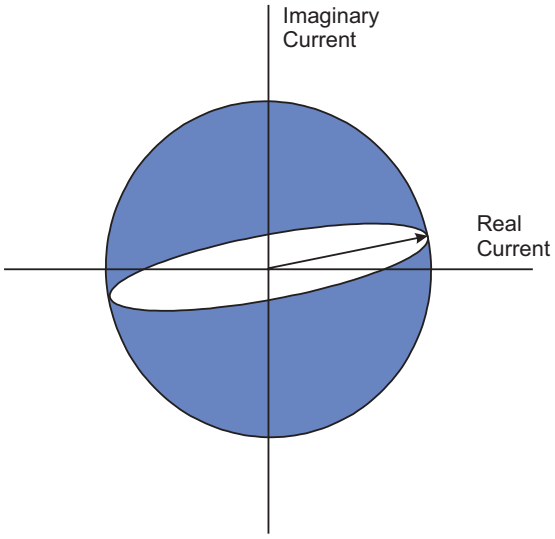


Figure 8–3: IMPROVED FAULT COVERAGE OF ADAPTIVE ELLIPTICAL RESTRAINT

The dynamic behavior of fault detection is controlled by filtering the severity quantity, yielding an inverse square dynamic response, with response times that vary inversely with the fault severity. Transient response time is 2 cycles for a fault that is twice as large as the restraint, going down to 0.5 cycle for a fault that is ten times as large as the restraint.

8.1.8 CLOCK SYNCHRONIZATION

Synchronization of data sampling clocks is needed in a digital differential protection scheme, because measurements must be made at the same time. Synchronization errors show up as phase angle and transient errors in phasor measurements at the terminals. By phase angle errors, we mean that identical currents produce phasors with different phase angles. By transient errors, we mean that when currents change at the same time, the effect is seen at different times at different measurement points. For best results, samples should be taken simultaneously at all terminals.

In the case of peer to peer architecture, synchronization is accomplished by synchronizing the clocks to each other rather than to a master clock. Each relay compares the phase of its clock to the phase of the other clocks and compares the frequency of its clock to the power system frequency and makes appropriate adjustments. The frequency and phase tracking algorithm keeps the measurements at all relays within a plus or minus 25 microsecond error during normal conditions for a 2 or 3 terminal system. For 4 or more terminals the error may be somewhat higher, depending on the quality of the communications channels. The algorithm is unconditionally stable. In the case of 2 and 3 terminal systems, asymmetric communications channel delay is automatically compensated for. In all cases, an estimate of phase error is computed and used to automatically adapt the restraint region to compensate. Frequency tracking is provided that will accommodate any frequency shift normally encountered in power systems.

8.1.9 FREQUENCY TRACKING AND PHASE LOCKING

Each relay has a digital clock that determines when to take data samples and which is phase synchronized to all other clocks in the system and frequency synchronized to the power system frequency. Phase synchronization drives the relative timing error between clocks to zero, and is needed to control the uncertainty in the phase angle of phasor measurements, which will be held to under 26 microseconds (0.6 degrees). Frequency synchronization to the power system eliminates a source of error in phasor measurements that arises when data samples do not exactly span one cycle.

The block diagram for clock control for a two terminal system is shown in Figure 8–4. Each relay makes a local estimate of the difference between the power system frequency and the clock frequency based on the rotation of phasors. Each relay also makes a local estimate of the time difference between its clock and the other clocks either by exchanging timing information over communications channels or from information that is in the current phasors, depending on whichever one is more accurate at any given time. A loop filter then uses the frequency and phase angle deviation information to make fine adjustments to the clock frequency.

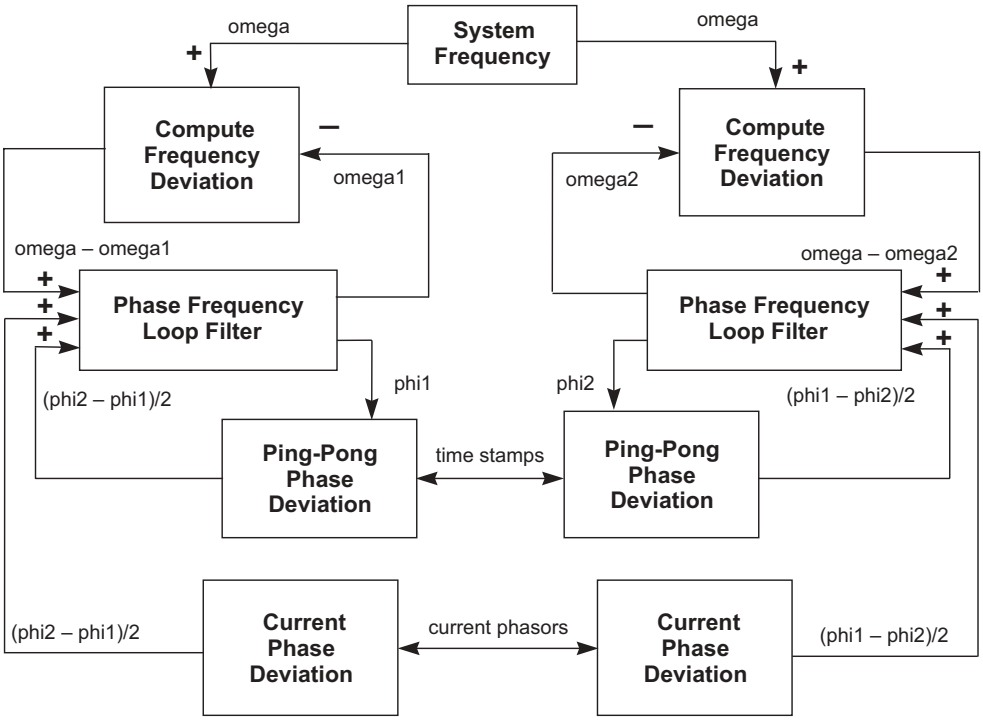


Figure 8–4: BLOCK DIAGRAM FOR CLOCK SYNCHRONIZATION IN A 2-TERMINAL SYSTEM

8.1.10 FREQUENCY DETECTION

Estimation of frequency deviation is done locally at each relay based on rotation of positive sequence current, or on rotation of positive sequence voltage, if it is available. The counter clockwise rotation rate is proportional to the difference between the desired clock frequency and the actual clock frequency. With the peer to peer architecture, there is redundant frequency tracking, so it is not necessary that all terminals perform frequency detection.

Normally each relay will detect frequency deviation, but if there is no current flowing nor voltage measurement available at a particular relay, it will not be able to detect frequency deviation. In that case, the frequency deviation input to the loop filter is set to zero and frequency tracking is still achieved because of phase locking to the other clocks. If frequency detection is lost at all terminals because there is no current flowing then the clocks continue to operate at the frequency present at the time of the loss of frequency detection. Tracking will resume as soon as there is current.

The rotational rate of phasors is equal to the difference between the power system frequency and the ratio of the sampling frequency divided by the number of samples per cycle. The correction is computed once per power system cycle at each relay. For conciseness, we use a phasor notation:

$$\overline{I(n)} = \mathrm{Re}(\mathrm{Phasor}_n) + j \cdot \mathrm{Im}(\mathrm{Phasor}_n)$$

$\overline{I_{a,k}(n)} = \overline{I(n)}$ for phase *a* from the *k*th terminal at time step *n*

$\overline{I_{b,k}(n)} = \overline{I(n)}$ for phase *b* from the *k*th terminal at time step *n*

$\overline{I_{c,k}(n)} = \overline{I(n)}$ for phase *c* from the *k*th terminal at time step *n*

Each terminal computes positive sequence current:

$$\overline{I_{pos,k}(n)} = \frac{1}{3}\left(\overline{I_{a,k}(n)} + \overline{I_{b,k}(n)} \cdot e^{j2\pi/3} + \overline{I_{c,k}(n)} \cdot e^{j2\pi/3}\right)$$

Each relay computes a quantity derived from the positive sequence current that is indicative of the amount of rotation from one cycle to the next, by computing the product of the positive sequence current times the complex conjugate of the positive sequence current from the previous cycle:

$$\overline{\mathrm{Deviation}_k(n)} = \overline{I_{pos,k}(n)} - \overline{I_{pos,k}(n-N)}^*$$

The angle of the deviation phasor for each relay is proportional to the frequency deviation at that terminal. Since the clock synchronization method maintains frequency synchronism, the frequency deviation is approximately the same for each relay. The clock deviation frequency is computed from the deviation phasor:

$$\mathrm{FrequencyDeviation} = \frac{\Delta f}{f} = \frac{\tan^{-1}\left(\mathrm{Im}(\overline{\mathrm{Deviation}}) / \mathrm{Re}(\overline{\mathrm{Deviation}})\right)}{2\pi}$$

Note that a four quadrant arctangent can be computed by taking the imaginary and the real part of the deviation separately for the two arguments of the four quadrant arctangent. Also note that the input to the loop filter is in radian frequency which is two pi times the frequency in cycles per second:

$$\Delta\omega = 2\pi \cdot \Delta f$$

So the radian frequency deviation can be calculated simply as:

$$\Delta\omega = \Delta f \cdot \tan^{-1}\left(\mathrm{Im}(\overline{\mathrm{Deviation}}) / \mathrm{Re}(\overline{\mathrm{Deviation}})\right)$$

8.1.11 PHASE DETECTION

There are two separate sources of clock phase information; exchange of time stamps over the communications channels and the current measurements themselves (although voltage measurements can be used to provide frequency information, they cannot be used for phase detection). Current measurements can generally provide the most accurate information, but are not always available and may contain large errors during faults or switching transients. Time stamped messages are the most reliable source of phase information but suffer from a phase offset due to a difference in the channel delays in each direction between a pair of relays. In some cases, one or both directions may be switched to a different physical path, leading to gross phase error.

For two or three terminal systems, the approach is:

- The primary source of phase information is current measurements (when available) and the secondary source is the time-tagged messages. The filter uses a single input that is switched back and forth between the two sources of phase angle information. This makes the system immune to changes in communications delays as long as current information is available. The rules for switching between the sources are:
  - •Phase angle deviations from both current information and ping-long information are always computed. The ping-pong algorithm has a wider range of validity, and is used to help decide which source of phase angle information is to be used by the filter.
  - •Phase angle deviation computed from currents is used whenever it is valid. Otherwise, phase angle information from the ping-pong algorithm is used.
  - •Phase angle deviation computed from currents is deemed valid whenever the currents are large enough, and when the deviation computed from the ping-pong information is below a fixed threshold (this threshold is ± half-cycle.)

For four or more terminals, the approach is:

- The only source of phase information is the time tagged message exchange, which is used for clock adjustment.
- During start up, the relays measure the minimum round trip channel delay. Channel delay in each direction is assumed to be 1/2 the round trip delay.
- During operation, the phase error is estimated as half the absolute value of the difference between the round trip channel delay and the start-up value.

In both cases, frequency deviation information is also used whenever available. The phase difference between a pair of clocks is computed by an exchange of time stamps. Each relay exchanges time stamps with all other relays that can be reached.

It is not necessary to exchange stamps with every relay, and the method works even with some of the channels failed. For each relay that a given relay can exchange time stamps with, the clock deviation is computed each time a complete set of time stamps arrives. The net deviation is the total deviation divided by the total number of relays involved in the exchange.

For example, in the case of two terminals, each relay computes a single time deviation from time stamps, and divides the result by two. In the case of three terminals, each relay computes two time deviations and divides the result by three. If a channel is lost, the single deviation that remains is divided by two.

Four time stamps are needed to compute round trip delay time and phase deviation. Three stamps are included in the message in each direction. The fourth time stamp is the time when the message is received. Each time a message is received the oldest two stamps of the four time stamps are saved to become the first two time stamps of the next outgoing message. The third time stamp of an outgoing message is the time when the message is transmitted. A fixed time shift is allowed between the stamp values and the actual events, provided the shift for outgoing message time stamps is the same for all relays, and the shift incoming message time stamps is also identical.

To reduce bandwidth requirements, time stamps are spread over 3 messages. In the case of systems with 4 messages per cycle, time stamps are sent out on three of the four messages, so a complete set is sent once per cycle. In the case of systems with 1 message per cycle, three time stamps are sent out each cycle in a single message. The transmit and receive time stamps are based on the first message in the sequence.

One of the strengths of this approach is that it is not necessary to explicitly identify or match time stamp messages. Usually, two of the time stamps in an outgoing message are simply taken from the last incoming message. The third time stamp is the transmittal time. However, there are two circumstances when these time stamps are not available. One situation is when the first message is transmitted by a given relay. The second is when the exchange is broken long enough to invalidate the last received set of time stamps (if the exchange is broken for longer than 66 ms, the time stamps from a given clock could roll over twice, invalidating time difference computations). In either of these situations, the next outgoing set of time stamps is a special start-up set containing transmittal time only. When such a message is received, nothing is computed from it, except the message time stamp and the received time stamp are saved for the next outgoing message (it is neither necessary nor desirable to “reset” the local clock when such a message is received).

Error analysis shows that time stamp requirements are not very stringent because of the smoothing behavior of the phase locked loop. The time stamp can be basically a sample count with enough bits to cover the worst round trip, including channel delay and processing delay. An 8 bit time stamp with 1 bit corresponding to 1/64 of a cycle will accommodate a round trip delay of up to 4 cycles, which should be more than adequate.

The computation of round trip delay and phase offset from four time stamps is as follows:

$$a = T_{i-2} - T_{i-3}$$
$$b = T_i - T_{i-1}$$
$$\delta_i = a + b$$
$$\theta_i = \frac{a - b}{2}$$

The Ts are the time stamps, with Ti the newest. Delta is the round trip delay. Theta is the clock offset, and is the correct sign for the feedback loop. Note that the time stamps are unsigned numbers that wrap around while ‘a’ and ‘b’ could be positive or negative. Delta must be positive. Theta could be positive or negative. Some care must be taken in the arithmetic to take into account possible roll over of any of the time stamps. If Ti-2 is greater than Ti-1, there was a roll over in the clock responsible for those two time stamps.

To correct for the roll over, subtract 256 from the round trip and subtract 128 from the phase angle. If Ti-3 is greater than Ti, add 256 to the round trip and add 128 to the phase angle. Also, if the above equations are computed using integer values of time stamps, a conversion to phase angle in radians is required by multiplying by π over 32.

Time stamp values are snapshots of the local 256 bit sample counter taken at the time of the transmission or receipt of the first message in a time stamp sequence. This could be done either in software or hardware, provided the jitter is limited to less than plus or minus 130 μs. A fixed bias in the time stamp is acceptable, provided it is the same for all terminals.

Another source of phase information in the case of a 2 or 3 terminal system are the current measurements. In the case of a two terminal system, phase angle deviation at a terminal is computed as follows:

$$\phi_1(n) = \frac{1}{2} \cdot \tan^{-1}\left(\frac{-\text{Im}(\overline{\boldsymbol{I}_{pos,\,2}(n)} \cdot \overline{\boldsymbol{I}_{pos,\,1}(n)}^{*})}{-\text{Re}(\overline{\boldsymbol{I}_{pos,\,2}(n)} \cdot \overline{\boldsymbol{I}_{pos,\,1}(n)}^{*})}\right)$$

Again, it is possible to use a four quadrant arctangent, in which case the minus signs are needed on the imaginary and the real part as shown. The subscript 1 refers to the current at the local peer and the subscript 2 refers to the current at the remote peer.

In the case of a three terminal system, the phase deviation at each terminal is computed as:

$$\phi_1(n) = \frac{\text{Re}((\overline{\boldsymbol{I}_{pos,\,3}(n)} - \overline{\boldsymbol{I}_{pos,\,2}(n)}) \cdot (\overline{\boldsymbol{I}_{pos,\,1}(n)}^{*} + \overline{\boldsymbol{I}_{pos,\,2}(n)}^{*} + \overline{\boldsymbol{I}_{pos,\,3}(n)}^{*}))}{\text{Im}(\overline{\boldsymbol{I}_{pos,\,2}(n)} \cdot \overline{\boldsymbol{I}_{pos,\,1}(n)}^{*} + \overline{\boldsymbol{I}_{pos,\,3}(n)} \cdot \overline{\boldsymbol{I}_{pos,\,2}(n)}^{*} + \overline{\boldsymbol{I}_{pos,\,1}(n)} \cdot \overline{\boldsymbol{I}_{pos,\,3}(n)}^{*})}$$

Numbering of the terminals is not critical. Subscript 1 refers to the local peer. Subscripts 2 and 3 refer to the other 2 peers. Swapping 2 and 3, flips the sign of both the numerator and the denominator.

In the case of 4 or more terminals, no phase information can be derived from the current measurements.

Regarding timing of the computations, the latest available phase and frequency deviation information is furnished to the loop filter once per cycle in the case of a 64 Kbaud communications channel, and once every 3 cycles in the case of a 9600 baud communications channel.

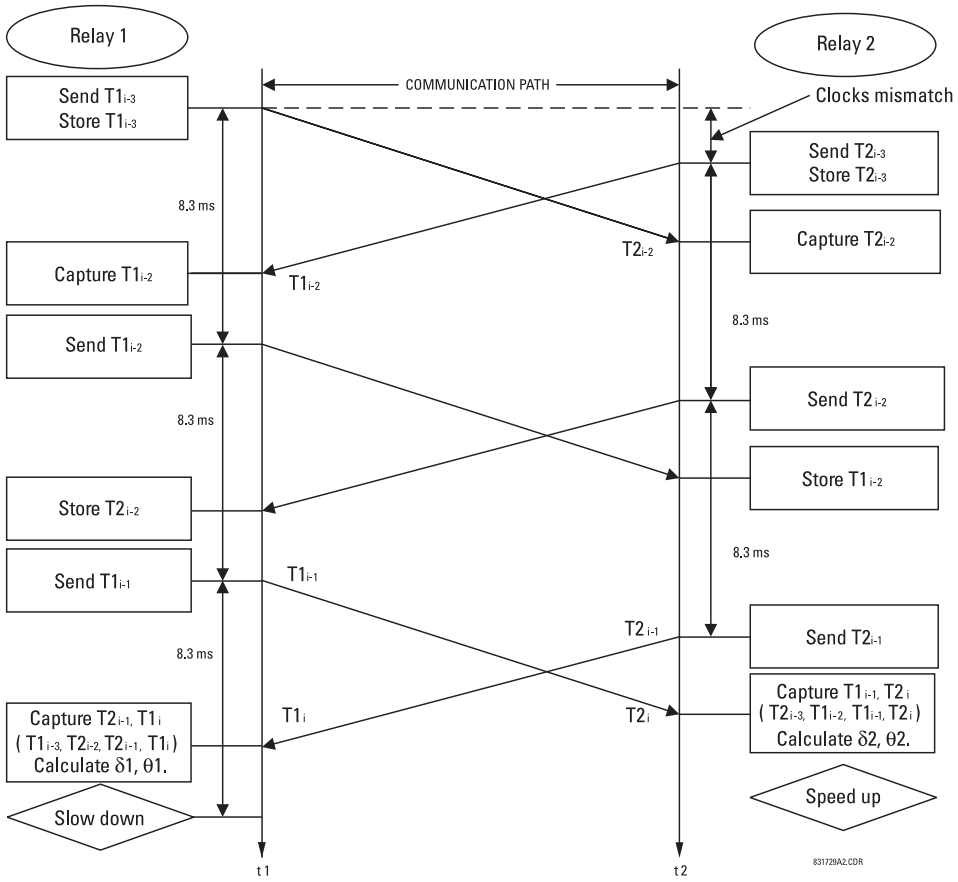


Figure 8–5: ROUND TRIP DELAY & CLOCK OFFSET COMPUTATION FROM TIME STAMPS

8.1.12 PHASE LOCKING FILTER

Filters are used in the phase locked loop to assure stability, to reduce phase and frequency noise. This is well known technology. The primary feedback mechanism shown in the Loop Block Diagram is phase angle information through the well known proportional plus integral (PI) filter. (The Z in the diagram refers to a unit delay, and 1 / (Z – 1) represents a simple digital first order integrator.) This loop is used to provide stability and zero steady state error. The filter is similar to the one described in reference [1], except in our application there is no need for an adaptive bandwidth. Also, we have extended the filter to include a frequency deviation input to provide frequency tracking.

A PI filter has two time parameters that determine dynamic behavior: the gain for the proportional term and the gain for the integral. Depending on the gains, the transient behavior of the loop can be underdamped, critically damped, or over damped. For this application, critically damped is a good choice.

This sets a constraint relating the two parameters. A second constraint is derived from the desired time constant of the loop. By considering the effects of both phase and frequency noise in this application it can be shown that optimum behavior results with a time constant for the main loop of about 10 seconds.

The primary loop uses a single input that is switched back and forth between the two sources of phase angle deviation which are; a) that computed from timestamps in the ping-pong algorithm and b) that computed from current measurements. This approach makes the current information the primary source, when it is available. This makes the system immune to changes in communications delays, as long as current information is available. The rules for switching are:

- Phase angle deviations from both current information and ping-pong information are always computed. The ping-pong algorithm has a wider range of validity, and is used to help decide which source of phase angle information is to be used by the filter.

- Phase angle deviation computed from currents is used whenever it is valid. Otherwise, phase angle information from the ping-pong algorithm is used.
- Phase angle deviation computed from currents is deemed valid whenever the currents are large enough, and when the deviation computed from the ping-pong information is below a fixed threshold (this threshold is plus or minus half-cycle).

A secondary loop is formed through the frequency deviation input of the filter. Whenever frequency deviation information is available, it is used for this input. Otherwise, the input is zero. Because frequency is the derivative of phase information, the appropriate filter for frequency deviation is simply an integrator, which is combined with the integrator of the PI filter for the phase. It is very important to combine these two integrators into a single function because it can be shown if two separate integrators are used, they can drift in opposite directions into saturation, because the loop would only drive their sum to zero.

In normal operation, frequency tracking at each terminal matches the tracking at all other terminals, because all terminals will measure approximately the same frequency deviation. However, if there is not enough current at a terminal to compute frequency deviation, frequency tracking at that terminal is accomplished indirectly via phase locking to other terminals. A small phase deviation must be present for the tracking to occur. To keep the deviation from exceeding the target of 0.01 radians, the slew rate of frequency tracking should be limited to about 0.0001 Hz per second. With a worst case step change of 0.1 Hz, the time constant of frequency tracking should be at least 1000 seconds.

Also shown in the loop is the clock itself, because it behaves like an integrator. The clock is implemented in hardware and software with a crystal oscillator and a counter.

Because the ratio of the time step of the integrators (1/60 second) to the shortest time constant (10 seconds) is so small (1/600), integrators can be implemented simply as the simple summations with a gain multiplier of the time step (1/60 second).

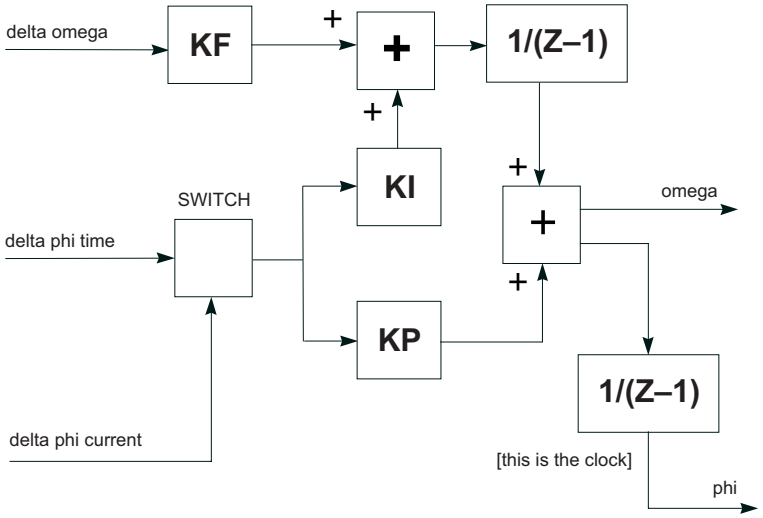


Figure 8–6: BLOCK DIAGRAM OF LOOP FILTER

There are 4 gains in the filter that must be selected once and for all as part of the design of the system. The gains are determined by the time step of the integrators, and the desired time constants of the system as follows:

$$KI = \frac{T_{repeat}}{T_{phase}^2}$$

$$KP = \frac{2}{T_{phase}}$$

$$KF = \frac{T_{repeat}}{T_{frequency}}$$

where: T_{repeat} = the time between execution of the filter algorithm
T_{phase} = time constant for the primary phase locked loop
$T_{frequency}$ = time constant for the frequency locked loop

The recommended time constants are 10 seconds for the time stamp phase locking, and 1000 seconds for frequency tracking. The time step for the integrators is 1/60 of a second, so all of the integrator gains are small.

8.1.13 CLOCK IMPLEMENTATION

Another new invention in the L90 relay system is the clock. Using the conventional approach to implementing a digital clock to achieve the desired goal for phase uncertainty of 0.01 radians. A variation of the concept used in sigma delta modulation can be used to greatly extend the effective resolution of the clock. For example, it is possible to get the effective resolution of a 32 bit counter and a 400 GHz oscillator without much trouble.

The concept is to implement a fractional count. The concept as applied in the L90 digital current differential relay is discussed below:

The existing crystal clock and 16 bit counter are used to control both time stamping and data sampling. The counter is loaded with a desired period, which is in effect for four data samples. Each time the period is counted out, data is sampled. After 4 samples (1/16 of a cycle), the counter is reloaded, possibly with a new value. The new idea is implemented completely in software.

Time periods between data samples are computed as a 32 bit multiple of the period of the clock, with a 16 bit integer and a 16 fraction. Two separate 16 bit registers are used to control the clock. One register controls the integer portion of the time period, the other is used to control the fractional portion. The integer register is used to reload the hardware counter every four samples.

There are two possible reload values for the counter: either the value in the integer register is used directly, or one is added to it, depending on the contents of the fraction register. The fraction register is used to carry a running total of the fractional portion of the desired time period. Each time the hardware counter is reloaded, the fractional portion of the desired period is added to the fractional register, occasionally generating a carry. Whenever a carry is generated, the counter reload value for the next period is increased by one for that period only. The fractional register is never reset, even when the desired period changes. Other clock related functions include time stamps and sequence numbers.

Phase noise analysis indicates that not many bits are needed for time stamps because of the smoothing effects of the loop filter. Basically, a simple integer count of the number of samples is adequate. That is, a resolution of 260 microseconds in the time stamps is adequate. Assuming a worst round trip channel delay of 4 cycles, an 8 bit counter is adequate for time stamping. Every 1/64 of a cycle when data is sampled, an 8 bit counter should be incremented and allowed to simply roll over to 0 after a count of 255 which should occur exactly every 4 cycles at the beginning of the cycle. Whenever a time stamp is needed, the time stamp counter is simply read.

A message sequence number is also needed with a granularity of 1/2 cycle. A message sequence number can be simply extracted from the 4 high order bits of the time stamp counter. Since the time stamps may or may not have any relationship to the message sequence number in a message, both are needed.

8.1.14 MATCHING PHASELETS

An algorithm is needed to match phaselets, detect lost messages, and detect communications channel failure. Channel failure is defined by a sequence of lost messages, where the length of the sequence is a design parameter. In any case, the sequence should be no longer than the maximum sequence number (4 cycles) in order to be able to match up messages when the channel is assumed to be operating normally.

A channel failure can be simply detected by a watchdog software timer which times the interval between consecutive incoming messages. If the interval exceeds a maximum limit, channel failure is declared and the channel recovery process is initiated.

While the channel is assumed to be operating normally, it is still possible for an occasional message to be lost, in which case fault protection is suspended for the time period that depends on that message, and is resumed on the next occasional message. A lost message is detected simply by looking at the sequence numbers of incoming messages. A lost message will show up as a gap in the sequence.

Sequence numbers are also used to match messages for the protection computation. Whenever a complete set of current measurements from all terminals with matching sequence numbers are available, the differential protection function is computed using that set of measurements.

8.1.15 START-UP

Initialization in our peer to peer architecture is done independently at each terminal. Relays can be turned on in any order with the power system either energized or de-energized. Synchronization and protection functions are accomplished automatically whenever enough information is available.

After a relay completes other initialization tasks such as resetting of buffer pointers and determining relay settings, initial values are computed for any state variables in the loop filters or the protection functions. The relay starts its clock at the nominal power system frequency. Phaselet information is computed and transmitted.

- Outgoing messages over a given channel are treated in the same way as during the channel recovery process. The special start-up message is sent each time containing only a single time step value.
- When incoming messages begin arriving over a channel, that channel is placed in service and the loop filters are started up for that channel.
- Whenever the total clock uncertainty is less than a fixed threshold, the phase locking filter is declared locked and differential protection is enabled.

8.1.16 HARDWARE AND COMMUNICATION REQUIREMENTS

The average total channel delay in each direction is not critical, provided the total round trip delay is less than 4 power system cycles. The jitter is important, and should be less than plus or minus 130 microseconds in each direction. The effect of a difference in the average delay between one direction and the other depends on the number of terminals. In the case of a 2 or 3 terminal system, the difference is not critical, and can even vary with time. In the case of a 4 or more terminal system, variation in the difference limits the sensitivity of the system.

- The allowable margin of 130 microseconds jitter includes jitter in servicing the interrupt generated by an incoming message. For both incoming and outgoing messages, the important parameter is the jitter between when the time stamp is read and when the message begins to go out or to come in.
- The quality of the crystal driving the clock and software sampling is not critical, because of the compensation provided by the phase and frequency tracking algorithm, unless it is desired to perform under or over frequency protection. From the point of view of current differential protection only, the important parameter is the rate of drift of crystal frequency, which should be less than 100 parts per million per minute.
- A 6 Mhz clock with a 16 bit hardware counter is adequate, provided the method is used for achieving the 32 bit resolution that is described in this document.
- An 8 bit time stamp is adequate provided time stamp messages are exchanged once per cycle.
- A 4 bit message sequence number is adequate.

Channel asymmetry (the difference in the transmitting and receiving paths channel delay) cannot be higher than 1 to 1.5 ms.

8.1.17 ON-LINE ESTIMATE OF MEASUREMENT ERRORS

GE's adaptive elliptical restraint characteristic is a good approximation to the cumulative effects of various sources of error in determining phasors. Sources of error include power system noise, transients, line charging current, current sensor gain, phase and saturation error, clock error, and asynchronous sampling. Errors that can be controlled are driven to zero by the system. For errors that cannot be controlled, the master computes the covariance matrix for each source of error for each phase. A total covariance matrix is computed for each phase by adding the matrices from each source.

The system computes the covariance matrix for errors caused by power system noise, harmonics, and transients. These errors arise because power system currents are not always exactly sinusoidal. The intensity of these errors varies with time, growing during fault conditions, switching operations, or load variations, for example. The system treats these errors as a Gaussian distribution in the real and in the imaginary part of each phasor, with a standard deviation that is estimated from the sum of the squares of the differences between the data samples and the sine function that is used to fit them. This error has a spectrum of frequencies. Current transformer saturation is included with noise and transient error.

The covariance matrix for noise, harmonics, transients, and current transformer saturation is computed as follows. First, the sum of the squares of the errors in the data samples is computed from the sum of squares information, phaselets, and phasors for each phase for each terminal at each time step *n*:

$$E_n^2 = \text{SumOfSquares}_n - (\text{Re}(\text{PhaseletSum}_n) \cdot \text{Re}(\text{Phasor}_n) + \text{Im}(\text{PhaseletSum}_n) \cdot \text{Im}(\text{Phasor}_n))$$

The covariance matrix is then computed as a function of the time index and window size using the previously defined transformation.

8.1.18 CT SATURATION DETECTION

Current differential protection is inherently dependent on adequate CT performance at all terminals of the protected line especially during external faults. CT saturation, particularly if happens at one terminal of the line only, introduces a spurious differential current that may cause the differential protection to misoperate.

The L90 applies a dedicated mechanism to cope with CT saturation and ensure security of the protection for external faults. The relay dynamically increases the weight of the square of errors (so-called sigma) portion in the total restraint quantity but for external faults only.

The following logic is applied:

- First, the terminal currents are compared against a threshold of 3 pu to detect overcurrent conditions that may be caused by a fault and may lead to CT saturation.
- For all the terminal currents that are above the 3 pu level, the relative angle difference is calculated. If all three terminals see significant current, then all three pairs (1, 2), (2, 3), and (1, 3) are considered and the maximum angle difference is used in further calculations.
- Depending on the angle difference between the terminal currents, the value of sigma used to calculate the adaptive restraint current is increased by the factor of 1, 3 or 5 as shown in the figure below. As it is seen from the figure, for internal faults factor "1" is used, but for external-"3" or "5". This allows relay to be sensitive for internal faults while robust for external faults with a possible CT saturation.

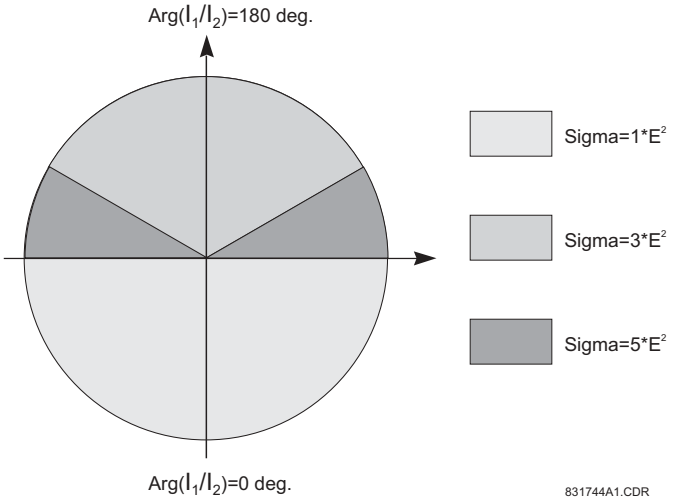


Figure 8–7: CT SATURATION ADAPTIVE RESTRAINT MULTIPLIER

8.1.19 CHARGING CURRENT COMPENSATION

The basic premise for the operation of differential protection schemes in general, and of the L90 line differential element in particular, is that the sum of the currents entering the protected zone is zero. In the case of a power system transmission line, this is not entirely true because of the capacitive charging current of the line. For short transmission lines the charging current is a small factor and can therefore be treated as an unknown error. In this application the L90 can be deployed without voltage sensors and the line charging current is included as a constant term in the total variance, increasing the differential restraint current. For long transmission lines the charging current is a significant factor, and should be computed to provide increased sensitivity to fault current.

Compensation for charging current requires the voltage at the terminals be supplied to the relays. The algorithm calculates $C \times dv/dt$ for each phase, which is then subtracted from the measured currents at both ends of the line. This is a simple approach that provides adequate compensation of the capacitive current at the fundamental power system frequency. Travelling waves on the transmission line are not compensated for, and contribute to restraint by increasing the measurement of errors in the data set.

The underlying single phase model for compensation for a two and three terminal system are shown below.

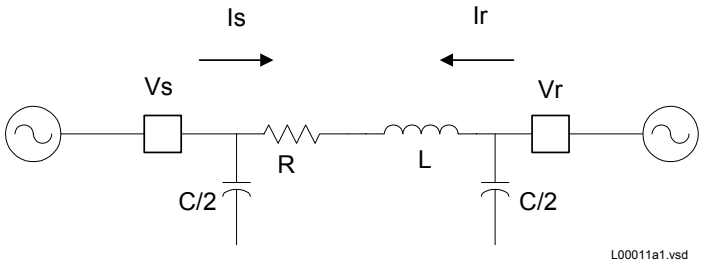


Figure 8–8: 2-TERMINAL TRANSMISSION LINE SINGLE PHASE MODEL FOR COMPENSATION

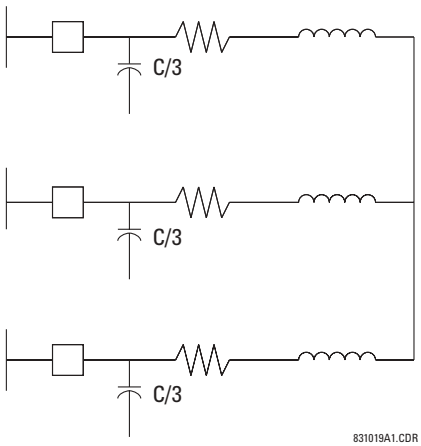


Figure 8–9: 3-TERMINAL TRANSMISSION LINE SINGLE PHASE MODEL FOR COMPENSATION

Apportioning the total capacitance among the terminals is not critical for compensation of the fundamental power system frequency charging current as long as the total capacitance is correct. Compensation at other frequencies will be approximate.

If the VTs are connected in wye, the compensation is accurate for both balanced conditions (i.e. all positive, negative and zero sequence components of the charging current are compensated). If the VTs are connected in delta, the compensation is accurate for positive and negative sequence components of the charging current. Since the zero sequence voltage is not available, the L90 cannot compensate for the zero sequence current.

The compensation scheme continues to work with the breakers open, provided the voltages are measured on the line side of the breakers.

For very long lines, the distributed nature of the line leads to the classical transmission line equations which can be solved for voltage and current profiles along the line. What is needed for the compensation model is the effective positive and zero sequence capacitance seen at the line terminals.

Finally, in some applications the effect of shunt reactors needs to be taken into account. With very long lines shunt reactors may be installed to provide some of the charging current required by the line. This reduces the amount of charging current flowing into the line. In this application, the setting for the line capacitance should be the residual capacitance remaining after subtracting the shunt inductive reactance from the total capacitive reactance at the power system frequency.

8.1.20 DIFFERENTIAL ELEMENT CHARACTERISTICS

The differential element is completely dependent on receiving data from the relay at the remote end of the line, therefore, upon startup, the differential element is disabled until the time synchronization system has aligned both relays to a common time base. After synchronization is achieved, the differential is enabled. Should the communications channel delay time increase, such as caused by path switching in a SONET system or failure of the communications power supply, the relay will act as outlined in the next section.

The L90 incorporates an adaptive differential algorithm based on the traditional percent differential principle. In the traditional percent differential scheme, the operating parameter is based on the phasor sum of currents in the zone and the restraint parameter is based on the scalar (or average scalar) sum of the currents in the protected zone - when the operating parameter divided by the restraint parameter is above the slope setting, the relay will operate. During an external fault, the operating parameter is relatively small compared to the restraint parameter, whereas for an internal fault, the operating parameter is relatively large compared to the restraint parameter. Because the traditional scheme is not adaptive, the element settings must allow for the maximum amount of error anticipated during an out-of-zone fault, when CT errors may be high and/or CT saturation may be experienced.

The major difference between the L90 differential scheme and a percent differential scheme is the use of an estimate of errors in the input currents to increase the restraint parameter during faults, permitting the use of more sensitive settings than those used in the traditional scheme. The inclusion of the adaptive feature in the scheme produces element characteristic equations that appear to be different from the traditional scheme, but the differences are minimal during system steady-state conditions. The element equations are shown in the OPERATING CONDITION CALCULATIONS section.

8.1.21 RELAY SYNCHRONIZATION

On startup of the relays, the channel status will be checked first. If channel status is OK, and BER and CRC values are below their limits, all relays will send a special "startup" message and the synchronization process will be initiated. It will take about 2 minutes to declare PFLL status as OK and to start performing current differential calculations. If one of the relays was powered off during the operation, the synchronization process will restart from the beginning. Relays tolerate channel delay (resulting sometimes in step change in communication paths) or interruptions up to 4 power cycles round trip time (about 66 ms at 60 Hz) without any deterioration in performance. If communications are interrupted for more than 4 cycles, the following applies:

In 2-terminal mode:

1. With second redundant channel, relays will not lose functionality at all if second channel is live.
2. With one channel only, relays have a 5 second time window. If the channel is restored within this time, it takes about 2-3 power cycles of valid PFLL calculations (and if estimated error is still within margin) to declare that PFLL is OK. If the channel is restored later than 5 seconds, PFLL at both relays will be declared as failed and the re-synch process will be initiated (about 2 minutes) after channel status becomes OK.

In 3-terminal mode:

1. If one of the channels fails, the configuration reverts from Master-Master to Master-Slave where the Master relay has both channels live. The Master relay PFLL keeps the 2 Slave relays in synchronization, and therefore there is no time limit for functionality. The PFLL of the Slave relays will be "suspended" (87L function will not be performed at these relays but they can still trip via DTT from the Master relay) until the channel is restored. If the estimated error is within margin upon channel restoration and after 2-3 power cycles of valid PFLL calculations, the PFLL will be declared as OK and the configuration will revert back to Master-Master.
2. If 2 channels fail, PFLL at all relays will be declared as failed and when the channels are back into service, the re-synch process will be initiated (about 2 minutes) after channel status becomes OK.

Depending on the system configuration (number of terminals and channels), the 87L function operability depends on the status of channel(s), status of synchronization, and status of channel(s) ID validation. All these states are available as FlexLogic™ operands, for viewing in Actual Values, logged in the event recorder (if events are enabled in 87L menu), and also trigger Targets (if targets are enabled in 87L menu). These FlexLogic™ operands are readily to be used to trigger alarm, lit LED and to be captured in oscillography.

There is, however, a single FlexLogic™ operand 87L BLOCKED, reflecting whether or not the local current differential function is blocked due to communications or settings problems. The state of this operand is based on the combination of conditions outlined above and it is recommended that it be used to enable backup protection if 87L is not available.

The FlexLogic™ operand 87L BLOCKED is set when the 87L function is enabled and any of the following three conditions apply:

1. Channel fail as indicated below:
    - At least one channel failed either at 3 Terminal or 2 Terminal-1 Channel systems.
    - Both channels failed at 2 Terminal-2 Channels
2. PFFL fail or suspended,
3. Channel ID failure detected on at least one channel at either system.

8.2.1 DEFINITIONS

I_{op}^2 = Operating parameter

I_{rest}^2 = Restraining parameter

$\overrightarrow{I\_L}$ = Local current phasor

$\overrightarrow{I\_R}$ = Remote current phasor

$S1$ = Slope 1 factor

$S2$ = Slope 2 factor

P = Pickup setting

BP = Breakpoint between 2 slopes

σ_{loc} = Dynamic correction factor for local phasor error estimated by the covariance matrix

σ_{rem} = Dynamic correction factor for remote phasor error estimated by the covariance matrix

$\overrightarrow{I\_R1}$ = Remote 1 current phasor

$\overrightarrow{I\_R2}$ = Remote 2 current phasor

σ_{rem1} = Dynamic correction factor for remote 1 phasor error estimated by the covariance matrix

σ_{rem2} = Dynamic correction factor for remote 2 phasor error estimated by the covariance matrix

where (see Section 8.1.18)

$$\sigma = \text{SumOfSquares}_n - (\text{Re}(\text{PhaseletSum}_n) \cdot \text{Re}(\text{Phasor}_n) + \text{Im}(\text{PhaseletSum}_n) \cdot \text{Im}(\text{Phasor}_n))$$

Trip Condition: $\frac{I_{op}^2}{I_{rest}^2} > 1$; Restraint Condition: $\frac{I_{op}^2}{I_{rest}^2} \le 1$

NOTE

The relays at all terminals are arranged so that current into the protected circuit is defined as 'positive flow'. This means that on a two terminal installation with a through current flow, a given phase current angle will be different by 180°. For this condition, the angle of the terminal with flow into the line could be 0° and the other terminal would be 180°.

8.2.2 2 TERMINAL MODE

The operating parameter is estimated with the following equation:

$$I_{op}^2 = \left|\overrightarrow{I\_L} + \overrightarrow{I\_R}\right|^2$$

The restraining parameter I_{rest}^2 is calculated with one of the following four equations depending on which corresponding condition is met:

1. If $\left|\overrightarrow{I\_L}\right| < \text{BP}$ and $\left|\overrightarrow{I\_R}\right| < \text{BP}$
   then $I_{rest}^2 = 2 \cdot S1^2 \cdot |I\_L|^2 + 2 \cdot S1^2 \cdot |I\_R|^2 + 2 \cdot P^2 + \sigma_{loc} + \sigma_{rem}$

2. If $\left|\overrightarrow{I\_L}\right| > \text{BP}$ and $\left|\overrightarrow{I\_R}\right| < \text{BP}$
   then $I_{rest}^2 = 2 \cdot S2^2 \cdot (|I\_L|^2 - \text{BP}^2) + 2 \cdot S1^2 \cdot \text{BP}^2 + 2 \cdot S1^2 \cdot |I\_R|^2 + 2 \cdot P^2 + \sigma_{loc} + \sigma_{rem}$

3. If $\left|\overrightarrow{I\_L}\right| < \text{BP}$ and $\left|\overrightarrow{I\_R}\right| > \text{BP}$

then $I_{rest}^2 = 2 \cdot S1^2 \cdot |I\_L|^2 + 2 \cdot S2^2 \cdot (|I\_R|^2 - BP^2) + 2 \cdot S1^2 \cdot BP^2 + 2 \cdot P^2 + \sigma_{loc} + \sigma_{rem}$

4. If $|\overrightarrow{I\_L}| > BP$ and $|\overrightarrow{I\_R}| > BP$
   then $I_{rest}^2 = (|I\_L|^2 - BP^2) + 2 \cdot S2^2 \cdot (|I\_R|^2 - BP^2) + 4 \cdot S1^2 \cdot BP^2 + 2 \cdot P^2 + \sigma_{loc} + \sigma_{rem}$

b) 3 TERMINAL MODE

Operating conditions are estimated with the following equation:

$$I_{op}^2 = |\overrightarrow{I\_L} + \overrightarrow{I\_R1} + \overrightarrow{I\_R2}|^2$$

I_{rest}^2 is calculated with one of the following 8 equations depending on which corresponding condition is met:

1. If $|\overrightarrow{I\_L}| < BP$ and $|\overrightarrow{I\_R1}| < BP$ and $|\overrightarrow{I\_R2}| < BP$
   then $I_{rest}^2 = \frac{4}{3}((S1^2 \cdot |I\_L|^2) + (S1^2 \cdot |I\_R1|^2) + (S1^2 \cdot |I\_R2|^2)) + 2P^2 + \frac{2}{3}(\sigma_{loc} + \sigma_{rem1} + \sigma_{rem2})$

2. If $|\overrightarrow{I\_L}| > BP$ and $|\overrightarrow{I\_R1}| < BP$ and $|\overrightarrow{I\_R2}| < BP$, then

$$I_{rest}^2 = \frac{4}{3}((S2^2 \cdot (|I\_L|^2 - BP^2)) + (S1^2 \cdot |I\_R1|^2) + (S1^2 \cdot |I\_R2|^2) + (S1^2 \cdot BP^2)) + 2P^2 + \frac{2}{3}(\sigma_{loc} + \sigma_{rem1} + \sigma_{rem2})$$

3. If $|\overrightarrow{I\_L}| > BP$ and $|\overrightarrow{I\_R1}| > BP$ and $|\overrightarrow{I\_R2}| < BP$, then

$$I_{rest}^2 = \frac{4}{3}((S2^2 \cdot (|I\_L|^2 - BP^2)) + (S2^2 \cdot (|I\_R1|^2 - BP^2)) + (S1^2 \cdot |I\_R2|^2) + 2(S1^2 \cdot BP^2)) + 2P^2 + \frac{2}{3}(\sigma_{loc} + \sigma_{rem1} + \sigma_{rem2})$$

4. If $|\overrightarrow{I\_L}| > BP$ and $|\overrightarrow{I\_R1}| > BP$ and $|\overrightarrow{I\_R2}| > BP$, then

$$I_{rest}^2 = \frac{4}{3}((S2^2 \cdot (|I\_L|^2 - BP^2)) + (S2^2 \cdot (|I\_R1|^2 - BP^2)) + (S2^2 \cdot (|I\_R2|^2 - BP^2)) + 3(S1^2 \cdot BP^2)) + 2P^2 + \frac{2}{3}(\sigma_{loc} + \sigma_{rem1} + \sigma_{rem2})$$

5. If $|\overrightarrow{I\_L}| < BP$ and $|\overrightarrow{I\_R1}| > BP$ and $|\overrightarrow{I\_R2}| > BP$, then

$$I_{rest}^2 = \frac{4}{3}((S1^2 \cdot |I\_L|^2) + (S2^2 \cdot (|I\_R1|^2 - BP^2)) + (S2^2 \cdot (|I\_R2|^2 - BP^2)) + 2(S1^2 \cdot BP^2)) + 2P^2 + \frac{2}{3}(\sigma_{loc} + \sigma_{rem1} + \sigma_{rem2})$$

6. If $|\overrightarrow{I\_L}| < BP$ and $|\overrightarrow{I\_R1}| < BP$ and $|\overrightarrow{I\_R2}| > BP$, then

$$I_{rest}^2 = \frac{4}{3}((S1^2 \cdot |I\_L|^2) + (S1^2 \cdot |I\_R1|^2) + (S2^2 \cdot (|I\_R2|^2 - BP^2)) + (S1^2 \cdot BP^2)) + 2P^2 + \frac{2}{3}(\sigma_{loc} + \sigma_{rem1} + \sigma_{rem2})$$

7. If $|\overrightarrow{I\_L}| > BP$ and $|\overrightarrow{I\_R1}| < BP$ and $|\overrightarrow{I\_R2}| > BP$, then

$$I_{rest}^2 = \frac{4}{3}((S2^2 \cdot (|I\_L|^2 - BP^2)) + (S1^2 \cdot |I\_R1|^2) + (S2^2 \cdot (|I\_R2|^2 - BP^2)) + 2(S1^2 \cdot BP^2)) + 2P^2 + \frac{2}{3}(\sigma_{loc} + \sigma_{rem1} + \sigma_{rem2})$$

8. If $|\overrightarrow{I\_L}| < BP$ and $|\overrightarrow{I\_R1}| > BP$ and $|\overrightarrow{I\_R2}| < BP$, then

$$I_{rest}^2 = \frac{4}{3}((S1^2 \cdot |I\_L|^2) + (S2^2 \cdot (|I\_R1|^2 - BP^2)) + (S1^2 \cdot |I\_R2|^2) + (S1^2 \cdot BP^2)) + 2P^2 + \frac{2}{3}(\sigma_{loc} + \sigma_{rem1} + \sigma_{rem2})$$

Characteristics of differential elements can be shown in the complex plane. The operating characteristics of the L90 are fundamentally dependant on the relative ratios of the local and remote current phasor magnitudes and the angles of σ_{loc} / σ_{rem} as shown in the following figure (RESTRAINT CHARACTERISTICS).

The main factors affecting the trip-restraint decisions are:

1. Difference in angles (+ real represents pure internal fault when currents are essentially in phase, – real represents external fault when currents are 180° apart).
2. The magnitude of remote current.
3. The magnitude of the local current.
4. Dynamically estimated errors in calculations.
5. Settings.

The following figure also shows the relay's capability to handle week-infeed conditions by increasing the restraint ellipse when the remote current is relatively small (1.5 pu). Therefore, uncertainty is greater when compared with higher remote currents (3 pu). The characteristic shown is also dependant on settings. The second graph shows how the relay's trip-restraint calculation is made with respect to the variation in angle difference between local and remote currents. The characteristic for 3 terminal mode is similar where both remote currents are combined together.

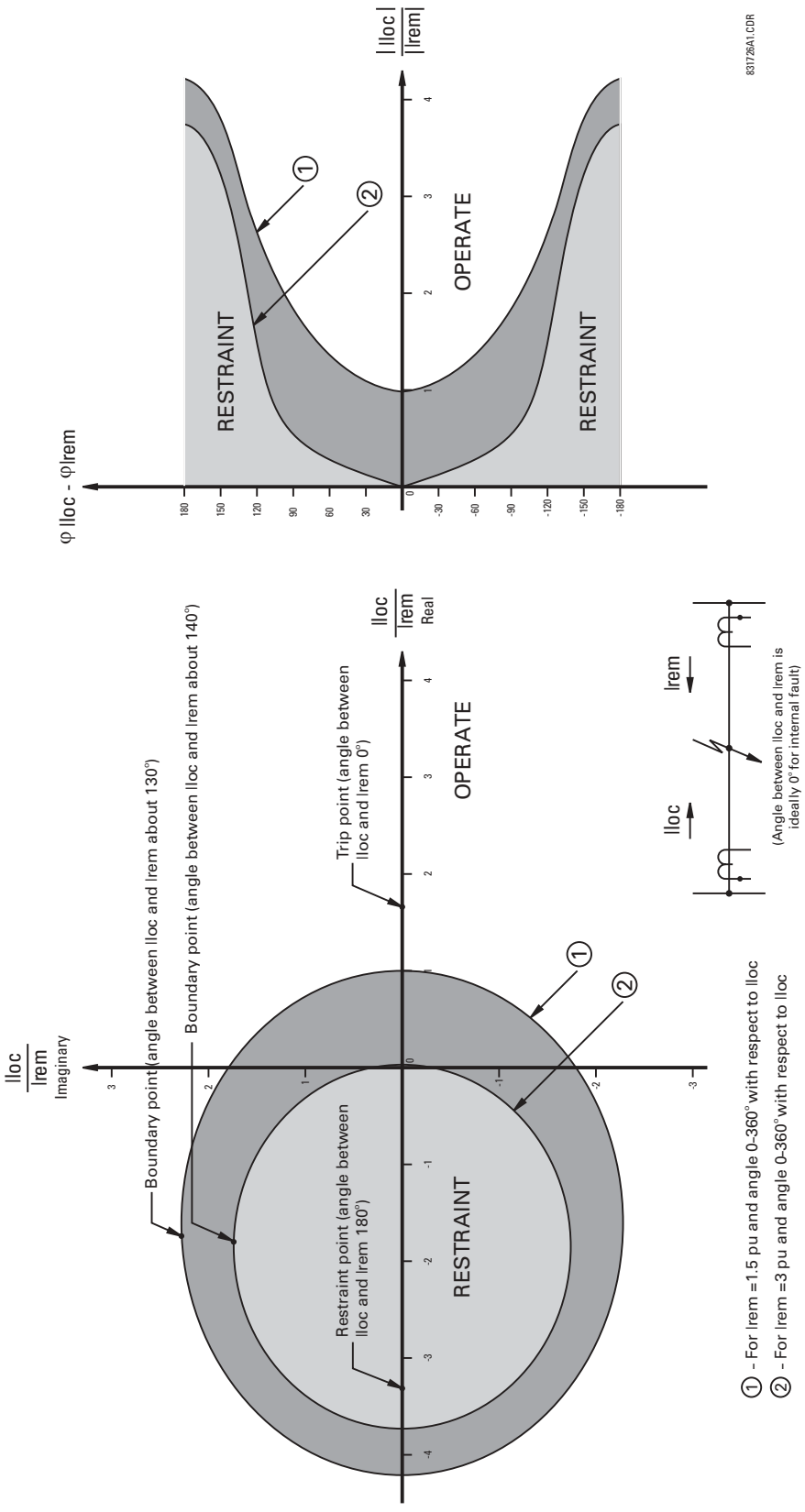


Figure 8–10: RESTRAINT CHARACTERISTICS

8.2.3 TRIP DECISION EXAMPLE

Settings: *S1* = 10%, *S2* = 10%, BP = 5 pu secondary, *P* = 0.5 pu

Assumed Current: *I*_L= 4.0 pu ∠0°, *I*_R= 0.8 pu ∠0°

The assumed condition is a radial line with a high resistance fault, source at the local end only, and through resistive load current.

$$I_{op}^2 = |I\_L + (-I\_R)|^2 = |4.0\angle 0° + 0.8\angle 0°|^2 = 23.04$$

As the current at both ends is less than the breakpoint of 5.0, equation (1), for 2-terminal mode, is used to calculate restraint.

$$\begin{aligned} I_{Rest}^2 &= (2 \cdot S_1^2 \cdot |I\_L|^2) + (2 \cdot S_1^2 \cdot |I\_R|^2) + 2P^2 + \sigma \\ &= (2 \cdot (0.1)^2 \cdot |4|^2) + (2 \cdot (0.1)^2 \cdot |0.8|^2) + 2 \cdot (0.5)^2 + 0 \\ &= 0.8328 \end{aligned}$$

where $\sigma = 0$, assuming a pure sine wave.

8.2.4 TRIP DECISION TEST

$$\frac{I_{Op}^2}{I_{Rest}^2} > 1 \Rightarrow \frac{23.04}{0.8328} = 27.67 > 1 \Rightarrow \text{Trip}$$

The use of the CURRENT DIFF PICKUP, CURRENT DIFF RESTRAINT 1, CURRENT DIFF RESTRAINT 2, and CURRENT DIFF BREAK PT are discussed in the SETTINGS chapter.

The following figure shows how the relay's main settings are affecting the restraint characteristics. Remote and local currents are 180° apart which represent an external fault. The breakpoint between two slopes indicates the point where the restraint area is becoming wider to override uncertainties coming from CT saturation, fault noise, harmonics etc. Increasing the slope percentage makes the restraint area wider.

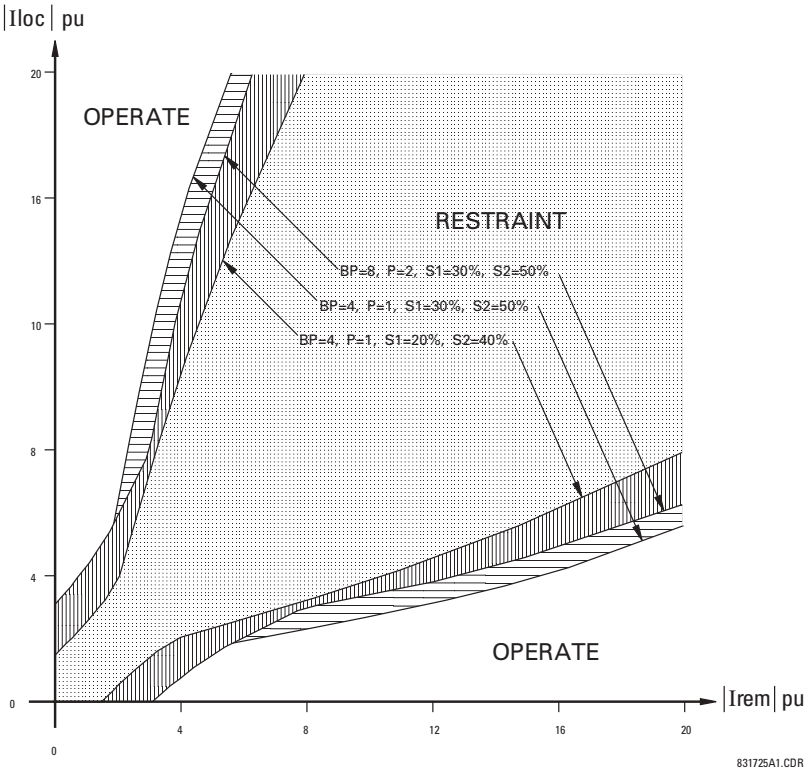


Figure 8–11: SETTINGS IMPACT ON RESTRAINT CHARACTERISTIC

9.1.1 INTRODUCTION

In general, proper selection of CTs is required to provide both adequate fault sensitivity and prevention of operation on high-current external faults that could result from CT saturation. The use of high quality CTs, such as class X, improves relay stability during transients and CT saturation, and can increase relay sensitivity. A current differential scheme is highly dependent on adequate signals from the source CTs. Ideally, CTs used for line current differential should be chosen based on good application practice as described below. If the available CTs do not meet the described criteria, the L90 will still provide good security for CT saturation for external faults. Its adaptive restraint characteristics, based on estimates of measurement errors and CT saturation detection, allow the relay to be secure on external faults while maintaining excellent performance for severe internal faults. Where CT characteristics do not meet criteria or where CTs at both ends may have different characteristics, the differential settings should be adjusted as per Section 9.2.1.

The capability of the CTs, and the connected burden, should be checked as follows:

1. The CTs should be class TPX or TPY (class TPZ should only be used after discussion with both the manufacturer of the CT and GE Multilin) or IEC class 5P20 or better.
2. The CT primary current rating should be somewhat higher than the maximum continuous current, but not extremely high relative to maximum load because the differential element minimum sensitivity setting is approximately 0.2 × CT rating (the L90 relay allows for different CT ratings at each of the terminals).
3. The VA rating of the CTs should be above the Secondary Burden × CT Rated Secondary Current. The maximum secondary burden for acceptable performance is:

$$R_b + R_r < \frac{\text{CT Rated VA}}{(\text{CT Secondary } I_{rated})^2}$$

   where: R_b = total (two-way) wiring resistance plus any other load
   R_r = relay burden at rated secondary current

4. The CT kneepoint voltage (per the V_k curves from the manufacturer) should be higher than the maximum secondary voltage during a fault. This can be estimated by:

$$V_k > I_{fp} \times \left(\frac{X}{R} + 1\right) \times (R_{CT} + R_L + R_r) \quad \text{for phase-phase faults}$$

$$V_k > I_{fg} \times \left(\frac{X}{R} + 1\right) \times (R_{CT} + 2R_L + R_r) \quad \text{for phase-ground faults}$$

   where: I_{fp} = maximum secondary phase-phase fault current
   I_{fg} = maximum secondary phase-ground fault current
   X / R = primary system reactance / resistance ratio
   R_{CT} = CT secondary winding resistance
   R_L = AC secondary wiring resistance (one-way)

9.1.2 CALCULATION EXAMPLE 1

To check performance of a class C400 ANSI/IEEE CT, ratios 2000/1800/1600/1500 : 5 A connected at 1500:5, and where:

- maximum I_{fp} = 14 000 A
- maximum I_{fg} = 12 000 A
- impedance angle of source and line = 78°
- CT secondary leads are 75 m of AWG No. 10.

BURDEN CHECK:

ANSI/IEEE class C400 requires that the CT can deliver 1 to 20 times the rated secondary current to a standard B-4 burden (4 Ω or lower) without exceeding a maximum ratio error of 10%.

The maximum allowed burden at the 1500/5 tap is $(1500/2000) \times 4 = 3\ \Omega$. Now,

$$R_{CT} = 0.75\ \Omega$$

$$R_r = \frac{0.2\ \text{VA}}{(5\ \text{A})^2} = 0.008\ \Omega$$

$$R_L = 2 \times 75\ \text{m} \times \frac{3.75\ \Omega}{1000\ \text{m}} = 2 \times 0.26\ \Omega = 0.528\ \Omega$$

Therefore, the Total Burden $= R_{CT} + R_r + R_L = 0.75\ \Omega + 0.008\ \Omega + 0.52\ \Omega = 1.28\ \Omega$. This is less than the allowed 3 Ω, which is OK.

KNEEPOINT VOLTAGE CHECK:

The maximum voltage available from the CT $= (1500/2000) \times 400 = 300\ \text{V}$.

The system X/R ratio $= \tan 78° = 4.71$.

The CT Voltage for maximum phase fault is:

$$V = \frac{14000\ \text{A}}{\text{ratio of 300:1}} \times (4.71 + 1) \times (0.75 + 0.26 + 0.008\ \Omega) = 271.26\ \text{V}\ (< 300\ \text{V, which is OK})$$

The CT Voltage for maximum ground fault is:

$$V = \frac{12000\ \text{A}}{\text{ratio of 300:1}} \times (4.71 + 1) \times (0.75 + 0.52 + 0.008\ \Omega) = 291.89\ \text{V}\ (< 300\ \text{V, which is OK})$$

The CT will provide acceptable performance in this application.

9.1.3 CALCULATION EXAMPLE 2

To check the performance of an IEC CT of class 5P20, 15 VA, ratio 1500:5 A, assume identical parameters as for Example Number 1.

BURDEN CHECK:

The IEC rating requires the CT deliver up to 20 times the rated secondary current without exceeding a maximum ratio error of 5%, to a burden of:

$$\text{Burden} = \frac{15\ \text{VA}}{(5\ \text{A})^2} = 0.6\ \Omega \text{ at the 5 A rated current}$$

The total Burden = $R_r + R_l$ = 0.008 + 0.52 = 0.528 Ω, which is less than the allowed 0.6 Ω, which is OK.

KNEEPOINT VOLTAGE CHECK:

Use the procedure shown for Example Number 1 above.

9.2.1 INTRODUCTION

NOTE

A program is available from the GE Multilin website that is quite helpful in selecting settings for the specific application. Checking the performance of selected element settings with respect to known power system fault parameters makes it relatively simple to choose the optimum settings for the application.

This program is also very useful for establishing test parameters. It is strongly recommended this program be downloaded.

The differential characteristic is primarily defined by four settings: CURRENT DIFF PICKUP, CURRENT DIFF RESTRAINT 1, CURRENT DIFF RESTRAINT 2 and CURRENT DIFF BREAK PT (Breakpoint). As is typical for current-based differential elements, the settings are a trade-off between operation on internal faults against restraint during external faults.

9.2.2 CURRENT DIFF PICKUP

This setting established the sensitivity of the element to high impedance faults, and it is therefore desirable to choose a low level, but this can cause a maloperation for an external fault causing CT saturation. The selection of this setting is influenced by the decision to use charging current compensation. If charging current compensation is Enabled, pickup should be set to a minimum of 150% of the steady-state line charging current, to a lower limit of 10% of CT rating. If charging current compensation is Disabled, pickup should be set to a minimum of 250% of the steady-state line charging current to a lower limit of 10% of CT rating.

If the CT at one terminal can saturate while the CTs at other terminals do not, this setting should be increased by approximately 20 to 50% (depending on how heavily saturated the one CT is while the other CTs are not saturated) of CT rating to prevent operation on a close-in external fault.

9.2.3 CURRENT DIFF RESTRAINT 1

This setting controls the element characteristic when current is below the breakpoint, where CT errors and saturation effects are not expected to be significant. The setting is used to provide sensitivity to high impedance internal faults, or when system configuration limits the fault current to low values. A setting of 10 to 20% is appropriate in most cases, but this should be raised to 30% if the CTs can perform quite differently during faults.

9.2.4 CURRENT DIFF RESTRAINT 2

This setting controls the element characteristic when current is above the breakpoint, where CT errors and saturation effects are expected to be significant. The setting is used to provide security against high current external faults. A setting of 30 to 40% is appropriate in most cases, but this should be raised to 50% if the CTs can perform quite differently during faults.

Note: settings RESTRAINT 1 and RESTRAINT 2 at the same value reverts dual slope bias characteristics into single slope bias characteristics.

9.2.5 CURRENT DIFF BREAK PT

This setting controls the threshold where the relay changes from using the Restraint 1 to the Restraint 2 characteristics, and is very important. Two approaches can be considered

1. Setting at 150 to 200% of the maximum emergency load current on the line, on the assumption that a maintained current above this level is a fault
2. Setting below the current level where CT saturation and spurious transient differential currents can be expected.

The first approach gives comparatively more security and less sensitivity; the second approach provides less security for more sensitivity.

9.2.6 CT TAP

If the CT ratios at the line terminals are different, the CURRENT DIFF CT TAP 1 (2) setting must be used to correct the ratios to a common base. In this case, a user should modify the setting CURRENT DIFF BREAK PT because the local current phasor is used as a reference to determine which differential equation is to be used. If the setting is not modified, the responses of individual relays during an external fault can be asymmetrical, as one relay can be below the breakpoint and the other above the breakpoint. There are two methods to overcome this potential problem:

1. Set RESTRAINT 1 and RESTRAINT 2 to the same value (say 40% or 50%). This converts the relay characteristics from dual slope into single slope and the breakpoint becomes immaterial.
2. Individually set the breakpoint in each relay in accordance with the local CT ratio and the CT TAP setting.

For example:

- 2-Terminal Configuration

  CT_{RELAY1} = 1000/5, CT_{RELAY2} = 2000/5, consequently CT TAP 1_{RELAY1} = 2 and CT TAP 1_{RELAY2} = 0.5. Choosing the RELAY1 as a reference with break point BREAK PT_{RELAY1} = 5.0, the break point at RELAY2 must be chosen as BREAK PT_{RELAY2} = BREAK PT_{RELAY1} x CT_{RELAY1} / CT_{RELAY2} = 2.5. The simple check for this is as follows: BREAK PT_{RELAY1} x CT_{RELAY1} should be equal to BREAK PT_{RELAY2} x CT_{RELAY2}.

- 3-Terminal Configuration

RELAY 1:	RELAY 2:	RELAY 3:
CT_{RELAY1} = 1000/5	CT_{RELAY2} = 2000/5	CT_{RELAY3} = 500/5

  Therefore;

CT TAP 1_{RELAY1} = 2.0	CT TAP 1_{RELAY2} = 0.5	CT TAP 1_{RELAY3} = 2.0
CT TAP 2_{RELAY1} = 0.5	CT TAP 2_{RELAY2} = 0.25	CT TAP 2_{RELAY3} = 4.0

  where: for RELAY1, Channel 1 communicates to RELAY2 and Channel 2 to RELAY3
  for RELAY2, Channel 1 communicates to RELAY1 and Channel 2 to RELAY3
  for RELAY3, Channel 1 communicates to RELAY1 and Channel 2 to RELAY2

  Choosing RELAY1 as a reference with a break point BREAK PT_{RELAY1} = 5.0 pu, the break points for RELAY2 and RELAY3 are determined as follows:

  BREAK PT_{RELAY2} = BREAK PT_{RELAY1} x CT_{RELAY1} / CT_{RELAY2} = 2.5 pu
  BREAK PT_{RELAY3} = BREAK PT_{RELAY1} x CT_{RELAY1} / CT_{RELAY3} = 10.0 pu

  Check;

  BREAK PT_{RELAY1} x CT_{RELAY1} = 5.0 x 1000/5 = 1000
  BREAK PT_{RELAY2} x CT_{RELAY2} = 2.5 x 2000/5 = 1000
  BREAK PT_{RELAY3} x CT_{RELAY3} = 10.0 x 500/5 = 1000

  During on-load tests, the differential current at all terminals should be the same and generally equal to the charging current, if the TAP and CT ratio settings are chosen correctly.

9.3.1 DESCRIPTION

Many high voltage lines have transformers tapped to the line serving as an economic approach to the supply of customer load. A typical configuration is shown in the figure below.

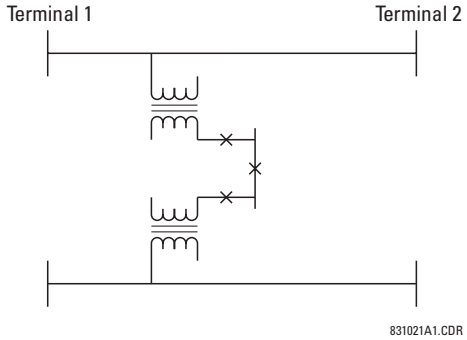


Figure 9–1: TYPICAL HV LINE CONFIGURATION

Two distinctly different approaches are available, Distance Backup and Distance Supervision, depending on which concerns are dominant. In either case, the distance function can provide a definite time backup feature to give a timed clearance for a failure of the L90 communications. Additionally, a POTT (Permissive Over-reaching Transfer Trip) scheme can be selected and activated after detection of an L90 communications failure, if an alternate lower bandwidth communications channel is available.

If **Distance Backup** is employed, dependability concerns usually relate to a failure of the communications. The distance elements can then effectively provide a means of fault identification and clearance. However, for a line with tapped transformers, a number of other issues need to be considered to ensure stability for the L90.

Any differential scheme has a potential problem when a LV fault occurs at the tapped transformer location, and the current at the tap is not measured. Because the transformer size can become quite large, the required increase in the differential setting to avoid operation for the LV bus fault can result in a loss of sensitivity.

If the tapped transformer is a source of zero sequence infeed, then the L90 zero-sequence current removal has to enabled as described in the next section.

The zero sequence infeed creates an apparent impedance setting issue for the backup ground distance and the zero sequence compensation term is also not accurate, so that the positive sequence reach setting must be increased to compensate. The phase distance reach setting may also have to be increased to cope with a transfer across the two transformers, but this is dependent on the termination and configuration of the parallel line.

Three terminal line applications generally will result in larger reach settings for the distance backup and require a calculation of the apparent impedance for a remote fault. This should be carried out for each of the three terminals, as the calculated apparent impedance will be different at each terminal.

Distance Supervision essentially offers a solution for the LV fault condition, but the differential setting must still be increased to avoid operation for an external L-g or L-L-g fault external ground fault. In addition, the distance element reach setting must still see all faults within the protected line and be less than the impedance for a LV bus fault

The effective SIR (source impedance ratio) for the LV fault generally is not high, so that CVT transients do not contribute to measuring errors.

If the distance supervision can be set to avoid operation for a transformer LV fault, then generally the filtering associated with the distance measuring algorithm will ensure no operation under magnetizing inrush conditions. The distance element can be safely set up to $2.5 \times V_{nom} / I_{peak}$, where V_{nom} is the system nominal voltage and I_{peak} is the peak value of the magnetizing inrush current.

For those applications where the tapped station is close to one terminal, then it may be difficult to set the distance supervision to reach the end of the line, and at the same time avoid operation for a LV fault. For this system configuration, a 3-terminal L90 should be utilized; the third terminal is then fed from CT on the high side of the tapped transformer.

9.3.2 PHASE DISTANCE

a) PHASE CURRENT SUPERVISION AND USE OF THE FUSE FAILURE ELEMENT

The phase-to-phase (delta) current is used to supervise the phase distance element, primarily to ensure that in a de-energized state the distance element will not be picked up due to noise or induced voltages, on the line.

However, this supervision feature may also be employed to prevent operation under fuse failure conditions. This obviously requires that the setting must be above maximum load current and less than the minimum fault conditions for which operation is expected. This potential problem may be avoided by the use of a separate fuse fail function, which means that the phase current supervision can be set much lower, typically 2 times the capacitance charging current of the line.

The usage of the fuse fail function is also important during double-contingency events such as an external fault during fuse fail conditions. The current supervision alone would not prevent maloperation in such circumstances.

It must be kept in mind that the Fuse Failure element provided on the L90 needs some time to detect fuse fail conditions. This may create a race between the Zone 2 and the Fuse Failure element. Therefore, for maximum security, it is recommended to both set the current supervision above the maximum load current and use the Fuse Failure function. The current supervision prevents maloperation immediately after the fuse fail condition giving some time for the Fuse Failure element to take over and block the distance elements permanently. This is of a secondary importance for time-delayed Zone 2 as the Fuse Failure element has some extra time for guaranteed operation. The current supervision may be set below the maximum load current for the time delayed zones.

Blocking distance elements during fuse fail conditions may not be acceptable in some applications and/or under some protection philosophies. Applied solutions may vary from not using the Fuse Failure element for blocking at all; through using it and modifying – through FlexLogic™ and multiple setting groups mechanisms – other protection functions or other relays to provide some protection after detecting fuse fail conditions and blocking the distance elements; to using it and accepting the fact that the distance protection will not respond to subsequent internal faults until the problem is addressed.

NOTE

To be fully operational, the Fuse Failure element must be enabled, and its output FlexLogic™ operand must be indicated as the blocking signal for the selected protection elements.

For convenience, the current supervision threshold incorporates the square root of 3 factor.

b) PHASE DISTANCE ZONE 2

The Zone 2 is an overreaching element, which essentially covers the whole of the line length with a time delay. The additional function for the Zone 2 is as a timed backup for faults on the remote bus. Typically the reach is set to 125% of the positive sequence impedance of the line, to ensure operation, with an adequate margin, for a fault at 100% of the line length. The necessary time delay must ensure that coordination is achieved with the clearance of a close-in fault on the next line section, including the breaker operating time.

9.3.3 GROUND DISTANCE

a) NEUTRAL CURRENT SUPERVISION

The current supervision for the ground distance elements responds to an internally calculated neutral current (3 x I_0). The setting for this element should be based on twice the zero-sequence line capacitance current or the maximum zero-sequence unbalance under maximum load conditions. This element should not be used to prevent an output when the load impedance is inside the distance characteristic on a steady state basis.

b) GROUND DISTANCE ZONE 2

To ensure that the Zone 2 can see 100% of the line, inter-circuit mutual effects must be considered, as they can contribute to a significant under-reach. Typically this may occur on double circuit lines, when both lines may carry the same current. An analytical study should be carried out to determine the appropriate reach setting.

The main purpose of this element is to operate for faults beyond the reach of the local Zone 1 element, and therefore a time delay must be used similar to the phase fault case.

9.4.1 DESCRIPTION

This scheme is intended for two-terminal line applications only.

This scheme uses an over-reaching Zone 2 distance element to essentially compare the direction to a fault at both the ends of the line.

Ground directional overcurrent functions available in the relay can be used in conjunction with the Zone 2 distance element to key the scheme and initiate its operation. This provides increased coverage for high-resistance faults.

Good directional integrity is the key requirement for an over-reaching forward-looking protection element used to supplement Zone 2. Even though any FlexLogic™ operand could be used for this purpose allowing the user to combine responses of various protection elements, or to apply extra conditions through FlexLogic™ equations, this extra signal is primarily meant to be the output operand from the Neutral Directional IOC. Both of these elements have separate forward (FWD) and reverse (REV) output operands. The forward indication should be used (NEUTRAL DIR OC1 FWD).

An important consideration is when one of the line terminals is open. It is then necessary to identify this condition and arrange for a continuous sending of the permissive signal or use a slower but more secure echo feature to send a signal to the other terminal, which is producing the fault infeed. With any echo scheme however, a means must be provided to avoid a permanent lock up of the transmit/receive loop. The echo co-ordination (ECHO DURATION) and lock-out (ECHO LOCKOUT) timers perform this function by ensuring that the permissive signal is echoed once for a guaranteed duration of time before going to a lockout for a settable period of time.

It should be recognized that in ring bus or breaker and a half situations, it may be the line disconnect or a combination of the disconnect and/or the breaker(s) status that is the indication that the terminal is open.

The POTT RX PICKUP DELAY timer is included in the permissive receive path to ride through spurious receive outputs that may be produced during external faults, when power line carrier is utilized as the communications medium.

No current reversal logic is included for the overreaching phase and ground distance elements, because long reaches are not usually required for two terminal lines. A situation can occur however, where the ground distance element will have an extended reach. This situation is encountered when it is desired to account for the zero sequence inter-circuit mutual coupling. This is not a problem for the ground distance elements in the L90 which do have a current reversal logic built into their design as part of the technique used to improve ground fault directionality.

Unlike the distance protection elements the ground directional overcurrent functions do not have their reach well defined, therefore the current reversal logic is incorporated for the extra signal supplementing Zone 2 in the scheme. The transient blocking approach for this POTT scheme is to recognize that a permissive signal has been received and then allow a settable time TRANS BLOCK PICKUP DELAY for the local forward looking directional element to pick up.

The scheme generates an output operand (POTT TX) that is used to transmit the signal to the remote end. Choices of communications channel include Remote Inputs/Outputs and telecommunications interfaces. When used with telecommunications facilities the output operand should be assigned to operate an output contact connected to key the transmitter at the interface. Power Line Carrier (PLC) channels are not recommended for this scheme since the PLC signal can be interrupted by a fault.

For proper operation of the scheme the Zone 2 phase and ground distance elements must be enabled, configured and set per rules of distance relaying. The LINE PICKUP element should be enabled, configured and set properly to detect line-end-open/weak-infeed conditions.

If used by this scheme, the selected ground directional overcurrent function(s) must be enabled, configured and set accordingly The output operand from the scheme (POTT OP) must be configured to interface with other relay functions, output contacts in particular, in order to make the scheme fully operational. Typically, the output operand should be programmed to initiate a trip, breaker fail, and auto-reclose, and drive a user-programmable LED as per user application.

9.5.1 DISTANCE SETTINGS ON SERIES COMPENSATED LINES

Traditionally, the reach setting of an underreaching distance function shall be set based on the net inductive impedance between the potential source of the relay and the far-end busbar, or location for which the zone must not overreach. Faults behind series capacitors on the protected and adjacent lines need to be considered for this purpose. For further illustration a sample system shown in the figure below is considered.

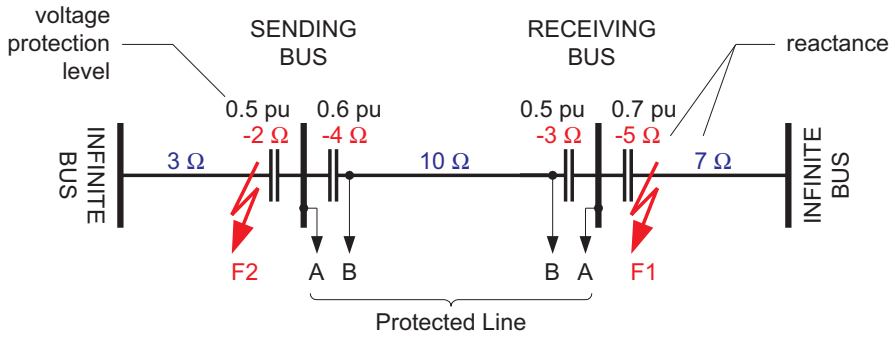


Figure 9–2: SAMPLE SERIES COMPENSATED SYSTEM

Assuming 20% security margin, the underreaching zone shall be set as follows.

At the SENDING BUS one must consider an external fault at F1 as the 5 Ω capacitor would contribute to the overreaching effect. Any fault behind F1 is less severe as extra inductive line impedance increases the apparent impedance:

Reach Setting: 0.8 x (10 – 3 – 5) = 1.6 Ω if the line-side (B) VTs are used
Reach Setting: 0.8 x (10 – 4 – 3 – 5) = –1.6 Ω if the bus-side (A) VTs are used

The negative value means that an underreaching zone cannot be used as the circuit between the potential source of the relay and an external fault for which the relay must not pick-up, is overcompensated, i.e. capacitive.

At the RECEIVING BUS, one must consider a fault at F2:

Reach Setting: 0.8 x (10 – 4 – 2) = 3.2 Ω if the line-side (B) VTs are used
Reach Setting: 0.8 x (10 – 4 – 3 – 2) = 0.8 Ω if the bus-side (A) VTs are used

Practically, however, to cope with the effect of sub-synchronous oscillations, one may need to reduce the reach even more. As the characteristics of sub-synchronous oscillations are in complex relations with fault and system parameters, no solid setting recommendations are given with respect to extra security margin for sub-synchronous oscillations. It is strongly recommended to use a power system simulator to verify the reach settings or to use an adaptive L90 feature for dynamic reach control.

If the adaptive reach control feature is used, the PHS DIST Z1 VOLT LEVEL setting shall be set accordingly.

This setting is a sum of the overvoltage protection levels for all the series capacitors located between the relay potential source and the far-end busbar, or location for which the zone must not overreach. The setting is entered in pu of the phase VT nominal voltage (RMS, not peak value).

If a minimum fault current level (phase current) is causing a voltage drop across a given capacitor that prompts its air gap to flash over or its MOV to carry practically all the current, then the series capacitor shall be excluded from the calculations (the capacitor is immediately by-passed by its overvoltage protection system and does not cause any overreach problems).

If a minimum fault current does not guarantee an immediate capacitor by-pass, then the capacitor must be included in the calculation: its overvoltage protection level, either air gap flash-over voltage or MOV knee-point voltage, shall be used (RMS, not peak value).

Assuming none of the series capacitors in the sample system is guaranteed to get by-passed, the following calculations apply:

For the SENDING BUS: 0.5 + 0.7 = 1.2 pu if the line-side (B) VTs are used
0.6 + 0.5 + 0.7 = 1.8 pu if the bus-side (A) VTs are used

For the RECEIVING BUS: 0.6 + 0.5 = 1.1 pu if the line-side (B) VTs are used
0.6 + 0.5 + 0.5 = 1.6 pu if the bus-side (A) VTs are used

9.6.1 DESCRIPTION

The L90 protection system could be applied to lines with tapped transformer(s) even if the latter has its windings connected in a grounded wye on the line side and the transformer(s) currents are not measured by the L90 protection system. The following approach is recommended.

If the setting **SYSTEM SETUP ⇨⇩ L90 POWER SYSTEM ⇨⇩ ZERO-SEQ CURRENT REMOVAL** is "Enabled", all relays at the line terminals are calculating zero-sequence for both local and remote currents and are removing this current from the phase currents. This ensures the differential current is immune to the zero-sequence current outfeed caused by the in-zone transformer with a primary wye-connected winding solidly grounded neutral.

At all terminals the following is being performed:

I_L_0 = (I_L_A + I_L_B + I_L_C) / 3) : local zero-sequence current
I_R_0 = (I_R_A + I_R_B + I_R_C) / 3 : remote zero-sequence current

Now, the I_PHASE – I_0 values (for Local and Remote) are being used instead of pure phase currents for differential and restraint current calculations. See the THEORY OF OPERATION chapter for additional details.

For example, the operating current in phase A is determined as:

I^2op_A = |(I_L_A – I_L_0) + (I_R_A – I_R_0) $|^2$: squared operating current, phase A

where: I_L_A = "local" current phase A
I_R_A = "remote" current phase A
I_L_0 = local zero-sequence current
I_R_0 = remote zero-sequence current
I^2op_A = operating (differential) squared current phase A

The restraint current is calculated in a similar way.

NOTE

When the **ZERO-SEQ CURRENT REMOVAL** feature is enabled, the modified (I_0 removed) differential current in all three phases is shown in the **ACTUAL VALUES ⇨⇩ METERING ⇨ 87L DIFFERENTIAL CURRENT** menu. Local and remote currents values are not changed.

9.6.2 TRANSFORMER LOAD CURRENTS

As the tapped line may be energized from one terminal only, or there may be a low current flowing through the line, the slope setting of the differential characteristic would not guarantee stability of the relay on transformer load currents. Consequently, a pickup setting must be risen accordingly in order to prevent maloperation. The L90 forms its restraint current in a unique way as explained in the THEORY OF OPERATION chapter. Unlike traditional approaches, the effects of slope and pickup settings are combined: the higher the slope, the lower the pickup setting required for the same restraining effect.

Assuming the line energized from one terminal and the current is below the lower break-point of the characteristic one should consider the following stability conditions in order to select the pickup (P) and slope (S_1) settings (I_{LOAD} is a maximum total load current of the tapped transformer(s)).

- **Two-terminal applications:**

  $$I_{op}^2 = I_{LOAD}^2$$
  $$I_{REST}^2 = 2S_1^2 I_{LOAD}^2 + 2P^2$$
  Stability condition: $2S_1^2 I_{LOAD}^2 + 2P^2 > I_{LOAD}^2$

- **Three-terminal applications:**

  $$I_{op}^2 = I_{LOAD}^2$$
  $$I_{REST}^2 = \frac{4}{3} S_1^2 I_{LOAD}^2 + 2P^2$$
  Stability condition: $\frac{4}{3} S_1^2 I_{LOAD}^2 + 2P^2 > I_{LOAD}^2$

The above calculations should take into account the requirement for the pickup setting resulting from line charging currents. Certainly, a security factor must be applied to the above stability conditions. Alternatively, distance supervision can be considered to prevent maloperation due to transformer load currents.

9.6.3 FAULTS AT THE LV SIDE OF THE TRANSFORMER(S)

Distance supervision should be used to prevent maloperation of the L90 protection system during faults on the LV side of the transformer(s). As explained in the DISTANCE BACKUP/SUPERVISION section, the distance elements should be set to overreach all the line terminals and at the same time safely underreach the LV busbars of all the tapped transformers. This may present some challenge particularly for long lines and large transformer tapped close to the substations. If the L90 system retrofits distance relays, there is a good chance that one can set the distance elements to satisfy the imposed requirements.

If more than one transformer is tapped, particularly on parallel lines, and the LV sides are interconnected, detailed short circuit studies may be needed to determine the distance settings.

9.6.4 EXTERNAL GROUND FAULTS

External ground faults behind the line terminals will be seen by the overreaching distance elements. At the same time, the tapped transformer(s), if connected in a grounded wye, will feed the zero-sequence current. This current is going to be seen at one L90 terminal only, will cause a spurious differential signal, and consequently, may cause maloperation.

The L90 ensures stability in such a case by removing the zero-sequence current from the phase cur-rents prior to calculating the operating and restraining signals (**SETTINGS** ⇨⇩ **SYSTEM SETUP** ⇨⇩ **L90 POWER SYSTEM** ⇨⇩ **ZERO-SEQ CURRENT REMOVAL** = "Enabled"). Removing the zero-sequence component from the phase currents may cause the L90 to overtrip healthy phases on internal ground fault. This is not a limitation, as the single-pole tripping is not recommended for lines with tapped transformers.

The following tables are provided to keep a record of settings to be used on a relay.

10.1.1 PRODUCT SETUP

Table 10–1: PRODUCT SETUP (Sheet 1 of 14)

SETTING	VALUE
PASSWORD SECURITY	
Access Level	
Command Password	
Setting Password	
Encrypted Command Password	
Encrypted Setting Password	
DISPLAY PROPERTIES	
Flash Message Time	
Default Message Timeout	
Default Message Intensity	
REAL TIME CLOCK	
IRIG-B Signal Type	
COMMUNICATIONS > SERIAL PORTS	
RS485 COM1 Baud Rate	
RS485 COM1 Parity	
RS485 COM2 Baud Rate	
RS485 COM2 Parity	
COMMUNICATIONS > NETWORK	
IP Address	
Subnet IP Mask	
Gateway IP Address	
OSI Network Address (NSAP)	
Ethernet Operation Mode	
Ethernet Primary Link Monitor	
Ethernet Secondary Link Monitor	
COMMUNICATIONS > MODBUS PROTOCOL	
Modbus Slave Address	
Modbus TCP Port Number	
COMMUNICATIONS > DNP PROTOCOL	
DNP Port	
DNP Address	
DNP Network Client Address 1	
DNP Network Client Address 2	
DNP TCP/UDP Port Number	
DNP Unsol Response Function	
DNP Unsol Response Timeout	
DNP Unsol Response Max Retries	
Unsol Response Dest Address	
User Map for DNP Analogs	
Number of Sources in Analog List	

Table 10–1: PRODUCT SETUP (Sheet 2 of 14)

SETTING	VALUE
DNP Current Scale Factor	
DNP Voltage Scale Factor	
DNP Power Scale Factor	
DNP Energy Scale Factor	
DNP Other Scale Factor	
DNP Current Default Deadband	
DNP Voltage Default Deadband	
DNP Power Default Deadband	
DNP Energy Default Deadband	
DNP Other Default Deadband	
DNP Time Sync In IIN Period	
DNP Message Fragment Size	
COMMUNICATIONS > UCA/MMS PROTOCOL	
Default GOOSE Update Time	
UCA Logical Device	
UCA/MMS TCP Port Number	
COMMUNICATIONS > WEB SERVER HTTP PROT.	
HTTP TCP Port Number	
COMMUNICATIONS > TFTP PROTOCOL	
TFTP Main UDP Port Number	
TFTP Data UDP Port 1 Number	
TFTP Data UDP Port 2 Number	
COMMUNICATIONS > IEC 60870-5-104 PROTOCOL	
IEC 60870-5-104 Function	
IEC TCP Port Number	
IEC Common Address of ASDU	
IEC Cyclic Data Period	
Number of Sources in MMENC1 List	
IEC Current Default Threshold	
IEC Voltage Default Threshold	
IEC Power Default Threshold	
IEC Energy Default Threshold	
IEC Other Default Threshold	
OSCILLOGRAPHY	
Number of Records	
Trigger Mode	
Trigger Position	
Trigger Source	
AC Input Waveforms	
FAULT REPORT	
Fault Report Source	

Table 10–1: PRODUCT SETUP (Sheet 3 of 14)

SETTING	VALUE
Fault Report Trigger	
OSCILLOGRAPHY > DIGITAL CHANNELS	
Digital Channel 1	
Digital Channel 2	
Digital Channel 3	
Digital Channel 4	
Digital Channel 5	
Digital Channel 6	
Digital Channel 7	
Digital Channel 8	
Digital Channel 9	
Digital Channel 10	
Digital Channel 11	
Digital Channel 12	
Digital Channel 13	
Digital Channel 14	
Digital Channel 15	
Digital Channel 16	
Digital Channel 17	
Digital Channel 18	
Digital Channel 19	
Digital Channel 20	
Digital Channel 21	
Digital Channel 22	
Digital Channel 23	
Digital Channel 24	
Digital Channel 25	
Digital Channel 26	
Digital Channel 27	
Digital Channel 28	
Digital Channel 29	
Digital Channel 30	
Digital Channel 31	
Digital Channel 32	
Digital Channel 33	
Digital Channel 34	
Digital Channel 35	
Digital Channel 36	
Digital Channel 37	
Digital Channel 38	
Digital Channel 39	
Digital Channel 40	
Digital Channel 41	
Digital Channel 42	
Digital Channel 43	
Digital Channel 44	
Digital Channel 45	

Table 10–1: PRODUCT SETUP (Sheet 4 of 14)

SETTING	VALUE
Digital Channel 46	
Digital Channel 47	
Digital Channel 48	
Digital Channel 49	
Digital Channel 50	
Digital Channel 51	
Digital Channel 52	
Digital Channel 53	
Digital Channel 54	
Digital Channel 55	
Digital Channel 56	
Digital Channel 57	
Digital Channel 58	
Digital Channel 59	
Digital Channel 60	
Digital Channel 61	
Digital Channel 62	
Digital Channel 63	
Digital Channel 64	
OSCILLOGRAPHY > ANALOG CHANNELS	
Analog Channel 1	
Analog Channel 2	
Analog Channel 3	
Analog Channel 4	
Analog Channel 5	
Analog Channel 6	
Analog Channel 7	
Analog Channel 8	
Analog Channel 9	
Analog Channel 10	
Analog Channel 11	
Analog Channel 12	
Analog Channel 13	
Analog Channel 14	
Analog Channel 15	
Analog Channel 16	
DATA LOGGER	
Rate	
Channel 1	
Channel 2	
Channel 3	
Channel 4	
Channel 5	
Channel 6	
Channel 7	
Channel 8	
Channel 9	

Table 10–1: PRODUCT SETUP (Sheet 5 of 14)

SETTING	VALUE
Channel 10	
Channel 11	
Channel 12	
Channel 13	
Channel 14	
Channel 15	
Channel 16	
DEMAND	
Current Demand Method	
Power Demand Method	
Demand Interval	
Demand Trigger	
USER PROGRAMMABLE LEDS	
Trip LED Input	
Alarm LED Input	
LED 1 Operand	
LED 1 Type	
LED 2 Operand	
LED 2 Type	
LED 3 Operand	
LED 3 Type	
LED 4 Operand	
LED 4 Type	
LED 5 Operand	
LED 5 Type	
LED 6 Operand	
LED 6 Type	
LED 7 Operand	
LED 7 Type	
LED 8 Operand	
LED 8 Type	
LED 9 Operand	
LED 9 Type	
LED 10 Operand	
LED 10 Type	
LED 11 Operand	
LED 11 Type	
LED 12 Operand	
LED 12 Type	
LED 13 Operand	
LED 13 Type	
LED 14 Operand	
LED 14 Type	
LED 15 Operand	
LED 15 Type	
LED 16 Operand	
LED 16 Type	

Table 10–1: PRODUCT SETUP (Sheet 6 of 14)

SETTING	VALUE
LED 17 Operand	
LED 17 Type	
LED 18 Operand	
LED 18 Type	
LED 19 Operand	
LED 19 Type	
LED 20 Operand	
LED 20 Type	
LED 21 Operand	
LED 21 Type	
LED 22 Operand	
LED 22 Type	
LED 23 Operand	
LED 23 Type	
LED 24 Operand	
LED 24 Type	
LED 25 Operand	
LED 25 Type	
LED 26 Operand	
LED 26 Type	
LED 27 Operand	
LED 27 Type	
LED 28 Operand	
LED 28 Type	
LED 29 Operand	
LED 29 Type	
LED 30 Operand	
LED 30 Type	
LED 31 Operand	
LED 31 Type	
LED 32 Operand	
LED 32 Type	
LED 33 Operand	
LED 33 Type	
LED 34 Operand	
LED 34 Type	
LED 35 Operand	
LED 35 Type	
LED 36 Operand	
LED 36 Type	
LED 37 Operand	
LED 37 Type	
LED 38 Operand	
LED 38 Type	
LED 39 Operand	
LED 39 Type	
LED 40 Operand	

Table 10–1: PRODUCT SETUP (Sheet 7 of 14)

SETTING	VALUE
LED 40 Type	
LED 41 Operand	
LED 41 Type	
LED 42 Operand	
LED 42 Type	
LED 43 Operand	
LED 43 Type	
LED 44 Operand	
LED 44 Type	
LED 45 Operand	
LED 45 Type	
LED 46 Operand	
LED 46 Type	
LED 47 Operand	
LED 47 Type	
LED 48 Operand	
LED 48 Type	
FLEX STATE PARAMETERS	
Flex State Parameter 1	
Flex State Parameter 2	
Flex State Parameter 3	
Flex State Parameter 4	
Flex State Parameter 5	
Flex State Parameter 6	
Flex State Parameter 7	
Flex State Parameter 8	
Flex State Parameter 9	
Flex State Parameter 10	
Flex State Parameter 11	
Flex State Parameter 12	
Flex State Parameter 13	
Flex State Parameter 14	
Flex State Parameter 15	
Flex State Parameter 16	
Flex State Parameter 17	
Flex State Parameter 18	
Flex State Parameter 19	
Flex State Parameter 20	
Flex State Parameter 21	
Flex State Parameter 22	
Flex State Parameter 23	
Flex State Parameter 24	
Flex State Parameter 25	
Flex State Parameter 26	
Flex State Parameter 27	
Flex State Parameter 28	
Flex State Parameter 29	

Table 10–1: PRODUCT SETUP (Sheet 8 of 14)

SETTING	VALUE
Flex State Parameter 30	
Flex State Parameter 31	
Flex State Parameter 32	
Flex State Parameter 33	
Flex State Parameter 34	
Flex State Parameter 35	
Flex State Parameter 36	
Flex State Parameter 37	
Flex State Parameter 38	
Flex State Parameter 39	
Flex State Parameter 40	
Flex State Parameter 41	
Flex State Parameter 42	
Flex State Parameter 43	
Flex State Parameter 44	
Flex State Parameter 45	
Flex State Parameter 46	
Flex State Parameter 47	
Flex State Parameter 48	
Flex State Parameter 49	
Flex State Parameter 50	
Flex State Parameter 51	
Flex State Parameter 52	
Flex State Parameter 53	
Flex State Parameter 54	
Flex State Parameter 55	
Flex State Parameter 56	
Flex State Parameter 57	
Flex State Parameter 58	
Flex State Parameter 59	
Flex State Parameter 60	
Flex State Parameter 61	
Flex State Parameter 62	
Flex State Parameter 63	
Flex State Parameter 64	
Flex State Parameter 65	
Flex State Parameter 66	
Flex State Parameter 67	
Flex State Parameter 68	
Flex State Parameter 69	
Flex State Parameter 70	
Flex State Parameter 71	
Flex State Parameter 72	
Flex State Parameter 73	
Flex State Parameter 74	
Flex State Parameter 75	
Flex State Parameter 76	

Table 10–1: PRODUCT SETUP (Sheet 9 of 14)

SETTING	VALUE
Flex State Parameter 77	
Flex State Parameter 78	
Flex State Parameter 79	
Flex State Parameter 80	
Flex State Parameter 81	
Flex State Parameter 82	
Flex State Parameter 83	
Flex State Parameter 84	
Flex State Parameter 85	
Flex State Parameter 86	
Flex State Parameter 87	
Flex State Parameter 88	
Flex State Parameter 89	
Flex State Parameter 90	
Flex State Parameter 91	
Flex State Parameter 92	
Flex State Parameter 93	
Flex State Parameter 94	
Flex State Parameter 95	
Flex State Parameter 96	
Flex State Parameter 97	
Flex State Parameter 98	
Flex State Parameter 99	
Flex State Parameter 100	
Flex State Parameter 101	
Flex State Parameter 102	
Flex State Parameter 103	
Flex State Parameter 104	
Flex State Parameter 105	
Flex State Parameter 106	
Flex State Parameter 107	
Flex State Parameter 108	
Flex State Parameter 109	
Flex State Parameter 110	
Flex State Parameter 111	
Flex State Parameter 112	
Flex State Parameter 113	
Flex State Parameter 114	
Flex State Parameter 115	
Flex State Parameter 116	
Flex State Parameter 117	
Flex State Parameter 118	
Flex State Parameter 119	
Flex State Parameter 120	
Flex State Parameter 121	
Flex State Parameter 122	
Flex State Parameter 123	

Table 10–1: PRODUCT SETUP (Sheet 10 of 14)

SETTING	VALUE
Flex State Parameter 124	
Flex State Parameter 125	
Flex State Parameter 126	
Flex State Parameter 127	
Flex State Parameter 128	
Flex State Parameter 129	
Flex State Parameter 130	
Flex State Parameter 131	
Flex State Parameter 132	
Flex State Parameter 133	
Flex State Parameter 134	
Flex State Parameter 135	
Flex State Parameter 136	
Flex State Parameter 137	
Flex State Parameter 138	
Flex State Parameter 139	
Flex State Parameter 140	
Flex State Parameter 141	
Flex State Parameter 142	
Flex State Parameter 143	
Flex State Parameter 144	
Flex State Parameter 145	
Flex State Parameter 146	
Flex State Parameter 147	
Flex State Parameter 148	
Flex State Parameter 149	
Flex State Parameter 150	
Flex State Parameter 151	
Flex State Parameter 152	
Flex State Parameter 153	
Flex State Parameter 154	
Flex State Parameter 155	
Flex State Parameter 156	
Flex State Parameter 157	
Flex State Parameter 158	
Flex State Parameter 159	
Flex State Parameter 160	
Flex State Parameter 161	
Flex State Parameter 162	
Flex State Parameter 163	
Flex State Parameter 164	
Flex State Parameter 165	
Flex State Parameter 166	
Flex State Parameter 167	
Flex State Parameter 168	
Flex State Parameter 169	
Flex State Parameter 170	

Table 10–1: PRODUCT SETUP (Sheet 11 of 14)

SETTING	VALUE
Flex State Parameter 171	
Flex State Parameter 172	
Flex State Parameter 173	
Flex State Parameter 174	
Flex State Parameter 175	
Flex State Parameter 176	
Flex State Parameter 177	
Flex State Parameter 178	
Flex State Parameter 179	
Flex State Parameter 180	
Flex State Parameter 181	
Flex State Parameter 182	
Flex State Parameter 183	
Flex State Parameter 184	
Flex State Parameter 185	
Flex State Parameter 186	
Flex State Parameter 187	
Flex State Parameter 188	
Flex State Parameter 189	
Flex State Parameter 190	
Flex State Parameter 191	
Flex State Parameter 192	
Flex State Parameter 193	
Flex State Parameter 194	
Flex State Parameter 195	
Flex State Parameter 196	
Flex State Parameter 197	
Flex State Parameter 198	
Flex State Parameter 199	
Flex State Parameter 200	
Flex State Parameter 201	
Flex State Parameter 202	
Flex State Parameter 203	
Flex State Parameter 204	
Flex State Parameter 205	
Flex State Parameter 206	
Flex State Parameter 207	
Flex State Parameter 208	
Flex State Parameter 209	
Flex State Parameter 210	
Flex State Parameter 211	
Flex State Parameter 212	
Flex State Parameter 213	
Flex State Parameter 214	
Flex State Parameter 215	
Flex State Parameter 216	
Flex State Parameter 217	

Table 10–1: PRODUCT SETUP (Sheet 12 of 14)

SETTING	VALUE
Flex State Parameter 218	
Flex State Parameter 219	
Flex State Parameter 220	
Flex State Parameter 221	
Flex State Parameter 222	
Flex State Parameter 223	
Flex State Parameter 224	
Flex State Parameter 225	
Flex State Parameter 226	
Flex State Parameter 227	
Flex State Parameter 228	
Flex State Parameter 229	
Flex State Parameter 230	
Flex State Parameter 231	
Flex State Parameter 232	
Flex State Parameter 233	
Flex State Parameter 234	
Flex State Parameter 235	
Flex State Parameter 236	
Flex State Parameter 237	
Flex State Parameter 238	
Flex State Parameter 239	
Flex State Parameter 240	
Flex State Parameter 241	
Flex State Parameter 242	
Flex State Parameter 243	
Flex State Parameter 244	
Flex State Parameter 245	
Flex State Parameter 246	
Flex State Parameter 247	
Flex State Parameter 248	
Flex State Parameter 249	
Flex State Parameter 250	
Flex State Parameter 251	
Flex State Parameter 252	
Flex State Parameter 253	
Flex State Parameter 254	
Flex State Parameter 255	
Flex State Parameter 256	
USER DISPLAY 1	
Disp 1 Top Line	
Disp 1 Bottom Line	
Disp 1 Item 1	
Disp 1 Item 2	
Disp 1 Item 3	
Disp 1 Item 4	
Disp 1 Item 5	

Table 10–1: PRODUCT SETUP (Sheet 13 of 14)

SETTING	VALUE
USER DISPLAY 2	
Disp 2 Top Line	
Disp 2 Bottom Line	
Disp 2 Item 1	
Disp 2 Item 2	
Disp 2 Item 3	
Disp 2 Item 4	
Disp 2 Item 5	
USER DISPLAY 3	
Disp 3 Top Line	
Disp 3 Bottom Line	
Disp 3 Item 1	
Disp 3 Item 2	
Disp 3 Item 3	
Disp 3 Item 4	
Disp 3 Item 5	
USER DISPLAY 4	
Disp 4 Top Line	
Disp 4 Bottom Line	
Disp 4 Item 1	
Disp 4 Item 2	
Disp 4 Item 3	
Disp 4 Item 4	
Disp 4 Item 5	
USER DISPLAY 5	
Disp 5 Top Line	
Disp 5 Bottom Line	
Disp 5 Item 1	
Disp 5 Item 2	
Disp 5 Item 3	
Disp 5 Item 4	
Disp 5 Item 5	
USER DISPLAY 6	
Disp 6 Top Line	
Disp 6 Bottom Line	
Disp 6 Item 1	
Disp 6 Item 2	
Disp 6 Item 3	
Disp 6 Item 4	
Disp 6 Item 5	
USER DISPLAY 7	
Disp 7 Top Line	
Disp 7 Bottom Line	
Disp 7 Item 1	
Disp 7 Item 2	
Disp 7 Item 3	
Disp 7 Item 4	

Table 10–1: PRODUCT SETUP (Sheet 14 of 14)

SETTING	VALUE
Disp 7 Item 5	
USER DISPLAY 8	
Disp 8 Top Line	
Disp 8 Bottom Line	
Disp 8 Item 1	
Disp 8 Item 2	
Disp 8 Item 3	
Disp 8 Item 4	
Disp 8 Item 5	
INSTALLATION	
Relay Settings	
Relay Name	

Table 10–2: SYSTEM SETUP (Sheet 1 of 4)

SETTING	VALUE
CURRENT BANK 1	
Phase CT _____ Primary	
Phase CT _____ Secondary	
Ground CT _____ Primary	
Ground CT _____ Secondary	
CURRENT BANK 2	
Phase CT _____ Primary	
Phase CT _____ Secondary	
Ground CT _____ Primary	
Ground CT _____ Secondary	
CURRENT BANK 3	
Phase CT _____ Primary	
Phase CT _____ Secondary	
Ground CT _____ Primary	
Ground CT _____ Secondary	
CURRENT BANK 4	
Phase CT _____ Primary	
Phase CT _____ Secondary	
Ground CT _____ Primary	
Ground CT _____ Secondary	
CURRENT BANK 5	
Phase CT _____ Primary	
Phase CT _____ Secondary	
Ground CT _____ Primary	
Ground CT _____ Secondary	
CURRENT BANK 6	
Phase CT _____ Primary	
Phase CT _____ Secondary	
Ground CT _____ Primary	
Ground CT _____ Secondary	
VOLTAGE BANK 1	
Phase VT _____ Connection	
Phase VT _____ Secondary	
Phase VT _____ Ratio	
Auxiliary VT _____ Connection	
Auxiliary VT _____ Secondary	
Auxiliary VT _____ Ratio	
VOLTAGE BANK 2	
Phase VT _____ Connection	
Phase VT _____ Secondary	
Phase VT _____ Ratio	
Auxiliary VT _____ Connection	
Auxiliary VT _____ Secondary	
Auxiliary VT _____ Ratio	

Table 10–2: SYSTEM SETUP (Sheet 2 of 4)

SETTING	VALUE
VOLTAGE BANK 3	
Phase VT _____ Connection	
Phase VT _____ Secondary	
Phase VT _____ Ratio	
Auxiliary VT _____ Connection	
Auxiliary VT _____ Secondary	
Auxiliary VT _____ Ratio	
POWER SYSTEM	
Nominal Frequency	
Phase Rotation	
Frequency and Phase Reference	
Frequency Tracking	
SIGNAL SOURCE 1	
Source 1 Name	
Source 1 Phase CT	
Source 1 Ground CT	
Source 1 Phase VT	
Source 1 Auxiliary VT	
SIGNAL SOURCE 2	
Source 2 Name	
Source 2 Phase CT	
Source 2 Ground CT	
Source 2 Phase VT	
Source 2 Auxiliary VT	
SIGNAL SOURCE 3	
Source 3 Name	
Source 3 Phase CT	
Source 3 Ground CT	
Source 3 Phase VT	
Source 3 Auxiliary VT	
SIGNAL SOURCE 4	
Source 4 Name	
Source 4 Phase CT	
Source 4 Ground CT	
Source 4 Phase VT	
Source 4 Auxiliary VT	
SIGNAL SOURCE 5	
Source 5 Name	
Source 5 Phase CT	
GSource 5 round CT	
Source 5 Phase VT	
Source 5 Auxiliary VT	
SIGNAL SOURCE 6	
Source 6 Name	

Table 10–2: SYSTEM SETUP (Sheet 3 of 4)

SETTING	VALUE
Source 6 Phase CT	
Source 6 Ground CT	
Source 6 Phase VT	
Source 6 Auxiliary VT	
L90 POWER SYSTEM	
Number of Terminals	
Number of Channels	
Charging Current Compensation	
Pos. Seq. Capacitive Reactance	
Zero Seq. Capacitive Reactance	
Zero Seq. Current Removal	
Local Relay ID Number	
Terminal 1 Relay ID Number	
Terminal 2 Relay ID Number	
LINE	
Pos. Seq. Impedance Magnitude	
Pos. Seq. Impedance Angle	
Zero Seq. Impedance Magnitude	
Zero Seq. Impedance Angle	
Line Length Units	
Line Length	
BREAKER 1	
Breaker 1 Function	
Breaker 1 Pushbutton Control	
Breaker 1 Name	
Breaker 1 Mode	
Breaker 1 Open	
Breaker 1 Close	
Breaker 1 ΦA/3-Pole	
Breaker 1 ΦB	
Breaker 1 ΦC	
Breaker 1 Ext Alarm	
Breaker 1 Alarm Delay	
Breaker 1 Out of Sv	
Breaker 1 Manual Close Recall Time	
BREAKER 2	
Breaker 2 Function	
Breaker 2 Pushbutton Control	
Breaker 2 Name	
Breaker 2 Mode	
Breaker 2 Open	
Breaker 2 Close	
Breaker 2 ΦA/3-Pole	
Breaker 2 ΦB	
Breaker 2 ΦC	
Breaker 2 Ext Alarm	
Breaker 2 Alarm Delay	

Table 10–2: SYSTEM SETUP (Sheet 4 of 4)

SETTING	VALUE
Breaker 2 Out of Sv	
Breaker 2 Manual Close Recall Time	
UCA SBO TIMER (FOR BREAKERS 1/2)	
UCA SBO Timeout	

Table 10–3: FLEXCURVE™ TABLE

RESET	TIME MS	RESET	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS
0.00		0.68		1.03		2.9		4.9		10.5	
0.05		0.70		1.05		3.0		5.0		11.0	
0.10		0.72		1.1		3.1		5.1		11.5	
0.15		0.74		1.2		3.2		5.2		12.0	
0.20		0.76		1.3		3.3		5.3		12.5	
0.25		0.78		1.4		3.4		5.4		13.0	
0.30		0.80		1.5		3.5		5.5		13.5	
0.35		0.82		1.6		3.6		5.6		14.0	
0.40		0.84		1.7		3.7		5.7		14.5	
0.45		0.86		1.8		3.8		5.8		15.0	
0.48		0.88		1.9		3.9		5.9		15.5	
0.50		0.90		2.0		4.0		6.0		16.0	
0.52		0.91		2.1		4.1		6.5		16.5	
0.54		0.92		2.2		4.2		7.0		17.0	
0.56		0.93		2.3		4.3		7.5		17.5	
0.58		0.94		2.4		4.4		8.0		18.0	
0.60		0.95		2.5		4.5		8.5		18.5	
0.62		0.96		2.6		4.6		9.0		19.0	
0.64		0.97		2.7		4.7		9.5		19.5	
0.66		0.98		2.8		4.8		10.0		20.0	

Table 10–4: FLEXCURVE™ TABLE

RESET	TIME MS	RESET	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS
0.00		0.68		1.03		2.9		4.9		10.5	
0.05		0.70		1.05		3.0		5.0		11.0	
0.10		0.72		1.1		3.1		5.1		11.5	
0.15		0.74		1.2		3.2		5.2		12.0	
0.20		0.76		1.3		3.3		5.3		12.5	
0.25		0.78		1.4		3.4		5.4		13.0	
0.30		0.80		1.5		3.5		5.5		13.5	
0.35		0.82		1.6		3.6		5.6		14.0	
0.40		0.84		1.7		3.7		5.7		14.5	
0.45		0.86		1.8		3.8		5.8		15.0	
0.48		0.88		1.9		3.9		5.9		15.5	
0.50		0.90		2.0		4.0		6.0		16.0	
0.52		0.91		2.1		4.1		6.5		16.5	
0.54		0.92		2.2		4.2		7.0		17.0	
0.56		0.93		2.3		4.3		7.5		17.5	
0.58		0.94		2.4		4.4		8.0		18.0	
0.60		0.95		2.5		4.5		8.5		18.5	
0.62		0.96		2.6		4.6		9.0		19.0	
0.64		0.97		2.7		4.7		9.5		19.5	
0.66		0.98		2.8		4.8		10.0		20.0	

Table 10–5: FLEXLOGIC™ (Sheet 1 of 17)

SETTING	VALUE
FLEXLOGIC EQUATION EDITOR	
FlexLogic Entry 1	
FlexLogic Entry 2	
FlexLogic Entry 3	
FlexLogic Entry 4	
FlexLogic Entry 5	
FlexLogic Entry 6	
FlexLogic Entry 7	
FlexLogic Entry 8	
FlexLogic Entry 9	
FlexLogic Entry 10	
FlexLogic Entry 11	
FlexLogic Entry 12	
FlexLogic Entry 13	
FlexLogic Entry 14	
FlexLogic Entry 15	
FlexLogic Entry 16	
FlexLogic Entry 17	
FlexLogic Entry 18	
FlexLogic Entry 19	
FlexLogic Entry 20	
FlexLogic Entry 21	
FlexLogic Entry 22	
FlexLogic Entry 23	
FlexLogic Entry 24	
FlexLogic Entry 25	
FlexLogic Entry 26	
FlexLogic Entry 27	
FlexLogic Entry 28	
FlexLogic Entry 29	
FlexLogic Entry 30	
FlexLogic Entry 31	
FlexLogic Entry 32	
FlexLogic Entry 33	
FlexLogic Entry 34	
FlexLogic Entry 35	
FlexLogic Entry 36	
FlexLogic Entry 37	
FlexLogic Entry 38	
FlexLogic Entry 39	
FlexLogic Entry 40	
FlexLogic Entry 41	
FlexLogic Entry 42	
FlexLogic Entry 43	

Table 10–5: FLEXLOGIC™ (Sheet 2 of 17)

SETTING	VALUE
FlexLogic Entry 44	
FlexLogic Entry 45	
FlexLogic Entry 46	
FlexLogic Entry 47	
FlexLogic Entry 48	
FlexLogic Entry 49	
FlexLogic Entry 50	
FlexLogic Entry 51	
FlexLogic Entry 52	
FlexLogic Entry 53	
FlexLogic Entry 54	
FlexLogic Entry 55	
FlexLogic Entry 56	
FlexLogic Entry 57	
FlexLogic Entry 58	
FlexLogic Entry 59	
FlexLogic Entry 60	
FlexLogic Entry 61	
FlexLogic Entry 62	
FlexLogic Entry 63	
FlexLogic Entry 64	
FlexLogic Entry 65	
FlexLogic Entry 66	
FlexLogic Entry 67	
FlexLogic Entry 68	
FlexLogic Entry 69	
FlexLogic Entry 70	
FlexLogic Entry 71	
FlexLogic Entry 72	
FlexLogic Entry 73	
FlexLogic Entry 74	
FlexLogic Entry 75	
FlexLogic Entry 76	
FlexLogic Entry 77	
FlexLogic Entry 78	
FlexLogic Entry 79	
FlexLogic Entry 80	
FlexLogic Entry 81	
FlexLogic Entry 82	
FlexLogic Entry 83	
FlexLogic Entry 84	
FlexLogic Entry 85	
FlexLogic Entry 86	
FlexLogic Entry 87	

Table 10–5: FLEXLOGIC™ (Sheet 3 of 17)

SETTING	VALUE
FlexLogic Entry 88	
FlexLogic Entry 89	
FlexLogic Entry 90	
FlexLogic Entry 91	
FlexLogic Entry 92	
FlexLogic Entry 93	
FlexLogic Entry 94	
FlexLogic Entry 95	
FlexLogic Entry 96	
FlexLogic Entry 97	
FlexLogic Entry 98	
FlexLogic Entry 99	
FlexLogic Entry 100	
FlexLogic Entry 101	
FlexLogic Entry 102	
FlexLogic Entry 103	
FlexLogic Entry 104	
FlexLogic Entry 105	
FlexLogic Entry 106	
FlexLogic Entry 107	
FlexLogic Entry 108	
FlexLogic Entry 109	
FlexLogic Entry 110	
FlexLogic Entry 111	
FlexLogic Entry 112	
FlexLogic Entry 113	
FlexLogic Entry 114	
FlexLogic Entry 115	
FlexLogic Entry 116	
FlexLogic Entry 117	
FlexLogic Entry 118	
FlexLogic Entry 119	
FlexLogic Entry 120	
FlexLogic Entry 121	
FlexLogic Entry 122	
FlexLogic Entry 123	
FlexLogic Entry 124	
FlexLogic Entry 125	
FlexLogic Entry 126	
FlexLogic Entry 127	
FlexLogic Entry 128	
FlexLogic Entry 129	
FlexLogic Entry 130	
FlexLogic Entry 131	
FlexLogic Entry 132	
FlexLogic Entry 133	
FlexLogic Entry 134	

Table 10–5: FLEXLOGIC™ (Sheet 4 of 17)

SETTING	VALUE
FlexLogic Entry 135	
FlexLogic Entry 136	
FlexLogic Entry 137	
FlexLogic Entry 138	
FlexLogic Entry 139	
FlexLogic Entry 140	
FlexLogic Entry 141	
FlexLogic Entry 142	
FlexLogic Entry 143	
FlexLogic Entry 144	
FlexLogic Entry 145	
FlexLogic Entry 146	
FlexLogic Entry 147	
FlexLogic Entry 148	
FlexLogic Entry 149	
FlexLogic Entry 150	
FlexLogic Entry 151	
FlexLogic Entry 152	
FlexLogic Entry 153	
FlexLogic Entry 154	
FlexLogic Entry 155	
FlexLogic Entry 156	
FlexLogic Entry 157	
FlexLogic Entry 158	
FlexLogic Entry 159	
FlexLogic Entry 160	
FlexLogic Entry 161	
FlexLogic Entry 162	
FlexLogic Entry 163	
FlexLogic Entry 164	
FlexLogic Entry 165	
FlexLogic Entry 166	
FlexLogic Entry 167	
FlexLogic Entry 168	
FlexLogic Entry 169	
FlexLogic Entry 170	
FlexLogic Entry 171	
FlexLogic Entry 172	
FlexLogic Entry 173	
FlexLogic Entry 174	
FlexLogic Entry 175	
FlexLogic Entry 176	
FlexLogic Entry 177	
FlexLogic Entry 178	
FlexLogic Entry 179	
FlexLogic Entry 180	
FlexLogic Entry 181	

Table 10–5: FLEXLOGIC™ (Sheet 5 of 17)

SETTING	VALUE
FlexLogic Entry 182	
FlexLogic Entry 183	
FlexLogic Entry 184	
FlexLogic Entry 185	
FlexLogic Entry 186	
FlexLogic Entry 187	
FlexLogic Entry 188	
FlexLogic Entry 189	
FlexLogic Entry 190	
FlexLogic Entry 191	
FlexLogic Entry 192	
FlexLogic Entry 193	
FlexLogic Entry 194	
FlexLogic Entry 195	
FlexLogic Entry 196	
FlexLogic Entry 197	
FlexLogic Entry 198	
FlexLogic Entry 199	
FlexLogic Entry 200	
FlexLogic Entry 201	
FlexLogic Entry 202	
FlexLogic Entry 203	
FlexLogic Entry 204	
FlexLogic Entry 205	
FlexLogic Entry 206	
FlexLogic Entry 207	
FlexLogic Entry 208	
FlexLogic Entry 209	
FlexLogic Entry 210	
FlexLogic Entry 211	
FlexLogic Entry 212	
FlexLogic Entry 213	
FlexLogic Entry 214	
FlexLogic Entry 215	
FlexLogic Entry 216	
FlexLogic Entry 217	
FlexLogic Entry 218	
FlexLogic Entry 219	
FlexLogic Entry 220	
FlexLogic Entry 221	
FlexLogic Entry 222	
FlexLogic Entry 223	
FlexLogic Entry 224	
FlexLogic Entry 225	
FlexLogic Entry 226	
FlexLogic Entry 227	
FlexLogic Entry 228	

Table 10–5: FLEXLOGIC™ (Sheet 6 of 17)

SETTING	VALUE
FlexLogic Entry 229	
FlexLogic Entry 230	
FlexLogic Entry 231	
FlexLogic Entry 232	
FlexLogic Entry 233	
FlexLogic Entry 234	
FlexLogic Entry 235	
FlexLogic Entry 236	
FlexLogic Entry 237	
FlexLogic Entry 238	
FlexLogic Entry 239	
FlexLogic Entry 240	
FlexLogic Entry 241	
FlexLogic Entry 242	
FlexLogic Entry 243	
FlexLogic Entry 244	
FlexLogic Entry 245	
FlexLogic Entry 246	
FlexLogic Entry 247	
FlexLogic Entry 248	
FlexLogic Entry 249	
FlexLogic Entry 250	
FlexLogic Entry 251	
FlexLogic Entry 252	
FlexLogic Entry 253	
FlexLogic Entry 254	
FlexLogic Entry 255	
FlexLogic Entry 256	
FlexLogic Entry 257	
FlexLogic Entry 258	
FlexLogic Entry 259	
FlexLogic Entry 260	
FlexLogic Entry 261	
FlexLogic Entry 262	
FlexLogic Entry 263	
FlexLogic Entry 264	
FlexLogic Entry 265	
FlexLogic Entry 266	
FlexLogic Entry 267	
FlexLogic Entry 268	
FlexLogic Entry 269	
FlexLogic Entry 270	
FlexLogic Entry 271	
FlexLogic Entry 272	
FlexLogic Entry 273	
FlexLogic Entry 274	
FlexLogic Entry 275	

Table 10–5: FLEXLOGIC™ (Sheet 7 of 17)

SETTING	VALUE
FlexLogic Entry 276	
FlexLogic Entry 277	
FlexLogic Entry 278	
FlexLogic Entry 279	
FlexLogic Entry 280	
FlexLogic Entry 281	
FlexLogic Entry 282	
FlexLogic Entry 283	
FlexLogic Entry 284	
FlexLogic Entry 285	
FlexLogic Entry 286	
FlexLogic Entry 287	
FlexLogic Entry 288	
FlexLogic Entry 289	
FlexLogic Entry 290	
FlexLogic Entry 291	
FlexLogic Entry 292	
FlexLogic Entry 293	
FlexLogic Entry 294	
FlexLogic Entry 295	
FlexLogic Entry 296	
FlexLogic Entry 297	
FlexLogic Entry 298	
FlexLogic Entry 299	
FlexLogic Entry 300	
FlexLogic Entry 301	
FlexLogic Entry 302	
FlexLogic Entry 303	
FlexLogic Entry 304	
FlexLogic Entry 305	
FlexLogic Entry 306	
FlexLogic Entry 307	
FlexLogic Entry 308	
FlexLogic Entry 309	
FlexLogic Entry 310	
FlexLogic Entry 311	
FlexLogic Entry 312	
FlexLogic Entry 313	
FlexLogic Entry 314	
FlexLogic Entry 315	
FlexLogic Entry 316	
FlexLogic Entry 317	
FlexLogic Entry 318	
FlexLogic Entry 319	
FlexLogic Entry 320	
FlexLogic Entry 321	
FlexLogic Entry 322	

Table 10–5: FLEXLOGIC™ (Sheet 8 of 17)

SETTING	VALUE
FlexLogic Entry 323	
FlexLogic Entry 324	
FlexLogic Entry 325	
FlexLogic Entry 326	
FlexLogic Entry 327	
FlexLogic Entry 328	
FlexLogic Entry 329	
FlexLogic Entry 330	
FlexLogic Entry 331	
FlexLogic Entry 332	
FlexLogic Entry 333	
FlexLogic Entry 334	
FlexLogic Entry 335	
FlexLogic Entry 336	
FlexLogic Entry 337	
FlexLogic Entry 338	
FlexLogic Entry 339	
FlexLogic Entry 340	
FlexLogic Entry 341	
FlexLogic Entry 342	
FlexLogic Entry 343	
FlexLogic Entry 344	
FlexLogic Entry 345	
FlexLogic Entry 346	
FlexLogic Entry 347	
FlexLogic Entry 348	
FlexLogic Entry 349	
FlexLogic Entry 350	
FlexLogic Entry 351	
FlexLogic Entry 352	
FlexLogic Entry 353	
FlexLogic Entry 354	
FlexLogic Entry 355	
FlexLogic Entry 356	
FlexLogic Entry 357	
FlexLogic Entry 358	
FlexLogic Entry 359	
FlexLogic Entry 360	
FlexLogic Entry 361	
FlexLogic Entry 362	
FlexLogic Entry 363	
FlexLogic Entry 364	
FlexLogic Entry 365	
FlexLogic Entry 366	
FlexLogic Entry 367	
FlexLogic Entry 368	
FlexLogic Entry 369	

Table 10–5: FLEXLOGIC™ (Sheet 9 of 17)

SETTING	VALUE
FlexLogic Entry 370	
FlexLogic Entry 371	
FlexLogic Entry 372	
FlexLogic Entry 373	
FlexLogic Entry 374	
FlexLogic Entry 375	
FlexLogic Entry 376	
FlexLogic Entry 377	
FlexLogic Entry 378	
FlexLogic Entry 379	
FlexLogic Entry 380	
FlexLogic Entry 381	
FlexLogic Entry 382	
FlexLogic Entry 383	
FlexLogic Entry 384	
FlexLogic Entry 385	
FlexLogic Entry 386	
FlexLogic Entry 387	
FlexLogic Entry 388	
FlexLogic Entry 389	
FlexLogic Entry 390	
FlexLogic Entry 391	
FlexLogic Entry 392	
FlexLogic Entry 393	
FlexLogic Entry 394	
FlexLogic Entry 395	
FlexLogic Entry 396	
FlexLogic Entry 397	
FlexLogic Entry 398	
FlexLogic Entry 399	
FlexLogic Entry 400	
FlexLogic Entry 401	
FlexLogic Entry 402	
FlexLogic Entry 403	
FlexLogic Entry 404	
FlexLogic Entry 405	
FlexLogic Entry 406	
FlexLogic Entry 407	
FlexLogic Entry 408	
FlexLogic Entry 409	
FlexLogic Entry 410	
FlexLogic Entry 411	
FlexLogic Entry 412	
FlexLogic Entry 413	
FlexLogic Entry 414	
FlexLogic Entry 415	
FlexLogic Entry 416	

Table 10–5: FLEXLOGIC™ (Sheet 10 of 17)

SETTING	VALUE
FlexLogic Entry 417	
FlexLogic Entry 418	
FlexLogic Entry 419	
FlexLogic Entry 420	
FlexLogic Entry 421	
FlexLogic Entry 422	
FlexLogic Entry 423	
FlexLogic Entry 424	
FlexLogic Entry 425	
FlexLogic Entry 426	
FlexLogic Entry 427	
FlexLogic Entry 428	
FlexLogic Entry 429	
FlexLogic Entry 430	
FlexLogic Entry 431	
FlexLogic Entry 432	
FlexLogic Entry 433	
FlexLogic Entry 434	
FlexLogic Entry 435	
FlexLogic Entry 436	
FlexLogic Entry 437	
FlexLogic Entry 438	
FlexLogic Entry 439	
FlexLogic Entry 440	
FlexLogic Entry 441	
FlexLogic Entry 442	
FlexLogic Entry 443	
FlexLogic Entry 444	
FlexLogic Entry 445	
FlexLogic Entry 446	
FlexLogic Entry 447	
FlexLogic Entry 448	
FlexLogic Entry 449	
FlexLogic Entry 450	
FlexLogic Entry 451	
FlexLogic Entry 452	
FlexLogic Entry 453	
FlexLogic Entry 454	
FlexLogic Entry 455	
FlexLogic Entry 456	
FlexLogic Entry 457	
FlexLogic Entry 458	
FlexLogic Entry 459	
FlexLogic Entry 460	
FlexLogic Entry 461	
FlexLogic Entry 462	
FlexLogic Entry 463	

Table 10–5: FLEXLOGIC™ (Sheet 11 of 17)

SETTING	VALUE
FlexLogic Entry 464	
FlexLogic Entry 465	
FlexLogic Entry 466	
FlexLogic Entry 467	
FlexLogic Entry 468	
FlexLogic Entry 469	
FlexLogic Entry 470	
FlexLogic Entry 471	
FlexLogic Entry 472	
FlexLogic Entry 473	
FlexLogic Entry 474	
FlexLogic Entry 475	
FlexLogic Entry 476	
FlexLogic Entry 477	
FlexLogic Entry 478	
FlexLogic Entry 479	
FlexLogic Entry 480	
FlexLogic Entry 481	
FlexLogic Entry 482	
FlexLogic Entry 483	
FlexLogic Entry 484	
FlexLogic Entry 485	
FlexLogic Entry 486	
FlexLogic Entry 487	
FlexLogic Entry 488	
FlexLogic Entry 489	
FlexLogic Entry 490	
FlexLogic Entry 491	
FlexLogic Entry 492	
FlexLogic Entry 493	
FlexLogic Entry 494	
FlexLogic Entry 495	
FlexLogic Entry 496	
FlexLogic Entry 497	
FlexLogic Entry 498	
FlexLogic Entry 499	
FlexLogic Entry 500	
FlexLogic Entry 501	
FlexLogic Entry 502	
FlexLogic Entry 503	
FlexLogic Entry 504	
FlexLogic Entry 505	
FlexLogic Entry 506	
FlexLogic Entry 507	
FlexLogic Entry 508	
FlexLogic Entry 509	
FlexLogic Entry 510	

Table 10–5: FLEXLOGIC™ (Sheet 12 of 17)

SETTING	VALUE
FlexLogic Entry 511	
FlexLogic Entry 512	
FLEXLOGIC TIMER 1	
FlexLogic Timer 1 Type	
FlexLogic Timer 1 Pickup Delay	
FlexLogic Timer 1 Dropout Delay	
FLEXLOGIC TIMER 2	
FlexLogic Timer 2 Type	
FlexLogic Timer 2 Pickup Delay	
FlexLogic Timer 2 Dropout Delay	
FLEXLOGIC TIMER 3	
FlexLogic Timer 3 Type	
FlexLogic Timer 3 Pickup Delay	
FlexLogic Timer 3 Dropout Delay	
FLEXLOGIC TIMER 4	
FlexLogic Timer 4 Type	
FlexLogic Timer 4 Pickup Delay	
FlexLogic Timer 4 Dropout Delay	
FLEXLOGIC TIMER 5	
FlexLogic Timer 5 Type	
FlexLogic Timer 5 Pickup Delay	
FlexLogic Timer 5 Dropout Delay	
FLEXLOGIC TIMER 6	
FlexLogic Timer 6 Type	
FlexLogic Timer 6 Pickup Delay	
FlexLogic Timer 6 Dropout Delay	
FLEXLOGIC TIMER 7	
FlexLogic Timer 7 Type	
FlexLogic Timer 7 Pickup Delay	
FlexLogic Timer 7 Dropout Delay	
FLEXLOGIC TIMER 8	
FlexLogic Timer 8 Type	
FlexLogic Timer 8 Pickup Delay	
FlexLogic Timer 8 Dropout Delay	
FLEXLOGIC TIMER 9	
FlexLogic Timer 9 Type	
FlexLogic Timer 9 Pickup Delay	
FlexLogic Timer 9 Dropout Delay	
FLEXLOGIC TIMER 10	
FlexLogic Timer 10 Type	
FlexLogic Timer 10 Pickup Delay	
FlexLogic Timer 10 Dropout Delay	
FLEXLOGIC TIMER 11	
FlexLogic Timer 11 Type	
FlexLogic Timer 11 Pickup Delay	
FlexLogic Timer 11 Dropout Delay	

Table 10–5: FLEXLOGIC™ (Sheet 13 of 17)

SETTING	VALUE
FLEXLOGIC TIMER 12	
FlexLogic Timer 12 Type	
FlexLogic Timer 12 Pickup Delay	
FlexLogic Timer 12 Dropout Delay	
FLEXLOGIC TIMER 13	
FlexLogic Timer 13 Type	
FlexLogic Timer 13 Pickup Delay	
FlexLogic Timer 13 Dropout Delay	
FLEXLOGIC TIMER 14	
FlexLogic Timer 14 Type	
FlexLogic Timer 14 Pickup Delay	
FlexLogic Timer 14 Dropout Delay	
FLEXLOGIC TIMER 15	
FlexLogic Timer 15 Type	
FlexLogic Timer 15 Pickup Delay	
FlexLogic Timer 15 Dropout Delay	
FLEXLOGIC TIMER 16	
FlexLogic Timer 16 Type	
FlexLogic Timer 16 Pickup Delay	
FlexLogic Timer 16 Dropout Delay	
FLEXLOGIC TIMER 17	
FlexLogic Timer 17 Type	
FlexLogic Timer 17 Pickup Delay	
FlexLogic Timer 17 Dropout Delay	
FLEXLOGIC TIMER 18	
FlexLogic Timer 18 Type	
FlexLogic Timer 18 Pickup Delay	
FlexLogic Timer 18 Dropout Delay	
FLEXLOGIC TIMER 19	
FlexLogic Timer 19 Type	
FlexLogic Timer 19 Pickup Delay	
FlexLogic Timer 19 Dropout Delay	
FLEXLOGIC TIMER 20	
FlexLogic Timer 20 Type	
FlexLogic Timer 20 Pickup Delay	
FlexLogic Timer 20 Dropout Delay	
FLEXLOGIC TIMER 21	
FlexLogic Timer 21 Type	
FlexLogic Timer 21 Pickup Delay	
FlexLogic Timer 21 Dropout Delay	
FLEXLOGIC TIMER 22	
FlexLogic Timer 22 Type	
FlexLogic Timer 22 Pickup Delay	
FlexLogic Timer 22 Dropout Delay	
FLEXLOGIC TIMER 23	
FlexLogic Timer 23 Type	
FlexLogic Timer 23 Pickup Delay	

Table 10–5: FLEXLOGIC™ (Sheet 14 of 17)

SETTING	VALUE
FlexLogic Timer 23 Dropout Delay	
FLEXLOGIC TIMER 24	
FlexLogic Timer 24 Type	
FlexLogic Timer 24 Pickup Delay	
FlexLogic Timer 24 Dropout Delay	
FLEXLOGIC TIMER 25	
FlexLogic Timer 25 Type	
FlexLogic Timer 25 Pickup Delay	
FlexLogic Timer 25 Dropout Delay	
FLEXLOGIC TIMER 26	
FlexLogic Timer 26 Type	
FlexLogic Timer 26 Pickup Delay	
FlexLogic Timer 26 Dropout Delay	
FLEXLOGIC TIMER 27	
FlexLogic Timer 27 Type	
FlexLogic Timer 27 Pickup Delay	
FlexLogic Timer 27 Dropout Delay	
FLEXLOGIC TIMER 28	
FlexLogic Timer 28 Type	
FlexLogic Timer 28 Pickup Delay	
FlexLogic Timer 28 Dropout Delay	
FLEXLOGIC TIMER 29	
FlexLogic Timer 29 Type	
FlexLogic Timer 29 Pickup Delay	
FlexLogic Timer 29 Dropout Delay	
FLEXLOGIC TIMER 30	
FlexLogic Timer 30 Type	
FlexLogic Timer 30 Pickup Delay	
FlexLogic Timer 30 Dropout Delay	
FLEXLOGIC TIMER 31	
FlexLogic Timer 31 Type	
FlexLogic Timer 31 Pickup Delay	
FlexLogic Timer 31 Dropout Delay	
FLEXLOGIC TIMER 32	
FlexLogic Timer 32 Type	
FlexLogic Timer 32 Pickup Delay	
FlexLogic Timer 32 Dropout Delay	
FLEXLELEMENT 1	
FlexElement 1 Function	
FlexElement 1 Name	
FlexElement 1 +IN	
FlexElement 1 –IN	
FlexElement 1 Input Mode	
FlexElement 1 Comp Mode	
FlexElement 1 Direction	
FlexElement 1 Pickup	
FlexElement 1 Hysteresis	

Table 10–5: FLEXLOGIC™ (Sheet 15 of 17)

SETTING	VALUE
FlexElement 1 dt Unit	
FlexElement 1 dt	
FlexElement 1 Pkp Delay	
FlexElement 1 Rst Delay	
FlexElement 1 Blk	
FlexElement 1 Target	
FlexElement 1 Events	
FLEXLELEMENT 2	
FlexElement 2 Function	
FlexElement 2 Name	
FlexElement 2 +IN	
FlexElement 2 –IN	
FlexElement 2 Input Mode	
FlexElement 2 Comp Mode	
FlexElement 2 Direction	
FlexElement 2 Pickup	
FlexElement 2 Hysteresis	
FlexElement 2 dt Unit	
FlexElement 2 dt	
FlexElement 2 Pkp Delay	
FlexElement 2 Rst Delay	
FlexElement 2 Blk	
FlexElement 2 Target	
FlexElement 2 Events	
FLEXLELEMENT 3	
FlexElement 3 Function	
FlexElement 3 Name	
FlexElement 3 +IN	
FlexElement 3 –IN	
FlexElement 3 Input Mode	
FlexElement 3 Comp Mode	
FlexElement 3 Direction	
FlexElement 3 Pickup	
FlexElement 3 Hysteresis	
FlexElement 3 dt Unit	
FlexElement 3 dt	
FlexElement 3 Pkp Delay	
FlexElement 3 Rst Delay	
FlexElement 3 Blk	
FlexElement 3 Target	
FlexElement 3 Events	
FLEXLELEMENT 4	
FlexElement 4 Function	
FlexElement 4 Name	
FlexElement 4 +IN	
FlexElement 4 –IN	
FlexElement 4 Input Mode	

Table 10–5: FLEXLOGIC™ (Sheet 16 of 17)

SETTING	VALUE
FlexElement 4 Comp Mode	
FlexElement 4 Direction	
FlexElement 4 Pickup	
FlexElement 4 Hysteresis	
FlexElement 4 dt Unit	
FlexElement 4 dt	
FlexElement 4 Pkp Delay	
FlexElement 4 Rst Delay	
FlexElement 4 Blk	
FlexElement 4 Target	
FlexElement 4 Events	
FLEXLELEMENT 5	
FlexElement 5 Function	
FlexElement 5 Name	
FlexElement 5 +IN	
FlexElement 5 –IN	
FlexElement 5 Input Mode	
FlexElement 5 Comp Mode	
FlexElement 5 Direction	
FlexElement 5 Pickup	
FlexElement 5 Hysteresis	
FlexElement 5 dt Unit	
FlexElement 5 dt	
FlexElement 5 Pkp Delay	
FlexElement 5 Rst Delay	
FlexElement 5 Blk	
FlexElement 5 Target	
FlexElement 5 Events	
FLEXLELEMENT 6	
FlexElement 6 Function	
FlexElement 6 Name	
FlexElement 6 +IN	
FlexElement 6 –IN	
FlexElement 6 Input Mode	
FlexElement 6 Comp Mode	
FlexElement 6 Direction	
FlexElement 6 Pickup	
FlexElement 6 Hysteresis	
FlexElement 6 dt Unit	
FlexElement 6 dt	
FlexElement 6 Pkp Delay	
FlexElement 6 Rst Delay	
FlexElement 6 Blk	
FlexElement 6 Target	
FlexElement 6 Events	
FLEXLELEMENT 7	
FlexElement 7 Function	

Table 10–5: FLEXLOGIC™ (Sheet 17 of 17)

SETTING	VALUE
FlexElement 7 Name	
FlexElement 7 +IN	
FlexElement 7 –IN	
FlexElement 7 Input Mode	
FlexElement 7 Comp Mode	
FlexElement 7 Direction	
FlexElement 7 Pickup	
FlexElement 7 Hysteresis	
FlexElement 7 dt Unit	
FlexElement 7 dt	
FlexElement 7 Pkp Delay	
FlexElement 7 Rst Delay	
FlexElement 7 Blk	
FlexElement 7 Target	
FlexElement 7 Events	
FLEXLELEMENT 8	
FlexElement 8 Function	
FlexElement 8 Name	
FlexElement 8 +IN	
FlexElement 8 –IN	
FlexElement 8 Input Mode	
FlexElement 8 Comp Mode	
FlexElement 8 Direction	
FlexElement 8 Pickup	
FlexElement 8 Hysteresis	
FlexElement 8 dt Unit	
FlexElement 8 dt	
FlexElement 8 Pkp Delay	
FlexElement 8 Rst Delay	
FlexElement 8 Blk	
FlexElement 8 Target	
FlexElement 8 Events	

Table 10–6: GROUPED ELEMENTS (Sheet 1 of 11)

SETTING	VALUE
DIFFERENTIAL ELEMENTS	
CURRENT DIFFERENTIAL	
Current Diff Function	
Current Diff Signal Source	
Current Diff Block	
Current Diff Pickup	
Current Diff CT Tap 1	
Current Diff CT Tap 2	
Current Diff Restraint 1	
Current Diff Restraint 2	
Current Diff Break Point	
Current Diff DTT	
Current Diff Key DTT	
Current Diff Target	
Current Diff Events	
STUB BUS	
Stub Bus Function	
Stub Bus Disconnect	
Stub Bus Trigger	
Stub Bus Target	
Stub Bus Events	
LINE ELEMENTS	
LINE PICKUP	
Line Pickup Function	
Line Pickup Signal Source	
Phase IOC Line Pickup	
Positive Seq. UV Pickup	
Line End Open Pickup Delay	
Line End Open Reset Delay	
Positive Seq. OV Pickup Delay	
AR CO-ORD Bypass	
AR CO-ORD Pickup Delay	
AR CO-ORD Reset Delay	
Line Pickup Block	
Line Pickup Target	
Line Pickup Events	
DISTANCE ELEMENTS	
DISTANCE	
Distance Source	
Memory Duration	
PHASE DISTANCE Z2	
Phs Dist Z2 Function	
Phs Dist Z2 Direction	
Phs Dist Z2 Shape	

Table 10–6: GROUPED ELEMENTS (Sheet 2 of 11)

SETTING	VALUE
Phs Dist Z2 Reach	
Phs Dist Z2 RCA	
Phs Dist Z2 Comp. Limit	
Phs Dist Z2 Dir RCA	
Phs Dist Z2 Dir Comp. Limit	
Phs Dist Z2 Quad Rgt Bld	
Phs Dist Z2 Quad Rgt Bld RCA	
Phs Dist Z2 Quad Lft Bld	
Phs Dist Z2 Quad Lft Bld RCA	
Phs Dist Z2 Supv	
Phs Dist Z2 Volt Level	
Phs Dist Z2 Delay	
Phs Dist Z2 Blk	
Phs Dist Z2 Target	
Phs Dist Z2 Events	
GROUND DISTANCE Z2	
Gnd Dist Z2 Function	
Gnd Dist Z2 Direction	
Gnd Dist Z2 Shape	
Gnd Dist Z2 Z0/Z2 Mag	
Gnd Dist Z2 Z0/Z2 Ang	
Gnd Dist Z2 Z0M/Z2 Mag	
Gnd Dist Z2 Z0M/Z2 Ang	
Gnd Dist Z2 Reach	
Gnd Dist Z2 RCA	
Gnd Dist Z2 Comp Limit	
Gnd Dist Z2 Dir RCA	
Gnd Dist Z2 Dir Comp Limit	
Gnd Dist Z2 Quad Rgt Bld	
Gnd Dist Z2 Quad Rgt Bld RCA	
Gnd Dist Z2 Quad Lft Bld	
Gnd Dist Z2 Quad Lft Bld RCA	
Gnd Dist Z2 Supv	
Gnd Dist Z2 Volt Level	
Gnd Dist Z2 Delay	
Gnd Dist Z2 Block	
Gnd Dist Z2 Target	
Gnd Dist Z2 Events	
POWER SWING DETECT	
Power Swing Function	
Power Swing Source	
Power Swing Mode	
Power Swing Supv	
Power Swing Fwd Reach	

Table 10–6: GROUPED ELEMENTS (Sheet 3 of 11)

SETTING	VALUE
Power Swing Fwd RCA	
Power Swing Rev Reach	
Power Swing Rev RCA	
Power Swing Outer Limit Angle	
Power Swing Middle Limit Angle	
Power Swing Inner Limit Angle	
Power Swing Pickup Delay 1	
Power Swing Reset Delay 1	
Power Swing Pickup Delay 2	
Power Swing Pickup Delay 3	
Power Swing Pickup Delay 4	
Power Swing Seal-In Delay 1	
Power Swing Trip Mode	
Power Swing Blk	
Power Swing Target	
Power Swing Events	
LOAD ENCROACHMENT	
Load Encroachment Function	
Load Encroachment Source	
Load Encroachment Min Volt	
Load Encroachment Reach	
Load Encroachment Angle	
Load Encroachment Pkp Delay	
Load Encroachment Rst Delay	
Load Encroachment Blk	
Load Encroachment Target	
Load Encroachment Events	
CURRENT ELEMENTS	
PHASE TOC1	
Phase TOC1 Function	
Phase TOC1 Signal Source	
Phase TOC1 Input	
Phase TOC1 Pickup	
Phase TOC1 Curve	
Phase TOC1 Multiplier	
Phase TOC1 Reset	
Phase TOC1 Voltage Restraint	
Phase TOC1 Block A	
Phase TOC1 Block B	
Phase TOC1 Block C	
Phase TOC1 Target	
Phase TOC1 Events	
PHASE TOC2	
Phase TOC2 Function	
Phase TOC2 Signal Source	
Phase TOC2 Input	
Phase TOC2 Pickup	

Table 10–6: GROUPED ELEMENTS (Sheet 4 of 11)

SETTING	VALUE
Phase TOC2 Curve	
Phase TOC2 Multiplier	
Phase TOC2 Reset	
Phase TOC2 Voltage Restraint	
Phase TOC2 Block A	
Phase TOC2 Block B	
Phase TOC2 Block C	
Phase TOC2 Target	
Phase TOC2 Events	
PHASE IOC1	
Phase IOC1 Function	
Phase IOC1 Signal Source	
Phase IOC1 Pickup	
Phase IOC1 Pickup Delay	
Phase IOC1 Reset Delay	
Phase IOC1 Block A	
Phase IOC1 Block B	
Phase IOC1 Block C	
Phase IOC1 Target	
Phase IOC1 Events	
PHASE IOC2	
Phase IOC2 Function	
Phase IOC2 Signal Source	
Phase IOC2 Pickup	
Phase IOC2 Pickup Delay	
Phase IOC2 Reset Delay	
Phase IOC2 Block A	
Phase IOC2 Block B	
Phase IOC2 Block C	
Phase IOC2 Target	
Phase IOC2 Events	
NEUTRAL TOC1	
Neutral TOC1 Function	
Neutral TOC1 Signal Source	
Neutral TOC1 Input	
Neutral TOC1 Pickup	
Neutral TOC1 Curve	
Neutral TOC1 TD Multiplier	
Neutral TOC1 Reset	
Neutral TOC1 Block	
Neutral TOC1 Target	
Neutral TOC1 Events	
NEUTRAL TOC2	
Neutral TOC2 Function	
Neutral TOC2 Signal Source	
Neutral TOC2 Input	
Neutral TOC2 Pickup	

Table 10–6: GROUPED ELEMENTS (Sheet 5 of 11)

SETTING	VALUE
Neutral TOC2 Curve	
Neutral TOC2 TD Multiplier	
Neutral TOC2 Reset	
Neutral TOC2 Block	
Neutral TOC2 Target	
Neutral TOC2 Events	
NEUTRAL IOC1	
Neutral IOC1 Function	
Neutral IOC1 Signal Source	
Neutral IOC1 Pickup	
Neutral IOC1 Pickup Delay	
Neutral IOC1 Reset Delay	
Neutral IOC1 Block	
Neutral IOC1 Target	
Neutral IOC1 Events	
NEUTRAL IOC2	
Neutral IOC2 Function	
Neutral IOC2 Signal Source	
Neutral IOC2 Pickup	
Neutral IOC2 Pickup Delay	
Neutral IOC2 Reset Delay	
Neutral IOC2 Block	
Neutral IOC2 Target	
Neutral IOC2 Events	
GROUND TOC1	
Ground TOC1 Function	
Ground TOC1 Signal Source	
Ground TOC1 Input	
Ground TOC1 Pickup	
Ground TOC1 Curve	
Ground TOC1 TD Multiplier	
Ground TOC1 Reset	
Ground TOC1 Block	
Ground TOC1 Target	
Ground TOC1 Events	
GROUND TOC2	
Ground TOC2 Function	
Ground TOC2 Signal Source	
Ground TOC2 Input	
Ground TOC2 Pickup	
Ground TOC2 Curve	
Ground TOC2 TD Multiplier	
Ground TOC2 Reset	
Ground TOC2 Block	
Ground TOC2 Target	
Ground TOC2 Events	

Table 10–6: GROUPED ELEMENTS (Sheet 6 of 11)

SETTING	VALUE
GROUND IOC1	
Ground IOC1 Function	
Ground IOC1 Signal Source	
Ground IOC1 Pickup	
Ground IOC1 Pickup Delay	
Ground IOC1 Reset Delay	
Ground IOC1 Block	
Ground IOC1 Target	
Ground IOC1 Events	
GROUND IOC2	
Ground IOC2 Function	
Ground IOC2 Signal Source	
Ground IOC2 Pickup	
Ground IOC2 Pickup Delay	
Ground IOC2 Reset Delay	
Ground IOC2 Block	
Ground IOC2 Target	
Ground IOC2 Events	
NEG SEQ TOC1	
Neg. Seq. TOC1 Function	
Neg. Seq. TOC1 Signal Source	
Neg. Seq. TOC1 Pickup	
Neg. Seq. TOC1 Curve	
Neg. Seq. TOC1 TD Multiplier	
Neg. Seq. TOC1 Reset	
Neg. Seq. TOC1 Block	
Neg. Seq. TOC1 Target	
Neg. Seq. TOC1 Events	
NEG SEQ TOC2	
Neg. Seq. TOC2 Function	
Neg. Seq. TOC2 Signal Source	
Neg. Seq. TOC2 Pickup	
Neg. Seq. TOC2 Curve	
Neg. Seq. TOC2 TD Multiplier	
Neg. Seq. TOC2 Reset	
Neg. Seq. TOC2 Block	
Neg. Seq. TOC2 Target	
Neg. Seq. TOC2 Events	
NEG SEQ IOC1	
Neg. Seq. IOC1 Function	
Neg. Seq. IOC1 Signal Source	
Neg. Seq. IOC1 Pickup	
Neg. Seq. IOC1 Pickup Delay	
Neg. Seq. IOC1 Reset Delay	
Neg. Seq. IOC1 Block	
Neg. Seq. IOC1 Target	
Neg. Seq. IOC1 Events	

Table 10–6: GROUPED ELEMENTS (Sheet 7 of 11)

SETTING	VALUE
NEG SEQ IOC2	
Neg. Seq. IOC2 Function	
Neg. Seq. IOC2 Signal Source	
Neg. Seq. IOC2 Pickup	
Neg. Seq. IOC2 Pickup Delay	
Neg. Seq. IOC2 Reset Delay	
Neg. Seq. IOC2 Block	
Neg. Seq. IOC2 Target	
Neg. Seq. IOC2 Events	
CURRENT DIRECTIONALS	
PHASE DIRECTIONAL 1	
Phase Dir 1 Function	
Phase Dir 1 Signal Source	
Phase Dir 1 Block	
Phase Dir 1 ECA	
Phase Dir Pol V1 Threshold	
Phase Dir 1 Block When V Mem Exp	
Phase Dir 1 Target	
Phase Dir 1 Events	
PHASE DIRECTIONAL 2	
Phase Dir 2 Function	
Phase Dir 2 Signal Source	
Phase Dir 2 Block	
Phase Dir 2 ECA	
Phase Dir Pol V2 Threshold	
Phase Dir 2 Block When V Mem Exp	
Phase Dir 2 Target	
Phase Dir 2 Events	
NEUTRAL DIRECTIONAL OC1	
Neutral Dir OC1 Function	
Neutral Dir OC1 Source	
Neutral Dir OC1 Polarizing	
Neutral Dir OC1 Pol Volt	
Neutral Dir OC1 Op Curr	
Neutral Dir OC1 Offeset	
Neutral Dir OC1 Fwd ECA	
Neutral Dir OC1 Fwd Limit Angle	
Neutral Dir OC1 Fwd Pickup	
Neutral Dir OC1 Rev Limit Angle	
Neutral Dir OC1 Rev Pickup	
Neutral Dir OC1 Blk	
Neutral Dir OC1 Target	
Neutral Dir OC1 Events	
NEUTRAL DIRECTIONAL OC2	
Neutral Dir OC2 Function	
Neutral Dir OC2 Source	
Neutral Dir OC2 Polarizing	

Table 10–6: GROUPED ELEMENTS (Sheet 8 of 11)

SETTING	VALUE
Neutral Dir OC2 Pol Volt	
Neutral Dir OC2 Op Curr	
Neutral Dir OC2 Offeset	
Neutral Dir OC2 Fwd ECA	
Neutral Dir OC2 Fwd Limit Angle	
Neutral Dir OC2 Fwd Pickup	
Neutral Dir OC2 Rev Limit Angle	
Neutral Dir OC2 Rev Pickup	
Neutral Dir OC2 Blk	
Neutral Dir OC2 Target	
Neutral Dir OC2 Events	
BREAKER FAILURE ELEMENTS	
BREAKER FAILURE 1	
BF1 Function	
BF1 Mode	
BF1 Source	
BF1 Use Amp Supv	
BF1 Use Seal-In	
BF1 3-Pole Initiate	
BF1 Block	
BF1 Ph Amp Supv Pickup	
BF1 N Amp Supv Pickup	
BF1 Use Timer 1	
BF1 Timer 1 Pickup Delay	
BF1 Use Timer 2	
BF1 Timer 2 Pickup Delay	
BF1 Use Timer 3	
BF1 Timer 3 Pickup Delay	
BF1 Bkr POS1 ΦA/3P	
BF1 Bkr POS2 ΦA/3P	
BF1 Breaker Test On	
BF1 Ph Amp Hiset Pickup	
BF1 N Amp Hiset Pickup	
BF1 Ph Amp Loset Pickup	
BF1 N Amp Loset Pickup	
BF1 Loset Time Delay	
BF1 Trip Dropout Delay	
BF1 Target	
BF1 Events	
BF1 Ph A Initiate	
BF1 Ph B Initiate	
BF1 Ph C Initiate	
BF1 Bkr POS1 ΦB	
BF1 Bkr POS1 ΦC	
BF1 Bkr POS2 ΦB	
BF1 Bkr POS2 ΦC	
BREAKER FAILURE 2	

Table 10–6: GROUPED ELEMENTS (Sheet 9 of 11)

SETTING	VALUE
BF2 Function	
BF2 Mode	
BF2 Source	
BF2 Use Amp Supv	
BF2 Use Seal-In	
BF2 3-Pole Initiate	
BF2 Block	
BF2 Ph Amp Supv Pickup	
BF2 N Amp Supv Pickup	
BF2 Use Timer 1	
BF2 Timer 1 Pickup Delay	
BF2 Use Timer 2	
BF2 Timer 2 Pickup Delay	
BF2 Use Timer 3	
BF2 Timer 3 Pickup Delay	
BF2 Bkr POS1 ΦA/3P	
BF2 Bkr POS2 ΦA/3P	
BF2 Breaker Test On	
BF2 Ph Amp Hiset Pickup	
BF2 N Amp Hiset Pickup	
BF2 Ph Amp Loset Pickup	
BF2 N Amp Loset Pickup	
BF2 Loset Time Delay	
BF2 Trip Dropout Delay	
BF2 Target	
BF2 Events	
BF2 Ph A Initiate	
BF2 Ph B Initiate	
BF2 Ph C Initiate	
BF2 Bkr POS1 ΦB	
BF2 Bkr POS1 ΦC	
BF2 Bkr POS2 ΦB	
BF2 Bkr POS2 ΦC	
VOLTAGE ELEMENTS	
PHASE UNDERVOLTAGE 1	
Phase UV1 Function	
Phase UV1 Signal Source	
Phase UV1 Mode	
Phase UV1 Pickup	
Phase UV1 Curve	
Phase UV1 Delay	
Phase UV1 Minimum Voltage	
Phase UV1 Block	
Phase UV1 Target	
Phase UV1 Events	
PHASE UNDERVOLTAGE 2	
Phase UV2 Function	

Table 10–6: GROUPED ELEMENTS (Sheet 10 of 11)

SETTING	VALUE
Phase UV2 Signal Source	
Phase UV2 Mode	
Phase UV2 Pickup	
Phase UV2 Curve	
Phase UV2 Delay	
Phase UV2 Minimum Voltage	
Phase UV2 Block	
Phase UV2 Target	
Phase UV2 Events	
PHASE OVERVOLTAGE 1	
Phase OV1 Function	
Phase OV1 Signal Source	
Phase OV1 Pickup	
Phase OV1 Delay	
Phase OV1 Reset Delay	
Phase OV1 Block	
Phase OV1 Target	
Phase OV1 Events	
NEUTRAL OVERVOLTAGE 1	
Neutral OV1 Function	
Neutral OV1 Signal Source	
Neutral OV1 Pickup	
Neutral OV1 Pickup Delay	
Neutral OV1 Reset Delay	
Neutral OV1 Block	
Neutral OV1 Target	
Neutral OV1 Events	
AUXILIARY UNDERVOLTAGE 1	
Aux UV1 Function	
Aux UV1 Signal Source	
Aux UV1 Pickup	
Aux UV1 Curve	
Aux UV1 Delay	
Aux UV1 Minimum Voltage	
Aux UV1 Block	
Aux UV1 Target	
Aux UV1 Events	
AUXILIARY OVERVOLTAGE 1	
Aux OV1 Function	
Aux OV1 Signal Source	
Aux OV1 Pickup	
Aux OV1 Pickup Delay	
Aux OV1 Reset Delay	
Aux OV1 Block	
Aux OV1 Target	
Aux OV1 Events	

Table 10–6: GROUPED ELEMENTS (Sheet 11 of 11)

SETTING	VALUE
SUPERVISING ELEMENTS	
DISTURBANCE DETECTOR	
DD Function	
DD Non-Current Supervision	
DD Control Logic	
DD Logic Seal-In	
DD Events	
OPEN POLE DETECTOR	
Open Pole Function	
Open Pole Block	
Open Pole Current Source	
Open Pole Current Pkp	
Open Pole Broken Conductor	
Open Pole Voltage Input	
Open Pole Voltage Source	
Open Pole ΦA Aux Co.	
Open Pole ΦB Aux Co.	
Open Pole ΦC Aux Co.	
Open Pole Pickup Delay	
Open Pole Target	
Open Pole Events	
87L TRIP	
87L Trip Function	
87L Trip Source	
87L Trip Mode	
87L Trip Supervision	
87L Trip Force 3-phase	
87L Trip Seal-In	
87L Trip Seal-In Pickup	
87L Trip Target	
87L Trip Events	

Table 10–7: CONTROL ELEMENTS (Sheet 1 of 9)

SETTING	VALUE
SETTING GROUPS	
Setting Groups Function	
Setting Groups Block	
Group 2 Activate On	
Group 3 Activate On	
Group 4 Activate On	
Group 5 Activate On	
Group 6 Activate On	
Group 7 Activate On	
Group 8 Activate On	
Setting Group Events	
SYNCHROCHECK 1	
Synchk1 Function	
Synchk1 Block	
Synchk1 V1 Source	
Synchk1 V2 Source	
Synchk1 Max Volt Diff	
Synchk1 Max Angle Diff	
Synchk1 Max Freq Diff	
Synchk1 Dead Source Select	
Synchk1 Dead V1 Max Volt	
Synchk1 Dead V2 Max Volt	
Synchk1 Line V1 Min Volt	
Synchk1 Line V2 Min Volt	
Synchk1 Target	
Synchk1 Events	
SYNCHROCHECK 2	
Synchk2 Function	
Synchk2 Block	
Synchk2 V1 Source	
Synchk2 V2 Source	
Synchk2 Max Volt Diff	
Synchk2 Max Angle Diff	
Synchk2 Max Freq Diff	
Synchk2 Dead Source Select	
Synchk2 Dead V1 Max Volt	
Synchk2 Dead V2 Max Volt	
Synchk2 Line V1 Min Volt	
Synchk2 Line V2 Min Volt	
Synchk2 Target	
Synchk2 Events	
AUTORECLOSE 1	
Function	
Initiate	

Table 10–7: CONTROL ELEMENTS (Sheet 2 of 9)

SETTING	VALUE
Block	
Max. Number of Shots	
Reduce Maximum to 1	
Reduce Maximum to 2	
Reduce Maximum to 3	
Manual Close	
Manual Reset from Lockout	
Reset Lockout If Breaker Closed	
Reset Lockout on Manual Close	
Breaker Closed	
Breaker Open	
Block Time Upon Manual Close	
Dead Time 1	
Dead Time 2	
Dead Time 3	
Dead Time 4	
Add Delay 1	
Delay 1	
Add Delay 2	
Delay 2	
Reset Lockout Delay	
Reset Time	
Incomplete Sequence Time	
Events	
DIGITAL ELEMENT 1	
Digital Element 1 Function	
Dig Elem 1 Name	
Dig Elem 1 Input	
Dig Elem 1 Pickup Delay	
Dig Elem 1 Reset Delay	
Dig Elem 1 Block	
Digital Element 1 Target	
Digital Element 1 Events	
DIGITAL ELEMENT 2	
Digital Element 2 Function	
Dig Elem 2 Name	
Dig Elem 2 Input	
Dig Elem 2 Pickup Delay	
Dig Elem 2 Reset Delay	
Dig Elem 2 Block	
Digital Element 2 Target	
Digital Element 2 Events	
DIGITAL ELEMENT 3	
Digital Element 3 Function	

Table 10–7: CONTROL ELEMENTS (Sheet 3 of 9)

SETTING	VALUE
Dig Elem 3 Name	
Dig Elem 3 Input	
Dig Elem 3 Pickup Delay	
Dig Elem 3 Reset Delay	
Dig Elem 3 Block	
Digital Element 3 Target	
Digital Element 3 Events	
DIGITAL ELEMENT 4	
Digital Element 4 Function	
Dig Elem 4 Name	
Dig Elem 4 Input	
Dig Elem 4 Pickup Delay	
Dig Elem 4 Reset Delay	
Dig Elem 4 Block	
Digital Element 4 Target	
Digital Element 4 Events	
DIGITAL ELEMENT 5	
Digital Element 5 Function	
Dig Elem 5 Name	
Dig Elem 5 Input	
Dig Elem 5 Pickup Delay	
Dig Elem 5 Reset Delay	
Dig Elem 5 Block	
Digital Element 5 Target	
Digital Element 5 Events	
DIGITAL ELEMENT 6	
Digital Element 6 Function	
Dig Elem 6 Name	
Dig Elem 6 Input	
Dig Elem 6 Pickup Delay	
Dig Elem 6 Reset Delay	
Dig Elem 6 Block	
Digital Element 6 Target	
Digital Element 6 Events	
DIGITAL ELEMENT 7	
Digital Element 7 Function	
Dig Elem 7 Name	
Dig Elem 7 Input	
Dig Elem 7 Pickup Delay	
Dig Elem 7 Reset Delay	
Dig Elem 7 Block	
Digital Element 7 Target	
Digital Element 7 Events	
DIGITAL ELEMENT 8	
Digital Element 8 Function	
Dig Elem 8 Name	
Dig Elem 8 Input	

Table 10–7: CONTROL ELEMENTS (Sheet 4 of 9)

SETTING	VALUE
Dig Elem 8 Pickup Delay	
Dig Elem 8 Reset Delay	
Dig Elem 8 Block	
Digital Element 8 Target	
Digital Element 8 Events	
DIGITAL ELEMENT 9	
Digital Element 9 Function	
Dig Elem 9 Name	
Dig Elem 9 Input	
Dig Elem 9 Pickup Delay	
Dig Elem 9 Reset Delay	
Dig Elem 9 Block	
Digital Element 9 Target	
Digital Element 9 Events	
DIGITAL ELEMENT 10	
Digital Element 10 Function	
Dig Elem 10 Name	
Dig Elem 10 Input	
Dig Elem 10 Pickup Delay	
Dig Elem 10 Reset Delay	
Dig Elem 10 Block	
Digital Element 10 Target	
Digital Element 10 Events	
DIGITAL ELEMENT 11	
Digital Element 11 Function	
Dig Elem 11 Name	
Dig Elem 11 Input	
Dig Elem 11 Pickup Delay	
Dig Elem 11 Reset Delay	
Dig Elem 11 Block	
Digital Element 11 Target	
Digital Element 11 Events	
DIGITAL ELEMENT 12	
Digital Element 12 Function	
Dig Elem 12 Name	
Dig Elem 12 Input	
Dig Elem 12 Pickup Delay	
Dig Elem 12 Reset Delay	
Dig Elem 12 Block	
Digital Element 12 Target	
Digital Element 12 Events	
DIGITAL ELEMENT 13	
Digital Element 13 Function	
Dig Elem 13 Name	
Dig Elem 13 Input	
Dig Elem 13 Pickup Delay	
Dig Elem 13 Reset Delay	

Table 10–7: CONTROL ELEMENTS (Sheet 5 of 9)

SETTING	VALUE
Dig Elem 13 Block	
Digital Element 13 Target	
Digital Element 13 Events	
DIGITAL ELEMENT 14	
Digital Element 14 Function	
Dig Elem 14 Name	
Dig Elem 14 Input	
Dig Elem 14 Pickup Delay	
Dig Elem 14 Reset Delay	
Dig Elem 14 Block	
Digital Element 14 Target	
Digital Element 14 Events	
DIGITAL ELEMENT 15	
Digital Element 15 Function	
Dig Elem 15 Name	
Dig Elem 15 Input	
Dig Elem 15 Pickup Delay	
Dig Elem 15 Reset Delay	
Dig Elem 15 Block	
Digital Element 15 Target	
Digital Element 15 Events	
DIGITAL ELEMENT 16	
Digital Element 16 Function	
Dig Elem 16 Name	
Dig Elem 16 Input	
Dig Elem 16 Pickup Delay	
Dig Elem 16 Reset Delay	
Dig Elem 16 Block	
Digital Element 16 Target	
Digital Element 16 Events	
DIGITAL COUNTER 1	
Counter 1 Function	
Counter 1 Name	
Counter 1 Units	
Counter 1 Preset	
Counter 1 Compare	
Counter 1 Up	
Counter 1 Down	
Counter 1 Block	
Counter 1 Set to Preset	
Counter 1 Reset	
Counter 1 Freeze/Reset	
Counter 1 Freeze/Count	
DIGITAL COUNTER 2	
Counter 2 Function	
Counter 2 Name	
Counter 2 Units	

Table 10–7: CONTROL ELEMENTS (Sheet 6 of 9)

SETTING	VALUE
Counter 2 Preset	
Counter 2 Compare	
Counter 2 Up	
Counter 2 Down	
Counter 2 Block	
Counter 2 Set to Preset	
Counter 2 Reset	
Counter 2 Freeze/Reset	
Counter 2 Freeze/Count	
DIGITAL COUNTER 3	
Counter 3 Function	
Counter 3 Name	
Counter 3 Units	
Counter 3 Preset	
Counter 3 Compare	
Counter 3 Up	
Counter 3 Down	
Counter 3 Block	
Counter 3 Set to Preset	
Counter 3 Reset	
Counter 3 Freeze/Reset	
Counter 3 Freeze/Count	
DIGITAL COUNTER 4	
Counter 4 Function	
Counter 4 Name	
Counter 4 Units	
Counter 4 Preset	
Counter 4 Compare	
Counter 4 Up	
Counter 4 Down	
Counter 4 Block	
Counter 4 Set to Preset	
Counter 4 Reset	
Counter 4 Freeze/Reset	
Counter 4 Freeze/Count	
DIGITAL COUNTER 5	
Counter 5 Function	
Counter 5 Name	
Counter 5 Units	
Counter 5 Preset	
Counter 5 Compare	
Counter 5 Up	
Counter 5 Down	
Counter 5 Block	
Counter 5 Set to Preset	
Counter 5 Reset	
Counter 5 Freeze/Reset	

Table 10–7: CONTROL ELEMENTS (Sheet 7 of 9)

SETTING	VALUE
Counter 5 Freeze/Count	
DIGITAL COUNTER 6	
Counter 6 Function	
Counter 6 Name	
Counter 6 Units	
Counter 6 Preset	
Counter 6 Compare	
Counter 6 Up	
Counter 6 Down	
Counter 6 Block	
Counter 6 Set to Preset	
Counter 6 Reset	
Counter 6 Freeze/Reset	
Counter 6 Freeze/Count	
DIGITAL COUNTER 7	
Counter 7 Function	
Counter 7 Name	
Counter 7 Units	
Counter 7 Preset	
Counter 7 Compare	
Counter 7 Up	
Counter 7 Down	
Counter 7 Block	
Counter 7 Set to Preset	
Counter 7 Reset	
Counter 7 Freeze/Reset	
Counter 7 Freeze/Count	
DIGITAL COUNTER 8	
Counter 8 Function	
Counter 8 Name	
Counter 8 Units	
Counter 8 Preset	
Counter 8 Compare	
Counter 8 Up	
Counter 8 Down	
Counter 8 Block	
Counter 8 Set to Preset	
Counter 8 Reset	
Counter 8 Freeze/Reset	
Counter 8 Freeze/Count	
BREAKER 1 ARCING CURRENT	
Bkr 1 Arc Amp Function	
Bkr 1 Arc Amp Source	
Bkr 1 Arc Amp Init	
Bkr 1 Arc Amp Delay	
Bkr 1 Arc Amp Limit	
Bkr 1 Arc Amp Block	

Table 10–7: CONTROL ELEMENTS (Sheet 8 of 9)

SETTING	VALUE
Bkr 1 Arc Amp Target	
Bkr 1 Arc Amp Events	
BREAKER 2 ARCING CURRENT	
Bkr 2 Arc Amp Function	
Bkr 2 Arc Amp Source	
Bkr 2 Arc Amp Init	
Bkr 2 Arc Amp Delay	
Bkr 2 Arc Amp Limit	
Bkr 2 Arc Amp Block	
Bkr 2 Arc Amp Target	
Bkr 2 Arc Amp Events	
CONTINUOUS MONITOR	
Cont Monitor Function	
Cont Monitor I-OP	
Cont Monitor I-SUPV	
Cont Monitor V-OP	
Cont Monitor V-SUPV	
Cont Monitor Target	
Cont Monitor Events	
CT FAILURE DETECTOR	
CT Fail Function	
CT Fail Block	
CT Fail I_0 Input 1	
CT Fail I_0 Input 1 Pickup	
CT Fail I_0 Input 2	
CT Fail I_0 Input 2 Pickup	
CT Fail V_0 Input	
CT Fail V_0 Input Pickup	
CT Fail Pickup Delay	
CT Fail Target	
CT Fail Events	
VT FUSE FAILURE	
VT Fuse Failure Function	
POTT SCHEME	
Function	
Permissive Echo	
RX Pickup Delay	
Trans Block Pickup Delay	
Trans Block Reset Delay	
Echo Duration	
Line End Open Pickup Delay	
Seal-In Delay	
Gnd Directional O/C Forward	
RX	
OPEN BREAKER ECHO	
Open Breaker Keying	
Brk 1 Aux. Contact	

Table 10–7: CONTROL ELEMENTS (Sheet 9 of 9)

SETTING	VALUE
Brk 1 Contact Supv.	
Brk 2 Aux. Contact	
Brk 2 Contact Supv.	
Open Breaker Keying PKP Delay	
Open Breaker Keying RST Delay	
Weak-Infeed Keying	
Weak-Infeed Supv	
Weak-Infeed PKP Dly	
Weak-Infeed RST Dly	

Table 10–8: CONTACT INPUTS

CONTACT INPUT	ID	DEBNCE TIME	EVENTS	THRESHOLD

10.6.2 VIRTUAL INPUTS

Table 10–9: VIRTUAL INPUTS

VIRTUAL INPUT	FUNCTION	ID	TYPE	EVENTS
Virtual Input 1				
Virtual Input 2				
Virtual Input 3				
Virtual Input 4				
Virtual Input 5				
Virtual Input 6				
Virtual Input 7				
Virtual Input 8				
Virtual Input 9				
Virtual Input 10				
Virtual Input 11				
Virtual Input 12				
Virtual Input 13				
Virtual Input 14				
Virtual Input 15				
Virtual Input 16				
Virtual Input 17				
Virtual Input 18				
Virtual Input 19				
Virtual Input 20				
Virtual Input 21				
Virtual Input 22				
Virtual Input 23				
Virtual Input 24				
Virtual Input 25				
Virtual Input 26				
Virtual Input 27				
Virtual Input 28				
Virtual Input 29				
Virtual Input 30				
Virtual Input 31				
Virtual Input 32				

10.6.3 UCA SBO TIMER

Table 10–10: UCA SBO TIMER

UCA SBO TIMER	
UCA SBO Timeout	

Table 10–11: CONTACT OUTPUTS

CONTACT OUTPUT	ID	OPERATE	SEAL-IN	EVENTS

Table 10–12: VIRTUAL OUTPUTS (Sheet 1 of 2)

VIRTUAL OUTPUT	ID	EVENTS
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
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30		
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		

Table 10–12: VIRTUAL OUTPUTS (Sheet 2 of 2)

VIRTUAL OUTPUT	ID	EVENTS
44		
45		
46		
47		
48		
49		
50		
51		
52		
53		
54		
55		
56		
57		
58		
59		
60		
61		
62		
63		
64		

Table 10–13: REMOTE DEVICES

REMOTE DEVICE	ID
Remote Device 1	
Remote Device 2	
Remote Device 3	
Remote Device 4	
Remote Device 5	
Remote Device 6	
Remote Device 7	
Remote Device 8	
Remote Device 9	
Remote Device 10	
Remote Device 11	
Remote Device 12	
Remote Device 13	
Remote Device 14	
Remote Device 15	
Remote Device 16	

Table 10–14: REMOTE INPUTS

REMOTE INPUT	REMOTE DEVICE	BIT PAIR	DEFAULT STATE	EVENTS
Remote Input 1				
Remote Input 2				
Remote Input 3				
Remote Input 4				
Remote Input 5				
Remote Input 6				
Remote Input 7				
Remote Input 8				
Remote Input 9				
Remote Input 10				
Remote Input 11				
Remote Input 12				
Remote Input 13				
Remote Input 14				
Remote Input 15				
Remote Input 16				
Remote Input 17				
Remote Input 18				
Remote Input 19				
Remote Input 20				
Remote Input 21				
Remote Input 22				
Remote Input 23				
Remote Input 24				
Remote Input 25				
Remote Input 26				
Remote Input 27				
Remote Input 28				
Remote Input 29				
Remote Input 30				
Remote Input 31				
Remote Input 32				

Table 10–15: REMOTE OUTPUTS (Sheet 1 of 2)

OUTPUT #	OPERAND	EVENTS
REMOTE OUTPUTS – DNA		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		

Table 10–15: REMOTE OUTPUTS (Sheet 2 of 2)

OUTPUT #	OPERAND	EVENTS
REMOTE OUTPUTS – UserSt		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		

10.6.9 DIRECT MESSAGING

Table 10–16: DIRECT MESSAGING (Sheet 1 of 2)

SETTING	VALUE
DIRECT INPUTS	
Direct Input 1-1	
Direct Input 1-2	
Direct Input 1-3	
Direct Input 1-4	
Direct Input 1-5	
Direct Input 1-6	
Direct Input 1-7	
Direct Input 1-8	
Direct Input 2-1	
Direct Input 2-2	
Direct Input 2-3	
Direct Input 2-4	
Direct Input 2-5	
Direct Input 2-6	
Direct Input 2-7	
Direct Input 2-8	

Table 10–16: DIRECT MESSAGING (Sheet 2 of 2)

SETTING	VALUE
DIRECT OUTPUTS	
Direct Output 1-1	
Direct Output 1-2	
Direct Output 1-3	
Direct Output 1-4	
Direct Output 1-5	
Direct Output 1-6	
Direct Output 1-7	
Direct Output 1-8	
Direct Output 2-1	
Direct Output 2-2	
Direct Output 2-3	
Direct Output 2-4	
Direct Output 2-5	
Direct Output 2-6	
Direct Output 2-7	
Direct Output 2-8	

10.6.10 RESETTING

SETTING	VALUE
RESETTING	
Reset Operand	

10.7.1 DCMA INPUTS

Table 10–17: DCMA INPUTS

DCMA INPUT	FUNCTION	ID	UNITS	RANGE	VALUES	
					MIN	MAX

Table 10–18: RTD INPUTS

RTD INPUT	FUNCTION	ID	TYPE

10.8.1 FORCE CONTACT INPUTS/OUTPUTS

Table 10–19: FORCE CONTACT INPUTS

FORCE CONTACT	INPUT

Table 10–20: FORCE CONTACT OUTPUTS

FORCE CONTACT	OUTPUT

10.8.2 CHANNEL TESTS

Table 10–21: CHANNEL TESTS

SETTING	VALUE
LOCAL LOOPBACK	
Function	
Channel Number	
REMOTE LOOPBACK	
Function	
Channel Number	

10.9.1 CHANNEL TESTING

The communications system transmits and receives data between two or three terminals for the 87L function. The system is designed to work with multiple channel options including direct and multiplexed optical fiber, G.703, and RS422. The speed is 64 Kbaud in a transparent synchronous mode with automatic synchronous character detection and CRC insertion.

The Local Loopback Channel Test verifies the L90 communication modules are working properly. The Remote Loopback Channel Test verifies the communication link between the relays meets requirements (BER less than 10^{-4}).

All tests are verified by using the internal channel monitoring and the monitoring in the actual values CHANNEL STATUS section. All of the tests presented in this section must be either OK or PASSED.

TEST PROCEDURES:

1. Verify that a type “W” module is placed in slot 'W' in both relays (e.g. W7J).
2. Interconnect the two relays using the proper media (e.g. single mode fiber cable) observing correct connection of receiving (Rx) and transmitting (Tx) communications paths and turn power on to both relays.
3. Verify that the Order Code in both relays is correct.
4. Cycle power off/on in both relays.
5. Verify and record that both relays indicate IN SERVICE on the front display.
6. Make the following setting change in both relays:

   GROUPED ELEMENTS ⇨⇩ GROUP 1 ⇨⇩ CURRENT DIFFERENTIAL ELEMENTS ⇨ CURRENT DIFFERENTIAL ⇨ CURRENT DIFF FUNCTION: "Enabled"
7. Verify and record that both relays have established communications with the following status checks:

   ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1 STATUS: "OK"
   ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 2 STATUS: "OK" (If used)
8. Make the following setting change in both relays: **TESTING ⇨ TEST MODE**: "Enabled"
9. Make the following setting change in both relays:

   TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ LOCAL LOOPBACK TEST ⇨⇩ LOCAL LOOPBACK CHANNEL NUMBER: "1"
10. Initiate the Local Loopback Channel Tests by making the following setting change:

    TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ LOCAL LOOPBACK TEST ⇨⇩ LOCAL LOOPBACK FUNCTION: "Yes"

    Expected result: In a few seconds “Yes” should change to “Local Loopback Test PASSED” and then to “No”, signifying the test was successfully completed and the communication modules operated properly.
11. If Channel 2 is used, make the following setting change and repeat Step 10 for Channel 2 as performed for channel 1:

    TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ LOCAL LOOPBACK TEST ⇨⇩ LOCAL LOOPBACK CHANNEL NUMBER: "2"
12. Verify and record that the Local Loopback Test was performed properly with the following status check:

    ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) LOCAL LOOPBACK STATUS: "OK"
13. Make the following setting change in both relays:

    TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK TEST ⇨⇩ REMOTE LOOPBACK CHANNEL NUMBER: "1"
14. Initiate the Remote Loopback Channel Tests by making the following setting change:

    TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK ⇨ REMOTE LOOPBACK FUNCTION: "Yes"

    Expected result: The "Running Remote Loopback Test" message appears; within 60 to 100 seconds the "Remote Loopback Test PASSED" message appears for a few seconds and then changes to "No", signifying the test was successfully completed and communications with the remote relay were successfully established. The "Remote Loopback Test FAILED" message indicates that either the communication link quality does not meet requirements (BER less than 10^{-4}) or the channel is not established – check the communications link connections.
15. If Channel 2 is used, make the following setting change and repeat Step 14 for Channel 2 as performed for channel 1:

    TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK TEST ⇨⇩ REMOTE LOOPBACK CHANNEL NUMBER: "2"

16. Verify and record the Remote Loopback Test was performed properly with the following status check:

    ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) REMOTE LOOPBACK STATUS: "OK"

17. Verify and record that Remote Loopback Test fails during communications failures as follows: start test as per Steps 13 to 14 and in 10 to 30 seconds disconnect the fiber Rx cable on the corresponding channel.

    Expected result: The "Running Remote Loopback Test" message appears. When the channel is momentarily cut off, the "Remote Loopback Test FAILED" message is displayed. The status check should read as follows: ACTUAL VALUES ⇩ STATUS ⇩ CHANNEL TESTS ⇨ CHANNEL 1(2) LOCAL LOOPBACK STATUS: "Fail"

18. Re-connect the fiber Rx cable. Repeat Steps 13 to 14 and verify that Remote Loopback Test performs properly again.

19. Verify and record that Remote Loopback Test fails if communications are not connected properly by disconnecting the fiber Rx cable and repeating Steps 13 to 14.

    Expected result: The ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) REMOTE LOOPBACK TEST: "Fail" message should be constantly on the display.

20. Repeat Steps 13 to 14 and verify that Remote Loopback Test is correct.

21. Make the following setting change in both relays: TESTING ⇨ TEST MODE: "Disabled"

NOTE

During channel tests, verify in the ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨ CHANNEL 1(2) LOST PACKETS display that the values are very low – even 0. If values are comparatively high, settings of communications equipment (if applicable) should be checked.

10.9.2 CLOCK SYNCHRONIZATION TESTS

The 87L clock synchronization is based upon a peer-to-peer architecture in which all relays are Masters. The relays are synchronized in a distributed fashion. The clocks are phase synchronized to each other and frequency synchronized to the power system frequency. The performance requirement for the clock synchronization is a maximum error of ±130 μs.

All tests are verified by using PFLL STATUS displays. All PFLL STATUS displays must be either OK or Fail.

TEST PROCEDURE:

1. Ensure that Steps 1 through 7 inclusive of the previous section are completed.

2. Verify and record that both relays have established communications with the following checks after 60 to 120 seconds:

   ACTUAL VALUES / STATUS / CHANNEL TESTS / CHANNEL 1(2) STATUS: "OK"
   ACTUAL VALUES / STATUS / CHANNEL TESTS / REMOTE LOOPBACK STATUS: "n/a"
   ACTUAL VALUES / STATUS / CHANNEL TESTS / PFLL STATUS: "OK"

3. Disconnect the fiber Channel 1(2) Tx cable for less than 66 ms.

   Expected result: ACTUAL VALUES / STATUS / CHANNEL TESTS / CHANNEL 1(2) STATUS: "OK"
   ACTUAL VALUES / STATUS / CHANNEL TESTS / REMOTE LOOPBACK STATUS: "n/a"
   ACTUAL VALUES / STATUS / CHANNEL TESTS / PFLL STATUS: "OK"

   If fault conditions are applied to the relay during these tests, it trips with a specified 87L operation time.

4. Disconnect the fiber Channel 1(2) Tx cable for more than 66 ms but less than 5 seconds.

   Expected result: ACTUAL VALUES / STATUS / CHANNEL TESTS / CHANNEL 1(2) STATUS: "OK"
   ACTUAL VALUES / STATUS / CHANNEL TESTS / REMOTE LOOPBACK STATUS: "n/a"
   ACTUAL VALUES / STATUS / CHANNEL TESTS / PFLL STATUS: "OK"

   If fault conditions are applied to the relay (after the channel is brought back) during these tests, it trips with a specified 87L operation time plus 50 to 80 ms required for establishing PFLL after such interruption.

5. Disconnect the fiber Channel 1(2) Tx cable for more than 5 seconds.

   Expected result: ACTUAL VALUES / STATUS / CHANNEL TESTS / CHANNEL 1(2) STATUS: "OK"
   ACTUAL VALUES / STATUS / CHANNEL TESTS / REMOTE LOOPBACK STATUS: "n/a"
   ACTUAL VALUES / STATUS / CHANNEL TESTS / PFLL STATUS: "Fail"

6. Reconnect the fiber Channel 1(2) Tx cable and in 60 to 120 seconds confirm that the relays have re-established communications again with the following status checks:

ACTUAL VALUES / STATUS / CHANNEL TESTS / CHANNEL 1(2) STATUS: "OK"
ACTUAL VALUES / STATUS / CHANNEL TESTS / REMOTE LOOPBACK STATUS: "n/a"
ACTUAL VALUES / STATUS / CHANNEL TESTS / PFLL STATUS: "OK"

7. Apply a current of 0.5 pu at a frequency 1 to 3% higher or lower than nominal only to local relay phase A to verify that frequency tracking will not affect PFLL when only one relay has a current input. Wait 200 sec. and verify the following:

   ACTUAL VALUES / STATUS / CHANNEL TESTS / PFLL STATUS: "OK"
   ACTUAL VALUES / METERING / TRACKING FREQUENCY: "50 Hz" or "60 Hz" (nominal)

NOTE

For 3-terminal configuration, the above-indicated tests should be carried out accordingly.

10.9.3 CURRENT DIFFERENTIAL

The 87L element has adaptive restraint and dual slope characteristics. The pickup slope settings and the breakpoint settings determine the element characteristics. The relay displays both local and remote current magnitudes and angles and the differential current which helps with start-up activities.

When a differential condition is detected, the output operands from the element will be asserted along with energization of faceplate event indicators.

TEST PROCEDURE:

1. Ensure that relay will not issue any undesired signals to other equipment.
2. Ensure that relays are connected to the proper communication media, communications tests have been performed and the CHANNEL and PFLL STATUS displays indicate OK.
3. Minimum pickup test with local current only:
   - •Ensure that all 87L setting are properly entered into the relay.
   - •Connect a test set to the relay to inject current into phase A.
   - •Slowly increase the current until the relay operates, and note the pickup value. The theoretical value of operating current below the breakpoint is given by the following formula, where P is the pickup setting and S_1 is the slope 1 setting (in decimal format):

     $$I_{op} = \sqrt{2 \times \frac{P^2}{1 - 2S_1^2}}$$

   - •Repeat the above test for different slope and pickup settings, if desired.
   - •Repeat the above tests for phases B and C.
4. Minimum pickup test with local current and simulated remote current (pure internal fault simulation):
   - •Disconnect the local relay from the communications channel.
   - •Loop back the transmit signal to the receive input on the back of the relay.
   - •Wait until the CHANNEL and PFLL status displays indicate OK.
   - •Slowly increase the current until the relay operates and note the pickup value. The theoretical value of operating current below breakpoint is given by the following formula:

     $$I_{op} = \sqrt{\frac{P^2}{2(1 - S_1^2)}}$$

   - •Repeat the above test for different slope and pickup settings, if desired.
   - •During the tests observe that the current phasor at **ACTUAL VALUES / METERING / 87L DIFF CURRENT / LOCAL IA**. This phasor should also be displayed at **ACTUAL VALUES / METERING / 87L DIFF CURRENT / TERMINAL 1(2) IA**. A phasor of twice the magnitude should be displayed at **ACTUAL VALUES / METERING / 87L DIFF CURRENT / IA DIFF**.
   - •Repeat the above tests for phases B and C.
   - •Restore the communication circuits to normal.

NOTE

Download the L90 Test software from the GE Power Management website (www.GEindustrial.com/pm) or contact GE Power Management for information about the L90 current differential test program which allows the user to simulate different operating conditions for verifying correct responses of the relays during commissioning activities.

10.9.4 LOCAL-REMOTE RELAY TESTS

a) DIRECT TRANSFER TRIP (DTT) TESTS

The direct transfer trip is a function by which one relay sends a signal to a remote relay to cause a trip of remote equipment.

The local relay trip outputs will close upon receiving a Direct Transfer Trip from the remote relay.

TEST PROCEDURE:

1. Ensure that relay will not issue any undesired signals to other equipment and all previous tests have been completed successfully.
2. Cycle power off/on in both relays.
3. Verify and record that both relays indicate IN SERVICE on the faceplate display.
4. Make the following setting change in both relays:

   SETTINGS / GROUPED ELEMENTS / LINE DIFFERENTIAL ELEMENTS / CURRENT DIFFERENTIAL / FUNCTION: Enabled
5. Verify and record that both relays have established communications by performing the following status check:

   ACTUAL VALUES / STATUS / CHANNEL TESTS / CHANNEL 1(2) STATUS: OK
6. At the remote relay, make the following setting change:

   SETTINGS / GROUPED ELEMENTS / LINE DIFFERENTIAL ELEMENTS / CURRENT DIFFERENTIAL DTT: Enabled
7. At the Local relay set"

   SETTINGS / INPUTS/OUTPUTS / CONTACT OUTPUT N1 to operand 87L DIFF RECVD DTT A.
   SETTINGS / INPUTS/OUTPUTS / CONTACT OUTPUT N2 to operand 87L DIFF RECVD DTT B.
   SETTINGS / INPUTS/OUTPUTS / CONTACT OUTPUT N3 to operand 87L DIFF RECVD DTT C.
8. At the Local relay, observe **ACTUAL VALUES / STATUS / CONTACT OUTPUTS / CONT OP N1** is in the “Off” state.
9. Apply current to phase A of the remote relay and increase until 87L operates.
10. At the Local relay, observe **ACTUAL VALUES / STATUS / CONTACT OUTPUTS / CONT OP N1** is now in the “On” state.
11. Repeat steps 8 through 10 for phases A and B and observe Contact Outputs N2 and N3, respectively.
12. Repeat steps 8 through 11 with the Remote and Local relays inter-changed.
13. Make the following setting change in both relays:

    SETTINGS / GROUPED ELEMENTS / CURRENT DIFFERENTIAL / FUNCTION: "Disabled"
14. At the Remote relay, set **SETTINGS / INPUTS/OUTPUTS / CONTACT INPUT N1** to operand CURRENT DIFF KEY DTT.
15. At the Local relay, observe under **ACTUAL VALUES / STATUS / CONTACT OUTPUTS** that **CONTACT OUTPUT N1**, **N2** and **N3** are “Off”.
16. At the Remote relay, set **SETTINGS / TESTING / FORCE CONTACT INPUTS / FORCE CONTACT INPUT N1** to “Closed”.
17. At the Local relay, observe under **ACTUAL VALUES / STATUS / CONTACT OUTPUTS** that **CONTACT OUTPUT N1**, **N2** and **N3** are now “On”.
18. At both the Local and Remote relays, return all settings to normal.

b) FINAL TESTS

As proper operation of the relay is fundamentally dependent on the correct installation and wiring of the CTs, it must be confirmed that correct data is brought into the relays by an on-load test in which simultaneous measurements of current and voltage phasors are made at all line terminals. These phasors and differential currents can be monitored at the **ACTUAL VALUES / METERING / 87L DIFFERENTIAL CURRENT** menu where all current magnitudes and angles can be observed and conclusions of proper relay interconnections can be made.

Table A–1: FLEXANALOG PARAMETERS (Sheet 1 of 4)

SETTING	DISPLAY TEXT	DESCRIPTION
6144	SRC 1 Ia RMS	SRC 1 Phase A Current RMS (A)
6146	SRC 1 Ib RMS	SRC 1 Phase B Current RMS (A)
6148	SRC 1 Ic RMS	SRC 1 Phase C Current RMS (A)
6150	SRC 1 In RMS	SRC 1 Neutral Current RMS (A)
6152	SRC 1 Ia Mag	SRC 1 Phase A Current Magnitude (A)
6154	SRC 1 Ia Angle	SRC 1 Phase A Current Angle (°)
6155	SRC 1 Ib Mag	SRC 1 Phase B Current Magnitude (A)
6157	SRC 1 Ib Angle	SRC 1 Phase B Current Angle (°)
6158	SRC 1 Ic Mag	SRC 1 Phase C Current Magnitude (A)
6160	SRC 1 Ic Angle	SRC 1 Phase C Current Angle (°)
6161	SRC 1 In Mag	SRC 1 Neutral Current Magnitude (A)
6163	SRC 1 In Angle	SRC 1 Neutral Current Angle (°)
6164	SRC 1 Ig RMS	SRC 1 Ground Current RMS (A)
6166	SRC 1 Ig Mag	SRC 1 Ground Current Magnitude (A)
6168	SRC 1 Ig Angle	SRC 1 Ground Current Angle (°)
6169	SRC 1 I_0 Mag	SRC 1 Zero Sequence Current Magnitude (A)
6171	SRC 1 I_0 Angle	SRC 1 Zero Sequence Current Angle (°)
6172	SRC 1 I_1 Mag	SRC 1 Positive Sequence Current Magnitude (A)
6174	SRC 1 I_1 Angle	SRC 1 Positive Sequence Current Angle (°)
6175	SRC 1 I_2 Mag	SRC 1 Negative Sequence Current Magnitude (A)
6177	SRC 1 I_2 Angle	SRC 1 Negative Sequence Current Angle (°)
6178	SRC 1 Igd Mag	SRC 1 Differential Ground Current Magnitude (A)
6180	SRC 1 Igd Angle	SRC 1 Differential Ground Current Angle (°)
6208	SRC 2 Ia RMS	SRC 2 Phase A Current RMS (A)
6210	SRC 2 Ib RMS	SRC 2 Phase B Current RMS (A)
6212	SRC 2 Ic RMS	SRC 2 Phase C Current RMS (A)
6214	SRC 2 In RMS	SRC 2 Neutral Current RMS (A)
6216	SRC 2 Ia Mag	SRC 2 Phase A Current Magnitude (A)
6218	SRC 2 Ia Angle	SRC 2 Phase A Current Angle (°)
6219	SRC 2 Ib Mag	SRC 2 Phase B Current Magnitude (A)
6221	SRC 2 Ib Angle	SRC 2 Phase B Current Angle (°)
6222	SRC 2 Ic Mag	SRC 2 Phase C Current Magnitude (A)
6224	SRC 2 Ic Angle	SRC 2 Phase C Current Angle (°)
6225	SRC 2 In Mag	SRC 2 Neutral Current Magnitude (A)
6227	SRC 2 In Angle	SRC 2 Neutral Current Angle (°)
6228	SRC 2 Ig RMS	SRC 2 Ground Current RMS (A)
6230	SRC 2 Ig Mag	SRC 2 Ground Current Magnitude (A)
6232	SRC 2 Ig Angle	SRC 2 Ground Current Angle (°)
6233	SRC 2 I_0 Mag	SRC 2 Zero Sequence Current Magnitude (A)
6235	SRC 2 I_0 Angle	SRC 2 Zero Sequence Current Angle (°)
6236	SRC 2 I_1 Mag	SRC 2 Positive Sequence Current Magnitude (A)
6238	SRC 2 I_1 Angle	SRC 2 Positive Sequence Current Angle (°)
6239	SRC 2 I_2 Mag	SRC 2 Negative Sequence Current Magnitude (A)
6241	SRC 2 I_2 Angle	SRC 2 Negative Sequence Current Angle (°)
6242	SRC 2 Igd Mag	SRC 2 Differential Ground Current Magnitude (A)
6244	SRC 2 Igd Angle	SRC 2 Differential Ground Current Angle (°)
6656	SRC 1 Vag RMS	SRC 1 Phase AG Voltage RMS (V)
6658	SRC 1 Vbg RMS	SRC 1 Phase BG Voltage RMS (V)

A

Table A–1: FLEXANALOG PARAMETERS (Sheet 2 of 4)

SETTING	DISPLAY TEXT	DESCRIPTION
6660	SRC 1 Vcg RMS	SRC 1 Phase CG Voltage RMS (V)
6662	SRC 1 Vag Mag	SRC 1 Phase AG Voltage Magnitude (V)
6664	SRC 1 Vag Angle	SRC 1 Phase AG Voltage Angle (°)
6665	SRC 1 Vbg Mag	SRC 1 Phase BG Voltage Magnitude (V)
6667	SRC 1 Vbg Angle	SRC 1 Phase BG Voltage Angle (°)
6668	SRC 1 Vcg Mag	SRC 1 Phase CG Voltage Magnitude (V)
6670	SRC 1 Vcg Angle	SRC 1 Phase CG Voltage Angle (°)
6671	SRC 1 Vab RMS	SRC 1 Phase AB Voltage RMS (V)
6673	SRC 1 Vbc RMS	SRC 1 Phase BC Voltage RMS (V)
6675	SRC 1 Vca RMS	SRC 1 Phase CA Voltage RMS (V)
6677	SRC 1 Vab Mag	SRC 1 Phase AB Voltage Magnitude (V)
6679	SRC 1 Vab Angle	SRC 1 Phase AB Voltage Angle (°)
6680	SRC 1 Vbc Mag	SRC 1 Phase BC Voltage Magnitude (V)
6682	SRC 1 Vbc Angle	SRC 1 Phase BC Voltage Angle (°)
6683	SRC 1 Vca Mag	SRC 1 Phase CA Voltage Magnitude (V)
6685	SRC 1 Vca Angle	SRC 1 Phase CA Voltage Angle (°)
6686	SRC 1 Vx RMS	SRC 1 Auxiliary Voltage RMS (V)
6688	SRC 1 Vx Mag	SRC 1 Auxiliary Voltage Magnitude (V)
6690	SRC 1 Vx Angle	SRC 1 Auxiliary Voltage Angle (°)
6691	SRC 1 V_0 Mag	SRC 1 Zero Sequence Voltage Magnitude (V)
6693	SRC 1 V_0 Angle	SRC 1 Zero Sequence Voltage Angle (°)
6694	SRC 1 V_1 Mag	SRC 1 Positive Sequence Voltage Magnitude (V)
6696	SRC 1 V_1 Angle	SRC 1 Positive Sequence Voltage Angle (°)
6697	SRC 1 V_2 Mag	SRC 1 Negative Sequence Voltage Magnitude (V)
6699	SRC 1 V_2 Angle	SRC 1 Negative Sequence Voltage Angle (°)
6720	SRC 2 Vag RMS	SRC 2 Phase AG Voltage RMS (V)
6722	SRC 2 Vbg RMS	SRC 2 Phase BG Voltage RMS (V)
6724	SRC 2 Vcg RMS	SRC 2 Phase CG Voltage RMS (V)
6726	SRC 2 Vag Mag	SRC 2 Phase AG Voltage Magnitude (V)
6728	SRC 2 Vag Angle	SRC 2 Phase AG Voltage Angle (°)
6729	SRC 2 Vbg Mag	SRC 2 Phase BG Voltage Magnitude (V)
6731	SRC 2 Vbg Angle	SRC 2 Phase BG Voltage Angle (°)
6732	SRC 2 Vcg Mag	SRC 2 Phase CG Voltage Magnitude (V)
6734	SRC 2 Vcg Angle	SRC 2 Phase CG Voltage Angle (°)
6735	SRC 2 Vab RMS	SRC 2 Phase AB Voltage RMS (V)
6737	SRC 2 Vbc RMS	SRC 2 Phase BC Voltage RMS (V)
6739	SRC 2 Vca RMS	SRC 2 Phase CA Voltage RMS (V)
6741	SRC 2 Vab Mag	SRC 2 Phase AB Voltage Magnitude (V)
6743	SRC 2 Vab Angle	SRC 2 Phase AB Voltage Angle (°)
6744	SRC 2 Vbc Mag	SRC 2 Phase BC Voltage Magnitude (V)
6746	SRC 2 Vbc Angle	SRC 2 Phase BC Voltage Angle (°)
6747	SRC 2 Vca Mag	SRC 2 Phase CA Voltage Magnitude (V)
6749	SRC 2 Vca Angle	SRC 2 Phase CA Voltage Angle (°)
6750	SRC 2 Vx RMS	SRC 2 Auxiliary Voltage RMS (V)
6752	SRC 2 Vx Mag	SRC 2 Auxiliary Voltage Magnitude (V)
6754	SRC 2 Vx Angle	SRC 2 Auxiliary Voltage Angle (°)
6755	SRC 2 V_0 Mag	SRC 2 Zero Sequence Voltage Magnitude (V)
6757	SRC 2 V_0 Angle	SRC 2 Zero Sequence Voltage Angle (°)
6758	SRC 2 V_1 Mag	SRC 2 Positive Sequence Voltage Magnitude (V)
6760	SRC 2 V_1 Angle	SRC 2 Positive Sequence Voltage Angle (°)
6761	SRC 2 V_2 Mag	SRC 2 Negative Sequence Voltage Magnitude (V)

Table A–1: FLEXANALOG PARAMETERS (Sheet 3 of 4)

SETTING	DISPLAY TEXT	DESCRIPTION
6763	SRC 2 V_2 Angle	SRC 2 Negative Sequence Voltage Angle (°)
7168	SRC 1 P	SRC 1 Three Phase Real Power (W)
7170	SRC 1 Pa	SRC 1 Phase A Real Power (W)
7172	SRC 1 Pb	SRC 1 Phase B Real Power (W)
7174	SRC 1 Pc	SRC 1 Phase C Real Power (W)
7176	SRC 1 Q	SRC 1 Three Phase Reactive Power (var)
7178	SRC 1 Qa	SRC 1 Phase A Reactive Power (var)
7180	SRC 1 Qb	SRC 1 Phase B Reactive Power (var)
7182	SRC 1 Qc	SRC 1 Phase C Reactive Power (var)
7184	SRC 1 S	SRC 1 Three Phase Apparent Power (VA)
7186	SRC 1 Sa	SRC 1 Phase A Apparent Power (VA)
7188	SRC 1 Sb	SRC 1 Phase B Apparent Power (VA)
7190	SRC 1 Sc	SRC 1 Phase C Apparent Power (VA)
7192	SRC 1 PF	SRC 1 Three Phase Power Factor
7193	SRC 1 Phase A PF	SRC 1 Phase A Power Factor
7194	SRC 1 Phase B PF	SRC 1 Phase B Power Factor
7195	SRC 1 Phase C PF	SRC 1 Phase C Power Factor
7200	SRC 2 P	SRC 2 Three Phase Real Power (W)
7202	SRC 2 Pa	SRC 2 Phase A Real Power (W)
7204	SRC 2 Pb	SRC 2 Phase B Real Power (W)
7206	SRC 2 Pc	SRC 2 Phase C Real Power (W)
7208	SRC 2 Q	SRC 2 Three Phase Reactive Power (var)
7210	SRC 2 Qa	SRC 2 Phase A Reactive Power (var)
7212	SRC 2 Qb	SRC 2 Phase B Reactive Power (var)
7214	SRC 2 Qc	SRC 2 Phase C Reactive Power (var)
7216	SRC 2 S	SRC 2 Three Phase Apparent Power (VA)
7218	SRC 2 Sa	SRC 2 Phase A Apparent Power (VA)
7220	SRC 2 Sb	SRC 2 Phase B Apparent Power (VA)
7222	SRC 2 Sc	SRC 2 Phase C Apparent Power (VA)
7224	SRC 2 PF	SRC 2 Three Phase Power Factor
7225	SRC 2 Phase A PF	SRC 2 Phase A Power Factor
7226	SRC 2 Phase B PF	SRC 2 Phase B Power Factor
7227	SRC 2 Phase C PF	SRC 2 Phase C Power Factor
7552	SRC 1 Frequency	SRC 1 Frequency (Hz)
7553	SRC 2 Frequency	SRC 2 Frequency (Hz)
8704	Brk 1 Arc Amp A	Breaker 1 Arcing Amp Phase A (kA2-cyc)
8706	Brk 1 Arc Amp B	Breaker 1 Arcing Amp Phase B (kA2-cyc)
8708	Brk 1 Arc Amp C	Breaker 1 Arcing Amp Phase C (kA2-cyc)
8710	Brk 2 Arc Amp A	Breaker 2 Arcing Amp Phase A (kA2-cyc)
8712	Brk 2 Arc Amp B	Breaker 2 Arcing Amp Phase B (kA2-cyc)
8714	Brk 2 Arc Amp C	Breaker 2 Arcing Amp Phase C (kA2-cyc)
9216	Synchchk 1 Delta V	Synchrocheck 1 Delta Voltage (V)
9218	Synchchk 1 Delta F	Synchrocheck 1 Delta Frequency (Hz)
9219	Synchchk 1 Delta Phs	Synchrocheck 1 Delta Phase (°)
9220	Synchchk 2 Delta V	Synchrocheck 2 Delta Voltage (V)
9222	Synchchk 2 Delta F	Synchrocheck 2 Delta Frequency (Hz)
9223	Synchchk 2 Delta Phs	Synchrocheck 2 Delta Phase (°)
9248	1 S1 S2 Angle	Power Swing S1 S2 Angle (°)
9344	Local IA Mag	Local IA Magnitude (A)
9346	Local IB Mag	Local IB Magnitude (A)
9348	Local IC Mag	Local IC Magnitude (A)

Table A–1: FLEXANALOG PARAMETERS (Sheet 4 of 4)

SETTING	DISPLAY TEXT	DESCRIPTION
9350	Terminal 1 IA Mag	Remote1 IA Magnitude (A)
9352	Terminal 1 IB Mag	Remote1 IB Magnitude (A)
9354	Terminal 1 IC Mag	Remote1 IC Magnitude (A)
9356	Terminal 2 IA Mag	Remote2 IA Magnitude (A)
9358	Terminal 2 IB Mag	Remote2 IB Magnitude (A)
9360	Terminal 2 IC Mag	Remote2 IC Magnitude (A)
9362	Diff Curr IA Mag	Differential Current IA Magnitude (A)
9364	Diff Curr IB Mag	Differential Current IB Magnitude (A)
9366	Diff Curr IC Mag	Differential Current IC Magnitude (A)
9368	Local IA Angle	Local IA Angle (°)
9369	Local IB Angle	Local IB Angle (°)
9370	Local IC Angle	Local IC Angle (°)
9371	Terminal 1 IA Angle	Remote1 IA Angle (°)
9372	Terminal 1 IB Angle	Remote1 IB Angle (°)
9373	Terminal 1 IC Angle	Remote1 IC Angle (°)
9374	Terminal 2 IA Angle	Remote2 IA Angle (°)
9375	Terminal 2 IB Angle	Remote2 IB Angle (°)
9376	Terminal 2 IC Angle	Remote2 IC Angle (°)
9377	Diff Curr IA Angle	Differential Current IA Angle (°)
9378	Diff Curr IB Angle	Differential Current IB Angle (°)
9379	Diff Curr IC Angle	Differential Current IC Angle (°)
9380	Op Square Curr IA	Op Square Current IA ()
9382	Op Square Curr IB	Op Square Current IB ()
9384	Op Square Curr IC	Op Square Current IC ()
9386	Rest Square Curr IA	Restraint Square Current IA ()
9388	Rest Square Curr IB	Restraint Square Current IB ()
9390	Rest Square Curr IC	Restraint Square Current IC ()
32768	Tracking Frequency	Tracking Frequency (Hz)
39425	FlexElement 1 OpSig	FlexElement 1 Actual
39427	FlexElement 2 OpSig	FlexElement 2 Actual
39429	FlexElement 3 OpSig	FlexElement 3 Actual
39431	FlexElement 4 OpSig	FlexElement 4 Actual
39433	FlexElement 5 OpSig	FlexElement 5 Actual
39435	FlexElement 6 OpSig	FlexElement 6 Actual
39437	FlexElement 7 OpSig	FlexElement 7 Actual
39439	FlexElement 8 OpSig	FlexElement 8 Actual
39441	FlexElement 9 OpSig	FlexElement 9 Actual
39443	FlexElement 10 OpSig	FlexElement 10 Actual
39445	FlexElement 11 OpSig	FlexElement 11 Actual
39447	FlexElement 12 OpSig	FlexElement 12 Actual
39449	FlexElement 13 OpSig	FlexElement 13 Actual
39451	FlexElement 14 OpSig	FlexElement 14 Actual
39453	FlexElement 15 OpSig	FlexElement 15 Actual
39455	FlexElement 16 OpSig	FlexElement 16 Actual
40960	Communications Group	Communications Group
40971	Active Setting Group	Current Setting Group

B.1.1 INTRODUCTION

The UR series relays support a number of communications protocols to allow connection to equipment such as personal computers, RTUs, SCADA masters, and programmable logic controllers. The Modicon Modbus RTU protocol is the most basic protocol supported by the UR. Modbus is available via RS232 or RS485 serial links or via ethernet (using the Modbus/TCP specification). The following description is intended primarily for users who wish to develop their own master communication drivers and applies to the serial Modbus RTU protocol. Note that:

- The UR always acts as a slave device, meaning that it never initiates communications; it only listens and responds to requests issued by a master computer.
- For Modbus®, a subset of the Remote Terminal Unit (RTU) protocol format is supported that allows extensive monitoring, programming, and control functions using read and write register commands.

B.1.2 PHYSICAL LAYER

The Modbus® RTU protocol is hardware-independent so that the physical layer can be any of a variety of standard hardware configurations including RS232 and RS485. The relay includes a faceplate (front panel) RS232 port and two rear terminal communications ports that may be configured as RS485, fiber optic, 10BaseT, or 10BaseF. Data flow is half-duplex in all configurations. See Chapter 3: HARDWARE for details on wiring.

Each data byte is transmitted in an asynchronous format consisting of 1 start bit, 8 data bits, 1 stop bit, and possibly 1 parity bit. This produces a 10 or 11 bit data frame. This can be important for transmission through modems at high bit rates (11 bit data frames are not supported by many modems at baud rates greater than 300).

The baud rate and parity are independently programmable for each communications port. Baud rates of 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, or 115200 bps are available. Even, odd, and no parity are available. Refer to the COMMUNICATIONS section of the SETTINGS chapter for further details.

The master device in any system must know the address of the slave device with which it is to communicate. The relay will not act on a request from a master if the address in the request does not match the relay's slave address (unless the address is the broadcast address – see below).

A single setting selects the slave address used for all ports, with the exception that for the faceplate port, the relay will accept any address when the Modbus® RTU protocol is used.

B.1.3 DATA LINK LAYER

Communications takes place in packets which are groups of asynchronously framed byte data. The master transmits a packet to the slave and the slave responds with a packet. The end of a packet is marked by 'dead-time' on the communications line. The following describes general format for both transmit and receive packets. For exact details on packet formatting, refer to subsequent sections describing each function code.

Table B–1: MODBUS PACKET FORMAT

DESCRIPTION	SIZE
SLAVE ADDRESS	1 byte
FUNCTION CODE	1 byte
DATA	N bytes
CRC	2 bytes
DEAD TIME	3.5 bytes transmission time

SLAVE ADDRESS

This is the address of the slave device that is intended to receive the packet sent by the master and to perform the desired action. Each slave device on a communications bus must have a unique address to prevent bus contention. All of the relay's ports have the same address which is programmable from 1 to 254; see Chapter 5 for details. Only the addressed slave will respond to a packet that starts with its address. Note that the faceplate port is an exception to this rule; it will act on a message containing any slave address.

A master transmit packet with a slave address of 0 indicates a broadcast command. All slaves on the communication link will take action based on the packet, but none will respond to the master. Broadcast mode is only recognized when associated with FUNCTION CODE 05h. For any other function code, a packet with broadcast mode slave address 0 will be ignored.

FUNCTION CODE

This is one of the supported functions codes of the unit which tells the slave what action to perform. See the SUPPORTED FUNCTION CODES section for complete details. An exception response from the slave is indicated by setting the high order bit of the function code in the response packet. See the EXCEPTION RESPONSES section for further details.

DATA

This will be a variable number of bytes depending on the function code. This may include actual values, settings, or addresses sent by the master to the slave or by the slave to the master.

CRC

This is a two byte error checking code. The RTU version of Modbus® includes a 16 bit cyclic redundancy check (CRC-16) with every packet which is an industry standard method used for error detection. If a Modbus® slave device receives a packet in which an error is indicated by the CRC, the slave device will not act upon or respond to the packet thus preventing any erroneous operations. See the CRC-16 ALGORITHM section for a description of how to calculate the CRC.

DEAD TIME

A packet is terminated when no data is received for a period of 3.5 byte transmission times (about 15 ms at 2400 bps, 2 ms at 19200 bps, and 300 µs at 115200 bps). Consequently, the transmitting device must not allow gaps between bytes longer than this interval. Once the dead time has expired without a new byte transmission, all slaves start listening for a new packet from the master except for the addressed slave.

B.1.4 CRC-16 ALGORITHM

The CRC-16 algorithm essentially treats the entire data stream (data bits only; start, stop and parity ignored) as one continuous binary number. This number is first shifted left 16 bits and then divided by a characteristic polynomial (1100000000000101B). The 16 bit remainder of the division is appended to the end of the packet, MSByte first. The resulting packet including CRC, when divided by the same polynomial at the receiver will give a zero remainder if no transmission errors have occurred. This algorithm requires the characteristic polynomial to be reverse bit ordered. The most significant bit of the characteristic polynomial is dropped, since it does not affect the value of the remainder.

Note: A C programming language implementation of the CRC algorithm will be provided upon request.

Table B–2: CRC-16 ALGORITHM

SYMBOLS:	-->	data transfer	
	A	16 bit working register	
	Alow	low order byte of A	
	Ahigh	high order byte of A	
	CRC	16 bit CRC-16 result	
	i,j	loop counters	
	(+)	logical EXCLUSIVE-OR operator	
	N	total number of data bytes	
	Di	i-th data byte (i = 0 to N-1)	
	G	16 bit characteristic polynomial = 1010000000000001 (binary) with MSbit dropped and bit order reversed	
	shr (x)	right shift operator (th LSbit of x is shifted into a carry flag, a '0' is shifted into the MSbit of x, all other bits are shifted right one location)	
ALGORITHM:	1.	FFFF (hex) --> A	
	2.	0 --> i	
	3.	0 --> j	
	4.	Di (+) Alow --> Alow	
	5.	j + 1 --> j	
	6.	shr (A)	
	7.	Is there a carry?	No: go to 8 Yes: G (+) A --> A and continue.
	8.	Is j = 8?	No: go to 5 Yes: continue
	9.	i + 1 --> i	
	10.	Is i = N?	No: go to 3 Yes: continue
	11.	A --> CRC	

B.2.1 SUPPORTED FUNCTION CODES

Modbus® officially defines function codes from 1 to 127 though only a small subset is generally needed. The relay supports some of these functions, as summarized in the following table. Subsequent sections describe each function code in detail.

FUNCTION CODE		MODBUS DEFINITION	GE POWER MANAGEMENT DEFINITION
HEX	DEC		
03	3	Read Holding Registers	Read Actual Values or Settings
04	4	Read Holding Registers	Read Actual Values or Settings
05	5	Force Single Coil	Execute Operation
06	6	Preset Single Register	Store Single Setting
10	16	Preset Multiple Registers	Store Multiple Settings

B.2.2 03/04H: READ ACTUAL VALUES/SETTINGS

This function code allows the master to read one or more consecutive data registers (actual values or settings) from a relay. Data registers are always 16 bit (two byte) values transmitted with high order byte first. The maximum number of registers that can be read in a single packet is 125. See the section MODBUS® MEMORY MAP for exact details on the data registers.

Since some PLC implementations of Modbus® only support one of function codes 03h and 04h, the relay interpretation allows either function code to be used for reading one or more consecutive data registers. The data starting address will determine the type of data being read. Function codes 03h and 04h are therefore identical.

The following table shows the format of the master and slave packets. The example shows a master device requesting 3 register values starting at address 4050h from slave device 11h (17 decimal); the slave device responds with the values 40, 300, and 0 from registers 4050h, 4051h, and 4052h, respectively.

Table B–3: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION	
PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11
FUNCTION CODE	04
DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	50
NUMBER OF REGISTERS - hi	00
NUMBER OF REGISTERS - lo	03
CRC - lo	A7
CRC - hi	4A

SLAVE RESPONSE	
PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11
FUNCTION CODE	04
BYTE COUNT	06
DATA #1 - hi	00
DATA #1 - lo	28
DATA #2 - hi	01
DATA #2 - lo	2C
DATA #3 - hi	00
DATA #3 - lo	00
CRC - lo	0D
CRC - hi	60

B.2.3 05H: EXECUTE OPERATION

This function code allows the master to perform various operations in the relay. Available operations are in the table SUMMARY OF OPERATION CODES.

The following table shows the format of the master and slave packets. The example shows a master device requesting the slave device 11H (17 dec) to perform a reset. The hi and lo CODE VALUE bytes always have the values 'FF' and '00' respectively and are a remnant of the original Modbus® definition of this function code.

Table B–4: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION	
PACKET FORMAT	**EXAMPLE (HEX)**
SLAVE ADDRESS	11
FUNCTION CODE	05
OPERATION CODE - hi	00
OPERATION CODE - lo	01
CODE VALUE - hi	FF
CODE VALUE - lo	00
CRC - lo	DF
CRC - hi	6A

SLAVE RESPONSE	
PACKET FORMAT	**EXAMPLE (HEX)**
SLAVE ADDRESS	11
FUNCTION CODE	05
OPERATION CODE - hi	00
OPERATION CODE - lo	01
CODE VALUE - hi	FF
CODE VALUE - lo	00
CRC - lo	DF
CRC - hi	6A

Table B–5: SUMMARY OF OPERATION CODES (FUNCTION CODE 05H)

OPERATION CODE (HEX)	DEFINITION	DESCRIPTION
0000	NO OPERATION	Does not do anything.
0001	RESET	Performs the same function as the faceplate RESET key.
0005	CLEAR EVENT RECORDS	Performs the same function as the faceplate **CLEAR EVENT RECORDS** menu command.
0006	CLEAR OSCILLOGRAPHY	Clears all oscillography records.
1000 to 101F	VIRTUAL IN 1-32 ON/OFF	Sets the states of Virtual Inputs 1 to 32 either "ON" or "OFF".

B.2.4 06H: STORE SINGLE SETTING

This function code allows the master to modify the contents of a single setting register in an relay. Setting registers are always 16 bit (two byte) values transmitted high order byte first.

The following table shows the format of the master and slave packets. The example shows a master device storing the value 200 at memory map address 4051h to slave device 11h (17 dec).

Table B–6: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION	
PACKET FORMAT	**EXAMPLE (HEX)**
SLAVE ADDRESS	11
FUNCTION CODE	06
DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	51
DATA - hi	00
DATA - lo	C8
CRC - lo	CE
CRC - hi	DD

SLAVE RESPONSE	
PACKET FORMAT	**EXAMPLE (HEX)**
SLAVE ADDRESS	11
FUNCTION CODE	06
DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	51
DATA - hi	00
DATA - lo	C8
CRC - lo	CE
CRC - hi	DD

B.2.5 10H: STORE MULTIPLE SETTINGS

This function code allows the master to modify the contents of a one or more consecutive setting registers in a relay. Setting registers are 16-bit (two byte) values transmitted high order byte first. The maximum number of setting registers that can be stored in a single packet is 60. The following table shows the format of the master and slave packets. The example shows a master device storing the value 200 at memory map address 4051h, and the value 1 at memory map address 4052h to slave device 11h (17 dec).

Table B–7: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION	
PACKET FORMAT	**EXAMPLE (HEX)**
SLAVE ADDRESS	11
FUNCTION CODE	10
DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	51
NUMBER OF SETTINGS - hi	00
NUMBER OF SETTINGS - lo	02
BYTE COUNT	04
DATA #1 - high order byte	00
DATA #1 - low order byte	C8
DATA #2 - high order byte	00
DATA #2 - low order byte	01
CRC - low order byte	12
CRC - high order byte	62

SLAVE RESPONSE	
PACKET FORMAT	**EXMAPLE (HEX)**
SLAVE ADDRESS	11
FUNCTION CODE	10
DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	51
NUMBER OF SETTINGS - hi	00
NUMBER OF SETTINGS - lo	02
CRC - lo	07
CRC - hi	64

B.2.6 EXCEPTION RESPONSES

Programming or operation errors usually happen because of illegal data in a packet. These errors result in an exception response from the slave. The slave detecting one of these errors sends a response packet to the master with the high order bit of the function code set to 1.

The following table shows the format of the master and slave packets. The example shows a master device sending the unsupported function code 39h to slave device 11.

Table B–8: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION	
PACKET FORMAT	**EXAMPLE (HEX)**
SLAVE ADDRESS	11
FUNCTION CODE	39
CRC - low order byte	CD
CRC - high order byte	F2

SLAVE RESPONSE	
PACKET FORMAT	**EXAMPLE (HEX)**
SLAVE ADDRESS	11
FUNCTION CODE	B9
ERROR CODE	01
CRC - low order byte	93
CRC - high order byte	95

B.3.1 OBTAINING UR FILES USING MODBUS® PROTOCOL

The UR relay has a generic file transfer facility, meaning that you use the same method to obtain all of the different types of files from the unit. The Modbus registers that implement file transfer are found in the "Modbus File Transfer (Read/Write)" and "Modbus File Transfer (Read Only)" modules, starting at address 3100 in the Modbus Memory Map. To read a file from the UR relay, use the following steps:

1. Write the filename to the "Name of file to read" register using a write multiple registers command. If the name is shorter than 80 characters, you may write only enough registers to include all the text of the filename. Filenames are not case sensitive.
2. Repeatedly read all the registers in "Modbus File Transfer (Read Only)" using a read multiple registers command. It is not necessary to read the entire data block, since the UR relay will remember which was the last register you read. The "position" register is initially zero and thereafter indicates how many bytes (2 times the number of registers) you have read so far. The "size of..." register indicates the number of bytes of data remaining to read, to a maximum of 244.
3. Keep reading until the "size of..." register is smaller than the number of bytes you are transferring. This condition indicates end of file. Discard any bytes you have read beyond the indicated block size.
4. If you need to re-try a block, read only the "size of.." and "block of data", without reading the position. The file pointer is only incremented when you read the position register, so the same data block will be returned as was read in the previous operation. On the next read, check to see if the position is where you expect it to be, and discard the previous block if it is not (this condition would indicate that the UR relay did not process your original read request).

The UR relay retains connection-specific file transfer information, so files may be read simultaneously on multiple Modbus connections.

a) OBTAINING FILES FROM THE UR USING OTHER PROTOCOLS

All the files available via Modbus may also be retrieved using the standard file transfer mechanisms in other protocols (for example, TFTP or MMS).

b) COMTRADE, OSCILLOGRAPHY AND DATA LOGGER FILES

Oscillography and data logger files are formatted using the COMTRADE file format per IEEE PC37.111 Draft 7c (02 September 1997). The files may be obtained in either text or binary COMTRADE format.

c) READING OSCILLOGRAPHY FILES

Familiarity with the oscillography feature is required to understand the following description. Refer to the OSCILLOGRAPHY section in the SETTINGS chapter for additional details.

The Oscillography_Number_of_Triggers register is incremented by one every time a new oscillography file is triggered (captured) and cleared to zero when oscillography data is cleared. When a new trigger occurs, the associated oscillography file is assigned a file identifier number equal to the incremented value of this register; the newest file number is equal to the Oscillography_Number_of_Triggers register. This register can be used to determine if any new data has been captured by periodically reading it to see if the value has changed; if the number has increased then new data is available.

The Oscillography_Number_of_Records setting specifies the maximum number of files (and the number of cycles of data per file) that can be stored in memory of the relay. The Oscillography_Available_Records register specifies the actual number of files that are stored and still available to be read out of the relay.

Writing ‘Yes’ (i.e. the value 1) to the Oscillography_Clear_Data register clears oscillography data files, clears both the Oscillography_Number_of_Triggers and Oscillography_Available_Records registers to zero, and sets the Oscillography_Last_Cleared_Date to the present date and time.

To read binary COMTRADE oscillography files, read the following filenames:

- OSCnnnn.CFG
- OSCnnn.DAT

Replace "nnn" with the desired oscillography trigger number. For ASCII format, use the following file names

- OSCAnnnn.CFG
- OSCAnnn.DAT

d) READING DATA LOGGER FILES

Familiarity with the data logger feature is required to understand this description. Refer to the DATA LOGGER section of Chapter 5 for details. To read the entire data logger in binary COMTRADE format, read the following files.

- datalog.cfg
- datalog.dat

To read the entire data logger in ASCII COMTRADE format, read the following files.

- dataloga.cfg
- dataloga.dat

To limit the range of records to be returned in the COMTRADE files, append the following to the filename before writing it:

- To read from a specific time to the end of the log: <space> startTime
- To read a specific range of records: <space> startTime <space> endTime
- Replace <startTime> and <endTime> with Julian dates (seconds since Jan. 1 1970) as numeric text.

e) READING EVENT RECORDER FILES

To read the entire event recorder contents in ASCII format (the only available format), use the following filename:

- `EVT.TXT`

To read from a specific record to the end of the log, use the following filename:

- `EVTnnn.TXT` (replace "nnn" with the desired starting record number)

f) READING FAULT REPORT FILES

Fault report data has been available via the UR file retrieval mechanism since firmware version 2.00. The file name is **`faultReport#####.htm`**. The ##### refers to the fault report record number. The fault report number is a counter that indicates how many fault reports have ever occurred. The counter rolls over at a value of 65535. Only the last ten fault reports are available for retrieval; a request for a non-existent fault report file will yield a null file. The current value fault report counter is available in “Number of Fault Reports” Modbus register at location 0x3020.

For example, if 14 fault reports have occurred then the files `faultReport5.htm`, `faultReport6.htm`, up to `faultReport14.htm` are available to be read. The expected use of this feature has an external master periodically polling the “Number of Fault Reports' register. If the value changes, then the master reads all the new files.

The contents of the file is in standard HTML notation and can be viewed via any commercial browser.

B.3.2 MODBUS® PASSWORD OPERATION

The COMMAND password is set up at memory location 4000. Storing a value of "0" removes COMMAND password protection. When reading the password setting, the encrypted value (zero if no password is set) is returned. COMMAND security is required to change the COMMAND password. Similarly, the SETTING password is set up at memory location 4002. These are the same settings and encrypted values found in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ PASSWORD SECURITY** menu via the keypad. Enabling password security for the faceplate display will also enable it for Modbus, and vice-versa.

To gain COMMAND level security access, the COMMAND password must be entered at memory location 4008. To gain SETTING level security access, the SETTING password must be entered at memory location 400A. The entered SETTING password must match the current SETTING password setting, or must be zero, to change settings or download firmware.

COMMAND and SETTING passwords each have a 30-minute timer. Each timer starts when you enter the particular password, and is re-started whenever you “use” it. For example, writing a setting re-starts the SETTING password timer and writing a command register or forcing a coil re-starts the COMMAND password timer. The value read at memory location 4010 can be used to confirm whether a COMMAND password is enabled or disabled (0 for Disabled). The value read at memory location 4011 can be used to confirm whether a SETTING password is enabled or disabled.

COMMAND or SETTING password security access is restricted to the particular port or particular TCP/IP connection on which the entry was made. Passwords must be entered when accessing the relay through other ports or connections, and the passwords must be re-entered after disconnecting and re-connecting on TCP/IP.

B

Table B–9: MODBUS MEMORY MAP (Sheet 1 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
Product Information (Read Only)						
0000	UR Product Type	0 to 65535	---	1	F001	0
0002	Product Version	0 to 655.35	---	0.01	F001	1
Product Information (Read Only -- Written by Factory)						
0010	Serial Number	---	---	---	F203	"0"
0020	Manufacturing Date	0 to 4294967295	---	1	F050	0
0022	Modification Number	0 to 65535	---	1	F001	0
0040	Order Code	---	---	---	F204	"Order Code x "
0090	Ethernet MAC Address	---	---	---	F072	0
0093	Reserved (13 items)	---	---	---	F001	0
00A0	CPU Module Serial Number	---	---	---	F203	(none)
00B0	CPU Supplier Serial Number	---	---	---	F203	(none)
00C0	Ethernet Sub Module Serial Number (8 items)	---	---	---	F203	(none)
Self Test Targets (Read Only)						
0200	Self Test States (2 items)	0 to 4294967295	0	1	F143	0
Front Panel (Read Only)						
0204	LED Column x State (9 items)	0 to 65535	---	1	F501	0
0220	Display Message	---	---	---	F204	(none)
Keypress Emulation (Read/Write)						
0280	Simulated keypress – write zero before each keystroke	0 to 26	---	1	F190	0 (No key – use between real key)
Virtual Input Commands (Read/Write Command) (32 modules)						
0400	Virtual Input x State	0 to 1	---	1	F108	0 (Off)
0401	...Repeated for module number 2					
0402	...Repeated for module number 3					
0403	...Repeated for module number 4					
0404	...Repeated for module number 5					
0405	...Repeated for module number 6					
0406	...Repeated for module number 7					
0407	...Repeated for module number 8					
0408	...Repeated for module number 9					
0409	...Repeated for module number 10					
040A	...Repeated for module number 11					
040B	...Repeated for module number 12					
040C	...Repeated for module number 13					
040D	...Repeated for module number 14					
040E	...Repeated for module number 15					
040F	...Repeated for module number 16					
0410	...Repeated for module number 17					
0411	...Repeated for module number 18					
0412	...Repeated for module number 19					
0413	...Repeated for module number 20					
0414	...Repeated for module number 21					
0415	...Repeated for module number 22					
0416	...Repeated for module number 23					
0417	...Repeated for module number 24					
0418	...Repeated for module number 25					
0419	...Repeated for module number 26					
041A	...Repeated for module number 27					
041B	...Repeated for module number 28					
041C	...Repeated for module number 29					

Table B–9: MODBUS MEMORY MAP (Sheet 2 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
041D	...Repeated for module number 30					
041E	...Repeated for module number 31					
041F	...Repeated for module number 32					
Digital Counter States (Read Only Non-Volatile) (8 modules)						
0800	Digital Counter x Value	–2147483647 to 2147483647	---	1	F004	0
0802	Digital Counter x Frozen	–2147483647 to 2147483647	---	1	F004	0
0804	Digital Counter x Frozen Time Stamp	0 to 4294967295	---	1	F050	0
0806	Digital Counter x Frozen Time Stamp us	0 to 4294967295	---	1	F003	0
0808	...Repeated for module number 2					
0810	...Repeated for module number 3					
0818	...Repeated for module number 4					
0820	...Repeated for module number 5					
0828	...Repeated for module number 6					
0830	...Repeated for module number 7					
0838	...Repeated for module number 8					
Flex States (Read Only)						
0900	Flex State Bits (16 items)	0 to 65535	---	1	F001	0
Element States (Read Only)						
1000	Element Operate States (64 items)	0 to 65535	---	1	F502	0
User Displays Actuals (Read Only)						
1080	Formatted user-definable displays (8 items)	---	---	---	F200	(none)
Modbus User Map Actuals (Read Only)						
1200	User Map Values (256 items)	0 to 65535	---	1	F001	0
Element Targets (Read Only)						
14C0	Target Sequence	0 to 65535	---	1	F001	0
14C1	Number of Targets	0 to 65535	---	1	F001	0
Element Targets (Read/Write)						
14C2	Target to Read	0 to 65535	---	1	F001	0
Element Targets (Read Only)						
14C3	Target Message	---	---	---	F200	"."
Digital I/O States (Read Only						
1500	Contact Input States (6 items)	0 to 65535	---	1	F500	0
1508	Virtual Input States (2 items)	0 to 65535	---	1	F500	0
1510	Contact Output States (4 items)	0 to 65535	---	1	F500	0
1518	Contact Output Current States (4 items)	0 to 65535	---	1	F500	0
1520	Contact Output Voltage States (4 items)	0 to 65535	---	1	F500	0
1528	Virtual Output States (4 items)	0 to 65535	---	1	F500	0
1530	Contact Output Detectors (4 items)	0 to 65535	---	1	F500	0
Remote I/O States (Read Only)						
1540	Remote Device x States	0 to 65535	---	1	F500	0
1542	Remote Input x States (2 items)	0 to 65535	---	1	F500	0
1550	Remote Devices Online	0 to 1	---	1	F126	0 (No)
Remote Device Status (Read Only) (16 modules)						
1551	Remote Device x StNum	0 to 4294967295	---	1	F003	0
1553	Remote Device x SqNum	0 to 4294967295	---	1	F003	0
1555	...Repeated for module number 2					
1559	...Repeated for module number 3					
155D	...Repeated for module number 4					
1561	...Repeated for module number 5					
1565	...Repeated for module number 6					
1569	...Repeated for module number 7					
156D	...Repeated for module number 8					
1571	...Repeated for module number 9					

Table B–9: MODBUS MEMORY MAP (Sheet 3 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
1575	...Repeated for module number 10					
1579	...Repeated for module number 11					
157D	...Repeated for module number 12					
1581	...Repeated for module number 13					
1585	...Repeated for module number 14					
1589	...Repeated for module number 15					
158D	...Repeated for module number 16					
Direct I/O States (Read Only)						
15A0	Direct Input x 1 State	0 to 1	---	1	F108	0 (Off)
15A1	Direct Input x 2 State	0 to 1	---	1	F108	0 (Off)
Ethernet Fibre Channel Status (Read/Write)						
1610	Ethernet Primary Fibre Channel Status	0 to 2	---	1	F134	0 (Fail)
1611	Ethernet Secondary Fibre Channel Status	0 to 2	---	1	F134	0 (Fail)
Data Logger Actuals (Read Only)						
1618	Data Logger Channel Count	0 to 16	CHNL	1	F001	0
1619	Time of oldest available samples	0 to 4294967295	seconds	1	F050	0
161B	Time of newest available samples	0 to 4294967295	seconds	1	F050	0
161D	Data Logger Duration	0 to 999.9	DAYS	0.1	F001	0
L90 Channel Status (Read Only)						
1620	L90 Channel 1 Status	0 to 2	---	1	F134	1 (OK)
1621	L90 Channel 1 Number of lost packets	0 to 65535	---	1	F001	0
1622	Channel 1 Local Loopback Status	0 to 2	---	1	F134	2 (n/a)
1623	Channel 1 Remote Loopback Status	0 to 2	---	1	F134	2 (n/a)
1626	L90 Channel 1 Loop Delay	0 to 200	ms	0.1	F001	0
1627	L90 Channel 2 Status	0 to 2	---	1	F134	2 (n/a)
1628	L90 Channel 2 Number of lost packets	0 to 65535	---	1	F001	0
1629	Channel 2 Local Loopback Status	0 to 2	---	1	F134	2 (n/a)
162A	Channel 2 Remote Loopback Status	0 to 2	---	1	F134	2 (n/a)
162B	L90 Network Status	0 to 2	---	1	F134	1 (OK)
162D	L90 Channel 2 Loop Delay	0 to 200	ms	0.1	F001	0
162E	Channel PFLL Status	0 to 2	---	1	F134	1 (OK)
L90 Channel Status (Read/Write Command)						
162F	L90 Channel Status Clear	0 to 1	---	1	F126	0 (No)
Source Current (Read Only) (6 modules)						
1800	Phase A Current RMS	0 to 999999.999	A	0.001	F060	0
1802	Phase B Current RMS	0 to 999999.999	A	0.001	F060	0
1804	Phase C Current RMS	0 to 999999.999	A	0.001	F060	0
1806	Neutral Current RMS	0 to 999999.999	A	0.001	F060	0
1808	Phase A Current Magnitude	0 to 999999.999	A	0.001	F060	0
180A	Phase A Current Angle	-359.9 to 0	°	0.1	F002	0
180B	Phase B Current Magnitude	0 to 999999.999	A	0.001	F060	0
180D	Phase B Current Angle	-359.9 to 0	°	0.1	F002	0
180E	Phase C Current Magnitude	0 to 999999.999	A	0.001	F060	0
1810	Phase C Current Angle	-359.9 to 0	°	0.1	F002	0
1811	Neutral Current Magnitude	0 to 999999.999	A	0.001	F060	0
1813	Neutral Current Angle	-359.9 to 0	°	0.1	F002	0
1814	Ground Current RMS	0 to 999999.999	A	0.001	F060	0
1816	Ground Current Magnitude	0 to 999999.999	A	0.001	F060	0
1818	Ground Current Angle	-359.9 to 0	°	0.1	F002	0
1819	Zero Sequence Current Magnitude	0 to 999999.999	A	0.001	F060	0
181B	Zero Sequence Current Angle	-359.9 to 0	°	0.1	F002	0
181C	Positive Sequence Current Magnitude	0 to 999999.999	A	0.001	F060	0
181E	Positive Sequence Current Angle	-359.9 to 0	°	0.1	F002	0
181F	Negative Sequence Current Magnitude	0 to 999999.999	A	0.001	F060	0

Table B–9: MODBUS MEMORY MAP (Sheet 4 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
1821	Negative Sequence Current Angle	-359.9 to 0	°	0.1	F002	0
1822	Differential Ground Current Magnitude	0 to 999999.999	A	0.001	F060	0
1824	Differential Ground Current Angle	-359.9 to 0	°	0.1	F002	0
1825	Reserved (27 items)	---	---	---	F001	0
1840	...Repeated for module number 2					
1880	...Repeated for module number 3					
18C0	...Repeated for module number 4					
1900	...Repeated for module number 5					
1940	...Repeated for module number 6					
Source Voltage (Read Only) (6 modules)						
1A00	Phase AG Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A02	Phase BG Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A04	Phase CG Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A06	Phase AG Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A08	Phase AG Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A09	Phase BG Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A0B	Phase BG Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A0C	Phase CG Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A0E	Phase CG Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A0F	Phase AB or AC Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A11	Phase BC or BA Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A13	Phase CA or CB Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A15	Phase AB or AC Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A17	Phase AB or AC Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A18	Phase BC or BA Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A1A	Phase BC or BA Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A1B	Phase CA or CB Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A1D	Phase CA or CB Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A1E	Auxiliary Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A20	Auxiliary Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A22	Auxiliary Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A23	Zero Sequence Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A25	Zero Sequence Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A26	Positive Sequence Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A28	Positive Sequence Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A29	Negative Sequence Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A2B	Negative Sequence Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A2C	Reserved (20 items)	---	---	---	F001	0
1A40	...Repeated for module number 2					
1A80	...Repeated for module number 3					
1AC0	...Repeated for module number 4					
1B00	...Repeated for module number 5					
1B40	...Repeated for module number 6					
Source Power (Read Only) (6 modules)						
1C00	Three Phase Real Power	-1000000000000 to 1000000000000	W	0.001	F060	0
1C02	Phase A Real Power	-1000000000000 to 1000000000000	W	0.001	F060	0
1C04	Phase B Real Power	-1000000000000 to 1000000000000	W	0.001	F060	0
1C06	Phase C Real Power	-1000000000000 to 1000000000000	W	0.001	F060	0
1C08	Three Phase Reactive Power	-1000000000000 to 1000000000000	var	0.001	F060	0
1C0A	Phase A Reactive Power	-1000000000000 to 1000000000000	var	0.001	F060	0

Table B–9: MODBUS MEMORY MAP (Sheet 5 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
1C0C	Phase B Reactive Power	-1000000000000 to 1000000000000	var	0.001	F060	0
1C0E	Phase C Reactive Power	-1000000000000 to 1000000000000	var	0.001	F060	0
1C10	Three Phase Apparent Power	-1000000000000 to 1000000000000	VA	0.001	F060	0
1C12	Phase A Apparent Power	-1000000000000 to 1000000000000	VA	0.001	F060	0
1C14	Phase B Apparent Power	-1000000000000 to 1000000000000	VA	0.001	F060	0
1C16	Phase C Apparent Power	-1000000000000 to 1000000000000	VA	0.001	F060	0
1C18	Three Phase Power Factor	-0.999 to 1	---	0.001	F013	0
1C19	Phase A Power Factor	-0.999 to 1	---	0.001	F013	0
1C1A	Phase B Power Factor	-0.999 to 1	---	0.001	F013	0
1C1B	Phase C Power Factor	-0.999 to 1	---	0.001	F013	0
1C1C	Reserved (4 items)	---	---	---	F001	0
1C20	...Repeated for module number 2					
1C40	...Repeated for module number 3					
1C60	...Repeated for module number 4					
1C80	...Repeated for module number 5					
1CA0	...Repeated for module number 6					
Source Energy (Read Only Non-Volatile) (6 modules)						
1D00	Positive Watthour	0 to 1000000000000	Wh	0.001	F060	0
1D02	Negative Watthour	0 to 1000000000000	Wh	0.001	F060	0
1D04	Positive Varhour	0 to 1000000000000	varh	0.001	F060	0
1D06	Negative Varhour	0 to 1000000000000	varh	0.001	F060	0
1D08	Reserved (8 items)	---	---	---	F001	0
1D10	...Repeated for module number 2					
1D20	...Repeated for module number 3					
1D30	...Repeated for module number 4					
1D40	...Repeated for module number 5					
1D50	...Repeated for module number 6					
Energy Commands (Read/Write Command)						
1D60	Energy Clear Command	0 to 1	---	1	F126	0 (No)
Source Frequency (Read Only) (6 modules)						
1D80	Frequency	2 to 90	Hz	0.01	F001	0
1D81	...Repeated for module number 2					
1D82	...Repeated for module number 3					
1D83	...Repeated for module number 4					
1D84	...Repeated for module number 5					
1D85	...Repeated for module number 6					
Source Demand (Read Only) (6 modules)						
1E00	Demand Ia	0 to 999999.999	A	0.001	F060	0
1E02	Demand Ib	0 to 999999.999	A	0.001	F060	0
1E04	Demand Ic	0 to 999999.999	A	0.001	F060	0
1E06	Demand Watt	0 to 999999.999	W	0.001	F060	0
1E08	Demand Var	0 to 999999.999	var	0.001	F060	0
1E0A	Demand Va	0 to 999999.999	VA	0.001	F060	0
1E0C	Reserved (4 items)	---	---	---	F001	0
1E10	...Repeated for module number 2					
1E20	...Repeated for module number 3					
1E30	...Repeated for module number 4					
1E40	...Repeated for module number 5					
1E50	...Repeated for module number 6					

Table B–9: MODBUS MEMORY MAP (Sheet 6 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
Source Demand Peaks (Read Only Non-Volatile) (6 modules)						
1E80	SRC X Demand Ia Max	0 to 999999.999	A	0.001	F060	0
1E82	SRC X Demand Ia Max Date	0 to 4294967295	---	1	F050	0
1E84	SRC X Demand Ib Max	0 to 999999.999	A	0.001	F060	0
1E86	SRC X Demand Ib Max Date	0 to 4294967295	---	1	F050	0
1E88	SRC X Demand Ic Max	0 to 999999.999	A	0.001	F060	0
1E8A	SRC X Demand Ic Max Date	0 to 4294967295	---	1	F050	0
1E8C	SRC X Demand Watt Max	0 to 999999.999	W	0.001	F060	0
1E8E	SRC X Demand Watt Max Date	0 to 4294967295	---	1	F050	0
1E90	SRC X Demand Var	0 to 999999.999	var	0.001	F060	0
1E92	SRC X Demand Var Max Date	0 to 4294967295	---	1	F050	0
1E94	SRC X Demand Va Max	0 to 999999.999	VA	0.001	F060	0
1E96	SRC X Demand Va Max Date	0 to 4294967295	---	1	F050	0
1E98	Reserved (8 items)	---	---	---	F001	0
1EA0	...Repeated for module number 2					
1EC0	...Repeated for module number 3					
1EE0	...Repeated for module number 4					
1F00	...Repeated for module number 5					
1F20	...Repeated for module number 6					
Breaker Arcing Current Actuals (Read Only Non-Volatile) (2 modules)						
2200	Breaker x Arcing Amp Phase A	0 to 99999999	kA2-cyc	1	F060	0
2202	Breaker x Arcing Amp Phase B	0 to 99999999	kA2-cyc	1	F060	0
2204	Breaker x Arcing Amp Phase C	0 to 99999999	kA2-cyc	1	F060	0
2206	...Repeated for module number 2					
Breaker Arcing Current Commands (Read/Write Command) (2 modules)						
220C	Breaker x Arcing Clear Command	0 to 1	---	1	F126	0 (No)
220D	...Repeated for module number 2					
Fault Location (Read Only)						
2350	Prefault Phase A Current Magnitude	0 to 999999.999	---	0.001	F060	0
2352	Prefault Phase B Current Magnitude	0 to 999999.999	---	0.001	F060	0
2354	Prefault Phase C Current Magnitude	0 to 999999.999	---	0.001	F060	0
2356	Prefault Zero Seq Current	0 to 999999.999	---	0.001	F060	0
2358	Prefault Pos Seq Current	0 to 999999.999	---	0.001	F060	0
235A	Prefault Neg Seq Current	0 to 999999.999	---	0.001	F060	0
235C	Prefault Phase A Voltage	0 to 999999.999	---	0.001	F060	0
235E	Prefault Phase B Voltage	0 to 999999.999	---	0.001	F060	0
2360	Prefault Phase C Voltage	0 to 999999.999	---	0.001	F060	0
Synchrocheck Actuals (Read Only) (2 modules)						
2400	Synchrocheck X Delta Voltage	-1000000000000 to 1000000000000	V	1	F060	0
2402	Synchrocheck X Delta Frequency	0 to 655.35	Hz	0.01	F001	0
2403	Synchrocheck X Delta Phase	0 to 359.9	°	0.1	F001	0
2404	...Repeated for module number 2					
Autoreclose Status (Read Only) (6 modules)						
2410	Autoreclose Count	0 to 65535	---	1	F001	0
2411	...Repeated for module number 2					
2412	...Repeated for module number 3					
2413	...Repeated for module number 4					
2414	...Repeated for module number 5					
2415	...Repeated for module number 6					
L90 Current Differential (Read Only)						
2480	Local IA Magnitude	0 to 999999.999	A	0.001	F060	0
2482	Local IB Magnitude	0 to 999999.999	A	0.001	F060	0
2484	Local IC Magnitude	0 to 999999.999	A	0.001	F060	0

Table B–9: MODBUS MEMORY MAP (Sheet 7 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
2486	Terminal 1 IA Magnitude	0 to 999999.999	A	0.001	F060	0
2488	Terminal 1 IB Magnitude	0 to 999999.999	A	0.001	F060	0
248A	Terminal 1 IC Magnitude	0 to 999999.999	A	0.001	F060	0
248C	Terminal 2 IA Magnitude	0 to 999999.999	A	0.001	F060	0
248E	Terminal 2 IB Magnitude	0 to 999999.999	A	0.001	F060	0
2490	Terminal 2 IC Magnitude	0 to 999999.999	A	0.001	F060	0
2492	Differential Current IA Magnitude	0 to 999999.999	A	0.001	F060	0
2494	Differential Current IB Magnitude	0 to 999999.999	A	0.001	F060	0
2496	Differential Current IC Magnitude	0 to 999999.999	A	0.001	F060	0
2498	Local IA Angle	-359.9 to 0	°	0.1	F002	0
2499	Local IB Angle	-359.9 to 0	°	0.1	F002	0
249A	Local IC Angle	-359.9 to 0	°	0.1	F002	0
249B	Terminal 1 IA Angle	-359.9 to 0	°	0.1	F002	0
249C	Terminal 1 IB Angle	-359.9 to 0	°	0.1	F002	0
249D	Terminal 1 IC Angle	-359.9 to 0	°	0.1	F002	0
249E	Terminal 2 IA Angle	-359.9 to 0	°	0.1	F002	0
249F	Terminal 2 IB Angle	-359.9 to 0	°	0.1	F002	0
24A0	Terminal 2 IC Angle	-359.9 to 0	°	0.1	F002	0
24A1	Differential Current IA Angle	-359.9 to 0	°	0.1	F002	0
24A2	Differential Current IB Angle	-359.9 to 0	°	0.1	F002	0
24A3	Differential Current IC Angle	-359.9 to 0	°	0.1	F002	0
24A4	Op Square Current IA	0 to 999999.999	---	0.001	F060	0
24A6	Op Square Current IB	0 to 999999.999	---	0.001	F060	0
24A8	Op Square Current IC	0 to 999999.999	---	0.001	F060	0
24AA	Restraint Square Current IA	0 to 999999.999	---	0.001	F060	0
24AC	Restraint Square Current IB	0 to 999999.999	---	0.001	F060	0
24AE	Restraint Square Current IC	0 to 999999.999	---	0.001	F060	0
Expanded FlexStates (Read Only)						
2B00	FlexStates, one per register (256 items)	0 to 1	---	1	F108	0 (Off)
Expanded Digital I/O states (Read Only)						
2D00	Contact Input States, one per register (96 items)	0 to 1	---	1	F108	0 (Off)
2D80	Contact Output States, one per register (64 items)	0 to 1	---	1	F108	0 (Off)
2E00	Virtual Output States, one per register (64 items)	0 to 1	---	1	F108	0 (Off)
Expanded Remote I/O Status (Read Only)						
2F00	Remote Device States, one per register (16 items)	0 to 1	---	1	F155	0 (Offline)
2F80	Remote Input States, one per register (32 items)	0 to 1	---	1	F108	0 (Off)
Oscillography Values (Read Only)						
3000	Oscillography Number of Triggers	0 to 65535	---	1	F001	0
3001	Oscillography Available Records	0 to 65535	---	1	F001	0
3002	Oscillography Last Cleared Date	0 to 400000000	---	1	F050	0
3004	Oscillography Number Of Cycles Per Record	0 to 65535	---	1	F001	0
Oscillography Commands (Read/Write Command)						
3005	Oscillography Force Trigger	0 to 1	---	1	F126	0 (No)
3011	Oscillography Clear Data	0 to 1	---	1	F126	0 (No)
Fault Report Indexing (Read Only Non-Volatile)						
3020	Number Of Fault Reports	0 to 65535	---	1	F001	0
Fault Reports (Read Only Non-Volatile) (10 modules)						
3030	Fault Time	0 to 4294967295	---	1	F050	0
3032	...Repeated for module number 2					
3034	...Repeated for module number 3					
3036	...Repeated for module number 4					
3038	...Repeated for module number 5					
303A	...Repeated for module number 6					
303C	...Repeated for module number 7					

Table B–9: MODBUS MEMORY MAP (Sheet 8 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
303E	...Repeated for module number 8					
3040	...Repeated for module number 9					
3042	...Repeated for module number 10					
Modbus File Transfer (Read/Write)						
3100	Name of file to read	---	---	---	F204	(none)
Modbus File Transfer (Read Only)						
3200	Character position of current block within file	0 to 4294967295	---	1	F003	0
3202	Size of currently-available data block	0 to 65535	---	1	F001	0
3203	Block of data from requested file (122 items)	0 to 65535	---	1	F001	0
Event Recorder (Read Only)						
3400	Events Since Last Clear	0 to 4294967295	---	1	F003	0
3402	Number of Available Events	0 to 4294967295	---	1	F003	0
3404	Event Recorder Last Cleared Date	0 to 4294967295	---	1	F050	0
Event Recorder (Read/Write Command)						
3406	Event Recorder Clear Command	0 to 1	---	1	F126	0 (No)
DCMA Input Values (Read Only) (24 modules)						
34C0	DCMA Inputs x Value	-9999.999 to 9999.999	---	0.001	F004	0
34C2	...Repeated for module number 2					
34C4	...Repeated for module number 3					
34C6	...Repeated for module number 4					
34C8	...Repeated for module number 5					
34CA	...Repeated for module number 6					
34CC	...Repeated for module number 7					
34CE	...Repeated for module number 8					
34D0	...Repeated for module number 9					
34D2	...Repeated for module number 10					
34D4	...Repeated for module number 11					
34D6	...Repeated for module number 12					
34D8	...Repeated for module number 13					
34DA	...Repeated for module number 14					
34DC	...Repeated for module number 15					
34DE	...Repeated for module number 16					
34E0	...Repeated for module number 17					
34E2	...Repeated for module number 18					
34E4	...Repeated for module number 19					
34E6	...Repeated for module number 20					
34E8	...Repeated for module number 21					
34EA	...Repeated for module number 22					
34EC	...Repeated for module number 23					
34EE	...Repeated for module number 24					
RTD Input Values (Read Only) (48 modules)						
34F0	RTD Inputs x Value	-32768 to 32767	°C	1	F002	0
34F1	...Repeated for module number 2					
34F2	...Repeated for module number 3					
34F3	...Repeated for module number 4					
34F4	...Repeated for module number 5					
34F5	...Repeated for module number 6					
34F6	...Repeated for module number 7					
34F7	...Repeated for module number 8					
34F8	...Repeated for module number 9					
34F9	...Repeated for module number 10					
34FA	...Repeated for module number 11					
34FB	...Repeated for module number 12					
34FC	...Repeated for module number 13					

Table B–9: MODBUS MEMORY MAP (Sheet 9 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
34FD	...Repeated for module number 14					
34FE	...Repeated for module number 15					
34FF	...Repeated for module number 16					
3500	...Repeated for module number 17					
3501	...Repeated for module number 18					
3502	...Repeated for module number 19					
3503	...Repeated for module number 20					
3504	...Repeated for module number 21					
3505	...Repeated for module number 22					
3506	...Repeated for module number 23					
3507	...Repeated for module number 24					
3508	...Repeated for module number 25					
3509	...Repeated for module number 26					
350A	...Repeated for module number 27					
350B	...Repeated for module number 28					
350C	...Repeated for module number 29					
350D	...Repeated for module number 30					
350E	...Repeated for module number 31					
350F	...Repeated for module number 32					
3510	...Repeated for module number 33					
3511	...Repeated for module number 34					
3512	...Repeated for module number 35					
3513	...Repeated for module number 36					
3514	...Repeated for module number 37					
3515	...Repeated for module number 38					
3516	...Repeated for module number 39					
3517	...Repeated for module number 40					
3518	...Repeated for module number 41					
3519	...Repeated for module number 42					
351A	...Repeated for module number 43					
351B	...Repeated for module number 44					
351C	...Repeated for module number 45					
351D	...Repeated for module number 46					
351E	...Repeated for module number 47					
351F	...Repeated for module number 48					
Ohm Input Values (Read Only) (2 modules)						
3520	Ohm Inputs x Value	0 to 65535	Ω	1	F001	0
3521	...Repeated for module number 2					
Passwords (Read/Write Command)						
4000	Command Password Setting	0 to 4294967295	---	1	F003	0
Passwords (Read/Write Setting)						
4002	Setting Password Setting	0 to 4294967295	---	1	F003	0
Passwords (Read/Write)						
4008	Command Password Entry	0 to 4294967295	---	1	F003	0
400A	Setting Password Entry	0 to 4294967295	---	1	F003	0
Passwords (Read Only)						
4010	Command Password Status	0 to 1	---	1	F102	0 (Disabled)
4011	Setting Password Status	0 to 1	---	1	F102	0 (Disabled)
Preferences (Read/Write Setting)						
4050	Flash Message Time	0.5 to 10	s	0.1	F001	10
4051	Default Message Timeout	10 to 900	s	1	F001	300
4052	Default Message Intensity	0 to 3	---	1	F101	0 (25%)
Communications (Read/Write Setting)						
407E	COM1 minimum response time	0 to 1000	ms	10	F001	0

Table B–9: MODBUS MEMORY MAP (Sheet 10 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
407F	COM2 minimum response time	0 to 1000	ms	10	F001	0
4080	Modbus Slave Address	1 to 254	---	1	F001	254
4083	RS485 Com1 Baud Rate	0 to 11	---	1	F112	5 (19200)
4084	RS485 Com1 Parity	0 to 2	---	1	F113	0 (None)
4085	RS485 Com2 Baud Rate	0 to 11	---	1	F112	5 (19200)
4086	RS485 Com2 Parity	0 to 2	---	1	F113	0 (None)
4087	IP Address	0 to 4294967295	---	1	F003	56554706
4089	IP Subnet Mask	0 to 4294967295	---	1	F003	4294966272
408B	Gateway IP Address	0 to 4294967295	---	1	F003	56554497
408D	Network Address NSAP	---	---	---	F074	0
4097	Default GOOSE Update Time	1 to 60	s	1	F001	60
4098	Ethernet Primary Fibre Channel Link Monitor	0 to 1	---	1	F102	0 (Disabled)
4099	Ethernet Secondary Fibre Channel Link Monitor	0 to 1	---	1	F102	0 (Disabled)
409A	DNP Port	0 to 4	---	1	F177	0 (NONE)
409B	DNP Address	0 to 65519	---	1	F001	255
409C	DNP Client Addresses (2 items)	0 to 4294967295	---	1	F003	0
40A0	TCP Port Number for the Modbus protocol	1 to 65535	---	1	F001	502
40A1	TCP/UDP Port Number for the DNP Protocol	1 to 65535	---	1	F001	20000
40A2	TCP Port Number for the UCA/MMS Protocol	1 to 65535	---	1	F001	102
40A3	TCP Port No. for the HTTP (Web Server) Protocol	1 to 65535	---	1	F001	80
40A4	Main UDP Port Number for the TFTP Protocol	1 to 65535	---	1	F001	69
40A5	Data Transfer UDP Port Numbers for the TFTP Protocol (zero means "automatic") (2 items)	0 to 65535	---	1	F001	0
40A7	DNP Unsolicited Responses Function	0 to 1	---	1	F102	0 (Disabled)
40A8	DNP Unsolicited Responses Timeout	0 to 60	s	1	F001	5
40A9	DNP Unsolicited Responses Max Retries	1 to 255	---	1	F001	10
40AA	DNP Unsolicited Responses Destination Address	0 to 65519	---	1	F001	1
40AB	Ethernet Operation Mode	0 to 1	---	1	F192	0 (Half-Duplex)
40AC	DNP User Map Function	0 to 1	---	1	F102	0 (Disabled)
40AD	DNP Number of Sources used in Analog points list	1 to 6	---	1	F001	1
40AE	DNP Current Scale Factor	0 to 5	---	1	F194	2 (1)
40AF	DNP Voltage Scale Factor	0 to 5	---	1	F194	2 (1)
40B0	DNP Power Scale Factor	0 to 5	---	1	F194	2 (1)
40B1	DNP Energy Scale Factor	0 to 5	---	1	F194	2 (1)
40B2	DNP Other Scale Factor	0 to 5	---	1	F194	2 (1)
40B3	DNP Current Default Deadband	0 to 65535	---	1	F001	30000
40B4	DNP Voltage Default Deadband	0 to 65535	---	1	F001	30000
40B5	DNP Power Default Deadband	0 to 65535	---	1	F001	30000
40B6	DNP Energy Default Deadband	0 to 65535	---	1	F001	30000
40B7	DNP Other Default Deadband	0 to 65535	---	1	F001	30000
40B8	DNP IIN Time Sync Bit Period	1 to 10080	min	1	F001	1440
40B9	DNP Message Fragment Size	30 to 2048	---	1	F001	240
40BA	DNP Client Address 3	0 to 4294967295	---	1	F003	0
40BC	DNP Client Address 4	0 to 4294967295	---	1	F003	0
40BE	DNP Client Address 5	0 to 4294967295	---	1	F003	0
40C0	DNP Communications Reserved (8 items)	0 to 1	---	1	F001	0
40C8	UCA Logical Device Name	---	---	---	F203	"UCADevice"
40D0	UCA Communications Reserved (16 items)	0 to 1	---	1	F001	0
40E0	TCP Port Number for the IEC 60870-5-104 Protocol	1 to 65535	---	1	F001	2404
40E1	IEC 60870-5-104 Protocol Function	0 to 1	---	1	F102	0 (Disabled)
40E2	IEC 60870-5-104 Protocol Common Addr of ASDU	0 to 65535	---	1	F001	0
40E3	IEC 60870-5-104 Protocol Cyclic Data Tx Period	1 to 65535	s	1	F001	60
40E4	IEC No. of Sources used in M_ME_NC_1 point list	1 to 6	---	1	F001	1
40E5	IEC Current Default Threshold	0 to 65535	---	1	F001	30000

Table B–9: MODBUS MEMORY MAP (Sheet 11 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
40E6	IEC Voltage Default Threshold	0 to 65535	---	1	F001	30000
40E7	IEC Power Default Threshold	0 to 65535	---	1	F001	30000
40E8	IEC Energy Default Threshold	0 to 65535	---	1	F001	30000
40E9	IEC Other Default Threshold	0 to 65535	---	1	F001	30000
40EA	IEC Communications Reserved (22 items)	0 to 1	---	1	F001	0
4100	DNP Binary Input Block of 16 Points (58 items)	0 to 58	---	1	F197	0 (Not Used)
Data Logger Commands (Read/Write Command)						
4170	Clear Data Logger	0 to 1	---	1	F126	0 (No)
Data Logger (Read/Write Setting)						
4180	Data Logger Rate	0 to 7	---	1	F178	1 (1 min)
4181	Data Logger Channel Settings (16 items)	---	---	---	F600	0
Clock (Read/Write Command)						
41A0	RTC Set Time	0 to 235959	---	1	F003	0
Clock (Read/Write Setting)						
41A2	SR Date Format	0 to 4294967295	---	1	F051	0
41A4	SR Time Format	0 to 4294967295	---	1	F052	0
41A6	IRIG-B Signal Type	0 to 2	---	1	F114	0 (None)
Fault Report Settings and Commands (Read/Write Setting)						
41B0	Fault Report Source	0 to 5	---	1	F167	0 (SRC 1)
41B1	Fault Report Trigger	0 to 65535	---	1	F300	0
Fault Report Settings and Commands (Read/Write Command)						
41B2	Fault Reports Clear Data Command	0 to 1	---	1	F126	0 (No)
Oscillography (Read/Write Setting)						
41C0	Oscillography Number of Records	1 to 64	---	1	F001	15
41C1	Oscillography Trigger Mode	0 to 1	---	1	F118	0 (Auto Overwrite)
41C2	Oscillography Trigger Position	0 to 100	%	1	F001	50
41C3	Oscillography Trigger Source	0 to 65535	---	1	F300	0
41C4	Oscillography AC Input Waveforms	0 to 4	---	1	F183	2 (16 samples/cycle)
41D0	Oscillography Analog Channel X (16 items)	0 to 65535	---	1	F600	0
4200	Oscillography Digital Channel X (63 items)	0 to 65535	---	1	F300	0
Trip and Alarm LEDs (Read/Write Setting)						
4260	Trip LED Input FlexLogic Operand	0 to 65535	---	1	F300	0
4261	Alarm LED Input FlexLogic Operand	0 to 65535	---	1	F300	0
User Programmable LEDs (Read/Write Setting) (48 modules)						
4280	FlexLogic Operand to Activate LED	0 to 65535	---	1	F300	0
4281	User LED type (latched or self-resetting)	0 to 1	---	1	F127	1 (Self-Reset)
4282	...Repeated for module number 2					
4284	...Repeated for module number 3					
4286	...Repeated for module number 4					
4288	...Repeated for module number 5					
428A	...Repeated for module number 6					
428C	...Repeated for module number 7					
428E	...Repeated for module number 8					
4290	...Repeated for module number 9					
4292	...Repeated for module number 10					
4294	...Repeated for module number 11					
4296	...Repeated for module number 12					
4298	...Repeated for module number 13					
429A	...Repeated for module number 14					
429C	...Repeated for module number 15					
429E	...Repeated for module number 16					
42A0	...Repeated for module number 17					
42A2	...Repeated for module number 18					
42A4	...Repeated for module number 19					

Table B–9: MODBUS MEMORY MAP (Sheet 12 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
42A6	...Repeated for module number 20					
42A8	...Repeated for module number 21					
42AA	...Repeated for module number 22					
42AC	...Repeated for module number 23					
42AE	...Repeated for module number 24					
42B0	...Repeated for module number 25					
42B2	...Repeated for module number 26					
42B4	...Repeated for module number 27					
42B6	...Repeated for module number 28					
42B8	...Repeated for module number 29					
42BA	...Repeated for module number 30					
42BC	...Repeated for module number 31					
42BE	...Repeated for module number 32					
42C0	...Repeated for module number 33					
42C2	...Repeated for module number 34					
42C4	...Repeated for module number 35					
42C6	...Repeated for module number 36					
42C8	...Repeated for module number 37					
42CA	...Repeated for module number 38					
42CC	...Repeated for module number 39					
42CE	...Repeated for module number 40					
42D0	...Repeated for module number 41					
42D2	...Repeated for module number 42					
42D4	...Repeated for module number 43					
42D6	...Repeated for module number 44					
42D8	...Repeated for module number 45					
42DA	...Repeated for module number 46					
42DC	...Repeated for module number 47					
42DE	...Repeated for module number 48					
Installation (Read/Write Setting)						
43E0	Relay Programmed State	0 to 1	---	1	F133	0 (Not Programmed)
43E1	Relay Name	---	---	---	F202	"Relay-1"
CT Settings (Read/Write Setting) (6 modules)						
4480	Phase CT Primary	1 to 65000	A	1	F001	1
4481	Phase CT Secondary	0 to 1	---	1	F123	0 (1 A)
4482	Ground CT Primary	1 to 65000	A	1	F001	1
4483	Ground CT Secondary	0 to 1	---	1	F123	0 (1 A)
4484	...Repeated for module number 2					
4488	...Repeated for module number 3					
448C	...Repeated for module number 4					
4490	...Repeated for module number 5					
4494	...Repeated for module number 6					
VT Settings (Read/Write Setting) (3 modules)						
4500	Phase VT Connection	0 to 1	---	1	F100	0 (Wye)
4501	Phase VT Secondary	50 to 240	V	0.1	F001	664
4502	Phase VT Ratio	1 to 24000	:1	1	F060	1
4504	Auxiliary VT Connection	0 to 6	---	1	F166	1 (Vag)
4505	Auxiliary VT Secondary	50 to 240	V	0.1	F001	664
4506	Auxiliary VT Ratio	1 to 24000	:1	1	F060	1
4508	...Repeated for module number 2					
4510	...Repeated for module number 3					
Source Settings (Read/Write Setting) (6 modules)						
4580	Source Name	---	---	---	F206	"SRC 1 "
4583	Source Phase CT	0 to 63	---	1	F400	0

Table B–9: MODBUS MEMORY MAP (Sheet 13 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
4584	Source Ground CT	0 to 63	---	1	F400	0
4585	Source Phase VT	0 to 63	---	1	F400	0
4586	Source Auxiliary VT	0 to 63	---	1	F400	0
4587	...Repeated for module number 2					
458E	...Repeated for module number 3					
4595	...Repeated for module number 4					
459C	...Repeated for module number 5					
45A3	...Repeated for module number 6					
Power System (Read/Write Setting)						
4600	Nominal Frequency	25 to 60	Hz	1	F001	60
4601	Phase Rotation	0 to 1	---	1	F106	0 (ABC)
4602	Frequency And Phase Reference	0 to 5	---	1	F167	0 (SRC 1)
4603	Frequency Tracking	0 to 1	---	1	F102	1 (Enabled)
L90 Power System (Read/Write Setting)						
4610	L90 Number of Terminals	2 to 3	---	1	F001	2
4611	L90 Number of Channels	1 to 2	---	1	F001	1
4612	Charging Current Compensation	0 to 1	---	1	F102	0 (Disabled)
4613	Positive Sequence Reactance	0.1 to 65.535	kÞ	0.001	F001	100
4614	Zero Sequence Reactance	0.1 to 65.535	kÞ	0.001	F001	100
4615	Zero Sequence Current Removal	0 to 1	---	1	F102	0 (Disabled)
4616	Local Relay ID	0 to 255	---	1	F001	0
4617	Terminal 1 ID	0 to 255	---	1	F001	0
4618	Terminal 2 ID	0 to 255	---	1	F001	0
Line (Read/Write Setting)						
46D0	Line Pos Seq Impedance	0.01 to 250	Þ	0.01	F001	300
46D1	Line Pos Seq Impedance Angle	25 to 90	°	1	F001	75
46D2	Line Zero Seq Impedance	0.01 to 650	Þ	0.01	F001	900
46D3	Line Zero Seq Impedance Angle	25 to 90	°	1	F001	75
46D4	Line Length Units	0 to 1	---	1	F147	0 (km)
46D5	Line Length	0 to 2000	---	0.1	F001	1000
Breaker Control Global Settings (Read/Write Setting)						
46F0	UCA XCBR x SelTimOut	1 to 60	s	1	F001	30
Breaker Control (Read/Write Setting) (2 modules)						
4700	Breaker x Function	0 to 1	---	1	F102	0 (Disabled)
4701	Breaker x Name	---	---	---	F206	"Bkr 1 "
4704	Breaker x Mode	0 to 1	---	1	F157	0 (3-Pole)
4705	Breaker x Open	0 to 65535	---	1	F300	0
4706	Breaker x Close	0 to 65535	---	1	F300	0
4707	Breaker x Phase A 3 Pole	0 to 65535	---	1	F300	0
4708	Breaker x Phase B	0 to 65535	---	1	F300	0
4709	Breaker x Phase C	0 to 65535	---	1	F300	0
470A	Breaker x External Alarm	0 to 65535	---	1	F300	0
470B	Breaker x Alarm Delay	0 to 1000000	s	0.001	F003	0
470D	Breaker x Push Button Control	0 to 1	---	1	F102	0 (Disabled)
470E	Breaker x Manual Close Recal Time	0 to 1000000	s	0.001	F003	0
4710	Breaker x UCA XCBR x SBOClass	1 to 2	---	1	F001	1
4711	Breaker x UCA XCBR x SBOEna	0 to 1	---	1	F102	0 (Disabled)
4712	Breaker x Out Of Service	0 to 65535	---	1	F300	0
4713	Reserved (5 items)	0 to 65535		1	F001	0
4718	...Repeated for module number 2					
Synchrocheck (Read/Write Setting) (2 modules)						
4780	Synchrocheck Function	0 to 1	---	1	F102	0 (Disabled)
4781	Synchrocheck V1 Source	0 to 5	---	1	F167	0 (SRC 1)
4782	Synchrocheck V2 Source	0 to 5	---	1	F167	1 (SRC 2)

Table B–9: MODBUS MEMORY MAP (Sheet 14 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
4783	Synchrocheck Max Volt Diff	0 to 100000	V	1	F060	10000
4785	Synchrocheck Max Angle Diff	0 to 100	°	1	F001	30
4786	Synchrocheck Max Freq Diff	0 to 2	Hz	0.01	F001	100
4787	Synchrocheck Dead Source Select	0 to 5	---	1	F176	1 (LV1 and DV2)
4788	Synchrocheck Dead V1 Max Volt	0 to 1.25	pu	0.01	F001	30
4789	Synchrocheck Dead V2 Max Volt	0 to 1.25	pu	0.01	F001	30
478A	Synchrocheck Live V1 Min Volt	0 to 1.25	pu	0.01	F001	70
478B	Synchrocheck Live V2 Min Volt	0 to 1.25	pu	0.01	F001	70
478C	Synchrocheck Target	0 to 2	---	1	F109	0 (Self-reset)
478D	Synchrocheck Events	0 to 1	---	1	F102	0 (Disabled)
478E	Synchrocheck Block	0 to 65535	---	1	F300	0
478F	Synchrocheck X Reserved	0 to 65535	---	1	F001	0
4790	...Repeated for module number 2					
Demand (Read/Write Setting)						
47D0	Demand Current Method	0 to 2	---	1	F139	0 (Thrm Exponential)
47D1	Demand Power Method	0 to 2	---	1	F139	0 (Thrm Exponential)
47D2	Demand Interval	0 to 5	---	1	F132	2 (15 MIN)
47D3	Demand Input	0 to 65535	---	1	F300	0
Demand (Read/Write Command)						
47D4	Demand Clear Record	0 to 1	---	1	F126	0 (No)
Flexcurve A (Read/Write Setting)						
4800	FlexCurve A (120 items)	0 to 65535	ms	1	F011	0
Flexcurve B (Read/Write Setting)						
48F0	FlexCurve B (120 items)	0 to 65535	ms	1	F011	0
Modbus User Map (Read/Write Setting)						
4A00	Modbus Address Settings for User Map (256 items)	0 to 65535	---	1	F001	0
User Displays Settings (Read/Write Setting) (8 modules)						
4C00	User display top line text	---	---	---	F202	" "
4C0A	User display bottom line text	---	---	---	F202	" "
4C14	Modbus addresses of displayed items (5 items)	0 to 65535	---	1	F001	0
4C19	Reserved (7 items)	---	---	---	F001	0
4C20	...Repeated for module number 2					
4C40	...Repeated for module number 3					
4C60	...Repeated for module number 4					
4C80	...Repeated for module number 5					
4CA0	...Repeated for module number 6					
4CC0	...Repeated for module number 7					
4CE0	...Repeated for module number 8					
FlexLogic™ (Read/Write Setting)						
5000	FlexLogic Entry (512 items)	0 to 65535	---	1	F300	16384
FlexLogic™ Timers (Read/Write Setting) (32 modules)						
5800	Timer x Type	0 to 2	---	1	F129	0 (millisecond)
5801	Timer x Pickup Delay	0 to 60000	---	1	F001	0
5802	Timer x Dropout Delay	0 to 60000	---	1	F001	0
5803	Timer x Reserved (5 items)	0 to 65535	---	1	F001	0
5808	...Repeated for module number 2					
5810	...Repeated for module number 3					
5818	...Repeated for module number 4					
5820	...Repeated for module number 5					
5828	...Repeated for module number 6					
5830	...Repeated for module number 7					
5838	...Repeated for module number 8					
5840	...Repeated for module number 9					
5848	...Repeated for module number 10					

Table B–9: MODBUS MEMORY MAP (Sheet 15 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
5850	...Repeated for module number 11					
5858	...Repeated for module number 12					
5860	...Repeated for module number 13					
5868	...Repeated for module number 14					
5870	...Repeated for module number 15					
5878	...Repeated for module number 16					
5880	...Repeated for module number 17					
5888	...Repeated for module number 18					
5890	...Repeated for module number 19					
5898	...Repeated for module number 20					
58A0	...Repeated for module number 21					
58A8	...Repeated for module number 22					
58B0	...Repeated for module number 23					
58B8	...Repeated for module number 24					
58C0	...Repeated for module number 25					
58C8	...Repeated for module number 26					
58D0	...Repeated for module number 27					
58D8	...Repeated for module number 28					
58E0	...Repeated for module number 29					
58E8	...Repeated for module number 30					
58F0	...Repeated for module number 31					
58F8	...Repeated for module number 32					
Phase TOC (Read/Write Grouped Setting) (6 modules)						
5900	Phase TOC Function	0 to 1	---	1	F102	0 (Disabled)
5901	Phase TOC Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5902	Phase TOC Input	0 to 1	---	1	F122	0 (Phasor)
5903	Phase TOC Pickup	0 to 30	pu	0.001	F001	1000
5904	Phase TOC Curve	0 to 14	---	1	F103	0 (IEEE Mod Inv)
5905	Phase TOC Multiplier	0 to 600	---	0.01	F001	100
5906	Phase TOC Reset	0 to 1	---	1	F104	0 (Instantaneous)
5907	Phase TOC Voltage Restraint	0 to 1	---	1	F102	0 (Disabled)
5908	Phase TOC Block For Each Phase (3 items)	0 to 65535	---	1	F300	0
590B	Phase TOC Target	0 to 2	---	1	F109	0 (Self-reset)
590C	Phase TOC Events	0 to 1	---	1	F102	0 (Disabled)
590D	Reserved (3 items)	0 to 1	---	1	F001	0
5910	...Repeated for module number 2					
5920	...Repeated for module number 3					
5930	...Repeated for module number 4					
5940	...Repeated for module number 5					
5950	...Repeated for module number 6					
Phase IOC (Read/Write Grouped Setting) (12 modules)						
5A00	Phase IOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5A01	Phase IOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5A02	Phase IOC1 Pickup	0 to 30	pu	0.001	F001	1000
5A03	Phase IOC1 Delay	0 to 600	s	0.01	F001	0
5A04	Phase IOC1 Reset Delay	0 to 600	s	0.01	F001	0
5A05	Phase IOC1 Block For Each Phase (3 items)	0 to 65535	---	1	F300	0
5A08	Phase IOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5A09	Phase IOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5A0A	Reserved (6 items)	0 to 1	---	1	F001	0
5A10	...Repeated for module number 2					
5A20	...Repeated for module number 3					
5A30	...Repeated for module number 4					
5A40	...Repeated for module number 5					

Table B–9: MODBUS MEMORY MAP (Sheet 16 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
5A50	...Repeated for module number 6					
5A60	...Repeated for module number 7					
5A70	...Repeated for module number 8					
5A80	...Repeated for module number 9					
5A90	...Repeated for module number 10					
5AA0	...Repeated for module number 11					
5AB0	...Repeated for module number 12					
Neutral TOC (Read/Write Grouped Setting) (6 modules)						
5B00	Neutral TOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5B01	Neutral TOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5B02	Neutral TOC1 Input	0 to 1	---	1	F122	0 (Phasor)
5B03	Neutral TOC1 Pickup	0 to 30	pu	0.001	F001	1000
5B04	Neutral TOC1 Curve	0 to 14	---	1	F103	0 (IEEE Mod Inv)
5B05	Neutral TOC1 Multiplier	0 to 600	---	0.01	F001	100
5B06	Neutral TOC1 Reset	0 to 1	---	1	F104	0 (Instantaneous)
5B07	Neutral TOC1 Block	0 to 65535	---	1	F300	0
5B08	Neutral TOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5B09	Neutral TOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5B0A	Reserved (6 items)	0 to 1	---	1	F001	0
5B10	...Repeated for module number 2					
5B20	...Repeated for module number 3					
5B30	...Repeated for module number 4					
5B40	...Repeated for module number 5					
5B50	...Repeated for module number 6					
Neutral IOC (Read/Write Grouped Setting) (12 modules)						
5C00	Neutral IOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5C01	Neutral IOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5C02	Neutral IOC1 Pickup	0 to 30	pu	0.001	F001	1000
5C03	Neutral IOC1 Delay	0 to 600	s	0.01	F001	0
5C04	Neutral IOC1 Reset Delay	0 to 600	s	0.01	F001	0
5C05	Neutral IOC1 Block	0 to 65535	---	1	F300	0
5C06	Neutral IOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5C07	Neutral IOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5C08	Reserved (8 items)	0 to 1	---	1	F001	0
5C10	...Repeated for module number 2					
5C20	...Repeated for module number 3					
5C30	...Repeated for module number 4					
5C40	...Repeated for module number 5					
5C50	...Repeated for module number 6					
5C60	...Repeated for module number 7					
5C70	...Repeated for module number 8					
5C80	...Repeated for module number 9					
5C90	...Repeated for module number 10					
5CA0	...Repeated for module number 11					
5CB0	...Repeated for module number 12					
Ground TOC (Read/Write Grouped Setting) (6 modules)						
5D00	Ground TOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5D01	Ground TOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5D02	Ground TOC1 Input	0 to 1	---	1	F122	0 (Phasor)
5D03	Ground TOC1 Pickup	0 to 30	pu	0.001	F001	1000
5D04	Ground TOC1 Curve	0 to 14	---	1	F103	0 (IEEE Mod Inv)
5D05	Ground TOC1 Multiplier	0 to 600	---	0.01	F001	100
5D06	Ground TOC1 Reset	0 to 1	---	1	F104	0 (Instantaneous)
5D07	Ground TOC1 Block	0 to 65535	---	1	F300	0

Table B–9: MODBUS MEMORY MAP (Sheet 17 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
5D08	Ground TOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5D09	Ground TOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5D0A	Reserved (6 items)	0 to 1	---	1	F001	0
5D10	...Repeated for module number 2					
5D20	...Repeated for module number 3					
5D30	...Repeated for module number 4					
5D40	...Repeated for module number 5					
5D50	...Repeated for module number 6					
Ground IOC (Read/Write Grouped Setting) (12 modules)						
5E00	Ground IOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5E01	Ground IOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5E02	Ground IOC1 Pickup	0 to 30	pu	0.001	F001	1000
5E03	Ground IOC1 Delay	0 to 600	s	0.01	F001	0
5E04	Ground IOC1 Reset Delay	0 to 600	s	0.01	F001	0
5E05	Ground IOC1 Block	0 to 65535	---	1	F300	0
5E06	Ground IOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5E07	Ground IOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5E08	Reserved (8 items)	0 to 1	---	1	F001	0
5E10	...Repeated for module number 2					
5E20	...Repeated for module number 3					
5E30	...Repeated for module number 4					
5E40	...Repeated for module number 5					
5E50	...Repeated for module number 6					
5E60	...Repeated for module number 7					
5E70	...Repeated for module number 8					
5E80	...Repeated for module number 9					
5E90	...Repeated for module number 10					
5EA0	...Repeated for module number 11					
5EB0	...Repeated for module number 12					
L90 Trip Logic (Read/Write Grouped Setting)						
5EE0	87L Trip Function	0 to 1	---	1	F102	0 (Disabled)
5EE1	87L Trip Source	0 to 5	---	1	F167	0 (SRC 1)
5EE2	87L Trip Mode	0 to 1	---	1	F157	0 (3-Pole)
5EE3	87L Trip Supervision	0 to 65535	---	1	F300	0
5EE4	87L Trip Force 3 Phase	0 to 65535	---	1	F300	0
5EE5	87L Trip Seal In	0 to 1	---	1	F102	0 (Disabled)
5EE6	87L Trip Seal In Pickup	0.2 to 0.8	pu	0.01	F001	20
5EE7	87L Trip Target	0 to 2	---	1	F109	0 (Self-reset)
5EE8	87L Trip Events	0 to 1	---	1	F102	0 (Disabled)
Stub Bus (Read/Write Grouped Setting)						
5F10	Stub Bus Function	0 to 1	---	1	F102	0 (Disabled)
5F11	Stub Bus Disconnect	0 to 65535	---	1	F300	0
5F12	Stub Bus Trigger	---	---	1	F300	0
5F13	Stub Bus Target	0 to 2	---	1	F109	0 (Self-reset)
5F14	Stub Bus Events	0 to 1	---	1	F102	0 (Disabled)
Disturbance Detector (Read/Write Grouped Setting)						
5F20	DD Function	0 to 1	---	1	F102	0 (Disabled)
5F21	DD Non Cur Supervision	0 to 65535	---	1	F300	0
5F22	DD Control Logic	0 to 65535	---	1	F300	0
5F23	DD Logic Seal In	0 to 65535	---	1	F300	0
5F24	DD Events	0 to 1	---	1	F102	0 (Disabled)
Differential 87L (Read/Write Grouped Setting)						
6000	87L Function	0 to 1	---	1	F102	0 (Disabled)
6001	87L Block	0 to 65535	---	1	F300	0

Table B–9: MODBUS MEMORY MAP (Sheet 18 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
6002	87L Signal Source	0 to 5	---	1	F167	0 (SRC 1)
6003	87L Minimum Phase Current Sensitivity	0.2 to 4	pu	0.01	F001	20
6004	87L Tap Setting	0.2 to 5	---	0.01	F001	100
6005	87L Phase Percent Restraint1	1 to 50	%	1	F001	30
6006	87L Phase Percent Restraint2	1 to 70	%	1	F001	50
6007	87L Phase Dual Slope Breakpoint	0 to 20	pu	0.1	F001	10
600C	87L Key DTT	0 to 1	---	1	F102	1 (Enabled)
600D	87L Diff Ext Key DTT	0 to 65535	---	1	F300	0
600E	87L Diff Target	0 to 2	---	1	F109	0 (Self-reset)
600F	87L Differential Event	0 to 1	---	1	F102	0 (Disabled)
6010	87L Tap2 Setting	0.2 to 5	---	0.01	F001	100
Open Pole Detect (Read/Write Grouped Setting)						
6040	Open Pole Detect Function	0 to 1	---	1	F102	0 (Disabled)
6041	Open Pole Detect Block	0 to 65535	---	1	F300	0
6042	Open Pole Detect A Aux Co	0 to 65535	---	1	F300	0
6043	Open Pole Detect B Aux Co	0 to 65535	---	1	F300	0
6044	Open Pole Detect C Aux Co	0 to 65535	---	1	F300	0
6045	Open Pole Detect Current Source	0 to 5	---	1	F167	0 (SRC 1)
6046	Open Pole Detect Current Pickup	0.05 to 20	pu	0.01	F001	20
6047	Open Pole Detect Voltage Source	0 to 5	---	1	F167	0 (SRC 1)
6048	Open Pole Detect Voltage Input	0 to 1	---	1	F102	0 (Disabled)
6049	Open Pole Detect Pickup Delay	0 to 65.535	s	0.001	F001	60
604A	Open Pole Detect Reset Delay	0 to 65.535	s	0.001	F001	100
604B	Open Pole Detect Target	0 to 2	---	1	F109	0 (Self-reset)
604C	Open Pole Detect Events	0 to 1	---	1	F102	0 (Disabled)
604D	Open Pole Detect Broken Co	0 to 1	---	1	F102	0 (Disabled)
CT Fail (Read/Write Setting)						
6120	CT Fail Function	0 to 1	---	1	F102	0 (Disabled)
6121	CT Fail Block	0 to 65535	---	1	F300	0
6122	CT Fail Current Source 1	0 to 5	---	1	F167	0 (SRC 1)
6123	CT Fail Current Pickup 1	0 to 2	pu	0.1	F001	2
6124	CT Fail Current Source 2	0 to 5	---	1	F167	1 (SRC 2)
6125	CT Fail Current Pickup 2	0 to 2	pu	0.1	F001	2
6126	CT Fail Voltage Source	0 to 5	---	1	F167	0 (SRC 1)
6127	CT Fail Voltage Pickup	0 to 2	pu	0.1	F001	2
6128	CT Fail Pickup Delay	0 to 65.535	s	0.001	F001	1000
6129	CT Fail Target	0 to 2	---	1	F109	0 (Self-reset)
612A	CT Fail Events	0 to 1	---	1	F102	0 (Disabled)
Cont Monitor (Read/Write Setting)						
6130	Cont Monitor Function	0 to 1	---	1	F102	0 (Disabled)
6131	Cont Monitor I OP	0 to 65535	---	1	F300	0
6132	Cont Monitor I Supervision	0 to 65535	---	1	F300	0
6133	Cont Monitor V OP	0 to 65535	---	1	F300	0
6134	Cont Monitor V Supervision	0 to 65535	---	1	F300	0
6135	Cont Monitor Target	0 to 2	---	1	F109	0 (Self-reset)
6136	Cont Monitor Events	0 to 1	---	1	F102	0 (Disabled)
Autoreclose (Read/Write Setting) (6 modules)						
6240	Autoreclose Function	0 to 1	---	1	F102	0 (Disabled)
6241	Autoreclose Initiate	0 to 65535	---	1	F300	0
6242	Autoreclose Block	0 to 65535	---	1	F300	0
6243	Autoreclose Max Number of Shots	1 to 4	---	1	F001	1
6244	Autoreclose Manual Close	0 to 65535	---	1	F300	0
6245	Autoreclose Manual Reset from LO	0 to 65535	---	1	F300	0
6246	Autoreclose Reset Lockout if Breaker Closed	0 to 1	---	1	F108	0 (Off)

Table B–9: MODBUS MEMORY MAP (Sheet 19 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
6247	Autoreclose Reset Lockout On Manual Close	0 to 1	---	1	F108	0 (Off)
6248	Autoreclose Breaker Closed	0 to 65535	---	1	F300	0
6249	Autoreclose Breaker Open	0 to 65535	---	1	F300	0
624A	Autoreclose Block Time Upon Manual Close	0 to 655.35	s	0.01	F001	1000
624B	Autoreclose Dead Time Shot 1	0 to 655.35	s	0.01	F001	100
624C	Autoreclose Dead Time Shot 2	0 to 655.35	s	0.01	F001	200
624D	Autoreclose Dead Time Shot 3	0 to 655.35	s	0.01	F001	300
624E	Autoreclose Dead Time Shot 4	0 to 655.35	s	0.01	F001	400
624F	Autoreclose Reset Lockout Delay	0 to 655.35	---	0.01	F001	6000
6250	Autoreclose Reset Time	0 to 655.35	s	0.01	F001	6000
6251	Autoreclose Incomplete Sequence Time	0 to 655.35	s	0.01	F001	500
6252	Autoreclose Events	0 to 1	---	1	F102	0 (Disabled)
6253	Autoreclose Reduce Max 1	0 to 65535	---	1	F300	0
6254	Autoreclose Reduce Max 2	0 to 65535	---	1	F300	0
6255	Autoreclose Reduce Max 3	0 to 65535	---	1	F300	0
6256	Autoreclose Add Delay 1	0 to 65535	---	1	F300	0
6257	Autoreclose Delay 1	0 to 655.35	s	0.01	F001	0
6258	Autoreclose Add Delay 2	0 to 65535	---	1	F300	0
6259	Autoreclose Delay 2	0 to 655.35	s	0.01	F001	0
625A	Autoreclose Reserved (4 items)	0 to 0.001	---	0.001	F001	0
625E	...Repeated for module number 2					
627C	...Repeated for module number 3					
629A	...Repeated for module number 4					
62B8	...Repeated for module number 5					
62D6	...Repeated for module number 6					
Negative Sequence TOC (Read/Write Grouped Setting) (2 modules)						
6300	Negative Sequence TOC1 Function	0 to 1	---	1	F102	0 (Disabled)
6301	Negative Sequence TOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
6302	Negative Sequence TOC1 Pickup	0 to 30	pu	0.001	F001	1000
6303	Negative Sequence TOC1 Curve	0 to 14	---	1	F103	0 (IEEE Mod Inv)
6304	Negative Sequence TOC1 Multiplier	0 to 600	---	0.01	F001	100
6305	Negative Sequence TOC1 Reset	0 to 1	---	1	F104	0 (Instantaneous)
6306	Negative Sequence TOC1 Block	0 to 65535	---	1	F300	0
6307	Negative Sequence TOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
6308	Negative Sequence TOC1 Events	0 to 1	---	1	F102	0 (Disabled)
6309	Reserved (7 items)	0 to 1	---	1	F001	0
6310	...Repeated for module number 2					
Negative Sequence IOC (Read/Write Grouped Setting) (2 modules)						
6400	Negative Sequence IOC1 Function	0 to 1	---	1	F102	0 (Disabled)
6401	Negative Sequence IOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
6402	Negative Sequence IOC1 Pickup	0 to 30	pu	0.001	F001	1000
6403	Negative Sequence IOC1 Delay	0 to 600	s	0.01	F001	0
6404	Negative Sequence IOC1 Reset Delay	0 to 600	s	0.01	F001	0
6405	Negative Sequence IOC1 Block	0 to 65535	---	1	F300	0
6406	Negative Sequence IOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
6407	Negative Sequence IOC1 Events	0 to 1	---	1	F102	0 (Disabled)
6408	Reserved (8 items)	0 to 1	---	1	F001	0
6410	...Repeated for module number 2					
Power Swing Detect (Read/Write Grouped Setting)						
65C0	Power Swing Function	0 to 1	---	1	F102	0 (Disabled)
65C1	Power Swing Source	0 to 5	---	1	F167	0 (SRC 1)
65C2	Power Swing Mode	0 to 1	---	1	F513	0 (Two Step)
65C3	Power Swing Supv	0.05 to 30	pu	0.001	F001	600
65C4	Power Swing Fwd Reach	0.1 to 500	ohms	0.01	F001	5000

Table B–9: MODBUS MEMORY MAP (Sheet 20 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
65C5	Power Swing Fwd Rca	40 to 90	°	1	F001	75
65C6	Power Swing Rev Reach	0.1 to 500	ohms	0.01	F001	5000
65C7	Power Swing Rev Rca	40 to 90	°	1	F001	75
65C8	Outer Limit Angle	40 to 140	°	1	F001	120
65C9	Middle Limit Angle	40 to 140	°	1	F001	90
65CA	Inner Limit Angle	40 to 140	°	1	F001	60
65CB	Delay 1 Pickup	0 to 65.535	s	0.001	F001	30
65CC	Delay 1 Reset	0 to 65.535	s	0.001	F001	50
65CD	Delay 2 Pickup	0 to 65.535	s	0.001	F001	17
65CE	Delay 3 Pickup	0 to 65.535	s	0.001	F001	9
65CF	Delay 4 Pickup	0 to 65.535	s	0.001	F001	17
65D0	Seal In Delay	0 to 65.535	s	0.001	F001	400
65D1	Trip Mode	0 to 1	---	1	F514	0 (Delayed)
65D2	Power Swing Block	0 to 65535	---	1	F300	0
65D3	Power Swing Target	0 to 2	---	1	F109	0 (Self-reset)
65D4	Power Swing Event	0 to 1	---	1	F102	0 (Disabled)
Load Encroachment (Read/Write Grouped Setting)						
6700	Load Encroachment Function	0 to 1	---	1	F102	0 (Disabled)
6701	Load Encroachment Source	0 to 5	---	1	F167	0 (SRC 1)
6702	Load Encroachment Min Volt	0 to 3	pu	0.001	F001	250
6703	Load Encroachment Reach	0.02 to 250	Þ	0.01	F001	100
6704	Load Encroachment Angle	5 to 50	°	1	F001	30
6705	Load Encroachment Pkp Delay	0 to 65.535	s	0.001	F001	0
6706	Load Encroachment Rst Delay	0 to 65.535	s	0.001	F001	0
6707	Load Encroachment Block	0 to 65535	---	1	F300	0
6708	Load Encroachment Target	0 to 2	---	1	F109	0 (Self-reset)
6709	Load Encroachment Events	0 to 1	---	1	F102	0 (Disabled)
670A	Load Encroachment Reserved (6 items)	0 to 65535	---	1	F001	0
Phase Undervoltage (Read/Write Grouped Setting) (2 modules)						
7000	Phase UV1 Function	0 to 1	---	1	F102	0 (Disabled)
7001	Phase UV1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
7002	Phase UV1 Pickup	0 to 3	pu	0.001	F001	1000
7003	Phase UV1 Curve	0 to 1	---	1	F111	0 (Definite Time)
7004	Phase UV1 Delay	0 to 600	s	0.01	F001	100
7005	Phase UV1 Minimum Voltage	0 to 3	pu	0.001	F001	100
7006	Phase UV1 Block	0 to 65535	---	1	F300	0
7007	Phase UV1 Target	0 to 2	---	1	F109	0 (Self-reset)
7008	Phase UV1 Events	0 to 1	---	1	F102	0 (Disabled)
7009	Phase UV Measurement Mode	0 to 1	---	1	F186	0 (Phase to Ground)
700A	Reserved (6 items)	0 to 1	---	1	F001	0
7010	...Repeated for module number 2					
Phase Overvoltage (Read/Write Grouped Setting)						
7100	Phase OV1 Function	0 to 1	---	1	F102	0 (Disabled)
7101	Phase OV1 Source	0 to 5	---	1	F167	0 (SRC 1)
7102	Phase OV1 Pickup	0 to 3	pu	0.001	F001	1000
7103	Phase OV1 Delay	0 to 600	s	0.01	F001	100
7104	Phase OV1 Reset Delay	0 to 600	s	0.01	F001	100
7105	Phase OV1 Block	0 to 65535	---	1	F300	0
7106	Phase OV1 Target	0 to 2	---	1	F109	0 (Self-reset)
7107	Phase OV1 Events	0 to 1	---	1	F102	0 (Disabled)
7108	Reserved (8 items)	0 to 1	---	1	F001	0
Distance (Read/Write Grouped Setting)						
7120	Distance Signal Source	0 to 5	---	1	F167	0 (SRC 1)
7121	Memory Duration	5 to 25	cycles	1	F001	10

Table B–9: MODBUS MEMORY MAP (Sheet 21 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
Line Pickup (Read/Write Grouped Setting)						
71F0	Line Pickup Function	0 to 1	---	1	F102	0 (Disabled)
71F1	Line Pickup Signal Source	0 to 5	---	1	F167	0 (SRC 1)
71F2	Line Pickup Phase IOC Pickup	0 to 30	pu	0.001	F001	1000
71F3	Line Pickup Pos Seq UV Pickup	0 to 3	pu	0.001	F001	700
71F4	Line End Open Pickup Delay	0 to 65.535	s	0.001	F001	150
71F5	Line End Open Reset Delay	0 to 65.535	s	0.001	F001	90
71F6	Line Pickup Pos Seq OV Pickup Delay	0 to 65.535	s	0.001	F001	40
71F7	Autoreclose Coordination Pickup Delay	0 to 65.535	s	0.001	F001	45
71F8	Autoreclose Coordination Reset Delay	0 to 65.535	s	0.001	F001	5
71F9	Autoreclose Coordination Bypass	0 to 1	---	1	F102	1 (Enabled)
71FA	Line Pickup Block	0 to 65535	---	1	F300	0
71FB	Line Pickup Target	0 to 2	---	1	F109	0 (Self-reset)
71FC	Line Pickup Events	0 to 1	---	1	F102	0 (Disabled)
Breaker Failure (Read/Write Grouped Setting) (2 modules)						
7200	Breaker Failure x Function	0 to 1	---	1	F102	0 (Disabled)
7201	Breaker Failure x Mode	0 to 1	---	1	F157	0 (3-Pole)
7208	Breaker Failure x Source	0 to 5	---	1	F167	0 (SRC 1)
7209	Breaker Failure x Amp Supervision	0 to 1	---	1	F126	1 (Yes)
720A	Breaker Failure x Use Seal-In	0 to 1	---	1	F126	1 (Yes)
720B	Breaker Failure x Three Pole Initiate	0 to 65535	---	1	F300	0
720C	Breaker Failure x Block	0 to 65535	---	1	F300	0
720D	Breaker Failure x Phase Amp Supv Pickup	0.001 to 30	pu	0.001	F001	1050
720E	Breaker Failure x Neutral Amp Supv Pickup	0.001 to 30	pu	0.001	F001	1050
720F	Breaker Failure x Use Timer 1	0 to 1	---	1	F126	1 (Yes)
7210	Breaker Failure x Timer 1 Pickup	0 to 65.535	s	0.001	F001	0
7211	Breaker Failure x Use Timer 2	0 to 1	---	1	F126	1 (Yes)
7212	Breaker Failure x Timer 2 Pickup	0 to 65.535	s	0.001	F001	0
7213	Breaker Failure x Use Timer 3	0 to 1	---	1	F126	1 (Yes)
7214	Breaker Failure x Timer 3 Pickup	0 to 65.535	s	0.001	F001	0
7215	Breaker Failure x Breaker Status 1 Phase A/3P	0 to 65535	---	1	F300	0
7216	Breaker Failure x Breaker Status 2 Phase A/3P	0 to 65535	---	1	F300	0
7217	Breaker Failure x Breaker Test On	0 to 65535	---	1	F300	0
7218	Breaker Failure x Phase Amp Hiset Pickup	0.001 to 30	pu	0.001	F001	1050
7219	Breaker Failure x Neutral Amp Hiset Pickup	0.001 to 30	pu	0.001	F001	1050
721A	Breaker Failure x Phase Amp Loset Pickup	0.001 to 30	pu	0.001	F001	1050
721B	Breaker Failure x Neutral Amp Loset Pickup	0.001 to 30	pu	0.001	F001	1050
721C	Breaker Failure x Loset Time	0 to 65.535	s	0.001	F001	0
721D	Breaker Failure x Trip Dropout Delay	0 to 65.535	s	0.001	F001	0
721E	Breaker Failure x Target	0 to 2	---	1	F109	0 (Self-reset)
721F	Breaker Failure x Events	0 to 1	---	1	F102	0 (Disabled)
7220	Breaker Failure x Phase A Initiate	0 to 65535	---	1	F300	0
7221	Breaker Failure x Phase B Initiate	0 to 65535	---	1	F300	0
7222	Breaker Failure x Phase C Initiate	0 to 65535	---	1	F300	0
7223	Breaker Failure x Breaker Status 1 Phase B	0 to 65535	---	1	F300	0
7224	Breaker Failure x Breaker Status 1 Phase C	0 to 65535	---	1	F300	0
7225	Breaker Failure x Breaker Status 2 Phase B	0 to 65535	---	1	F300	0
7226	Breaker Failure x Breaker Status 2 Phase C	0 to 65535	---	1	F300	0
7227	...Repeated for module number 2					
Phase Directional (Read/Write Grouped Setting) (2 modules)						
7260	Phase DIR 1 Function	0 to 1	---	1	F102	0 (Disabled)
7261	Phase DIR 1 Source	0 to 5	---	1	F167	0 (SRC 1)
7262	Phase DIR 1 Block	0 to 65535	---	1	F300	0
7263	Phase DIR 1 ECA	0 to 359	---	1	F001	30

Table B–9: MODBUS MEMORY MAP (Sheet 22 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
7264	Phase DIR 1 Pol V Threshold	0 to 3	pu	0.001	F001	50
7265	Phase DIR 1 Block OC	0 to 1	---	1	F126	0 (No)
7266	Phase DIR 1 Target	0 to 2	---	1	F109	0 (Self-reset)
7267	Phase DIR 1 Events	0 to 1	---	1	F102	0 (Disabled)
7268	Reserved (8 items)	0 to 1	---	1	F001	0
7270	...Repeated for module number 2					
Neutral Directional OC (Read/Write Grouped Setting) (2 modules)						
7280	Neutral DIR OC1 Function	0 to 1	---	1	F102	0 (Disabled)
7281	Neutral DIR OC1 Source	0 to 5	---	1	F167	0 (SRC 1)
7282	Neutral DIR OC1 Polarizing	0 to 2	---	1	F230	0 (Voltage)
7283	Neutral DIR OC1 Forward ECA	-90 to 90	° Lag	1	F002	75
7284	Neutral DIR OC1 Forward Limit Angle	40 to 90	°	1	F001	90
7285	Neutral DIR OC1 Forward Pickup	0.002 to 30	pu	0.001	F001	50
7286	Neutral DIR OC1 Reverse Limit Angle	40 to 90	°	1	F001	90
7287	Neutral DIR OC1 Reverse Pickup	0.002 to 30	pu	0.001	F001	50
7288	Neutral DIR OC1 Target	0 to 2	---	1	F109	0 (Self-reset)
7289	Neutral DIR OC1 Block	0 to 65535	---	1	F300	0
728A	Neutral DIR OC1 Events	0 to 1	---	1	F102	0 (Disabled)
728B	Neutral DIR OC X Polarizing Voltage	0 to 1	---	1	F231	0 (Calculated V0)
728C	Neutral DIR OC X Op Current	0 to 1	---	1	F196	0 (Calculated 3I0)
728D	Neutral DIR OC X Offset	0 to 250	Þ	0.01	F001	0
728E	Reserved (2 items)	0 to 1	---	1	F001	0
7290	...Repeated for module number 2					
Breaker Arcing Current Settings (Read/Write Setting) (2 modules)						
72C0	Breaker x Arcing Amp Function	0 to 1	---	1	F102	0 (Disabled)
72C1	Breaker x Arcing Amp Source	0 to 5	---	1	F167	0 (SRC 1)
72C2	Breaker x Arcing Amp Init	0 to 65535	---	1	F300	0
72C3	Breaker x Arcing Amp Delay	0 to 65.535	s	0.001	F001	0
72C4	Breaker x Arcing Amp Limit	0 to 50000	kA2-cyc	1	F001	1000
72C5	Breaker x Arcing Amp Block	0 to 65535	---	1	F300	0
72C6	Breaker x Arcing Amp Target	0 to 2	---	1	F109	0 (Self-reset)
72C7	Breaker x Arcing Amp Events	0 to 1	---	1	F102	0 (Disabled)
72C8	...Repeated for module number 2					
DCMA Inputs (Read/Write Setting) (24 modules)						
7300	DCMA Inputs x Function	0 to 1	---	1	F102	0 (Disabled)
7301	DCMA Inputs x ID	---	---	---	F205	"DCMA Ip 1 "
7307	DCMA Inputs x Reserved 1 (4 items)	0 to 65535	---	1	F001	0
730B	DCMA Inputs x Units	---	---	---	F206	"mA"
730E	DCMA Inputs x Range	0 to 6	---	1	F173	6 (4 to 20 mA)
730F	DCMA Inputs x Minimum Value	-9999.999 to 9999.999	---	0.001	F004	4000
7311	DCMA Inputs x Maximum Value	-9999.999 to 9999.999	---	0.001	F004	20000
7313	DCMA Inputs x Reserved (5 items)	0 to 65535	---	1	F001	0
7318	...Repeated for module number 2					
7330	...Repeated for module number 3					
7348	...Repeated for module number 4					
7360	...Repeated for module number 5					
7378	...Repeated for module number 6					
7390	...Repeated for module number 7					
73A8	...Repeated for module number 8					
73C0	...Repeated for module number 9					
73D8	...Repeated for module number 10					
73F0	...Repeated for module number 11					
7408	...Repeated for module number 12					
7420	...Repeated for module number 13					

Table B–9: MODBUS MEMORY MAP (Sheet 23 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
7438	...Repeated for module number 14					
7450	...Repeated for module number 15					
7468	...Repeated for module number 16					
7480	...Repeated for module number 17					
7498	...Repeated for module number 18					
74B0	...Repeated for module number 19					
74C8	...Repeated for module number 20					
74E0	...Repeated for module number 21					
74F8	...Repeated for module number 22					
7510	...Repeated for module number 23					
7528	...Repeated for module number 24					
RTD Inputs (Read/Write Setting) (48 modules)						
7540	RTD Inputs x Function	0 to 1	---	1	F102	0 (Disabled)
7541	RTD Inputs x ID	---	---	---	F205	"RTD Ip 1 "
7547	RTD Inputs x Reserved 1 (4 items)	0 to 65535	---	1	F001	0
754B	RTD Inputs x Type	0 to 3	---	1	F174	0 (100 Ω Platinum)
754C	RTD Inputs x Reserved 2 (4 items)	0 to 65535	---	1	F001	0
7550	...Repeated for module number 2					
7560	...Repeated for module number 3					
7570	...Repeated for module number 4					
7580	...Repeated for module number 5					
7590	...Repeated for module number 6					
75A0	...Repeated for module number 7					
75B0	...Repeated for module number 8					
75C0	...Repeated for module number 9					
75D0	...Repeated for module number 10					
75E0	...Repeated for module number 11					
75F0	...Repeated for module number 12					
7600	...Repeated for module number 13					
7610	...Repeated for module number 14					
7620	...Repeated for module number 15					
7630	...Repeated for module number 16					
7640	...Repeated for module number 17					
7650	...Repeated for module number 18					
7660	...Repeated for module number 19					
7670	...Repeated for module number 20					
7680	...Repeated for module number 21					
7690	...Repeated for module number 22					
76A0	...Repeated for module number 23					
76B0	...Repeated for module number 24					
76C0	...Repeated for module number 25					
76D0	...Repeated for module number 26					
76E0	...Repeated for module number 27					
76F0	...Repeated for module number 28					
7700	...Repeated for module number 29					
7710	...Repeated for module number 30					
7720	...Repeated for module number 31					
7730	...Repeated for module number 32					
7740	...Repeated for module number 33					
7750	...Repeated for module number 34					
7760	...Repeated for module number 35					
7770	...Repeated for module number 36					
7780	...Repeated for module number 37					
7790	...Repeated for module number 38					

Table B–9: MODBUS MEMORY MAP (Sheet 24 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
77A0	...Repeated for module number 39					
77B0	...Repeated for module number 40					
77C0	...Repeated for module number 41					
77D0	...Repeated for module number 42					
77E0	...Repeated for module number 43					
77F0	...Repeated for module number 44					
7800	...Repeated for module number 45					
7810	...Repeated for module number 46					
7820	...Repeated for module number 47					
7830	...Repeated for module number 48					
Ohm Inputs (Read/Write Setting) (2 modules)						
7840	Ohm Inputs x Function	0 to 1	---	1	F102	0 (Disabled)
7841	Ohm Inputs x ID	---	---	---	F205	"Ohm Ip 1 "
7847	Ohm Inputs x Reserved (9 items)	0 to 65535	---	1	F001	0
7850	...Repeated for module number 2					
Backup Phase Distance (Read/Write Grouped Setting)						
7A20	Phase Distance Z2 Function	0 to 1	---	1	F102	0 (Disabled)
7A21	Phase Distance Z2 Current Supervision	0.05 to 30	pu	0.001	F001	200
7A22	Phase Distance Z2 Reach	0.02 to 250	Þ	0.01	F001	200
7A23	Phase Distance Z2 Direction	0 to 1	---	1	F154	0 (Forward)
7A24	Phase Distance Z2 Comparator Limit	30 to 90	°	1	F001	90
7A25	Phase Distance Z2 Delay	0 to 65.535	s	0.001	F001	0
7A26	Phase Distance Z2 Block	0 to 65535	---	1	F300	0
7A27	Phase Distance Z2 Target	0 to 2	---	1	F109	0 (Self-reset)
7A28	Phase Distance Z2 Events	0 to 1	---	1	F102	0 (Disabled)
7A29	Phase Distance Z2 Shape	0 to 1	---	1	F120	0 (Mho)
7A2A	Phase Distance Z2 RCA	30 to 90	°	1	F001	85
7A2B	Phase Distance Z2 DIR RCA	30 to 90	°	1	F001	85
7A2C	Phase Distance Z2 DIR Comp Limit	30 to 90	°	1	F001	90
7A2D	Phase Distance Z2 Quad Right Blinder	0.02 to 500	Þ	0.01	F001	1000
7A2E	Phase Distance Z2 Quad Right Blinder RCA	60 to 90	°	1	F001	85
7A2F	Phase Distance Z2 Quad Left Blinder	0.02 to 500	Þ	0.01	F001	1000
7A30	Phase Distance Z2 Quad Left Blinder RCA	60 to 90	°	1	F001	85
7A31	Phase Distance Z2 Volt Limit	0 to 5	pu	0.001	F001	0
Backup Ground Distance (Read/Write Grouped Setting)						
7A40	Ground Distance Z2 Function	0 to 1	---	1	F102	0 (Disabled)
7A41	Ground Distance Z2 Current Supervision	0.05 to 30	pu	0.001	F001	200
7A42	Ground Distance Z2 Reach	0.02 to 250	Þ	0.01	F001	200
7A43	Ground Distance Z2 Direction	0 to 1	---	1	F154	0 (Forward)
7A44	Ground Distance Z2 Comp Limit	30 to 90	°	1	F001	90
7A45	Ground Distance Z2 Delay	0 to 65.535	s	0.001	F001	0
7A46	Ground Distance Z2 Block	0 to 65535	---	1	F300	0
7A47	Ground Distance Z2 Target	0 to 2	---	1	F109	0 (Self-reset)
7A48	Ground Distance Z2 Events	0 to 1	---	1	F102	0 (Disabled)
7A49	Ground Distance Z2 Shape	0 to 1	---	1	F120	0 (Mho)
7A4A	Ground Distance Z2 Z0/Z1 Mag	0.5 to 7	---	0.01	F001	270
7A4B	Ground Distance Z2 Z0/Z1 Ang	-90 to 90	°	1	F002	0
7A4C	Ground Distance Z2 RCA	30 to 90	°	1	F001	85
7A4D	Ground Distance Z2 DIR RCA	30 to 90	°	1	F001	85
7A4E	Ground Distance Z2 DIR Comp Limit	30 to 90	°	1	F001	90
7A4F	Ground Distance Z2 Quad Right Blinder	0.02 to 500	Þ	0.01	F001	1000
7A50	Ground Distance Z2 Quad Right Blinder RCA	60 to 90	°	1	F001	85
7A51	Ground Distance Z2 Quad Left Blinder	0.02 to 500	Þ	0.01	F001	1000
7A52	Ground Distance Z2 Quad Left Blinder RCA	60 to 90	°	1	F001	85

Table B–9: MODBUS MEMORY MAP (Sheet 25 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
7A53	Ground Distance Z2 Z0M Z1 Mag	0 to 7	---	0.01	F001	0
7A54	Ground Distance Z2 Z0M Z1 Ang	-90 to 90	°	1	F002	0
7A55	Ground Distance Z2 Volt Level	0 to 5	pu	0.001	F001	0
Frequency (Read Only)						
8000	Tracking Frequency	2 to 90	Hz	0.01	F001	0
FlexState Settings (Read/Write Setting)						
8800	FlexState Parameters (256 items)	---	---	---	F300	0
FlexElement (Read/Write Setting) (16 modules)						
9000	FlexElement Function	0 to 1	---	1	F102	0 (Disabled)
9001	FlexElement Name	---	---	---	F206	"FxE \x040"
9004	FlexElement InputP	0 to 65535	---	1	F600	0
9005	FlexElement InputM	0 to 65535	---	1	F600	0
9006	FlexElement Compare	0 to 1	---	1	F516	0 (LEVEL)
9007	FlexElement Input	0 to 1	---	1	F515	0 (SIGNED)
9008	FlexElement Direction	0 to 1	---	1	F517	0 (OVER)
9009	FlexElement Hysteresis	0.1 to 50	%	0.1	F001	30
900A	FlexElement Pickup	-90 to 90	pu	0.001	F004	1000
900C	FlexElement DeltaT Units	0 to 2	---	1	F518	0 (Milliseconds)
900D	FlexElement DeltaT	20 to 86400	---	1	F003	20
900F	FlexElement Pkp Delay	0 to 65.535	s	0.001	F001	0
9010	FlexElement Rst Delay	0 to 65.535	s	0.001	F001	0
9011	FlexElement Block	0 to 65535	---	1	F300	0
9012	FlexElement Target	0 to 2	---	1	F109	0 (Self-reset)
9013	FlexElement Events	0 to 1	---	1	F102	0 (Disabled)
9014	...Repeated for module number 2					
9028	...Repeated for module number 3					
903C	...Repeated for module number 4					
9050	...Repeated for module number 5					
9064	...Repeated for module number 6					
9078	...Repeated for module number 7					
908C	...Repeated for module number 8					
90A0	...Repeated for module number 9					
90B4	...Repeated for module number 10					
90C8	...Repeated for module number 11					
90DC	...Repeated for module number 12					
90F0	...Repeated for module number 13					
9104	...Repeated for module number 14					
9118	...Repeated for module number 15					
912C	...Repeated for module number 16					
FlexElement Actuals (Read Only) (16 modules)						
9A01	FlexElement Actual	-2147483.647 to 2147483.647	---	0.001	F004	0
9A03	...Repeated for module number 2					
9A05	...Repeated for module number 3					
9A07	...Repeated for module number 4					
9A09	...Repeated for module number 5					
9A0B	...Repeated for module number 6					
9A0D	...Repeated for module number 7					
9A0F	...Repeated for module number 8					
9A11	...Repeated for module number 9					
9A13	...Repeated for module number 10					
9A15	...Repeated for module number 11					
9A17	...Repeated for module number 12					
9A19	...Repeated for module number 13					

Table B–9: MODBUS MEMORY MAP (Sheet 26 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
9A1B	...Repeated for module number 14					
9A1D	...Repeated for module number 15					
9A1F	...Repeated for module number 16					
Setting Groups (Read/Write Setting)						
A000	Setting Group for Modbus Comm (0 means group 1)	0 to 7	---	1	F001	0
A001	Setting Groups Block	0 to 65535	---	1	F300	0
A002	FlexLogic Operands to Activate Grps 2 to 8 (7 items)	0 to 65535	---	1	F300	0
A009	Setting Group Function	0 to 1	---	1	F102	0 (Disabled)
A00A	Setting Group Events	0 to 1	---	1	F102	0 (Disabled)
Setting Groups (Read Only)						
A00B	Current Setting Group	0 to 7	---	1	F001	0
VT Fuse Failure (Read/Write Setting) (6 modules)						
A040	VT Fuse Failure Function	0 to 1	---	1	F102	0 (Disabled)
A041	...Repeated for module number 2					
A042	...Repeated for module number 3					
A043	...Repeated for module number 4					
A044	...Repeated for module number 5					
A045	...Repeated for module number 6					
Pilot POTT (Read/Write Setting)						
A070	POTT Scheme Function	0 to 1	---	1	F102	0 (Disabled)
A071	POTT Permissive Echo	0 to 1	---	1	F102	0 (Disabled)
A072	POTT Rx Pickup Delay	0 to 65.535	s	0.001	F001	0
A073	POTT Transient Block Pickup Delay	0 to 65.535	s	0.001	F001	20
A074	POTT Transient Block Reset Delay	0 to 65.535	s	0.001	F001	90
A075	POTT Echo Duration	0 to 65.535	s	0.001	F001	100
A076	POTT Line End Open Pickup Delay	0 to 65.535	s	0.001	F001	50
A077	POTT Seal In Delay	0 to 65.535	s	0.001	F001	400
A078	POTT Ground Direction OC Forward	0 to 65535	---	1	F300	0
A079	POTT Rx	0 to 65535	---	1	F300	0
A07A	POTT Echo Lockout	0 to 65.535	s	0.001	F001	250
Digital Elements (Read/Write Setting) (16 modules)						
B000	Digital Element x Function	0 to 1	---	1	F102	0 (Disabled)
B001	Digital Element x Name	---	---	---	F203	"Dig Element 1 "
B015	Digital Element x Input	0 to 65535	---	1	F300	0
B016	Digital Element x Pickup Delay	0 to 999999.999	s	0.001	F003	0
B018	Digital Element x Reset Delay	0 to 999999.999	s	0.001	F003	0
B01A	Digital Element x Block	0 to 65535	---	1	F300	0
B01B	Digital Element x Target	0 to 2	---	1	F109	0 (Self-reset)
B01C	Digital Element x Events	0 to 1	---	1	F102	0 (Disabled)
B01D	Digital Element x Reserved (3 items)	---	---	---	F001	0
B020	...Repeated for module number 2					
B040	...Repeated for module number 3					
B060	...Repeated for module number 4					
B080	...Repeated for module number 5					
B0A0	...Repeated for module number 6					
B0C0	...Repeated for module number 7					
B0E0	...Repeated for module number 8					
B100	...Repeated for module number 9					
B120	...Repeated for module number 10					
B140	...Repeated for module number 11					
B160	...Repeated for module number 12					
B180	...Repeated for module number 13					
B1A0	...Repeated for module number 14					
B1C0	...Repeated for module number 15					

Table B–9: MODBUS MEMORY MAP (Sheet 27 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
B1E0	...Repeated for module number 16					
Digital Counter (Read/Write Setting) (8 modules)						
B300	Digital Counter x Function	0 to 1	---	1	F102	0 (Disabled)
B301	Digital Counter x Name	---	---	---	F205	"Counter 1 "
B307	Digital Counter x Units	---	---	---	F206	(none)
B30A	Digital Counter x Block	0 to 65535	---	1	F300	0
B30B	Digital Counter x Up	0 to 65535	---	1	F300	0
B30C	Digital Counter x Down	0 to 65535	---	1	F300	0
B30D	Digital Counter x Preset	-2147483647 to 2147483647	---	1	F004	0
B30F	Digital Counter x Compare	-2147483647 to 2147483647	---	1	F004	0
B311	Digital Counter x Reset	0 to 65535	---	1	F300	0
B312	Digital Counter x Freeze/Reset	0 to 65535	---	1	F300	0
B313	Digital Counter x Freeze/Count	0 to 65535	---	1	F300	0
B314	Digital Counter Set To Preset	0 to 65535	---	1	F300	0
B315	Digital Counter x Reserved (11 items)	---	---	---	F001	0
B320	...Repeated for module number 2					
B340	...Repeated for module number 3					
B360	...Repeated for module number 4					
B380	...Repeated for module number 5					
B3A0	...Repeated for module number 6					
B3C0	...Repeated for module number 7					
B3E0	...Repeated for module number 8					
Contact Inputs (Read/Write Setting) (96 modules)						
C000	Contact Input x Name	---	---	---	F205	"Cont Ip 1 "
C006	Contact Input x Events	0 to 1	---	1	F102	0 (Disabled)
C007	Contact Input x Debounce Time	0 to 16	ms	0.5	F001	20
C008	...Repeated for module number 2					
C010	...Repeated for module number 3					
C018	...Repeated for module number 4					
C020	...Repeated for module number 5					
C028	...Repeated for module number 6					
C030	...Repeated for module number 7					
C038	...Repeated for module number 8					
C040	...Repeated for module number 9					
C048	...Repeated for module number 10					
C050	...Repeated for module number 11					
C058	...Repeated for module number 12					
C060	...Repeated for module number 13					
C068	...Repeated for module number 14					
C070	...Repeated for module number 15					
C078	...Repeated for module number 16					
C080	...Repeated for module number 17					
C088	...Repeated for module number 18					
C090	...Repeated for module number 19					
C098	...Repeated for module number 20					
C0A0	...Repeated for module number 21					
C0A8	...Repeated for module number 22					
C0B0	...Repeated for module number 23					
C0B8	...Repeated for module number 24					
C0C0	...Repeated for module number 25					
C0C8	...Repeated for module number 26					
C0D0	...Repeated for module number 27					
C0D8	...Repeated for module number 28					

Table B–9: MODBUS MEMORY MAP (Sheet 28 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
C0E0	...Repeated for module number 29					
C0E8	...Repeated for module number 30					
C0F0	...Repeated for module number 31					
C0F8	...Repeated for module number 32					
C100	...Repeated for module number 33					
C108	...Repeated for module number 34					
C110	...Repeated for module number 35					
C118	...Repeated for module number 36					
C120	...Repeated for module number 37					
C128	...Repeated for module number 38					
C130	...Repeated for module number 39					
C138	...Repeated for module number 40					
C140	...Repeated for module number 41					
C148	...Repeated for module number 42					
C150	...Repeated for module number 43					
C158	...Repeated for module number 44					
C160	...Repeated for module number 45					
C168	...Repeated for module number 46					
C170	...Repeated for module number 47					
C178	...Repeated for module number 48					
C180	...Repeated for module number 49					
C188	...Repeated for module number 50					
C190	...Repeated for module number 51					
C198	...Repeated for module number 52					
C1A0	...Repeated for module number 53					
C1A8	...Repeated for module number 54					
C1B0	...Repeated for module number 55					
C1B8	...Repeated for module number 56					
C1C0	...Repeated for module number 57					
C1C8	...Repeated for module number 58					
C1D0	...Repeated for module number 59					
C1D8	...Repeated for module number 60					
C1E0	...Repeated for module number 61					
C1E8	...Repeated for module number 62					
C1F0	...Repeated for module number 63					
C1F8	...Repeated for module number 64					
C200	...Repeated for module number 65					
C208	...Repeated for module number 66					
C210	...Repeated for module number 67					
C218	...Repeated for module number 68					
C220	...Repeated for module number 69					
C228	...Repeated for module number 70					
C230	...Repeated for module number 71					
C238	...Repeated for module number 72					
C240	...Repeated for module number 73					
C248	...Repeated for module number 74					
C250	...Repeated for module number 75					
C258	...Repeated for module number 76					
C260	...Repeated for module number 77					
C268	...Repeated for module number 78					
C270	...Repeated for module number 79					
C278	...Repeated for module number 80					
C280	...Repeated for module number 81					
C288	...Repeated for module number 82					

Table B–9: MODBUS MEMORY MAP (Sheet 29 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
C290	...Repeated for module number 83					
C298	...Repeated for module number 84					
C2A0	...Repeated for module number 85					
C2A8	...Repeated for module number 86					
C2B0	...Repeated for module number 87					
C2B8	...Repeated for module number 88					
C2C0	...Repeated for module number 89					
C2C8	...Repeated for module number 90					
C2D0	...Repeated for module number 91					
C2D8	...Repeated for module number 92					
C2E0	...Repeated for module number 93					
C2E8	...Repeated for module number 94					
C2F0	...Repeated for module number 95					
C2F8	...Repeated for module number 96					
Contact Input Thresholds (Read/Write Setting)						
C600	Contact Input x Threshold (24 items)	0 to 3	---	1	F128	1 (33 Vdc)
Virtual Inputs Global Settings (Read/Write Setting)						
C680	Virtual Inputs SBO Timeout	1 to 60	s	1	F001	30
Virtual Inputs (Read/Write Setting) (32 modules)						
C690	Virtual Input x Function	0 to 1	---	1	F102	0 (Disabled)
C691	Virtual Input x Name	---	---	---	F205	"Virt Ip 1 "
C69B	Virtual Input x Programmed Type	0 to 1	---	1	F127	0 (Latched)
C69C	Virtual Input x Events	0 to 1	---	1	F102	0 (Disabled)
C69D	Virtual Input x UCA SBOClass	1 to 2	---	1	F001	1
C69E	Virtual Input x UCA SBOEna	0 to 1	---	1	F102	0 (Disabled)
C69F	Virtual Input x Reserved	---	---	---	F001	0
C6A0	...Repeated for module number 2					
C6B0	...Repeated for module number 3					
C6C0	...Repeated for module number 4					
C6D0	...Repeated for module number 5					
C6E0	...Repeated for module number 6					
C6F0	...Repeated for module number 7					
C700	...Repeated for module number 8					
C710	...Repeated for module number 9					
C720	...Repeated for module number 10					
C730	...Repeated for module number 11					
C740	...Repeated for module number 12					
C750	...Repeated for module number 13					
C760	...Repeated for module number 14					
C770	...Repeated for module number 15					
C780	...Repeated for module number 16					
C790	...Repeated for module number 17					
C7A0	...Repeated for module number 18					
C7B0	...Repeated for module number 19					
C7C0	...Repeated for module number 20					
C7D0	...Repeated for module number 21					
C7E0	...Repeated for module number 22					
C7F0	...Repeated for module number 23					
C800	...Repeated for module number 24					
C810	...Repeated for module number 25					
C820	...Repeated for module number 26					
C830	...Repeated for module number 27					
C840	...Repeated for module number 28					
C850	...Repeated for module number 29					

Table B–9: MODBUS MEMORY MAP (Sheet 30 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
C860	...Repeated for module number 30					
C870	...Repeated for module number 31					
C880	...Repeated for module number 32					
Virtual Outputs (Read/Write Setting) (64 modules)						
CC90	Virtual Output x Name	---	---	---	F205	"Virt Op 1 "
CC9A	Virtual Output x Events	0 to 1	---	1	F102	0 (Disabled)
CC9B	Virtual Output x Reserved (5 items)	---	---	---	F001	0
CCA0	...Repeated for module number 2					
CCB0	...Repeated for module number 3					
CCC0	...Repeated for module number 4					
CCD0	...Repeated for module number 5					
CCE0	...Repeated for module number 6					
CCF0	...Repeated for module number 7					
CD00	...Repeated for module number 8					
CD10	...Repeated for module number 9					
CD20	...Repeated for module number 10					
CD30	...Repeated for module number 11					
CD40	...Repeated for module number 12					
CD50	...Repeated for module number 13					
CD60	...Repeated for module number 14					
CD70	...Repeated for module number 15					
CD80	...Repeated for module number 16					
CD90	...Repeated for module number 17					
CDA0	...Repeated for module number 18					
CDB0	...Repeated for module number 19					
CDC0	...Repeated for module number 20					
CDD0	...Repeated for module number 21					
CDE0	...Repeated for module number 22					
CDF0	...Repeated for module number 23					
CE00	...Repeated for module number 24					
CE10	...Repeated for module number 25					
CE20	...Repeated for module number 26					
CE30	...Repeated for module number 27					
CE40	...Repeated for module number 28					
CE50	...Repeated for module number 29					
CE60	...Repeated for module number 30					
CE70	...Repeated for module number 31					
CE80	...Repeated for module number 32					
CE90	...Repeated for module number 33					
CEA0	...Repeated for module number 34					
CEB0	...Repeated for module number 35					
CEC0	...Repeated for module number 36					
CED0	...Repeated for module number 37					
CEE0	...Repeated for module number 38					
CEF0	...Repeated for module number 39					
CF00	...Repeated for module number 40					
CF10	...Repeated for module number 41					
CF20	...Repeated for module number 42					
CF30	...Repeated for module number 43					
CF40	...Repeated for module number 44					
CF50	...Repeated for module number 45					
CF60	...Repeated for module number 46					
CF70	...Repeated for module number 47					
CF80	...Repeated for module number 48					

Table B–9: MODBUS MEMORY MAP (Sheet 31 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
CF90	...Repeated for module number 49					
CFA0	...Repeated for module number 50					
CFB0	...Repeated for module number 51					
CFC0	...Repeated for module number 52					
CFD0	...Repeated for module number 53					
CFE0	...Repeated for module number 54					
CFF0	...Repeated for module number 55					
D000	...Repeated for module number 56					
D010	...Repeated for module number 57					
D020	...Repeated for module number 58					
D030	...Repeated for module number 59					
D040	...Repeated for module number 60					
D050	...Repeated for module number 61					
D060	...Repeated for module number 62					
D070	...Repeated for module number 63					
D080	...Repeated for module number 64					
Mandatory (Read/Write Setting)						
D280	Test Mode Function	0 to 1	---	1	F102	0 (Disabled)
Contact Outputs (Read/Write Setting) (64 modules)						
D290	Contact Output x Name	---	---	---	F205	"Cont Op 1 "
D29A	Contact Output x Operation	0 to 65535	---	1	F300	0
D29B	Contact Output x Seal-In	0 to 65535	---	1	F300	0
D29C	Reserved	---	---	1	F001	0
D29D	Contact Output x Events	0 to 1	---	1	F102	1 (Enabled)
D29E	Reserved (2 items)	---	---	---	F001	0
D2A0	...Repeated for module number 2					
D2B0	...Repeated for module number 3					
D2C0	...Repeated for module number 4					
D2D0	...Repeated for module number 5					
D2E0	...Repeated for module number 6					
D2F0	...Repeated for module number 7					
D300	...Repeated for module number 8					
D310	...Repeated for module number 9					
D320	...Repeated for module number 10					
D330	...Repeated for module number 11					
D340	...Repeated for module number 12					
D350	...Repeated for module number 13					
D360	...Repeated for module number 14					
D370	...Repeated for module number 15					
D380	...Repeated for module number 16					
D390	...Repeated for module number 17					
D3A0	...Repeated for module number 18					
D3B0	...Repeated for module number 19					
D3C0	...Repeated for module number 20					
D3D0	...Repeated for module number 21					
D3E0	...Repeated for module number 22					
D3F0	...Repeated for module number 23					
D400	...Repeated for module number 24					
D410	...Repeated for module number 25					
D420	...Repeated for module number 26					
D430	...Repeated for module number 27					
D440	...Repeated for module number 28					
D450	...Repeated for module number 29					
D460	...Repeated for module number 30					

Table B–9: MODBUS MEMORY MAP (Sheet 32 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
D470	...Repeated for module number 31					
D480	...Repeated for module number 32					
D490	...Repeated for module number 33					
D4A0	...Repeated for module number 34					
D4B0	...Repeated for module number 35					
D4C0	...Repeated for module number 36					
D4D0	...Repeated for module number 37					
D4E0	...Repeated for module number 38					
D4F0	...Repeated for module number 39					
D500	...Repeated for module number 40					
D510	...Repeated for module number 41					
D520	...Repeated for module number 42					
D530	...Repeated for module number 43					
D540	...Repeated for module number 44					
D550	...Repeated for module number 45					
D560	...Repeated for module number 46					
D570	...Repeated for module number 47					
D580	...Repeated for module number 48					
D590	...Repeated for module number 49					
D5A0	...Repeated for module number 50					
D5B0	...Repeated for module number 51					
D5C0	...Repeated for module number 52					
D5D0	...Repeated for module number 53					
D5E0	...Repeated for module number 54					
D5F0	...Repeated for module number 55					
D600	...Repeated for module number 56					
D610	...Repeated for module number 57					
D620	...Repeated for module number 58					
D630	...Repeated for module number 59					
D640	...Repeated for module number 60					
D650	...Repeated for module number 61					
D660	...Repeated for module number 62					
D670	...Repeated for module number 63					
D680	...Repeated for module number 64					
Reset (Read/Write Setting)						
D800	FlexLogic operand which initiates a reset	0 to 65535	---	1	F300	0
Force Contact Inputs (Read/Write Setting)						
D8B0	Force Contact Input x State (96 items)	0 to 2	---	1	F144	0 (Disabled)
Force Contact Outputs (Read/Write Setting)						
D910	Force Contact Output x State (64 items)	0 to 3	---	1	F131	0 (Disabled)
L90 Channel Tests (Read/Write)						
DA00	Local Loopback Function	0 to 1	---	1	F126	0 (No)
DA01	Local Loopback Channel	1 to 2	---	1	F001	1
DA03	Remote Loopback Function	0 to 1	---	1	F126	0 (No)
DA04	Remote Loopback Channel	1 to 2	---	1	F001	1
Direct I/O Settings (Read/Write Setting)						
DB00	Direct Input Default States (8 items)	0 to 1	---	1	F108	0 (Off)
DB08	Direct Input Default States (8 items)	0 to 1	---	1	F108	0 (Off)
DB10	Direct Output x 1 Operand (8 items)	0 to 65535	---	1	F300	0
DB18	Direct Output x 2 Operand (8 items)	0 to 65535	---	1	F300	0
Remote Devices (Read/Write Setting) (16 modules)						
E000	Remote Device x ID	---	---	---	F202	"Remote Device 1 "
E00A	...Repeated for module number 2					
E014	...Repeated for module number 3					

Table B–9: MODBUS MEMORY MAP (Sheet 33 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
E01E	...Repeated for module number 4					
E028	...Repeated for module number 5					
E032	...Repeated for module number 6					
E03C	...Repeated for module number 7					
E046	...Repeated for module number 8					
E050	...Repeated for module number 9					
E05A	...Repeated for module number 10					
E064	...Repeated for module number 11					
E06E	...Repeated for module number 12					
E078	...Repeated for module number 13					
E082	...Repeated for module number 14					
E08C	...Repeated for module number 15					
E096	...Repeated for module number 16					
Remote Inputs (Read/Write Setting) (32 modules)						
E100	Remote Input x Device	1 to 16	---	1	F001	1
E101	Remote Input x Bit Pair	0 to 64	---	1	F156	0 (None)
E102	Remote Input x Default State	0 to 1	---	1	F108	0 (Off)
E103	Remote Input x Events	0 to 1	---	1	F102	0 (Disabled)
E104	...Repeated for module number 2					
E108	...Repeated for module number 3					
E10C	...Repeated for module number 4					
E110	...Repeated for module number 5					
E114	...Repeated for module number 6					
E118	...Repeated for module number 7					
E11C	...Repeated for module number 8					
E120	...Repeated for module number 9					
E124	...Repeated for module number 10					
E128	...Repeated for module number 11					
E12C	...Repeated for module number 12					
E130	...Repeated for module number 13					
E134	...Repeated for module number 14					
E138	...Repeated for module number 15					
E13C	...Repeated for module number 16					
E140	...Repeated for module number 17					
E144	...Repeated for module number 18					
E148	...Repeated for module number 19					
E14C	...Repeated for module number 20					
E150	...Repeated for module number 21					
E154	...Repeated for module number 22					
E158	...Repeated for module number 23					
E15C	...Repeated for module number 24					
E160	...Repeated for module number 25					
E164	...Repeated for module number 26					
E168	...Repeated for module number 27					
E16C	...Repeated for module number 28					
E170	...Repeated for module number 29					
E174	...Repeated for module number 30					
E178	...Repeated for module number 31					
E17C	...Repeated for module number 32					
Remote Output DNA Pairs (Read/Write Setting) (32 modules)						
E600	Remote Output DNA x Operand	0 to 65535	---	1	F300	0
E601	Remote Output DNA x Events	0 to 1	---	1	F102	0 (Disabled)
E602	Remote Output DNA x Reserved (2 items)	0 to 1	---	1	F001	0
E604	...Repeated for module number 2					

Table B–9: MODBUS MEMORY MAP (Sheet 34 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
E608	...Repeated for module number 3					
E60C	...Repeated for module number 4					
E610	...Repeated for module number 5					
E614	...Repeated for module number 6					
E618	...Repeated for module number 7					
E61C	...Repeated for module number 8					
E620	...Repeated for module number 9					
E624	...Repeated for module number 10					
E628	...Repeated for module number 11					
E62C	...Repeated for module number 12					
E630	...Repeated for module number 13					
E634	...Repeated for module number 14					
E638	...Repeated for module number 15					
E63C	...Repeated for module number 16					
E640	...Repeated for module number 17					
E644	...Repeated for module number 18					
E648	...Repeated for module number 19					
E64C	...Repeated for module number 20					
E650	...Repeated for module number 21					
E654	...Repeated for module number 22					
E658	...Repeated for module number 23					
E65C	...Repeated for module number 24					
E660	...Repeated for module number 25					
E664	...Repeated for module number 26					
E668	...Repeated for module number 27					
E66C	...Repeated for module number 28					
E670	...Repeated for module number 29					
E674	...Repeated for module number 30					
E678	...Repeated for module number 31					
E67C	...Repeated for module number 32					
Remote Output UserSt Pairs (Read/Write Setting) (32 modules)						
E680	Remote Output UserSt x Operand	0 to 65535	---	1	F300	0
E681	Remote Output UserSt x Events	0 to 1	---	1	F102	0 (Disabled)
E682	Remote Output UserSt x Reserved (2 items)	0 to 1	---	1	F001	0
E684	...Repeated for module number 2					
E688	...Repeated for module number 3					
E68C	...Repeated for module number 4					
E690	...Repeated for module number 5					
E694	...Repeated for module number 6					
E698	...Repeated for module number 7					
E69C	...Repeated for module number 8					
E6A0	...Repeated for module number 9					
E6A4	...Repeated for module number 10					
E6A8	...Repeated for module number 11					
E6AC	...Repeated for module number 12					
E6B0	...Repeated for module number 13					
E6B4	...Repeated for module number 14					
E6B8	...Repeated for module number 15					
E6BC	...Repeated for module number 16					
E6C0	...Repeated for module number 17					
E6C4	...Repeated for module number 18					
E6C8	...Repeated for module number 19					
E6CC	...Repeated for module number 20					
E6D0	...Repeated for module number 21					

Table B–9: MODBUS MEMORY MAP (Sheet 35 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
E6D4	...Repeated for module number 22					
E6D8	...Repeated for module number 23					
E6DC	...Repeated for module number 24					
E6E0	...Repeated for module number 25					
E6E4	...Repeated for module number 26					
E6E8	...Repeated for module number 27					
E6EC	...Repeated for module number 28					
E6F0	...Repeated for module number 29					
E6F4	...Repeated for module number 30					
E6F8	...Repeated for module number 31					
E6FC	...Repeated for module number 32					
Factory Service Password Protection (Read/Write)						
F000	Modbus Factory Password	0 to 4294967295	---	1	F003	0
Factory Service Password Protection (Read Only)						
F002	Factory Service Password Status	0 to 1	---	1	F102	0 (Disabled)
Factory Service - Initialization (Read Only -- Written by Factory)						
F008	Load Default Settings	0 to 1	---	1	F126	0 (No)
F009	Reboot Relay	0 to 1	---	1	F126	0 (No)
Factory Service - Calibration (Read Only -- Written by Factory)						
F010	Calibration	0 to 1	---	1	F102	0 (Disabled)
F011	DSP Card to Calibrate	0 to 15	---	1	F172	0 (F)
F012	Channel to Calibrate	0 to 7	---	1	F001	0
F013	Channel Type	0 to 6	---	1	F140	0 (Disabled)
F014	Channel Name	---	---	---	F201	"0"
Factory Service - Calibration (Read Only)						
F018	A/D Counts	-32767 to 32767	---	1	F002	0
Factory Service - Calibration (Read Only -- Written by Factory)						
F019	Offset	-32767 to 32767	---	1	F002	0
F01B	Gain Stage	0 to 1	---	1	F135	0 (x1)
F01C	CT Winding	0 to 1	---	1	F123	0 (1 A)
Factory Service - Calibration (Read Only)						
F01D	Measured Input	0 to 300	---	0.0001	F060	0
Factory Service - Calibration (Read Only -- Written by Factory)						
F01F	Gain Parameter	0.8 to 1.2	---	0.0001	F060	1
Factory Service - Calibration (Read Only)						
F02A	DSP Calibration Date	0 to 4294967295	---	1	F050	0
Factory Service - Debug Data (Read Only -- Written by Factory)						
F040	Debug Data 16 (16 items)	-32767 to 32767	---	1	F002	0
F050	Debug Data 32 (16 items)	-2147483647 to 2147483647	---	1	F004	0
Transducer Calibration (Read Only -- Written by Factory)						
F0A0	Transducer Calibration Function	0 to 1	---	1	F102	0 (Disabled)
F0A1	Transducer Card to Calibrate	0 to 15	---	1	F172	0 (F)
F0A2	Transducer Channel to Calibrate	0 to 7	---	1	F001	0
F0A3	Transducer Channel to Calibrate Type	0 to 3	---	1	F171	0 (dcmA IN)
F0A4	Transducer Channel to Calibrate Gain Stage	0 to 1	---	1	F170	0 (LOW)
Transducer Calibration (Read Only)						
F0A5	Transducer Channel to Calibrate Counts	0 to 4095	---	1	F001	0
Transducer Calibration (Read Only -- Written by Factory)						
F0A6	Transducer Channel to Calibrate Offset	-4096 to 4095	---	1	F002	0
F0A7	Transducer Channel to Calibrate Value	-1.1 to 366.5	---	0.001	F004	0
F0A9	Transducer Channel to Calibrate Gain	0.8 to 1.2	---	0.0001	F060	1
F0AB	Transducer Calibration Date	0 to 4294967295	---	1	F050	0

Table B–9: MODBUS MEMORY MAP (Sheet 36 of 38)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
Transducer Calibration (Read Only)						
F0AD	Transducer Channel to Calibrate Units	---	---	---	F206	(none)
Factory Service Software Revisions (Read Only)						
F0F0	Compile Date	0 to 4294967295	---	1	F050	0
F0F3	Boot Version	0 to 655.35	---	0.01	F001	1
F0F4	Front Panel Version	0 to 655.35	---	0.01	F001	1
F0F5	Boot Date	0 to 4294967295	---	1	F050	0
Factory Service - Serial EEPROM (Read Only -- Written by Factory)						
F100	Serial EEPROM Enable	0 to 1	---	1	F102	0 (Disabled)
F101	Serial EEPROM Slot	0 to 15	---	1	F172	0 (F)
F102	Serial EEPROM Load Factory Defaults	0 to 1	---	1	F126	0 (No)
F110	Serial EEPROM Module Serial Number	---	---	---	F203	(none)
F120	Serial EEPROM Supplier Serial Number	---	---	---	F203	(none)
F130	Serial EEPROM Sub Module Serial Number (8 items)	---	---	---	F203	(none)
Factory Service CPU Diagnostics (Read Only Non-Volatile)						
F200	Operating Hours	0 to 4294967295	---	1	F050	0
Factory Service CPU Diagnostics (Read Only)						
F210	DSP Spurious Interrupt Counter	0 to 4294967295	---	1	F003	0
Factory Service CPU Diagnostics (Read Only -- Written by Factory)						
F220	Real Time Profiling	0 to 1	---	1	F102	0 (Disabled)
F221	Enable Windview	0 to 1	---	1	F102	0 (Disabled)
F222	Factory Reload Cause	---	---	---	F200	(none)
F236	Clear Diagnostics	0 to 1	---	1	F126	0 (No)
Factory Service CPU Performance (Read Only)						
F300	CPU Utilization	0 to 100	%	0.1	F001	0
Factory Service CPU Performance (Read/Write)						
F301	CPU Overload	0 to 6553.5	%	0.1	F001	0
Factory Service CPU Performance (Read Only)						
F302	Protection Pass Time	0 to 65535	us	1	F001	0
Factory Service CPU Performance (Read/Write)						
F303	Protection Pass Worst Time	0 to 65535	us	1	F001	0
Factory Service DSP Diagnostics (Read Only) (3 modules)						
F380	DSP Checksum Error Counter	0 to 4294967295	---	1	F003	0
F382	DSP Corrupt Settings Counter	0 to 4294967295	---	1	F003	0
F384	DSP Out Of Sequence Error Counter	0 to 4294967295	---	1	F003	0
F386	DSP Flags Error Counter	0 to 4294967295	---	1	F003	0
F38D	DSP Error Flags	0 to 65535	---	1	F001	0
F38E	DSP Error Code	0 to 65535	---	1	F001	0
F38F	DSP Usage	0 to 100	---	0.1	F001	0
F390	...Repeated for module number 2					
F3A0	...Repeated for module number 3					
Factory Service FlexAnalog Distance (Read Only)						
F800	Distance Iab Magnitude	0 to 999999.999	pu	1	F060	0
F802	Distance Iab Angle	-180 to 180	°	0.01	F002	0
F803	Distance Ibc Magnitude	0 to 999999.999	pu	1	F060	0
F805	Distance Ibc Angle	-180 to 180	°	0.01	F002	0
F806	Distance Ica Magnitude	0 to 999999.999	pu	1	F060	0
F808	Distance Ica Angle	-180 to 180	°	0.01	F002	0
F809	Distance IabZ Vab Angle (4 items)	-180 to 180	°	0.01	F002	0
F80D	Distance IbcZ Vbc Angle (4 items)	-180 to 180	°	0.01	F002	0
F811	Distance IcaZ Vca Angle (4 items)	-180 to 180	°	0.01	F002	0
F815	Distance IagZ Vag Angle (4 items)	-180 to 180	°	0.01	F002	0
F819	Distance IbgZ Vbg Angle (4 items)	-180 to 180	°	0.01	F002	0
F81D	Distance IcgZ Vcg Angle (4 items)	-180 to 180	°	0.01	F002	0

Table B–9: MODBUS MEMORY MAP (Sheet 37 of 38)

ADDR	REGISTER NAME	RA
F821	Distance I2Za Angle	-180 to 180
F822	Distance I2Zb Angle	-180 to 180
F823	Distance I2Zc Angle	-180 to 180
F824	Distance Alpha IabZ Vab Angle	-180 to 180
F825	Distance Alpha IbcZ Vbc Angle	-180 to 180
F826	Distance Alpha IcaZ Vca Angle	-180 to 180
F827	Distance Alpha IagZ Vag Angle	-180 to 180
F828	Distance Alpha IbgZ Vbg Angle	-180 to 180
F829	Distance Alpha IcgZ Vcg Angle	-180 to 180
F82A	Distance IabZR Vab IabZR Angle (4 items)	-180 to 180
F82E	Distance IbcZR Vbc IbcZR Angle (4 items)	-180 to 180
F832	UNDEFINED (4 items)	-180 to 180
F836	Distance IabZR Vab IabZR Angle (4 items)	-180 to 180
F83A	Distance IbcZR Vbc IbcZR Angle (4 items)	-180 to 180
F83E	Distance IcaZR Vca IcaZR Angle (4 items)	-180 to 180
F842	Distance IagZR Vag IagZR Angle (4 items)	-180 to 180
F846	Distance IbgZR Vbg IbgZR Angle (4 items)	-180 to 180
F84A	Distance IcgZR Vcg IcgZR Angle (4 items)	-180 to 180
F84E	Distance IagZL Vag IagZL Angle (4 items)	-180 to 180
F852	Distance IbgZL Vbg IbgZL Angle (4 items)	-180 to 180
F856	Distance IcgZL Vcg IcgZL Angle (4 items)	-180 to 180
Modbus File Transfer Area 2 (Read/Write)		
FA00	Name of file to read	---
Modbus File Transfer Area 2 (Read Only)		
FB00	Character position of current block within file	0 to 4294967295
FB02	Size of currently-available data block	0 to 65535
FB03	Block of data from requested file (122 items)	0 to 65535
Neutral Overvoltage (Read/Write Grouped Setting) (3 modules)		
FC00	Neutral OV X Function	0 to 1
FC01	Neutral OV X Signal Source	0 to 5
FC02	Neutral OV X Pickup	0 to 1.25
FC03	Neutral OV X Pickup Delay	0 to 600
FC04	Neutral OV X Reset Delay	0 to 600
FC05	Neutral OV X Block	0 to 65535
FC06	Neutral OV X Target	0 to 2
FC07	Neutral OV X Events	0 to 1
FC08	Neutral OV Reserved (8 items)	0 to 65535
FC10	...Repeated for module number 2	
FC20	...Repeated for module number 3	
Auxiliary Overvoltage (Read/Write Grouped Setting) (3 modules)		
FC30	Auxiliary OV X Function	0 to 1
FC31	Auxiliary OV X Signal Source	0 to 5
FC32	Auxiliary OV X Pickup	0 to 3
FC33	Auxiliary OV X Pickup Delay	0 to 600
FC34	Auxiliary OV X Reset Delay	0 to 600
FC35	Auxiliary OV X Block	0 to 65535
FC36	Auxiliary OV X Target	0 to 2
FC37	Auxiliary OV X Events	0 to 1
FC38	Auxiliary OV X Reserved (8 items)	0 to 65535
FC40	...Repeated for module number 2	
FC50	...Repeated for module number 3	
Auxiliary Undervoltage (Read/Write Grouped Setting) (3 modules)		
FC60	Auxiliary UV X Function	0 to 1
FC61	Auxiliary UV X Signal Source	0 to 5

Table B–9: MODBUS MEMORY MAP (Sheet 38 of 38)

ADDR	REGISTER NAME				RANGE
F862	Auxiliary UV X Pickup	pu	0.001	F002	0 to 3
F863	Auxiliary UV X Delay	s	0.01	F002	0 to 600
F864	Auxiliary UV X Curve		0.01	F002	0 to 1
F865	Auxiliary UV X Minimum Voltage	pu	0.001	F002	0 to 3
F866	Auxiliary UV X Block		0.01	F002	0 to 65535
F867	Auxiliary UV X Target		0.01	F002	0 to 2
F868	Auxiliary UV X Events		0.01	F002	0 to 1
F869	Auxiliary UV X Reserved (7 items)		0.01	F002	0 to 65535
F870	...Repeated for module number 2		0.01	F002	
F880	...Repeated for module number 3		0.01	F002	
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		°	0.01	F002	0
		---	---	F204	(none)
		---	1	F003	0
		---	1	F001	0
		---	1	F001	0
		---	1	F102	0 (Disabled)
		---	1	F167	0 (SRC 1)
		pu	0.001	F001	300
		s	0.01	F001	100
		s	0.01	F001	100
		---	1	F300	0
		---	1	F109	0 (Self-reset)
		---	1	F102	0 (Disabled)
		---	1	F001	0
		---	1	F102	0 (Disabled)
		---	1	F167	0 (SRC 1)
		pu	0.001	F001	300
		s	0.01	F001	100
		s	0.01	F001	100
		---	1	F300	0
		---	1	F109	0 (Self-reset)
		---	1	F102	0 (Disabled)
		---	1	F001	0
		---	1	F102	0 (Disabled)
		---	1	F167	0 (SRC 1)

F001
UR_UINT16 UNSIGNED 16 BIT INTEGER

F002
UR_SINT16 SIGNED 16 BIT INTEGER

F003
UR_UINT32 UNSIGNED 32 BIT INTEGER (2 registers)

High order word is stored in the first register.
Low order word is stored in the second register.

F004
UR_SINT32 SIGNED 32 BIT INTEGER (2 registers)

High order word is stored in the first register/
Low order word is stored in the second register.

F005
UR_UINT8 UNSIGNED 8 BIT INTEGER

F006
UR_SINT8 SIGNED 8 BIT INTEGER

F011
UR_UINT16 FLEXCURVE DATA (120 points)

A FlexCurve is an array of 120 consecutive data points (x, y) which are interpolated to generate a smooth curve. The y-axis is the user defined trip or operation time setting; the x-axis is the pickup ratio and is pre-defined. Refer to format F119 for a listing of the pickup ratios; the enumeration value for the pickup ratio indicates the offset into the FlexCurve base address where the corresponding time value is stored.

F012
DISPLAY_SCALE DISPLAY SCALING
(unsigned 16-bit integer)

MSB indicates the SI units as a power of ten. LSB indicates the number of decimal points to display.

Example: Current values are stored as 32 bit numbers with three decimal places and base units in Amps. If the retrieved value is 12345.678 A and the display scale equals 0x0302 then the displayed value on the unit is 12.35 kA.

F013
POWER_FACTOR PWR FACTOR (SIGNED 16 BIT INTEGER)

Positive values indicate lagging power factor; negative values indicate leading.

F040
UR_UINT48 48-BIT UNSIGNED INTEGER

F050
UR_UINT32 TIME and DATE (UNSIGNED 32 BIT INTEGER)

Gives the current time in seconds elapsed since 00:00:00 January 1, 1970.

F051
UR_UINT32 DATE in SR format (alternate format for F050)

First 16 bits are Month/Day (MM/DD/xxxx). Month: 1=January, 2=February,...,12=December; Day: 1 to 31 in steps of 1
Last 16 bits are Year (xx/xx/YYYY): 1970 to 2106 in steps of 1

F052
UR_UINT32 TIME in SR format (alternate format for F050)

First 16 bits are Hours/Minutes (HH:MM:xx.xxx).
Hours: 0=12am, 1=1am,...,12=12pm,...23=11pm;
Minutes: 0 to 59 in steps of 1

Last 16 bits are Seconds (xx:xx:.SS.SSS): 0=00.000s, 1=00.001,...,59999=59.999s)

F060
FLOATING_POINT IEE FLOATING POINT (32 bits)

F070
HEX2 2 BYTES - 4 ASCII DIGITS

F071
HEX4 4 BYTES - 8 ASCII DIGITS

F072
HEX6 6 BYTES - 12 ASCII DIGITS

F073
HEX8 8 BYTES - 16 ASCII DIGITS

F074
HEX20 20 BYTES - 40 ASCII DIGITS

F100
ENUMERATION: VT CONNECTION TYPE

0 = Wye; 1 = Delta

F101
ENUMERATION: MESSAGE DISPLAY INTENSITY

0 = 25%, 1 = 50%, 2 = 75%, 3 = 100%

F102
ENUMERATION: DISABLED/ENABLED

0 = Disabled; 1 = Enabled

F103
ENUMERATION: CURVE SHAPES

bitmask	curve shape
0	IEEE Mod Inv
1	IEEE Very Inv
2	IEEE Ext Inv
3	IEC Curve A
4	IEC Curve B
5	IEC Curve C
6	IEC Short Inv
7	IAC Ext Inv

bitmask	curve shape
8	IAC Very Inv
9	IAC Inverse
10	IAC Short Inv
11	I2t
12	Definite Time
13	Flexcurve A
14	Flexcurve B

F104
ENUMERATION: RESET TYPE

0 = Instantaneous, 1 = Timed, 2 = Linear

F105
ENUMERATION: LOGIC INPUT

0 = Disabled, 1 = Input 1, 2 = Input 2

F106
ENUMERATION: PHASE ROTATION

0 = ABC, 1 = ACB

F108
ENUMERATION: OFF/ON

0 = Off, 1 = On

F109
ENUMERATION: CONTACT OUTPUT OPERATION

0 = Self-reset, 1 = Latched, 2 = Disabled

F110
ENUMERATION: CONTACT OUTPUT LED CONTROL

0 = Trip, 1 = Alarm, 2 = None

F111
ENUMERATION: UNDERVOLTAGE CURVE SHAPES

0 = Definite Time, 1 = Inverse Time

F112
ENUMERATION: RS485 BAUD RATES

bitmask	value
0	300
1	1200
2	2400
3	4800

bitmask	value
4	9600
5	19200
6	38400
7	57600

bitmask	value
8	115200
9	14400
10	28800
11	33600

F113
ENUMERATION: PARITY

0 = None, 1 = Odd, 2 = Even

F114
ENUMERATION: IRIG-B SIGNAL TYPE

0 = None, 1 = DC Shift, 2 = Amplitude Modulated

F115
ENUMERATION: BREAKER STATUS

0 = Auxiliary A, 1 = Auxiliary B

F117
ENUMERATION: NUMBER OF OSCILLOGRAPHY RECORDS

0 = 1×72 cycles, 1 = 3×36 cycles, 2 = 7×18 cycles, 3 = 15×9 cycles

F118
ENUMERATION: OSCILLOGRAPHY MODE

0 = Automatic Overwrite, 1 = Protected

B

F119
ENUMERATION: FLEXCURVE PICKUP RATIOS

mask	value	mask	value	mask	value	mask	value
0	0.00	30	0.88	60	2.90	90	5.90
1	0.05	31	0.90	61	3.00	91	6.00
2	0.10	32	0.91	62	3.10	92	6.50
3	0.15	33	0.92	63	3.20	93	7.00
4	0.20	34	0.93	64	3.30	94	7.50
5	0.25	35	0.94	65	3.40	95	8.00
6	0.30	36	0.95	66	3.50	96	8.50
7	0.35	37	0.96	67	3.60	97	9.00
8	0.40	38	0.97	68	3.70	98	9.50
9	0.45	39	0.98	69	3.80	99	10.00
10	0.48	40	1.03	70	3.90	100	10.50
11	0.50	41	1.05	71	4.00	101	11.00
12	0.52	42	1.10	72	4.10	102	11.50
13	0.54	43	1.20	73	4.20	103	12.00
14	0.56	44	1.30	74	4.30	104	12.50
15	0.58	45	1.40	75	4.40	105	13.00
16	0.60	46	1.50	76	4.50	106	13.50
17	0.62	47	1.60	77	4.60	107	14.00
18	0.64	48	1.70	78	4.70	108	14.50
19	0.66	49	1.80	79	4.80	109	15.00
20	0.68	50	1.90	80	4.90	110	15.50
21	0.70	51	2.00	81	5.00	111	16.00
22	0.72	52	2.10	82	5.10	112	16.50
23	0.74	53	2.20	83	5.20	113	17.00
24	0.76	54	2.30	84	5.30	114	17.50
25	0.78	55	2.40	85	5.40	115	18.00
26	0.80	56	2.50	86	5.50	116	18.50
27	0.82	57	2.60	87	5.60	117	19.00
28	0.84	58	2.70	88	5.70	118	19.50
29	0.86	59	2.80	89	5.80	119	20.00

F120
ENUMERATION: DISTANCE SHAPE

0 = Mho, 1 = Quad

F122
ENUMERATION: ELEMENT INPUT SIGNAL TYPE

0 = Phasor, 1 = RMS

F123
ENUMERATION: CT SECONDARY

0 = 1 A, 1 = 5 A

F124
ENUMERATION: LIST OF ELEMENTS

bitmask	element
0	PHASE IOC1
1	PHASE IOC2
2	PHASE IOC3
3	PHASE IOC4
4	PHASE IOC5
5	PHASE IOC6
6	PHASE IOC7
7	PHASE IOC8
8	PHASE IOC9
9	PHASE IOC10
10	PHASE IOC11
11	PHASE IOC12
16	PHASE TOC1
17	PHASE TOC2
18	PHASE TOC3
19	PHASE TOC4
20	PHASE TOC5
21	PHASE TOC6
24	PH DIR1
25	PH DIR2
32	NEUTRAL IOC1
33	NEUTRAL IOC2
34	NEUTRAL IOC3
35	NEUTRAL IOC4
36	NEUTRAL IOC5
37	NEUTRAL IOC6
38	NEUTRAL IOC7
39	NEUTRAL IOC8
40	NEUTRAL IOC9
41	NEUTRAL IOC10
42	NEUTRAL IOC11
43	NEUTRAL IOC12
48	NEUTRAL TOC1
49	NEUTRAL TOC2
50	NEUTRAL TOC3
51	NEUTRAL TOC4
52	NEUTRAL TOC5
53	NEUTRAL TOC6
56	NTRL DIR
57	NTRL DIR
60	NEG SEQ
61	NEG SEQ
64	GROUND IOC1
65	GROUND IOC2
66	GROUND IOC3

bitmask	element
67	GROUND IOC4
68	GROUND IOC5
69	GROUND IOC6
70	GROUND IOC7
71	GROUND IOC8
72	GROUND IOC9
73	GROUND IOC10
74	GROUND IOC11
75	GROUND IOC12
80	GROUND TOC1
81	GROUND TOC2
82	GROUND TOC3
83	GROUND TOC4
84	GROUND TOC5
85	GROUND TOC6
96	NEG SEQ
97	NEG SEQ
112	NEG SEQ
113	NEG SEQ
120	NEG SEQ
140	AUX UV1
141	AUX UV2
142	AUX UV3
144	PHASE UV1
145	PHASE UV2
148	AUX OV1
149	AUX OV2
150	AUX OV3
152	PHASE OV1
156	NEUTRAL OV1
157	NEUTRAL OV2
158	NEUTRAL OV3
161	PH DIST 2
168	LINE PICKUP
177	GND DIST 2
180	LOAD ENCHR
184	DUTT
185	PUTT
186	POTT
187	HYBRID POTT
188	BLOCK SCHEME
190	POWER SWING
224	SRC1 VT
225	SRC2 VT
226	SRC3 VT
227	SRC4 VT
228	SRC5 VT
229	SRC6 VT

bitmask	element
232	SRC1 50DD
233	SRC2 50DD
234	SRC3 50DD
235	SRC4 50DD
236	SRC5 50DD
237	SRC6 50DD
240	87L DIFF
241	87L DIFF
242	OPEN POLE
244	50DD
245	CONT MONITOR
246	CT FAIL
247	CT TROUBLE1
248	CT TROUBLE2
249	87L TRIP
250	STUB BUS
256	87PC
265	STATOR DIFF
272	BREAKER 1
273	BREAKER 2
280	BKR FAIL
281	BKR FAIL
288	BKR ARC
289	BKR ARC
296	ACCDNT ENRG
300	LOSS EXCIT
304	AR 1
305	AR 2
306	AR 3
307	AR 4
308	AR 5
309	AR 6
312	SYNC 1
313	SYNC 2
320	COLD LOAD
321	COLD LOAD
324	AMP UNBALANCE
325	AMP UNBALANCE
330	3RD HARM
336	SETTING GROUP
337	RESET
344	OVERFREQ 1
345	OVERFREQ 2
346	OVERFREQ 3
347	OVERFREQ 4
352	UNDERFREQ 1
353	UNDERFREQ 2
354	UNDERFREQ 3

bitmask	element
355	UNDERFREQ 4
356	UNDERFREQ 5
357	UNDERFREQ 6
400	FLEX ELEMENT 1
401	FLEX ELEMENT 2
402	FLEX ELEMENT 3
403	FLEX ELEMENT 4
404	FLEX ELEMENT 5
405	FLEX ELEMENT 6
406	FLEX ELEMENT 7
407	FLEX ELEMENT 8
408	FLEX ELEMENT 9
409	FLEX ELEMENT 10
410	FLEX ELEMENT 11
411	FLEX ELEMENT 12
412	FLEX ELEMENT 13
413	FLEX ELEMENT 14
414	FLEX ELEMENT 15
415	FLEX ELEMENT 16
512	DIG ELEM 1
513	DIG ELEM 2
514	DIG ELEM 3
515	DIG ELEM 4
516	DIG ELEM 5
517	DIG ELEM 6
518	DIG ELEM 7
519	DIG ELEM 8
520	DIG ELEM 9
521	DIG ELEM 10
522	DIG ELEM 11
523	DIG ELEM 12
524	DIG ELEM 13
525	DIG ELEM 14
526	DIG ELEM 15
527	DIG ELEM 16
544	COUNTER 1
545	COUNTER 2
546	COUNTER 3
547	COUNTER 4
548	COUNTER 5
549	COUNTER 6
550	COUNTER 7
551	COUNTER 8

F125
ENUMERATION: ACCESS LEVEL

0 = Restricted; 1 = Command, 2 = Setting, 3 = Factory Service

F126
ENUMERATION: NO/YES CHOICE

0 = No, 1 = Yes

F127
ENUMERATION: LATCHED OR SELF-RESETTING

0 = Latched, 1 = Self-Reset

F128
ENUMERATION: CONTACT INPUT THRESHOLD

0 = 16 Vdc, 1 = 30 Vdc, 2 = 80 Vdc, 3 =140 Vdc

F129
ENUMERATION: FLEXLOGIC TIMER TYPE

0 = millisecond, 1 = second, 2 = minute

F130
ENUMERATION: SIMULATION MODE

0 = Off. 1 = Pre-Fault, 2 = Fault, 3 = Post-Fault

F131
ENUMERATION: FORCED CONTACT OUTPUT STATE

0 = Disabled, 1 = Energized, 2 = De-energized, 3 = Freeze

F133
ENUMERATION: PROGRAM STATE

0 = Not Programmed, 1 = Programmed

F134
ENUMERATION: PASS/FAIL

0 = Fail, 1 = OK, 2 = n/a

F135
ENUMERATION: GAIN CALIBRATION

0 = 0x1, 1 = 1x16

F136
ENUMERATION: NUMBER OF OSCILLOGRAPHY RECORDS

0 = 31 x 8 cycles, 1 = 15 x 16 cycles, 2 = 7 x 32 cycles
3 = 3 x 64 cycles, 4 = 1 x 128 cycles

F138
ENUMERATION: OSCILLOGRAPHY FILE TYPE

0 = Data File, 1 = Configuration File, 2 = Header File

F140
ENUMERATION: CURRENT, SENS CURRENT, VOLTAGE, DISABLED

0 = Disabled, 1 = Current 46A, 2 = Voltage 280V, 3 = Current 4.6A
4 = Current 2A, 5 = Notched 4.6A, 6 = Notched 2A

F141
ENUMERATION: SELF TEST ERROR

bitmask	error
0	ANY SELF TESTS
1	IRIG-B FAILURE
2	DSP ERROR
4	NO DSP INTERRUPTS
5	UNIT NOT CALIBRATED
9	PROTOTYPE FIRMWARE
10	FLEXLOGIC ERR TOKEN
11	EQUIPMENT MISMATCH
13	UNIT NOT PROGRAMMED
14	SYSTEM EXCEPTION
19	BATTERY FAIL
20	PRI ETHERNET FAIL
21	SEC ETHERNET FAIL
22	EEPROM DATA ERROR
23	SRAM DATA ERROR
24	PROGRAM MEMORY
25	WATCHDOG ERROR
26	LOW ON MEMORY
27	REMOTE DEVICE OFF
30	ANY MINOR ERROR
31	ANY MAJOR ERROR

F142
ENUMERATION: EVENT RECORDER ACCESS FILE TYPE

0 = All Record Data, 1 = Headers Only, 2 = Numeric Event Cause

F143
UR_UINT32: 32 BIT ERROR CODE (F141 specifies bit number)

A bit value of 0 = no error, 1 = error

F144
ENUMERATION: FORCED CONTACT INPUT STATE

0 = Disabled, 1 = Open, 2 = Closed

F145
ENUMERATION: ALPHABET LETTER

bitmask	type	bitmask	type	bitmask	type	bitmask	type
0	null	7	G	14	N	21	U
1	A	8	H	15	O	22	V
2	B	9	I	16	P	23	W
3	C	10	J	17	Q	24	X
4	D	11	K	18	R	25	Y
5	E	12	L	19	S	26	Z
6	F	13	M	20	T		

F146
ENUMERATION: MISC. EVENT CAUSES

bitmask	definition
0	EVENTS CLEARED
1	OSCILLOGRAPHY TRIGGERED
2	DATE/TIME CHANGED
3	DEF SETTINGS LOADED
4	TEST MODE ON
5	TEST MODE OFF
6	POWER ON
7	POWER OFF
8	RELAY IN SERVICE
9	RELAY OUT OF SERVICE
10	WATCHDOG RESET
11	OSCILLOGRAPHY CLEAR
12	REBOOT COMMAND

F147
ENUMERATION: LINE LENGTH UNITS

0 = km, 1 = miles

F148
ENUMERATION: FAULT TYPE

bitmask	fault type
0	NA
1	AG
2	BG
3	CG
4	AB
5	BC
6	AC
7	ABG
8	BCG
9	ACG
10	ABC
11	ABCG

F149
ENUMERATION: 87L PHASE COMP SCHEME SELECTION

bitmask	phase comp scheme
0	2TL-PT-DPC-3FC
1	2TL-BL-DPC-3FC
2	2TL-PT-SPC-2FC
3	2TL-BL-SPC-2FC
4	2TL-BL-DPC-2FC
5	3TL-PT-SPC-3FC
6	3TL-BL-SPC-3FC

F150
ENUMERATION: 87L PHASE COMP SCHEME SIGNAL SELECTION

0 = MIXED I_2 - K*I_1, 1 = 3I_0

F151
ENUMERATION: RTD SELECTION

bitmask	RTD#	bitmask	RTD#	bitmask	RTD#
0	NONE	17	RTD 17	33	RTD 33
1	RTD 1	18	RTD 18	34	RTD 34
2	RTD 2	19	RTD 19	35	RTD 35
3	RTD 3	20	RTD 20	36	RTD 36
4	RTD 4	21	RTD 21	37	RTD 37
5	RTD 5	22	RTD 22	38	RTD 38
6	RTD 6	23	RTD 23	39	RTD 39
7	RTD 7	24	RTD 24	40	RTD 40
8	RTD 8	25	RTD 25	41	RTD 41
9	RTD 9	26	RTD 26	42	RTD 42
10	RTD 10	27	RTD 27	43	RTD 43
11	RTD 11	28	RTD 28	44	RTD 44
12	RTD 12	29	RTD 29	45	RTD 45
13	RTD 13	30	RTD 30	46	RTD 46
14	RTD 14	31	RTD 31	47	RTD 47
15	RTD 15	32	RTD 32	48	RTD 48
16	RTD 16				

F152
ENUMERATION: SETTING GROUP

0 = Active Group, 1 = Group 1, 2 = Group 2, 3 = Group 3
4 = Group 4, 5 = Group 5, 6 = Group 6, 7 = Group 7, 8 = Group 8

F154
ENUMERATION: DISTANCE DIRECTION

0 = Forward, 1 = Reverse

F155
ENUMERATION: REMOTE DEVICE STATE

0 = Offline, 1 = Online

F156
ENUMERATION: REMOTE INPUT BIT PAIRS

bitmask	RTD#	bitmask	RTD#	bitmask	RTD#
0	NONE	22	DNA-22	44	UserSt-12
1	DNA-1	23	DNA-23	45	UserSt-13
2	DNA-2	24	DNA-24	46	UserSt-14
3	DNA-3	25	DNA-25	47	UserSt-15
4	DNA-4	26	DNA-26	48	UserSt-16
5	DNA-5	27	DNA-27	49	UserSt-17
6	DNA-6	28	DNA-28	50	UserSt-18
7	DNA-7	29	DNA-29	51	UserSt-19
8	DNA-8	30	DNA-30	52	UserSt-20
9	DNA-9	31	DNA-31	53	UserSt-21
10	DNA-10	32	DNA-32	54	UserSt-22
11	DNA-11	33	UserSt-1	55	UserSt-23
12	DNA-12	34	UserSt-2	56	UserSt-24
13	DNA-13	35	UserSt-3	57	UserSt-25
14	DNA-14	36	UserSt-4	58	UserSt-26
15	DNA-15	37	UserSt-5	59	UserSt-27
16	DNA-16	38	UserSt-6	60	UserSt-28
17	DNA-17	39	UserSt-7	61	UserSt-29
18	DNA-18	40	UserSt-8	62	UserSt-30
19	DNA-19	41	UserSt-9	63	UserSt-31
20	DNA-20	42	UserSt-10	64	UserSt-32
21	DNA-21	43	UserSt-11		

F157
ENUMERATION: BREAKER MODE

0 = 3-Pole, 1 = 1-Pole

F158
ENUMERATION: SCHEME CALIBRATION TEST

0 = Normal, 1 = Symmetry 1, 2 = Symmetry 2, 3 = Delay 1
4 = Delay 2

F159
ENUMERATION: BREAKER AUX CONTACT KEYING

0 = 52a, 1 = 52b, 2 = None

F166
ENUMERATION: AUXILIARY VT CONNECTION TYPE

0 = Vn, 1 = Vag, 2 = Vbg, 3 = Vcg, 4 = Vab, 5 = Vbc, 6 = Vca

F167
ENUMERATION: SIGNAL SOURCE

0 = SRC 1, 1 = SRC 2, 2 = SRC 3, 3 = SRC 4,
4 = SRC 5, 5 = SRC 6

F168
ENUMERATION: INRUSH INHIBIT FUNCTION

0 = Disabled, 1 = 2nd

F169
ENUMERATION: OVEREXCITATION INHIBIT FUNCTION

0 = Disabled, 1 = 5th

F170
ENUMERATION: LOW/HIGH OFFSET & GAIN TRANSDUCER I/O SELECTION

0 = LOW, 1 = HIGH

F171
ENUMERATION: TRANSDUCER CHANNEL INPUT TYPE

0 = dcmA IN, 1 = OHMS IN, 2 = RTD IN, 3 = dcmA OUT

F172
ENUMERATION: SLOT LETTERS

bitmask	slot	bitmask	slot	bitmask	slot	bitmask	slot
0	F	4	K	8	P	12	U
1	G	5	L	9	R	13	V
2	H	6	M	10	S	14	W
3	J	7	N	11	T	15	X

F173
ENUMERATION: TRANSDUCER DCMA I/O RANGE

bitmask	dcmA I/O range
0	0 to –1 mA
1	0 to 1 mA
2	–1 to 1 mA
3	0 to 5 mA
4	0 to 10 mA
5	0 to 20 mA
6	4 to 20 mA

F174
ENUMERATION: TRANSDUCER RTD INPUT TYPE

0 = 100 Ohm Platinum, 1 = 120 Ohm Nickel,
2 = 100 Ohm Nickel, 3 = 10 Ohm Copper

F175
ENUMERATION: PHASE LETTERS

0 = A, 1 = B, 2 = C

F176
ENUMERATION: SYNCHROCHECK DEAD SOURCE SELECT

bitmask	synchrocheck dead source
0	None
1	LV1 and DV2
2	DV1 and LV2
3	DV1 or DV2
4	DV1 Xor DV2
5	DV1 and DV2

F177
ENUMERATION: COMMUNICATION PORT

0 = NONE, 1 = COM1-RS485, 2 = COM2-RS485,
3 = FRONT PANEL-RS232, 4 = NETWORK

F178
ENUMERATION: DATA LOGGER RATES

0 = 1 sec, 1 = 1 min, 2 = 5 min, 3 = 10 min, 4 = 15 min,
5 = 20 min, 6 = 30 min, 7 = 60 min

F180
ENUMERATION: PHASE/GROUND

0 = PHASE, 1 = GROUND

F181
ENUMERATION: ODD/EVEN/NONE

0 = ODD, 1 = EVEN, 2 = NONE

F183
ENUMERATION AC INPUT WAVEFORMS

bitmask	definition
0	Off
1	8 samples/cycle
2	16 samples/cycle
3	32 samples/cycle
4	64 samples/cycle

F185
ENUMERATION PHASE A,B,C, GROUND SELECTOR

0 = A, 1 = B, 2 = C, 3 = G

F186
ENUMERATION MEASUREMENT MODE

0 = Phase to Ground, 1 = Phase to Phase

F190
ENUMERATION Simulated Keypress

bitmask	keypress
0	--- use between real keys
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	0
11	Decimal Pt
12	Plus/Minus

bitmask	keypress
13	Value Up
14	Value Down
15	Message Up
16	Message Down
17	Message Left
18	Message Right
19	Menu
20	Help
21	Escape
22	Enter
23	Reset
24	User 1
25	User 2
26	User 3

F192
ENUMERATION ETHERNET OPERATION MODE

0 = Half-Duplex, 1 = Full-Duplex

F194
ENUMERATION DNP SCALE

A bitmask of 0 = 0.01, 1 = 0.1, 2 = 1, 3 = 10, 4 = 100, 5 = 1000

F195
ENUMERATION SINGLE POLE TRIP MODE

A bitmask of 0 = Disabled, 1 = 3 Pole Only, 2 = 3 Pole & 1 Pole

F196
ENUMERATION NEUTRAL DIR OC OPERATE CURRENT

0 = Calculated 3I0, 1 = Measured IG

F197
ENUMERATION DNP BINARY INPUT POINT BLOCK

bitmask	Input Point Block
0	Not Used
1	Virtual Inputs 1 to 16
2	Virtual Inputs 17 to 32
3	Virtual Outputs 1 to 16
4	Virtual Outputs 17 to 32
5	Virtual Outputs 33 to 48
6	Virtual Outputs 49 to 64
7	Contact Inputs 1 to 16
8	Contact Inputs 17 to 32
9	Contact Inputs 33 to 48
10	Contact Inputs 49 to 64
11	Contact Inputs 65 to 80
12	Contact Inputs 81 to 96
13	Contact Outputs 1 to 16
14	Contact Outputs 17 to 32
15	Contact Outputs 33 to 48
16	Contact Outputs 49 to 64
17	Remote Inputs 1 to 16
18	Remote Inputs 17 to 32
19	Remote Devs 1 to 16
20	Elements 1 to 16
21	Elements 17 to 32
22	Elements 33 to 48
23	Elements 49 to 64
24	Elements 65 to 80
25	Elements 81 to 96
26	Elements 97 to 112
27	Elements 113 to 128
28	Elements 129 to 144
29	Elements 145 to 160
30	Elements 161 to 176
31	Elements 177 to 192
32	Elements 193 to 208
33	Elements 209 to 224
34	Elements 225 to 240
35	Elements 241 to 256
36	Elements 257 to 272
37	Elements 273 to 288
38	Elements 289 to 304
39	Elements 305 to 320
40	Elements 321 to 336
41	Elements 337 to 352
42	Elements 353 to 368
43	Elements 369 to 384
44	Elements 385 to 400
45	Elements 401 to 406

bitmask	Input Point Block
46	Elements 417 to 432
47	Elements 433 to 448
48	Elements 449 to 464
49	Elements 465 to 480
50	Elements 481 to 496
51	Elements 497 to 512
52	Elements 513 to 528
53	Elements 529 to 544
54	Elements 545 to 560
55	LED States 1 to 16
56	LED States 17 to 32
57	Self Tests 1 to 16
58	Self Tests 17 to 32

F200
TEXT40 40 CHARACTER ASCII TEXT

20 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

F201
TEXT8 8 CHARACTER ASCII PASSCODE

4 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

F202
TEXT20 20 CHARACTER ASCII TEXT

10 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

F203
TEXT16 16 CHARACTER ASCII TEXT

F204
TEXT80 80 CHARACTER ASCII TEXT

F205
TEXT12 12 CHARACTER ASCII TEXT

F206
TEXT6 6 CHARACTER ASCII TEXT

F207
TEXT4 4 CHARACTER ASCII TEXT

F208
TEXT2 2 CHARACTER ASCII TEXT

F222
ENUMERATION TEST ENUMERATION

0 = Test Enumeration 0, 1 = Test Enumeration 1

F230
ENUMERATION DIRECTIONAL POLARIZING

0 = Voltage, 1 = Current, 2 = Dual

F231
ENUMERATION POLARIZING VOLTAGE

0 = Calculated V0, 1 = Measured VX

F300
UR_UINT16 FLEXLOGIC BASE TYPE (6 bit type)

The FlexLogic™ BASE type is 6 bits and is combined with a 9 bit descriptor and 1 bit for protection element to form a 16 bit value. The combined bits are of the form: PTTTTTTDDDDDDDDD, where P bit if set, indicates that the FlexLogic™ type is associated with a protection element state and T represents bits for the BASE type, and D represents bits for the descriptor.

The values in square brackets indicate the base type with P prefix [PTTTTTT] and the values in round brackets indicate the descriptor range.

[0] Off(0) this is boolean FALSE value
[0] On (1)This is boolean TRUE value
[2] CONTACT INPUTS (1 - 96)
[3] CONTACT INPUTS OFF (1-96)
[4] VIRTUAL INPUTS (1-64)
[6] VIRTUAL OUTPUTS (1-64)
[10] CONTACT OUTPUTS VOLTAGE DETECTED (1-64)
[11] CONTACT OUTPUTS VOLTAGE OFF DETECTED (1-64)
[12] CONTACT OUTPUTS CURRENT DETECTED (1-64)
[13] CONTACT OUTPUTS CURRENT OFF DETECTED (1-64)
[14] REMOTE INPUTS (1-32)
[28] INSERT (Via Keypad only)
[32] END
[34] NOT (1 INPUT)
[36] 2 INPUT XOR (0)
[38] LATCH SET/RESET (2 INPUTS)
[40] OR (2-16 INPUTS)
[42] AND (2-16 INPUTS)
[44] NOR (2-16 INPUTS)
[46] NAND (2-16 INPUTS)
[48] TIMER (1-32)
[50] ASSIGN VIRTUAL OUTPUT (1 - 64)
[52] SELF-TEST ERROR (See F141 for range)
[56] ACTIVE SETTING GROUP (1-8)
[62] MISCELLANEOUS EVENTS (See F146 for range)
[64-127] ELEMENT STATES
(Refer to Memory Map Element States Section)

F400
UR_UINT16 CT/VT BANK SELECTION

bitmask	bank selection
0	Card 1 Contact 1 to 4
1	Card 1 Contact 5 to 8
2	Card 2 Contact 1 to 4
3	Card 2 Contact 5 to 8
4	Card 3 Contact 1 to 4
5	Card 3 Contact 5 to 8

F500
UR_UINT16 PACKED BITFIELD

First register indicates I/O state with bits 0(MSB)-15(LSB) corresponding to I/0 state 1-16. The second register indicates I/O state with bits 0-15 corresponding to I/0 state 17-32 (if required) The third register indicates I/O state with bits 0-15 corresponding to I/0 state 33-48 (if required). The fourth register indicates I/O state with bits 0-15 corresponding to I/0 state 49-64 (if required).

The number of registers required is determined by the specific data item. A bit value of 0 = Off, 1 = On

F501
UR_UINT16 LED STATUS

Low byte of register indicates LED status with bit 0 representing the top LED and bit 7 the bottom LED. A bit value of 1 indicates the LED is on, 0 indicates the LED is off.

F502
BITFIELD ELEMENT OPERATE STATES

Each bit contains the operate state for an element. See the F124 format code for a list of element IDs. The operate bit for element ID X is bit [X mod 16] in register [X/16].

F504
BITFIELD 3 PHASE ELEMENT STATE

bitmask	element state
0	Pickup
1	Operate
2	Pickup Phase A
3	Pickup Phase B
4	Pickup Phase C
5	Operate Phase A
6	Operate Phase B
7	Operate Phase C

F505
BITFIELD CONTACT OUTPUT STATE

0 = Contact State, 1 = Voltage Detected, 2 = Current Detected

F506|
BITFIELD 1 PHASE ELEMENT STATE

0 = Pickup, 1 = Operate

F507
BITFIELD COUNTER ELEMENT STATE

0 = Count Greater Than, 1 = Count Equal To, 2 = Count Less Than

F509
BITFIELD SIMPLE ELEMENT STATE

0 = Operate

F510
BITFIELD 87L ELEMENT STATE

bitmask	87L Element State
0	Operate A
1	Operate B
2	Operate C
3	Received DTT
4	Operate
5	Key DTT
6	PFLL FAIL
7	PFLL OK
8	Channel 1 FAIL
9	Channel 2 FAIL
10	Channel 1 Lost Packet
11	Channel 2 Lost Packet
12	Channel 1 CRC Fail
13	Channel 2 CRC Fail

F511
BITFIELD 3 PHASE SIMPLE ELEMENT STATE

0 = Operate, 1 = Operate A, 2 = Operate B, 3 = Operate C

F513
ENUMERATION POWER SWING MODE

0 = Two Step, 1 = Three Step

F514
ENUMERATION POWER SWING TRIP MODE

0 = Delayed, 1 = Early

F515
ENUMERATION ELEMENT INPUT MODE

0 = SIGNED, 1 = ABSOLUTE

F516
ENUMERATION ELEMENT COMPARE MODE

0 = LEVEL, 1 = DELTA

F517
ENUMERATION ELEMENT DIRECTION OPERATION

0 = OVER, 1 = UNDER

F518
ENUMERATION FlexElement Units

0 = Milliseconds, 1 = Seconds, 2 = Minutes

F600
UR_UINT16 FlexAnalog Parameter

The 16-bit value corresponds to the modbus address of the value to be used when this parameter is selected. Only certain values may be used as FlexAnalogs (basically all the metering quantities used in protection)

MMI_FLASH ENUMERATION
Flash message definitions for Front-panel MMI

bitmask	Flash Message
1	ADJUSTED VALUE HAS BEEN STORED
2	ENTERED PASSCODE IS INVALID
3	COMMAND EXECUTED
4	DEFAULT MESSAGE HAS BEEN ADDED
5	DEFAULT MESSAGE HAS BEEN REMOVED
6	INPUT FUNCTION IS ALREADY ASSIGNED
7	PRESS [ENTER] TO ADD AS DEFAULT
8	PRESS [ENTER] TO REMOVE MESSAGE
9	PRESS [ENTER] TO BEGIN TEXT EDIT
10	ENTRY MISMATCH - CODE NOT STORED
11	PRESSED KEY IS INVALID HERE
12	INVALID KEY: MUST BE IN LOCAL MODE
13	NEW PASSWORD HAS BEEN STORED
14	PLEASE ENTER A NON-ZERO PASSCODE
15	NO ACTIVE TARGETS (TESTING LEDS)
16	OUT OF RANGE - VALUE NOT STORED
17	RESETTING LATCHED CONDITIONS
18	SETPOINT ACCESS IS NOW ALLOWED
19	SETPOINT ACCESS DENIED (PASSCODE)
20	SETPOINT ACCESS IS NOW RESTRICTED
21	NEW SETTING HAS BEEN STORED
22	SETPOINT ACCESS DENIED (SWITCH)
23	DATA NOT ACCEPTED
24	NOT ALL CONDITIONS HAVE BEEN RESET
25	DATE NOT ACCEPTED IRIGB IS ENABLED
26	NOT EXECUTED
27	DISPLAY ADDED TO USER DISPLAY LIST
28	DISPLAY NOT ADDED TO USER DISPLAY LIST
29	DISPLAY REMOVED FROM USER DISPLAY LIST

MMI_PASSWORD_TYPE ENUMERATION
Password types for display in password prompts

bitmask	password type
0	No
1	MASTER
2	SETTING
3	COMMAND
4	FACTORY

MMI_SETTING_TYPE ENUMERATION
Setting types for display in web pages

bitmask	Setting Type
0	Unrestricted Setting
1	Master-accessed Setting
2	Setting
3	Command
4	Factory Setting

C.1.1 UCA

The **Utility Communications Architecture** (UCA) version 2 represents an attempt by utilities and vendors of electronic equipment to produce standardized communications systems. There is a set of reference documents available from the Electric Power Research Institute (EPRI) and vendors of UCA/MMS software libraries that describe the complete capabilities of the UCA. Following, is a description of the subset of UCA/MMS features that are supported by the UR relay. The reference document set includes:

- Introduction to UCA version 2
- Generic Object Models for Substation & Feeder Equipment (GOMSFE)
- Common Application Service Models (CASM) and Mapping to MMS
- UCA Version 2 Profiles

These documents can be obtained from ftp://www.sisconet.com/epri/subdemo/uca2.0. It is strongly recommended that all those involved with any UCA implementation obtain this document set.

COMMUNICATION PROFILES:

The UCA specifies a number of possibilities for communicating with electronic devices based on the OSI Reference Model. The UR relay uses the seven layer OSI stack (TP4/CLNP and TCP/IP profiles). Refer to the "UCA Version 2 Profiles" reference document for details.

The TP4/CLNP profile requires the UR relay to have a network address or Network Service Access Point (NSAP) in order to establish a communication link. The TCP/IP profile requires the UR relay to have an IP address in order to establish a communication link. These addresses are set in the **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **NETWORK** menu. Note that the UR relay supports UCA operation over the TP4/CLNP or the TCP/IP stacks and also supports operation over both stacks simultaneously. It is possible to have up to two simultaneous connections. This is in addition to DNP and Modbus/TCP (non-UCA) connections.

C.1.2 MMS

The UCA specifies the use of the **Manufacturing Message Specification** (MMS) at the upper (Application) layer for transfer of real-time data. This protocol has been in existence for a number of years and provides a set of services suitable for the transfer of data within a substation LAN environment. Data can be grouped to form objects and be mapped to MMS services. Refer to the “GOMSFE” and “CASM” reference documents for details.

SUPPORTED OBJECTS:

The "GOMSFE" document describes a number of communication objects. Within these objects are items, some of which are mandatory and some of which are optional, depending on the implementation. The UR relay supports the following GOMSFE objects:

• DI (device identity)	• PHIZ (high impedance ground detector)
• GCTL (generic control)	• PIOC (instantaneous overcurrent relay)
• GIND (generic indicator)	• POVR (overvoltage relay)
• GLOBE (global data)	• PTOC (time overcurrent relay)
• MMXU (polyphase measurement unit)	• PUVR (under voltage relay)
• PBRL (phase balance current relay)	• PVPH (volts per hertz relay)
• PBRO (basic relay object)	• ctRATO (CT ratio information)
• PDIF (differential relay)	• vtRATO (VT ratio information)
• PDIS (distance)	• RREC (reclosing relay)
• PDOC (directional overcurrent)	• RSYN (synchronizing or synchronism-check relay)
• PFRQ (frequency relay)	• XCBR (circuit breaker)

UCA data can be accessed through the "UCADevice" MMS domain.

PEER-TO-PEER COMMUNICATION:

Peer-to-peer communication of digital state information, using the UCA GOOSE data object, is supported via the use of the UR Remote Inputs/Outputs feature. This feature allows digital points to be transferred between any UCA conforming devices.

FILE SERVICES:

MMS file services are supported to allow transfer of Oscillography, Event Record, or other files from a UR relay.

COMMUNICATION SOFTWARE UTILITIES:

The exact structure and values of the implemented objects implemented can be seen by connecting to a UR relay with an MMS browser, such as the “MMS Object Explorer and AXS4-MMS DDE/OPC” server from Sisco Inc.

NON-UCA DATA:

The UR relay makes available a number of non-UCA data items. These data items can be accessed through the "UR" MMS domain. UCA data can be accessed through the "UCADevice" MMS domain.

a) PROTOCOL IMPLEMENTATION AND CONFORMANCE STATEMENT (PICS)

NOTE

The UR relay functions as a server only; a UR relay cannot be configured as a client. Thus, the following list of supported services is for server operation only:

The MMS supported services are as follows:

CONNECTION MANAGEMENT SERVICES:

- Initiate
- Conclude
- Cancel
- Abort
- Reject

VMD SUPPORT SERVICES:

- Status
- GetNameList
- Identify

VARIABLE ACCESS SERVICES:

- Read
- Write
- InformationReport
- GetVariableAccessAttributes
- GetNamedVariableListAttributes

OPERATOR COMMUNICATION SERVICES:

(none)

SEMAPHORE MANAGEMENT SERVICES:

(none)

DOMAIN MANAGEMENT SERVICES:

- GetDomainAttributes

PROGRAM INVOCATION MANAGEMENT SERVICES:

(none)

EVENT MANAGEMENT SERVICES:

(none)

JOURNAL MANAGEMENT SERVICES:

(none)

FILE MANAGEMENT SERVICES:

- ObtainFile
- FileOpen
- FileRead
- FileClose
- FileDirectory

The following MMS parameters are supported:

- STR1 (Arrays)
- STR2 (Structures)
- NEST (Nesting Levels of STR1 and STR2) - 1
- VNAM (Named Variables)
- VADR (Unnamed Variables)
- VALT (Alternate Access Variables)
- VLIS (Named Variable Lists)
- REAL (ASN.1 REAL Type)

b) MODEL IMPLEMENTATION CONFORMANCE (MIC)

This section provides details of the UCA object models supported by the UR relay. Note that not all of the protective device functions are applicable to all UR relays.

Table C–1: DEVICE IDENTITY – DI

NAME	M/O	RWEC
Name	m	rw
Class	o	rw
d	o	rw
Own	o	rw
Loc	o	rw
VndID	m	r
CommID	o	rw

Table C–2: GENERIC CONTROL – GCTL

FC	NAME	CLASS	RWECS	DESCRIPTION
ST	BO<n>	SI	rw	Generic Single Point Indication
CO	BO<n>	SI	rw	Generic Binary Output
CF	BO<n>	SBOCF	rw	SBO Configuration
DC	LN	d	rw	Description for brick
	BO<n>	d	rw	Description for each point

NOTE

Actual instantiation of GCTL objects is as follows:

GCTL1 = Virtual Inputs (32 total points – SI1 to SI32); includes SBO functionality.

Table C–3: GENERIC INDICATOR – GIND

FC	NAME	CLASS	RWECS	DESCRIPTION
ST	SIG<n>	SIG	r	Generic Indication (block of 16)
DC	LN	d	rw	Description for brick
RP	BrcbST	BasRCB	rw	Controls reporting of STATUS

NOTE

Actual instantiation of GIND objects is as follows:

GIND1 = Contact Inputs (96 total points – SIG1 to SIG6)
GIND2 = Contact Outputs (64 total points – SIG1 to SIG4)
GIND3 = Virtual Inputs (32 total points – SIG1 to SIG2)
GIND4 = Virtual Outputs (64 total points – SIG1 to SIG4)
GIND5 = Remote Inputs (32 total points – SIG1 to SIG2)
GIND6 = Flexstates (16 total points – SIG1 representing Flexstates 1 to 16)

Table C–4: GLOBAL DATA – GLOBE

FC	OBJECT NAME	CLASS	RWECS	DESCRIPTION
ST	ModeDS	SIT	r	Device is: in test, off-line, available, or unhealthy
	LocRemDS	SIT	r	The mode of control, local or remote (DevST)
	ActSG	INT8U	r	Active Settings Group
	EditSG	INT8u	r	Settings Group selected for read/write operation
CO	CopySG	INT8U	w	Selects Settings Group for read/writer operation
	IndRs	BOOL	w	Resets ALL targets
CF	ClockTOD	BTIME	rw	Date and time
RP	GOOSE	PACT	rw	Reports IED Inputs and Ouputs

Table C–5: MEASUREMENT UNIT (POLYPHASE) – MMXU

OBJECT NAME	CLASS	RWECS	DESCRIPTION
V	WYE	rw	Voltage on phase A, B, C to G
PPV	DELTA	rw	Voltage on AB, BC, CA
A	WYE	rw	Current in phase A, B, C, and N
W	WYE	rw	Watts in phase A, B, C
TotW	AI	rw	Total watts in all three phases
Var	WYE	rw	Vars in phase A, B, C
TotVar	AI	rw	Total vars in all three phases
VA	WYE	rw	VA in phase A, B, C
TotVA	AI	rw	Total VA in all 3 phases
PF	WYE	rw	Power Factor for phase A, B, C
AvgPF	AI	rw	Average Power Factor for all three phases
Hz	AI	rw	Power system frequency
All MMXU.MX	ACF	rw	Configuration of ALL included MMXU.MX
LN	d	rw	Description for brick
All MMXU.MX	d	rw	Description of ALL included MMXU.MX
BrcbMX	BasRCB	rw	Controls reporting of measurements

NOTE

Actual instantiation of MMXU objects is as follows:

1 MMXU per Source (as determined from the ‘product order code’)

Table C–6: PROTECTIVE ELEMENTS

FC	OBJECT NAME	CLASS	RWECS	DESCRIPTION
ST	Out	BOOL	r	1 = Element operated, 2 = Element not operated
	Tar	PhsTar	r	Targets since last reset
	FctDS	SIT	r	Function is enabled/disabled
	PuGrp	INT8U	r	Settings group selected for use
CO	EnaDisFct	DCO	w	1 = Element function enabled, 0 = disabled
	RsTar	BO	w	Reset ALL Elements/Targets
	RsLat	BO	w	Reset ALL Elements/Targets
DC	LN	d	rw	Description for brick
	ElementSt	d	r	Element state string

The following GOMSFE objects are defined by the object model described via the above table:

- PBRO (basic relay object)
- PDIF (differential relay)
- PDIS (distance)
- PDOC (directional overcurrent)
- PFRQ (frequency relay)
- PHIZ (high impedance ground detector)
- PIOC (instantaneous overcurrent relay)
- POVR (over voltage relay)
- PTOC (time overcurrent relay)
- PUVR (under voltage relay)
- RSYN (synchronizing or synchronism-check relay)
- POVR (overvoltage)
- PVPH (volts per hertz relay)
- PBRL (phase balance current relay)

NOTE Actual instantiation of these objects is determined by the number of the corresponding elements present in the UR as per the ‘product order code’.

Table C–7: CT RATIO INFORMATION – ctRATO

OBJECT NAME	CLASS	RWECS	DESCRIPTION
PhsARat	RATIO	rw	Primary/secondary winding ratio
NeutARat	RATIO	rw	Primary/secondary winding ratio
LN	d	rw	Description for brick

NOTE Actual instantiation of ctRATO objects is as follows:

1 ctRATO per Source (as determined from the ‘product order code’).

Table C–8: VT RATIO INFORMATION – vtRATO

OBJECT NAME	CLASS	RWECS	DESCRIPTION
PhsVRat	RATIO	rw	Primary/secondary winding ratio
LN	d	rw	Description for brick

NOTE Actual instantiation of vtRATO objects is as follows:

1 vtRATO per Source (as determined from the ‘product order code’).

Table C–9: RECLOSING RELAY – RREC

FC	OBJECT NAME	CLASS	RWECS	DESCRIPTION
ST	Out	BOOL	r	1 = Element operated, 2 = Element not operated
	FctDS	SIT	r	Function is enabled/disabled
	PuGrp	INT8U	r	Settings group selected for use
SG	ReclSeq	SHOTS	rw	Reclosing Sequence
CO	EnaDisFct	DCO	w	1 = Element function enabled, 0 = disabled
	RsTar	BO	w	Reset ALL Elements/Targets
	RsLat	BO	w	Reset ALL Elements/Targets
CF	ReclSeq	ACF	rw	Configuration for RREC.SG
DC	LN	d	rw	Description for brick
	ElementSt	d	r	Element state string

NOTE

Actual instantiation of RREC objects is determined by the number of autoreclose elements present in the UR as per the ‘product order code’.

Also note that the SHOTS class data (i.e. Tmr1, Tmr2, Tmr3, Tmr4, RsTmr) is specified to be of type INT16S (16 bit signed integer); this data type is not large enough to properly display the full range of these settings from the UR. Numbers larger than 32768 will be displayed incorrectly.

C.1.3 UCA REPORTING

A built-in TCP/IP connection timeout of two minutes is employed by the UR to detect "dead" connections. If there is no data traffic on a TCP connection for greater than two minutes, the connection will be aborted by the UR. This frees up the connection to be used by other clients. Therefore, when using UCA reporting, clients should configure BasRCB objects such that an integrity report will be issued at least every 2 minutes (120000 ms). This ensures that the UR will not abort the connection. If other MMS data is being polled on the same connection at least once every 2 minutes, this timeout will not apply.

D.1.1 INTEROPERABILTY DOCUMENT

This document is adapted from the IEC 60870-5-104 standard. For ths section the boxes indicate the following: ☒ – used in standard direction; ☐ – not used; ■ – cannot be selected in IEC 60870-5-104 standard.

1. SYSTEM OR DEVICE:

- ☐ System Definition
- ☐ Controlling Station Definition (Master)
- ☒ **Controlled Station Definition (Slave)**

2. NETWORK CONFIGURATION:

- ■ ~~Point-to-Point~~
- ■ ~~Multiple Point-to-Point~~
- ■ ~~Multipoint~~
- ■ ~~Multipoint Star~~

3. PHYSICAL LAYER

Transmission Speed (control direction):

Unbalanced Interchange Circuit V.24/V.28 Standard:	Unbalanced Interchange Circuit V.24/V.28 Recommended if >1200 bits/s:	Balanced Interchange Circuit X.24/X.27:
■ ~~100 bits/sec.~~ ■ ~~200 bits/sec.~~ ■ ~~300 bits/sec.~~ ■ ~~600 bits/sec.~~ ■ ~~1200 bits/sec.~~	■ ~~2400 bits/sec.~~ ■ ~~4800 bits/sec.~~ ■ ~~9600 bits/sec.~~	■ ~~2400 bits/sec.~~ ■ ~~4800 bits/sec.~~ ■ ~~9600 bits/sec.~~ ■ ~~19200 bits/sec.~~ ■ ~~38400 bits/sec.~~ ■ ~~56000 bits/sec.~~ ■ ~~64000 bits/sec.~~

Transmission Speed (monitor direction):

Unbalanced Interchange Circuit V.24/V.28 Standard:	Unbalanced Interchange Circuit V.24/V.28 Recommended if >1200 bits/s:	Balanced Interchange Circuit X.24/X.27:
■ ~~100 bits/sec.~~ ■ ~~200 bits/sec.~~ ■ ~~300 bits/sec.~~ ■ ~~600 bits/sec.~~ ■ ~~1200 bits/sec.~~	■ ~~2400 bits/sec.~~ ■ ~~4800 bits/sec.~~ ■ ~~9600 bits/sec.~~	■ ~~2400 bits/sec.~~ ■ ~~4800 bits/sec.~~ ■ ~~9600 bits/sec.~~ ■ ~~19200 bits/sec.~~ ■ ~~38400 bits/sec.~~ ■ ~~56000 bits/sec.~~ ■ ~~64000 bits/sec.~~

4. LINK LAYER

Link Transmission Procedure:	Address Field of the Link:
■ ~~Balanced Transmision~~ ■ ~~Unbalanced Transmission~~	■ ~~Not Present (Balanced Transmission Only)~~ ■ ~~One Octet~~ ■ ~~Two Octets~~ ■ ~~Structured~~ ■ ~~Unstructured~~
Frame Length (maximum length, number of octets): Not selectable in companion IEC 60870-5-104 standard	

When using an unbalanced link layer, the following ADSU types are returned in class 2 messages (low priority) with the indicated causes of transmission:

- ~~The standard assignment of ADSUs to class 2 messages is used as follows~~:
- ~~A special assignment of ADSUs to class 2 messages is used as follows~~:

5. APPLICATION LAYER

Transmission Mode for Application Data:
Mode 1 (least significant octet first), as defined in Clause 4.10 of IEC 60870-5-4, is used exclusively in this companion stanadard.

Common Address of ADSU:

- ~~One Octet~~
- ☒ Two Octets

Information Object Address:

- ~~One Octet~~
- ~~Two Octets~~
- ☒ Three Octets
- ☒ Structured
- ☒ Unstructured

Cause of Transmission:

- ~~One Octet~~
- ☒ Two Octets (with originator address). Originator address is set to zero if not used.

Maximum Length of APDU: 253 (the maximum length may be reduced by the system.

Selection of standard ASDUs:

For the following lists, the boxes indicate the following: ☒ – used in standard direction; ☐ – not used; ■ – cannot be selected in IEC 60870-5-104 standard.

Process information in monitor direction

☒ <1> := Single-point information	M_SP_NA_1
■ ~~<2> := Single-point information with time tag~~	~~M_SP_TA_1~~
☐ <3> := Double-point information	M_DP_NA_1
■ ~~<4> := Double-point information with time tag~~	~~M_DP_TA_1~~
☐ <5> := Step position information	M_ST_NA_1
■ ~~<6> := Step position information with time tag~~	~~M_ST_TA_1~~
☐ <7> := Bitstring of 32 bits	M_BO_NA_1
■ ~~<8> := Bitstring of 32 bits with time tag~~	~~M_BO_TA_1~~
☐ <9> := Measured value, normalized value	M_ME_NA_1
■ ~~<10> := Measured value, normalized value with time tag~~	~~M_NE_TA_1~~
☐ <11> := Measured value, scaled value	M_ME_NB_1
■ ~~<12> := Measured value, scaled value with time tag~~	~~M_NE_TB_1~~
☒ <13> := Measured value, short floating point value	M_ME_NC_1
■ ~~<14> := Measured value, short floating point value with time tag~~	~~M_NE_TC_1~~
☒ <15> := Integrated totals	M_IT_NA_1
■ ~~<16> := Integrated totals with time tag~~	~~M_IT_TA_1~~
■ ~~<17> := Event of protection equipment with time tag~~	~~M_EP_TA_1~~
■ ~~<18> := Packed start events of protection equipment with time tag~~	~~M_EP_TB_1~~
■ ~~<19> := Packed output circuit information of protection equipment with time tag~~	~~M_EP_TC_1~~
☐ <20> := Packed single-point information with status change detection	M_SP_NA_1

☐ <21> := Measured value, normalized value without quantity descriptor	M_ME_ND_1
☒ <30> := Single-point information with time tag CP56Time2a	M_SP_TB_1
☐ <31> := Double-point information wiht time tag CP56Time2a	M_DP_TB_1
☐ <32> := Step position information with time tag CP56Time2a	M_ST_TB_1
☐ <33> := Bitstring of 32 bits with time tag CP56Time2a	M_BO_TB_1
☐ <34> := Measured value, normalized value with time tag CP56Time2a	M_ME_TD_1
☐ <35> := Measured value, scaled value with time tag CP56Time2a	M_ME_TE_1
☐ <36> := Measured value, short floating point value with time tag CP56Time2a	M_ME_TF_1
☒ <37> := Integrated totals with time tag CP56Time2a	M_IT_TB_1
☐ <38> := Event of protection equipment with time tag CP56Time2a	M_EP_TD_1
☐ <39> := Packed start events of protection equipment with time tag CP56Time2a	M_EP_TE_1
☐ <40> := Packed output circuit information of protection equipment with time tag CP56Time2a	M_EP_TF_1

Either the ASDUs of the set <2>, <4>, <6>, <8>, <10>, <12>, <14>, <16>, <17>, <18>, and <19> or of the set <30> to <40> are used.

Process information in control direction

☒ <45> := Single command	C_SC_NA_1
☐ <46> := Double command	C_DC_NA_1
☐ <47> := Regulating step command	C_RC_NA_1
☐ <48> := Set point command, normalized value	C_SE_NA_1
☐ <49> := Set point command, scaled value	C_SE_NB_1
☐ <50> := Set point command, short floating point value	C_SE_NC_1
☐ <51> := Bitstring of 32 bits	C_BO_NA_1
☒ <58> := Single command with time tag CP56Time2a	C_SC_TA_1
☐ <59> := Double command with time tag CP56Time2a	C_DC_TA_1
☐ <60> := Regulating step command with time tag CP56Time2a	C_RC_TA_1
☐ <61> := Set point command, normalized value with time tag CP56Time2a	C_SE_TA_1
☐ <62> := Set point command, scaled value with time tag CP56Time2a	C_SE_TB_1
☐ <63> := Set point command, short floating point value with time tag CP56Time2a	C_SE_TC_1
☐ <64> := Bitstring of 32 bits with time tag CP56Time2a	C_BO_TA_1

Either the ASDUs of the set <45> to <51> or of the set <58> to <64> are used.

System information in monitor direction

☒ <70> := End of initialization	M_EI_NA_1

System information in control direction

☒ <100> := Interrogation command	C_IC_NA_1
☒ <101> := Counter interrogation command	C_CI_NA_1
☒ <102> := Read command	C_RD_NA_1
☒ <103> := Clock synchronization command (see Clause 7.6 in standard)	C_CS_NA_1
■ ~~<104> := Test command~~	~~C_TS_NA_1~~
☒ <105> := Reset process command	C_RP_NA_1
■ <106> := Delay acquisition command	C_CD_NA_1
☒ <107> := Test command with time tag CP56Time2a	C_TS_TA_1

Parameter in control direction

- ☐ <110> := Parameter of measured value, normalized value — PE_ME_NA_1
- ☐ <111> := Parameter of measured value, scaled value — PE_ME_NB_1
- ☒ <112> := Parameter of measured value, short floating point value — PE_ME_NC_1
- ☐ <113> := Parameter activation — PE_AC_NA_1

File transfer

- ☐ <120> := File Ready — F_FR_NA_1
- ☐ <121> := Section Ready — F_SR_NA_1
- ☐ <122> := Call directory, select file, call file, call section — F_SC_NA_1
- ☐ <123> := Last section, last segment — F_LS_NA_1
- ☐ <124> := Ack file, ack section — F_AF_NA_1
- ☐ <125> := Segment — F_SG_NA_1
- ☐ <126> := Directory (blank or X, available only in monitor [standard] direction) — C_CD_NA_1

Type identifier and cause of transmission assignments
(station-specific parameters)

In the following table:

- Shaded boxes are not required.
- Black boxes are not permitted in this companion standard.
- Blank boxes indicate functions or ASDU not used.
- '**X**' if only used in the standard direction

TYPE IDENTIFICATION		CAUSE OF TRANSMISSION																	
		PERIODIC, CYCLIC	BACKGROUND SCAN	SPONTANEOUS	INITIALIZED	REQUEST OR REQUESTED	ACTIVATION	ACTIVATION CONFIRMATION	DEACTIVATION	DEACTIVATION CONFIRMATION	ACTIVATION TERMINATION	RETURN INFO CAUSED BY LOCAL CMD	FILE TRANSFER	INTERROGATED BY GROUP <NUMBER>	REQUEST BY GROUP <N> COUNTER REQ	UNKNOWN TYPE IDENTIFICATION	UNKNOWN CAUSE OF TRANSMISSION	UNKNOWN COMMON ADDRESS OF ADSU	UNKNOWN INFORMATION OBJECT ADDR	UNKNOWN INFORMATION OBJECT ADDR
NO.	MNEMONIC	1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<1>	M_SP_NA_1			X		X						X	X		X					
<2>	M_SP_TA_1																			
<3>	M_DP_NA_1																			
<4>	M_DP_TA_1																			
<5>	M_ST_NA_1																			
<6>	M_ST_TA_1																			
<7>	M_BO_NA_1																			
<8>	M_BO_TA_1																			

TYPE IDENTIFICATION		CAUSE OF TRANSMISSION																	
		PERIODIC, CYCLIC	BACKGROUND SCAN	SPONTANEOUS	INITIALIZED	REQUEST OR REQUESTED	ACTIVATION	ACTIVATION CONFIRMATION	DEACTIVATION	DEACTIVATION CONFIRMATION	ACTIVATION TERMINATION	RETURN INFO CAUSED BY LOCAL CMD	FILE TRANSFER	INTERROGATED BY GROUP <NUMBER>	REQUEST BY GROUP <N> COUNTER REQ	UNKNOWN TYPE IDENTIFICATION	UNKNOWN CAUSE OF TRANSMISSION	UNKNOWN COMMON ADDRESS OF ADSU	UNKNOWN INFORMATION OBJECT ADDR	UNKNOWN INFORMATION OBJECT ADDR
NO.	MNEMONIC	1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<9>	M_ME_NA_1																			
<10>	M_ME_TA_1																			
<11>	M_ME_NB_1																			
<12>	M_ME_TB_1																			
<13>	M_ME_NC_1	X		X		X									X					
<14>	M_ME_TC_1																			
<15>	M_IT_NA_1			X												X				
<16>	M_IT_TA_1																			
<17>	M_EP_TA_1																			
<18>	M_EP_TB_1																			
<19>	M_EP_TC_1																			
<20>	M_PS_NA_1																			
<21>	M_ME_ND_1																			
<30>	M_SP_TB_1			X								X	X							
<31>	M_DP_TB_1																			
<32>	M_ST_TB_1																			
<33>	M_BO_TB_1																			
<34>	M_ME_TD_1																			
<35>	M_ME_TE_1																			
<36>	M_ME_TF_1																			
<37>	M_IT_TB_1			X												X				
<38>	M_EP_TD_1																			
<39>	M_EP_TE_1																			
<40>	M_EP_TF_1																			
<45>	C_SC_NA_1						X	X	X	X	X									
<46>	C_DC_NA_1																			
<47>	C_RC_NA_1																			
<48>	C_SE_NA_1																			
<49>	C_SE_NB_1																			

D

TYPE IDENTIFICATION		CAUSE OF TRANSMISSION																		
		PERIODIC, CYCLIC	BACKGROUND SCAN	SPONTANEOUS	INITIALIZED	REQUEST OR REQUESTED	ACTIVATION	ACTIVATION CONFIRMATION	DEACTIVATION	DEACTIVATION CONFIRMATION	ACTIVATION TERMINATION	RETURN INFO CAUSED BY LOCAL CMD	FILE TRANSFER	INTERROGATED BY GROUP <NUMBER>	REQUEST BY GROUP <N> COUNTER REQ	UNKNOWN TYPE IDENTIFICATION	UNKNOWN CAUSE OF TRANSMISSION	UNKNOWN COMMON ADDRESS OF ADSU	UNKNOWN INFORMATION OBJECT ADDR	UNKNOWN INFORMATION OBJECT ADDR
NO.	MNEMONIC	1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<50>	C_SE_NC_1																			
<51>	C_BO_NA_1																			
<58>	C_SC_TA_1						X	X	X	X	X									
<59>	C_DC_TA_1																			
<60>	C_RC_TA_1																			
<61>	C_SE_TA_1																			
<62>	C_SE_TB_1																			
<63>	C_SE_TC_1																			
<64>	C_BO_TA_1																			
<70>	M_EI_NA_1*)				X															
<100>	C_IC_NA_1						X	X	X	X	X									
<101>	C_CI_NA_1						X	X			X									
<102>	C_RD_NA_1					X														
<103>	C_CS_NA_1			X			X	X												
<104>	C_TS_NA_1																			
<105>	C_RP_NA_1						X	X												
<106>	C_CD_NA_1																			
<107>	C_TS_TA_1																			
<110>	P_ME_NA_1																			
<111>	P_ME_NB_1																			
<112>	P_ME_NC_1						X	X							X					
<113>	P_AC_NA_1																			
<120>	F_FR_NA_1																			
<121>	F_SR_NA_1																			
<122>	F_SC_NA_1																			
<123>	F_LS_NA_1																			
<124>	F_AF_NA_1																			
<125>	F_SG_NA_1																			
<126>	F_DR_TA_1*)																			

6. BASIC APPLICATION FUNCTIONS

Station Initialization:

☒ Remote initialization

Cyclic Data Transmission:

☒ Cyclic data transmission

Read Procedure:

☒ Read procedure

Spontaneous Transmission:

☒ Spontaneous transmission

Double transmission of information objects with cause of transmission spontaneous:

The following type identifications may be transmitted in succession caused by a single status change of an information object. The particular information object addresses for which double transmission is enabled are defined in a project-specific list.

☐ Single point information: M_SP_NA_1, M_SP_TA_1, M_SP_TB_1, and M_PS_NA_1

☐ Double point information: M_DP_NA_1, M_DP_TA_1, and M_DP_TB_1

☐ Step position information: M_ST_NA_1, M_ST_TA_1, and M_ST_TB_1

☐ Bitstring of 32 bits: M_BO_NA_1, M_BO_TA_1, and M_BO_TB_1 (if defined for a specific project)

☐ Measured value, normalized value: M_ME_NA_1, M_ME_TA_1, M_ME_ND_1, and M_ME_TD_1

☐ Measured value, scaled value: M_ME_NB_1, M_ME_TB_1, and M_ME_TE_1

☐ Measured value, short floating point number: M_ME_NC_1, M_ME_TC_1, and M_ME_TF_1

Station interrogation:

☒ Global

☒ Group 1	☒ Group 5	☒ Group 9	☒ Group 13
☒ Group 2	☒ Group 6	☒ Group 10	☒ Group 14
☒ Group 3	☒ Group 7	☒ Group 11	☒ Group 15
☒ Group 4	☒ Group 8	☒ Group 12	☒ Group 16

Clock synchronization:

☒ Clock synchronization (optional, see Clause 7.6)

Command transmission:

☒ Direct command transmission

☐ Direct setpoint command transmission

☒ Select and execute command

☐ Select and execute setpoint command

☒ C_SE ACTTERM used

☒ No additional definition

☒ Short pulse duration (duration determined by a system parameter in the outstation)

☒ Long pulse duration (duration determined by a system parameter in the outstation)

☒ Persistent output

☒ Supervision of maximum delay in command direction of commands and setpoint commands

Maximum allowable delay of commands and setpoint commands: **10 s**

Transmission of integrated totals:

- ☒ Mode A: Local freeze with spontaneous transmission
- ☒ Mode B: Local freeze with counter interrogation
- ☒ Mode C: Freeze and transmit by counter-interrogation commands
- ☒ Mode D: Freeze by counter-interrogation command, frozen values reported simultaneously

- ☒ Counter read
- ☒ Counter freeze without reset
- ☒ Counter freeze with reset
- ☒ Counter reset

- ☒ General request counter
- ☒ Request counter group 1
- ☒ Request counter group 2
- ☒ Request counter group 3
- ☒ Request counter group 4

Parameter loading:

- ☒ Threshold value
- ☐ Smoothing factor
- ☐ Low limit for transmission of measured values
- ☐ High limit for transmission of measured values

Parameter activation:

- ☐ Activation/deactivation of persistent cyclic or periodic transmission of the addressed object

Test procedure:

- ☐ Test procedure

File transfer:

File transfer in monitor direction:

- ☐ Transparent file
- ☐ Transmission of disturbance data of protection equipment
- ☐ Transmission of sequences of events
- ☐ Transmission of sequences of recorded analog values

File transfer in control direction:

- ☐ Transparent file

Background scan:

- ☐ Background scan

Acquisition of transmission delay:

- ■ ~~Acquisition of transmission delay~~

Definition of time outs:

PARAMETER	DEFAULT VALUE	REMARKS	SELECTED VALUE
t_0	30 s	Timeout of connection establishment	120 s
t_1	15 s	Timeout of send or test APDUs	15 s
t_2	10 s	Timeout for acknowlegements in case of no data messages $t_2 < t_1$	10 s
t_3	20 s	Timeout for sending test frames in case of a long idle state	20 s

Maximum range of values for all time outs: 1 to 255 s, accuracy 1 s

Maximum number of outstanding I-format APDUs *k* and latest acknowledge APDUs (*w*):

PARAMETER	DEFAULT VALUE	REMARKS	SELECTED VALUE
k	12 APDUs	Maximum difference receive sequence number to send state variable	12 APDUs
w	8 APDUs	Latest acknowledge after receiving *w* I-format APDUs	8 APDUs

Maximum range of values *k*: 1 to 32767 ($2^{15} - 1$) APDUs, accuracy 1 APDU

Maximum range of values *w*: 1 to 32767 APDUs, accuracy 1 APDU
Recommendation: *w* should not exceed two-thirds of *k*.

Portnumber:

PARAMETER	VALUE	REMARKS
Portnumber	2404	In all cases

RFC 2200 suite:

RFC 2200 is an official Internet Standard which describes the state of standardization of protocols used in the Internet as determined by the Internet Architecture Board (IAB). It offers a broad spectrum of actual standards used in the Internet. The suitable selection of documents from RFC 2200 defined in this standard for given projects has to be chosen by the user of this standard.

- ☒ Ethernet 802.3
- ☐ Serial X.21 interface
- ☐ Other selection(s) from RFC 2200 (list below if selected)

Table D–1: IEC 60870-5-104 POINTS LIST (Sheet 1 of 4)

POINTS	DESCRIPTION	UNITS
M_ME_NC_1 POINTS		
2000	SRC 1 Phase A Current RMS	A
2001	SRC 1 Phase B Current RMS	A
2002	SRC 1 Phase C Current RMS	A
2003	SRC 1 Neutral Current RMS	A
2004	SRC 1 Phase A Current Magnitude	A
2005	SRC 1 Phase A Current Angle	degrees
2006	SRC 1 Phase B Current Magnitude	A
2007	SRC 1 Phase B Current Angle	degrees
2008	SRC 1 Phase C Current Magnitude	A
2009	SRC 1 Phase C Current Angle	degrees
2010	SRC 1 Neutral Current Magnitude	A
2011	SRC 1 Neutral Current Angle	degrees
2012	SRC 1 Ground Current RMS	A
2013	SRC 1 Ground Current Magnitude	A
2014	SRC 1 Ground Current Angle	degrees
2015	SRC 1 Zero Seq Current Magnitude	A
2016	SRC 1 Zero Sequence Current Angle	degrees
2017	SRC 1 Positive Seq Current Magnitude	A
2018	SRC 1 Positive Seq Current Angle	degrees
2019	SRC 1 Negative Seq Current Magnitude	A
2020	SRC 1 Negative Seq Current Angle	degrees
2021	SRC 1 Diff Ground Current Magnitude	A
2022	SRC 1 Diff Ground Current Angle	degrees
2023	SRC 1 Phase AG Voltage RMS	V
2024	SRC 1 Phase BG Voltage RMS	V
2025	SRC 1 Phase CG Voltage RMS	V
2026	SRC 1 Phase AG Voltage Magnitude	V
2027	SRC 1 Phase AG Voltage Angle	degrees
2028	SRC 1 Phase BG Voltage Magnitude	V
2029	SRC 1 Phase BG Voltage Angle	degrees
2030	SRC 1 Phase CG Voltage Magnitude	V
2031	SRC 1 Phase CG Voltage Angle	degrees
2032	SRC 1 Phase AB Voltage RMS	V
2033	SRC 1 Phase BC Voltage RMS	V
2034	SRC 1 Phase CA Voltage RMS	V
2035	SRC 1 Phase AB Voltage Magnitude	V
2036	SRC 1 Phase AB Voltage Angle	degrees
2037	SRC 1 Phase BC Voltage Magnitude	V
2038	SRC 1 Phase BC Voltage Angle	degrees
2039	SRC 1 Phase CA Voltage Magnitude	V
2040	SRC 1 Phase CA Voltage Angle	degrees
2041	SRC 1 Auxiliary Voltage RMS	V
2042	SRC 1 Auxiliary Voltage Magnitude	V
2043	SRC 1 Auxiliary Voltage Angle	degrees
2044	SRC 1 Zero Seq Voltage Magnitude	V

Table D–1: IEC 60870-5-104 POINTS LIST (Sheet 2 of 4)

POINTS	DESCRIPTION	UNITS
2045	SRC 1 Zero Sequence Voltage Angle	degrees
2046	SRC 1 Positive Seq Voltage Magnitude	V
2047	SRC 1 Positive Seq Voltage Angle	degrees
2048	SRC 1 Negative Seq Voltage Magnitude	V
2049	SRC 1 Negative Seq Voltage Angle	degrees
2050	SRC 1 Three Phase Real Power	W
2051	SRC 1 Phase A Real Power	W
2052	SRC 1 Phase B Real Power	W
2053	SRC 1 Phase C Real Power	W
2054	SRC 1 Three Phase Reactive Power	var
2055	SRC 1 Phase A Reactive Power	var
2056	SRC 1 Phase B Reactive Power	var
2057	SRC 1 Phase C Reactive Power	var
2058	SRC 1 Three Phase Apparent Power	VA
2059	SRC 1 Phase A Apparent Power	VA
2060	SRC 1 Phase B Apparent Power	VA
2061	SRC 1 Phase C Apparent Power	VA
2062	SRC 1 Three Phase Power Factor	none
2063	SRC 1 Phase A Power Factor	none
2064	SRC 1 Phase B Power Factor	none
2065	SRC 1 Phase C Power Factor	none
2066	SRC 1 Frequency	Hz
2067	Breaker 1 Arcing Amp Phase A	kA2-cyc
2068	Breaker 1 Arcing Amp Phase B	kA2-cyc
2069	Breaker 1 Arcing Amp Phase C	kA2-cyc
2070	Breaker 2 Arcing Amp Phase A	kA2-cyc
2071	Breaker 2 Arcing Amp Phase B	kA2-cyc
2072	Breaker 2 Arcing Amp Phase C	kA2-cyc
2073	Synchrocheck 1 Delta Voltage	V
2074	Synchrocheck 1 Delta Frequency	Hz
2075	Synchrocheck 1 Delta Phase	degrees
2076	Synchrocheck 2 Delta Voltage	V
2077	Synchrocheck 2 Delta Frequency	Hz
2078	Synchrocheck 2 Delta Phase	degrees
2079	Power Swing S1 S2 Angle	degrees
2080	Local IA Magnitude	A
2081	Local IB Magnitude	A
2082	Local IC Magnitude	A
2083	Remote1 IA Magnitude	A
2084	Remote1 IB Magnitude	A
2085	Remote1 IC Magnitude	A
2086	Remote2 IA Magnitude	A
2087	Remote2 IB Magnitude	A
2088	Remote2 IC Magnitude	A
2089	Differential Current IA Magnitude	A
2090	Differential Current IB Magnitude	A

Table D–1: IEC 60870-5-104 POINTS LIST (Sheet 3 of 4)

POINTS	DESCRIPTION	UNITS
2091	Differential Current IC Magnitude	A
2092	Local IA Angle	degrees
2093	Local IB Angle	degrees
2094	Local IC Angle	degrees
2095	Remote1 IA Angle	degrees
2096	Remote1 IB Angle	degrees
2097	Remote1 IC Angle	degrees
2098	Remote2 IA Angle	degrees
2099	Remote2 IB Angle	degrees
2100	Remote2 IC Angle	degrees
2101	Differential Current IA Angle	degrees
2102	Differential Current IB Angle	degrees
2103	Differential Current IC Angle	degrees
2104	Op Square Current IA	
2105	Op Square Current IB	
2106	Op Square Current IC	
2107	Restraint Square Current IA	
2108	Restraint Square Current IB	
2109	Restraint Square Current IC	
2110	Tracking Frequency	Hz
2111	FlexElement 1 Actual	none
2112	FlexElement 2 Actual	none
2113	FlexElement 3 Actual	none
2114	FlexElement 4 Actual	none
2115	FlexElement 5 Actual	none
2116	FlexElement 6 Actual	none
2117	FlexElement 7 Actual	none
2118	FlexElement 8 Actual	none
2119	FlexElement 9 Actual	none
2120	FlexElement 10 Actual	none
2121	FlexElement 11 Actual	none
2122	FlexElement 12 Actual	none
2123	FlexElement 13 Actual	none
2124	FlexElement 14 Actual	none
2125	FlexElement 15 Actual	none
2126	FlexElement 16 Actual	none
2127	Current Setting Group	none
P_ME_NC_1 POINTS		
5000 - 5127	Threshold values for M_ME_NC_1 points	-
M_SP_NA_1 POINTS		
100 - 115	Virtual Input States[0]	-
116 - 131	Virtual Input States[1]	-
132 - 147	Virtual Output States[0]	-
148 - 163	Virtual Output States[1]	-
164 - 179	Virtual Output States[2]	-
180 - 195	Virtual Output States[3]	-
196 - 211	Contact Input States[0]	-
212 - 227	Contact Input States[1]	-
228 - 243	Contact Input States[2]	-

Table D–1: IEC 60870-5-104 POINTS LIST (Sheet 4 of 4)

POINTS	DESCRIPTION	UNITS
244 - 259	Contact Input States[3]	-
260 - 275	Contact Input States[4]	-
276 - 291	Contact Input States[5]	-
292 - 307	Contact Output States[0]	-
308 - 323	Contact Output States[1]	-
324 - 339	Contact Output States[2]	-
340 - 355	Contact Output States[3]	-
356 - 371	Remote Input x States[0]	-
372 - 387	Remote Input x States[1]	-
388 - 403	Remote Device x States	-
404 - 419	LED Column x State[0]	-
420 - 435	LED Column x State[1]	-
C_SC_NA_1 POINTS		
Points	Description	-
1100 - 1115	Virtual Input States[0] - No Select Required	-
1116 - 1131	Virtual Input States[1] - Select Required	-
M_IT_NA_1 POINTS		
Point	Description	-
4000	Digital Counter 1 Value	-
4001	Digital Counter 2 Value	-
4002	Digital Counter 3 Value	-
4003	Digital Counter 4 Value	-
4004	Digital Counter 5 Value	-
4005	Digital Counter 6 Value	-
4006	Digital Counter 7 Value	-
4007	Digital Counter 8 Value	-

E.1.1 DNP V3.00 DEVICE PROFILE

The following table provides a "Device Profile Document" in the standard format defined in the DNP 3.0 Subset Definitions Document.

Table E–1: DNP V3.00 DEVICE PROFILE (Sheet 1 of 3)

(Also see the IMPLEMENTATION TABLE in the following section)	
Vendor Name: **General Electric Power Management**	
Device Name: **UR Series Relay**	
Highest DNP Level Supported: For Requests: **Level 2** For Responses: **Level 2**	**Device Function:** ☐ Master ☒ **Slave**
Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table): **Binary Inputs (Object 1)** **Binary Input Changes (Object 2)** **Binary Outputs (Object 10)** **Binary Counters (Object 20)** **Frozen Counters (Object 21)** **Counter Change Event (Object 22)** **Frozen Counter Event (Object 23)** **Analog Inputs (Object 30)** **Analog Input Changes (Object 32)** **Analog Deadbands (Object 34)**	
Maximum Data Link Frame Size (octets): Transmitted: **292** Received: **292**	**Maximum Application Fragment Size (octets):** Transmitted: **240** Received: **2048**
Maximum Data Link Re-tries: ☐ **None** ☒ Fixed at 2 ☐ Configurable	**Maximum Application Layer Re-tries:** ☒ None ☐ Configurable
Requires Data Link Layer Confirmation: ☒ Never ☐ Always ☐ Sometimes ☐ Configurable	

Table E–1: DNP V3.00 DEVICE PROFILE (Sheet 2 of 3)

Requires Application Layer Confirmation:

- ☐ Never
- ☐ Always
- ☒ When reporting Event Data
- ☒ When sending multi-fragment responses
- ☐ Sometimes
- ☐ Configurable

Timeouts while waiting for:

Data Link Confirm:	☐ None	☒ **Fixed at 3 s**	☐ Variable	☐ Configurable
Complete Appl. Fragment:	☒ **None**	☐ Fixed at ____	☐ Variable	☐ Configurable
Application Confirm:	☐ None	☒ **Fixed at 4 s**	☐ Variable	☐ Configurable
Complete Appl. Response:	☒ **None**	☐ Fixed at ____	☐ Variable	☐ Configurable

Others:

Transmission Delay:	**No intentional delay**
Inter-character Timeout:	**50 ms**
Need Time Delay:	**Configurable (default = 24 hrs.)**
Select/Operate Arm Timeout:	**10 s**
Binary input change scanning period:	**8 times per power system cycle**
Packed binary change process period:	**1 s**
Analog input change scanning period:	**500 ms**
Counter change scanning period:	**500 ms**
Frozen counter event scanning period:	**500 ms**
Unsolicited response notification delay:	**500 ms**
Unsolicited response retry delay	**configurable 0 to 60 sec.**

Sends/Executes Control Operations:

WRITE Binary Outputs	☒ **Never**	☐ Always	☐ Sometimes	☐ Configurable
SELECT/OPERATE	☐ Never	☒ **Always**	☐ Sometimes	☐ Configurable
DIRECT OPERATE	☐ Never	☒ **Always**	☐ Sometimes	☐ Configurable
DIRECT OPERATE – NO ACK	☐ Never	☒ **Always**	☐ Sometimes	☐ Configurable

Count > 1	☒ **Never**	☐ Always	☐ Sometimes	☐ Configurable
Pulse On	☐ Never	☐ Always	☒ **Sometimes**	☐ Configurable
Pulse Off	☐ Never	☐ Always	☒ **Sometimes**	☐ Configurable
Latch On	☐ Never	☐ Always	☒ **Sometimes**	☐ Configurable
Latch Off	☐ Never	☐ Always	☒ **Sometimes**	☐ Configurable
Queue	☒ **Never**	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ **Never**	☐ Always	☐ Sometimes	☐ Configurable

Explanation of 'Sometimes': Object 12 points are mapped to UR Virtual Inputs. The persistence of Virtual Inputs is determined by the **VIRTUAL INPUT X TYPE** settings. Both "Pulse On" and "Latch On" operations perform the same function in the UR; that is, the appropriate Virtual Input is put into the "On" state. If the Virtual Input is set to "Self-Reset", it will reset after one pass of FlexLogic™. The On/Off times and Count value are ignored. "Pulse Off" and "Latch Off" operations put the appropriate Virtual Input into the "Off" state. "Trip" and "Close" operations both put the appropriate Virtual Input into the "On" state.

Table E–1: DNP V3.00 DEVICE PROFILE (Sheet 3 of 3)

Reports Binary Input Change Events when no specific variation requested: ❒ Never ☒ **Only time-tagged** ❒ Only non-time-tagged ❒ Configurable	**Reports time-tagged Binary Input Change Events when no specific variation requested:** ❒ Never ☒ Binary Input Change With Time ❒ Binary Input Change With Relative Time ❒ Configurable (attach explanation)
Sends Unsolicited Responses: ❒ **Never** ☒ Configurable ❒ Only certain objects ❒ Sometimes (attach explanation) ☒ ENABLE/DISABLE unsolicited Function codes supported	**Sends Static Data in Unsolicited Responses:** ☒ Never ❒ When Device Restarts ❒ When Status Flags Change No other options are permitted.
Default Counter Object/Variation: ❒ No Counters Reported ❒ Configurable (attach explanation) ☒ **Default Object: 20** **Default Variation: 1** ☒ **Point-by-point list attached**	**Counters Roll Over at:** ❒ No Counters Reported ❒ Configurable (attach explanation) ☒ **16 Bits (Counter 8)** ☒ **32 Bits (Counters 0 to 7, 9)** ❒ Other Value: _____ ☒ **Point-by-point list attached**
Sends Multi-Fragment Responses: ☒ **Yes** ❒ No	

E.2.1 IMPLEMENTATION TABLE

The following table identifies the variations, function codes, and qualifiers supported by the UR in both request messages and in response messages. For static (non-change-event) objects, requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01. Static object requests sent with qualifiers 17 or 28 will be responded with qualifiers 17 or 28. For change-event objects, qualifiers 17 or 28 are always responded.

Table E–2: IMPLEMENTATION TABLE (Sheet 1 of 4)

OBJECT			REQUEST		RESPONSE	
OBJECT NO.	VARIATION NO.	DESCRIPTION	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)
1	0	Binary Input (Variation 0 is used to request default variation)	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	1	Binary Input	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	2	Binary Input with Status *(default – see Note 1)*	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
2	0	Binary Input Change (Variation 0 is used to request default variation)	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
	1	Binary Input Change without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	2	Binary Input Change with Time *(default – see Note 1)*	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response 130 (unsol. resp.)	17, 28 (index)
10	0	Binary Output Status (Variation 0 is used to request default variation)	1 (read)	00, 01(start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	2	Binary Output Status *(default – see Note 1)*	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
12	1	Control Relay Output Block	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, noack)	00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	echo of request
20	0	Binary Counter (Variation 0 is used to request default variation)	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01(start-stop) 06(no range, or all) 07, 08(limited qty) 17, 28(index)		
	1	32-Bit Binary Counter *(default – see Note 1)*	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*

Note 1: A Default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Type 30 (Analog Input) data is limited to data that is actually possible to be used in the UR, based on the product order code. For example, Signal Source data from source numbers that cannot be used is not included. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the UR is not restarted, but the DNP process is restarted.

Table E–2: IMPLEMENTATION TABLE (Sheet 2 of 4)

OBJECT			REQUEST		RESPONSE	
OBJECT NO.	VARIATION NO.	DESCRIPTION	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)
20 con't	2	16-Bit Binary Counter	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	5	32-Bit Binary Counter without Flag	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	6	16-Bit Binary Counter without Flag	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
21	0	Frozen Counter (Variation 0 is used to request default variation)	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	1	32-Bit Frozen Counter *(default – see Note 1)*	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	2	16-Bit Frozen Counter	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	9	32-Bit Frozen Counter without Flag	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	10	16-Bit Frozen Counter without Flag	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
22	0	Counter Change Event (Variation 0 is used to request default variation)	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
	1	32-Bit Counter Change Event *(default – see Note 1)*	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	5	32-Bit Counter Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
23	0	Frozen Counter Event (Variation 0 is used to request default variation)	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
	1	32-Bit Frozen Counter Event *(default – see Note 1)*	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	5	32-Bit Frozen Counter Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)

Note 1: A Default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Type 30 (Analog Input) data is limited to data that is actually possible to be used in the UR, based on the product order code. For example, Signal Source data from source numbers that cannot be used is not included. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the UR is not restarted, but the DNP process is restarted.

Table E–2: IMPLEMENTATION TABLE (Sheet 3 of 4)

OBJECT			REQUEST		RESPONSE	
OBJECT NO.	VARIATION NO.	DESCRIPTION	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)
30	0	Analog Input (Variation 0 is used to request default variation)	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	1	32-Bit Analog Input *(default – see Note 1)*	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	2	16-Bit Analog Input	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	3	32-Bit Analog Input without Flag	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	4	16-Bit Analog Input without Flag	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	5	short floating point	1 (read) 22 (assign class)	00, 01 (start-stop) 06(no range, or all) 07, 08(limited qty) 17, 28(index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
32	0	Analog Change Event (Variation 0 is used to request default variation)	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
	1	32-Bit Analog Change Event without Time *(default – see Note 1)*	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	2	16-Bit Analog Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	3	32-Bit Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	4	16-Bit Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	5	short floating point Analog Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	7	short floating point Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
34	0	Analog Input Reporting Deadband (Variation 0 is used to request default variation)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	1	16-bit Analog Input Reporting Deadband (default – see Note 1)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
			2 (write)	00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)		

Note 1: A Default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Type 30 (Analog Input) data is limited to data that is actually possible to be used in the UR, based on the product order code. For example, Signal Source data from source numbers that cannot be used is not included. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the UR is not restarted, but the DNP process is restarted.

Table E–2: IMPLEMENTATION TABLE (Sheet 4 of 4)

OBJECT			REQUEST		RESPONSE	
OBJECT NO.	VARIATION NO.	DESCRIPTION	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)
34 con't	2	32-bit Analog Input Reporting Deadband (default – see Note 1)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
			2 (write)	00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)		
	3	Short floating point Analog Input Reporting Deadband	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
50	0	Time and Date	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	1	Time and Date (default – see Note 1)	1 (read) 2 (write)	00, 01 (start-stop) 06 (no range, or all) 07 (limited qty=1) 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
52	2	Time Delay Fine			129 (response)	07 (limited qty) (qty = 1)
60	0	Class 0, 1, 2, and 3 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all)		
	1	Class 0 Data	1 (read) 22 (assign class)	06 (no range, or all)		
	2	Class 1 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07, 08 (limited qty)		
	3	Class 2 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07, 08 (limited qty)		
	4	Class 3 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07, 08 (limited qty)		
80	1	Internal Indications	2 (write)	00 (start-stop) (index must =7)		
---		No Object (function code only) *see Note 3*	13 (cold restart)			
---		No Object (function code only)	14 (warm restart)			
---		No Object (function code only)	23 (delay meas.)			

Note 1: A Default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Type 30 (Analog Input) data is limited to data that is actually possible to be used in the UR, based on the product order code. For example, Signal Source data from source numbers that cannot be used is not included. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the UR is not restarted, but the DNP process is restarted.

E.3.1 BINARY INPUT POINTS

The following table lists both Binary Counters (Object 20) and Frozen Counters (Object 21). When a freeze function is performed on a Binary Counter point, the frozen value is available in the corresponding Frozen Counter point.

BINARY INPUT POINTS

Static (Steady-State) Object Number: **1**

Change Event Object Number: **2**

Request Function Codes supported: **1 (read), 22 (assign class)**

Static Variation reported when variation 0 requested: **2 (Binary Input with status)**

Change Event Variation reported when variation 0 requested: **2 (Binary Input Change with Time)**

Change Event Scan Rate: **8 times per power system cycle**

Change Event Buffer Size: **1000**

Table E–3: BINARY INPUTS (Sheet 1 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
0	Virtual Input 1	2
1	Virtual Input 2	2
2	Virtual Input 3	2
3	Virtual Input 4	2
4	Virtual Input 5	2
5	Virtual Input 6	2
6	Virtual Input 7	2
7	Virtual Input 8	2
8	Virtual Input 9	2
9	Virtual Input 10	2
10	Virtual Input 11	2
11	Virtual Input 12	2
12	Virtual Input 13	2
13	Virtual Input 14	2
14	Virtual Input 15	2
15	Virtual Input 16	2
16	Virtual Input 17	2
17	Virtual Input 18	2
18	Virtual Input 19	2
19	Virtual Input 20	2
20	Virtual Input 21	2
21	Virtual Input 22	2
22	Virtual Input 23	2
23	Virtual Input 24	2
24	Virtual Input 25	2
25	Virtual Input 26	2
26	Virtual Input 27	2
27	Virtual Input 28	2
28	Virtual Input 29	2
29	Virtual Input 30	2
30	Virtual Input 31	2
31	Virtual Input 32	2

Table E–3: BINARY INPUTS (Sheet 2 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
32	Virtual Output 1	2
33	Virtual Output 2	2
34	Virtual Output 3	2
35	Virtual Output 4	2
36	Virtual Output 5	2
37	Virtual Output 6	2
38	Virtual Output 7	2
39	Virtual Output 8	2
40	Virtual Output 9	2
41	Virtual Output 10	2
42	Virtual Output 11	2
43	Virtual Output 12	2
44	Virtual Output 13	2
45	Virtual Output 14	2
46	Virtual Output 15	2
47	Virtual Output 16	2
48	Virtual Output 17	2
49	Virtual Output 18	2
50	Virtual Output 19	2
51	Virtual Output 20	2
52	Virtual Output 21	2
53	Virtual Output 22	2
54	Virtual Output 23	2
55	Virtual Output 24	2
56	Virtual Output 25	2
57	Virtual Output 26	2
58	Virtual Output 27	2
59	Virtual Output 28	2
60	Virtual Output 29	2
61	Virtual Output 30	2
62	Virtual Output 31	2
63	Virtual Output 32	2

Table E–3: BINARY INPUTS (Sheet 3 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
64	Virtual Output 33	2
65	Virtual Output 34	2
66	Virtual Output 35	2
67	Virtual Output 36	2
68	Virtual Output 37	2
69	Virtual Output 38	2
70	Virtual Output 39	2
71	Virtual Output 40	2
72	Virtual Output 41	2
73	Virtual Output 42	2
74	Virtual Output 43	2
75	Virtual Output 44	2
76	Virtual Output 45	2
77	Virtual Output 46	2
78	Virtual Output 47	2
79	Virtual Output 48	2
80	Virtual Output 49	2
81	Virtual Output 50	2
82	Virtual Output 51	2
83	Virtual Output 52	2
84	Virtual Output 53	2
85	Virtual Output 54	2
86	Virtual Output 55	2
87	Virtual Output 56	2
88	Virtual Output 57	2
89	Virtual Output 58	2
90	Virtual Output 59	2
91	Virtual Output 60	2
92	Virtual Output 61	2
93	Virtual Output 62	2
94	Virtual Output 63	2
95	Virtual Output 64	2
96	Contact Input 1	1
97	Contact Input 2	1
98	Contact Input 3	1
99	Contact Input 4	1
100	Contact Input 5	1
101	Contact Input 6	1
102	Contact Input 7	1
103	Contact Input 8	1
104	Contact Input 9	1
105	Contact Input 10	1
106	Contact Input 11	1
107	Contact Input 12	1
108	Contact Input 13	1
109	Contact Input 14	1
110	Contact Input 15	1
111	Contact Input 16	1
112	Contact Input 17	1
113	Contact Input 18	1
114	Contact Input 19	1

Table E–3: BINARY INPUTS (Sheet 4 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
115	Contact Input 20	1
116	Contact Input 21	1
117	Contact Input 22	1
118	Contact Input 23	1
119	Contact Input 24	1
120	Contact Input 25	1
121	Contact Input 26	1
122	Contact Input 27	1
123	Contact Input 28	1
124	Contact Input 29	1
125	Contact Input 30	1
126	Contact Input 31	1
127	Contact Input 32	1
128	Contact Input 33	1
129	Contact Input 34	1
130	Contact Input 35	1
131	Contact Input 36	1
132	Contact Input 37	1
133	Contact Input 38	1
134	Contact Input 39	1
135	Contact Input 40	1
136	Contact Input 41	1
137	Contact Input 42	1
138	Contact Input 43	1
139	Contact Input 44	1
140	Contact Input 45	1
141	Contact Input 46	1
142	Contact Input 47	1
143	Contact Input 48	1
144	Contact Input 49	1
145	Contact Input 50	1
146	Contact Input 51	1
147	Contact Input 52	1
148	Contact Input 53	1
149	Contact Input 54	1
150	Contact Input 55	1
151	Contact Input 56	1
152	Contact Input 57	1
153	Contact Input 58	1
154	Contact Input 59	1
155	Contact Input 60	1
156	Contact Input 61	1
157	Contact Input 62	1
158	Contact Input 63	1
159	Contact Input 64	1
160	Contact Input 65	1
161	Contact Input 66	1
162	Contact Input 67	1
163	Contact Input 68	1
164	Contact Input 69	1
165	Contact Input 70	1

Table E–3: BINARY INPUTS (Sheet 5 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
166	Contact Input 71	1
167	Contact Input 72	1
168	Contact Input 73	1
169	Contact Input 74	1
170	Contact Input 75	1
171	Contact Input 76	1
172	Contact Input 77	1
173	Contact Input 78	1
174	Contact Input 79	1
175	Contact Input 80	1
176	Contact Input 81	1
177	Contact Input 82	1
178	Contact Input 83	1
179	Contact Input 84	1
180	Contact Input 85	1
181	Contact Input 86	1
182	Contact Input 87	1
183	Contact Input 88	1
184	Contact Input 89	1
185	Contact Input 90	1
186	Contact Input 91	1
187	Contact Input 92	1
188	Contact Input 93	1
189	Contact Input 94	1
190	Contact Input 95	1
191	Contact Input 96	1
192	Contact Output 1	1
193	Contact Output 2	1
194	Contact Output 3	1
195	Contact Output 4	1
196	Contact Output 5	1
197	Contact Output 6	1
198	Contact Output 7	1
199	Contact Output 8	1
200	Contact Output 9	1
201	Contact Output 10	1
202	Contact Output 11	1
203	Contact Output 12	1
204	Contact Output 13	1
205	Contact Output 14	1
206	Contact Output 15	1
207	Contact Output 16	1
208	Contact Output 17	1
209	Contact Output 18	1
210	Contact Output 19	1
211	Contact Output 20	1
212	Contact Output 21	1
213	Contact Output 22	1
214	Contact Output 23	1
215	Contact Output 24	1
216	Contact Output 25	1

Table E–3: BINARY INPUTS (Sheet 6 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
217	Contact Output 26	1
218	Contact Output 27	1
219	Contact Output 28	1
220	Contact Output 29	1
221	Contact Output 30	1
222	Contact Output 31	1
223	Contact Output 32	1
224	Contact Output 33	1
225	Contact Output 34	1
226	Contact Output 35	1
227	Contact Output 36	1
228	Contact Output 37	1
229	Contact Output 38	1
230	Contact Output 39	1
231	Contact Output 40	1
232	Contact Output 41	1
233	Contact Output 42	1
234	Contact Output 43	1
235	Contact Output 44	1
236	Contact Output 45	1
237	Contact Output 46	1
238	Contact Output 47	1
239	Contact Output 48	1
240	Contact Output 49	1
241	Contact Output 50	1
242	Contact Output 51	1
243	Contact Output 52	1
244	Contact Output 53	1
245	Contact Output 54	1
246	Contact Output 55	1
247	Contact Output 56	1
248	Contact Output 57	1
249	Contact Output 58	1
250	Contact Output 59	1
251	Contact Output 60	1
252	Contact Output 61	1
253	Contact Output 62	1
254	Contact Output 63	1
255	Contact Output 64	1
256	Remote Input 1	1
257	Remote Input 2	1
258	Remote Input 3	1
259	Remote Input 4	1
260	Remote Input 5	1
261	Remote Input 6	1
262	Remote Input 7	1
263	Remote Input 8	1
264	Remote Input 9	1
265	Remote Input 10	1
266	Remote Input 11	1
267	Remote Input 12	1

Table E–3: BINARY INPUTS (Sheet 7 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
268	Remote Input 13	1
269	Remote Input 14	1
270	Remote Input 15	1
271	Remote Input 16	1
272	Remote Input 17	1
273	Remote Input 18	1
274	Remote Input 19	1
275	Remote Input 20	1
276	Remote Input 21	1
277	Remote Input 22	1
278	Remote Input 23	1
279	Remote Input 24	1
280	Remote Input 25	1
281	Remote Input 26	1
282	Remote Input 27	1
283	Remote Input 28	1
284	Remote Input 29	1
285	Remote Input 30	1
286	Remote Input 31	1
287	Remote Input 32	1
288	Remote Device 1	1
289	Remote Device 2	1
290	Remote Device 3	1
291	Remote Device 4	1
292	Remote Device 5	1
293	Remote Device 6	1
294	Remote Device 7	1
295	Remote Device 8	1
296	Remote Device 9	1
297	Remote Device 10	1
298	Remote Device 11	1
299	Remote Device 12	1
300	Remote Device 13	1
301	Remote Device 14	1
302	Remote Device 15	1
303	Remote Device 16	1
304	PHASE IOC1 Element OP	1
305	PHASE IOC2 Element OP	1
320	PHASE TOC1 Element OP	1
321	PHASE TOC2 Element OP	1
328	PH DIR1 Element OP	1
329	PH DIR2 Element OP	1
336	NEUTRAL IOC1 Element OP	1
337	NEUTRAL IOC2 Element OP	1
352	NEUTRAL TOC1 Element OP	1
353	NEUTRAL TOC2 Element OP	1
360	NTRL DIR OC1 Element OP	1
361	NTRL DIR OC2 Element OP	1
368	GROUND IOC1 Element OP	1
369	GROUND IOC2 Element OP	1
384	GROUND TOC1 Element OP	1

Table E–3: BINARY INPUTS (Sheet 8 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
385	GROUND TOC2 Element OP	1
400	NEG SEQ IOC1 Element OP	1
401	NEG SEQ IOC2 Element OP	1
416	NEG SEQ TOC1 Element OP	1
417	NEG SEQ TOC2 Element OP	1
444	AUX UV1 Element OP	1
448	PHASE UV1 Element OP	1
449	PHASE UV2 Element OP	1
452	AUX OV1 Element OP	1
456	PHASE OV1 Element OP	1
460	NEUTRAL OV1 Element OP	1
465	PH DIST Z2 Element OP	1
472	LINE PICKUP Element OP	1
481	GND DIST Z2 Element OP	1
484	LOAD ENCHR Element OP	1
490	POTT Element OP	1
494	POWER SWING Element OP	1
528	SRC1 VT FUSE FAIL Elem OP	1
529	SRC2 VT FUSE FAIL Elem OP	1
530	SRC3 VT FUSE FAIL Elem OP	1
531	SRC4 VT FUSE FAIL Elem OP	1
532	SRC5 VT FUSE FAIL Elem OP	1
533	SRC6 VT FUSE FAIL Elem OP	1
536	SRC1 50DD Element OP	1
537	SRC2 50DD Element OP	1
538	SRC3 50DD Element OP	1
539	SRC4 50DD Element OP	1
540	SRC5 50DD Element OP	1
541	SRC6 50DD Element OP	1
544	87L DIFF Element OP	1
545	87L DIFF Element OP	1
546	OPEN POLE Element OP	1
548	50DD Element OP	1
549	CONT MONITOR Element OP	1
550	CT FAIL Element OP	1
553	87L TRIP Element OP	1
554	STUB BUS Element OP	1
576	BREAKER 1 Element OP	1
577	BREAKER 2 Element OP	1
584	BKR FAIL 1 Element OP	1
585	BKR FAIL 2 Element OP	1
592	BKR ARC 1 Element OP	1
593	BKR ARC 2 Element OP	1
608	AR 1 Element OP	1
609	AR 2 Element OP	1
610	AR 3 Element OP	1
611	AR 4 Element OP	1
612	AR 5 Element OP	1
613	AR 6 Element OP	1
616	SYNC 1 Element OP	1
617	SYNC 2 Element OP	1

Table E–3: BINARY INPUTS (Sheet 9 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
640	SETTING GROUP Element OP	1
641	RESET Element OP	1
704	FLEXELEMENT 1 Element OP	1
705	FLEXELEMENT 2 Element OP	1
706	FLEXELEMENT 3 Element OP	1
707	FLEXELEMENT 4 Element OP	1
708	FLEXELEMENT 5 Element OP	1
709	FLEXELEMENT 6 Element OP	1
710	FLEXELEMENT 7 Element OP	1
711	FLEXELEMENT 8 Element OP	1
816	DIG ELEM 1 Element OP	1
817	DIG ELEM 2 Element OP	1
818	DIG ELEM 3 Element OP	1
819	DIG ELEM 4 Element OP	1
820	DIG ELEM 5 Element OP	1
821	DIG ELEM 6 Element OP	1
822	DIG ELEM 7 Element OP	1
823	DIG ELEM 8 Element OP	1
824	DIG ELEM 9 Element OP	1
825	DIG ELEM 10 Element OP	1
826	DIG ELEM 11 Element OP	1
827	DIG ELEM 12 Element OP	1
828	DIG ELEM 13 Element OP	1
829	DIG ELEM 14 Element OP	1
830	DIG ELEM 15 Element OP	1
831	DIG ELEM 16 Element OP	1
848	COUNTER 1 Element OP	1
849	COUNTER 2 Element OP	1
850	COUNTER 3 Element OP	1
851	COUNTER 4 Element OP	1
852	COUNTER 5 Element OP	1
853	COUNTER 6 Element OP	1
854	COUNTER 7 Element OP	1
855	COUNTER 8 Element OP	1
864	LED State 1 (IN SERVICE)	1
865	LED State 2 (TROUBLE)	1
866	LED State 3 (TEST MODE)	1
867	LED State 4 (TRIP)	1
868	LED State 5 (ALARM)	1
869	LED State 6(PICKUP)	1
880	LED State 9 (VOLTAGE)	1
881	LED State 10 (CURRENT)	1
882	LED State 11 (FREQUENCY)	1
883	LED State 12 (OTHER)	1
884	LED State 13 (PHASE A)	1
885	LED State 14 (PHASE B)	1
886	LED State 15 (PHASE C)	1
887	LED State 16 (NTL/GROUND)	1
899	BATTERY FAIL	1
900	PRI ETHERNET FAIL	1
901	SEC ETHERNET FAIL	1

Table E–3: BINARY INPUTS (Sheet 10 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
902	EPROM DATA ERROR	1
903	SRAM DATA ERROR	1
904	PROGRAM MEMORY	1
905	WATCHDOG ERROR	1
906	LOW ON MEMORY	1
907	REMOTE DEVICE OFF	1
910	ANY MINOR ERROR	1
911	ANY MAJOR ERROR	1
912	ANY SELF-TESTS	1
913	IRIG-B FAILURE	1
914	DSP ERROR	1
915	NOT USED	
916	NO DSP INTERUPTS	1
917	UNIT NOT CALIBRATED	1
921	PROTOTYPE FIRMWARE	1
922	FLEXLOGIC ERR TOKEN	1
923	EQUIPMENT MISMATCH	1
925	UNIT NOT PROGRAMMED	1
926	SYSTEM EXCEPTION	1

Supported Control Relay Output Block fields: Pulse On, Pulse Off, Latch On, Latch Off, Paired Trip, Paired Close.

BINARY OUTPUT STATUS POINTS

Object Number: **10**

Request Function Codes supported: **1 (read)**

Default Variation reported when variation 0 requested: **2 (Binary Output Status)**

CONTROL RELAY OUTPUT BLOCKS

Object Number: **12**

Request Function Codes supported: **3 (select), 4 (operate), 5 (direct operate),6 (direct operate, noack)**

Table E–4: BINARY/CONTROL OUTPUT POINT LIST

POINT INDEX	NAME/DESCRIPTION
0	Virtual Input 1
1	Virtual Input 2
2	Virtual Input 3
3	Virtual Input 4
4	Virtual Input 5
5	Virtual Input 6
6	Virtual Input 7
7	Virtual Input 8
8	Virtual Input 9
9	Virtual Input 10
10	Virtual Input 11
11	Virtual Input 12
12	Virtual Input 13
13	Virtual Input 14
14	Virtual Input 15
15	Virtual Input 16
16	Virtual Input 17
17	Virtual Input 18
18	Virtual Input 19
19	Virtual Input 20
20	Virtual Input 21
21	Virtual Input 22
22	Virtual Input 23
23	Virtual Input 24
24	Virtual Input 25
25	Virtual Input 26
26	Virtual Input 27
27	Virtual Input 28
28	Virtual Input 29
29	Virtual Input 30
30	Virtual Input 31
31	Virtual Input 32

E.3.3 COUNTERS

The following table lists both Binary Counters (Object 20) and Frozen Counters (Object 21). When a freeze function is performed on a Binary Counter point, the frozen value is available in the corresponding Frozen Counter point.

BINARY COUNTERS

Static (Steady-State) Object Number: **20**

Change Event Object Number: **22**

Request Function Codes supported: **1 (read), 7 (freeze), 8 (freeze noack), 9 (freeze and clear), 10 (freeze and clear, noack), 22 (assign class)**

Static Variation reported when variation 0 requested: **1 (32-Bit Binary Counter with Flag)**

Change Event Variation reported when variation 0 requested: **1 (32-Bit Counter Change Event without time)**

Change Event Buffer Size: **10**

Default Class for all points: **2**

FROZEN COUNTERS

Static (Steady-State) Object Number: **21**

Change Event Object Number: **23**

Request Function Codes supported: **1 (read)**

Static Variation reported when variation 0 requested: **1 (32-Bit Frozen Counter with Flag)**

Change Event Variation reported when variation 0 requested: **1 (32-Bit Frozen Counter Event without time)**

Change Event Buffer Size: **10**

Default Class for all points: **2**

Table E–5: BINARY and FROZEN COUNTERS

POINT INDEX	NAME/DESCRIPTION
0	Digital Counter 1
1	Digital Counter 2
2	Digital Counter 3
3	Digital Counter 4
4	Digital Counter 5
5	Digital Counter 6
6	Digital Counter 7
7	Digital Counter 8
8	Oscillography Trigger Count
9	Events Since Last Clear

Note that a counter freeze command has no meaning for counters 8 and 9.

E.3.4 ANALOG INPUTS

The following table lists Analog Inputs (Object 30). It is important to note that 16-bit and 32-bit variations of Analog Inputs are transmitted through DNP as signed numbers. Even for analog input points that are not valid as negative values, the maximum positive representation is 32767. This is a DNP requirement.

The deadbands for all Analog Input points are in the same units as the Analog Input quantity. For example, an Analog Input quantity measured in volts has a corresponding deadband in units of volts. This is in conformance with DNP Technical Bulletin 9809-001 Analog Input Reporting Deadband. Relay settings are available to set default deadband values according to data type. Deadbands for individual Analog Input Points can be set using DNP Object 34.

When using the UR in DNP systems with limited memory, the ANALOG INPUT POINTS LIST below may be replaced with a user-definable list. This user-definable list uses the same settings as the Modbus User Map and can be configured with the MODBUS USER MAP settings. When used with DNP, each entry in the Modbus User Map represents the starting Modbus address of a data item available as a DNP Analog Input point. To enable use of the Modbus User Map for DNP Analog Input points, set the **USER MAP FOR DNP ANALOGS** setting to Enabled (this setting is in the **PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL** menu). The new DNP Analog points list can be checked via the "DNP Analog Input Points List" webpage, accessible from the "Device Information menu" webpage.

NOTE

After changing the **USER MAP FOR DNP ANALOGS** setting, the relay must be powered off and then back on for the setting to take effect.

Only Source 1 data points are shown in the following table. If the **NUMBER OF SOURCES IN ANALOG LIST** setting is increased, data points for subsequent sources will be added to the list immediately following the Source 1 data points.

Units for Analog Input points are as follows:

- Current: A
- Voltage: V
- Real Power: W
- Reactive Power: var
- Apparent Power: VA
- Energy Wh, varh
- Frequency: Hz
- Angle: degrees
- Ohm Input: Ohms
- RTD Input: degrees C

Static (Steady-State) Object Number: **30**

Change Event Object Number: **32**

Request Function Codes supported: **1 (read), 2 (write, deadbands only), 22 (assign class)**

Static Variation reported when variation 0 requested: **1 (32-Bit Analog Input)**

Change Event Variation reported when variation 0 requested: **1 (Analog Change Event w/o Time)**

Change Event Scan Rate: defaults to **500 ms.**

Change Event Buffer Size: **800**

Default Class for all Points: **1**

Table E–6: ANALOG INPUT POINTS (Sheet 1 of 3)

POINT	DESCRIPTION
0	SRC 1 Phase A Current RMS
1	SRC 1 Phase B Current RMS
2	SRC 1 Phase C Current RMS
3	SRC 1 Neutral Current RMS
4	SRC 1 Phase A Current Magnitude
5	SRC 1 Phase A Current Angle
6	SRC 1 Phase B Current Magnitude
7	SRC 1 Phase B Current Angle
8	SRC 1 Phase C Current Magnitude
9	SRC 1 Phase C Current Angle
10	SRC 1 Neutral Current Magnitude
11	SRC 1 Neutral Current Angle
12	SRC 1 Ground Current RMS
13	SRC 1 Ground Current Magnitude
14	SRC 1 Ground Current Angle
15	SRC 1 Zero Sequence Current Magnitude
16	SRC 1 Zero Sequence Current Angle
17	SRC 1 Positive Sequence Current Magnitude
18	SRC 1 Positive Sequence Current Angle
19	SRC 1 Negative Sequence Current Magnitude
20	SRC 1 Negative Sequence Current Angle
21	SRC 1 Differential Ground Current Magnitude
22	SRC 1 Differential Ground Current Angle
23	SRC 1 Phase AG Voltage RMS
24	SRC 1 Phase BG Voltage RMS
25	SRC 1 Phase CG Voltage RMS
26	SRC 1 Phase AG Voltage Magnitude
27	SRC 1 Phase AG Voltage Angle
28	SRC 1 Phase BG Voltage Magnitude
29	SRC 1 Phase BG Voltage Angle
30	SRC 1 Phase CG Voltage Magnitude
31	SRC 1 Phase CG Voltage Angle
32	SRC 1 Phase AB Voltage RMS
33	SRC 1 Phase BC Voltage RMS
34	SRC 1 Phase CA Voltage RMS
35	SRC 1 Phase AB Voltage Magnitude
36	SRC 1 Phase AB Voltage Angle
37	SRC 1 Phase BC Voltage Magnitude
38	SRC 1 Phase BC Voltage Angle
39	SRC 1 Phase CA Voltage Magnitude
40	SRC 1 Phase CA Voltage Angle
41	SRC 1 Auxiliary Voltage RMS
42	SRC 1 Auxiliary Voltage Magnitude
43	SRC 1 Auxiliary Voltage Angle
44	SRC 1 Zero Sequence Voltage Magnitude
45	SRC 1 Zero Sequence Voltage Angle
46	SRC 1 Positive Sequence Voltage Magnitude

Table E–6: ANALOG INPUT POINTS (Sheet 2 of 3)

POINT	DESCRIPTION
47	SRC 1 Positive Sequence Voltage Angle
48	SRC 1 Negative Sequence Voltage Magnitude
49	SRC 1 Negative Sequence Voltage Angle
50	SRC 1 Three Phase Real Power
51	SRC 1 Phase A Real Power
52	SRC 1 Phase B Real Power
53	SRC 1 Phase C Real Power
54	SRC 1 Three Phase Reactive Power
55	SRC 1 Phase A Reactive Power
56	SRC 1 Phase B Reactive Power
57	SRC 1 Phase C Reactive Power
58	SRC 1 Three Phase Apparent Power
59	SRC 1 Phase A Apparent Power
60	SRC 1 Phase B Apparent Power
61	SRC 1 Phase C Apparent Power
62	SRC 1 Three Phase Power Factor
63	SRC 1 Phase A Power Factor
64	SRC 1 Phase B Power Factor
65	SRC 1 Phase C Power Factor
66	SRC 1 Positive Watthour
67	SRC 1 Negative Watthour
68	SRC 1 Positive Varhour
69	SRC 1 Negative Varhour
70	SRC 1 Frequency
71	SRC 1 Demand Ia
72	SRC 1 Demand Ib
73	SRC 1 Demand Ic
74	SRC 1 Demand Watt
75	SRC 1 Demand Var
76	SRC 1 Demand Va
77	Breaker 1 Arcing Amp Phase A
78	Breaker 1 Arcing Amp Phase B
79	Breaker 1 Arcing Amp Phase C
80	Breaker 2 Arcing Amp Phase A
81	Breaker 2 Arcing Amp Phase B
82	Breaker 2 Arcing Amp Phase C
83	Synchrocheck 1 Delta Voltage
84	Synchrocheck 1 Delta Frequency
85	Synchrocheck 1 Delta Phase
86	Synchrocheck 2 Delta Voltage
87	Synchrocheck 2 Delta Frequency
88	Synchrocheck 2 Delta Phase
89	Local IA Magnitude
90	Local IB Magnitude
91	Local IC Magnitude
92	Remote1 IA Magnitude
93	Remote1 IB Magnitude

Table E–6: ANALOG INPUT POINTS (Sheet 3 of 3)

POINT	DESCRIPTION
94	Remote1 IC Magnitude
95	Remote2 IA Magnitude
96	Remote2 IB Magnitude
97	Remote2 IC Magnitude
98	Differential Current IA Magnitude
99	Differential Current IB Magnitude
100	Differential Current IC Magnitude
101	Local IA Angle
102	Local IB Angle
103	Local IC Angle
104	Remote1 IA Angle
105	Remote1 IB Angle
106	Remote1 IC Angle
107	Remote2 IA Angle
108	Remote2 IB Angle
109	Remote2 IC Angle
110	Differential Current IA Angle
111	Differential Current IB Angle
112	Differential Current IC Angle
113	Op Square Current IA
114	Op Square Current IB
115	Op Square Current IC
116	Restraint Square Current IA
117	Restraint Square Current IB
118	Restraint Square Current IC
119	Tracking Frequency
120	FlexElement 1 Actual
121	FlexElement 2 Actual
122	FlexElement 3 Actual
123	FlexElement 4 Actual
124	FlexElement 5 Actual
125	FlexElement 6 Actual
126	FlexElement 7 Actual
127	FlexElement 8 Actual
128	FlexElement 9 Actual
129	FlexElement 10 Actual
130	FlexElement 11 Actual
131	FlexElement 12 Actual
132	FlexElement 13 Actual
133	FlexElement 14 Actual
134	FlexElement 15 Actual
135	FlexElement 16 Actual
136	Current Setting Group

F.1.1 REVISION HISTORY

Table F–1: REVISION HISTORY

MANUAL P/N	L90 REVISION	RELEASE DATE	ECO
1601-0081-A1	1.0X	04 November 1998	N/A
1601-0081-A2	1.0X	09 December 1998	URL-039
1601-0081-A3	1.5X	25 June 1999	URL-051
1601-0081-A4	1.5X	10 August 1999	URL-055
1601-0081-A5	1.5X	02 September 1999	URL-057
1601-0081-A6	2.0X	17 December 1999	URL-063
1601-0081-A7	2.0X	26 January 2000	URL-064
1601-0081-A7-2	2.0X	07 April 2000	URL-068
1601-0081-A8	2.2X	12 May 2000	URL-067
1601-0081-A9	2.2X	14 June 2000	URL-070
1601-0081-A9-2	2.2X	21 June 2000	URL-071
1601-0081-A9-2a	2.2X	28 June 2000	URL-071a
1601-0081-B1	2.4X	08 September 2000	URL-075
1601-0081-B2	2.4X	03 November 2000	URL-077
1601-0081-B3	2.6X	08 March 2001	URL-079
1601-0081-B4	2.8X	24 September 2001	URL-088
1601-0081-B5	2.9X	03 December 2001	URL-090
1601-0081-B8	2.9X	10 September 2004	URX-162

F.1.2 CHANGES TO L90 MANUAL

F

Table F–2: MAJOR UPDATES FOR L90 MANUAL-B8

PAGE (B5)	CHANGE	DESCRIPTION
Title	Update	Manual part number from B5 to B8
E-8	Update	Updated BINARY INPUTS table

Table F–3: MAJOR UPDATES FOR L90 MANUAL-B5 (Sheet 1 of 2)

PAGE(s) (B4)	CHANGE	DESCRIPTION
Title	Update	Manual part number from B4 to B5
2-5	Update	Updated ORDER CODES table to include 7T Inter-Relay Communications option
2-8	Update	Updated CHANNEL MONITOR section
5-29	Update	Updated description for Local ID Number in L90 POWER SYSTEM section
5-36	Update	Updated FLEXLOGIC™ OPERANDS table
5-53 to 5-55	Update	Updated CURRENT DIFFERENTIAL section to reflect updates to description and scheme logic
5-60	Update	Updated PHASE DISTANCE Z2 sub-section
5-66	Update	Updated GROUND DISTANCE Z2 sub-section to reflect updates to settings
5-115	Update	Updated description for DISTURBANCE DETECTOR sub-section
8-6	Update	Updated BLOCK DIAGRAM FOR CLOCK SYNCHRONIZATION to reflect 2.9X firmware
8-16	Update	Updated RELAY SYNCHRONIZATION section

Table F–3: MAJOR UPDATES FOR L90 MANUAL-B5 (Sheet 2 of 2)

PAGE(s) (B4)	CHANGE	DESCRIPTION
9-1	Update	Updated INTRODUCTION TO L90 CT REQUIREMENTS section
9-6	Add	Added PHASE DISTANCE, GROUND DISTANCE, POTT SIGNALING SCHEMES, and SERIES COMPENSATED LINES sections
10-1	Update	Updated COMMISSIONING chapter to reflect changes to revision 2.9X firmware
B-9	Update	Updated MODBUS MEMORY MAP to reflect revision 2.9X firmware
D-1	Add	Added IEC 60870-5-104 INTEROPERABILITY DOCUMENT section

Table F–4: MAJOR UPDATES FOR L90 MANUAL-B4 (Sheet 1 of 2)

PAGE (B3)	CHANGE	DESCRIPTION
Title	Update	Manual part number from B3 to B4
2-3	Update	Updated SINGLE LINE DIAGRAM from 813706AR to 813706AS
2-4	Update	Updated DEVICE NUMBERS AND FUNCTIONS table
2-4	Update	Updated ADDITIONAL DEVICE FUNCTIONS table
2-5	Update	Updated ORDER CODES table
2-6	Update	Updated ORDER CODES FOR REPLACEMENT MODULES table
2-19	Add	Added specifications for NEUTRAL OVERVOLTAGE, AUXILIARY UNDERVOLTAGE, AUXILIARY OVERVOLTAGE, and LOAD ENCROACHMENT elements
2-20	Add	Added USER-PROGRAMMABLE ELEMENTS section
2-21	Add	Added specifications for TRANSDUCER I/O
2-23	Update	Updated INTER-RELAY COMMUNICATIONS specifications for 1550 nm Fiber
3-14	Update	Updated DIGITAL I/O MODULE WIRING diagram to 827719CR
3-17	Add	Added TRANSDUCER I/O module section
3-22	Update	Updated LASER FIBER MODULES diagram from 812703A2 to 812703A3
3-30	Add	Added G.703 & FIBER INTERFACE section
4-10	Remove	Removed DEFAULT LABELS FOR LED PANEL 3 section
5-11	Update	Updated COMMUNICATIONS section to include updated settings for DNP 3.0 and IEC 60870-5-104 communications protocols
5-41	Update	Updated FLEXLOGIC™ OPERANDS table
5-55	Update	Updated FLEXLOGIC™ EQUATION EDITOR section
5-57	Add	Added FLEXELEMENTS™ settings section
5-61	Update	Updated CURRENT DIFFERENTIAL SCHEME LOGIC diagram to 827056A8
5-67	Update	Updated PHASE DISTANCE Z2 sub-section to reflect new settings and scheme logic
5-70	Update	Updated GROUND DISTANCE Z2 sub-section to reflect new settings and scheme logic
5-80	Add	Added LOAD ENCROACHMENT section
5-96	Update	Updated NEUTRAL TOC SCHEME LOGIC diagram to 827034A3
5-99	Update	Updated NEUTRAL DIRECTIONAL OC1/OC2 sub-section to reflect new settings and scheme logic
5-122	Update	Updated VOLTAGE ELEMENTS menu to reflect Auxiliary UV/OV and Neutral OV elements
5-126	Add	Added AUXILIARY UV1 sub-section
5-126	Add	Added AUXILIARY OV1 sub-section
5-126	Add	Added NEUTRAL OVERVOLTAGE sub-section
5-127	Update	Updated DISTURBANCE DETECTOR sub-section
5-131	Update	Updated OPEN POLE DETECTOR SCHEME LOGIC diagram to 827047A6
5-146	Update	Updated AUTORECLOSE SCHEME LOGIC (Sheet 1 of 2) diagram to 827081AC
5-180	Add	Added TRANSDUCER I/O settings section

Table F–4: MAJOR UPDATES FOR L90 MANUAL-B4 (Sheet 2 of 2)

PAGE (B3)	CHANGE	DESCRIPTION
6-7	Update	Updated description for CHANNEL TESTS
6-17	Add	Added FLEXELEMENTS™ actual values section
6-17	Add	Added TRANSDUCER I/O actual values section
7-4	Update	Updated MAJOR and MINOR SELF-TEST ERROR MESSAGES tables
8-16	Remove	Removed ESTIMATE OF PHASE UNCERTAINTY section
8-19	Add	Added CT SATURATION DETECTION section
10-	Update	Chapter 10: COMMISSIONING updated to reflect settings changes for revision 2.8X firmware
B-11	Update	MODBUS MEMORY MAP updated for version 2.8X firmware
E-1	Update	Updated DNP 3.0 DEVICE PROFILE DOCUMENT table
E-4	Update	Updated DNP 3.0 IMPLEMENTATION table
E-9	Update	Updated BINARY INPUT PONTS table

F.2.1 ABBREVIATIONS

A ..... ampere
AC ..... alternating current
A/D ..... analog to digital
AE ..... accidental energization
AE ..... application entity
AMP ..... ampere
ANSI ..... American National Standards Institute
AR ..... automatic reclosure
AUTO ..... automatic
AUX ..... auxiliary
AVG ..... average

BER ..... bit error rate
BF ..... breaker fail
BFI ..... breaker failure initiate
BKR ..... breaker
BLK ..... block
BLKG ..... blocking
BPNT ..... breakpoint of a characteristic

CAP ..... capacitor
CC ..... coupling capacitor
CCVT ..... coupling capacitor voltage transformer
CFG ..... configure / configurable
.CFG ..... file name extension for oscillography files
CHK ..... check
CHNL ..... channel
CLS ..... close
CLSD ..... closed
CMND ..... command
CMPRSN ..... comparison
CO ..... contact output
COM ..... communication
COMM ..... communications
COMP ..... compensated
CONN ..... connection
CO-ORD ..... coordination
CPU ..... central processing unit
CRT, CRNT .... current
CT ..... current transformer
CVT ..... capacitive voltage transformer

D/A ..... digital to analog
DC (dc) ..... direct current
DD ..... disturbance detector
DFLT ..... default
DGNST ..... diagnostics
DI ..... digital input
DIFF ..... differential
DIR ..... directional
DISCREP ..... discrepancy
DIST ..... distance
DMD ..... demand
DPO ..... dropout
DSP ..... digital signal processor
DTT ..... direct transfer trip
DUTT ..... direct under-reaching transfer trip

EPRI ..... Electric Power Research Institute
.EVT ..... file name extension for event recorder files
EXT ..... extension

F ..... field
FAIL ..... failure
FD ..... fault detector
FDH ..... fault detector high-set
FDL ..... fault detector low-set
FLA ..... full load current
FO ..... fiber optic
FREQ ..... frequency
FSK ..... frequency-shift keying
FWD ..... forward

G ..... generator
GE ..... General Electric
GND ..... ground
GNTR ..... generator

GOOSE ..... general object oriented substation event

HARM ..... harmonic / harmonics
HGF ..... high-impedance ground fault (CT)
HIZ ..... high-impedance & arcing ground
HMI ..... human-machine interface
HYB ..... hybrid

I ..... instantaneous
I_0 ..... zero sequence current
I_1 ..... positive sequence current
I_2 ..... negative sequence current
IA ..... phase A current
IAB ..... phase A minus B current
IB ..... phase B current
IBC ..... phase B minus C current
IC ..... phase C current
ICA ..... phase C minus A current
ID ..... identification
IEEE ..... Institute of Electrical & Electronic Engineers
IG ..... ground (not residual) current
Igd ..... differential ground current
IN ..... CT residual current (3Io) or input
INC SEQ ..... incomplete sequence
INIT ..... initiate
INST ..... instantaneous
INV ..... inverse
I/O ..... input/output
IOC ..... instantaneous overcurrent
IOV ..... instantaneous overvoltage
IRIG ..... inter-range instrumentation group
IUV ..... instantaneous undervoltage

K0 ..... zero sequence current compensation
kA ..... kiloAmpere
kV ..... kiloVolt

LED ..... light emitting diode
LEO ..... line end open
LOOP ..... loopback
LPU ..... line pickup
LRA ..... locked-rotor current
LTC ..... load tap-changer

M ..... machine
mA ..... milliAmpere
MAN ..... manual / manually
MMI ..... man machine interface
MMS ..... Manufacturing Message Specification
MSG ..... message
MTA ..... maximum torque angle
MTR ..... motor
MVA ..... MegaVolt-Ampere (total 3-phase)
MVA_A ..... MegaVolt-Ampere (phase A)
MVA_B ..... MegaVolt-Ampere (phase B)
MVA_C ..... MegaVolt-Ampere (phase C)
MVAR ..... MegaVar (total 3-phase)
MVAR_A ..... MegaVar (phase A)
MVAR_B ..... MegaVar (phase B)
MVAR_C ..... MegaVar (phase C)
MVARH ..... MegaVar-Hour
MW ..... MegaWatt (total 3-phase)
MW_A ..... MegaWatt (phase A)
MW_B ..... MegaWatt (phase B)
MW_C ..... MegaWatt (phase C)
MWH ..... MegaWatt-Hour

N ..... neutral
N/A, n/a ..... not applicable
NEG ..... negative
NMPLT ..... nameplate
NOM ..... nominal
NTR ..... neutral

O ..... over
OC, O/C ..... overcurrent
O/P, Op ..... output
OP ..... operate

OPER ..... operate
OPERATG ..... operating
O/S ..... operating system
OSB ..... out-of-step blocking
OUT ..... output
OV ..... overvoltage
OVERFREQ ... overfrequency
OVLD ..... overload

P ..... phase
PC ..... phase comparison, personal computer
PCNT ..... percent
PF ..... power factor (total 3-phase)
PF_A ..... power factor (phase A)
PF_B ..... power factor (phase B)
PF_C ..... power factor (phase C)
PHS ..... phase
PKP ..... pickup
PLC ..... power line carrier
POS ..... positive
POTT ..... permissive over-reaching transfer trip
PRESS ..... pressure
PROT ..... protection
PSEL ..... presentation selector
pu ..... per unit
PUIB ..... pickup current block
PUIT ..... pickup current trip
PUTT ..... permissive under-reaching transfer trip
PWM ..... pulse width modulated
PWR ..... power

R ..... rate, reverse
REM ..... remote
REV ..... reverse
RI ..... reclose initiate
RIP ..... reclose in progress
ROD ..... remote open detector
RST ..... reset
RSTR ..... restrained
RTD ..... resistance temperature detector
RTU ..... remote terminal unit
RX (Rx) ..... receive, receiver

s ..... second
S ..... sensitive
SAT ..... CT saturation
SBO ..... select before operate
SEL ..... select / selector / selection
SENS ..... sensitive
SEQ ..... sequence
SIR ..... source impedance ratio
SRC ..... source
SSB ..... single side band
SSEL ..... session selector
STATS ..... statistics
SUPN ..... supervision
SUPV ..... supervise / supervision
SV ..... supervision
SYNCHCHK .... synchrocheck

T ..... time, transformer
TC ..... thermal capacity
TD MULT ..... time dial multiplier
TEMP ..... temperature
THD ..... total harmonic distortion
TOC ..... time overcurrent
TOV ..... time overvoltage
TRANS ..... transient
TRANSF ..... transfer
TSEL ..... transport selector
TUC ..... time undercurrent
TUV ..... time undervoltage
TX (Tx) ..... transmit, transmitter

U ..... under
UC ..... undercurrent
UCA ..... Utility Communications Architecture
UNBAL ..... unbalance
UR ..... universal relay
.URS ..... file name extension for settings files
UV ..... undervoltage

V/Hz ..... Volts per Hertz
V_0 ..... zero sequence voltage
V_1 ..... positive sequence voltage
V_2 ..... negative sequence voltage
VA ..... phase A voltage
VAB ..... phase A to B voltage
VAG ..... phase A to ground voltage
VARH ..... var-hour voltage
VB ..... phase B voltage
VBA ..... phase B to A voltage
VBG ..... phase B to ground voltage
VC ..... phase C voltage
VCA ..... phase C to A voltage
VCG ..... phase C to ground voltage
VF ..... variable frequency
VIBR ..... vibration
VT ..... voltage transformer
VTFF ..... voltage transformer fuse failure
VTLOS ..... voltage transformer loss of signal

WDG ..... winding
WH ..... Watt-hour
w/ opt ..... with option
WRT ..... with respect to

X ..... reactance
XDUCER ..... transducer
XFMR ..... transformer

Z ..... impedance

F

F.3.1 LIST OF TABLES

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F.3.2 LIST OF FIGURES

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F

GE MULTILIN RELAY WARRANTY

General Electric Multilin Inc. (GE Multilin) warrants each relay it manufactures to be free from defects in material and workmanship under normal use and service for a period of 24 months from date of shipment from factory.

In the event of a failure covered by warranty, GE Multilin will undertake to repair or replace the relay providing the warrantor determined that it is defective and it is returned with all transportation charges prepaid to an authorized service centre or the factory. Repairs or replacement under warranty will be made without charge.

Warranty shall not apply to any relay which has been subject to misuse, negligence, accident, incorrect installation or use not in accordance with instructions nor any unit that has been altered outside a GE Multilin authorized factory outlet.

GE Multilin is not liable for special, indirect or consequential damages or for loss of profit or for expenses sustained as a result of a relay malfunction, incorrect application or adjustment.

For complete text of Warranty (including limitations and disclaimers), refer to the GE Multilin Standard Conditions of Sale.

Numerics

A

B

C

D

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