ADDENDUM

This Addendum contains information that relates to the F60 Feeder Management Relay relay, version 4.9x. This addendum lists a number of information items that appear in the instruction manual GEK-113206A (revision M2) but are not included in the current F60 operations.

The following functions/items are not yet available with the current version of the F60 relay:

- Signal Sources SRC 5 and SRC 6

Version 4.0x and higher releases of the F60 relay includes new hardware (CPU and CT/VT modules).

- The new CPU modules are specified with the following order codes: 9E, 9G, 9H, 9J, 9K, 9L, 9M, 9N, 9P, and 9R.
- The new CT/VT modules are specified with the following order codes: 8F, 8G, 8H, 8J.

The following table maps the relationship between the old CPU and CT/VT modules to the newer versions:

<table>
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<tr>
<th>MODULE</th>
<th>OLD</th>
<th>NEW</th>
<th>DESCRIPTION</th>
</tr>
</thead>
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<tr>
<td>CPU</td>
<td>9A</td>
<td>9E</td>
<td>RS485 and RS485 (Modbus RTU, DNP)</td>
</tr>
<tr>
<td></td>
<td>9C</td>
<td>9G</td>
<td>RS485 and 10Base-F (Ethernet, Modbus TCP/IP, DNP)</td>
</tr>
<tr>
<td></td>
<td>9D</td>
<td>9H</td>
<td>RS485 and redundant 10Base-F (Ethernet, Modbus TCP/IP, DNP)</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>9J</td>
<td>RS485 and multi-mode ST 100Base-FX</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>9K</td>
<td>RS485 and multi-mode ST redundant 100Base-FX</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>9L</td>
<td>RS485 and single mode SC 100Base-FX</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>9M</td>
<td>RS485 and single mode SC redundant 100Base-FX</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>9N</td>
<td>RS485 and 10/100Base-T</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>9P</td>
<td>RS485 and single mode ST 100Base-FX</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>9R</td>
<td>RS485 and single mode ST redundant 100Base-FX</td>
</tr>
<tr>
<td>CT/VT</td>
<td>8A</td>
<td>8F</td>
<td>Standard 4CT/4VT</td>
</tr>
<tr>
<td></td>
<td>8B</td>
<td>8G</td>
<td>Sensitive Ground 4CT/4VT</td>
</tr>
<tr>
<td></td>
<td>8C</td>
<td>8H</td>
<td>Standard 8CT</td>
</tr>
<tr>
<td></td>
<td>8D</td>
<td>8J</td>
<td>Sensitive Ground 8CT/8VT</td>
</tr>
</tbody>
</table>

The new CT/VT modules can only be used with the new CPUs (9E, 9G, 9H, 9J, 9K, 9L, 9M, 9N, 9P, 9R), and the old CT/VT modules can only be used with the old CPU modules (9A, 9C, 9D). To prevent any hardware mismatches, the new CPU and CT/VT modules have blue labels and a warning sticker stating "Attn.: Ensure CPU and DSP module label colors are the same!". In the event that there is a mismatch between the CPU and CT/VT module, the relay will not function and a DSP ERROR or HARDWARE MISMATCH error will be displayed.

All other input/output modules are compatible with the new hardware.

With respect to the firmware, firmware versions 4.0x and higher are only compatible with the new CPU and CT/VT modules. Previous versions of the firmware (3.4x and earlier) are only compatible with the older CPU and CT/VT modules.
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INDEX
Please read this chapter to help guide you through the initial setup of your new relay.

### 1.1 IMPORTANT PROCEDURES

#### 1.1.1 CAUTIONS AND WARNINGS

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

![Figure 1–1: REAR NAMEPLATE (EXAMPLE)](https://example.com/figure1.png)

- Ensure that the following items are included:
  - Instruction Manual
  - GE enerVista CD (includes the EnerVista UR Setup software and manuals in PDF format)
  - mounting screws
  - registration card (attached as the last page of the manual)
- Fill out the registration form and return 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 website at http://www.GEindustrial.com/multilin.

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)
**FAX:** (905) 201-2098
**E-MAIL:** gemultilin@indsys.ge.com
**HOME PAGE:** http://www.GEindustrial.com/multilin
Historically, substation protection, control, and metering functions were performed with electromechanical equipment. This first generation of equipment was gradually replaced by analog electronic equipment, most of which emulated the single-function approach of their electromechanical precursors. Both of these technologies required expensive cabling and auxiliary equipment to produce functioning systems.

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

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

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

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

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

![Figure 1–2: UR CONCEPT BLOCK DIAGRAM](image)

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-series 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 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-series relays support 1 A and 5 A CTs.

The remote inputs and outputs provide a means of sharing digital point state information between remote UR-series devices. The remote outputs interface to the remote inputs of other UR-series devices. Remote outputs are FlexLogic™ operands inserted into IEC 61850 GSSE and GOOSE messages.

The direct inputs and outputs provide a means of sharing digital point states between a number of UR-series IEDs over a dedicated fiber (single or multimode), RS422, or G.703 interface. No switching equipment is required as the IEDs are connected directly in a ring or redundant (dual) ring configuration. This feature is optimized for speed and intended for pilot-aided schemes, distributed logic applications, or the extension of the input/output capabilities of a single relay chassis.
c) UR SCAN OPERATION

The UR-series devices operate in a cyclic scan fashion. The device 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.

![Figure 1–3: UR-SERIES SCAN OPERATION](image)

1.2.3 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, Input/Output 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-series platform-based applications.

1.2.4 IMPORTANT CONCEPTS

As described above, the architecture of the UR-series relays differ from previous devices. 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 the UR-series elements can be found in the Introduction to Elements section in Chapter 5. An example of a simple element, and some of the organization of this manual, can be found in the Digital Elements section. An explanation of the use of inputs from CTs and VTs is in the Introduction to AC Sources section in Chapter 5. A description of how digital signals are used and routed within the relay is contained in the Introduction to FlexLogic™ section in Chapter 5.
The faceplate keypad and display or the EnerVista UR Setup software interface can be used to communicate with the relay. The EnerVista UR Setup software interface is the preferred method to edit settings and view actual values because the PC monitor can display more information in a simple comprehensible format.

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

- Pentium class or higher processor (Pentium II 300 MHz or higher recommended)
- Windows 95, 98, 98SE, ME, NT 4.0 (Service Pack 4 or higher), 2000, XP
- Internet Explorer 4.0 or higher
- 128 MB of RAM (256 MB recommended)
- 200 MB of available space on system drive and 200 MB of available space on installation drive
- Video capable of displaying 800 x 600 or higher in high-color mode (16-bit color)
- RS232 and/or Ethernet port for communications to the relay

The following qualified modems have been tested to be compliant with the F60 and the EnerVista UR Setup software.

- US Robotics external 56K FaxModem 5686
- US Robotics external Sportster 56K X2
- PCTEL 2304WT V.92 MDC internal modem

### 1.3.2 INSTALLATION

After ensuring the minimum requirements for using EnerVista UR Setup are met (see previous section), use the following procedure to install the EnerVista UR Setup from the enclosed GE enerVista CD.

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

5. In the enerVista Launch Pad window, click the **Install Software** button and select the “F60 Feeder Management Relay” from the Install Software window as shown below. Select the “Web” option to ensure the most recent software
1.3 ENERVISTA UR SETUP SOFTWARE 1 GETTING STARTED

release, or select “CD” if you do not have a web connection, then click the Check Now button to list software items for the F60.

6. Select the F60 software program and release notes (if desired) from the list and click the Download Now button to obtain the installation program.

7. enerVista Launchpad will obtain the installation program from the Web or CD. Once the download is complete, double-click the installation program to install the EnerVista UR Setup software.

8. Select the complete path, including the new directory name, where the EnerVista UR Setup will be installed.

9. Click on Next to begin the installation. The files will be installed in the directory indicated and the installation program will automatically create icons and add EnerVista UR Setup to the Windows start menu.
10. Click Finish to end the installation. The F60 device will be added to the list of installed IEDs in the enerVista Launchpad window, as shown below.

1.3.3 CONNECTING ENERVISTA UR SETUP WITH THE F60

This section is intended as a quick start guide to using the EnerVista UR Setup software. Please refer to the EnerVista UR Setup Help File and Chapter 4 of this manual 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. To setup the relay for Ethernet communications, it will be necessary to define a Site, then add the relay as a Device at that site.

1. Install and start the latest version of the EnerVista UR Setup software (available from the GE enerVista CD or online from http://www.GEindustrial.com/multilin (see previous section for installation instructions).

2. Select the “UR” device from the enerVista Launchpad to start EnerVista UR Setup.

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

4. Enter the desired site name in the “Site Name” field. If desired, a short description of site can also be entered along with the display order of devices defined for the site. Click the OK button when complete.

5. The new site will appear in the upper-left list in the EnerVista UR Setup window. Click on the new site name and then click the Device Setup button to re-open the Device Setup window.

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

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

8. Select “Ethernet” from the Interface drop-down list. This will display a number of interface parameters that must be entered for proper Ethernet functionality.

   • Enter the relay IP address (from SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ NETWORK ➔ IP ADDRESS) in the “IP Address” field.

   • Enter the relay Modbus address (from the PRODUCT SETUP ➔ COMMUNICATIONS ➔ MODBUS PROTOCOL ➔ MODBUS SLAVE ADDRESS setting) in the “Slave Address” field.

   • Enter the Modbus port address (from the PRODUCT SETUP ➔ COMMUNICATIONS ➔ MODBUS PROTOCOL ➔ MODBUS TCP PORT NUMBER setting) in the “Modbus Port” field.

9. Click the Read Order Code button to connect to the F60 device and upload the order code. If an communications error occurs, ensure that the three EnerVista UR Setup values entered in the previous step correspond to the relay setting values.
1.3 ENERVISTA UR SETUP SOFTWARE

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

The Site Device has now been configured for Ethernet communications. Proceed to Section c) 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. Install and start the latest version of the EnerVista UR Setup software (available from the GE eneVista CD or online from http://www.GEindustrial.com/multilin.

2. Select the Device Setup button to open the Device Setup window and click the Add Site button to define a new site.

3. Enter the desired site name in the “Site Name” field. If desired, a short description of site can also be entered along with the display order of devices defined for the site. Click the OK button when complete.

4. The new site will appear in the upper-left list in the EnerVista UR Setup window. Click on the new site name and then click the Device Setup button to re-open the Device Setup window.

5. Click the Add Device button to define the new device.

6. Enter the desired name in the “Device Name” field and a description (optional) of the site.

7. Select “Serial” from the Interface drop-down list. This will display a number of interface parameters that must be entered for proper serial communications.

   • Enter the relay slave address and COM port values (from the SETTINGS → PRODUCT SETUP → COMMUNICATIONS → SERIAL PORTS menu) in the “Slave Address” and “COM Port” fields.

   • Enter the physical communications parameters (baud rate and parity settings) in their respective fields.

8. Click the Read Order Code button to connect to the F60 device and upload the order code. If an communications error occurs, ensure that the EnerVista UR Setup serial communications values entered in the previous step correspond to the relay setting values.

9. Click “OK” when the relay order code has been received. The new device will be added to the Site List window (or Online window) located in the top left corner of the main EnerVista UR Setup 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. Open the Display Properties window through the Site List tree as shown below:
2. The Display Properties window will open with a status indicator on the lower left of the EnerVista UR Setup window.

3. If the status indicator is red, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay and that the relay has been properly setup for communications (steps A and B earlier).

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

4. The Display Properties settings can now be edited, printed, or changed according to user specifications.

   Refer to Chapter 4 in this manual and the EnerVista UR Setup Help File for more information about the using the EnerVista UR Setup software interface.
Please refer to Chapter 3: Hardware for detailed mounting and wiring instructions. Review all WARNINGS and CAUTIONS carefully.

1.4.2 COMMUNICATIONS

The EnerVista UR Setup 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 CPU Communications Ports section of Chapter 3.

To communicate through the F60 rear RS485 port from a PC RS232 port, the GE Multilin RS232/RS485 converter box is required. This device (catalog number F485) connects to the computer using a “straight-through” serial cable. A shielded twisted-pair (20, 22, or 24 AWG) connects the F485 converter to the F60 rear communications port. The converter terminals (+, −, GND) are connected to the F60 communication module (+, −, COM) terminals. Refer to the CPU Communications Ports section in Chapter 3 for option details. The line should be terminated with an R-C network (i.e. 120 Ω, 1 nF) as described in the Chapter 3.

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. An optional liquid crystal display (LCD) is also available. 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.
Display messages are organized into ‘pages’ under the following headings: Actual Values, Settings, Commands, and Targets. The \texttt{MENU} key navigates through these pages. Each heading page is broken down further into logical subgroups.

The \texttt{MESSAGE} \texttt{VALUE} \texttt{HELP} \texttt{ENTER} keys navigate through the subgroups. The \texttt{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 \texttt{HELP} key initiates and advance to the next character in text edit mode or enters a decimal point. The \texttt{HELP} key may be pressed at any time for context sensitive help messages. The \texttt{ENTER} key stores altered setting values.

### 1.5.2 MENU NAVIGATION

Press the \texttt{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 \texttt{MENU} key advances through the main heading pages as illustrated below.

```

\begin{tabular}{|c|c|c|c|}
\hline
\texttt{MENU} & \texttt{MENU} & \texttt{MENU} & \texttt{MENU} \\
\texttt{ACTUAL VALUES} & \texttt{SETTINGS} & \texttt{COMMANDS} & \texttt{TARGETS} \\
\hline
\texttt{MESSAGE} & \texttt{MESSAGE} & \texttt{MESSAGE} & \texttt{MESSAGE} \\
\texttt{STATUS} & \texttt{PRODUCT SETUP} & \texttt{VIRTUAL INPUTS} & No Active Targets \\
\hline
\end{tabular}
```

Press the \texttt{MESSAGE} key from a header display displays specific information for the header category. Conversely, continually pressing the \texttt{MESSAGE} key from a setting value or actual value display returns to the header display.

### 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 \texttt{MESSAGE} \texttt{VALUE} keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the \texttt{MESSAGE} key from a header display displays specific information for the header category. Conversely, continually pressing the \texttt{MESSAGE} key from a setting value or actual value display returns to the header display.
1.5 USING THE RELAY

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 LED will be on and the In Service LED 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

To put the relay in the “Programmed” state, press either of the VALUE keys once and then press . The faceplate Trouble LED will turn off and the In Service LED will turn on. The settings for the relay can be programmed manually (refer to Chapter 5) via the faceplate keypad or remotely (refer to the EnerVista UR Setup Help file) via the EnerVista UR Setup software interface.

1.5.5 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, COMMAND and SETTING:

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
   • operate user-programmable pushbuttons

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

Refer to the Changing Settings section in Chapter 4 for complete instructions on setting up security level passwords.

1.5.6 FLEXLOGIC™ CUSTOMIZATION

FlexLogic™ equation editing is required for setting up user-defined logic for customizing the relay operations. See the FlexLogic™ section in Chapter 5 for additional details.
Templated tables for charting all the required settings before entering them via the keypad are available from the GE Multilin website at http://www.GEindustrial.com/multilin.

The F60 requires a minimum amount of maintenance when it is commissioned into service. The F60 is a microprocessor-based relay and its characteristics do not change over time. As such no further functional tests are required.

Furthermore the F60 performs a number of ongoing self-tests and takes the necessary action in case of any major errors (see the Relay Self-Test section in Chapter 7 for details). However, it is recommended that maintenance on the F60 be scheduled with other system maintenance. This maintenance may involve the following.

In-service maintenance:
1. Visual verification of the analog values integrity such as voltage and current (in comparison to other devices on the corresponding system).
2. Visual verification of active alarms, relay display messages, and LED indications.
3. LED test.
4. Visual inspection for any damage, corrosion, dust, or loose wires.
5. Event recorder file download with further events analysis.

Out-of-service maintenance:
1. Check wiring connections for firmness.
2. Analog values (currents, voltages, RTDs, analog inputs) injection test and metering accuracy verification. Calibrated test equipment is required.
3. Protection elements setpoints verification (analog values injection or visual verification of setting file entries against relay settings schedule).
4. Contact inputs and outputs verification. This test can be conducted by direct change of state forcing or as part of the system functional testing.
5. Visual inspection for any damage, corrosion, or dust.
6. Event recorder file download with further events analysis.
7. LED Test and pushbutton continuity check.

Unscheduled maintenance such as during a disturbance causing system interruption:
1. View the event recorder and oscillography or fault report for correct operation of inputs, outputs, and elements.

If it is concluded that the relay or one of its modules is of concern, contact GE Multilin or one of its representatives for prompt service.
The F60 Feeder Management Relay is a microprocessor based relay designed for feeder protection.

Overvoltage and undervoltage protection, overfrequency and underfrequency protection, breaker failure protection, directional current supervision, fault diagnostics, RTU, and programmable logic functions are provided. This relay also provides phase, neutral, ground and negative sequence, instantaneous and time overcurrent protection. The time overcurrent function provides multiple curve shapes or FlexCurves™ for optimum co-ordination. Automatic reclosing, synchrocheck, and line fault locator features are also provided. When equipped with a type 8Z CT/VT module, an element for detecting high impedance faults is provided.

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

Diagnostic features include a sequence of records capable of storing 1024 time-tagged events. The internal clock used for time-tagging can be synchronized with an IRIG-B signal or via the SNTP protocol over the Ethernet port. This precise time stamping allows the sequence of events to be determined throughout the system. 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 personal computer (PC). These tools significantly reduce troubleshooting time and simplify report generation in the event of a system fault.

A faceplate RS232 port may be used to connect to a PC for the programming of settings and the monitoring of actual values. A variety of communications modules are available. Two rear RS485 ports 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 IEC 61850, Modbus®/TCP, and TFTP protocols, and allows access to the relay via any standard web browser (F60 web pages). The IEC 60870-5-104 protocol is supported on the Ethernet port. DNP 3.0 and IEC 60870-5-104 cannot be enabled at the same time.

The F60 IEDs use flash memory technology which allows field upgrading as new features are added. The following Single Line Diagram illustrates the relay functionality using ANSI (American National Standards Institute) device numbers.

### Table 2–1: ANSI DEVICE NUMBERS AND FUNCTIONS

<table>
<thead>
<tr>
<th>DEVICE NUMBER</th>
<th>FUNCTION</th>
<th>DEVICE NUMBER</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 (2)</td>
<td>Synchrocheck</td>
<td>51_2 (2)</td>
<td>Negative Sequence Time Overcurrent</td>
</tr>
<tr>
<td>27P (2)</td>
<td>Phase Undervoltage</td>
<td>52</td>
<td>AC Circuit Breaker</td>
</tr>
<tr>
<td>27X</td>
<td>Auxiliary Undervoltage</td>
<td>59N</td>
<td>Neutral Overvoltage</td>
</tr>
<tr>
<td>32</td>
<td>Sensitive Directional Power</td>
<td>59P</td>
<td>Phase Overvoltage</td>
</tr>
<tr>
<td>50BF / 50NBF (2)</td>
<td>Breaker Failure</td>
<td>59X</td>
<td>Auxiliary Overvoltage</td>
</tr>
<tr>
<td>50DD</td>
<td>Disturbance Detector</td>
<td>59_2</td>
<td>Negative Sequence Overvoltage</td>
</tr>
<tr>
<td>50G (2)</td>
<td>Ground Instantaneous Overcurrent</td>
<td>67N (2)</td>
<td>Neutral Directional Overcurrent</td>
</tr>
<tr>
<td>50N (2)</td>
<td>Neutral Instantaneous Overcurrent</td>
<td>67P (2)</td>
<td>Phase Directional</td>
</tr>
<tr>
<td>50P (2)</td>
<td>Phase Instantaneous Overcurrent</td>
<td>67_2 (2)</td>
<td>Negative Sequence Directional Overcurrent</td>
</tr>
<tr>
<td>50_2 (2)</td>
<td>Negative Sequence Instantaneous Overcurrent</td>
<td>79</td>
<td>Automatic Recloser</td>
</tr>
<tr>
<td>51G (2)</td>
<td>Ground Time Overcurrent</td>
<td>81O (4)</td>
<td>Overfrequency</td>
</tr>
<tr>
<td>51N (2)</td>
<td>Neutral Time Overcurrent</td>
<td>81U (6)</td>
<td>Underfrequency</td>
</tr>
<tr>
<td>51P (2)</td>
<td>Phase Time Overcurrent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 2.1 INTRODUCTION

#### 2.1.2 ORDERING

The relay is available as a 19-inch rack horizontal mount unit or a reduced size (¾) vertical mount unit, and consists of the following modules: power supply, CPU, CT/VT, digital input/output, transducer input/output. Each of these modules can be supplied in a number of configurations specified at the time of ordering. The information required to completely specify the relay is provided in the following tables (see Chapter 3 for full details of relay modules).

#### Table 2–2: OTHER DEVICE FUNCTIONS

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>FUNCTION</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaker Arcing Current (I^2t)</td>
<td>Fault Detector and Fault Report</td>
<td>Oscillography</td>
</tr>
<tr>
<td>Breaker Control (2)</td>
<td>Fault Locator</td>
<td>Setting Groups (6)</td>
</tr>
<tr>
<td>Cold Load Pickup (2)</td>
<td>FlexElements™ (8)</td>
<td>Time Synchronization over SNTP</td>
</tr>
<tr>
<td>Contact Inputs (up to 96)</td>
<td>FlexLogic™ Equations</td>
<td>Transducer Inputs/Outputs</td>
</tr>
<tr>
<td>Contact Outputs (up to 64)</td>
<td>High Impedance Fault Detection (Hi-Z)</td>
<td>User Definable Displays</td>
</tr>
<tr>
<td>Control Pushbuttons</td>
<td>IEC 61850 Communications (optional)</td>
<td>User Programmable LEDs</td>
</tr>
<tr>
<td>Data Logger</td>
<td>Load Encroachment</td>
<td>User Programmable Pushbuttons</td>
</tr>
<tr>
<td>Demand</td>
<td>Metering: Current, Voltage, Power, PF, Energy, Frequency, Harmonics, THD</td>
<td>User Programmable Self-Tests</td>
</tr>
<tr>
<td>Digital Counters (8)</td>
<td>Modbus User Map</td>
<td>Virtual Inputs (64)</td>
</tr>
<tr>
<td>Digital Elements (48)</td>
<td>Non-Volatile User Map</td>
<td>Virtual Outputs (96)</td>
</tr>
<tr>
<td>Direct Inputs/Outputs (32)</td>
<td>Non-Volatile Latches</td>
<td>VT Fuse Failure</td>
</tr>
<tr>
<td>Event Recorder</td>
<td>Non-Volatile Selector Switch</td>
<td></td>
</tr>
</tbody>
</table>

---

**Figure 2–1: SINGLE LINE DIAGRAM**

---
<table>
<thead>
<tr>
<th>Module</th>
<th>Communi- cations</th>
<th>CPU Options</th>
<th>Display Options</th>
<th>Power Options</th>
<th>Mounting Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>F60</td>
<td>Ethernet Global Data (EGD)</td>
<td>Multi Software Options</td>
<td>English display</td>
<td>Sensitive Ground 4CT/4VT</td>
<td>Full Size Horizontal Mount</td>
</tr>
<tr>
<td></td>
<td>IEC 61850</td>
<td>High Performance</td>
<td>Russian display with 4 small and 12 large programmable pushbuttons</td>
<td>Hi-Z 4CT (required for high-impedance fault detection element)</td>
<td>Standard 8CT</td>
</tr>
<tr>
<td></td>
<td>Ethernet Global Data (EGD); not available for Type E CPUs</td>
<td>No Software Options</td>
<td>Chinese display with 4 small and 12 large programmable pushbuttons</td>
<td>Standard 8CT</td>
<td>Full Size Vertical Mount</td>
</tr>
<tr>
<td></td>
<td>Ethernet Global Data (EGD) and IEC 61850; not available for Type E CPUs</td>
<td>No Software Options</td>
<td>Chinese display</td>
<td>Sensitive Ground 4CT</td>
<td>Wall Mountable Vertical Mount</td>
</tr>
<tr>
<td></td>
<td>Ethernet Global Data (EGD); not available for Type E CPUs</td>
<td>No Software Options</td>
<td>English display</td>
<td>Hi-Z 4CT (required for high-impedance fault detection element)</td>
<td>Wall Mountable Vertical Mount</td>
</tr>
</tbody>
</table>

**Table 2-3: F60 ORDER CODES (HORIZONTAL UNITS)**

<table>
<thead>
<tr>
<th>Module</th>
<th>Communi- cations</th>
<th>CPU Options</th>
<th>Display Options</th>
<th>Power Options</th>
<th>Mounting Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>F60</td>
<td>Ethernet Global Data (EGD)</td>
<td>Multi Software Options</td>
<td>English display</td>
<td>Sensitive Ground 4CT/4VT</td>
<td>Full Size Horizontal Mount</td>
</tr>
<tr>
<td></td>
<td>IEC 61850</td>
<td>High Performance</td>
<td>Russian display with 4 small and 12 large programmable pushbuttons</td>
<td>Hi-Z 4CT (required for high-impedance fault detection element)</td>
<td>Standard 8CT</td>
</tr>
<tr>
<td></td>
<td>Ethernet Global Data (EGD); not available for Type E CPUs</td>
<td>No Software Options</td>
<td>Chinese display with 4 small and 12 large programmable pushbuttons</td>
<td>Standard 8CT</td>
<td>Full Size Vertical Mount</td>
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<tr>
<td></td>
<td>Ethernet Global Data (EGD) and IEC 61850; not available for Type E CPUs</td>
<td>No Software Options</td>
<td>Chinese display</td>
<td>Sensitive Ground 4CT</td>
<td>Wall Mountable Vertical Mount</td>
</tr>
<tr>
<td></td>
<td>Ethernet Global Data (EGD); not available for Type E CPUs</td>
<td>No Software Options</td>
<td>Chinese display</td>
<td>Hi-Z 4CT (required for high-impedance fault detection element)</td>
<td>Wall Mountable Vertical Mount</td>
</tr>
</tbody>
</table>

2.1 INTRODUCTION
2.1 INTRODUCTION

2 PRODUCT DESCRIPTION

Table 2–4: F60 ORDER CODES (REDUCED SIZE VERTICAL UNITS)

<table>
<thead>
<tr>
<th>BASE UNIT</th>
<th>CPU</th>
<th>SOFTWARE</th>
<th>MOUNT/COATING</th>
<th>POWER SUPPLY</th>
<th>CT/VT MODULES</th>
<th>DIGITAL INPUTS/OUTPUTS</th>
<th>TRANSUCER INPUTS/OUTPUTS</th>
<th>INTER-RELAY COMMUNICATIONS</th>
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For the last module, slot P is used for digital and transducer input/output modules; slot R is used for inter-relay communications modules.

NOTE: Vertical (3/4 rack) with harsh environmental coating.

Base Unit: Reduced Size Vertical Mount (see note regarding PR slot below)

CPU: Select a maximum of 4 per unit

Communications: Ethernet Global Data (EGD) and IEC 61850; not available for Type E CPUs.

Inter-Relay Communications: 125 / 250 V AC/DC power supply.

CT/VT Modules: Standard 4CT/4VT

Digital Inputs/Outputs: 16 digital inputs with Auto-Burnishing

Transducer Inputs/Outputs: 4 dcmA inputs only one 5A module is available

For GE Multilin 2-4 F60 Feeder Management Relay
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 2-5: ORDER CODES FOR REPLACEMENT MODULES

<table>
<thead>
<tr>
<th>POWER SUPPLY</th>
<th>ORDER CODES</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 / 250 V AC/DC</td>
<td>1L</td>
</tr>
<tr>
<td>24 to 48 V (DC only)</td>
<td>1L</td>
</tr>
<tr>
<td>redundant 125 / 250 V AC/DC</td>
<td>1L</td>
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<tr>
<td>redundant 24 to 48 V (DC only)</td>
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<td>9P</td>
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<td>FACEPLATE/DISPLAY</td>
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<td>DIGITAL INPUTS/OUTPUTS</td>
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<td>CT/VT MODUL PERS (NOT AVAILABLE FOR THE C30)</td>
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<td>UR INTER-RELAY COMMUNICATIONS</td>
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GE Multilin

F60 Feeder Management Relay

2-5
2.2 SPECIFICATIONS

SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE

2.2.1 PROTECTION ELEMENTS

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.

**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; I²t; FlexCurves™ (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)

**NEGATIVE SEQUENCE TOC**

- **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)
- **Curve shapes:** IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/Extremely Inverse; I²t; FlexCurves™ (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)

**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:** <16 ms at 3 × Pickup at 60 Hz (Phase/Neutral IOC)
  - <20 ms at 3 × Pickup at 60 Hz (Neutral IOC)
- **Timing accuracy:** Operate at 1.5 × Pickup ±3% or ±4 ms (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})
  - A/B/C 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: \( 3 \times (|I_0| - K \times |I_1|) \), \( IG \)
Restraint, \( K \): 0.000 to 0.500 in steps of 0.001
Characteristic angle: \( -90^\circ \) to \( 90^\circ \) in steps of 1
Limit angle: 40 to 90° in steps of 1, independent for forward and reverse
Angle accuracy: \( \pm 2^\circ \)
Offset impedance: 0.00 to 250.00 Ω in steps of 0.01
Pickup level: 0.002 to 30.000 pu in steps of 0.01
Dropout level: 97 to 98%
Operation time: < 16 ms at 3 × Pickup at 60 Hz

NEGATIVE SEQUENCE DIRECTIONAL OC
Directionality: Co-existing forward and reverse
Polarizing: Voltage
Polarizing voltage: \( V_2 \)
Operating current: \( I_2 \)
Level sensing:
  - Zero-sequence: \( |I_0| - K \times |I_1| \)
  - Negative-sequence: \( |I_2| - K \times |I_1| \)
Restraint, \( K \): 0.000 to 0.500 in steps of 0.001
Characteristic angle: 0 to 90° in steps of 1
Limit angle: 40 to 90° in steps of 1, independent for forward and reverse
Angle accuracy: \( \pm 2^\circ \)
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
Dropout level: 97 to 98%
Operation time: < 16 ms at 3 × Pickup at 60 Hz

SENSITIVE DIRECTIONAL POWER
Measured power: 3-phase, true RMS
Number of stages: 2
Characteristic angle: 0 to 359° in steps of 1
Calibration angle: 0.00 to 0.95° in steps of 0.05
Minimum power: –1.200 to 1.200 pu in steps of 0.001
Pickup level accuracy: \( \pm 1\% \) or \( \pm 0.001 \) pu, whichever is greater
Hysteresis: 2% or 0.001 pu, whichever is greater
Pickup delay: 0 to 600.00 s in steps of 0.01
Time accuracy: \( \pm 3\% \) or \( \pm 4 \) ms, whichever is greater
Operate time: 50 ms

PHASE UNDERVOLTAGE
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: \( \pm 0.5\% \) 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
\( \pm 3\% \) of operate time or \( \pm 4 \) ms (whichever is greater)

AUXILIARY UNDERVOLTAGE
Pickup level: 0.000 to 3.000 pu in steps of 0.001
Dropout level: 97 to 98% of Pickup
Level accuracy: \( \pm 0.5\% \) 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: \( \pm 3\% \) or \( \pm 4 \) 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: \( \pm 0.5\% \) of reading from 10 to 208 V
Curve shapes: GE IAV Inverse, Definite Time
Curve multiplier: Time dial = 0.00 to 600.00 in steps of 0.01
Operate time: < 30 ms at 1.10 × Pickup at 60 Hz
Timing accuracy: \( \pm 3\% \) or \( \pm 4 \) ms (whichever is greater)

NEUTRAL OVERVOLTAGE
Pickup level: 0.000 to 3.000 pu in steps of 0.001
Dropout level: 97 to 98% of Pickup
Level accuracy: \( \pm 0.5\% \) of reading from 10 to 208 V
Curve shapes: GE IAV Inverse, Definite Time
Curve multiplier: Time Dial = 0.00 to 600.00 in steps of 0.01
Reset delay: 0 to 600.00 s in steps of 0.01
Operate time: < 30 ms at 1.10 × Pickup at 60 Hz
Timing accuracy: \( \pm 3\% \) or \( \pm 20 \) 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: \( \pm 0.5\% \) 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
Reset delay: 0 to 600.00 s in steps of 0.01
Operate time: < 30 ms at 1.10 × Pickup at 60 Hz
Timing accuracy: \( \pm 3\% \) or \( \pm 4 \) ms (whichever is greater)

NEGATIVE SEQUENCE OVERVOLTAGE
Pickup level: 0.000 to 1.250 pu in steps of 0.001
Dropout level: 97 to 98% of Pickup
Level accuracy: \( \pm 0.5\% \) 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
Reset delay: 0 to 600.00 s in steps of 0.01
Time accuracy: \( \pm 3\% \) or \( \pm 20 \) ms (whichever is greater)
Operate time: < 30 ms at 1.10 × Pickup at 60 Hz
<table>
<thead>
<tr>
<th>Feature</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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<tr>
<td>Minimum signal</td>
<td>0.10 to 1.25 pu in steps of 0.01</td>
</tr>
<tr>
<td>Pickup level</td>
<td>20.00 to 65.00 Hz in steps of 0.01</td>
</tr>
<tr>
<td>Dropout level</td>
<td>Pickup + 0.03 Hz</td>
</tr>
<tr>
<td>Level accuracy</td>
<td>±0.01 Hz</td>
</tr>
<tr>
<td>Time delay</td>
<td>0 to 65.53 s in steps of 0.001</td>
</tr>
<tr>
<td>Time accuracy</td>
<td>±3% or 4 ms, whichever is greater</td>
</tr>
<tr>
<td><strong>OVERFREQUENCY</strong></td>
<td></td>
</tr>
<tr>
<td>Pickup level</td>
<td>20.00 to 65.00 Hz in steps of 0.01</td>
</tr>
<tr>
<td>Dropout level</td>
<td>Pickup – 0.03 Hz</td>
</tr>
<tr>
<td>Level accuracy</td>
<td>±0.01 Hz</td>
</tr>
<tr>
<td>Time delay</td>
<td>0 to 65.53 s in steps of 0.001</td>
</tr>
<tr>
<td>Time accuracy</td>
<td>±3% or 4 ms, whichever is greater</td>
</tr>
<tr>
<td><strong>RATE OF CHANGE OF FREQUENCY</strong></td>
<td></td>
</tr>
<tr>
<td>df/dt trend</td>
<td>increasing, decreasing, bi-directional</td>
</tr>
<tr>
<td>df/dt pickup level</td>
<td>0.10 to 15.00 Hz/s in steps of 0.01</td>
</tr>
<tr>
<td>df/dt dropout level</td>
<td>96% of pickup</td>
</tr>
<tr>
<td>df/dt level accuracy</td>
<td>80 mHz/s or 3.5%, whichever is greater</td>
</tr>
<tr>
<td>Overvoltage supv.</td>
<td>0.100 to 3.000 pu in steps of 0.001</td>
</tr>
<tr>
<td>Overcurrent supv.</td>
<td>0.000 to 30.000 pu in steps of 0.001</td>
</tr>
<tr>
<td>Pickup delay</td>
<td>0 to 65.53 s in steps of 0.001</td>
</tr>
<tr>
<td>Reset delay</td>
<td>0 to 65.53 s in steps of 0.001</td>
</tr>
<tr>
<td>Time accuracy</td>
<td>±3% or ±4 ms, whichever is greater</td>
</tr>
<tr>
<td>95% settling time for df/dt</td>
<td>&lt; 24 cycles</td>
</tr>
<tr>
<td>Operate time</td>
<td>at 2 × pickup: 12 cycles</td>
</tr>
<tr>
<td></td>
<td>at 3 × pickup: 8 cycles</td>
</tr>
<tr>
<td></td>
<td>at 5 × pickup: 6 cycles</td>
</tr>
<tr>
<td><strong>BREAKER FAILURE</strong></td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>1-pole, 3-pole</td>
</tr>
<tr>
<td>Current supervision</td>
<td>phase, neutral current</td>
</tr>
<tr>
<td>Current supv. pickup</td>
<td>0.001 to 30.000 pu in steps of 0.001</td>
</tr>
<tr>
<td>Current supv. dropout</td>
<td>97 to 98% of pickup</td>
</tr>
<tr>
<td>Current supv. accuracy</td>
<td>0.1 to 2.0 × CT rating: ±0.75% of reading or ±2% of rated (whichever is greater)</td>
</tr>
<tr>
<td></td>
<td>above 2 × CT rating: ±2.5% of reading</td>
</tr>
<tr>
<td><strong>BREAKER ARCING CURRENT</strong></td>
<td></td>
</tr>
<tr>
<td>Principle</td>
<td>accumulates breaker duty ($i^2t$) and measures fault duration</td>
</tr>
<tr>
<td>Initiation</td>
<td>programmable per phase from any FlexLogic™ operand</td>
</tr>
<tr>
<td>Compensation for auxiliary relays</td>
<td>0 to 65.53 s in steps of 0.001</td>
</tr>
<tr>
<td>Alarm threshold</td>
<td>0 to 50000 kA2-cycle in steps of 1</td>
</tr>
<tr>
<td>Fault duration accuracy</td>
<td>0.25 of a power cycle</td>
</tr>
<tr>
<td>Availability</td>
<td>1 per CT bank with a minimum of 2</td>
</tr>
<tr>
<td><strong>BREAKER FLASHOVER</strong></td>
<td></td>
</tr>
<tr>
<td>Operating quantity</td>
<td>phase current, voltage and voltage difference</td>
</tr>
<tr>
<td>Pickup level voltage</td>
<td>0 to 1.500 pu in steps of 0.001</td>
</tr>
<tr>
<td>Dropout level voltage</td>
<td>97 to 98% of pickup</td>
</tr>
<tr>
<td>Pickup level current</td>
<td>0 to 1.500 pu in steps of 0.001</td>
</tr>
<tr>
<td>Dropout level current</td>
<td>97 to 98% of pickup</td>
</tr>
<tr>
<td>Level accuracy</td>
<td>±0.5% or ±0.1% of rated, whichever is greater</td>
</tr>
<tr>
<td>Pickup delay</td>
<td>0 to 65.53 s in steps of 0.001</td>
</tr>
<tr>
<td>Time accuracy</td>
<td>±3% or ±42 ms, whichever is greater</td>
</tr>
<tr>
<td>Operate time</td>
<td>&lt;42 ms at 1.10 × pickup at 60 Hz</td>
</tr>
<tr>
<td><strong>SYNCHROCHECK</strong></td>
<td></td>
</tr>
<tr>
<td>Max voltage difference</td>
<td>0 to 400000 V in steps of 1</td>
</tr>
<tr>
<td>Max angle difference</td>
<td>0 to 100° in steps of 1</td>
</tr>
<tr>
<td>Max freq. difference</td>
<td>0.00 to 2.00 Hz in steps of 0.01</td>
</tr>
<tr>
<td>Hysteresis for max. freq. diff.</td>
<td>0.00 to 0.10 Hz in steps of 0.01</td>
</tr>
<tr>
<td>Dead source function</td>
<td>None, LV1 &amp; DV2, DV1 &amp; LV2, DV1 or DV2, DV1 xor DV2, DV1 &amp; DV2 (L = Live, D = Dead)</td>
</tr>
<tr>
<td><strong>AUTORECLOSURE</strong></td>
<td></td>
</tr>
<tr>
<td>Single breaker applications</td>
<td>3-pole tripping schemes</td>
</tr>
<tr>
<td>Up to 4 reclose attempts</td>
<td>before lockout</td>
</tr>
<tr>
<td>Independent dead time setting</td>
<td>before each shot</td>
</tr>
<tr>
<td>Possibility of changing</td>
<td>protection settings after each shot with FlexLogic™</td>
</tr>
<tr>
<td><strong>LOAD ENCROACHMENT</strong></td>
<td></td>
</tr>
<tr>
<td>Responds to</td>
<td>Positive-sequence quantities</td>
</tr>
<tr>
<td>Minimum voltage</td>
<td>0.000 to 3.000 pu in steps of 0.001</td>
</tr>
<tr>
<td>Reach (sec. Ω)</td>
<td>0.02 to 250.00 Ω in steps of 0.01</td>
</tr>
<tr>
<td>Impedance accuracy</td>
<td>±5%</td>
</tr>
<tr>
<td>Angle</td>
<td>5 to 50° in steps of 1</td>
</tr>
<tr>
<td>Angle accuracy</td>
<td>±2°</td>
</tr>
<tr>
<td>Pickup delay</td>
<td>0 to 65.53 s in steps of 0.001</td>
</tr>
<tr>
<td>Reset delay</td>
<td>0 to 65.53 s in steps of 0.001</td>
</tr>
<tr>
<td>Time accuracy</td>
<td>±3% or ±4 ms, whichever is greater</td>
</tr>
<tr>
<td>Operate time</td>
<td>&lt; 30 ms at 60 Hz</td>
</tr>
</tbody>
</table>
2.2.2 USER-PROGRAMMABLE ELEMENTS

**FLEXLOGIC™**
- **Programming language:** Reverse Polish Notation with graphical visualization (keypad programmable)
- **Lines of code:** 512
- **Internal variables:** 64
- **Supported operations:** NOT, XOR, OR (2 to 16 inputs), AND (2 to 16 inputs), NOR (2 to 16 inputs), NAND (2 to 16 inputs), Latch (Reset dominant), Edge Detectors, Timers
- **Inputs:** any logical variable, contact, or virtual input
- **Number of timers:** 32
- **Pickup delay:** 0 to 60000 (ms, sec., min.) in steps of 1
- **Dropout delay:** 0 to 60000 (ms, sec., min.) in steps of 1

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

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

**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 & dropout delay:** 0.000 to 65.535 s in steps of 0.001

**NON-VOLATILE LATCHES**
- **Type:** Set-dominant or Reset-dominant
- **Number:** 16 (individually programmed)
- **Output:** Stored in non-volatile memory
- **Execution sequence:** As input prior to protection, control, and FlexLogic™

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

**LED TEST**
- **Number of tests:** 3, interruptible at any time
- **Duration of full test:** approximately 3 minutes
- **Test sequence 1:** all LEDs on
- **Test sequence 2:** all LEDs off, one LED at a time on for 1 s
- **Test sequence 3:** all LEDs on, one LED at a time off for 1 s

**USER-DEFINABLE DISPLAYS**
- **Number of displays:** 16
- **Lines of display:** 2 × 20 alphanumeric characters
- **Parameters:** up to 5, any Modbus register addresses
- **Invoking and scrolling:** keypad, or any user-programmable condition, including pushbuttons

**CONTROL PUSHBUTTONS**
- **Number of pushbuttons:** 7
- **Operation:** drive FlexLogic™ operands

**USER-PROGRAMMABLE PUSHBUTTONS (OPTIONAL)**
- **Number of pushbuttons:** 12
- **Mode:** Self-Reset, Latched
- **Display message:** 2 lines of 20 characters each

**SELECTION SWITCH**
- **Number of elements:** 2
- **Upper position limit:** 1 to 7 in steps of 1
- **Selecting mode:** Time-out or Acknowledge
- **Time-out timer:** 3.0 to 60.0 s in steps of 0.1
- **Control inputs:** step-up and 3-bit
- **Power-up mode:** restore from non-volatile memory or synchronize to a 3-bit control input or Synch/Restore mode
2.2 SPECIFICATIONS

2.2.3 MONITORING

OSCILLOGRAPHY
Maximum 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

DATA LOGGER
Number of channels: 1 to 16
Parameters: Any available analog actual value
Sampling rate: 15 to 360000 ms in steps of 1
Trigger: any FlexLogic™ operand
Mode: continuous or triggered
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

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

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)
ZLine%error + (user data)
METHOD%error + (Chapter 6)
RELAY ACCURACY%error + (1.5%)

HI-Z
Detections: ArcSuspected, ArcDetected, DownedConductor, PhaseIdentification

2.2.4 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

REAL POWER (WATTS)
Accuracy of reading at
−0.8 < PF ≤ −1.0 and 0.8 < PF ≤ 1.0

REACTIVE POWER (VARS)
Accuracy: ±1.0% of reading at −0.2 ≤ PF ≤ 0.2

APPARENT POWER (VA)
Accuracy: ±1.0% of reading

WATT-HOURS (POSITIVE AND NEGATIVE)
Accuracy: ±2.0% of reading
Range: ±10 to 2 × 10^9 MWh
Parameters: 3-phase only
Update rate: 50 ms

VAR-HOURS (POSITIVE AND NEGATIVE)
Accuracy: ±2.0% of reading
Range: ±10 to 2 × 10^9 Mvarh
Parameters: 3-phase only
Update rate: 50 ms

CURRENT HARMONICS
Harmonics: 2nd to 25th harmonic; per phase, displayed as a % of f1 (fundamental frequency phasor)
THD: % of f1
Accuracy:
HARMONICS: 1. f1 > 0.4pu: (0.20% + 0.035%/harmonic) of reading or 0.15% of f1, whichever is greater
2. f1 < 0.4pu: as above plus %error of f1
THD: 1. f1 > 0.4pu: (0.25% + 0.035%/harmonic) of reading or 0.20% of f1, whichever is greater
2. f1 < 0.4pu: as above plus %error of f1

VOLTAGE HARMONICS
Harmonics: 2nd to 25th harmonic; per phase, displayed as a % of f1 (fundamental frequency phasor)
THD: % of f1
Accuracy:
HARMONICS: 1. f1 > 0.4pu: (0.20% + 0.035%/harmonic) of reading or 0.15% of f1, whichever is greater
2. f1 < 0.4pu: as above plus %error of f1
THD: 1. f1 > 0.4pu: (0.25% + 0.035%/harmonic) of reading or 0.20% of f1, whichever is greater
2. f1 < 0.4pu: as above plus %error of f1
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)

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%

2.2.5 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: 0.02 to 46 × CT rating RMS symmetrical
Sensitive Ground/HI-Z CT module: 0.002 to 4.6 × CT rating RMS symmetrical
Current withstand:
20 ms at 250 times rated
1 sec. at 100 times rated
continuous at 3 times rated

AC VOLTAGE
CT rated secondary: 50.0 to 240.0 V
VT ratio: 1.00 to 24000.00
Nominal frequency: 20 to 65 Hz
Relay burden: < 0.25 VA at 120 V
Conversion range: 1 to 275 V
Voltage withstand:
continuous at 260 V to neutral
1 min./hr at 420 V to neutral

CONTACT INPUTS
Dry contacts: 1000 Ω maximum
Wet contacts: 300 V DC maximum
Selectable thresholds: 17 V, 33 V, 84 V, 166 V
Tolerance: ±10%
Contacts per common return: 4
Recognition time: < 1 ms
Debounce time: 0.0 to 16.0 ms in steps of 0.5
Continuous current draw: 3 mA (when energized)

CONTACT INPUTS WITH AUTO-BURNISHING
Dry contacts: 1000 Ω maximum
Wet contacts: 300 V DC maximum
Selectable thresholds: 17 V, 33 V, 84 V, 166 V
Tolerance: ±10%
Contacts per common return: 2
Recognition time: < 1 ms
Debounce time: 0.0 to 16.0 ms in steps of 0.5
Continuous current draw: 3 mA (when energized)
Auto-burnish impulse current: 50 to 70 mA
Duration of auto-burnish impulse: 25 to 50 ms

DCMA INPUTS
Current input (mA DC): 0 to –1, 0 to +1, –1 to +1, 0 to 5, 0 to 10, 0 to 20, 4 to 20 (programmable)
Input impedance: 379 Ω ±10%
Conversion range: –1 to + 20 mA DC
Accuracy: ±0.2% of full scale
Type: Passive

RTD INPUTS
Types (3-wire): 100 Ω Platinum, 100 & 120 Ω Nickel, 10 Ω Copper
Sensing current: 5 mA
Range: –50 to +250°C
Accuracy: ±2°C
Isolation: 36 V pk-pk

IRIG-B INPUT
Amplitude modulation: 1 to 10 V pk-pk
DC shift: TTL
Input impedance: 22 kΩ
Isolation: 2 kV

REMOTE INPUTS (MMS GOOSE)
Number of input points: 32, configured from 64 incoming bit pairs
Number of remote devices: 16
Default states on loss of comms.: On, Off, Latest/Off, Latest/On

DIRECT INPUTS
Number of input points: 32
No. of remote devices: 16
Default states on loss of comms.: On, Off, Latest/Off, Latest/On
Ring configuration: Yes, No
Data rate: 64 or 128 kbps
CRC: 32-bit
CRC alarm:
Responding to: Rate of messages failing the CRC
Monitoring message count: 10 to 10000 in steps of 1
Alarm threshold: 1 to 1000 in steps of 1
Unreturned message alarm:
Responding to: Rate of unreturned messages in the ring configuration
Monitoring message count: 10 to 10000 in steps of 1
Alarm threshold: 1 to 1000 in steps of 1

TELEPROTECTION
Number of input points: 16
No. of remote devices: 3
Default states on loss of comms.: On, Off, Latest/Off, Latest/On
Ring configuration: No
Data rate: 64 or 128 kbps
CRC: 32-bit
2.2 SPECIFICATIONS

2.2.6 POWER SUPPLY

LOW RANGE
Nominal DC voltage: 24 to 48 V
Min/max DC voltage: 20 / 60 V
Voltage loss hold-up: 20 ms duration at nominal
NOTE: Low range is DC only.

HIGH RANGE
Nominal DC voltage: 125 to 250 V
Min/max DC voltage: 88 / 300 V
Nominal AC voltage: 100 to 240 V at 50/60 Hz
Min/max AC voltage: 88 / 265 V at 25 to 100 Hz
Voltage loss hold-up: 200 ms duration at nominal

ALL RANGES
Volt withstand: $2 \times \text{Highest Nominal Voltage for 10 ms}$
Power consumption:
- typical = 15 to 20 W/VA
- maximum = 50 W/VA
- contact factory for exact order code consumption

INTERNAL FUSE
RATINGS
- Low range power supply: 8 A / 250 V
- High range power supply: 4 A / 250 V

interrupting Capacity
- AC: 100 000 A RMS symmetrical
- DC: 10 000 A

2.2.7 OUTPUTS

FORM-A RELAY
Make and carry for 0.2 s: 30 A as per ANSI C37.90
Carry continuous: 6 A
Break (DC inductive, L/R = 40 ms):

<table>
<thead>
<tr>
<th>VOLTAGE</th>
<th>CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 V</td>
<td>1 A</td>
</tr>
<tr>
<td>48 V</td>
<td>0.5 A</td>
</tr>
<tr>
<td>125 V</td>
<td>0.3 A</td>
</tr>
<tr>
<td>250 V</td>
<td>0.2 A</td>
</tr>
</tbody>
</table>

Operate time: < 4 ms
Contact material: silver alloy

LATCHING RELAY
Make and carry for 0.2 s: 30 A as per ANSI C37.90
Carry continuous: 6 A
Break at L/R of 40 ms: 0.25 A DC max.
Operate time: < 4 ms
Contact material: silver alloy
Control: separate operate and reset inputs
Control mode: operate-dominant or reset-dominant

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 s: 30 A as per ANSI C37.90
Carry continuous: 8 A
Break (DC inductive, L/R = 40 ms):

<table>
<thead>
<tr>
<th>VOLTAGE</th>
<th>CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 V</td>
<td>1 A</td>
</tr>
<tr>
<td>48 V</td>
<td>0.5 A</td>
</tr>
<tr>
<td>125 V</td>
<td>0.3 A</td>
</tr>
<tr>
<td>250 V</td>
<td>0.2 A</td>
</tr>
</tbody>
</table>

Operate time: < 8 ms
Contact material: silver alloy

FAST FORM-C RELAY
Make and carry: 0.1 A max. (resistive load)
Minimum load impedance:

<table>
<thead>
<tr>
<th>INPUT VOLTAGE</th>
<th>IMPEDANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 V DC</td>
<td>20 KΩ</td>
</tr>
<tr>
<td>120 V DC</td>
<td>5 KΩ</td>
</tr>
<tr>
<td>48 V DC</td>
<td>2 KΩ</td>
</tr>
<tr>
<td>24 V DC</td>
<td>2 KΩ</td>
</tr>
</tbody>
</table>

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: 100 Ω, 2 W

SOLID-STATE OUTPUT RELAY
Operate and release time: <100 μs
Maximum voltage: 265 V DC
Maximum continuous current: 5 A at 45°C; 4 A at 65°C
Make and carry:
- for 0.2 s: 30 A as per ANSI C37.90
- for 0.03 s: 300 A

Breaking capacity:

UL508 | Utility application (autoreclose scheme) | Industrial application
---|---|---

<table>
<thead>
<tr>
<th>Operations/interval</th>
<th>5000 ops / 1 s-On, 9 s-Off</th>
<th>5 ops / 0.2 s-On, 0.2 s-Off within 1 minute</th>
<th>1000 ops / 0.2 s-On, 30 s-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break capability (0 to 250 V DC)</td>
<td>3.2 A L/R = 10 ms</td>
<td>10 A L/R = 40 ms</td>
<td>10 A L/R = 40 ms</td>
</tr>
<tr>
<td></td>
<td>1.6 A L/R = 20 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.8 A L/R = 40 ms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IRIG-B OUTPUT
Amplitude: 10 V peak-peak RS485 level
Maximum load: 100 ohms
Time delay: 1 ms for AM input
40 μs for DC-shift input
Isolation: 2 kV

CONTROL POWER EXTERNAL OUTPUT (FOR DRY CONTACT INPUT)
Capacity: 100 mA DC at 48 V DC
Isolation: ±300 Vpk

REMOTE OUTPUTS (IEC 61850 GSSE/GOOSE)
Standard output points: 32
User output points: 32

DIRECT OUTPUTS
Output points: 32

DCMA OUTPUTS
Range: –1 to 1 mA, 0 to 1 mA, 4 to 20 mA
Max. load resistance: 12 kΩ for –1 to 1 mA range
12 kΩ for 0 to 1 mA range
600 Ω for 4 to 20 mA range
Accuracy: ±0.75% of full-scale for 0 to 1 mA range
±0.5% of full-scale for –1 to 1 mA range
±0.75% of full-scale for 0 to 20 mA range
99% Settling time to a step change: 100 ms
Isolation: 1.5 kV
Driving signal: any FlexAnalog quantity
Upper and lower limit for the driving signal: –90 to 90 pu in steps of 0.001

2.2.8 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
Isolation: 2 kV

ETHERNET (FIBER)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>FIBER TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10MB MULTI-MODE</td>
</tr>
<tr>
<td>Wavelength</td>
<td>820 nm</td>
</tr>
<tr>
<td>Connector</td>
<td>ST</td>
</tr>
<tr>
<td>Transmit power</td>
<td>–20 dBm</td>
</tr>
<tr>
<td>Receiver sensitivity</td>
<td>–30 dBm</td>
</tr>
<tr>
<td>Power budget</td>
<td>10 dB</td>
</tr>
<tr>
<td>Maximum input power</td>
<td>–7.6 dBm</td>
</tr>
<tr>
<td>Typical distance</td>
<td>1.65 km</td>
</tr>
<tr>
<td>Duplex</td>
<td>full/half</td>
</tr>
<tr>
<td>Redundancy</td>
<td>yes</td>
</tr>
</tbody>
</table>

ETHERNET (COPPER)
Modes: 10 MB, 10/100 MB (auto-detect)
Connector: RJ45
SNTP clock synchronization error: <10 ms (typical)
2.2 SPECIFICATIONS

2.2.9 INTER-RELAY COMMUNICATIONS

SHIELDED TWISTED-PAIR INTERFACE OPTIONS

<table>
<thead>
<tr>
<th>INTERFACE TYPE</th>
<th>TYPICAL DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS422</td>
<td>1200 m</td>
</tr>
<tr>
<td>G.703</td>
<td>100 m</td>
</tr>
</tbody>
</table>

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

LINK POWER BUDGET

<table>
<thead>
<tr>
<th>Emitter, Fiber Type</th>
<th>Transmit Power</th>
<th>Received Sensitivity</th>
<th>Power Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>820 nm LED, Multimode</td>
<td>-20 dBm</td>
<td>-30 dBm</td>
<td>10 dB</td>
</tr>
<tr>
<td>1300 nm LED, Multimode</td>
<td>-21 dBm</td>
<td>-30 dBm</td>
<td>9 dB</td>
</tr>
<tr>
<td>1300 nm ELED, Singlemode</td>
<td>-21 dBm</td>
<td>-30 dBm</td>
<td>9 dB</td>
</tr>
<tr>
<td>1300 nm Laser, Singlemode</td>
<td>-1 dBm</td>
<td>-30 dBm</td>
<td>29 dB</td>
</tr>
<tr>
<td>1550 nm Laser, Singlemode</td>
<td>+5 dBm</td>
<td>-30 dBm</td>
<td>35 dB</td>
</tr>
</tbody>
</table>

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

MAXIMUM OPTICAL INPUT POWER

<table>
<thead>
<tr>
<th>Emitter, Fiber Type</th>
<th>Max. Optical Input Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>820 nm LED, Multimode</td>
<td>-7.6 dBm</td>
</tr>
<tr>
<td>1300 nm LED, Multimode</td>
<td>-11 dBm</td>
</tr>
<tr>
<td>1300 nm ELED, Singlemode</td>
<td>-14 dBm</td>
</tr>
<tr>
<td>1300 nm Laser, Singlemode</td>
<td>-14 dBm</td>
</tr>
<tr>
<td>1550 nm Laser, Singlemode</td>
<td>-14 dBm</td>
</tr>
</tbody>
</table>

TYPICAL LINK DISTANCE

<table>
<thead>
<tr>
<th>Emitter Type</th>
<th>Fiber Type</th>
<th>Connector Type</th>
<th>Typical Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>820 nm LED</td>
<td>Multimode</td>
<td>ST</td>
<td>1.65 km</td>
</tr>
<tr>
<td>1300 nm LED</td>
<td>Multimode</td>
<td>ST</td>
<td>3.8 km</td>
</tr>
<tr>
<td>1300 nm ELED</td>
<td>Singlemode</td>
<td>ST</td>
<td>11.4 km</td>
</tr>
<tr>
<td>1300 nm Laser</td>
<td>Singlemode</td>
<td>ST</td>
<td>64 km</td>
</tr>
<tr>
<td>1550 nm Laser</td>
<td>Singlemode</td>
<td>ST</td>
<td>105 km</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Connector Type</th>
<th>Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST</td>
<td>2 dB</td>
</tr>
</tbody>
</table>

FIBER LOSSES

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Losses (dB/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>820 nm multimode</td>
<td>3 dB/km</td>
</tr>
<tr>
<td>1300 nm multimode</td>
<td>1 dB/km</td>
</tr>
<tr>
<td>1300 nm singlemode</td>
<td>0.35 dB/km</td>
</tr>
<tr>
<td>1550 nm singlemode</td>
<td>0.25 dB/km</td>
</tr>
</tbody>
</table>

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.

Compensated difference in transmitting and receiving (channel asymmetry) channel delays using GPS satellite clock: 10 ms

2.2.10 ENVIRONMENTAL

AMBIENT TEMPERATURES

<table>
<thead>
<tr>
<th>Condition</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>-40 to 60°C</td>
</tr>
<tr>
<td>Storage</td>
<td>-40 to 80°C</td>
</tr>
</tbody>
</table>

The LCD contrast may be impaired at temperatures less than -20°C.

OTHER

<table>
<thead>
<tr>
<th>Condition</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity (non-condensing)</td>
<td>IEC 60068-2-30, 95%, Variant 1, 6 days</td>
</tr>
<tr>
<td>Altitude</td>
<td>Up to 2000 m</td>
</tr>
<tr>
<td>Installation Class</td>
<td>II</td>
</tr>
</tbody>
</table>
2 PRODUCT DESCRIPTION

2.2 SPECIFICATIONS

2.2.11 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: ANSI/IEEE C37.90, IEC 60255-6
- 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
- Pulse magnetic field immunity: IEC 61000-4-9
- Vibration test (sinusoidal): IEC 60255-21-1
- Shock and bump: IEC 60255-21-2
- Seismic: IEC 60255-21-3
- Cold: IEC 60028-2-1, 16 h at –40°C
- Dry heat: IEC 60028-2-2, 16 h at 85°C

Type test report available upon request.

2.2.12 PRODUCTION TESTS

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

2.2.13 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

2.2.14 MAINTENANCE

MOUNTING
Attach mounting brackets using 20 inch-pounds (±2 inch-pounds) of torque.

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

Units that are stored in a de-energized state should be powered up once per year, for one hour continuously, to avoid deterioration of electrolytic capacitors.
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 3–2: F60 VERTICAL SIDE MOUNTING INSTALLATION
Figure 3–3: F60 VERTICAL SIDE MOUNTING REAR DIMENSIONS

Figure 3–4: F60 HORIZONTAL MOUNTING AND DIMENSIONS
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 below. This allows for easy accessibility of the modules for withdrawal.

• MODULE 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. Modules with current input provide automatic shorting of external CT circuits.

• MODULE 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.

All CPU modules except the 9E are equipped with 10Base-T or 10Base-F Ethernet connectors. These connectors must be individually disconnected from the module before it can be removed from the chassis.

The version 4.0 release of the F60 relay includes new hardware (CPU and CT/VT modules). The new CPU modules are specified with the following order codes: 9E, 9G, 9H, 9J, 9K, 9L, 9M, 9N, 9P, 9R. The new CT/VT modules are specified with the following order codes: 8F, 8G, 8H, 8J.

The new CT/VT modules (8F, 8G, 8H, 8J) can only be used with new CPUs (9E, 9G, 9H, 9J, 9K, 9L, 9M, 9N, 9P, 9R); similarly, old CT/VT modules (8A, 8B, 8C, 8D) can only be used with old CPUs (9A, 9C, 9D). To prevent hardware mismatches, the new modules have blue labels and a warning sticker stating “Attn.: Ensure CPU and DSP module label colors are the same!”. In the event that there is a mismatch between the CPU and CT/VT module, the relay will not function and a DSP ERROR or HARDWARE MISMATCH error will be displayed.

All other input/output modules are compatible with the new hardware. Firmware versions 4.0x and higher are only compatible with the new CPU and CT/VT modules. Previous versions of the firmware (3.4x and earlier) are only compatible with the older CPU and CT/VT modules.
Do not touch any rear terminals while the relay is energized!

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 3–6: REAR TERMINAL VIEW

Figure 3–7: EXAMPLE OF MODULES IN F AND H SLOTS
This diagram is based on the following order code: F60-E00-HCH-F8F-H6B-M6K-P6C-P6D-U6A.
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.

Figure 3–8: TYPICAL WIRING DIAGRAM
This wiring diagram is based on the following order code: F60-H00-HCH-F8F-H6B-M8Z-P6C-Uxx-Wxx. This diagram provides 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.

Figure 3–9: TYPICAL WIRING DIAGRAM WITH HI-Z
The dielectric strength of the UR-series module hardware is shown in the following table:

Table 3–1: DIELECTRIC STRENGTH OF UR-SERIES MODULE HARDWARE

<table>
<thead>
<tr>
<th>MODULE TYPE</th>
<th>MODULE FUNCTION</th>
<th>TERMINALS FROM</th>
<th>TERMINALS TO</th>
<th>DIELECTRIC STRENGTH (AC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power Supply</td>
<td>High (+); Low (+); (-)</td>
<td>Chassis</td>
<td>2000 V AC for 1 minute</td>
</tr>
<tr>
<td>1</td>
<td>Power Supply</td>
<td>48 V DC (+) and (-)</td>
<td>Chassis</td>
<td>2000 V AC for 1 minute</td>
</tr>
<tr>
<td>1</td>
<td>Power Supply</td>
<td>Relay Terminals</td>
<td>Chassis</td>
<td>2000 V AC for 1 minute</td>
</tr>
<tr>
<td>2</td>
<td>Reserved</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>Reserved</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>Reserved</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>Analog Inputs/Outputs</td>
<td>All except 8b</td>
<td>Chassis</td>
<td>&lt; 50 V DC</td>
</tr>
<tr>
<td>6</td>
<td>Digital Inputs/Outputs</td>
<td>All</td>
<td>Chassis</td>
<td>2000 V AC for 1 minute</td>
</tr>
<tr>
<td>7</td>
<td>G.703</td>
<td>All except 2b, 3a, 7b, 8a</td>
<td>Chassis</td>
<td>2000 V AC for 1 minute</td>
</tr>
<tr>
<td>8</td>
<td>CT/VT</td>
<td>All</td>
<td>Chassis</td>
<td>2000 V AC for 1 minute</td>
</tr>
<tr>
<td>9</td>
<td>CPU</td>
<td>All</td>
<td>Chassis</td>
<td>2000 V AC for 1 minute</td>
</tr>
</tbody>
</table>

Filter networks and transient protection clamps are used in the hardware to prevent damage caused by high peak voltage transients, radio frequency interference (RFI), and electromagnetic interference (EMI). These protective components can be damaged by application of the ANSI/IEEE C37.90 specified test voltage for a period longer than the specified one minute.
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 F60 relay, like almost all electronic relays, contains electrolytic capacitors. These capacitors are well known to be subject to deterioration over time if voltage is not applied periodically. Deterioration can be avoided by powering the relays up once a year.

The power supply module can be ordered for two possible voltage ranges, with or without a redundant power option. Each range has a dedicated input connection for proper operation. The ranges are as shown below (see the Technical Specifications section of Chapter 2 for additional details):

- LO range: 24 to 48 V (DC only) nominal
- HI range: 125 to 250 V nominal

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

The power supply module provides 48 V DC power for dry contact input connections and a critical failure relay (see the Typical Wiring Diagram earlier). The critical failure relay is a Form-C that will be energized once control power is applied and the relay has successfully booted up with no critical self-test failures. If on-going self-test diagnostic checks detect a critical failure (see the Self-Test Errors table in Chapter 7) or control power is lost, the relay will de-energize.

For high reliability systems, the F60 has a redundant option in which two F60 power supplies are placed in parallel on the bus. If one of the power supplies become faulted, the second power supply will assume the full load of the relay without any interruptions. Each power supply has a green LED on the front of the module to indicate it is functional. The critical fail relay of the module will also indicate a faulted power supply.

An LED on the front of the module shows the status of the power supply:

<table>
<thead>
<tr>
<th>LED INDICATION</th>
<th>POWER SUPPLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>OK</td>
</tr>
<tr>
<td>ON / OFF CYCLING</td>
<td>Failure</td>
</tr>
<tr>
<td>OFF</td>
<td>Failure</td>
</tr>
</tbody>
</table>

![Figure 3–10: CONTROL POWER CONNECTION](image-url)
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) CT INPUTS

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 8F) or with a sensitive ground input (Type 8G) which is 10 times more sensitive (see the Technical Specifications section for additional 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.

b) VT 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.
Wherever a tilde “~” symbol appears, substitute with the Slot Position of the module.

A feeder relay with the high impedance fault detection (Hi-Z) element typically includes two CT/VT modules: one Type 8F or 8G and one Type 8Z. For correct operation of the Hi-Z element, the ground current terminals of the two CT modules must be connected to a ground current source, either a zero-sequence CT (see the Typical Wiring Diagram with Hi-Z earlier in this chapter) or, if a zero-sequence CT is not available, to the neutral conductor of the Phase CTs (see the following diagram).
3.2.6 CONTACT INPUTS/OUTPUTS

Every digital input/output module has 24 terminal connections. They are arranged as three terminals per row, with eight 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.

The digital inputs are grouped with a common return. The F60 has two versions of grouping: four inputs per common return and two inputs per common return. When a digital input/output module is ordered, four inputs per common is used. The four inputs per common allows for high-density inputs in combination with outputs, with a compromise of four inputs sharing one common. If the inputs must be isolated per row, then two inputs per common return should be selected (4D module).

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-SERIES FORM-A / SOLID STATE (SSR) OUTPUT CONTACTS:

Some Form-A/SSR 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 for the Form-A outputs with:

a) optional voltage monitor
b) optional current monitor
c) with no monitoring

![Diagram of Form-A contacts with voltage and current monitoring options](827821A5.CDR)
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 to the Digital Elements section of Chapter 5 for an example of how Form-A/SSR contacts can be applied for breaker trip circuit integrity monitoring.

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!

**WARNING**

**USE OF FORM-A/SSR OUTPUTS IN HIGH IMPEDANCE CIRCUITS**

For Form-A/SSR 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.

Wherever a tilde “~” symbol appears, substitute with the slot position of the module; wherever a number sign "#" appears, substitute the contact number.

When current monitoring is used to seal-in the Form-A/SSR 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 3–2: DIGITAL INPUT/OUTPUT MODULE ASSIGNMENTS**

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### 3.2 Wiring

#### 3.2.1 Terminal Assignment and Output

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Figure 3–16: DIGITAL INPUT/OUTPUT MODULE WIRING (1 of 2)
Figure 3–17: DIGITAL INPUT/OUTPUT MODULE WIRING (2 of 2)

**CAUTION**
CORRECT POLARITY MUST BE OBSERVED FOR ALL CONTACT INPUT AND SOLID STATE OUTPUT CONNECTIONS FOR PROPER FUNCTIONALITY.
CONTACT INPUTS:

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.

![Diagram of Contact Input Connections](image)

Figure 3–18: DRY AND WET CONTACT INPUT CONNECTIONS

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

CONTACT OUTPUTS:

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.

There is no provision in the relay to detect a DC ground fault on 48 V DC control power external output. We recommend using an external DC supply.
USE OF CONTACT INPUTS WITH AUTO-BURNISHING:

The contact inputs sense a change of the state of the external device contact based on the measured current. When external devices are located in a harsh industrial environment (either outdoor or indoor), their contacts can be exposed to various types of contamination. Normally, there is a thin film of insulating sulfidation, oxidation, or contaminates on the surface of the contacts, sometimes making it difficult or impossible to detect a change of the state. This film must be removed to establish circuit continuity—an impulse of higher than normal current can accomplish this.

The contact inputs with auto-burnish create a high current impulse when the threshold is reached to burn off this oxidation layer as a maintenance to the contacts. Afterwards the contact input current is reduced to a steady-state current. The impulse will have a 5 second delay after a contact input changes state.

**Figure 3–19: CURRENT THROUGH CONTACT INPUTS WITH AUTO-BURNISHING**

Regular contact inputs limit current to less than 3 mA to reduce station battery burden. In contrast, contact inputs with auto-burnishing allow currents up to 50 to 70 mA at the first instance when the change of state was sensed. Then, within 25 to 50 ms, this current is slowly reduced to 3 mA as indicated above. The 50 to 70 mA peak current burns any film on the contacts, allowing for proper sensing of state changes. If the external device contact is bouncing, the auto-burnishing starts when external device contact bouncing is over.

Another important difference between the auto-burnishing input module and the regular input modules is that only two contact inputs have common ground, as opposed to four contact inputs sharing one common ground (refer to the Digital Input/Output Module Wiring diagrams). This is beneficial when connecting contact inputs to separate voltage sources. Consequently, the threshold voltage setting is also defined per group of two contact inputs.

The auto-burnish feature can be disabled or enabled using the DIP switches found on each daughter card. There is a DIP switch for each contact, for a total of 16 inputs.

**Figure 3–20: AUTO-BURNISH DIP SWITCHES**

The auto-burnish circuitry has an internal fuse for safety purposes. During regular maintenance, the auto-burnish functionality can be checked using an oscilloscope.
Transducer input 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.

Transducer output modules provide DC current outputs in several standard dcmA ranges. Software is provided to configure virtually any analog quantity used in the relay to drive the analog outputs.

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 current outputs require a twisted-pair shielded cable, where the shield is grounded at one end only. The figure below illustrates the transducer module types (5A, 5C, 5D, 5E, and 5F) and channel arrangements that may be ordered for the relay.

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

![Figure 3–21: TRANSDUCER INPUT/OUTPUT MODULE WIRING](827831AB-X1.CDR)
3.2 WIRING
3 HARDWARE

3.2.8 RS232 FACEPLATE 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 EnerVista UR Setup software provided with the relay. Cabling for the RS232 port is shown in the following figure for both 9 pin and 25 pin connectors.

The baud rate for this port is fixed at 19200 bps.

![Figure 3–22: RS232 FACEPLATE PORT CONNECTION](image)

3.2.9 CPU COMMUNICATION PORTS

a) OPTIONS

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.

The CPU modules do not require a surge ground connection.

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</table>
b) 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.
3.2 WIRING

Figure 3–24: RS485 SERIAL CONNECTION

c) 10BASE-FL AND 100BASE-FX FIBER OPTIC PORTS

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 or 100Mbps. Optical fiber may be connected to the relay supporting a wavelength of 820 nm in multi-mode or 1310 nm in multi-mode and single-mode. The 10 Mbps rate is available for CPU modules 9G and 9H; 100Mbps is available for modules 9J, 9K, 9L, and 9M. The 9H, 9K and 9M modules have 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 for 10 Mbps. 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, 62.5 µm for 100 Mbps. For optical power budgeting, splices are required every 1 km for the transmitter/receiver pair. When splicing optical fibers, the diameter and numerical aperture of each fiber must be the same. In order to engage or disengage the ST type connector, only a quarter turn of the coupling is required.
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.

The IRIG-B repeater provides an amplified DC-shift IRIG-B signal to other equipment. By using one IRIG-B serial connection, several UR-series relays can be synchronized. The IRIG-B repeater has a bypass function to maintain the time signal even when a relay in the series is powered down.
3.3 DIRECT INPUT/OUTPUT COMMUNICATIONS

3.3.1 DESCRIPTION

The F60 direct inputs/outputs feature makes use of the Type 7 series of communications modules. These modules are also used by the L90 Line Differential Relay for inter-relay communications. The direct input/output feature uses the communications channel(s) provided by these modules to exchange digital state information between relays. This feature is available on all UR-series relay models except for the L90 Line Differential relay.

The communications channels are normally connected in a ring configuration as shown below. The transmitter of one module is connected to the receiver of the next module. The transmitter of this second module is then connected to the receiver of the next module in the ring. This is continued to form a communications ring. The figure below illustrates a ring of four UR-series relays with the following connections: UR1-Tx to UR2-Rx, UR2-Tx to UR3-Rx, UR3-Tx to UR4-Rx, and UR4-Tx to UR1-Rx. A maximum of sixteen (16) UR-series relays can be connected in a single ring.

![Figure 3–27: DIRECT INPUT/OUTPUT SINGLE CHANNEL CONNECTION](image1)

The interconnection for dual-channel Type 7 communications modules is shown below. Two channel modules allow for a redundant ring configuration. That is, two rings can be created to provide an additional independent data path. The required connections are: UR1-Tx1 to UR2-Rx1, UR2-Tx1 to UR3-Rx1, UR3-Tx1 to UR4-Rx1, and UR4-Tx1 to UR1-Rx1 for the first ring; and UR1-Tx2 to UR4-Rx2, UR4-Tx2 to UR3-Rx2, UR3-Tx2 to UR2-Rx2, and UR2-Tx2 to UR1-Rx2 for the second ring.

![Figure 3–28: DIRECT INPUT/OUTPUT DUAL CHANNEL CONNECTION](image2)

The following diagram shows the connection for three UR-series relays using two independent communication channels. UR1 and UR3 have single Type 7 communication modules; UR2 has a dual-channel module. The two communication channels can be of different types, depending on the Type 7 modules used. To allow the direct input/output data to ‘cross-over’ from Channel 1 to Channel 2 on UR2, the DIRECT I/O CHANNEL CROSSOVER setting should be “Enabled” on UR2. This forces UR2 to forward messages received on Rx1 out Tx2, and messages received on Rx2 out Tx1.
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3.3 DIRECT INPUT/OUTPUT COMMUNICATIONS

The interconnection requirements are described in further detail in this section for each specific variation of Type 7 communications module. These modules are listed in the following table. All fiber modules use ST type connectors.

Table 3–3: CHANNEL COMMUNICATION OPTIONS

<table>
<thead>
<tr>
<th>MODULE</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td>C37.94SM, 1300 nm, single-mode, ELED, 1 channel single-mode</td>
</tr>
<tr>
<td>2B</td>
<td>C37.94SM, 1300 nm, single-mode, ELED, 2 channel single-mode</td>
</tr>
<tr>
<td>7A</td>
<td>820 nm, multi-mode, LED, 1 channel</td>
</tr>
<tr>
<td>7B</td>
<td>1300 nm, multi-mode, LED, 1 channel</td>
</tr>
<tr>
<td>7C</td>
<td>1300 nm, single-mode, ELED, 1 channel</td>
</tr>
<tr>
<td>7D</td>
<td>1300 nm, single-mode, LASER, 1 channel</td>
</tr>
<tr>
<td>7E</td>
<td>Channel 1: G.703, Channel 2: 820 nm, multi-mode</td>
</tr>
<tr>
<td>7F</td>
<td>Channel 1: G.703, Channel 2: 1300 nm, multi-mode</td>
</tr>
<tr>
<td>7G</td>
<td>Channel 1: G.703, Channel 2: 1300 nm, single-mode ELED</td>
</tr>
<tr>
<td>7H</td>
<td>820 nm, multi-mode, LED, 2 channels</td>
</tr>
<tr>
<td>7I</td>
<td>1300 nm, multi-mode, LED, 2 channels</td>
</tr>
<tr>
<td>7J</td>
<td>1300 nm, single-mode, ELED, 2 channels</td>
</tr>
<tr>
<td>7K</td>
<td>1300 nm, single-mode, LASER, 2 channels</td>
</tr>
<tr>
<td>7L</td>
<td>Channel 1: RS422, Channel 2: 820 nm, multi-mode, LED</td>
</tr>
<tr>
<td>7M</td>
<td>Channel 1: RS422, Channel 2: 1300 nm, multi-mode, LED</td>
</tr>
<tr>
<td>7N</td>
<td>Channel 1: RS422, Channel 2: 1300 nm, single-mode, ELED</td>
</tr>
<tr>
<td>7P</td>
<td>Channel 1: RS422, Channel 2: 1300 nm, single-mode, LASER</td>
</tr>
<tr>
<td>7Q</td>
<td>Channel 1: G.703, Channel 2: 1300 nm, single-mode, LASER</td>
</tr>
<tr>
<td>7R</td>
<td>G.703, 1 channel</td>
</tr>
<tr>
<td>7S</td>
<td>G.703, 2 channels</td>
</tr>
<tr>
<td>7T</td>
<td>RS422, 1 channel</td>
</tr>
<tr>
<td>7W</td>
<td>RS422, 2 channels</td>
</tr>
<tr>
<td>72</td>
<td>1550 nm, single-mode, LASER, 1 channel</td>
</tr>
<tr>
<td>73</td>
<td>1550 nm, single-mode, LASER, 2 channels</td>
</tr>
<tr>
<td>74</td>
<td>Channel 1 - RS422; Channel 2 - 1550 nm, single-mode, LASER</td>
</tr>
<tr>
<td>75</td>
<td>Channel 1 - G.703; Channel 2 - 1550 nm, single-mode, LASER</td>
</tr>
<tr>
<td>76</td>
<td>IEEE C37.94, 820 nm, multi-mode, LED, 1 channel</td>
</tr>
<tr>
<td>77</td>
<td>IEEE C37.94, 820 nm, multi-mode, LED, 2 channels</td>
</tr>
</tbody>
</table>

OBSERVING ANY FIBER TRANSMITTER OUTPUT MAY CAUSE INJURY TO THE EYE.
3.3 DIRECT INPUT/OUTPUT COMMUNICATIONS

3.3.2 FIBER: LED AND ELED TRANSMITTERS

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

![Figure 3–30: LED AND ELED FIBER MODULES](image)

*WARNING*

3.3.3 FIBER-LASER TRANSMITTERS

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

![Figure 3–31: LASER FIBER MODULES](image)

*WARNING*

When using a LASER Interface, attenuators may be necessary to ensure that you do not exceed Maximum Optical Input Power to the receiver.
3.3.4 G.703 INTERFACE

a) DESCRIPTION

The following figure shows the 64K ITU G.703 co-directional interface configuration.

The G.703 module is fixed at 64 kbps only. The SETTINGS ⇒ PRODUCT SETUP ⇒ DIRECT I/O ⇒ DIRECT I/O DATA RATE setting is not applicable to this module.

AWG 24 twisted shielded pair is recommended for external connections, with the shield grounded 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 3–32: 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 3–33: TYPICAL PIN INTERCONNECTION BETWEEN TWO G.703 INTERFACES

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 PROCEDURES

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.

2. Remove the module cover screw.

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

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

5. Replace the top cover and the cover screw.
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 3–34: G.703 TIMING SELECTION SWITCH SETTING](image)

**Table 3–4: G.703 TIMING SELECTIONS**

<table>
<thead>
<tr>
<th>SWITCHES</th>
<th>FUNCTION</th>
</tr>
</thead>
</table>
| S1       | OFF → Octet Timing Disabled  
           | ON → Octet Timing 8 kHz |
| S5 and S6| S5 = OFF and S6 = OFF → Loop Timing Mode  
           | S5 = ON and S6 = OFF → Internal Timing Mode  
           | S5 = OFF and S6 = ON → Minimum Remote Loopback Mode  
           | S5 = ON and S6 = ON → Dual Loopback Mode |

**c) OCTET TIMING (SWITCH 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 F60s are connected back to back, Octet Timing should be disabled (OFF).

**d) TIMING MODES (SWITCHES S5 AND S6)**

There are two timing modes for the G.703 module: internal timing mode and loop timing mode (default).

- **Internal Timing Mode**: The system clock is generated internally. Therefore, the G.703 timing selection should be in the Internal Timing Mode for back-to-back (UR-to-UR) connections. For back-to-back connections, set for Octet Timing (S1 = OFF) and Timing Mode = Internal Timing (S5 = ON and S6 = OFF).

- **Loop Timing Mode**: The system clock is derived from the received line signal. Therefore, the G.703 timing selection should be in Loop Timing Mode for connections to higher order systems. For connection to a higher order system (UR-to-multiplexer, factory defaults), set to Octet Timing (S1 = ON) and set Timing Mode = Loop Timing (S5 = OFF and S6 = OFF).
The switch settings for the internal and loop timing modes are shown below:

**e) TEST MODES (SWITCHES S5 AND 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 DIRECT INPUT/OUTPUT COMMUNICATIONS

#### 3.3.5 RS422 INTERFACE

**a) DESCRIPTION**

The following figure shows the RS422 2-terminal interface configuration at 64 kbps. AWG 24 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.

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

---

**Figure 3–35: 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 3–36: TYPICAL PIN INTERCONNECTION BETWEEN TWO RS422 INTERFACES**

**b) TWO CHANNEL APPLICATIONS VIA MULTIPLEXERS**

The RS422 Interface may be used for single or two channel applications over SONET/SDH and/or multiplexed systems. When used in single channel applications, the RS422 interface links to higher order systems in a typical fashion observing transmit (Tx), receive (Rx), and send timing (ST) connections. However, when used in two channel applications, certain criteria must be followed since there is one clock input for the two RS422 channels. The system will function correctly if the following connections are observed and your data module has a terminal timing feature. 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, two channel 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 below. 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.
3 HARDWARE

3.3 DIRECT INPUT/OUTPUT COMMUNICATIONS

Data module 1 provides timing to the F60 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. The data module pin numbers have been omitted in the figure above since they may vary depending on the manufacturer.

c) TRANSIT 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 3–37: TIMING CONFIGURATION FOR RS422 TWO-CHANNEL, 3-TERMINAL APPLICATION

Figure 3–38: 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 AND 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 24 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.

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

![Figure 3-39: RS422 AND FIBER INTERFACE CONNECTION](image)

Connections shown above are for multiplexers configured as DCE (Data Communications Equipment) units.

3.3.7 G.703 AND FIBER INTERFACE

The figure below shows the combined G.703 plus Fiber interface configuration at 64K baud. The 7E, 7F, 7G, 7Q, and 75 modules are used in configurations where Channel 1 is employed via the G.703 interface (possibly with a multiplexer) and Channel 2 via direct fiber. AWG 24 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 previous sections for more details on the G.703 and Fiber interfaces.

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

![Figure 3-40: G.703 AND FIBER INTERFACE CONNECTION](image)
The UR-series IEEE C37.94 communication modules (76 and 77) are designed to interface with IEEE C37.94 compliant digital multiplexers and/or an IEEE C37.94 compliant interface converter for use with direct input/output applications for firmware revisions 3.30 and higher. The IEEE C37.94 standard defines a point-to-point optical link for synchronous data between a multiplexer and a teleprotection device. This data is typically 64 kbps, but the standard provides for speeds up to 64\(n\) kbps, where \(n = 1, 2, \ldots, 12\). The UR-series C37.94 communication module is 64 kbps only with \(n\) fixed at 1. The frame is a valid International Telecommunications Union (ITU-T) recommended G.704 pattern from the standpoint of framing and data rate. The frame is 256 bits and is repeated at a frame rate of 8000 Hz, with a resultant bit rate of 2048 kbps.

The specifications for the module are as follows:

- IEEE standard: C37.94 for 1 × 64 kbps optical fiber interface
- Fiber optic cable type: 50 mm or 62.5 mm core diameter optical fiber
- Fiber optic mode: multi-mode
- Fiber optic cable length: up to 2 km
- Fiber optic connector: type ST
- Wavelength: 830 ±40 nm
- Connection: as per all fiber optic connections, a Tx to Rx connection is required.

The UR-series C37.94 communication module can be connected directly to any compliant digital multiplexer that supports the IEEE C37.94 standard as shown below.

The UR-series C37.94 communication module can be connected to the electrical interface (G.703, RS422, or X.21) of a non-compliant digital multiplexer via an optical-to-electrical interface converter that supports the IEEE C37.94 standard, as shown below.

The UR-series C37.94 communication module has six (6) switches that are used to set the clock configuration. The functions of these control switches is shown below.

For the Internal Timing Mode, the system clock is generated internally. Therefore, the timing switch selection should be Internal Timing for Relay 1 and Loop Timed for Relay 2. There must be only one timing source configured.

For the Looped Timing Mode, the system clock is derived from the received line signal. Therefore, the timing selection should be in Loop Timing Mode for connections to higher order systems.

The C37.94 communications module cover removal procedure is as follows:
1. Remove the C37.94 module (76 or 77):
   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.

2. Remove the module cover screw.

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

4. Set the Timing Selection Switches (Channel 1, Channel 2) to the desired timing modes (see description above).

5. Replace the top cover and the cover screw.

6. Re-insert the C37.94 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 3-41: IEEE C37.94 TIMING SELECTION SWITCH SETTING](image-url)
The UR-series C37.94SM communication modules (2A and 2B) are designed to interface with modified IEEE C37.94 compliant digital multiplexers and/or IEEE C37.94 compliant interface converters that have been converted from 820 nm multimode fiber optics to 1300 nm ELED single-mode fiber optics. The IEEE C37.94 standard defines a point-to-point optical link for synchronous data between a multiplexer and a teleprotection device. This data is typically 64 kbps, but the standard provides for speeds up to $64n$ kbps, where $n = 1, 2, \ldots, 12$. The UR-series C37.94SM communication module is 64 kbps only with $n$ fixed at 1. The frame is a valid International Telecommunications Union (ITU-T) recommended G.704 pattern from the standpoint of framing and data rate. The frame is 256 bits and is repeated at a frame rate of 8000 Hz, with a resultant bit rate of 2048 kbps.

The specifications for the module are as follows:

- Emulated IEEE standard: emulates C37.94 for $1 \times 64$ kbps optical fiber interface (modules set to $n = 1$ or 64 kbps)
- Fiber optic cable type: 9/125 μm core diameter optical fiber
- Fiber optic mode: single-mode, ELED compatible with HP HFBR-1315T transmitter and HP HFBR-2316T receiver
- Fiber optic cable length: up to 10 km
- Fiber optic connector: type ST
- Wavelength: 1300 ±40 nm
- Connection: as per all fiber optic connections, a Tx to Rx connection is required.

The UR-series C37.94SM communication module can be connected directly to any compliant digital multiplexer that supports C37.94SM as shown below.

It can also be connected directly to any other UR-series relay with a C37.94SM module as shown below.

The UR-series C37.94SM communication module has six (6) switches that are used to set the clock configuration. The functions of these control switches is shown below.

For the Internal Timing Mode, the system clock is generated internally. Therefore, the timing switch selection should be Internal Timing for Relay 1 and Loop Timed for Relay 2. There must be only one timing source configured.

For the Looped Timing Mode, the system clock is derived from the received line signal. Therefore, the timing selection should be in Loop Timing Mode for connections to higher order systems.

The C37.94SM communications module cover removal procedure is as follows:

1. Remove the C37.94SM module (modules 2A or 2B):
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.

2. Remove the module cover screw.
3. Remove the top cover by sliding it towards the rear and then lift it upwards.
4. Set the Timing Selection Switches (Channel 1, Channel 2) to the desired timing modes (see description above).
5. Replace the top cover and the cover screw.
6. Re-insert the C37.94SM 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 3–42: C37.94SM TIMING SELECTION SWITCH SETTING
4 HUMAN INTERFACES 4.1 ENERVISTA UR SETUP SOFTWARE INTERFACE

4.1.1 INTRODUCTION

The EnerVista UR Setup 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).

The EnerVista UR Setup software 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 EnerVista UR Setup software, provided with every F60 relay, can be run from any computer supporting Microsoft Windows® 95, 98, NT, 2000, ME, and XP. This chapter provides a summary of the basic EnerVista UR Setup software interface features. The EnerVista UR Setup Help File provides details for getting started and using the EnerVista UR Setup software interface.

4.1.2 CREATING A SITE LIST

To start using the EnerVista UR Setup software, a site definition and device definition must first be created. See the EnerVista UR Setup Help File or refer to the Connecting EnerVista UR Setup with the F60 section in Chapter 1 for details.

4.1.3 ENERVISTA UR SETUP SOFTWARE OVERVIEW

a) ENGAGING A DEVICE

The EnerVista UR Setup 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 EnerVista UR Setup 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 AND EDITING FLEXLOGIC™

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 one of the following:

- **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) FILE SUPPORT

- **Execution**: Any EnerVista UR Setup 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 (has a URS extension) 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.

g) FIRMWARE UPGRADES
The firmware of a F60 device can be upgraded, locally or remotely, via the EnerVista UR Setup software. The corresponding instructions are provided by the EnerVista UR Setup Help file under the topic “Upgrading Firmware”.

**NOTE**
Modbus addresses assigned to firmware modules, features, settings, and corresponding data items (i.e. default values, minimum/maximum 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 EnerVista UR Setup 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: ENERVISTA UR SETUP SOFTWARE MAIN WINDOW
The keypad/display/LED interface is one of two alternate human interfaces supported. The other alternate human interface is implemented via the EnerVista UR Setup software. The 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-SERIES HORIZONTAL FACEPLATE PANELS

Figure 4-3: UR-SERIES 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 ➔ RESETING 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](image)

**STATUS INDICATORS:**

- **IN SERVICE**: Indicates that control power is applied; all monitored inputs/outputs 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 AND 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.

<table>
<thead>
<tr>
<th>USER-PROGRAMMABLE LEDS</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
<th>G6</th>
<th>G7</th>
<th>G8</th>
</tr>
</thead>
<tbody>
<tr>
<td>(9)</td>
<td>G1</td>
<td>G2</td>
<td>G3</td>
<td>G4</td>
<td>G5</td>
<td>G6</td>
<td>G7</td>
<td>G8</td>
</tr>
<tr>
<td>(10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(16)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

c) DEFAULT LABELS FOR LED PANEL 2

The default labels are intended to represent:

- **GROUP 1...6**: 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.

Firmware revisions 2.9x and earlier support eight user setting groups; revisions 3.0x and higher support six setting groups. For convenience of users using earlier firmware revisions, the relay panel shows eight setting groups. Please note that the LEDs, despite their default labels, are fully user-programmable.

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 Chapter 5. The LEDs are fully user-programmable. The default labels can be replaced by user-printed labels for both panels as explained in the following section.

<table>
<thead>
<tr>
<th>SETTINGS IN USE</th>
<th>BREAKER 1</th>
<th>SYNCHROCHECK</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>OPEN</td>
<td>NO1 IN-SYNCH</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>CLOSED</td>
<td>NO2 IN-SYNCH</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>TROUBLE</td>
<td>RECLOSE</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>BREAKER 2</td>
<td>ENABLED</td>
</tr>
<tr>
<td>GROUP 5</td>
<td>OPEN</td>
<td>DISABLED</td>
</tr>
<tr>
<td>GROUP 6</td>
<td>CLOSED</td>
<td>IN PROGRESS</td>
</tr>
<tr>
<td>GROUP 7</td>
<td>TROUBLE</td>
<td>LOCKED OUT</td>
</tr>
</tbody>
</table>

Figure 4–6: LED PANEL 2 (DEFAULT LABELS)
d) INSTALLING THE CUSTOMIZED DISPLAY MODULE

Custom labeling of an LED-only panel is facilitated through a Microsoft Word file available from the following URL:

http://www.GEindustrial.com/multilin/support/ur/

This file provides templates and instructions for creating appropriate labeling for the LED panel. The following procedures are contained in the downloadable file. The 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 (GE Multilin Part Number: 1501-0014).

2. Pop out the LED Module and/or the 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.

e) CUSTOMIZING THE DISPLAY MODULE

The following items are required to customize the F60 display module:

- Black and white or color printer (color preferred).
- Microsoft Word 97 or later software for editing the template.
- 1 each of: 8.5" x 11" white paper, exacto knife, ruler, custom display module (GE Multilin Part Number: 1516-0069), and a custom module cover (GE Multilin Part Number: 1502-0015).

1. Open the LED panel customization template with Microsoft Word. Add text in places of the LED x text placeholders on the template(s). Delete unused place holders as required.

2. When complete, save the Word file to your local PC for future use.

3. Print the template(s) to a local printer.

4. From the printout, cut-out the Background Template from the three windows, using the cropmarks as a guide.

5. Put the Background Template on top of the custom display module (GE Multilin Part Number: 1513-0069) and snap the clear custom module cover (GE Multilin Part Number: 1502-0015) over it and the templates.
4.2 FACEPLATE INTERFACE

4.2.3 DISPLAY

All messages are displayed on a 2 × 20 character vacuum fluorescent display to make them visible under poor lighting conditions. An optional liquid crystal display (LCD) is also available. 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.

4.2.4 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 enter 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 keys store altered setting values.

4.2.5 BREAKER CONTROL

a) DESCRIPTION

The F60 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 FUNCTION setting is “Enabled” for each breaker.

b) CONTROL MODE SELECTION AND 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 PUSH BUTTON CONTROL setting is “Enabled” for each breaker.

c) 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.

d) 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.
4 HUMAN INTERFACES

4.2 FACEPLATE INTERFACE

**e) 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.

**4.2.6 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.

```
<table>
<thead>
<tr>
<th>ACTUAL VALUES</th>
<th>SETTINGS</th>
<th>COMMANDS</th>
<th>TARGETS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

Press **MENU** to enter menu levels:

```
<table>
<thead>
<tr>
<th>ACTUAL VALUES</th>
<th>SETTINGS</th>
<th>COMMANDS</th>
<th>VIRTUAL INPUTS</th>
<th>STATUS</th>
<th>PRODUCT SETUP</th>
<th>PRODUCT SETUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No Active</td>
<td></td>
<td>Targets</td>
</tr>
</tbody>
</table>
```

Press **MENU** to select desired display.

```
User Display 1
```

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.

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.

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 BKRL-(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 BKRL-(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) **BKRL-(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.
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.

<table>
<thead>
<tr>
<th>HIGHEST LEVEL</th>
<th>LOWEST LEVEL (SETTING VALUE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ ■ SETTINGS</td>
<td>▼ ■ PASSWORD</td>
</tr>
<tr>
<td>■ ■ PRODUCT SETUP</td>
<td>▼ ■ SECURITY</td>
</tr>
<tr>
<td>■ ■ SETTINGS</td>
<td>■ ■ PRODUCT SETUP</td>
</tr>
<tr>
<td>■ ■ SYSTEM SETUP</td>
<td>■ ■ SYSTEM SETUP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c) EXAMPLE MENU NAVIGATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ ■ ACTUAL VALUES</td>
</tr>
<tr>
<td>■ ■ STATUS</td>
</tr>
<tr>
<td>■ ■ SETTINGS</td>
</tr>
<tr>
<td>■ ■ PRODUCT SETUP</td>
</tr>
<tr>
<td>■ ■ SYSTEM SETUP</td>
</tr>
<tr>
<td>■ ■ SYSTEM SETUP</td>
</tr>
<tr>
<td>■ PASSWORD</td>
</tr>
<tr>
<td>■ SECURITY</td>
</tr>
<tr>
<td>ACCESS LEVEL: Restricted</td>
</tr>
<tr>
<td>■ PASSWORD</td>
</tr>
<tr>
<td>■ SECURITY</td>
</tr>
<tr>
<td>DISPLAY</td>
</tr>
<tr>
<td>■ PROPERTIES</td>
</tr>
<tr>
<td>FLASH MESSAGE</td>
</tr>
<tr>
<td>TIME: 1.0 s</td>
</tr>
<tr>
<td>DEFAULT MESSAGE</td>
</tr>
<tr>
<td>INTENSITY: 25%</td>
</tr>
</tbody>
</table>
4 HUMAN INTERFACES

4.2 FACEPLATE INTERFACE

4.2.7 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.

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.

NEW SETTING HAS BEEN STORED

Until ENTER is pressed, editing changes are not registered by the relay. Therefore, press ENTER 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 HELP 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.
There are several places where text messages may be programmed to allow the relay to be customized for specific applications. One example is the Message Scratchpad. Use the following procedure to enter alphanumeric text messages.

For example: to enter the text, “Breaker #1”

1. Press \m to enter text edit mode.
2. Press the VALUE keys until the character 'B' appears; press \m 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 \help to view context sensitive help. Flash messages will sequentially appear for several seconds each. For the case of a text setting message, pressing \help displays how to edit and store new values.

d) ACTIVATING THE RELAY

When the relay is powered up, the Trouble LED will be on, the In Service LED off, and this message displayed, indicating 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 remains 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 keys 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 LED will turn on.
e) ENTERING INITIAL PASSWORDS

To enter the initial Setting (or Command) Password, proceed as follows:

1. Press the 
   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 key and the display will prompt you to ENTER NEW PASSWORD.
6. Type in a numerical password (up to 10 characters) and press the key.
7. When the VERIFY NEW PASSWORD is displayed, re-type in the same password and press .
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.
g) INVALID PASSWORD ENTRY

In the event that an incorrect Command or Setting password has been entered via the faceplate interface three times within a three-minute time span, the LOCAL ACCESS DENIED FlexLogic™ operand will be set to “On” and the F60 will not allow Settings or Command access via the faceplate interface for the next ten minutes. The TOO MANY ATTEMPTS – BLOCKED FOR 10 MIN! flash message will appear upon activation of the ten minute timeout or any other time a user attempts any change to the defined tier during the ten minute timeout. The LOCAL ACCESS DENIED FlexLogic™ operand will be set to “Off” after the expiration of the ten-minute timeout.

In the event that an incorrect Command or Setting password has been entered via the any external communications interface three times within a three-minute time span, the REMOTE ACCESS DENIED FlexLogic™ operand will be set to “On” and the F60 will not allow Settings or Command access via the any external communications interface for the next ten minutes. The REMOTE ACCESS DENIED FlexLogic™ operand will be set to “Off” after the expiration of the ten-minute timeout.
## 5 SETTINGS

### 5.1 OVERVIEW

#### 5.1.1 SETTINGS MAIN MENU

<table>
<thead>
<tr>
<th>SETTINGS</th>
<th>PASSWORD</th>
<th>See page 5-8.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SECURITY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DISPLAY</td>
<td>See page 5-9.</td>
</tr>
<tr>
<td></td>
<td>PROPERTIES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLEAR RELAY</td>
<td>See page 5-11.</td>
</tr>
<tr>
<td></td>
<td>RECORDS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>COMMUNICATIONS</td>
<td>See page 5-12.</td>
</tr>
<tr>
<td></td>
<td>MODBUS USER MAP</td>
<td>See page 5-23.</td>
</tr>
<tr>
<td></td>
<td>REAL TIME</td>
<td>See page 5-24.</td>
</tr>
<tr>
<td></td>
<td>CLOCK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FAULT REPORTS</td>
<td>See page 5-24.</td>
</tr>
<tr>
<td></td>
<td>OSCILLOGRAPHY</td>
<td>See page 5-25.</td>
</tr>
<tr>
<td></td>
<td>DATA LOGGER</td>
<td>See page 5-27.</td>
</tr>
<tr>
<td></td>
<td>DEMAND</td>
<td>See page 5-29.</td>
</tr>
<tr>
<td></td>
<td>USER-PROGRAMMABLE</td>
<td>See page 5-30.</td>
</tr>
<tr>
<td></td>
<td>LEDS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>USER-PROGRAMMABLE</td>
<td>See page 5-33.</td>
</tr>
<tr>
<td></td>
<td>SELF TESTS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CONTROL</td>
<td>See page 5-34.</td>
</tr>
<tr>
<td></td>
<td>PUSHBUTTONS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>USER-PROGRAMMABLE</td>
<td>See page 5-35.</td>
</tr>
<tr>
<td></td>
<td>PUSHBUTTONS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FLEX STATE</td>
<td>See page 5-36.</td>
</tr>
<tr>
<td></td>
<td>PARAMETERS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>USER-DEFINABLE</td>
<td>See page 5-37.</td>
</tr>
<tr>
<td></td>
<td>DISPLAYS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DIRECT I/O</td>
<td>See page 5-39.</td>
</tr>
<tr>
<td></td>
<td>TELEPROTECTION</td>
<td>See page 5-44.</td>
</tr>
<tr>
<td></td>
<td>INSTALLATION</td>
<td>See page 5-45.</td>
</tr>
<tr>
<td></td>
<td>AC INPUTS</td>
<td>See page 5-46.</td>
</tr>
<tr>
<td></td>
<td>SYSTEM SETUP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>POWER SYSTEM</td>
<td>See page 5-47.</td>
</tr>
</tbody>
</table>

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**GE Multilin**

**F60 Feeder Management Relay**

*5-1*
## 5.1 OVERVIEW

### SIGNAL SOURCES
See page 5-48.

### BREAKERS
See page 5-50.

### FLEXCURVES
See page 5-53.

### SETTINGS

#### FLEXLOGIC

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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 six alternate sets of settings, in setting groups numbered 1 through 6. The performance of a GROUPED element is defined by the setting group that is active at a given time. The performance of a CONTROL element is independent of the selected active setting group.

The main characteristics of an element are shown on the element logic diagram. This includes the input(s), settings, fixed logic, and the output operands 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:

\[
pu \text{ quantity} = \frac{(actual \text{ quantity})}{(base \text{ quantity})}
\]

- 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 primary voltage of the protected system which corresponds (based on VT ratio and connection) to secondary VT voltage applied to the relay. For example, on a system with a 13.8 kV nominal primary voltage and with 14400:120 V Delta-connected VTs, the secondary nominal voltage (1 pu) would be:

\[
\frac{13800 \times 120}{14400} = 115 \text{ V} \quad (EQ \ 5.1)
\]

For Wye-connected VTs, the secondary nominal voltage (1 pu) would be:

\[
\frac{13800 \times 120}{\sqrt{3}} = 66.4 \text{ V} \quad (EQ \ 5.2)
\]

Many 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.
5 SETTINGS

• **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, events are 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 F60 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 3I₀ 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. These requirements can be satisfied with a single UR, equipped with sufficient CT and VT input channels, by selecting the parameter to measure. 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 measure is partially performed by the design of a measuring element or protection/control comparator by identifying the type of parameter (fundamental frequency phasor, harmonic phasor, symmetrical component, total waveform RMS magnitude, phase-phase or phase-ground voltage, etc.) to measure. The user completes the process by selecting the instrument transformer input channels to use and some of the parameters calculated from these channels. The input parameters available include the summation of currents from multiple input channels. For the summed currents of phase, 3I₀, and ground current, current from CTs with different ratios are adjusted to a single ratio before summation.

A mechanism called a “Source” configures the routing of CT and VT input channels to measurement sub-systems. Sources, in the context of UR series relays, refer to the logical grouping of current and voltage signals such that one source contains all the signals required to measure the load or fault in a particular power apparatus. A given source may contain all or some of the following signals: three-phase currents, single-phase ground current, three-phase voltages and an auxiliary voltage from a single VT for checking for synchronism.

To illustrate the concept of Sources, as applied to current inputs only, consider the breaker-and-a-half scheme below. In this application, the current flows as shown by the arrows. Some current flows through the upper bus bar to some other location or power equipment, and some current flows into transformer Winding 1. The current into Winding 1 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 require access to the net current for transformer protection, but some elements may need access to the individual currents from CT1 and CT2.
In conventional analog or electronic relays, the sum of the currents is obtained from an appropriate external connection of all CTs through which any portion of the current for the element being protected could flow. Auxiliary CTs are required to perform ratio matching if the ratios of the primary CTs to be summed are not identical. In the UR series of relays, 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; for example, as additional information to calculate a restraint current, or to allow the provision of additional protection features that operate on the individual currents such as breaker failure.

Given the flexibility of this approach, it becomes necessary to add configuration settings to the platform to allow the user to select which sets of CT inputs will be added to form the net current into the protected device.

The internal grouping of current and voltage signals forms an internal source. This source can be given a specific name through the settings, and becomes available to protection and metering 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 above diagram, the configures one Source to be the sum of CT1 and CT2 and can 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 CONFIGURATION**

CT and VT input channels are contained in CT/VT modules. 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 contains up to eight input channels, numbered 1 through 8. The channel numbering corresponds to the module terminal numbering 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:

<table>
<thead>
<tr>
<th>INCREASING SLOT POSITION LETTER —&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT/VT MODULE 1</td>
</tr>
<tr>
<td>&lt; bank 1 &gt;</td>
</tr>
<tr>
<td>&lt; bank 2 &gt;</td>
</tr>
</tbody>
</table>

---

**Figure 5–1: BREAKER-AND-A-HALF SCHEME**

---
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.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>MAXIMUM NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT/VT Module</td>
<td>2</td>
</tr>
<tr>
<td>CT Bank (3 phase channels, 1 ground channel)</td>
<td>4</td>
</tr>
<tr>
<td>VT Bank (3 phase channels, 1 auxiliary channel)</td>
<td>2</td>
</tr>
</tbody>
</table>

**c) CT/VT INPUT CHANNEL CONFIGURATION**

Upon relay startup, configuration settings for every bank of current or voltage input channels in the relay are automatically generated 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 follows for a maximum configuration: F1, F5, M1, M5, U1, and U5.

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.
Two levels of password security are provided: Command and Setting. The following command operations are under pass-
word supervision:
operating the breakers via faceplate keypad, changing the state of virtual inputs, clearing the event records, clearing
the oscillography records, clearing fault reports, changing the date and time, clearing the breaker arcing amps, clearing
energy records, clearing the data logger, user-programmable pushbuttons

The following setting operations are under password supervision:
changing any setting, test mode operation
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 one to ten numerical char-
acters. 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 with the corresponding ENCRYPTED PASSWORD.

In the event that an incorrect Command or Setting password has been entered via the faceplate interface three times within
a three-minute time span, the LOCAL ACCESS DENIED FlexLogic™ operand will be set to "On" and the F60 will not allow
Settings or Command access via the faceplate interface for the next ten minutes. The TOO MANY ATTEMPTS – BLOCKED
FOR 10 MIN! flash message will appear upon activation of the ten minute timeout or any other time a user attempts any
change to the defined tier during the ten minute timeout. The LOCAL ACCESS DENIED FlexLogic™ operand will be set to
"Off" after the expiration of the ten-minute timeout.

In the event that an incorrect Command or Setting password has been entered via the any external communications inter-
face three times within a three-minute time span, the REMOTE ACCESS DENIED FlexLogic™ operand will be set to "On" and
the F60 will not allow Settings or Command access via the any external communications interface for the next ten minutes. The REMOTE ACCESS DENIED FlexLogic™ operand will be set to "Off" after the expiration of the ten-minute timeout.

The F60 provides a means to raise an alarm upon failed password entry. Should password verification fail while accessing
a password-protected level of the relay (either settings or commands), the UNAUTHORIZED ACCESS FlexLogic™ operand is
asserted. The operand can be programmed to raise an alarm via contact outputs or communications. This feature can be
used to protect against both unauthorized and accidental access attempts.
The UNAUTHORIZED ACCESS operand is reset with the **COMMANDS ➔ CLEAR RECORDS ➔ RESET UNAUTHORIZED ALARMS** command. Therefore, to apply this feature with security, the command level should be password-protected. The operand does not generate events or targets. If these are required, the operand can be assigned to a digital element programmed with event logs and/or targets enabled.

If the Setting and Command passwords are identical, this one password allows access to both commands and settings.

When EnerVista UR Setup is used to access a particular level, the user will continue to have access to that level as long as there are open windows in the EnerVista UR Setup software. To re-establish the password security feature, all windows must be closed for at least 30 minutes.

### 5.2.2 DISPLAY PROPERTIES

**PATH:** SETTINGS ➔ PRODUCT SETUP ➔ DISPLAY PROPERTIES

<table>
<thead>
<tr>
<th><strong>MESSAGE</strong></th>
<th><strong>PROPERTY</strong></th>
<th><strong>CURRENT CUT-OFF LEVEL</strong></th>
<th><strong>VOLTAGE CUT-OFF LEVEL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DIPLAY</strong></td>
<td><strong>PROPERTY</strong></td>
<td><strong>LANGUAGE:</strong> English</td>
<td></td>
</tr>
<tr>
<td><strong>MESSAGE</strong></td>
<td><strong>FLASH MESSAGE TIME:</strong> 1.0 s</td>
<td><strong>DEFAULT MESSAGE TIMEOUT:</strong> 300 s</td>
<td><strong>DEFAULT MESSAGE INTENSITY:</strong> 25 %</td>
</tr>
<tr>
<td><strong>MESSAGE</strong></td>
<td><strong>SCREEN SAVER FEATURE:</strong> Disabled</td>
<td><strong>SCREEN SAVER WAIT TIME:</strong> 30 min</td>
<td><strong>CURRENT CUT-OFF LEVEL:</strong> 0.020 pu</td>
</tr>
<tr>
<td><strong>MESSAGE</strong></td>
<td><strong>VOLTAGE CUT-OFF LEVEL:</strong> 1.0 V</td>
<td><strong>DEFAULT MESSAGE</strong></td>
<td><strong>FLASH MESSAGE TIME:</strong> 1.0 s</td>
</tr>
</tbody>
</table>

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

- **LANGUAGE:** This setting selects the language used to display settings, actual values, and targets. The range is dependent on the order code of the relay.

- **FLASH MESSAGE TIME:** 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 duration of a flash message on the display can be changed to accommodate different reading rates.

- **DEFAULT MESSAGE TIMEOUT:** If the keypad is inactive for a period of time, the relay automatically reverts to a default message. The inactivity time is modified via this setting to ensure messages remain on the screen long enough during programming or reading of actual values.

- **DEFAULT MESSAGE INTENSITY:** To extend phosphor life in the vacuum fluorescent display, the brightness can be attenuated during default message display. During keypad interrogation, the display always operates at full brightness.

- **SCREEN SAVER FEATURE** and **SCREEN SAVER WAIT TIME:** These settings are only visible if the F60 has a liquid crystal display (LCD) and control its backlighting. When the **SCREEN SAVER FEATURE** is “Enabled”, the LCD backlighting is turned off after the **DEFAULT MESSAGE TIMEOUT** followed by the **SCREEN SAVER WAIT TIME**, providing that no keys have been pressed and no target messages are active. When a keypress occurs or a target becomes active, the LCD backlighting is turned on.

- **CURRENT CUT-OFF LEVEL:** This setting modifies the current cut-off threshold. Very low currents (1 to 2% of the rated value) are very susceptible to noise. Some customers prefer very low currents to display as zero, while others prefer the current be displayed even when the value reflects noise rather than the actual signal. The F60 applies a cut-off value to the magnitudes and angles of the measured currents. If the magnitude is below the cut-off level, it is substi-
tuted with zero. This applies to phase and ground current phasors as well as true RMS values and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Note that the cut-off level for the sensitive ground input is 10 times lower than the **CURRENT CUT-OFF LEVEL** setting value. Raw current samples available via oscillography are not subject to cut-off.

- **VOLTAGE CUT-OFF LEVEL**: This setting modifies the voltage cut-off threshold. Very low secondary voltage measurements (at the fractional volt level) can be affected by noise. Some customers prefer these low voltages to be displayed as zero, while others prefer the voltage to be displayed even when the value reflects noise rather than the actual signal. The F60 applies a cut-off value to the magnitudes and angles of the measured voltages. If the magnitude is below the cut-off level, it is substituted with zero. This operation applies to phase and auxiliary voltages, and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Raw samples of the voltages available via oscillography are not subject cut-off.

The **CURRENT CUT-OFF LEVEL** and the **VOLTAGE CUT-OFF LEVEL** are used to determine the metered power cut-off levels. The power cut-off level is calculated as shown below. For Delta connections:

\[
3\text{-phase power cut-off} = \sqrt{3} \times \frac{\text{CURRENT CUT-OFF LEVEL} \times \text{VOLTAGE CUT-OFF LEVEL} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \text{(EQ 5.3)}
\]

For Wye connections:

\[
3\text{-phase power cut-off} = \frac{3 \times \text{CURRENT CUT-OFF LEVEL} \times \text{VOLTAGE CUT-OFF LEVEL} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \text{(EQ 5.4)}
\]

\[
\text{per-phase power cut-off} = \frac{\text{CURRENT CUT-OFF LEVEL} \times \text{VOLTAGE CUT-OFF LEVEL} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \text{(EQ 5.5)}
\]

where VT primary = VT secondary × VT ratio and CT primary = CT secondary × CT ratio.

For example, given the following settings:

- **CURRENT CUT-OFF LEVEL**: “0.02 pu”
- **VOLTAGE CUT-OFF LEVEL**: “1.0 V”
- **PHASE CT PRIMARY**: “100 A”
- **PHASE VT SECONDARY**: “66.4 V”
- **PHASE VT RATIO**: “208.00 : 1”
- **PHASE VT CONNECTION**: “Delta”.

We have:

\[
\text{VT primary} = \text{VT secondary} \times \text{VT ratio} = 66.4 \text{ V} \times 208 = 13811.2 \text{ V}
\]

The power cut-off is therefore:

\[
\text{power cut-off} = \left(\sqrt{3} \times 0.02 \text{ pu} \times 1.0 \text{ V} \times 100 \text{ A} \times 13811.2 \text{ V}\right) / 66.4 \text{ V}
\]

\[
= 720.5 \text{ watts}
\]

Any calculated power value below this cut-off will not be displayed. As well, the three-phase energy data will not accumulate if the total power from all three phases does not exceed the power cut-off.

**NOTE** Lower the **VOLTAGE CUT-OFF LEVEL** and **CURRENT CUT-OFF LEVEL** with care as the relay accepts lower signals as valid measurements. Unless dictated otherwise by a specific application, the default settings of “0.02 pu” for **CURRENT CUT-OFF LEVEL** and “1.0 V” for **VOLTAGE CUT-OFF LEVEL** are recommended.
5.2.3 CLEAR RELAY RECORDS

Selected records can be cleared from user-programmable conditions with FlexLogic™ operands. Assigning user-programmable pushbuttons to clear specific records are typical applications for these commands. Since the F60 responds to rising edges of the configured FlexLogic™ operands, they must be asserted for at least 50 ms to take effect.

Clearing records with user-programmable operands is not protected by the command password. However, user-programmable pushbuttons are protected by the command password. Thus, if they are used to clear records, the user-programmable pushbuttons can provide extra security if required.

For example, to assign User-Programmable Pushbutton 1 to clear demand records, the following settings should be applied.

1. Assign the clear demand function to Pushbutton 1 by making the following change in the SETTINGS ➔ PRODUCT SETUP ➔ CLEAR RELAY RECORDS menu:
   CLEAR DEMAND: "PUSHBUTTON 1 ON"

2. Set the properties for User-Programmable Pushbutton 1 by making the following changes in the SETTINGS ➔ PRODUCT SETUP ➔ USER-PROGRAMMABLE PUSHBUTTONS ➔ USER PUSHBUTTON 1 menu:
   PUSHBUTTON 1 FUNCTION: "Self-reset"
   PUSHBTN 1 DROP-OUT TIME: "0.20 s"
5.2.4 COMMUNICATIONS

a) MAIN MENU

PATH: SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS

- COMMUNICATIONS
- SERIAL PORTS
  - NETWORK
    - See page 5-13.
  - MODBUS PROTOCOL
    - See page 5-13.
  - DNP PROTOCOL
    - See page 5-14.
  - DNP / IEC104
    - See page 5-17.
  - IEC 61850 PROTOCOL
    - See page 5-18.
  - WEB SERVER
    - HTTP PROTOCOL
      - See page 5-20.
    - TFTP PROTOCOL
      - See page 5-20.
  - IEC 60870-5-104
    - See page 5-21.
  - Sntp Protocol
    - See page 5-21.
  - Egd Protocol
    - See page 5-22.

b) SERIAL PORTS

PATH: SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ SERIAL PORTS

- SERIAL PORTS
  - RS485 COM1 BAUD
    - RATE: 19200
    - Range: 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, 115200. Only active if CPU Type E is ordered.
  - RS485 COM1 PARITY:
    - None
    - Range: None, Odd, Even
    - Only active if CPU Type E is ordered
  - RS485 COM1 RESPONSE
    - MIN TIME: 0 ms
    - Range: 0 to 1000 ms in steps of 10
    - Only active if CPU Type E is ordered
  - RS485 COM2 BAUD
    - RATE: 19200
    - Range: 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, 115200
  - RS485 COM2 PARITY:
    - None
    - Range: None, Odd, Even
  - RS485 COM2 RESPONSE
    - MIN TIME: 0 ms
    - Range: 0 to 1000 ms in steps of 10

The F60 is equipped with up to 3 independent serial communication ports. The faceplate RS232 port is intended for local use and is fixed at 19200 baud and no parity. The rear COM1 port type is selected when ordering: either an Ethernet or 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 computer running EnerVista UR Setup. This software can download and upload setting files, view measured parameters, and upgrade the relay firmware. A maximum of 32 relays can be daisy-chained and connected to a DCS, PLC or PC using the RS485 ports.

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.

c) NETWORK

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ NETWORK

These messages appear only if the F60 is ordered with an Ethernet card.

The IP addresses are used with the DNP, Modbus/TCP, IEC 61580, IEC 60870-5-104, TFTP, and HTTP protocols. The NSAP address is used with the IEC 61850 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 and should normally be left at their default values, but may be changed if required (for example, to allow access to multiple UR-series relays behind a router). By setting a different TCP/UDP PORT NUMBER for a given protocol on each UR-series relay, the router can map the relays to the same external IP address. The client software (EnerVista UR Setup, for example) must be configured to use the correct port number if these settings are used.

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).

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.

d) MODBUS PROTOCOL

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ MODBUS PROTOCOL

The serial communication ports utilize the Modbus protocol, unless configured for DNP or IEC 60870-5-104 operation (see descriptions below). This allows the EnerVista UR Setup software to be used. The UR operates as a Modbus slave device only. When using Modbus protocol on the RS232 port, the F60 will respond regardless of the MODBUS SLAVE ADDRESS programmed. For the RS485 ports each F60 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.

Changes to the MODBUS TCP PORT NUMBER setting will not take effect until the F60 is restarted.
### 5.2 PRODUCT SETUP

#### 5 SETTINGS

**e) DNP PROTOCOL**

**PATH:** SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ DNP PROTOCOL

<table>
<thead>
<tr>
<th>Message</th>
<th>Setting</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>DNP PROTOCOL</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>DNP CHANNELS</strong></td>
<td>Range: see sub-menu below</td>
</tr>
<tr>
<td></td>
<td><strong>DNP ADDRESS:</strong></td>
<td>Range: 0 to 65519 in steps of 1</td>
</tr>
<tr>
<td></td>
<td><strong>DNP NETWORK</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>DNP TCP/UDP PORT NUMBER:</strong></td>
<td>20000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP UNSOL RESPONSE FUNCTION:</strong></td>
<td>Enabled, Disabled</td>
</tr>
<tr>
<td></td>
<td><strong>DNP UNSOL RESPONSE TIMEOUT:</strong></td>
<td>5 s</td>
</tr>
<tr>
<td></td>
<td><strong>DNP UNSOL RESPONSE MAX RETRIES:</strong></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td><strong>DNP UNSOL RESPONSE DEST ADDRESS:</strong></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><strong>DNP CURRENT SCALE FACTOR:</strong></td>
<td>0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP VOLTAGE SCALE FACTOR:</strong></td>
<td>0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP POWER SCALE FACTOR:</strong></td>
<td>0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP ENERGY SCALE FACTOR:</strong></td>
<td>0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP OTHER SCALE FACTOR:</strong></td>
<td>0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP CURRENT DEFAULT DEADBAND:</strong></td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP VOLTAGE DEFAULT DEADBAND:</strong></td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP POWER DEFAULT DEADBAND:</strong></td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP ENERGY DEFAULT DEADBAND:</strong></td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP OTHER DEFAULT DEADBAND:</strong></td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td><strong>DNP TIME SYNC IIN PERIOD:</strong></td>
<td>1440 min</td>
</tr>
<tr>
<td></td>
<td><strong>DNP MESSAGE FRAGMENT SIZE:</strong></td>
<td>240</td>
</tr>
<tr>
<td></td>
<td><strong>DNP OBJECT 1 DEFAULT VARIATION:</strong></td>
<td>1, 2</td>
</tr>
</tbody>
</table>
The F60 supports the Distributed Network Protocol (DNP) version 3.0. The F60 can be used as a DNP slave device connected to multiple DNP masters (usually an RTU or a SCADA master station). Since the F60 maintains two sets of DNP data change buffers and connection information, two DNP masters can actively communicate with the F60 at one time.

The DNP Channels sub-menu is shown below.

**NOTE**

Changes to the DNP CHANNEL 1(2) PORT settings will take effect only after power has been cycled to the relay.

The DNP NETWORK CLIENT ADDRESS settings can force the F60 to respond to a maximum of five specific DNP masters. The settings in this sub-menu are shown below.
The **DNP UNSOL RESPONSE FUNCTION** should be "Disabled" for RS485 applications since there is no collision avoidance mechanism. The **DNP UNSOL RESPONSE TIMEOUT** sets the time the F60 waits for a DNP master to confirm an unsolicited response. The **DNP UNSOL RESPONSE MAX RETRIES** setting determines the number of times the F60 retransmits an unsolicited response without receiving confirmation from the master; a value of "255" allows infinite re-tries. The **DNP UNSOL RESPONSE DEST ADDRESS** is the DNP address to which all unsolicited responses are sent. The IP address to which unsolicited responses are sent is determined by the F60 from the current TCP connection or the most recent UDP message.

The **DNP SCALE FACTOR** settings are numbers used to scale Analog Input point values. These settings group the F60 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 F60 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 determine when to trigger unsolicited responses containing Analog Input data. These settings group the F60 Analog Input data into types: current, voltage, power, energy, and other. Each setting represents the default deadband value for all Analog Input points of that type. For example, to trigger unsolicited responses from the F60 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 deadband default values. DNP Object 34 points can be used to change deadband values, from the default, for each individual DNP Analog Input point. Whenever power is removed and re-applied to the F60, 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 F60. 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.

When the DNP data points (analog inputs and/or binary inputs) are configured for Ethernet-enabled relays, check the “DNP Points Lists” F60 web page to view the points lists. This page can be viewed with a web browser by entering the F60 IP address to access the F60 “Main Menu”, then by selecting the “Device Information Menu” > “DNP Points Lists” menu item.

The **DNP OBJECT N DEFAULT VARIATION** settings allow the user to select the DNP default variation number for object types 1, 2, 20, 21, 22, 23, 30, and 32. The default variation refers to the variation response when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Refer to the **DNP Implementation** section in Appendix E for additional details.

The DNP binary outputs typically map one-to-one to IED data points. That is, each DNP binary output controls a single physical or virtual control point in an IED. In the F60 relay, DNP binary outputs are mapped to virtual inputs. However, some legacy DNP implementations use a mapping of one DNP binary output to two physical or virtual control points to support the concept of trip/close (for circuit breakers) or raise/lower (for tap changers) using a single control point. That is, the DNP master can operate a single point for both trip and close, or raise and lower, operations. The F60 can be configured to support paired control points, with each paired control point operating two virtual inputs. The **DNP NUMBER OF PAIRED CONTROL POINTS** setting allows configuration of from 0 to 32 binary output paired controls. Points not configured as paired operate on a one-to-one basis.
The **DNP ADDRESS** setting is the DNP slave address. This number identifies the F60 on a DNP communications link. Each DNP slave should be assigned a unique address.

### f) DNP / IEC 60870-5-104 POINT LISTS

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ DNP / IEC104 POINT LISTS**

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

The menu for the binary input points (DNP) or MSP points (IEC 60870-5-104) is shown below.

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ DNP / IEC104 POINT LISTS ➔ BINARY INPUT / MSP POINTS**

Up to 256 binary input points can be configured for the DNP or IEC 60870-5-104 protocols. The points are configured by assigning an appropriate FlexLogic™ operand. Refer to the *Introduction to FlexLogic™* section in this chapter for the full range of assignable operands.

The menu for the analog input points (DNP) or MME points (IEC 60870-5-104) is shown below.

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ DNP / IEC104 POINT LISTS ➔ ANALOG INPUT / MME POINTS**

Up to 256 analog input points can be configured for the DNP or IEC 60870-5-104 protocols. The analog point list is configured by assigning an appropriate FlexAnalog parameter to each point. Refer to Appendix A: *FlexAnalog Parameters* for the full range of assignable parameters.

The DNP / IEC 60870-5-104 point lists always begin with point 0 and end at the first “Off” value. Since DNP / IEC 60870-5-104 point lists must be in one continuous block, any points assigned after the first “Off” point are ignored.

Changes to the DNP / IEC 60870-5-104 point lists will not take effect until the F60 is restarted.
### g) IEC 61850 PROTOCOL

**PATH:** SETTINGS → PRODUCT SETUP → COMMUNICATIONS → IEC 61850 PROTOCOL → GSSE / GOOSE CONFIGURATION

<table>
<thead>
<tr>
<th>Message</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSSE / GOOSE</td>
<td><strong>REMOTE I/O TRANSFER</strong></td>
<td>None, GSSE, GOOSE</td>
</tr>
<tr>
<td></td>
<td><strong>DEFAULT GSSE/GOOSE:</strong></td>
<td>1 to 60 s in steps of 1</td>
</tr>
<tr>
<td></td>
<td><strong>UPDATE TIME:</strong></td>
<td>60 s</td>
</tr>
<tr>
<td>GOOSE TRANSMIT VLAN</td>
<td><strong>PRIORITY:</strong></td>
<td>0 to 7 in steps of 1</td>
</tr>
<tr>
<td></td>
<td><strong>ID:</strong></td>
<td>0</td>
</tr>
<tr>
<td>GSSE / GOOSE</td>
<td><strong>GOOSE TRANSMIT VLAN</strong></td>
<td>0 to 4095 in steps of 1</td>
</tr>
<tr>
<td></td>
<td><strong>ETYPE APPID:</strong></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><strong>MESSAGE:</strong></td>
<td>GSSE / GOOSE</td>
</tr>
<tr>
<td>SERVER</td>
<td><strong>LD NAME:</strong></td>
<td>IECDevice</td>
</tr>
<tr>
<td><strong>CONFIGURATION</strong></td>
<td><strong>INCLUDE NON-IEC DATA:</strong></td>
<td>Disabled, Enabled</td>
</tr>
<tr>
<td></td>
<td><strong>NUMBER OF STATUS POINTS IN GGI01:</strong></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td><strong>SERVER SCANNING:</strong></td>
<td>Disabled, Enabled</td>
</tr>
<tr>
<td>CLEAR XCBR1 OpCnt</td>
<td><strong>CLEAR XCBR1 OpCnt:</strong></td>
<td>No</td>
</tr>
<tr>
<td>CLEAR XCBR2 OpCnt</td>
<td><strong>CLEAR XCBR2 OpCnt:</strong></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td><strong>MMXU DEADBANDS</strong></td>
<td>MMXU1 DEADBANDS</td>
</tr>
<tr>
<td></td>
<td><strong>MMXU2 DEADBANDS</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>MMXU3 DEADBANDS</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>MMXU4 DEADBANDS</strong></td>
<td></td>
</tr>
</tbody>
</table>
The F60 Feeder Management Relay is provided with optional IEC 61850 communications capability. This feature is specified as a software option at the time of ordering. Refer to the Ordering section of chapter 2 for additional details. The IEC 61850 protocol feature are not available if CPU Type E is ordered.

The F60 supports the Manufacturing Message Specification (MMS) protocol as specified by IEC 61850. MMS is supported over two protocol stacks: TCP/IP over ethernet and TP4/CLNP (OSI) over ethernet. The F60 operates as an IEC 61850 server. The Remote Inputs/Outputs section in this chapter describe the peer-to-peer GSSE/GOOSE message scheme.

The REMOTE IO TRANSFER METHOD selects the method used to transfer remote input/output data. This can be either IEC 61850 GSSE, IEC 61850 GOOSE, or none (remote inputs/outputs disabled). GOOSE messages are more efficient and can make use of Ethernet priority tagging and virtual LAN functionality. All relays exchanging remote input/output data must be set to the same transfer method.

The DEFAULT GSSE/GOOSE UPDATE TIME sets the time between GSSE or GOOSE messages when there are no remote output state changes to be sent. When remote output data changes, GSSE or GOOSE messages are sent immediately. This setting controls the steady-state ‘heartbeat’ time interval.

The GOOSE TRANSMIT VLAN PRIORITY setting indicates the Ethernet priority of GOOSE messages. This allows GOOSE messages to have higher priority than other Ethernet data. The GOOSE TRANSMIT ETYPE APPID setting allows the selection of a specific application ID for each GOOSE sending device. This value can be left at its default if the feature is not required. Both the GOOSE TRANSMIT VLAN PRIORITY and GOOSE TRANSMIT ETYPE APPID settings are required by IEC 61850.

The LD NAME setting represents the MMS domain name (IEC 61850 logical device) where all IEC/MMS logical nodes are located. The IEC/MMS TCP PORT NUMBER setting allows the user to change the TCP port number for MMS connections. The INCLUDE NON-IEC DATA setting determines whether or not the “UR” MMS domain will be available. This domain contains a large number of UR-series specific data items that are not available in the IEC 61850 logical nodes. This data does not follow the IEC 61850 naming conventions. For communications schemes that strictly follow the IEC 61850 standard, this setting should be “Disabled”.

The NUMBER OF STATUS POINTS IN GGIO1 setting determines the number of “Ind” (single point status indications) that are instantiated in the GGIO1 logical node. The indication points in GGIO1 are mapped to FlexStates in the F60. These FlexStates allow user-customized access to the FlexLogic™ operand states in the relay.

The SERVER SCANNING feature should be set to “Disabled” when IEC 61850 client/server functionality is not required. IEC 61850 has two modes of functionality: GOOSE/GSSE inter-device communication and client/server communication. If the GOOSE/GSSE functionality is required without the IEC 61850 client server feature, then server scanning can be disabled to increase CPU resources. When server scanning is disabled, there will be not updated to the IEC 61850 logical node status values in the F60. Clients will still be able to connect to the server (F60 relay), but most data values will not be updated. This setting does not affect GOOSE/GSSE operation.

Changes to the LD NAME, NUMBER OF STATUS POINTS IN GGIO1, and SERVER SCANNING settings will not take effect until the F60 is restarted.

The CLEAR XCBR1(2) OpCnt settings represent the breaker operating counters. As breakers operate by opening and closing, the XCBR operating counter status attribute (OpCnt) increments with every operation. Frequent breaker operation may result in very large OpCnt values over time. This setting allows the OpCnt to be reset to “0” for XCBR1 and XCBR2.

The IEC 61850 logical node name prefix settings are used to create name prefixes to uniquely identify each logical node. For example, the logical node “PTOC1” may have the name prefix “abc”. The full logical node name will then be “abcMMXU1”. Valid characters for the logical node name prefixes are upper and lowercase letters, numbers, and the underscore (_) character, and the first character in the prefix must be a letter. This conforms to the IEC 61850 standard.
The MMXU deadband settings represent the deadband values used to determine when the update the MMXU “mag” and “cVal” values from the associated “instmag” and “instcVal” values. The “mag” and “cVal” values are used for the IEC 61850 buffered and unbuffered reports. These settings correspond to the associated “db” data items in the CF functional constraint of the MMXU logical node, as per the IEC 61850 standard. According to IEC 61850-7-3, the db value “shall represent the percentage of difference between the maximum and minimum in units of 0.00%”. Thus, it is important to know the maximum value for each MMXU measured quantity, since this represents the 100.00% value for the deadband.

The minimum value for all quantities is 0; the maximum values are as follows:

- phase current: $46 \times \text{phase CT primary setting}$
- neutral current: $46 \times \text{ground CT primary setting}$
- voltage: $275 \times \text{VT ratio setting}$
- power (real, reactive, and apparent): $46 \times \text{phase CT primary setting} \times 275 \times \text{VT ratio setting} \times 90\text{ Hz}$
- power factor: 2

The GGIO2 control configuration settings are used to set the control model for each input. The available choices are “0” (status only), “1” (direct control), and “2” (SBO with normal security). The GGIO2 control points are used to control the F60 virtual inputs.

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

**h) WEB SERVER HTTP PROTOCOL**

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ WEB SERVER HTTP PROTOCOL**

```
WEB SERVER
HTTP PROTOCOL

HTTP TCP PORT
NUMBER: 80
```

The F60 contains an embedded web server and 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 F60 has the ethernet option installed. The web pages are organized as a series of menus that can be accessed starting at the F60 “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 F60 into the “Address” box on the web browser.

**i) TFTP PROTOCOL**

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ TFTP PROTOCOL**

```
TFTP PROTOCOL

TFTP MAIN UDP PORT
NUMBER: 69

TFTP DATA UDP PORT 1
NUMBER: 0

TFTP DATA UDP PORT 2
NUMBER: 0
```

The Trivial File Transfer Protocol (TFTP) can be used to transfer files from the F60 over a network. The F60 operates as a TFTP server. TFTP client software is available from various sources, including Microsoft Windows NT. The `dir.txt` file obtained from the F60 contains a list and description of all available files (event records, oscillography, etc.).
The F60 supports the IEC 60870-5-104 protocol. The F60 can be used as an IEC 60870-5-104 slave device connected to a maximum of two masters (usually either an RTU or a SCADA master station). Since the F60 maintains two sets of IEC 60870-5-104 data change buffers, no more than two masters should actively communicate with the F60 at one time.

The IEC CURRENT DEFAULT THRESHOLD settings are used to determine when to trigger spontaneous responses containing M_ME_NC_1 analog data. These settings group the F60 analog data into types: current, voltage, power, energy, and other. Each setting represents the default threshold value for all M_ME_NC_1 analog points of that type. For example, to trigger spontaneous responses from the F60 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 F60, the default thresholds will be in effect.

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).

The F60 supports the Simple Network Time Protocol specified in RFC-2030. With SNTP, the F60 can obtain clock time over an Ethernet network. The F60 acts as an SNTP client to receive time values from an SNTP/NTP server, usually a dedicated product using a GPS receiver to provide an accurate time. Both unicast and broadcast SNTP are supported.
If SNTP functionality is enabled at the same time as IRIG-B, the IRIG-B signal provides the time value to the F60 clock for as long as a valid signal is present. If the IRIG-B signal is removed, the time obtained from the SNTP server is used. If either SNTP or IRIG-B is enabled, the F60 clock value cannot be changed using the front panel keypad.

To use SNTP in unicast mode, **SNTP SERVER IP ADDR** must be set to the SNTP/NTP server IP address. Once this address is set and **SNTP FUNCTION** is “Enabled”, the F60 attempts to obtain time values from the SNTP/NTP server. Since many time values are obtained and averaged, it generally takes three to four minutes until the F60 clock is closely synchronized with the SNTP/NTP server. It may take up to two minutes for the F60 to signal an SNTP self-test error if the server is offline.

To use SNTP in broadcast mode, set the **SNTP SERVER IP ADDR** setting to “0.0.0.0” and **SNTP FUNCTION** to “Enabled”. The F60 then listens to SNTP messages sent to the “all ones” broadcast address for the subnet. The F60 waits up to eighteen minutes (>1024 seconds) without receiving an SNTP broadcast message before signaling an SNTP self-test error.

The UR-series relays do not support the multicast or anycast SNTP functionality.

**EGD PROTOCOL**

The F60 Feeder Management Relay is provided with optional Ethernet Global Data (EGD) communications capability. This feature is specified as a software option at the time of ordering. Refer to the **Ordering** section of chapter 2 for additional details. The Ethernet Global Data (EGD) protocol feature is not available if CPU Type E is ordered.

The relay supports one fast Ethernet Global Data (EGD) exchange and two slow EGD exchanges. There are 20 data items in the fast-produced EGD exchange and 50 data items in each slow-produced exchange.

Ethernet Global Data (EGD) is a suite of protocols used for the real-time transfer of data for display and control purposes. The relay can be configured to ‘produce’ EGD data exchanges, and other devices can be configured to ‘consume’ EGD data exchanges. The number of produced exchanges (up to three), the data items in each exchange (up to 50), and the exchange production rate can be configured.

EGD cannot be used to transfer data between UR-series relays. The relay supports EGD production only. An EGD exchange will not be transmitted unless the destination address is non-zero, and at least the first data item address is set to a valid Modbus register address. Note that the default setting value of “0” is considered invalid.

The settings menu for the fast EGD exchange is shown below:

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ COMMUNICATIONS ➔ EGD PROTOCOL ➔ FAST PROD EXCH 1 CONFIGURATION**

- **EXCH 1 FUNCTION:**
  - Range: Disable, Enable

- **EXCH 1 DESTINATION:**
  - Range: standard IP address

- **EXCH 1 DATA RATE:**
  - 50 to 1000 ms in steps of 1

- **EXCH 1 DATA ITEM 1:**
  - 0 to 65535 in steps of 1
  - (Modbus register address range)

- **EXCH 1 DATA ITEM 20:**
  - 0 to 65535 in steps of 1
  - (Modbus register address range)
Fast exchanges (50 to 1000 ms) are generally used in control schemes. The F60 has one fast exchange (Exchange 1) and two slow exchanges (Exchanges 2 and 3).

The settings menu for the slow EGD exchanges is shown below:

**PATH:** SETTINGS \[→\] PRODUCT SETUP \[→\] COMMUNICATIONS \[→\] EGD PROTOCOL \[→\] SLOW PROD EXCH 1(2) CONFIGURATION

Slow EGD exchanges (500 to 1000 ms) are generally used for the transfer and display of data items. The settings for the fast and slow exchanges are described below:

- **EXCH 1 DESTINATION:** This setting specifies the destination IP address of the produced EGD exchange. This is usually unicast or broadcast.

- **EXCH 1 DATA RATE:** This setting specifies the rate at which this EGD exchange is transmitted. If the setting is 50 ms, the exchange data will be updated and sent once every 50 ms. If the setting is 1000 ms, the exchange data will be updated and sent once per second. EGD exchange 1 has a setting range of 50 to 1000 ms. Exchanges 2 and 3 have a setting range of 500 to 1000 ms.

- **EXCH 1 DATA ITEM 1 to 20/50:** These settings specify the data items that are part of this EGD exchange. Almost any data from the F60 memory map can be configured to be included in an EGD exchange. The settings are the starting Modbus register address for the data item in decimal format. Refer to Appendix B for the complete Modbus memory map. Note that the Modbus memory map displays shows addresses in hexadecimal format; as such, it will be necessary to convert these values to decimal format before entering them as values for these setpoints.

To select a data item to be part of an exchange, it is only necessary to choose the starting Modbus address of the item. That is, for items occupying more than one Modbus register (e.g. 32 bit integers and floating point values), only the first Modbus address is required. The EGD exchange configured with these settings contains the data items up to the first setting that contains a Modbus address with no data, or 0. That is, if the first three settings contain valid Modbus addresses and the fourth is 0, the produced EGD exchange will contain three data items.

**5.2.5 MODBUS USER MAP**

**PATH:** SETTINGS \[→\] PRODUCT SETUP \[→\] MODBUS USER MAP

The Modbus User Map provides read-only access for up to 256 registers. To obtain a memory map value, enter the desired address in the `ADDRESS` line (this value must be converted from hex to decimal format). The corresponding value is displayed in the `VALUE` line. A value of “0” in subsequent register `ADDRESS` lines automatically returns values for the previous `ADDRESS` lines incremented by “1”. An address value of “0” in the initial register means “none” and values of “0” will be displayed for all registers. Different `ADDRESS` values can be entered as required in any of the register positions.
5.2 PRODUCT SETUP

5.2.6 REAL TIME CLOCK

PATH: SETTINGS ➔ PRODUCT SETUP ➔ REAL TIME CLOCK

The date and time can be synchronized to a known time base and to other relays using an IRIG-B signal. It has the same accuracy as an electronic watch, approximately ±1 minute per month. If an IRIG-B signal is connected to the relay, only the current year needs to be entered. See the COMMANDS ➔ SET DATE AND TIME menu to manually set the relay clock.

The REAL TIME CLOCK EVENTS setting allows changes to the date and/or time to be captured in the event record.

5.2.7 FAULT REPORTS

PATH: SETTINGS ➔ PRODUCT SETUP ➔ FAULT REPORTS ➔ FAULT REPORT 1

The F60 relay supports one fault report and an associated fault locator. The signal source and trigger condition, as well as the characteristics of the line or feeder, are entered in this menu.

The fault report stores data, in non-volatile memory, pertinent to an event when triggered. The captured data contained in the FaultReport.txt file includes:

- Fault report number
- Name of the relay, programmed by the user
- Firmware revision of the relay
- Date and time of trigger
- Name of trigger (specific operand)
- Line/Feeder ID via the name of a configured signal source
- Active setting group at the time of trigger
- Pre-fault current and voltage phasors (one-quarter cycle before the trigger)
- Fault current and voltage phasors (three-quarter cycle after the trigger)
- Elements operated at the time of triggering
• Events: 9 before trigger and 7 after trigger (only available via the relay webpage)
• Fault duration times for each breaker (created by the Breaker Arcing Current feature)

The fault locator does not report fault type or location if the source VTs are connected in the Delta configuration.

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. To include fault duration times in the fault report, the user must enable and configure Breaker Arcing Current feature for each of the breakers. Fault duration is reported on a per-phase basis.

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 overwriting of fault events, the disturbance detector should not be used to trigger a fault report. A FAULT RPT TRIG event is automatically created when the report is triggered.

If a number of protection elements are ORed to create a fault report trigger, the first operation of any element causing the OR gate output to become high triggers a fault report. However, if other elements operate during the fault and the first operated element has not been reset (the OR gate output is still high), the fault report is not triggered again. Considering the reset time of protection elements, there is very little chance that fault report can be triggered twice in this manner. 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 fifteen (15) files. An sixteenth (16th) trigger overwrites the oldest file.

The EnerVista UR Setup software 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 1 SOURCE setting selects the source for input currents and voltages and disturbance detection. The FAULT 1 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. The FAULT REPORT 1 Z1 MAG and FAULT REPORT 1 Z0 MAG impedances are entered in secondary ohms.

See the ACTUAL VALUES ➔ RECORDS ➔ FAULT REPORTS menu for additional details.

### 5.2.8 OSCILLOGRAPHY

a) MAIN MENU

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ OSCILLOGRAPHY**

- **NUMBER OF RECORDS:**
  - 15
  - Range: 1 to 64 in steps of 1
- **TRIGGER MODE:**
  - Automatic Overwrite
  - Range: Automatic Overwrite, Protected
- **TRIGGER POSITION:**
  - 50%
  - Range: 0 to 100% in steps of 1
- **TRIGGER SOURCE:**
  - Off
  - Range: FlexLogic™ operand
- **AC INPUT WAVEFORMS:**
  - 16 samples/cycle
  - Range: Off, 8, 16, 32, 64 samples/cycle
- **DIGITAL CHANNELS**
- **ANALOG CHANNELS**

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

<table>
<thead>
<tr>
<th># RECORDS</th>
<th># CT/VTS</th>
<th>SAMPLE RATE</th>
<th># DIGITALS</th>
<th># ANALOGS</th>
<th>CYCLES/RECORD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>1872.0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>1685.0</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>276.0</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>16</td>
<td>16</td>
<td>4</td>
<td>219.5</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>16</td>
<td>16</td>
<td>4</td>
<td>93.5</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>16</td>
<td>64</td>
<td>16</td>
<td>93.5</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>32</td>
<td>64</td>
<td>16</td>
<td>57.6</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>64</td>
<td>64</td>
<td>16</td>
<td>32.3</td>
</tr>
<tr>
<td>32</td>
<td>2</td>
<td>64</td>
<td>64</td>
<td>16</td>
<td>9.5</td>
</tr>
</tbody>
</table>

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

Set the **TRIGGER POSITION** to a percentage 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.

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

### b) DIGITAL CHANNELS

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ OSCILLOGRAPHY ➔ DIGITAL CHANNELS**

- **DIGITAL CHANNEL 1:** Off
  - Range: FlexLogic™ operand
- **DIGITAL CHANNEL 63:** Off
  - Range: FlexLogic™ operand

A **DIGITAL CHANNEL** setting selects the FlexLogic™ operand state 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. Upon startup, the relay will automatically prepare the parameter list.

### c) ANALOG CHANNELS

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ OSCILLOGRAPHY ➔ ANALOG CHANNELS**

- **ANALOG CHANNEL 1:** Off
  - Range: Off, any FlexAnalog parameter
  - See Appendix A for complete list.
- **ANALOG CHANNEL 16:** Off
  - Range: Off, any FlexAnalog parameter
  - See Appendix A for complete list.
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. A list of all possible analog metering actual value parameters is 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:

\[\text{<slot_letter><terminal_number>—}\text{<I or V><phase A, B, or C, or 4th input>}\]

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.

The source harmonic indices appear as oscillography analog channels numbered from 0 to 23. These correspond directly to the to the 2nd to 25th harmonics in the relay as follows:

- Analog channel 0 ↔ 2nd harmonic
- Analog channel 1 ↔ 3rd harmonic
- ...  
- Analog channel 23 ↔ 25th harmonic

### 5.2.9 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 EnerVista UR Setup 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. Example storage capacities for a system frequency of 60 Hz are shown in the following table.
5.2 PRODUCT SETUP

Table 5–2: DATA LOGGER STORAGE CAPACITY EXAMPLE

<table>
<thead>
<tr>
<th>SAMPLING RATE</th>
<th>CHANNELS</th>
<th>DAYS</th>
<th>STORAGE CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 ms</td>
<td>1</td>
<td>0.1</td>
<td>954 s</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0.1</td>
<td>120 s</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.1</td>
<td>107 s</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.1</td>
<td>60 s</td>
</tr>
<tr>
<td>1000 ms</td>
<td>1</td>
<td>0.7</td>
<td>65457 s</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0.1</td>
<td>8182 s</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.1</td>
<td>7273 s</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.1</td>
<td>4091 s</td>
</tr>
<tr>
<td>60000 ms</td>
<td>1</td>
<td>45.4</td>
<td>3927420 s</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>5.6</td>
<td>490920 s</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>5</td>
<td>436380 s</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>2.8</td>
<td>254460 s</td>
</tr>
<tr>
<td>3600000 ms</td>
<td>1</td>
<td>2727.5</td>
<td>235645200 s</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>340.9</td>
<td>29455200 s</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>303</td>
<td>26182800 s</td>
</tr>
</tbody>
</table>

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

- **DATA LOGGER MODE**: This setting configures the mode in which the data logger will operate. When set to “Continuous”, the data logger will actively record any configured channels at the rate as defined by the **DATA LOGGER RATE**. The data logger will be idle in this mode if no channels are configured. When set to “Trigger”, the data logger will begin to record any configured channels at the instance of the rising edge of the **DATA LOGGER TRIGGER** source FlexLogic™ operand. The Data Logger will ignore all subsequent triggers and will continue to record data until the active record is full. Once the data logger is full a **CLEAR DATA LOGGER** command is required to clear the data logger record before a new record can be started. Performing the **CLEAR DATA LOGGER** command will also stop the current record and reset the data logger to be ready for the next trigger.

- **DATA LOGGER TRIGGER**: This setting selects the signal used to trigger the start of a new data logger record. Any FlexLogic™ operand can be used as the trigger source. The **DATA LOGGER TRIGGER** setting only applies when the mode is set to “Trigger”.

- **DATA LOGGER RATE**: This setting selects the time interval at which the actual value data will be recorded.

- **DATA LOGGER CHNL 1(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. A list of all possible analog metering actual value parameters is shown 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 over-writing old data.
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:

\[ d(t) = D(1 - e^{-kt}) \]  

(EQ 5.6)

where:  
- \( d \) = demand value after applying input quantity for time \( t \) (in minutes)  
- \( D \) = input quantity (constant), and \( k = \frac{2.3}{\text{thermal 90\% response time}} \).

The 90% thermal response time characteristic of 15 minutes is illustrated below. 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.

![Figure 5–2: THERMAL DEMAND CHARACTERISTIC](image)

**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.
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.

5.2.11 USER-PROGRAMMABLE LEDS

a) MAIN MENU

PATH: SETTINGS → PRODUCT SETUP → USER-PROGRAMMABLE LEDS

- USER-PROGRAMMABLE LEDS
- LED TEST
- TRIP & ALARM LEDs
- USER-PROGRAMMABLE LED1
- USER-PROGRAMMABLE LED2
- USER-PROGRAMMABLE LED48

b) LED TEST

PATH: SETTINGS → PRODUCT SETUP → USER-PROGRAMMABLE LEDS → LED TEST

- LED TEST
- LED TEST FUNCTION: Disabled, Enabled.
- LED TEST CONTROL: Off

When enabled, the LED Test can be initiated from any digital input or user-programmable condition such as user-programmable pushbutton. The control operand is configured under the LED TEST CONTROL setting. The test covers all LEDs, including the LEDs of the optional user-programmable pushbuttons.

The test consists of three stages.

Stage 1: All 62 LEDs on the relay are illuminated. This is a quick test to verify if any of the LEDs is "burned". This stage lasts as long as the control input is on, up to a maximum of 1 minute. After 1 minute, the test will end.

Stage 2: All the LEDs are turned off, and then one LED at a time turns on for 1 second, then back off. The test routine starts at the top left panel, moving from the top to bottom of each LED column. This test checks for hardware failures that lead to more than one LED being turned on from a single logic point. This stage can be interrupted at any time.

Stage 3: All the LEDs are turned on. One LED at a time turns off for 1 second, then back on. The test routine starts at the top left panel moving from top to bottom of each column of the LEDs. This test checks for hardware failures that lead to more than one LED being turned off from a single logic point. This stage can be interrupted at any time.

When testing is in progress, the LEDs are controlled by the test sequence, rather than the protection, control, and monitoring features. However, the LED control mechanism accepts all the changes to LED states generated by the relay and stores the actual LED states (On or Off) in memory. When the test completes, the LEDs reflect the actual state resulting from relay response during testing. The Reset pushbutton will not clear any targets when the LED Test is in progress.
A dedicated FlexLogic™ operand, LED TEST IN PROGRESS, is set for the duration of the test. When the test sequence is initiated, the LED Test Initiated event is stored in the Event Recorder.

The entire test procedure is user-controlled. In particular, Stage 1 can last as long as necessary, and Stages 2 and 3 can be interrupted. The test responds to the position and rising edges of the control input defined by the LED TEST CONTROL setting. The control pulses must last at least 250 ms to take effect. The following diagram explains how the test is executed.

**Figure 5–3: LED TEST SEQUENCE**

**APPLICATION EXAMPLE 1:**

Assume one needs to check if any of the LEDs is “burned” through User-Programmable Pushbutton 1. The following settings should be applied. Configure User-Programmable Pushbutton 1 by making the following entries in the SETTINGS → PRODUCT SETUP → USER-PROGRAMMABLE PUSHBUTTONS → USER PUSHBUTTON 1 menu:

**PUSHBUTTON 1 FUNCTION:** “Self-reset”  
**PUSHBTN 1 DROP-OUT TIME:** “0.10 s”

Configure the LED test to recognize User-Programmable Pushbutton 1 by making the following entries in the SETTINGS → PRODUCT SETUP → USER-PROGRAMMABLE LEDs → LED TEST menu:

**LED TEST FUNCTION:** “Enabled”  
**LED TEST CONTROL:** “PUSHBUTTON 1 ON”

The test will be initiated when the User-Programmable Pushbutton 1 is pressed. The pushbutton should remain pressed for as long as the LEDs are being visually inspected. When finished, the pushbutton should be released. The relay will then automatically start Stage 2. At this point forward, test may be aborted by pressing the pushbutton.

**APPLICATION EXAMPLE 2:**

Assume one needs to check if any LEDs are “burned” as well as exercise one LED at a time to check for other failures. This is to be performed via User-Programmable Pushbutton 1.
After applying the settings in Application Example 1, hold down the pushbutton as long as necessary to test all LEDs. Next, release the pushbutton to automatically start Stage 2. Once Stage 2 has started, the pushbutton can be released. When Stage 2 is completed, Stage 3 will automatically start. The test may be aborted at any time by pressing the pushbutton.

c) TRIP AND ALARM LEDS

Path: Settings ⇒ Product Setup ⇒ User-Programmable LEDs ⇒ Trip & Alarm 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.

d) USER-PROGRAMMABLE LED 1(48)

Path: Settings ⇒ Product Setup ⇒ User-Programmable LEDs ⇒ User-Programmable LED 1(48)

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 Chapter 4 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

<table>
<thead>
<tr>
<th>Setting</th>
<th>Parameter</th>
<th>Setting</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED 1 Operand</td>
<td>Setting Group Act 1</td>
<td>LED 13 Operand</td>
<td>Off</td>
</tr>
<tr>
<td>LED 2 Operand</td>
<td>Setting Group Act 2</td>
<td>LED 14 Operand</td>
<td>Breaker 2 Open</td>
</tr>
<tr>
<td>LED 3 Operand</td>
<td>Setting Group Act 3</td>
<td>LED 15 Operand</td>
<td>Breaker 2 Closed</td>
</tr>
<tr>
<td>LED 4 Operand</td>
<td>Setting Group Act 4</td>
<td>LED 16 Operand</td>
<td>Breaker 2 Trouble</td>
</tr>
<tr>
<td>LED 5 Operand</td>
<td>Setting Group Act 5</td>
<td>LED 17 Operand</td>
<td>Sync 1 Sync Op</td>
</tr>
<tr>
<td>LED 6 Operand</td>
<td>Setting Group Act 6</td>
<td>LED 18 Operand</td>
<td>Sync 2 Sync Op</td>
</tr>
<tr>
<td>LED 7 Operand</td>
<td>Off</td>
<td>LED 19 Operand</td>
<td>Off</td>
</tr>
<tr>
<td>LED 8 Operand</td>
<td>Off</td>
<td>LED 20 Operand</td>
<td>Off</td>
</tr>
<tr>
<td>LED 9 Operand</td>
<td>Breaker 1 Open</td>
<td>LED 21 Operand</td>
<td>Ar Enabled</td>
</tr>
<tr>
<td>LED 10 Operand</td>
<td>Breaker 1 Closed</td>
<td>LED 22 Operand</td>
<td>Ar Disabled</td>
</tr>
<tr>
<td>LED 11 Operand</td>
<td>Breaker 1 Trouble</td>
<td>LED 23 Operand</td>
<td>Ar Rip</td>
</tr>
<tr>
<td>LED 12 Operand</td>
<td>Off</td>
<td>LED 24 Operand</td>
<td>Ar Lo</td>
</tr>
</tbody>
</table>

Refer to the Control of Setting Groups example in the Control Elements section of this chapter for group activation.
5.2.12 USER-PROGRAMMABLE SELF-TESTS

All major self-test alarms are reported automatically with their corresponding FlexLogic™ operands, events, and targets. Most of the Minor Alarms can be disabled if desired.

When in the “Disabled” mode, minor alarms will not assert a FlexLogic™ operand, write to the event recorder, display target messages. Moreover, they will not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When in the “Enabled” mode, minor alarms continue to function along with other major and minor alarms. Refer to the Relay Self-Tests section in Chapter 7 for additional information on major and minor self-test alarms.

### USER-PROGRAMMABLE SELF TESTS

<table>
<thead>
<tr>
<th>Message</th>
<th>Function</th>
<th>Range</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT RING BREAK</td>
<td>Enabled</td>
<td>Disabled, Enabled. Valid for units equipped with Direct Input/Output module.</td>
<td></td>
</tr>
<tr>
<td>DIRECT DEVICE OFF</td>
<td>Enabled</td>
<td>Disabled, Enabled. Valid for units equipped with Direct Input/Output module.</td>
<td></td>
</tr>
<tr>
<td>REMOTE DEVICE OFF</td>
<td>Enabled</td>
<td>Disabled, Enabled. Valid for units that contain a CPU with Ethernet capability.</td>
<td></td>
</tr>
<tr>
<td>PRI. ETHERNET FAIL</td>
<td>Disabled</td>
<td>Disabled, Enabled. Valid for units that contain a CPU with a primary fiber port.</td>
<td></td>
</tr>
<tr>
<td>SEC. ETHERNET FAIL</td>
<td>Disabled</td>
<td>Disabled, Enabled. Valid for units that contain a CPU with a redundant fiber port.</td>
<td></td>
</tr>
<tr>
<td>BATTERY FAIL</td>
<td>Enabled</td>
<td>Disabled, Enabled.</td>
<td></td>
</tr>
<tr>
<td>SNTP FAIL</td>
<td>Enabled</td>
<td>Disabled, Enabled. Valid for units that contain a CPU with Ethernet capability.</td>
<td></td>
</tr>
<tr>
<td>IRIG-B FAIL</td>
<td>Enabled</td>
<td>Disabled, Enabled.</td>
<td></td>
</tr>
</tbody>
</table>
The three standard pushbuttons located on the top left panel of the faceplate are user-programmable and can be used for various applications such as performing an LED test, switching setting groups, and invoking and scrolling though user-programmable displays, etc. Firmware revisions 3.2x and older use these three pushbuttons for manual breaker control. This functionality has been retained – if the Breaker Control feature is configured to use the three pushbuttons, they cannot be used as user-programmable control pushbuttons. The location of the control pushbuttons in the following figure.

An additional four control pushbuttons are included when the F60 is ordered with twelve user programmable pushbuttons.

Control pushbuttons are not typically used for critical operations and are not protected by the control password. However, by supervising their output operands, the user can dynamically enable or disable control pushbuttons for security reasons.

Each control pushbutton asserts its own FlexLogic™ operand, CONTROL PUSHBTN 1(7) ON. These operands should be configured appropriately to perform the desired function. The operand remains asserted as long as the pushbutton is pressed and resets when the pushbutton is released. A dropout delay of 100 ms is incorporated to ensure fast pushbutton manipulation will be recognized by various features that may use control pushbuttons as inputs.

An event is logged in the Event Record (as per user setting) when a control pushbutton is pressed; no event is logged when the pushbutton is released. The faceplate keys (including control keys) cannot be operated simultaneously – a given key must be released before the next one can be pressed.

The control pushbuttons become user-programmable only if the Breaker Control feature is not configured for manual control via the User 1 through 3 pushbuttons as shown below. If configured for manual control, Breaker Control typically uses the larger, optional user-programmable pushbuttons, making the control pushbuttons available for other user applications.

![Figure 5-4: CONTROL PUSHBUTTONS](image)

![Figure 5-5: CONTROL PUSHBUTTON LOGIC](image)
5.2.14 USER-PROGRAMMABLE PUSHBUTTONS

The F60 has 12 optional user-programmable pushbuttons available, each configured via 12 identical menus. The pushbuttons provide an easy and error-free method of manually entering digital information (On, Off) into FlexLogic™ equations as well as protection and control elements. Typical applications include breaker control, autorecloser blocking, ground protection blocking, and setting groups changes.

The user-configurable pushbuttons are shown below. They can be custom labeled with a factory-provided template, available online at http://www.GEmultilin.com.

![User-Programmable Pushbuttons](image)

**Figure 5–6: USER-PROGRAMMABLE PUSHBUTTONS**

Each pushbutton asserts its own On and Off FlexLogic™ operands, respectively. FlexLogic™ operands should be used to program desired pushbutton actions. The operand names are PUSHBUTTON 1 ON and PUSHBUTTON 1 OFF.

A pushbutton may be programmed to latch or self-reset. An indicating LED next to each pushbutton signals the present status of the corresponding "On" FlexLogic™ operand. When set to "Latched", the state of each pushbutton is stored in non-volatile memory which is maintained during any supply power loss.

Pushbuttons states can be logged by the Event Recorder and displayed as target messages. User-defined messages can also be associated with each pushbutton and displayed when the pushbutton is ON.

- **PUSHBUTTON 1 FUNCTION**: This setting selects the characteristic of the pushbutton. If set to “Disabled”, the pushbutton is deactivated and the corresponding FlexLogic™ operands (both “On” and “Off”) are de-asserted. If set to “Self-reset”, the control logic of the pushbutton asserts the “On” corresponding FlexLogic™ operand as long as the pushbutton is being pressed. As soon as the pushbutton is released, the FlexLogic™ operand is de-asserted. The “Off” operand is asserted/de-asserted accordingly.

- If set to “Latched”, the control logic alternates the state of the corresponding FlexLogic™ operand between “On” and “Off” on each push of the button. When operating in “Latched” mode, FlexLogic™ operand states are stored in non-volatile memory. Should power be lost, the correct pushbutton state is retained upon subsequent power up of the relay.
• **PUSHBTN 1 ID TEXT**: This setting specifies the top 20-character line of the user-programmable message and is intended to provide ID information of the pushbutton. Refer to the User-Definable Displays section for instructions on how to enter alphanumeric characters from the keypad.

• **PUSHBTN 1 ON TEXT**: This setting specifies the bottom 20-character line of the user-programmable message and is displayed when the pushbutton is in the “on” position. Refer to the User-Definable Displays section for instructions on entering alphanumeric characters from the keypad.

• **PUSHBTN 1 OFF TEXT**: This setting specifies the bottom 20-character line of the user-programmable message and is displayed when the pushbutton is activated from the On to the Off position and the **PUSHBUTTON 1 FUNCTION** is “Latched”. This message is not displayed when the **PUSHBUTTON 1 FUNCTION** is “Self-reset” as the pushbutton operand status is implied to be “Off” upon its release. All user text messaging durations for the pushbuttons are configured with the **PRODUCT SETUP ➔ DISPLAY PROPERTIES ➔ FLASH MESSAGE TIME** setting.

• **PUSHBTN 1 DROP-OUT TIME**: This setting specifies a drop-out time delay for a pushbutton in the self-reset mode. A typical applications for this setting is providing a select-before-operate functionality. The selecting pushbutton should have the drop-out time set to a desired value. The operating pushbutton should be logically ANDed with the selecting pushbutton in FlexLogic™. The selecting pushbutton LED remains on for the duration of the drop-out time, signaling the time window for the intended operation.

For example, consider a relay with the following settings: **PUSHBTN 1 ID TEXT**: “AUTORECLOSER”, **PUSHBTN 1 ON TEXT**: “DISABLED - CALL 2199”, and **PUSHBTN 1 OFF TEXT**: “ENABLED”. When Pushbutton 1 changes its state to the “On” position, the following **AUTOCLOSER DISABLED – Call 2199** message is displayed: When Pushbutton 1 changes its state to the “Off” position, the message will change to **AUTORECLOSER ENABLED**.

User-programmable pushbuttons require a type HP relay faceplate. If an HP-type faceplate was ordered separately, the relay order code must be changed to indicate the HP faceplate option. This can be done via EnerVista UR Setup with the **Maintenance > Enable Pushbutton** command.

### 5.2.15 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.
5.2.16 USER-DEFINABLE DISPLAYS

a) MAIN MENU

PATH: SETTINGS ➔ PRODUCT SETUP ➔ USER-DEFINABLE DISPLAYS

- USER-DEFINABLE DISPLAYS

  - INVOKE AND SCROLL: Off
  - USER DISPLAY 1
  - USER DISPLAY 16

This menu provides a mechanism for manually creating up to 16 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.

Once programmed, the user-definable displays can be viewed in two ways.

- **KEYPAD**: Use the Menu key to select the USER DISPLAYS menu item to access the first user-definable display (note that only the programmed screens are displayed). The screens can be scrolled using the Up and Down keys. The display disappears after the default message time-out period specified by the PRODUCT SETUP ➔ DISPLAY PROPERTIES ➔ DEFAULT MESSAGE TIMEOUT setting.

- **USER-PROGRAMMABLE CONTROL INPUT**: The user-definable displays also respond to the INVOKE AND SCROLL setting. Any FlexLogic™ operand (in particular, the user-programmable pushbutton operands), can be used to navigate the programmed displays.

  On the rising edge of the configured operand (such as when the pushbutton is pressed), the displays are invoked by showing the last user-definable display shown during the previous activity. From this moment onward, the operand acts exactly as the Down key and allows scrolling through the configured displays. The last display wraps up to the first one. The INVOKE AND SCROLL input and the Down keypad key operate concurrently.

  When the default timer expires (set by the DEFAULT MESSAGE TIMEOUT setting), the relay will start to cycle through the user displays. The next activity of the INVOKE AND SCROLL input stops the cycling at the currently displayed user display, not at the first user-defined display. The INVOKE AND SCROLL pulses must last for at least 250 ms to take effect.

b) USER DISPLAY 1(16)

PATH: SETTINGS ➔ PRODUCT SETUP ➔ USER-DEFINABLE DISPLAYS ➔ USER DISPLAY 1(16)

- USER DISPLAY 1

  - DISP 1 TOP LINE:
  - DISP 1 BOTTOM LINE:
  - DISP 1 ITEM 1: 0
  - DISP 1 ITEM 2: 0
  - DISP 1 ITEM 3: 0
  - DISP 1 ITEM 4: 0
  - DISP 1 ITEM 5: 0

  Range: up to 20 alphanumeric characters

  Range: up to 20 alphanumeric characters

  Range: 0 to 65535 in steps of 1

  Range: 0 to 65535 in steps of 1

  Range: 0 to 65535 in steps of 1

  Range: 0 to 65535 in steps of 1

  Range: 0 to 65535 in steps of 1
5.2 PRODUCT SETUP

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 indicates 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 and 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 EnerVista UR Setup interface (preferred for convenience). The following procedure shows how to enter text characters in the top and bottom lines from the faceplate keypad:

1. Select the line to be edited.
2. Press the **Enter** 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 **Enter** 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 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 address, then manually convert it to decimal form before entering it (EnerVista UR Setup usage conveniently facilitates 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.

An example User Display setup and result is shown below:

<table>
<thead>
<tr>
<th>USER DISPLAY 1</th>
<th>DISP 1 TOP LINE:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current X ~ A</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DISP 1 BOTTOM LINE:</td>
</tr>
<tr>
<td></td>
<td>Current Y ~ A</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DISP 1 ITEM 1:</td>
</tr>
<tr>
<td></td>
<td>6016</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DISP 1 ITEM 2:</td>
</tr>
<tr>
<td></td>
<td>6357</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DISP 1 ITEM 3:</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DISP 1 ITEM 4:</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DISP 1 ITEM 5:</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

**USER DISPLAYS**

| Current X | 0.850 A |
| Current Y | 0.327 A |

Shows user-defined text with first Tilde marker.

Shows user-defined text with second Tilde marker.

Shows decimal form of user-selected Modbus Register Address, corresponding to first Tilde marker.

Shows decimal form of user-selected Modbus Register Address, corresponding to 2nd Tilde marker.

This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.

This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.

This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.

Shows the resultant display content.
5.2.17 DIRECT INPUTS/OUTPUTS

**a) MAIN MENU**

**PATH:** SETTINGS $\Rightarrow$ PRODUCT SETUP $\Rightarrow$ DIRECT I/O

<table>
<thead>
<tr>
<th>MESSAGE</th>
<th>DIRECT OUTPUT DEVICE ID: 1</th>
<th>Range: 1 to 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESSAGE</td>
<td>DIRECT I/O CH1 RING CONFIGURATION: Yes</td>
<td>Range: Yes, No</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIRECT I/O CH2 RING CONFIGURATION: Yes</td>
<td>Range: Yes, No</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIRECT I/O DATA RATE: 64 kbps</td>
<td>Range: 64 kbps, 128 kbps</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIRECT I/O CHANNEL CROSSOVER: Disabled</td>
<td>Range: Disabled, Enabled</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>CRC ALARM CH1</td>
<td>See page 5-43.</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>CRC ALARM CH2</td>
<td>See page 5-43.</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>UNRETURNED MESSAGES ALARM CH1</td>
<td>See page 5-43.</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>UNRETURNED MESSAGES ALARM CH2</td>
<td>See page 5-43.</td>
</tr>
</tbody>
</table>

Direct inputs/outputs are intended for exchange of status information (inputs and outputs) between UR-series relays connected directly via Type-7 digital communications cards. The mechanism is very similar to IEC 61850 GSSE, except that communications takes place over a non-switchable isolated network and is optimized for speed. On Type 7 cards that support two channels, direct output messages are sent from both channels simultaneously. This effectively sends direct output messages both ways around a ring configuration. On Type 7 cards that support one channel, direct output messages are sent only in one direction. Messages will be resent (forwarded) when it is determined that the message did not originate at the receiver.

Direct output message timing is similar to GSSE message timing. Integrity messages (with no state changes) are sent at least every 1000 ms. Messages with state changes are sent within the main pass scanning the inputs and asserting the outputs unless the communication channel bandwidth has been exceeded. Two Self-Tests are performed and signaled by the following FlexLogic™ operands:

1. **DIRECT RING BREAK** (direct input/output ring break). This FlexLogic™ operand indicates that direct output messages sent from a UR-series relay are not being received back by the relay.
2. **DIRECT DEVICE 1(16) OFF** (direct device offline). This FlexLogic™ operand indicates that direct output messages from at least one direct device are not being received.

Direct input/output settings are similar to remote input/output settings. The equivalent of the remote device name strings for direct inputs/outputs is the **DIRECT OUTPUT DEVICE ID**. The **DIRECT OUTPUT DEVICE ID** identifies the relay in all direct output messages. All UR-series IEDs in a ring should have unique numbers assigned. The IED ID is used to identify the sender of the direct input/output message.

If the direct input/output scheme is configured to operate in a ring (**DIRECT I/O RING CONFIGURATION**: "Yes"), all direct output messages should be received back. If not, the Direct Input/Output Ring Break self-test is triggered. The self-test error is signaled by the **DIRECT RING BREAK** FlexLogic™ operand.

Select the **DIRECT I/O DATA RATE** to match the data capabilities of the communications channel. Back-to-back connections of the local relays configured with the 7A, 7B, 7C, 7D, 7H, 7I, 7J, 7K, 72 and 73 fiber optic communication cards may be set to 128 kbps. For local relays configured with all other communication cards (i.e. 7E, 7F, 7G, 7L, 7M, 7N, 7P, 7R, 7S, 7T, 7W, 74, 75, 76 and 77), the baud rate will be set to 64 kbps. All IEDs communicating over direct inputs/outputs must be set to...
the same data rate. UR-series IEDs equipped with dual-channel communications cards apply the same data rate to both channels. Delivery time for direct input/output messages is approximately 0.2 of a power system cycle at 128 kbps and 0.4 of a power system cycle at 64 kbps, per each ‘bridge’.

The G.703 and RS422 modules are fixed at 64 kbps only. The SETTINGS → PRODUCT SETUP → DIRECT I/O DATA RATE setting is not applicable to these modules.

The DIRECT I/O CHANNEL CROSSOVER setting applies to F60s with dual-channel communication cards and allows crossing over messages from Channel 1 to Channel 2. This places all UR-series IEDs into one direct input/output network regardless of the physical media of the two communication channels.

The following application examples illustrate the basic concepts for direct input/output configuration. Please refer to the Inputs/Outputs section in this chapter for information on configuring FlexLogic™ operands (flags, bits) to be exchanged.

**EXAMPLE 1: EXTENDING THE INPUT/OUTPUT CAPABILITIES OF A UR-SERIES RELAY**

Consider an application that requires additional quantities of digital inputs and/or output contacts and/or lines of programmable logic that exceed the capabilities of a single UR-series chassis. The problem is solved by adding an extra UR-series IED, such as the C30, to satisfy the additional input/output and programmable logic requirements. The two IEDs are connected via single-channel digital communication cards as shown in the figure below.

![Figure 5–7: INPUT/OUTPUT EXTENSION VIA DIRECT INPUTS/OUTPUTS](image)

In the above application, the following settings should be applied:

**UR IED 1:**
- **DIRECT OUTPUT DEVICE ID:** "1"
- **DIRECT I/O RING CONFIGURATION:** "Yes"
- **DIRECT I/O DATA RATE:** "128 kbps"

**UR IED 2:**
- **DIRECT OUTPUT DEVICE ID:** "2"
- **DIRECT I/O RING CONFIGURATION:** "Yes"
- **DIRECT I/O DATA RATE:** "128 kbps"

The message delivery time is about 0.2 of power cycle in both ways (at 128 kbps); i.e., from Device 1 to Device 2, and from Device 2 to Device 1. Different communications cards can be selected by the user for this back-to-back connection (fiber, G.703, or RS422).

**EXAMPLE 2: INTERLOCKING BUSBAR PROTECTION**

A simple interlocking busbar protection scheme could be accomplished by sending a blocking signal from downstream devices, say 2, 3, and 4, to the upstream device that monitors a single incomer of the busbar, as shown below.

![Figure 5–8: SAMPLE INTERLOCKING BUSBAR PROTECTION SCHEME](image)
For increased reliability, a dual-ring configuration (shown below) is recommended for this application.

![Diagram of Interlocking Bus Protection Scheme via Direct Inputs/Outputs](image)

**Figure 5–9: INTERLOCKING BUS PROTECTION SCHEME VIA DIRECT INPUTS/OUTPUTS**

In the above application, the following settings should be applied:

- **UR IED 1:** DIRECT OUTPUT DEVICE ID: “1”
  - DIRECT I/O RING CONFIGURATION: “Yes”

- **UR IED 2:** DIRECT OUTPUT DEVICE ID: “2”
  - DIRECT I/O RING CONFIGURATION: “Yes”

- **UR IED 3:** DIRECT OUTPUT DEVICE ID: “3”
  - DIRECT I/O RING CONFIGURATION: “Yes”

- **UR IED 4:** DIRECT OUTPUT DEVICE ID: “4”
  - DIRECT I/O RING CONFIGURATION: “Yes”

Message delivery time is approximately 0.2 of power system cycle (at 128 kbps) times number of ‘bridges’ between the origin and destination. Dual-ring configuration effectively reduces the maximum ‘communications distance’ by a factor of two.

In this configuration the following delivery times are expected (at 128 kbps) if both rings are healthy:

- IED 1 to IED 2: 0.2 of power system cycle
- IED 1 to IED 3: 0.4 of power system cycle
- IED 1 to IED 4: 0.2 of power system cycle
- IED 2 to IED 3: 0.2 of power system cycle
- IED 2 to IED 4: 0.4 of power system cycle
- IED 3 to IED 4: 0.2 of power system cycle

If one ring is broken (say TX2/RX2) the delivery times are as follows:

- IED 1 to IED 2: 0.2 of power system cycle
- IED 1 to IED 3: 0.4 of power system cycle
- IED 1 to IED 4: 0.6 of power system cycle
- IED 2 to IED 3: 0.2 of power system cycle
- IED 2 to IED 4: 0.4 of power system cycle
- IED 3 to IED 4: 0.2 of power system cycle

A coordinating timer for this bus protection scheme could be selected to cover the worst case scenario (0.4 of power system cycle). Upon detecting a broken ring, the coordination time should be adaptively increased to 0.6 of power system cycle. The complete application requires addressing a number of issues such as failure of both the communications rings, failure or out-of-service conditions of one of the relays, etc. Self-monitoring flags of the direct inputs/outputs feature would be primarily used to address these concerns.

**EXAMPLE 3: PILOT-AIDED SCHEMES**

Consider the three-terminal line protection application shown below:

![Diagram of Three-Terminal Line Application](image)

**Figure 5–10: THREE-TERMINAL LINE APPLICATION**

A permissive pilot-aided scheme could be implemented in a two-ring configuration as shown below (IEDs 1 and 2 constitute a first ring, while IEDs 2 and 3 constitute a second ring):
In the above application, the following settings should be applied:

<table>
<thead>
<tr>
<th>IED</th>
<th>Direct Output Device ID</th>
<th>Direct I/O Ring Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>IED 1</td>
<td>“1”</td>
<td>“Yes”</td>
</tr>
<tr>
<td>IED 2</td>
<td>“2”</td>
<td>“Yes”</td>
</tr>
<tr>
<td>IED 3</td>
<td>“3”</td>
<td>“Yes”</td>
</tr>
</tbody>
</table>

In this configuration the following delivery times are expected (at 128 kbps):

- IED 1 to IED 2: 0.2 of power system cycle;
- IED 1 to IED 3: 0.5 of power system cycle;
- IED 2 to IED 3: 0.2 of power system cycle

In the above scheme, IEDs 1 and 3 do not communicate directly. IED 2 must be configured to forward the messages as explained in the *Inputs/Outputs* section. A blocking pilot-aided scheme should be implemented with more security and, ideally, faster message delivery time. This could be accomplished using a dual-ring configuration as shown below.

In the above application, the following settings should be applied:

<table>
<thead>
<tr>
<th>IED</th>
<th>Direct Output Device ID</th>
<th>Direct I/O Ring Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>IED 1</td>
<td>“1”</td>
<td>“Yes”</td>
</tr>
<tr>
<td>IED 2</td>
<td>“2”</td>
<td>“Yes”</td>
</tr>
<tr>
<td>IED 3</td>
<td>“3”</td>
<td>“Yes”</td>
</tr>
</tbody>
</table>

In this configuration the following delivery times are expected (at 128 kbps) if both the rings are healthy:

- IED 1 to IED 2: 0.2 of power system cycle;
- IED 1 to IED 3: 0.2 of power system cycle;
- IED 2 to IED 3: 0.2 of power system cycle

The two communications configurations could be applied to both permissive and blocking schemes. Speed, reliability and cost should be taken into account when selecting the required architecture.
The F60 checks integrity of the incoming direct input/output messages using a 32-bit CRC. The CRC Alarm function is available for monitoring the communication medium noise by tracking the rate of messages failing the CRC check. The monitoring function counts all incoming messages, including messages that failed the CRC check. A separate counter adds up messages that failed the CRC check. When the failed CRC counter reaches the user-defined level specified by the CRC ALARM CH1 THRESHOLD setting within the user-defined message count CRC ALARM 1 CH1 COUNT, the DIR IO CH1 CRC ALARM FlexLogic™ operand is set.

When the total message counter reaches the user-defined maximum specified by the CRC ALARM CH1 MESSAGE COUNT setting, both the counters reset and the monitoring process is restarted.

The operand shall be configured to drive an output contact, user-programmable LED, or selected communication-based output. Latching and acknowledging conditions - if required - should be programmed accordingly.

The CRC Alarm function is available on a per-channel basis. The total number of direct input/output messages that failed the CRC check is available as the ACTUAL VALUES STATUS DIRECT INPUTS CRC FAIL COUNT CH1(2) actual value.

- **Message Count and Length of the Monitoring Window:** To monitor communications integrity, the relay sends 1 message per second (at 64 kbps) or 2 messages per second (128 kbps) even if there is no change in the direct outputs. For example, setting the CRC ALARM CH1 MESSAGE COUNT to “10000”, corresponds a time window of about 160 minutes at 64 kbps and 80 minutes at 128 kbps. If the messages are sent faster as a result of direct outputs activity, the monitoring time interval will shorten. This should be taken into account when determining the CRC ALARM CH1 MESSAGE COUNT setting. For example, if the requirement is a maximum monitoring time interval of 10 minutes at 64 kbps, then the CRC ALARM CH1 MESSAGE COUNT should be set to $10 \times 60 \times 1 = 600$.

- **Correlation of Failed CRC and Bit Error Rate (BER):** The CRC check may fail if one or more bits in a packet are corrupted. Therefore, an exact correlation between the CRC fail rate and the BER is not possible. Under certain assumptions an approximation can be made as follows. A direct input/output packet containing 20 bytes results in 160 bits of data being sent and therefore, a transmission of 63 packets is equivalent to 10,000 bits. A BER of $10^{-4}$ implies 1 bit error for every 10,000 bits sent/received. Assuming the best case of only 1 bit error in a failed packet, having 1 failed packet for every 63 received is about equal to a BER of $10^{-5}$.

c) **UNRETURNED MESSAGES ALARM CH1(2)**

The F60 checks integrity of the direct input/output communication ring by counting unreturned messages. In the ring configuration, all messages originating at a given device should return within a pre-defined period of time. The Unreturned Messages Alarm function is available for monitoring the integrity of the communication ring by tracking the rate of unreturned
messages. This function counts all the outgoing messages and a separate counter adds the messages have failed to return. When the unreturned messages counter reaches the user-definable level specified by the **UNRET MSGS ALARM CH1 THRESHOLD** setting and within the user-defined message count **UNRET MSGS ALARM CH1 COUNT**, the **DIR IO CH1 UNRET ALM FlexLogic™** operand is set.

When the total message counter reaches the user-defined maximum specified by the **UNRET MSGS ALARM CH1 MESSAGE COUNT** setting, both the counters reset and the monitoring process is restarted.

The operand shall be configured to drive an output contact, user-programmable LED, or selected communication-based output. Latching and acknowledging conditions, if required, should be programmed accordingly.

The Unreturned Messages Alarm function is available on a per-channel basis and is active only in the ring configuration. The total number of unreturned input/output messages is available as the **ACTUAL VALUES STATUS DIRECT INPUTS UNRETURNED MSG COUNT CH1(2)** actual value.

### 5.2.18 TELEPROTECTION

**PATH: SETTINGS ➔ PRODUCT SETUP ➔ TELEPROTECTION**

<table>
<thead>
<tr>
<th>TELEPROTECTION</th>
<th>TELEPROTECTION FUNCTION: Disabled</th>
<th>Range: Disabled, Enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESSAGE</td>
<td>NUMBER OF TERMINALS: 2</td>
<td>Range: 2, 3</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>NUMBER OF COMM CHANNELS: 1</td>
<td>Range: 1, 2</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>LOCAL RELAY ID NUMBER: 0</td>
<td>Range: 0 to 255 in steps of 1</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>TERMINAL 1 RELAY ID NUMBER: 0</td>
<td>Range: 0 to 255 in steps of 1</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>TERMINAL 2 RELAY ID NUMBER: 0</td>
<td>Range: 0 to 255 in steps of 1</td>
</tr>
</tbody>
</table>

Digital teleprotection functionality is designed to transfer protection commands between 2 or 3 relays in a secure, fast, dependable, and deterministic fashion. Possible applications are permissive or blocking pilot schemes and direct transfer trip (DTT). Teleprotection can be applied over any analog or digital channels and any communications media, such as direct fiber, copper wires, optical networks, or microwave radio links. A mixture of communication media is possible.

Once teleprotection is enabled and the teleprotection input/outputs are configured, data packets are transmitted continuously every 1/4 cycle (3/8 cycle if using C37.94 modules) from peer-to-peer. Security of communication channel data is achieved by using CRC-32 on the data packet.

Teleprotection inputs/outputs and direct inputs/outputs are mutually exclusive – as such, they cannot be used simultaneously. Once teleprotection inputs/outputs are enabled, direct inputs/outputs are blocked, and vice versa.

- **NUMBER OF TERMINALS**: Specifies whether the teleprotection system operates between 2 peers or 3 peers.
- **NUMBER OF CHANNELS**: Specifies how many channels are used. If the **NUMBER OF TERMINALS** is “3” (three-terminal system), set the **NUMBER OF CHANNELS** to “2”. For a two-terminal system, the **NUMBER OF CHANNELS** can set to “1” or “2” (redundant channels).
- **LOCAL RELAY ID NUMBER, TERMINAL 1 RELAY ID NUMBER, and TERMINAL 2 RELAY ID NUMBER**: In installations that use multiplexers or modems, it is desirable to ensure that the data used by the relays protecting a given line is from the correct relays. The teleprotection function performs this check by reading the message ID sent by transmitting relays and comparing it to the programmed ID in the receiving relay. This check is also used to block inputs if inadvertently set to loopback mode or data is being received from a wrong relay by checking the ID on a received channel. If an incorrect ID is found on a channel during normal operation, the **TELEPROT CH1(2) ID FAIL FlexLogic™** operand is set, driving the event with the same name and blocking the teleprotection inputs. For commissioning purposes, the result of channel identification is also shown in the **STATUS CHANNEL TESTS VALIDITY OF CHANNEL CONFIGURATION** actual value. The default value of “0” for the **LOCAL RELAY ID NUMBER** indicates that relay ID is not to be checked.
5 SETTINGS

On two-terminal two-channel systems, the same **LOCAL RELAY ID NUMBER** is transmitted over both channels; as such, only the **TERMINAL 1 ID NUMBER** has to be programmed on the receiving end.

5.2 PRODUCT SETUP

5.2.19 INSTALLATION

**PATH: SETTINGS Ö PRODUCT SETUP Ö INSTALLATION**

- **RELAY SETTINGS**:  
  Range: Not Programmed, Programmed
  
  - **RELAY NAME**:  
    Range: up to 20 alphanumeric characters

To safeguard against the installation of a relay without any entered settings, 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 at the factory. The **UNIT NOT PROGRAMMED** self-test error message is displayed 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 IEC 61850 protocol.
5.3 SYSTEM SETUP

5.3.1 AC INPUTS

a) CURRENT BANKS

PATH: SETTINGS ➔ SYSTEM SETUP ➔ AC INPUTS ➔ CURRENT BANK F1(F5)

Because energy parameters are accumulated, these values should be recorded and then reset immediately prior to changing CT characteristics.

Two banks of phase/ground CTs can be set, where the current banks are denoted in the following format (X represents the module slot position letter):

\[ X_a \]

where \( X = \{F\} \) and \( a = \{1, 5\} \).

See the Introduction to AC Sources section at the beginning of this chapter for additional details.

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 \((I_A + I_B + I_C = \text{Neutral Current} = 3I_o)\) 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. Refer to Chapter 3 for more details on CT connections.

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).

The following example illustrates how multiple CT inputs (current banks) are summed as one source current. Given if the following current banks:

- **F1**: CT bank with 500:1 ratio
- **F5**: CT bank with 1000:1 ratio

The following rule applies:

\[ \text{SRC 1} = F1 + F5 \]  

(EQ 5.7)

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 created by a 1000:1 CT before summation. If a protection element is set up to act on SRC 1 currents, then a pickup level of 1 pu will operate on 1000 A primary.

The same rule applies for current sums from CTs with different secondary taps (5 A and 1 A).
b) VOLTAGE BANKS

Because energy parameters are accumulated, these values should be recorded and then reset immediately prior to changing VT characteristics.

One bank of phase/auxiliary VTs can be set, where voltage banks are denoted in the following format (X represents the module slot position letter):

\[ X_a \]

\[ X = \{F\} \text{ and } a = \{5\}. \]

See the Introduction to AC Sources section at the beginning of this chapter for additional details.

With VTs installed, the relay can perform voltage measurements as well as power calculations. Enter the Phase VT F5 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 Chapter 3 for details.

The nominal Phase VT F5 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. \(\frac{13800}{14400} \times 120\). For a Wye connection, the voltage value entered must be the phase to neutral voltage which would be \(\frac{115}{\sqrt{3}} = 66.4\).

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. \(\frac{14400}{120}\).

If the Phase VT F5 Connection is set to “Delta”, the relay will not calculate voltage harmonics.

### 5.3.2 POWER SYSTEM

<table>
<thead>
<tr>
<th>POWER SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOMINAL FREQUENCY:</td>
</tr>
<tr>
<td>PHASE ROTATION:</td>
</tr>
<tr>
<td>FREQUENCY AND PHASE REFERENCE:</td>
</tr>
<tr>
<td>FREQUENCY TRACKING:</td>
</tr>
</tbody>
</table>

Range: 25 to 60 Hz in steps of 1

Range: ABC, ACB

Range: SRC 1, SRC 2

Range: Disabled, Enabled
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 take 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-series 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-series relays provided the relays have an IRIG-B connection.

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

### 5.3.3 SIGNAL SOURCES

Two identical source menus are available. The "SRC 1" text can be replaced by with a user-defined name appropriate for the associated source.

“F” represents the module slot position. The number directly following this 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 on this concept.

It is possible to select the sum of up to six (6) 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 from the available inputs. Users must select the specific input parameters to be measured by every element in the relevant settings menu. The internal design of the element specifies which type of parameter to use and provides a setting for source selection. In 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 setting 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 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 the actual values.

Disturbance Detectors (Internal):

The 50DD element is a sensitive current disturbance detector that detects 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 each Source. The 50DD function responds to the changes in magnitude of the sequence currents. The disturbance detector scheme logic is as follows:

Figure 5–13: DISTURBANCE DETECTOR LOGIC DIAGRAM

The disturbance detector responds to the change in currents of twice the current cut-off level. The default cut-off threshold is 0.02 pu; thus by default the disturbance detector responds to a change of 0.04 pu. The metering sensitivity setting (PRODUCT SETUP ⇒ DISPLAY PROPERTIES ⇒ CURRENT CUT-OFF LEVEL) controls the sensitivity of the disturbance detector accordingly.
A description of the operation of the breaker control and status monitoring features is provided in Chapter 4. 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 1.

- **BREAKER 1(2) FUNCTION**: Set to "Enable" to allow the operation of any breaker control feature.
- **BREAKER 1(2) PUSH BUTTON CONTROL**: Set to "Enable" to allow faceplate push button operations.
- **BREAKER 1(2) NAME**: Assign a user-defined name (up to 6 characters) to the breaker. This name will be used in flash messages related to Breaker 1.
- **BREAKER 1(2) 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(2) OPEN**: Selects an operand that creates a programmable signal to operate an output relay to open Breaker No. 1.
- **BREAKER 1(2) CLOSE**: Selects an operand that creates a programmable signal to operate an output relay to close Breaker No. 1.
- **BREAKER 1(2) ØA/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(2) FB:** 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(2) FC:** 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(2) EXT ALARM:** Selects an operand, usually an external contact input, connected to a breaker alarm reporting contact.
- **BREAKER 1(2) 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.
- **MANUAL CLOSE RECALL1 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.
- **BREAKER 1(2) OUT OF SV:** Selects an operand indicating that Breaker 1(2) is out-of-service.
- **XCBR ST.LOC OPERAND:** Selects a FlexLogic™ operand to provide a value for the IEC 61850 XCBR1(2) StLoc data item.
Figure 5–14: DUAL BREAKER CONTROL SCHEME LOGIC
a) SETTINGS

**PATH:** SETTINGS ➔ SYSTEM SETUP ➔ FLEXCURVES ➔ FLEXCURVE A(D)

FlexCurves™ A through D 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, B, C, or D).

### Table 5-4: FLEXCURVE™ TABLE

<table>
<thead>
<tr>
<th>RESET TIME MS</th>
<th>OPERATE TIME MS</th>
<th>OPERATE TIME MS</th>
<th>OPERATE TIME MS</th>
<th>OPERATE TIME MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.03</td>
<td>2.9</td>
<td>4.9</td>
<td>10.5</td>
</tr>
<tr>
<td>0.05</td>
<td>1.05</td>
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<td>5.0</td>
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<td>5.1</td>
<td>11.5</td>
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<td>3.2</td>
<td>5.2</td>
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<td>2.8</td>
<td>4.8</td>
<td>10.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

**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 that is close to 1.00 pu.
b) FLEXCURVE™ CONFIGURATION WITH ENERVISTA UR SETUP

The EnerVista UR Setup software allows for easy configuration and management of FlexCurves™ and their associated data points. Prospective FlexCurves™ can be configured from a selection of standard curves to provide the best approximate fit, then specific data points can be edited afterwards. Alternately, curve data can be imported from a specified file (.csv format) by selecting the Import Data From EnerVista UR Setup setting.

Curves and data can be exported, viewed, and cleared by clicking the appropriate buttons. FlexCurves™ are customized by editing the operating time (ms) values at pre-defined per-unit current multiples. Note that the pickup multiples start at zero (implying the "reset time"), operating time below pickup, and operating time above pickup.

c) RECLOSER CURVE EDITING

Recloser Curve selection is special in that recloser curves can be shaped into a composite curve with a minimum response time and a fixed time above a specified pickup multiples. There are 41 recloser curve types supported. These definite operating times are useful to coordinate operating times, typically at higher currents and where upstream and downstream protective devices have different operating characteristics. The Recloser Curve configuration window shown below appears when the Initialize From EnerVista UR Setup setting is set to “Recloser Curve” and the Initialize FlexCurve button is clicked.

Figure 5–15: RECLOSER CURVE INITIALIZATION

Multiplier and Adder settings only affect the curve portion of the characteristic and not the MRT and HCT settings. The HCT settings override the MRT settings for multiples of pickup greater than the HCT Ratio.
d) EXAMPLE
A composite curve can be created from the GE_111 standard with MRT = 200 ms and HCT initially disabled and then enabled at 8 times pickup with an operating time of 30 ms. At approximately 4 times pickup, the curve operating time is equal to the MRT and from then onwards the operating time remains at 200 ms (see below).

Figure 5–16: COMPOSITE RECLOSER CURVE WITH HCT DISABLED
With the HCT feature enabled, the operating time reduces to 30 ms for pickup multiples exceeding 8 times pickup.

Figure 5–17: COMPOSITE RECLOSER CURVE WITH HCT ENABLED

Configuring a composite curve with an increase in operating time at increased pickup multiples is not allowed. If this is attempted, the EnerVista UR Setup software generates an error message and discards the proposed changes.

e) STANDARD RECLOSER CURVES
The standard Recloser curves available for the F60 are displayed in the following graphs.
5.3 SYSTEM SETUP

5 SETTINGS

Figure 5–18: RECLOSER CURVES GE101 TO GE106

Figure 5–19: RECLOSER CURVES GE113, GE120, GE138 AND GE142
5 SETTINGS

5.3 SYSTEM SETUP

Figure 5–20: RECLOSER CURVES GE134, GE137, GE140, GE151 AND GE201

Figure 5–21: RECLOSER CURVES GE131, GE141, GE152, AND GE200
Figure 5–22: RECLOSER CURVES GE133, GE161, GE162, GE163, GE164 AND GE165

Figure 5–23: RECLOSER CURVES GE116, GE117, GE118, GE132, GE136, AND GE139
Figure 5–24: RECLOSER CURVES GE107, GE111, GE112, GE114, GE115, GE121, AND GE122

Figure 5–25: RECLOSER CURVES GE119, GE135, AND GE202
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-series relay involved in this process are shown below.

![UR Architecture Overview Diagram](image_url)

The states of all digital signals used in the F60 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 below.

**Table 5–5: F60 FLEXLOGIC™ OPERAND TYPES**

<table>
<thead>
<tr>
<th>OPERAND TYPE</th>
<th>STATE</th>
<th>EXAMPLE FORMAT</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Input</td>
<td>On</td>
<td>Cont Ip On</td>
<td>Voltage is presently applied to the input (external contact closed).</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>Cont Ip Off</td>
<td>Voltage is presently not applied to the input (external contact open).</td>
</tr>
<tr>
<td>Contact Output</td>
<td>Voltage On</td>
<td>Cont Op 1 VOn</td>
<td>Voltage exists across the contact.</td>
</tr>
<tr>
<td></td>
<td>Voltage Off</td>
<td>Cont Op 1 VOff</td>
<td>Voltage does not exists across the contact.</td>
</tr>
<tr>
<td></td>
<td>Current On</td>
<td>Cont Op 1 IOn</td>
<td>Current is flowing through the contact.</td>
</tr>
<tr>
<td></td>
<td>Current Off</td>
<td>Cont Op 1 IOff</td>
<td>Current is not flowing through the contact.</td>
</tr>
<tr>
<td>Direct Input</td>
<td>On</td>
<td>DIRECT INPUT 1 On</td>
<td>The direct input is presently in the ON state.</td>
</tr>
<tr>
<td>Element (Analog)</td>
<td>Pickup</td>
<td>PHASE TOC1 PKP</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>Dropout</td>
<td>PHASE TOC1 DPO</td>
<td>This operand is the logical inverse of the above PKP operand.</td>
</tr>
<tr>
<td></td>
<td>Operate</td>
<td>PHASE TOC1 OP</td>
<td>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.</td>
</tr>
<tr>
<td>Block</td>
<td>PH DIR1 BLK</td>
<td></td>
<td>The output of the comparator is set to the block function.</td>
</tr>
<tr>
<td>Element (Digital)</td>
<td>Pickup</td>
<td>Dig Element 1 PKP</td>
<td>The input operand is at logic 1.</td>
</tr>
<tr>
<td></td>
<td>Dropout</td>
<td>Dig Element 1 DPO</td>
<td>This operand is the logical inverse of the above PKP operand.</td>
</tr>
<tr>
<td></td>
<td>Operate</td>
<td>Dig Element 1 OP</td>
<td>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.</td>
</tr>
<tr>
<td>Element (Digital Counter)</td>
<td>Higher than</td>
<td>Counter 1 HI</td>
<td>The number of pulses counted is above the set number.</td>
</tr>
<tr>
<td></td>
<td>Equal to</td>
<td>Counter 1 EQL</td>
<td>The number of pulses counted is equal to the set number.</td>
</tr>
<tr>
<td></td>
<td>Lower than</td>
<td>Counter 1 LO</td>
<td>The number of pulses counted is below the set number.</td>
</tr>
<tr>
<td>Fixed</td>
<td>On</td>
<td>On</td>
<td>Logic 1</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>Off</td>
<td>Logic 0</td>
</tr>
<tr>
<td>Remote Input</td>
<td>On</td>
<td>REMOTE INPUT 1 On</td>
<td>The remote input is presently in the ON state.</td>
</tr>
<tr>
<td>Virtual Input</td>
<td>On</td>
<td>Virt Ip 1 On</td>
<td>The virtual input is presently in the ON state.</td>
</tr>
<tr>
<td>Virtual Output</td>
<td>On</td>
<td>Virt Op 1 On</td>
<td>The virtual output is presently in the set state (i.e. evaluation of the equation which produces this virtual output results in a “1”).</td>
</tr>
</tbody>
</table>
The operands available for this relay are listed alphabetically by types in the following table.

### Table 5–6: F60 FLEXLOGIC™ OPERANDS (Sheet 1 of 6)

<table>
<thead>
<tr>
<th>OPERAND TYPE</th>
<th>OPERAND SYNTAX</th>
<th>OPERAND DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL PUSHPBUTTONS</td>
<td>CONTROL PUSHTN n ON</td>
<td>Control Pushbutton n (n = 1 to 7) is being pressed.</td>
</tr>
<tr>
<td>DIRECT DEVICES</td>
<td>DIRECT DEVICE 10n</td>
<td>Flag is set, logic=1</td>
</tr>
<tr>
<td></td>
<td>↓</td>
<td>Flag is set, logic=1</td>
</tr>
<tr>
<td></td>
<td>DIRECT DEVICE 160n</td>
<td>Flag is set, logic=1</td>
</tr>
<tr>
<td></td>
<td>↓</td>
<td>Flag is set, logic=1</td>
</tr>
<tr>
<td></td>
<td>DIRECT DEVICE 100f</td>
<td>Flag is set, logic=1</td>
</tr>
<tr>
<td></td>
<td>↓</td>
<td>Flag is set, logic=1</td>
</tr>
<tr>
<td>DIRECT INPUT/OUTPUT CHANNEL</td>
<td>DIR IO CH1(2) CRC ALARM</td>
<td>The rate of Direct Input messages received on Channel 1(2) and failing the CRC</td>
</tr>
<tr>
<td>MONITORING</td>
<td>DIR IO CRC ALARM</td>
<td>exceeded the user-specified level.</td>
</tr>
<tr>
<td></td>
<td>DIR IO CH1(2) UNRET ALM</td>
<td>The rate of Direct Input messages failing the CRC exceeded the user-specified</td>
</tr>
<tr>
<td></td>
<td>DIR IO UNRET ALM</td>
<td>level on Channel 1 or 2.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The rate of returned direct input/output messages exceeded the user-specified</td>
</tr>
<tr>
<td>ELEMENT:</td>
<td>Autoreclose</td>
<td>Autoreclose 1 is enabled</td>
</tr>
<tr>
<td>(per CT bank)</td>
<td>AR1 ENABLED</td>
<td>Autoreclose 1 is in progress</td>
</tr>
<tr>
<td></td>
<td>AR1 RIP</td>
<td>Autoreclose 1 is locked out</td>
</tr>
<tr>
<td></td>
<td>AR1 BLK FROM MAN CLS</td>
<td>Autoreclose 1 is temporarily disabled</td>
</tr>
<tr>
<td></td>
<td>AR1 CLOSE</td>
<td>Autoreclose 1 close command is issued</td>
</tr>
<tr>
<td></td>
<td>AR1 SHOT CNT=0</td>
<td>Autoreclose 1 shot count is 0</td>
</tr>
<tr>
<td></td>
<td>↓</td>
<td>Autoreclose 1 shot count is 4</td>
</tr>
<tr>
<td></td>
<td>AR1 SHOT CNT=4</td>
<td>Autoreclose 1 is disabled</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ELEMENT:</td>
<td>Auxiliary Overvoltage</td>
<td>Auxiliary Overvoltage element has picked up</td>
</tr>
<tr>
<td></td>
<td>AUX OV1 PKP</td>
<td>Auxiliary Overvoltage element has dropped out</td>
</tr>
<tr>
<td></td>
<td>AUX OV1 DPO</td>
<td>Auxiliary Overvoltage element has operated</td>
</tr>
<tr>
<td></td>
<td>AUX OV1 OP</td>
<td></td>
</tr>
<tr>
<td>ELEMENT:</td>
<td>Auxiliary Undervoltage</td>
<td>Auxiliary Undervoltage element has picked up</td>
</tr>
<tr>
<td></td>
<td>AUX UV1 PKP</td>
<td>Auxiliary Undervoltage element has dropped out</td>
</tr>
<tr>
<td></td>
<td>AUX UV1 DPO</td>
<td>Auxiliary Undervoltage element has operated</td>
</tr>
<tr>
<td></td>
<td>AUX UV1 OP</td>
<td></td>
</tr>
<tr>
<td>ELEMENT:</td>
<td>Breaker Arcing</td>
<td>Breaker Arcing Current 1 has operated</td>
</tr>
<tr>
<td></td>
<td>BKR ARC 1 OP</td>
<td>Breaker Arcing Current 2 has operated</td>
</tr>
<tr>
<td></td>
<td>BKR ARC 2 OP</td>
<td></td>
</tr>
<tr>
<td>ELEMENT:</td>
<td>Breaker Failure</td>
<td>Breaker Failure 1 re-trip phase A (only for 1-pole schemes)</td>
</tr>
<tr>
<td></td>
<td>BKR FAIL 1 RETRIPA</td>
<td>Breaker Failure 1 re-trip phase B (only for 1-pole schemes)</td>
</tr>
<tr>
<td></td>
<td>BKR FAIL 1 RETRIPB</td>
<td>Breaker Failure 1 re-trip phase C (only for 1-pole schemes)</td>
</tr>
<tr>
<td></td>
<td>BKR FAIL 1 RETRIPC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BKR FAIL 1 RETRIP</td>
<td>Breaker Failure 1 re-trip 3-phase</td>
</tr>
<tr>
<td></td>
<td>BKR FAIL 1 T1 OP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BKR FAIL 1 T2 OP</td>
<td>Breaker Failure 1 Timer 1 is operated</td>
</tr>
<tr>
<td></td>
<td>BKR FAIL 1 T3 OP</td>
<td>Breaker Failure 1 Timer 2 is operated</td>
</tr>
<tr>
<td></td>
<td>BKR FAIL 1 TRIP OP</td>
<td>Breaker Failure 1 Timer 3 is operated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ELEMENT:</td>
<td>Breaker Flashover</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR PKP A</td>
<td>Breaker 1 Flashover element phase A has picked up</td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR PKP B</td>
<td>Breaker 1 Flashover element phase B has picked up</td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR PKP C</td>
<td>Breaker 1 Flashover element phase C has picked up</td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR OP A</td>
<td>Breaker 1 Flashover element has operated</td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR OP B</td>
<td>Breaker 1 Flashover element phase B has operated</td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR OP C</td>
<td>Breaker 1 Flashover element phase C has operated</td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR DPO A</td>
<td>Breaker 1 Flashover element phase A has dropped out</td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR DPO B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR DPO C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BKR 1 FLSHOVR DPO</td>
<td>Breaker 1 Flashover element phase B has dropped out</td>
</tr>
<tr>
<td></td>
<td>BKR 2 FLSHOVR...</td>
<td>Same set of operands as shown for BKR 1 FLSHOVR</td>
</tr>
</tbody>
</table>
Table 5–6: F60 FLEXLOGIC™ OPERANDS (Sheet 2 of 6)

<table>
<thead>
<tr>
<th>OPERAND TYPE</th>
<th>OPERAND SYNTAX</th>
<th>OPERAND DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEMENT: Breaker Control</td>
<td>BREAKER 1 OFF CMD</td>
<td>Breaker 1 OFF command</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 ON CMD</td>
<td>Breaker 1 ON command</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 A CLSD</td>
<td>Breaker 1 phase A is closed</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 B CLSD</td>
<td>Breaker 1 phase B is closed</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 C CLSD</td>
<td>Breaker 1 phase C is closed</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 CLOSED</td>
<td>Breaker 1 is closed</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 OPEN</td>
<td>Breaker 1 is open</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 DISCREP</td>
<td>Breaker 1 has discrepancy</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 TROUBLE</td>
<td>Breaker 1 trouble alarm</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 MNL CLS</td>
<td>Breaker 1 manual close</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 TRIP A</td>
<td>Breaker 1 trip phase A command</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 TRIP B</td>
<td>Breaker 1 trip phase B command</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 TRIP C</td>
<td>Breaker 1 trip phase C command</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 ANY P OPEN</td>
<td>At least one pole of Breaker 1 is open</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 ONE P OPEN</td>
<td>Only one pole of Breaker 1 is open</td>
</tr>
<tr>
<td></td>
<td>BREAKER 1 OOS</td>
<td>Breaker 1 is out of service</td>
</tr>
</tbody>
</table>

| ELEMENT: Cold Load Pickup | COLD LOAD 1 OP         | Cold Load Pickup element 1 has operated                  |
|                         | COLD LOAD 2 OP         | Cold Load Pickup element 2 has operated                  |

| ELEMENT: Digital Counters | Counter 1 HI           | Digital Counter 1 output is ‘more than’ comparison value |
|                         | Counter 1 EQL          | Digital Counter 1 output is ‘equal to’ comparison value  |
|                         | Counter 1 LO           | Digital Counter 1 output is ‘less than’ comparison value |
|                         | Counter 8 HI           | Digital Counter 8 output is ‘more than’ comparison value |
|                         | Counter 8 EQL          | Digital Counter 8 output is ‘equal to’ comparison value  |
|                         | Counter 8 LO           | Digital Counter 8 output is ‘less than’ comparison value |

| ELEMENT: Digital Elements | Dig Element 1 PKP      | Digital Element 1 is picked up                           |
|                         | Dig Element 1 OP       | Digital Element 1 is operated                            |
|                         | Dig Element 1 DPO      | Digital Element 1 is dropped out                          |
|                         | Dig Element 14 PKP     | Digital Element 14 is picked up                          |
|                         | Dig Element 14 OP      | Digital Element 14 is operated                            |
|                         | Dig Element 14 DPO     | Digital Element 14 is dropped out                          |

| ELEMENT: Sensitive Directional Power | DIR POWER 1 STG1 PKP | Stage 1 of the Directional Power element 1 has picked up |
|                                      | DIR POWER 1 STG2 PKP | Stage 2 of the Directional Power element 1 has picked up |
|                                      | DIR POWER 1 STG1 DPO | Stage 1 of the Directional Power element 1 has dropped out |
|                                      | DIR POWER 1 STG2 DPO | Stage 2 of the Directional Power element 1 has dropped out |
|                                      | DIR POWER 1 STG1 OP  | Stage 1 of the Directional Power element 1 has operated  |
|                                      | DIR POWER 1 STG2 OP  | Stage 2 of the Directional Power element 1 has operated  |
|                                      | DIR POWER 1 PKP      | The Directional Power element has picked up               |
|                                      | DIR POWER 1 DPO      | The Directional Power element has dropped out             |
|                                      | DIR POWER 1 OP       | The Directional Power element has operated                |

| ELEMENT: Frequency Rate of Change | FREQUENCY RATE n PKP  | The n-th Frequency Rate of Change element has picked up  |
|                                  | FREQUENCY RATE n DPO  | The n-th Frequency Rate of Change element has dropped out |
|                                  | FREQUENCY RATE n OP   | The n-th Frequency Rate of Change element has operated    |

| ELEMENT: FlexElements™ | Fx 1 PKP    | FlexElement™ 1 has picked up |
|                       | Fx 1 OP     | FlexElement™ 1 has operated  |
|                       | Fx 1 DPO    | FlexElement™ 1 has dropped out |
|                       | Fx 8 PKP    | FlexElement™ 8 has picked up |
|                       | Fx 8 OP     | FlexElement™ 8 has operated  |
|                       | Fx 8 DPO    | FlexElement™ 8 has dropped out |

| ELEMENT: Ground Instantaneous Overcurrent | GROUND IOC1 PKP  | Ground Instantaneous Overcurrent 1 has picked up       |
|                                           | GROUND IOC1 OP   | Ground Instantaneous Overcurrent 1 has operated        |
|                                           | GROUND IOC1 DPO  | Ground Instantaneous Overcurrent 1 has dropped out      |

| ELEMENT: Ground Time Overcurrent | GROUND TOC1 PKP | Ground Time Overcurrent 1 has picked up                 |
|                                  | GROUND TOC1 OP  | Ground Time Overcurrent 1 has operated                   |
|                                  | GROUND TOC1 DPO | Ground Time Overcurrent 1 has dropped out                |

| ELEMENT: Ground Time Overcurrent 2 | GROUND TOC2     | Same set of operands as shown for GROUND TOC 1          |
### Table 5–6: F60 FLEXLOGIC™ OPERANDS (Sheet 3 of 6)

<table>
<thead>
<tr>
<th>OPERAND TYPE</th>
<th>OPERAND SYNTAX</th>
<th>OPERAND DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEMENT</td>
<td>HI-Z ARC DETECTED</td>
<td>The Hi-Z element has operated</td>
</tr>
<tr>
<td>High Impedance Fault Detection (Hi-Z)</td>
<td>HI-Z ARC DETECTED-A</td>
<td>The Hi-Z Phase A element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z ARC DETECTED-B</td>
<td>The Hi-Z Phase B element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z ARC DETECTED-C</td>
<td>The Hi-Z Phase C element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z ARC DETECTED-N</td>
<td>The Hi-Z Neutral element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z DOWNED COND</td>
<td>The Hi-Z Downed Conductor element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z DOWNED COND-A</td>
<td>The Hi-Z Downed Conductor Phase A element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z DOWNED COND-B</td>
<td>The Hi-Z Downed Conductor Phase B element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z DOWNED COND-C</td>
<td>The Hi-Z Downed Conductor Phase C element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z DOWNED COND-N</td>
<td>The Hi-Z Downed Conductor Neutral element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z ARC SUSPECTED</td>
<td>The Hi-Z Arcing Suspected element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z ARC SUSPECTED-A</td>
<td>The Hi-Z Arcing Suspected Phase A element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z ARC SUSPECTED-B</td>
<td>The Hi-Z Arcing Suspected Phase B element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z ARC SUSPECTED-C</td>
<td>The Hi-Z Arcing Suspected Phase C element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z ARC SUSPECTED-N</td>
<td>The Hi-Z Arcing Suspected Neutral element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z IOC A</td>
<td>The Hi-Z IOC A element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z IOC B</td>
<td>The Hi-Z IOC B element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z IOC C</td>
<td>The Hi-Z IOC C element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z LOSS OF LOAD-A</td>
<td>The Hi-Z Phase A Loss of Load element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z LOSS OF LOAD-B</td>
<td>The Hi-Z Phase B Loss of Load element has operated</td>
</tr>
<tr>
<td></td>
<td>HI-Z LOSS OF LOAD-C</td>
<td>The Hi-Z Phase C Loss of Load element has operated</td>
</tr>
<tr>
<td>ELEMENT</td>
<td>LATCH 1 ON</td>
<td>Non-Volatile Latch 1 is ON (Logic = 1)</td>
</tr>
<tr>
<td>Non-Volatile Latches</td>
<td>LATCH 1 OFF</td>
<td>Non-Voltage Latch 1 is OFF (Logic = 0)</td>
</tr>
<tr>
<td></td>
<td>↓</td>
<td>Non-Volatile Latch 16 is ON (Logic = 1)</td>
</tr>
<tr>
<td></td>
<td>↓</td>
<td>Non-Voltage Latch 16 is OFF (Logic = 0)</td>
</tr>
<tr>
<td>ELEMENT: Load Encroachment</td>
<td>LOAD ENCHR PKP</td>
<td>Load Encroachment has picked up</td>
</tr>
<tr>
<td></td>
<td>LOAD ENCHR OP</td>
<td>Load Encroachment has operated</td>
</tr>
<tr>
<td></td>
<td>LOAD ENCHR DPO</td>
<td>Load Encroachment has dropped out</td>
</tr>
<tr>
<td>ELEMENT: Negative Sequence Directional Overcurrent</td>
<td>NEG SEQ DIR OC1 FWD</td>
<td>Negative Sequence Directional OC1 Forward has operated</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ DIR OC1 REV</td>
<td>Negative Sequence Directional OC1 Reverse has operated</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ DIR OC2 FWD</td>
<td>Negative Sequence Directional OC2 Forward has operated</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ DIR OC2 REV</td>
<td>Negative Sequence Directional OC2 Reverse has operated</td>
</tr>
<tr>
<td>ELEMENT: Negative Sequence Instantaneous Overcurrent</td>
<td>NEG SEQ IOC1 PKP</td>
<td>Negative Sequence Instantaneous Overcurrent 1 has picked up</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ IOC1 OP</td>
<td>Negative Sequence Instantaneous Overcurrent 1 has operated</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ IOC1 DPO</td>
<td>Negative Sequence Instantaneous Overcurrent 1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ IOC2</td>
<td>Same set of operands as shown for NEG SEQ IOC1</td>
</tr>
<tr>
<td>ELEMENT: Negative Sequence Overvoltage</td>
<td>NEG SEQ OV PKP</td>
<td>Negative Sequence Overvoltage element has picked up</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ OV DPO</td>
<td>Negative Sequence Overvoltage element has dropped out</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ OV OP</td>
<td>Negative Sequence Overvoltage element has operated</td>
</tr>
<tr>
<td>ELEMENT: Negative Sequence Time Overcurrent</td>
<td>NEG SEQ TOC1 PKP</td>
<td>Negative Sequence Time Overcurrent 1 has picked up</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ TOC1 OP</td>
<td>Negative Sequence Time Overcurrent 1 has operated</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ TOC1 DPO</td>
<td>Negative Sequence Time Overcurrent 1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>NEG SEQ TOC2</td>
<td>Same set of operands as shown for NEG SEQ TOC1</td>
</tr>
<tr>
<td>ELEMENT: Neutral Instantaneous Overcurrent</td>
<td>NEUTRAL IOC1 PKP</td>
<td>Neutral Instantaneous Overcurrent 1 has picked up</td>
</tr>
<tr>
<td></td>
<td>NEUTRAL IOC1 OP</td>
<td>Neutral Instantaneous Overcurrent 1 has operated</td>
</tr>
<tr>
<td></td>
<td>NEUTRAL IOC1 DPO</td>
<td>Neutral Instantaneous Overcurrent 1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>NEUTRAL IOC2</td>
<td>Same set of operands as shown for NEUTRAL IOC1</td>
</tr>
<tr>
<td>ELEMENT: Neutral Overvoltage</td>
<td>NEUTRAL OV1 PKP</td>
<td>Neutral Overvoltage element has picked up</td>
</tr>
<tr>
<td></td>
<td>NEUTRAL OV1 DPO</td>
<td>Neutral Overvoltage element has dropped out</td>
</tr>
<tr>
<td></td>
<td>NEUTRAL OV1 OP</td>
<td>Neutral Overvoltage element has operated</td>
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<tr>
<td>ELEMENT: Neutral Time Overcurrent</td>
<td>NEUTRAL TOC1 PKP</td>
<td>Neutral Time Overcurrent 1 has picked up</td>
</tr>
<tr>
<td></td>
<td>NEUTRAL TOC1 OP</td>
<td>Neutral Time Overcurrent 1 has operated</td>
</tr>
<tr>
<td></td>
<td>NEUTRAL TOC1 DPO</td>
<td>Neutral Time Overcurrent 1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>NEUTRAL TOC2</td>
<td>Same set of operands as shown for NEUTRAL TOC1</td>
</tr>
<tr>
<td>ELEMENT: Neutral Directional Overcurrent</td>
<td>NTRL DIR OC1 FWD</td>
<td>Neutral Directional OC1 Forward has operated</td>
</tr>
<tr>
<td></td>
<td>NTRL DIR OC1 REV</td>
<td>Neutral Directional OC1 Reverse has operated</td>
</tr>
<tr>
<td></td>
<td>NTRL DIR OC2</td>
<td>Same set of operands as shown for NTRL DIR OC1</td>
</tr>
<tr>
<td>ELEMENT: Overfrequency</td>
<td>OVERFREQ 1 PKP</td>
<td>Overfrequency 1 has picked up</td>
</tr>
<tr>
<td></td>
<td>OVERFREQ 1 OP</td>
<td>Overfrequency 1 has operated</td>
</tr>
<tr>
<td></td>
<td>OVERFREQ 1 DPO</td>
<td>Overfrequency 1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>OVERFREQ 2 to 4</td>
<td>Same set of operands as shown for OVERFREQ 1</td>
</tr>
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### Table 5–6: F60 FLEXLOGIC™ OPERANDS (Sheet 4 of 6)

<table>
<thead>
<tr>
<th>OPERAND TYPE</th>
<th>OPERAND SYNTAX</th>
<th>OPERAND DESCRIPTION</th>
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<tbody>
<tr>
<td><strong>ELEMENT:</strong></td>
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<td></td>
</tr>
<tr>
<td>Phase Directional</td>
<td>PH DIR1 BLK A</td>
<td>Phase A Directional 1 Block</td>
</tr>
<tr>
<td>Overcurrent</td>
<td>PH DIR1 BLK B</td>
<td>Phase B Directional 1 Block</td>
</tr>
<tr>
<td></td>
<td>PH DIR1 BLK C</td>
<td>Phase C Directional 1 Block</td>
</tr>
<tr>
<td></td>
<td>PH DIR1 BLK</td>
<td>Phase Directional 1 Block</td>
</tr>
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<td>PH DIR2</td>
<td>Same set of operands as shown for PH DIR1</td>
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<td></td>
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<td><strong>ELEMENT:</strong></td>
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<td></td>
</tr>
<tr>
<td>Phase</td>
<td>PHASE IOC1 PKP</td>
<td>At least one phase of PHASE IOC1 has picked up</td>
</tr>
<tr>
<td>Instantaneous</td>
<td>PHASE IOC1 OP</td>
<td>At least one phase of PHASE IOC1 has operated</td>
</tr>
<tr>
<td>Overcurrent</td>
<td>PHASE IOC1 DPO</td>
<td>At least one phase of PHASE IOC1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 PKP A</td>
<td>Phase A of PHASE IOC1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 PKP B</td>
<td>Phase B of PHASE IOC1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 PKP C</td>
<td>Phase C of PHASE IOC1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 OP A</td>
<td>Phase A of PHASE IOC1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 OP B</td>
<td>Phase B of PHASE IOC1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 OP C</td>
<td>Phase C of PHASE IOC1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 DPO A</td>
<td>Phase A of PHASE IOC1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 DPO B</td>
<td>Phase B of PHASE IOC1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE IOC1 DPO C</td>
<td>Phase C of PHASE IOC1 has dropped out</td>
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<td>PHASE IOC2</td>
<td>Same set of operands as shown for PHASE IOC1</td>
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<tr>
<td><strong>ELEMENT:</strong></td>
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<td>Phase</td>
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<td>At least one phase of Overvoltage 1 has picked up</td>
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<tr>
<td>Overvoltage</td>
<td>PHASE OV1 OP</td>
<td>At least one phase of Overvoltage 1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE OV1 DPO</td>
<td>At least one phase of Overvoltage 1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE OV1 PKP A</td>
<td>Phase A of Overvoltage 1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE OV1 PKP B</td>
<td>Phase B of Overvoltage 1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE OV1 PKP C</td>
<td>Phase C of Overvoltage 1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE OV1 OP A</td>
<td>Phase A of Overvoltage 1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE OV1 OP B</td>
<td>Phase B of Overvoltage 1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE OV1 OP C</td>
<td>Phase C of Overvoltage 1 has operated</td>
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<tr>
<td></td>
<td>PHASE OV1 DPO A</td>
<td>Phase A of Overvoltage 1 has dropped out</td>
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<tr>
<td></td>
<td>PHASE OV1 DPO B</td>
<td>Phase B of Overvoltage 1 has dropped out</td>
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<td>PHASE OV1 DPO C</td>
<td>Phase C of Overvoltage 1 has dropped out</td>
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<td>PHASE OV2</td>
<td>Same set of operands as shown for PHASE OV1</td>
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<td><strong>ELEMENT:</strong></td>
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<td>Phase</td>
<td>PHASE TOC1 PKP</td>
<td>At least one phase of PHASE TOC1 has picked up</td>
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<tr>
<td>Time</td>
<td>PHASE TOC1 OP</td>
<td>At least one phase of PHASE TOC1 has operated</td>
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<td>PHASE TOC1 DPO</td>
<td>At least one phase of PHASE TOC1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE TOC1 PKP A</td>
<td>Phase A of PHASE TOC1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE TOC1 PKP B</td>
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</tr>
<tr>
<td></td>
<td>PHASE TOC1 PKP C</td>
<td>Phase C of PHASE TOC1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE TOC1 OP A</td>
<td>Phase A of PHASE TOC1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE TOC1 OP B</td>
<td>Phase B of PHASE TOC1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE TOC1 OP C</td>
<td>Phase C of PHASE TOC1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE TOC1 DPO A</td>
<td>Phase A of PHASE TOC1 has dropped out</td>
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<tr>
<td></td>
<td>PHASE TOC1 DPO B</td>
<td>Phase B of PHASE TOC1 has dropped out</td>
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<td></td>
<td>PHASE TOC1 DPO C</td>
<td>Phase C of PHASE TOC1 has dropped out</td>
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<tr>
<td></td>
<td>PHASE TOC2</td>
<td>Same set of operands as shown for PHASE TOC1</td>
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<td><strong>ELEMENT:</strong></td>
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<td>Phase</td>
<td>PHASE UV1 PKP</td>
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<tr>
<td>Undervoltage</td>
<td>PHASE UV1 OP</td>
<td>At least one phase of UV1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 DPO</td>
<td>At least one phase of UV1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 PKP A</td>
<td>Phase A of UV1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 PKP B</td>
<td>Phase B of UV1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 PKP C</td>
<td>Phase C of UV1 has picked up</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 OP A</td>
<td>Phase A of UV1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 OP B</td>
<td>Phase B of UV1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 OP C</td>
<td>Phase C of UV1 has operated</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 DPO A</td>
<td>Phase A of UV1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 DPO B</td>
<td>Phase B of UV1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE UV1 DPO C</td>
<td>Phase C of UV1 has dropped out</td>
</tr>
<tr>
<td></td>
<td>PHASE UV2</td>
<td>Same set of operands as shown for PHASE UV1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ELEMENT:</strong></td>
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<td></td>
</tr>
<tr>
<td>Selector Switch</td>
<td>SELECTOR 1 POS Y</td>
<td>Selector Switch 1 is in Position Y (mutually exclusive operands).</td>
</tr>
<tr>
<td></td>
<td>SELECTOR 1 BIT 0</td>
<td>First bit of the 3-bit word encoding position of Selector 1.</td>
</tr>
<tr>
<td></td>
<td>SELECTOR 1 BIT 1</td>
<td>Second bit of the 3-bit word encoding position of Selector 1.</td>
</tr>
<tr>
<td></td>
<td>SELECTOR 1 BIT 2</td>
<td>Third bit of the 3-bit word encoding position of Selector 1.</td>
</tr>
<tr>
<td></td>
<td>SELECTOR 1 STP ALARM</td>
<td>Position of Selector 1 has been pre-selected with the stepping up control input but not acknowledged.</td>
</tr>
<tr>
<td></td>
<td>SELECTOR 1 BIT ALARM</td>
<td>Position of Selector 1 has been pre-selected with the 3-bit control input but not acknowledged.</td>
</tr>
<tr>
<td></td>
<td>SELECTOR 1 ALARM</td>
<td>Position of Selector 1 has been pre-selected but not acknowledged.</td>
</tr>
<tr>
<td></td>
<td>SELECTOR 1 PWR ALARM</td>
<td>Position of Selector Switch 1 is undetermined or restored from memory when the relay powers up and synchronizes to the 3-bit input.</td>
</tr>
<tr>
<td></td>
<td>SELECTOR 2</td>
<td>Same set of operands as shown above for SELECTOR 1</td>
</tr>
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</table>
Table 5–6: F60 FLEXLOGIC™ OPERANDS (Sheet 5 of 6)

<table>
<thead>
<tr>
<th>ELEMENT TYPE</th>
<th>OPERAND TYPE</th>
<th>OPERAND SYNTAX</th>
<th>OPERAND DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting Group</td>
<td>SETTING GROUP ACT 1</td>
<td>Setting Group 1 is active</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SETTING GROUP ACT 6</td>
<td>Setting Group 6 is active</td>
<td></td>
</tr>
<tr>
<td>Disturbance Detector</td>
<td>SRCx 50DD OP</td>
<td>Source x Disturbance Detector has operated</td>
<td></td>
</tr>
<tr>
<td>VTFF (Voltage Transformer Fuse Failure)</td>
<td>SRCx VT FUSE FAIL OP</td>
<td>Source x VT Fuse Failure detector has operated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SRCx VT FUSE FAIL DPO</td>
<td>Source x VT Fuse Failure detector has dropped out</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SRCx VT FUSE FAIL VOL LOSS</td>
<td>Source x has lost voltage signals (V2 below 15% AND V1 below 5% of nominal)</td>
<td></td>
</tr>
<tr>
<td>Synchrocheck</td>
<td>SYNC 1 DEAD S OP</td>
<td>Synchrocheck 1 dead source has operated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 DEAD S DPO</td>
<td>Synchrocheck 1 dead source has dropped out</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 SYNC OP</td>
<td>Synchrocheck 1 in synchronization has operated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 SYNC DPO</td>
<td>Synchrocheck 1 in synchronization has dropped out</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 CLS OP</td>
<td>Synchrocheck 1 close has operated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 CLS DPO</td>
<td>Synchrocheck 1 close has dropped out</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 V1 ABOVE MIN</td>
<td>Synchrocheck 1 V1 is above the minimum live voltage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 V1 BELOW MAX</td>
<td>Synchrocheck 1 V1 is below the maximum dead voltage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 V2 ABOVE MIN</td>
<td>Synchrocheck 1 V2 is above the minimum live voltage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYNC 1 V2 BELOW MAX</td>
<td>Synchrocheck 1 V2 is below the maximum dead voltage</td>
<td></td>
</tr>
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<td></td>
<td>SYNC 2</td>
<td>Same set of operands as shown for SYNC 1</td>
<td></td>
</tr>
<tr>
<td>Teleprotection Inputs/Outputs</td>
<td>TELEPRO CH1 FAIL</td>
<td>Channel 1 failed</td>
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<tr>
<td></td>
<td>TELEPRO CH2 FAIL</td>
<td>Channel 2 failed</td>
<td></td>
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<tr>
<td></td>
<td>TELEPRO CH1 ID FAIL</td>
<td>The ID check for a peer relay on channel 1 has failed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TELEPRO CH2 ID FAIL</td>
<td>The ID check for a peer relay on channel 2 has failed</td>
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<tr>
<td></td>
<td>TELEPRO CH1 CRC FAIL</td>
<td>CRC detected packet corruption on channel 1</td>
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<tr>
<td></td>
<td>TELEPRO CH2 CRC FAIL</td>
<td>CRC detected packet corruption on channel 2</td>
<td></td>
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<tr>
<td></td>
<td>TELEPRO CH1 PKT LOST</td>
<td>CRC detected lost packet on channel 1</td>
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<td></td>
<td>TELEPRO CH2 PKT LOST</td>
<td>CRC detected lost packet on channel 2</td>
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<tr>
<td></td>
<td>TELEPRO INPUT 1-1 On</td>
<td>Flag is set, Logic =1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TELEPRO INPUT 1-16 On</td>
<td>Flag is set, Logic =1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TELEPRO INPUT 2-1 On</td>
<td>Flag is set, Logic =1</td>
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<td></td>
<td>TELEPRO INPUT 2-16 On</td>
<td>Flag is set, Logic =1</td>
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<tr>
<td>Underfrequency</td>
<td>UNDERFREQ 1 PKP</td>
<td>Underfrequency 1 has picked up</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UNDERFREQ 1 OP</td>
<td>Underfrequency 1 has operated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UNDERFREQ 1 DPO</td>
<td>Underfrequency 1 has dropped out</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UNDERFREQ 2 to 6</td>
<td>Same set of operands as shown for UNDERFREQ 1 above</td>
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<tr>
<td>FIXED OPERANDS</td>
<td>Off</td>
<td>Logic = 0. Does nothing and may be used as a delimiter in an equation list; used as ‘Disable’ by other features.</td>
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<td>On</td>
<td>Logic = 1. Can be used as a test setting.</td>
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<td>Contact Inputs</td>
<td>Cont Ip 1 On</td>
<td>(will not appear unless ordered)</td>
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<tr>
<td></td>
<td>Cont Ip 2 On</td>
<td>(will not appear unless ordered)</td>
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<tr>
<td></td>
<td>Cont Ip 1 Off</td>
<td>(will not appear unless ordered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cont Ip 2 Off</td>
<td>(will not appear unless ordered)</td>
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</tr>
<tr>
<td>Contact Outputs, Current (from detector on Form-A output only)</td>
<td>Cont Op 1 IOn</td>
<td>(will not appear unless ordered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cont Op 2 IOn</td>
<td>(will not appear unless ordered)</td>
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</tr>
<tr>
<td></td>
<td>Cont Op 1 IOff</td>
<td>(will not appear unless ordered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cont Op 2 IOff</td>
<td>(will not appear unless ordered)</td>
<td></td>
</tr>
<tr>
<td>Contact Outputs, Voltage (from detector on Form-A output only)</td>
<td>Cont Op 1 VOn</td>
<td>(will not appear unless ordered)</td>
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<tr>
<td></td>
<td>Cont Op 2 VOn</td>
<td>(will not appear unless ordered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cont Op 1 VOff</td>
<td>(will not appear unless ordered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cont Op 2 VOff</td>
<td>(will not appear unless ordered)</td>
<td></td>
</tr>
<tr>
<td>Direct Inputs</td>
<td>DIRECT INPUT 1 On</td>
<td>Flag is set, logic=1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DIRECT INPUT 32 On</td>
<td>Flag is set, logic=1</td>
<td></td>
</tr>
<tr>
<td>Remote Inputs</td>
<td>REMOTE INPUT 1 On</td>
<td>Flag is set, logic=1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>REMOTE INPUT 32 On</td>
<td>Flag is set, logic=1</td>
<td></td>
</tr>
</tbody>
</table>
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 FlexLogic™ operators table above.

Table 5–7: FLEXLOGIC™ GATE CHARACTERISTICS

<table>
<thead>
<tr>
<th>GATES</th>
<th>NUMBER OF INPUTS</th>
<th>OUTPUT IS ‘1’ (= ON) IF...</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT</td>
<td>1</td>
<td>input is ‘0’</td>
</tr>
<tr>
<td>OR</td>
<td>2 to 16</td>
<td>any input is ‘1’</td>
</tr>
<tr>
<td>AND</td>
<td>2 to 16</td>
<td>all inputs are ‘1’</td>
</tr>
<tr>
<td>NOR</td>
<td>2 to 16</td>
<td>all inputs are ‘0’</td>
</tr>
<tr>
<td>NAND</td>
<td>2 to 16</td>
<td>any input is ‘0’</td>
</tr>
<tr>
<td>XOR</td>
<td>2</td>
<td>only one input is ‘1’</td>
</tr>
</tbody>
</table>
5.4 FLEXLOGIC™

5 SETTINGS

Table 5–8: FLEXLOGIC™ OPERATORS

<table>
<thead>
<tr>
<th>TYPE</th>
<th>SYNTAX</th>
<th>DESCRIPTION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Editor</td>
<td>INSERT</td>
<td>Insert a parameter in an equation list.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DELETE</td>
<td>Delete a parameter from an equation list.</td>
<td></td>
</tr>
<tr>
<td>End</td>
<td>END</td>
<td>The first END encountered signifies the last entry in the list of processed FLEXLOGIC™ parameters.</td>
<td></td>
</tr>
<tr>
<td>One Shot</td>
<td>POSITIVE ONE SHOT</td>
<td>One shot that responds to a positive going edge.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NEGATIVE ONE SHOT</td>
<td>One shot that responds to a negative going edge.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DUAL ONE SHOT</td>
<td>One shot that responds to both the positive and negative going edges.</td>
<td></td>
</tr>
<tr>
<td>Logic Gate</td>
<td>NOT</td>
<td>Logical Not</td>
<td>Operates on the previous parameter.</td>
</tr>
<tr>
<td></td>
<td>OR(2)</td>
<td>2 input OR gate</td>
<td>Operates on the 2 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>OR(16)</td>
<td>16 input OR gate</td>
<td>Operates on the 16 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>AND(2)</td>
<td>2 input AND gate</td>
<td>Operates on the 2 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>AND(16)</td>
<td>16 input AND gate</td>
<td>Operates on the 16 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>NOR(2)</td>
<td>2 input NOR gate</td>
<td>Operates on the 2 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>NOR(16)</td>
<td>16 input NOR gate</td>
<td>Operates on the 16 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>NAND(2)</td>
<td>2 input NAND gate</td>
<td>Operates on the 2 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>NAND(16)</td>
<td>16 input NAND gate</td>
<td>Operates on the 16 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>XOR(2)</td>
<td>2 input Exclusive OR gate</td>
<td>Operates on the 2 previous parameters.</td>
</tr>
<tr>
<td></td>
<td>LATCH (S,R)</td>
<td>Latch (Set, Reset) - reset-dominant</td>
<td>The parameter preceding LATCH(S,R) is the Reset input. The parameter preceding the Reset input is the Set input.</td>
</tr>
<tr>
<td>Timer</td>
<td>TIMER 1</td>
<td>Timer set with FLEXLOGIC™ Timer 1 settings.</td>
<td>The timer is started by the preceding parameter. The output of the timer is TIMER #.</td>
</tr>
<tr>
<td></td>
<td>TIMER 32</td>
<td>Timer set with FLEXLOGIC™ Timer 32 settings.</td>
<td></td>
</tr>
<tr>
<td>Assign Virtual Output</td>
<td>= Virt Op 1</td>
<td>Assigns previous FLEXLOGIC™ parameter to Virtual Output 1.</td>
<td>The virtual output is set by the preceding parameter.</td>
</tr>
<tr>
<td></td>
<td>= Virt Op 96</td>
<td>Assigns previous FLEXLOGIC™ parameter to Virtual Output 96.</td>
<td></td>
</tr>
</tbody>
</table>

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.

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 settings, all FlexLogic™ equations are re-compiled whenever any new setting value is entered, so all latches are automatically reset. If it is necessary to re-initialize FlexLogic™ during testing, for example, it is suggested to power the unit down and then back up.
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 96) can only be properly assigned once.

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 AND(16), 17 through 25 to AND(9), and the outputs from these two gates to 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.
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 5–29: LOGIC FOR VIRTUAL OUTPUT 3](827027A0.VSD)

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 5–30: LOGIC FOR VIRTUAL OUTPUT 4](827028A0.VSD)

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 5–31: FLEXLOGIC™ WORKSHEET](827029A0.VSD)

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:

\[
\text{DIG ELEM 2 OP} \quad \text{Cont Ip H1c On} \quad \text{NOT} \quad \text{AND(2)} \quad \text{= Virt Op 3}
\]

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 the Logic for Virtual Output 3 diagram as a check.

Figure 5–32: FLEXLOGIC™ EQUATION 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:

\[
\begin{align*}
&[85] \text{Virt Op 4 On} \\
&[86] \text{Virt Op 1 On} \\
&[87] \text{Virt Op 2 On} \\
&[88] \text{Virt Ip 1 On} \\
&[89] \text{DIG ELEM 1 PKP} \\
&[90] \text{XOR(2)} \\
&[91] \text{Virt Op 3 On} \\
&[92] \text{OR(4)} \\
&[93] \text{LATCH (S,R)} \\
&[94] \text{Virt Op 3 On} \\
&[95] \text{TIMER 1} \\
&[96] \text{Cont Ip Hlc On} \\
&[97] \text{OR(3)} \\
&[98] \text{TIMER 2} \\
&[99] = \text{Virt Op 4}
\end{align*}
\]

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 the Logic for Virtual Output 4 diagram as a check.

![Figure 5–33: FLEXLOGIC™ EQUATION FOR VIRTUAL OUTPUT 4](image)

7. Now write the complete FlexLogic™ expression required to implement the 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 logic, this may be difficult to achieve, but in most cases will not cause problems as all 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 Hlc On
NOT
AND(2)
```
5 SETTINGS

5.4 FLEXLOGIC™

= 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

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

There are 32 identical FlexLogic™ timers available. 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**: Sets the time delay to pickup. If a pickup delay is not required, set this function to "0".
- **TIMER 1 DROPOUT DELAY**: Sets the time delay to dropout. If a dropout delay is not required, set this function to "0".
### 5.4 FLEXLOGIC™ 5 SETTINGS

#### 5.4.7 FLEXELEMENTS™

**PATH: SETTING ➔ FLEXLOGIC ➔ FLEXELEMENTS ➔ FLEXELEMENT 1(8)**

<table>
<thead>
<tr>
<th>Message</th>
<th>Setting</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLEXELEMENT 1 NAME:</td>
<td>FxE1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 +IN:</td>
<td>Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 -IN:</td>
<td>Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 INPUT MODE:</td>
<td>Signed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 COMP MODE:</td>
<td>Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 DIRECTION:</td>
<td>Over</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 PICKUP:</td>
<td>1.000 pu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 HYSTERESIS:</td>
<td>3.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 dt UNIT:</td>
<td>milliseconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 dt:</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 PKP DELAY:</td>
<td>0.000 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 RST DELAY:</td>
<td>0.000 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 BLK:</td>
<td>Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 TARGET:</td>
<td>Self-reset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLEXELEMENT 1 EVENTS:</td>
<td>Disabled</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 5–34: 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 or 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 “Level”. 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 5–35: 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 5–36: 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 per-unit values using the following definitions of the base units:

**Table 5–9: FLEXELEMENT™ BASE UNITS**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BREAKER ARCING AMPS (Brk X Arc Amp A, B, and C)</td>
<td>BASE = 2000 kA² × cycle</td>
</tr>
<tr>
<td>dcmA</td>
<td>BASE = maximum value of the DCMA INPUT MAX setting for the two transducers configured under the +IN and –IN inputs.</td>
</tr>
<tr>
<td>FREQUENCY</td>
<td>f_BASE = 1 Hz</td>
</tr>
<tr>
<td>FREQUENCY RATE OF CHANGE</td>
<td>df/dt_BASE = 1 Hz/s</td>
</tr>
<tr>
<td>PHASE ANGLE</td>
<td>ϕ_BASE = 360 degrees (see the UR angle referencing convention)</td>
</tr>
<tr>
<td>POWER FACTOR</td>
<td>P_F_BASE = 1.00</td>
</tr>
<tr>
<td>RTDs</td>
<td>BASE = 100°C</td>
</tr>
<tr>
<td>SENSITIVE DIR POWER (Sns Dir Power)</td>
<td>P_BASE = maximum value of 3 × V_BASE × I_BASE for the +IN and –IN inputs of the sources configured for the sensitive power directional element(s).</td>
</tr>
<tr>
<td>SOURCE CURRENT</td>
<td>I_BASE = maximum nominal primary RMS value of the +IN and –IN inputs</td>
</tr>
<tr>
<td>SOURCE ENERGY (Positive and Negative Watthours, Positive and Negative Varhours)</td>
<td>E_BASE = 10000 MWh or MVAh, respectively</td>
</tr>
<tr>
<td>SOURCE THD &amp; HARMONICS</td>
<td>P_BASE = maximum value of V_BASE × I_BASE for the +IN and –IN inputs</td>
</tr>
<tr>
<td>SOURCE VOLTAGE</td>
<td>V_BASE = maximum nominal primary RMS value of the +IN and –IN inputs</td>
</tr>
<tr>
<td>SYNCHROCHECK (Max Delta Volts)</td>
<td>V_BASE = maximum primary RMS value of all the sources related to the +IN and –IN inputs</td>
</tr>
</tbody>
</table>

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.
The non-volatile latches provide a permanent logical flag that is stored safely and will not reset upon reboot after the relay is powered down. Typical applications include sustaining operator commands or permanently block relay functions, such as Autorecloser, until a deliberate HMI action resets the latch. The settings, logic, and element operation are described below:

- **LATCH 1 TYPE**: This setting characterizes Latch 1 to be Set- or Reset-dominant.
- **LATCH 1 SET**: If asserted, the specified FlexLogic™ operands 'sets' Latch 1.
- **LATCH 1 RESET**: If asserted, the specified FlexLogic™ operand 'resets' Latch 1.

### Figure 5–37: NON-VOLATILE LATCH OPERATION TABLE (N=1 to 16) AND LOGIC

<table>
<thead>
<tr>
<th>LATCH N TYPE</th>
<th>LATCH N SET</th>
<th>LATCH N RESET</th>
<th>LATCH N ON</th>
<th>LATCH N OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reset Dominant</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>OFF</td>
<td>OFF</td>
<td>Previous State</td>
<td>Previous State</td>
</tr>
<tr>
<td></td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>Set Dominant</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>OFF</td>
<td>OFF</td>
<td>Previous State</td>
<td>Previous State</td>
</tr>
<tr>
<td></td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
</tbody>
</table>
Each protection element can be assigned up to six different sets of settings according to Setting Group designations 1 to 6. The performance of these elements is defined by the active Setting Group at a given time. Multiple setting groups allow the user to conveniently change protection settings for different operating situations (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 later in this chapter). See also the Introduction to Elements section at the beginning of this chapter.

### 5.5.2 SETTING GROUP

PATH: SETTINGS ➔ GROUPED ELEMENTS ➔ SETTING GROUP 1(6)

- **SETTING GROUP 1**
  - LOAD ENCROACHMENT
  - MESSAGE
  - PHASE CURRENT
  - MESSAGE
  - NEUTRAL CURRENT
  - MESSAGE
  - GROUND CURRENT
  - MESSAGE
  - NEGATIVE SEQUENCE CURRENT
  - MESSAGE
  - BREAKER FAILURE
  - MESSAGE
  - VOLTAGE ELEMENTS
  - MESSAGE
  - SENSITIVE DIRECTIONAL POWER

Each of the six 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 LOAD ENCROACHMENT

The Load Encroachment element responds to the positive-sequence voltage and current and applies a characteristic shown in the figure below.

![Figure 5–38: LOAD ENCROACHMENT CHARACTERISTIC](image)

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.
• **LOAD ENRCHMT 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 F60 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 X5 ➔ PHASE VT SECONDARY** is the p.u. base for this setting.

• **LOAD ENRCHMT REACH:** This setting specifies the resistive reach of the element as shown in the Load Encroachment Characteristic diagram. This setting should be entered in secondary ohms and be calculated as the positive-sequence resistance seen by the relay under maximum load conditions and unity power factor.

• **LOAD ENRCHMT ANGLE:** This setting specifies the size of the blocking region as shown on the Load Encroachment Characteristic diagram and applies to the positive sequence impedance.

![Figure 5–39: LOAD ENRCHMT APPLIED TO DISTANCE ELEMENT](image1)

![Figure 5–40: LOAD ENRCHMT SCHEME LOGIC](image2)
5.5.4 PHASE CURRENT

a) MAIN MENU

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ PHASE CURRENT

- PHASE CURRENT
- PHASE TOC1: See page 5–87.
- PHASE TOC2: See page 5–87.
- PHASE IOC1: See page 5–89.
- PHASE IOC2: See page 5–89.
- PHASE DIRECTIONAL 1: See page 5–90.
- PHASE DIRECTIONAL 2: See page 5–90.

The F60 Feeder Management Relay has two (2) phase time overcurrent, two (2) phase instantaneous overcurrent, and two (2) phase directional overcurrent elements.

b) INVERSE TIME OVERCURRENT CHARACTERISTICS

The inverse time overcurrent curves used by the time overcurrent elements are the IEEE, IEC, GE Type IAC, and $I^2t$ standard curve shapes. This allows for simplified coordination with downstream devices. If however, none of these curve shapes is adequate, FlexCurves™ may be used to customize the inverse time curve characteristics. The Definite Time curve is also an option that may be appropriate if only simple protection is required.

Table 5–10: OVERCURRENT CURVE TYPES

<table>
<thead>
<tr>
<th>IEEE</th>
<th>IEC</th>
<th>GE TYPE IAC</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Inv.</td>
<td>IEC Curve A (BS142)</td>
<td>IAC Extremely Inv.</td>
<td>$I^2t$</td>
</tr>
<tr>
<td>Very Inverse</td>
<td>IEC Curve B (BS142)</td>
<td>IAC Very Inverse</td>
<td>FlexCurves™ A, B, C, and D</td>
</tr>
<tr>
<td>Moderately Inv.</td>
<td>IEC Curve C (BS142)</td>
<td>IAC Inverse</td>
<td>Recloser Curves</td>
</tr>
<tr>
<td>Short Inverse</td>
<td>IEC Short Inverse</td>
<td>IAC Short Inverse</td>
<td>Definite Time</td>
</tr>
<tr>
<td></td>
<td>IEC Short Inverse</td>
<td>IAC Short Inverse</td>
<td></td>
</tr>
</tbody>
</table>

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.
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:

\[
T = TDM \times \left[ \frac{A}{I_{\text{pickup}}} + B \right]^{p - 1} \quad \text{and} \quad T_{\text{RESET}} = TDM \times \left[ \frac{t_r}{I_{\text{pickup}}} \right]^{2 - 1}
\]  

(EQ 5.8)

where: \( T \) = operate time (in seconds), \( TDM \) = Multiplier setting, \( I = \) input current, \( I_{\text{pickup}} = \) Pickup Current setting
\( A, B, p = \) constants, \( T_{\text{RESET}} = \) reset time in seconds (assuming energy capacity is 100% and \( \text{RESET} \) is “Timed”), \( t_r = \) characteristic constant

<table>
<thead>
<tr>
<th>IEEE CURVE SHAPE</th>
<th>A</th>
<th>B</th>
<th>P</th>
<th>TR</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Extremely Inverse</td>
<td>28.2</td>
<td>0.1217</td>
<td>2.0000</td>
<td>29.1</td>
</tr>
<tr>
<td>IEEE Very Inverse</td>
<td>19.61</td>
<td>0.491</td>
<td>2.0000</td>
<td>21.6</td>
</tr>
<tr>
<td>IEEE Moderately Inverse</td>
<td>0.0515</td>
<td>0.1140</td>
<td>0.02000</td>
<td>4.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MULTIPLIER (TDM)</th>
<th>CURRENT ( I/I_{\text{pickup}} )</th>
<th>1.5</th>
<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
<th>9.0</th>
<th>10.0</th>
</tr>
</thead>
</table>
| 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 |
| 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 |

| 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 |
5.5 GROUPED ELEMENTS

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:

\[
T = TDM \times \left[ \left( \frac{K}{I/pickup} \right)^E - 1 \right], \\
T_{RESET} = TDM \times \left[ \left( \frac{l_{\text{set}}}{I/pickup} \right)^2 - 1 \right]
\]

(EQ 5.9)

where: \(T\) = operate time (in seconds), \(TDM\) = Multiplier setting, \(I\) = input current, \(I/pickup\) = Pickup Current setting, \(K\), \(E\) = constants, \(t_r\) = characteristic constant, and \(T_{RESET}\) = reset time in seconds (assuming energy capacity is 100% and \(RESET\) is “Timed”)

Table 5–13: IEC (BS) INVERSE TIME CURVE CONSTANTS

<table>
<thead>
<tr>
<th>IEC (BS) CURVE SHAPE</th>
<th>K</th>
<th>E</th>
<th>TR</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC Curve A (BS142)</td>
<td>0.140</td>
<td>0.020</td>
<td>9.7</td>
</tr>
<tr>
<td>IEC Curve B (BS142)</td>
<td>13.500</td>
<td>1.000</td>
<td>43.2</td>
</tr>
<tr>
<td>IEC Curve C (BS142)</td>
<td>80.000</td>
<td>2.000</td>
<td>58.2</td>
</tr>
<tr>
<td>IEC Short Inverse</td>
<td>0.050</td>
<td>0.040</td>
<td>0.500</td>
</tr>
</tbody>
</table>

Table 5–14: IEC CURVE TRIP TIMES (IN SECONDS)

<table>
<thead>
<tr>
<th>MULTIPLIER Current (I / I/pickup)</th>
<th>1.5</th>
<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
<th>9.0</th>
<th>10.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC CURVE A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>0.860</td>
<td>0.501</td>
<td>0.315</td>
<td>0.249</td>
<td>0.214</td>
<td>0.192</td>
<td>0.176</td>
<td>0.165</td>
<td>0.156</td>
<td>0.149</td>
</tr>
<tr>
<td>0.10</td>
<td>1.719</td>
<td>1.003</td>
<td>0.630</td>
<td>0.498</td>
<td>0.428</td>
<td>0.384</td>
<td>0.353</td>
<td>0.330</td>
<td>0.312</td>
<td>0.297</td>
</tr>
<tr>
<td>0.20</td>
<td>3.439</td>
<td>2.006</td>
<td>1.260</td>
<td>0.996</td>
<td>0.856</td>
<td>0.767</td>
<td>0.706</td>
<td>0.659</td>
<td>0.623</td>
<td>0.594</td>
</tr>
<tr>
<td>0.40</td>
<td>6.878</td>
<td>4.012</td>
<td>2.521</td>
<td>1.992</td>
<td>1.712</td>
<td>1.535</td>
<td>1.411</td>
<td>1.319</td>
<td>1.247</td>
<td>1.188</td>
</tr>
<tr>
<td>0.60</td>
<td>10.317</td>
<td>6.017</td>
<td>3.781</td>
<td>2.988</td>
<td>2.568</td>
<td>2.302</td>
<td>2.117</td>
<td>1.978</td>
<td>1.870</td>
<td>1.782</td>
</tr>
<tr>
<td>0.80</td>
<td>13.755</td>
<td>8.023</td>
<td>5.042</td>
<td>3.984</td>
<td>3.424</td>
<td>3.070</td>
<td>2.822</td>
<td>2.637</td>
<td>2.493</td>
<td>2.376</td>
</tr>
<tr>
<td>IEC CURVE B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>1.350</td>
<td>0.675</td>
<td>0.338</td>
<td>0.225</td>
<td>0.169</td>
<td>0.135</td>
<td>0.113</td>
<td>0.096</td>
<td>0.084</td>
<td>0.075</td>
</tr>
<tr>
<td>0.10</td>
<td>2.700</td>
<td>1.350</td>
<td>0.675</td>
<td>0.450</td>
<td>0.338</td>
<td>0.270</td>
<td>0.225</td>
<td>0.193</td>
<td>0.169</td>
<td>0.150</td>
</tr>
<tr>
<td>0.20</td>
<td>5.400</td>
<td>2.700</td>
<td>1.350</td>
<td>0.900</td>
<td>0.675</td>
<td>0.540</td>
<td>0.450</td>
<td>0.386</td>
<td>0.338</td>
<td>0.300</td>
</tr>
<tr>
<td>0.40</td>
<td>10.800</td>
<td>5.400</td>
<td>2.700</td>
<td>1.800</td>
<td>1.350</td>
<td>1.080</td>
<td>0.900</td>
<td>0.771</td>
<td>0.675</td>
<td>0.600</td>
</tr>
<tr>
<td>0.60</td>
<td>16.200</td>
<td>8.100</td>
<td>4.050</td>
<td>2.700</td>
<td>2.025</td>
<td>1.620</td>
<td>1.350</td>
<td>1.157</td>
<td>1.013</td>
<td>0.900</td>
</tr>
<tr>
<td>0.80</td>
<td>21.600</td>
<td>10.800</td>
<td>5.400</td>
<td>3.600</td>
<td>2.700</td>
<td>2.160</td>
<td>1.800</td>
<td>1.543</td>
<td>1.350</td>
<td>1.200</td>
</tr>
<tr>
<td>1.00</td>
<td>27.000</td>
<td>13.500</td>
<td>6.750</td>
<td>4.500</td>
<td>3.375</td>
<td>2.700</td>
<td>2.250</td>
<td>1.929</td>
<td>1.688</td>
<td>1.500</td>
</tr>
<tr>
<td>IEC CURVE C</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>3.200</td>
<td>1.333</td>
<td>0.500</td>
<td>0.267</td>
<td>0.167</td>
<td>0.114</td>
<td>0.083</td>
<td>0.063</td>
<td>0.050</td>
<td>0.040</td>
</tr>
<tr>
<td>0.10</td>
<td>6.400</td>
<td>2.667</td>
<td>1.000</td>
<td>0.533</td>
<td>0.333</td>
<td>0.229</td>
<td>0.167</td>
<td>0.127</td>
<td>0.100</td>
<td>0.081</td>
</tr>
<tr>
<td>0.20</td>
<td>12.800</td>
<td>5.333</td>
<td>2.000</td>
<td>1.067</td>
<td>0.667</td>
<td>0.457</td>
<td>0.333</td>
<td>0.254</td>
<td>0.200</td>
<td>0.162</td>
</tr>
<tr>
<td>0.40</td>
<td>25.600</td>
<td>10.667</td>
<td>4.000</td>
<td>2.133</td>
<td>1.333</td>
<td>0.914</td>
<td>0.667</td>
<td>0.508</td>
<td>0.400</td>
<td>0.323</td>
</tr>
<tr>
<td>0.60</td>
<td>38.400</td>
<td>16.000</td>
<td>6.000</td>
<td>3.200</td>
<td>2.000</td>
<td>1.371</td>
<td>1.000</td>
<td>0.762</td>
<td>0.600</td>
<td>0.485</td>
</tr>
<tr>
<td>0.80</td>
<td>51.200</td>
<td>21.333</td>
<td>8.000</td>
<td>4.267</td>
<td>2.667</td>
<td>1.829</td>
<td>1.333</td>
<td>1.016</td>
<td>0.800</td>
<td>0.646</td>
</tr>
<tr>
<td>1.00</td>
<td>64.000</td>
<td>26.667</td>
<td>10.000</td>
<td>5.333</td>
<td>3.333</td>
<td>2.286</td>
<td>1.667</td>
<td>1.270</td>
<td>1.000</td>
<td>0.808</td>
</tr>
<tr>
<td>IEC SHORT TIME</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>0.153</td>
<td>0.089</td>
<td>0.056</td>
<td>0.044</td>
<td>0.038</td>
<td>0.034</td>
<td>0.031</td>
<td>0.029</td>
<td>0.027</td>
<td>0.026</td>
</tr>
<tr>
<td>0.10</td>
<td>0.306</td>
<td>0.178</td>
<td>0.111</td>
<td>0.088</td>
<td>0.075</td>
<td>0.067</td>
<td>0.062</td>
<td>0.058</td>
<td>0.054</td>
<td>0.052</td>
</tr>
<tr>
<td>0.20</td>
<td>0.612</td>
<td>0.356</td>
<td>0.223</td>
<td>0.175</td>
<td>0.150</td>
<td>0.135</td>
<td>0.124</td>
<td>0.115</td>
<td>0.109</td>
<td>0.104</td>
</tr>
<tr>
<td>0.40</td>
<td>1.223</td>
<td>0.711</td>
<td>0.445</td>
<td>0.351</td>
<td>0.301</td>
<td>0.269</td>
<td>0.247</td>
<td>0.231</td>
<td>0.218</td>
<td>0.207</td>
</tr>
<tr>
<td>0.60</td>
<td>1.835</td>
<td>1.067</td>
<td>0.668</td>
<td>0.526</td>
<td>0.451</td>
<td>0.404</td>
<td>0.371</td>
<td>0.346</td>
<td>0.327</td>
<td>0.311</td>
</tr>
<tr>
<td>0.80</td>
<td>2.446</td>
<td>1.423</td>
<td>0.890</td>
<td>0.702</td>
<td>0.602</td>
<td>0.538</td>
<td>0.494</td>
<td>0.461</td>
<td>0.435</td>
<td>0.415</td>
</tr>
<tr>
<td>1.00</td>
<td>3.058</td>
<td>1.778</td>
<td>1.113</td>
<td>0.877</td>
<td>0.752</td>
<td>0.673</td>
<td>0.618</td>
<td>0.576</td>
<td>0.544</td>
<td>0.518</td>
</tr>
</tbody>
</table>
IAC CURVES:

The curves for the General Electric type IAC relay family are derived from the formulae:

\[
T = TDM \times \left( A + \frac{B}{(I/I_{pkp}) - C} + \frac{D}{((I/I_{pkp}) - C)^2} + \frac{E}{((I/I_{pkp}) - C)^3} \right), \quad T_{RESET} = TDM \times \frac{t_r}{(I/I_{pkp})^2 - 1}
\]

where: \( T \) = operate time (in seconds), \( TDM = \) Multiplier setting, \( I = \) Input current, \( I_{pkp} = \) Pickup Current setting, \( A \) to \( E \) = constants, \( t_r = \) characteristic constant, and \( T_{RESET} = \) reset time in seconds (assuming energy capacity is 100% and \( \text{RESET} \) is "Timed")

Table 5–15: GE TYPE IAC INVERSE TIME CURVE CONSTANTS

<table>
<thead>
<tr>
<th>IAC CURVE SHAPE</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>T R</th>
</tr>
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<tr>
<td>IAC Extreme Inverse</td>
<td>0.0040</td>
<td>0.6379</td>
<td>0.6200</td>
<td>1.7872</td>
<td>0.2461</td>
<td>6.006</td>
</tr>
<tr>
<td>IAC Very Inverse</td>
<td>0.0900</td>
<td>0.7955</td>
<td>0.1000</td>
<td>–1.2885</td>
<td>7.9586</td>
<td>4.678</td>
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<tr>
<td>IAC Inverse</td>
<td>0.2078</td>
<td>0.8630</td>
<td>0.8000</td>
<td>–0.4180</td>
<td>0.1947</td>
<td>0.990</td>
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<tr>
<td>IAC Short Inverse</td>
<td>0.0428</td>
<td>0.0609</td>
<td>0.6200</td>
<td>–0.0010</td>
<td>0.0221</td>
<td>0.222</td>
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Table 5–16: IAC CURVE TRIP TIMES

<table>
<thead>
<tr>
<th>MULTIPLIER (TDM)</th>
<th>CURRENT ((I/I_{pickup}))</th>
<th>1.5</th>
<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
<th>9.0</th>
<th>10.0</th>
</tr>
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<tbody>
<tr>
<td>IAC EXTREMELY INVERSE</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>0.5</td>
<td>1.699</td>
<td>0.749</td>
<td>0.303</td>
<td>0.178</td>
<td>0.123</td>
<td>0.093</td>
<td>0.074</td>
<td>0.062</td>
<td>0.053</td>
<td>0.046</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>3.398</td>
<td>1.498</td>
<td>0.606</td>
<td>0.356</td>
<td>0.246</td>
<td>0.186</td>
<td>0.149</td>
<td>0.124</td>
<td>0.106</td>
<td>0.093</td>
<td></td>
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<tr>
<td>2.0</td>
<td>6.796</td>
<td>2.997</td>
<td>1.212</td>
<td>0.711</td>
<td>0.491</td>
<td>0.372</td>
<td>0.298</td>
<td>0.248</td>
<td>0.212</td>
<td>0.185</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
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<td>5.993</td>
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<td>1.422</td>
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<tr>
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<td>3.635</td>
<td>2.133</td>
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<td>0.893</td>
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</tbody>
</table>
I2t CURVES:
The curves for the $I^2t$ are derived from the formulae:

$$T = \text{TDM} \times \left[ \frac{100}{\left( \frac{I}{I_{\text{pickup}}} \right)^2} \right], \quad T_{\text{RESET}} = \text{TDM} \times \left[ \frac{100}{\left( \frac{I}{I_{\text{pickup}}} \right)^2} \right]$$  \hspace{1cm} (EQ 5.11)

where: $T$ = Operate Time (sec.); $\text{TDM}$ = Multiplier Setting; $I$ = Input Current; $I_{\text{pickup}}$ = Pickup Current Setting;

$T_{\text{RESET}}$ = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

<table>
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<tr>
<th>MULTIPLIER (TDM)</th>
<th>1.5</th>
<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
<th>9.0</th>
<th>10.0</th>
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<tbody>
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<td>0.01</td>
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<td>0.25</td>
<td>0.11</td>
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<td>0.04</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
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</tr>
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</tr>
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<td>2.78</td>
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<td>40.00</td>
<td>27.78</td>
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<td>15.63</td>
<td>12.35</td>
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</tr>
<tr>
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<td>625.00</td>
<td>400.00</td>
<td>277.78</td>
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<td>3750.00</td>
<td>2400.00</td>
<td>1666.70</td>
<td>1224.50</td>
<td>937.50</td>
<td>740.74</td>
<td>600.00</td>
</tr>
</tbody>
</table>

FLEXCURVES™:
The custom FlexCurves™ are described in detail in the FlexCurves™ section of this chapter. The curve shapes for the FlexCurves™ are derived from the formulae:

$$T = \text{TDM} \times \left[ \text{FlexCurve Time at} \left( \frac{I}{I_{\text{pickup}}} \right) \right] \text{ when} \left( \frac{I}{I_{\text{pickup}}} \right) \geq 1.00$$  \hspace{1cm} (EQ 5.12)

$$T_{\text{RESET}} = \text{TDM} \times \left[ \text{FlexCurve Time at} \left( \frac{I}{I_{\text{pickup}}} \right) \right] \text{ when} \left( \frac{I}{I_{\text{pickup}}} \right) \leq 0.98$$  \hspace{1cm} (EQ 5.13)

where: $T$ = Operate Time (sec.); $\text{TDM}$ = Multiplier setting

$I$ = Input Current, $I_{\text{pickup}}$ = Pickup Current setting

$T_{\text{RESET}}$ = 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.

$$T = \text{TDM} \text{ in seconds, when} I > I_{\text{pickup}}$$  \hspace{1cm} (EQ 5.14)

$$T_{\text{RESET}} = -\text{TDM} \text{ in seconds}$$  \hspace{1cm} (EQ 5.15)

where: $T$ = Operate Time (sec.); $\text{TDM}$ = Multiplier setting

$I$ = Input Current, $I_{\text{pickup}}$ = Pickup Current setting

$T_{\text{RESET}}$ = Reset Time in seconds (assuming energy capacity is 100% and RESET: Timed)

RECLOSER CURVES:
The F60 uses the FlexCurve™ feature to facilitate programming of 41 recloser curves. Please refer to the FlexCurve™ section in this chapter for additional details.
c) PHASE TIME OVERCURRENT (ANSI 51P)

PATH: SETTINGS ➔ GROUPED ELEMENTS ➔ SETTING GROUP 1(6) ➔ PHASE CURRENT ➔ PHASE TOC1(2)

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 Curves Characteristic sub-section earlier 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 PHASE TOC1 PICKUP setting. If the voltage restraint feature is disabled, the pickup level always remains at the setting value.
Figure 5–41: PHASE TOC VOLTAGE RESTRAINT CHARACTERISTIC

Figure 5–42: PHASE TOC1 SCHEME LOGIC
d) PHASE INSTANTANEOUS OVERCURRENT (ANSI 50P)

**PATH:** SETTINGS ➔ GROUPED ELEMENTS ➔ SETTING GROUP 1(6) ➔ PHASE CURRENT ➔ PHASE IOC 1

- **PHASE IOC1**
  - **FUNCTION:** Disabled
  - **PHASE IOC1 SIGNAL SOURCE:** SRC 1
  - **PHASE IOC1 PICKUP:** 1.000 pu
  - **PHASE IOC1 PICKUP DELAY:** 0.00 s
  - **PHASE IOC1 RESET DELAY:** 0.00 s
  - **PHASE IOC1 BLOCK A:** Off
  - **PHASE IOC1 BLOCK B:** Off
  - **PHASE IOC1 BLOCK C:** Off
  - **PHASE IOC1 TARGET:** Self-reset
  - **PHASE IOC1 EVENTS:** Disabled

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.

**Message**

- **Range:** Disabled, Enabled
- **Range:** SRC 1, SRC 2
- **Range:** 0.00 to 30.000 pu in steps of 0.001
- **Range:** 0.00 to 600.00 s in steps of 0.01
- **Range:** 0.00 to 600.00 s in steps of 0.01
- **Range:** FlexLogic™ operand
- **Range:** FlexLogic™ operand
- **Range:** FlexLogic™ operand
- **Range:** Self-reset, Latched, Disabled
- **Range:** Disabled, Enabled

**Figure 5–43: PHASE IOC1 SCHEME LOGIC**
**5.5 GROUPED ELEMENTS**

### 5 SETTINGS

#### e) PHASE DIRECTIONAL OVERCURRENT (ANSI 67P)

**PATH: SETTINGS ➔ GROUPED ELEMENTS ➔ SETTING GROUP 1(6) ➔ PHASE CURRENT ➔ PHASE DIRECTIONAL 1(2)**

**PHASE CURRENT**

**FUNCTION**

- **Range:** Disabled, Enabled

**MESSAGE**

- **PHASE DIR 1 SIGNAL**
  - **SOURCE:** SRC 1, SRC 2

- **PHASE DIR 1 BLOCK:**
  - **OFF**
  - **Range:** FlexLogic™ operand

- **PHASE DIR 1 ECA:**
  - **Range:** 0 to 359° in steps of 1

- **PHASE DIR 1 POL V1 THRESHOLD:**
  - **Range:** 0.000 to 3.000 pu in steps of 0.001

- **PHASE DIR 1 BLOCK WHEN V MEM EXP:**
  - **Range:** No, Yes

- **PHASE DIR 1 TARGET:**
  - **Self-reset, Latched, Disabled

- **PHASE DIR 1 EVENTS:**
  - **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.

![Figure 5-44: PHASE A DIRECTIONAL POLARIZATION](image)

**Phasors for Phase A Polarization:**

- \( V_{Pol} = V_{BC} \times (1/\text{ECA}) \) = polarizing voltage
- \( IA = \text{operating current} \)
- \( \text{ECA} = \text{Element Characteristic Angle at } 30° \)

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 VTs used to measure the polarizing voltage, a ‘voltage memory’ feature is incorporated. This feature stores the polarizing voltage the moment before the voltage collapses, and uses it to determine direction. The voltage memory remains valid for one second after the voltage has collapsed.

The main component of the phase directional element is the phase angle comparator with two inputs: the operating signal (phase current) and the polarizing signal (the line voltage, shifted in the leading direction by the characteristic angle, ECA).

The following table shows the operating and polarizing signals used for phase directional control:

<table>
<thead>
<tr>
<th>PHASE</th>
<th>OPERATING SIGNAL</th>
<th>POLARIZING SIGNAL $V_{pol}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ABC PHASE SEQUENCE</td>
</tr>
<tr>
<td>A</td>
<td>Angle of IA</td>
<td>Angle of VBC $\times (1\angle ECA)$</td>
</tr>
<tr>
<td>B</td>
<td>Angle of IB</td>
<td>Angle of VCA $\times (1\angle ECA)$</td>
</tr>
<tr>
<td>C</td>
<td>Angle of IC</td>
<td>Angle of VAB $\times (1\angle ECA)$</td>
</tr>
</tbody>
</table>

**MODE OF OPERATION:**

- When the function is “Disabled”, or the operating current is below 5% $\times$ CT nominal, the element output is “0”.
- When the function is “Enabled”, the operating current is above 5% $\times$ CT nominal, and the polarizing voltage is above the set threshold, the element output is dependent on the phase angle between the operating and polarizing signals:
  - The element output is logic “0” when the operating current is within polarizing voltage $\pm$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 **BLOCK WHEN V MEM EXP** is 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 the UR-series 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 "0.700 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.

The Phase Directional element responds to the forward load current. In the case of a following reverse fault, the element needs some time – in the order of 8 ms – to establish a blocking signal. Some protection elements such as instantaneous overcurrent may respond to reverse faults before the blocking signal is established. Therefore, a coordination time of at least 10 ms must be added to all the instantaneous protection elements under the supervision of the Phase Directional element. If current reversal is of a concern, a longer delay – in the order of 20 ms – may be needed.
5.5 GROUPED ELEMENTS  

5 SETTINGS

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**Figure 5-45: PHASE DIRECTIONAL SCHEME LOGIC**

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5.5.5 NEUTRAL CURRENT

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**a) MAIN MENU**

PATH: SETTING 

**GROUPED ELEMENTS** 

**SETTING GROUP 1(6)** 

**PHASE CURRENT**

---

**NEUTRAL CURRENT**

MESSAGE

**NEUTRAL TOC1** See page 5-93.

MESSAGE

**NEUTRAL TOC2** See page 5-93.

MESSAGE

**NEUTRAL IOC1** See page 5-94.

MESSAGE

**NEUTRAL IOC2** See page 5-94.

MESSAGE

**NEUTRAL DIRECTIONAL OC1** See page 5-95.

MESSAGE

**NEUTRAL DIRECTIONAL OC2** See page 5-95.

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The F60 Feeder Management Relay has two (2) Neutral Time Overcurrent, two (2) Neutral Instantaneous Overcurrent, and two (2) Neutral Directional Overcurrent elements.
b) NEUTRAL TIME OVERCURRENT (ANSI 51N)

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 5–46: NEUTRAL TOC1 SCHEME LOGIC](image-url)
c) NEUTRAL INSTANTANEOUS OVERCURRENT (ANSI 50N)

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:

\[ I_{op} = 3 \times (|I_0| - K \cdot |I_1|) \quad \text{where} \quad K = \frac{1}{16} \]  

(EQ 5.16)

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: \( I_{op} = 0.9375 \times I_{injected} \); three-phase pure zero-sequence injection: \( I_{op} = 3 \times I_{injected} \)).
There are two Neutral Directional Overcurrent protection elements available. The element provides both forward and reverse fault direction indications the NEUTRAL DIR OC1 FWD and NEUTRAL DIR OC1 REV operands, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as “forward” or “reverse", respectively (directional unit).

The overcurrent unit responds to the magnitude of a fundamental frequency phasor of the either the neutral current calculated from the phase currents or the ground current. There are two separate pickup settings for the forward- and reverse-looking functions, respectively. If set to use the calculated $3I_0$, the element applies a “positive-sequence restraint” for better performance: a small user-programmable portion of the positive–sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity.

$$I_{op} = 3 \times (|I_0| - K \times |I_1|)$$  \hspace{1cm} (EQ 5.17)

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from:

- System unbalances under heavy load conditions.
5.5 GROUPED ELEMENTS

- 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: \( I_{op} = (1 - K) \times I_{injected} \); three-phase pure zero-sequence injection: \( I_{op} = 3 \times I_{injected} \)).

The positive-sequence restraint is removed for low currents. If the positive-sequence current is below 0.8 pu, the restraint is removed by changing the constant \( K \) to zero. This facilitates better response to high-resistance faults when the unbalance is very small and there is no danger of excessive CT errors as the current is low.

The direction 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 5–18: Quantities for “Calculates 3I0” Configuration

<table>
<thead>
<tr>
<th>Polarizing Mode</th>
<th>Direction</th>
<th>Compared Phasors</th>
<th>Overcurrent Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>Forward</td>
<td>(-V_0 + Z_{offset} \times I_0)</td>
<td>(I_0 \times 1 \angle ECA)</td>
</tr>
<tr>
<td></td>
<td>Reverse</td>
<td>(-V_0 + Z_{offset} \times I_0)</td>
<td>(-I_0 \times 1 \angle ECA)</td>
</tr>
<tr>
<td>Current</td>
<td>Forward</td>
<td>IG</td>
<td>I_0</td>
</tr>
<tr>
<td></td>
<td>Reverse</td>
<td>IG</td>
<td>-I_0</td>
</tr>
<tr>
<td>Dual</td>
<td>Forward</td>
<td>(-V_0 + Z_{offset} \times I_0)</td>
<td>(I_0 \times 1 \angle ECA) or IG</td>
</tr>
<tr>
<td></td>
<td>Reverse</td>
<td>(-V_0 + Z_{offset} \times I_0)</td>
<td>(-I_0 \times 1 \angle ECA) or IG</td>
</tr>
</tbody>
</table>

\[ I_{op} = \begin{cases} 3 \times (|I_0| - K \times |I_1|) & \text{if } |I_1| > 0.8 \text{ pu} \\ 3 \times |I_0| & \text{if } |I_1| \leq 0.8 \text{ pu} \end{cases} \]

### Table 5–19: Quantities for “Measured IG” Configuration

<table>
<thead>
<tr>
<th>Polarizing Mode</th>
<th>Direction</th>
<th>Compared Phasors</th>
<th>Overcurrent Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>Forward</td>
<td>(-V_0 + Z_{offset} \times \frac{IG}{3})</td>
<td>(IG \times 1 \angle ECA)</td>
</tr>
<tr>
<td></td>
<td>Reverse</td>
<td>(-V_0 + Z_{offset} \times \frac{IG}{3})</td>
<td>(-IG \times 1 \angle ECA)</td>
</tr>
</tbody>
</table>

where: \( V_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG}) \) = zero sequence voltage,

\( I_0 = \frac{1}{3}I_N = \frac{1}{3}(I_A + I_B + I_C) \) = zero sequence current,

\( ECA \) = element characteristic angle and \( IG \) = 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.

The figure below shows the voltage-polarized phase angle comparator characteristics for a phase A to ground fault, with:

- \( ECA = 90^\circ \) (element characteristic angle = centerline of operating characteristic)
- \( FWD LA = 80^\circ \) (forward limit angle = the ± angular limit with the ECA for operation)
- \( REV LA = 80^\circ \) (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.

Figure 5–48: NEUTRAL DIRECTIONAL VOLTAGE-POLARIZED CHARACTERISTICS

- **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 \( V_x \), 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 (\( V_x \)), 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 CT must be connected between the ground and neutral point of an adequate local source of ground current. The ground current must be higher than 0.05 pu to be validated as a polarizing signal. If the polarizing signal is not valid, neither forward nor reverse indication is given.

    For a choice of current polarizing, it is recommended that the polarizing signal be analyzed to ensure that a known direction is maintained irrespective of the fault location. For example, if using an autotransformer neutral current as a polarizing source, it should be ensured that a reversal of the ground current does not occur for a high-side fault. The low-side system impedance should be assumed minimal when checking for this condition. A similar situation arises for a Wye/Delta/Wye transformer, where current in one transformer winding neutral may reverse when faults on both sides of the transformer are considered.

  - If “Dual” polarizing is selected, the element performs both directional comparisons as described above. A given direction is confirmed if either voltage or current comparators indicate so. If a conflicting (simultaneous forward and reverse) indication occurs, the forward direction overrides the reverse direction.

- **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**. If this setting is “Measured IG”, then the **NEUTRAL DIR OC1 POLARIZING** setting must be “Voltage”, as it is not possible to use the ground current as an operating and polarizing signal simultaneously.

• **NEUTRAL DIR OC1 POS-SEQ RESTRAINT:** This setting controls the amount of the positive-sequence restraint. Set to 0.063 for backward compatibility with firmware revision 3.40 and older. Set to zero to remove the restraint. Set higher if large system unbalances or poor CT performance are expected.

• **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. In regular applications, the offset impedance ensures proper operation even if the zero-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the zero-sequence impedance of the protected circuit. Practically, it shall be several times smaller. The offset impedance shall be entered in secondary ohms.

• **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 5–49: NEUTRAL DIRECTIONAL OVERCURRENT LOGIC

NOTE:
1) CURRENT POLARIZING IS POSSIBLE ONLY IN RELAYS WITH THE GROUND CURRENT INPUTS CONNECTED TO AN ADEQUATE CURRENT POLARIZING SOURCE.
2) GROUND CURRENT CAN NOT BE USED FOR POLARIZATION AND OPERATION SIMULTANEOUSLY.
3) POSITIVE SEQUENCE RESTRAINT IS NOT APPLIED WHEN \( I_1 \) IS BELOW 0.8pu.

NEUTRAL DIR OC1
FUNCTION:
Current
Polarizing
Voltage
Offset
Disabled=0
Enabled=1

NEUTRAL DIR OC1 BLK.

Source:
Voltage
Calculated \( V_0 \)
Ground \( V_{1G} \)

PICKUP:
\[ |3V_0 - K I_1|_R \]
\[ 3|I_0|_R \]

LIMIT ANGLE:
\( I_{G} \)
\( 0.05 \) pu

CURR:
\( 1.25 \) cy
\( 1.5 \) cy

OFFSET:
\( 3V_0 - K I_1 \)
\( |I_0|_R \)

POLARIZING:
\( I_{G} \)

NEUTRAL DIR OC1 FWD

NEUTRAL DIR OC1 REV

NEUTRAL DIR OC1 FWD LIM ANGLE

NEUTRAL DIR OC1 REV LIM ANGLE

NEUTRAL DIR OC1 OFFSET

NEUTRAL DIR OC1 POS-SEQ RESTRAINT

NEUTRAL DIR OC1 CURR

NEUTRAL DIR OC1 OP CURR

NEUTRAL DIR OC1 REV PICKUP

NEUTRAL DIR OC1 FWD PICKUP

NEUTRAL DIR OC1 OFF=0

NEUTRAL DIR OC1 ON=1
### 5.5 GROUPED ELEMENTS

#### 5.5.6 GROUND CURRENT

**a) GROUND TIME OVERCURRENT (ANSI 51G)**

**PATH:** SETTINGS $\rightarrow$ GROUPED ELEMENTS $\rightarrow$ SETTING GROUP 1(6) $\rightarrow$ GROUND CURRENT $\rightarrow$ GROUND TOC1(2)

<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUND TOC1 FUNCTION</td>
<td>Disabled</td>
<td>Disabled, Enabled</td>
</tr>
<tr>
<td>GROUND TOC1 SIGNAL SOURCE</td>
<td>SRC 1, SRC 2</td>
<td></td>
</tr>
<tr>
<td>GROUND TOC1 INPUT</td>
<td>Phasor</td>
<td></td>
</tr>
<tr>
<td>GROUND TOC1 PICKUP</td>
<td>1.000 pu</td>
<td></td>
</tr>
<tr>
<td>GROUND TOC1 CURVE</td>
<td>IEEE Mod Inv</td>
<td></td>
</tr>
<tr>
<td>GROUND TOC1 TD MULTIPLIER</td>
<td>1.00</td>
<td>0.00 to 600.00 in steps of 0.01</td>
</tr>
<tr>
<td>GROUND TOC1 RESET</td>
<td>Instantaneous</td>
<td></td>
</tr>
<tr>
<td>GROUND TOC1 BLOCK</td>
<td>Off</td>
<td></td>
</tr>
<tr>
<td>GROUND TOC1 TARGET</td>
<td>Self-reset</td>
<td></td>
</tr>
<tr>
<td>GROUND TOC1 EVENTS</td>
<td>Disabled</td>
<td></td>
</tr>
</tbody>
</table>

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.

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.

![Figure 5–50: GROUND TOC1 SCHEME LOGIC](image)

---

**NOTE**

- **FUNCTION:** Disabled = 0
- **SOURCE:** IG ≥ PICKUP
- **BLOCK:** Off = 0

---

**Figure 5–50: GROUND TOC1 SCHEME LOGIC**
b) GROUND INSTANTANEOUS OVERCURRENT (ANSI 50G)

The Ground Instantaneous Overcurrent element may be used as an instantaneous element with no intentional delay or as a Definite Time element. The ground current input is the quantity measured by the ground input CT and is the fundamental phasor magnitude.

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.
5.5 GROUPED ELEMENTS

5.5.7 NEGATIVE SEQUENCE CURRENT

a) MAIN MENU

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ PHASE CURRENT

The F60 Feeder Management Relay has two (2) Negative Sequence Time Overcurrent, two (2) Negative Sequence Instantaneous Overcurrent, and two (2) Negative Sequence Directional Overcurrent elements.

See page 5-103.

See page 5-104.

See page 5-105.
b) NEGATIVE SEQUENCE TIME OVERCURRENT (ANSI 51_2)

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 Characteristics sub-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.

### Table 5-52: NEGATIVE SEQUENCE TOC1 SCHEME LOGIC

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNCTION</td>
<td>Disabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>SIGNAL SOURCE</td>
<td>SRC 1</td>
<td>SRC 2</td>
</tr>
<tr>
<td>PICKUP</td>
<td>1.000 pu</td>
<td>0.000 to 30.000 pu in steps of 0.001</td>
</tr>
<tr>
<td>CURVE</td>
<td>IEEE Mod Inv</td>
<td>see OVERCURRENT CURVE TYPES table</td>
</tr>
<tr>
<td>TD MULTIPLIER</td>
<td>1.00</td>
<td>0.00 to 600.00 in steps of 0.01</td>
</tr>
<tr>
<td>RESET</td>
<td>Instantaneous</td>
<td>FlexLogic™ operand</td>
</tr>
<tr>
<td>BLOCK</td>
<td>Off</td>
<td>Self-reset, Latched, Disabled</td>
</tr>
<tr>
<td>TARGET</td>
<td>Self-reset</td>
<td>Disabled, Enabled</td>
</tr>
<tr>
<td>EVENTS</td>
<td>Disabled</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

![Figure 5–52: NEGATIVE SEQUENCE TOC1 SCHEME LOGIC](image)
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:

\[
I_{op} = |I_2| - K \cdot |I_1| \quad \text{where} \quad K = \frac{1}{8} \tag{EQ 5.18}
\]

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: \( I_{op} = I_{injected} \)).
d) NEGATIVE SEQUENCE DIRECTIONAL OVERCURRENT (ANSI 67_2)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ NEGATIVE SEQUENCE CURRENT ⇒ NEG SEQ DIR OC1(2)

There are two Negative Sequence Directional Overcurrent protection elements available. The element provides both forward and reverse fault direction indications through its output operands NEG SEQ DIR OC1 FWD and NEG SEQ DIR OC1 REV, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as ‘forward’ or ‘reverse’, respectively (directional unit).

The overcurrent unit of the element essentially responds to the magnitude of a fundamental frequency phasor of either the negative-sequence or zero-sequence current as per user selection. The zero-sequence current should not be mistaken with the neutral current (factor 3 difference).

A ‘positive-sequence restraint’ is applied for better performance: a small user-programmable portion of the positive-sequence current magnitude is subtracted from the negative- or zero-sequence current magnitude, respectively, when forming the element operating quantity.

\[
I_{op} = ||I_2| - K \times |I_1| \quad \text{or} \quad I_{op} = ||I_0| - K \times |I_1| \quad \text{EQ 5.19}
\]

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative- and zero-sequence currents resulting from:

- System unbalances under heavy load conditions.
- Transformation errors of Current Transformers (CTs).
- Fault inception and switch-off transients.
The positive-sequence restraint must be considered when testing for pick-up accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay:

- single-phase injection: \( I_{op} = \frac{1}{3} \times (1 - K) \times I_{injected} \)
- three-phase pure zero- or negative-sequence injection, respectively: \( I_{op} = I_{injected} \)
- the directional unit uses the negative-sequence current and voltage for fault direction discrimination

The following table defines the Negative Sequence Directional Overcurrent element.

<table>
<thead>
<tr>
<th>MODE</th>
<th>OPERATING CURRENT</th>
<th>DIRECTION</th>
<th>COMPARED PHASORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative-Sequence</td>
<td>( I_{op} =</td>
<td>I_2</td>
<td>- K \times</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reverse</td>
<td>(-V_2 + Z_{offset} \times I_2)</td>
</tr>
<tr>
<td>Zero-Sequence</td>
<td>( I_{op} =</td>
<td>I_0</td>
<td>- K \times</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reverse</td>
<td>(-V_2 + Z_{offset} \times I_2)</td>
</tr>
</tbody>
</table>

The negative-sequence voltage must be higher than the PRODUCT SETUP ➔ DISPLAY PROPERTIES ➔ VOLTAGE CUT-OFF LEVEL value to be validated for use as a polarizing signal. If the polarizing signal is not validated neither forward nor reverse indication is given. The following figure explains the usage of the voltage polarized directional unit of the element.

The figure below shows the phase angle comparator characteristics for a Phase A to ground fault, with settings of:

- ECA = 75° (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 Negative Sequence Directional Overcurrent element to ‘directionalize’ other protection elements.
**NEG SEQ 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 negative-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the negative-sequence impedance of the protected circuit. Practically, it shall be several times smaller. The offset impedance shall be entered in secondary ohms. See the Theory of Operation chapter for additional details.

**NEG SEQ DIR OC1 TYPE**: This setting selects the operating mode for the overcurrent unit of the element. The choices are “Neg Sequence” and “Zero Sequence”. In some applications it is advantageous to use a directional negative-sequence overcurrent function instead of a directional zero-sequence overcurrent function as inter-circuit mutual effects are minimized.

**NEG SEQ DIR OC1 POS-SEQ RESTRAINT**: This setting controls the amount of the positive-sequence restraint. Set to 0.063 (in “Zero Sequence” mode) or 0.125 (in “Neg Sequence” mode) for backward compatibility with firmware revision 3.40 and older. Set to zero to remove the restraint. Set higher if large system unbalances or poor CT performance are expected.

**NEG SEQ DIR OC1 FWD ECA**: This setting select the element characteristic angle (ECA) for the forward direction. The element characteristic angle in the reverse direction is the angle set for the forward direction shifted by 180°.

**NEG SEQ DIR OC1 FWD LIMIT ANGLE**: This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.

**NEG SEQ DIR OC1 FWD PICKUP**: This setting defines the pickup level for the overcurrent unit in the forward direction. Upon **NEG SEQ DIR OC1 TYPE** selection, this pickup threshold applies to zero- or negative-sequence current. When selecting this setting it must be kept in mind that the design uses a ‘positive-sequence restraint’ technique.

**NEG SEQ DIR OC1 REV LIMIT ANGLE**: This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.

**NEG SEQ DIR OC1 REV PICKUP**: This setting defines the pickup level for the overcurrent unit in the reverse direction. Upon **NEG SEQ DIR OC1 TYPE** selection, this pickup threshold applies to zero- or negative-sequence current. When selecting this setting it must be kept in mind that the design uses a ‘positive-sequence restraint’ technique.
### 5.5 GROUPED ELEMENTS

#### 5.5.8 BREAKER FAILURE

**Path:** SETTINGS → GROUPED ELEMENTS → SETTING GROUP 1(6) → BREAKER FAILURE → BREAKER FAILURE 1(2)

<table>
<thead>
<tr>
<th><strong>Breaker Failure 1</strong></th>
<th><strong>Message</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BF1 Function:</strong></td>
<td>Disabled</td>
</tr>
<tr>
<td><strong>BF1 Mode:</strong></td>
<td>3-Pole</td>
</tr>
<tr>
<td><strong>BF1 Source:</strong></td>
<td>SRC 1</td>
</tr>
<tr>
<td><strong>BF1 Use Amp Supv:</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>BF1 Use Seal-In:</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>BF1 3-Pole Initiate:</strong></td>
<td>Off</td>
</tr>
<tr>
<td><strong>BF1 Block:</strong></td>
<td>Off</td>
</tr>
<tr>
<td><strong>BF1 Ph Amp Supv PickUp:</strong></td>
<td>1.050 pu</td>
</tr>
<tr>
<td><strong>BF1 N Amp Supv PickUp:</strong></td>
<td>1.050 pu</td>
</tr>
<tr>
<td><strong>BF1 Use Timer 1:</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>BF1 Timer 1 PickUp Delay:</strong></td>
<td>0.000 s</td>
</tr>
<tr>
<td><strong>BF1 Use Timer 2:</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>BF1 Timer 2 PickUp Delay:</strong></td>
<td>0.000 s</td>
</tr>
<tr>
<td><strong>BF1 Use Timer 3:</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>BF1 Timer 3 PickUp Delay:</strong></td>
<td>0.000 s</td>
</tr>
<tr>
<td><strong>BF1 Bkr Pos1 φA/3P:</strong></td>
<td>Off</td>
</tr>
<tr>
<td><strong>BF1 Bkr Pos2 φA/3P:</strong></td>
<td>Off</td>
</tr>
<tr>
<td><strong>BF1 Breaker Test On:</strong></td>
<td>Off</td>
</tr>
<tr>
<td><strong>BF1 Ph Amp HiSet PickUp:</strong></td>
<td>1.050 pu</td>
</tr>
<tr>
<td><strong>BF1 N Amp HiSet PickUp:</strong></td>
<td>1.050 pu</td>
</tr>
<tr>
<td><strong>BF1 Ph Amp LoSet PickUp:</strong></td>
<td>1.050 pu</td>
</tr>
</tbody>
</table>

Range: FlexLogic™ operand
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, Hi-set and Lo-set, that allow the supervision level to change from a current which flows before a breaker inserts an opening resistor into the faulted circuit to a lower level after resistor insertion. The Hi-set detector is enabled after timeout of Timer 1 or 2, along with a timer that will enable the Lo-set detector after its delay interval. The delay interval between Hi-set and Lo-set is the expected breaker opening time. Both current detectors provide a fast operating time for currents at small multiples of the pickup value. The overcurrent detectors are required to operate after the breaker failure delay interval to eliminate the need for very fast resetting overcurrent detectors.

Timer 3 logic (Slow Path) is supervised by a breaker auxiliary contact and a control switch contact used to indicate that the breaker is in/out of service, disabling this path when the breaker is out of service for maintenance. There is no current level check in this logic as it is intended to detect low magnitude faults and it is therefore the slowest to operate.

**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 5–56: BREAKER FAILURE MAIN PATH SEQUENCE](image-url)
The current supervision elements reset in less than 0.7 of a power cycle up to the multiple of pickup of 100 (threshold set at 0.01 of the actual fault current) as shown below.

![Figure 5–57: BREAKER FAILURE OVERCURRENT SUPERVISION RESET TIME](image)

**Figure 5–57: BREAKER FAILURE OVERCURRENT SUPERVISION RESET TIME**

**SETTINGS:**

- **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 selects 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:** 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. This setting is valid only for three-pole tripping schemes.
- **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.
- **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 F60 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 below 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 sets 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**: 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. This setting is valid only for 3-pole breaker failure schemes.

- **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**: 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). This setting is valid only for 3-pole breaker failure schemes.

- **BF1 LOSET TIME DELAY**: Sets 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 / BF1 PH C INITIATE**: 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. This setting is only valid for 1-pole breaker failure schemes.

- **BF1 BKR POS1 φB / BF1 BKR POS 1 φC**: 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. This setting is valid only for 1-pole breaker failure schemes.

- **BF1 BKR POS2 φB**: 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. This setting is valid only for 1-pole breaker failure schemes.

- **BF1 BKR POS2 φC**: 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. This setting is valid only for 1-pole breaker failure schemes.

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 5–58: BREAKER FAILURE 1-POLE [INITIATE] (Sheet 1 of 2)
Figure 5–59: BREAKER FAILURE 1-POLE [TIMERS] (Sheet 2 of 2)
Figure 5–60: BREAKER FAILURE 3-POLE [INITIATE] (Sheet 1 of 2)
Figure 5–61: BREAKER FAILURE 3-POLE [TIMERS] (Sheet 2 of 2)
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.

\[
T = \frac{D}{1 - \frac{V}{V_{\text{pickup}}}}
\]

where:  
- \(T\) = Operating Time  
- \(D\) = Undervoltage Delay Setting  
- \(D = 0.00\) operates instantaneously  
- \(V\) = Secondary Voltage applied to the relay  
- \(V_{\text{pickup}}\) = Pickup Level  

**NOTE**  
At 0% of pickup, the operating time equals the UNDervoltage DELAY setting.

![Figure 5–62: INVERSE TIME UNDervoltage CURVES](image-url)
b) PHASE UNDERVOLTAGE (ANSI 27P)

This 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 for Delta VT connection) or as a 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. 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 5–63: PHASE UNDERVOLTAGE1 SCHEME LOGIC**
c) PHASE OVERVOLTAGE (ANSI 59P)

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 below.

### PHASE OVERVOLTAGE 1

- **FUNCTION:** Disabled
- **PHASE OVL SIGNAL SOURCE:** SRC 1
- **PHASE OVL PICKUP:** 1.000 pu
- **PHASE OVL PICKUP DELAY:** 1.00 s
- **PHASE OVL RESET DELAY:** 1.00 s
- **PHASE OVL BLOCK:** Off
- **PHASE OVL TARGET:** Self-reset
- **PHASE OVL EVENTS:** Disabled

### Figure 5–64: PHASE OVERVOLTAGE SCHEME LOGIC
There are three neutral overvoltage elements available. The neutral overvoltage element can be used to detect asymmetrical system voltage condition due to a ground fault or to the loss of one or two phases of the source. The element responds to the system neutral voltage \(3V_0\), calculated from the phase voltages. The nominal secondary voltage of the phase voltage channels entered under SETTINGS \(\Rightarrow\) SYSTEM SETUP \(\Rightarrow\) AC INPUTS \(\Rightarrow\) VOLTAGE BANK \(\Rightarrow\) PHASE VT SECONDARY is the p.u. base used when setting the pickup level.

The Neutral Overvoltage element can provide a time-delayed operating characteristic versus the applied voltage (initialized from FlexCurves A, B, or C) or be used as a definite time element. The NEUTRAL OV1(3) CURVE setting applies only if the NEUTRAL OV1(3) CURVE setting is “Definite time”. The source assigned to this element must be configured for a phase VT.

VT errors and normal voltage unbalance must be considered when setting this element. This function requires the VTs to be Wye connected.

![Figure 5–65: NEUTRAL OVERVOLTAGE1 SCHEME LOGIC](image)
e) NEGATIVE SEQUENCE OVERVOLTAGE (ANSI 59.2)

The negative sequence overvoltage element may be used to detect loss of one or two phases of the source, a reversed phase sequence of voltage, or a non-symmetrical system voltage condition.

![Diagram of NEG SEQ OV Scheme Logic](image)

**Figure 5–66: NEG SEQ OV SCHEME LOGIC**
5.5 GROUPED ELEMENTS

5 SETTINGS

f) AUXILIARY UNDERVOLTAGE (ANSI 27X)

This element is intended for monitoring undervoltage conditions of the auxiliary voltage. The **AUX UV1 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 **AUX UV1 DELAY** setting selects the minimum operating time of the auxiliary undervoltage element. Both **AUX UV1 PICKUP** and **AUX UV1 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 5–67: AUXILIARY UNDERVOLTAGE SCHEME LOGIC](image)

**Figure 5–67: AUXILIARY UNDERVOLTAGE SCHEME LOGIC**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Secondary Voltage Bank X5</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUX UV1 FUNCTION</td>
<td>FlexLogic™ operand</td>
<td>Enabled=1, Disabled=0</td>
</tr>
<tr>
<td>AUX UV1 BLOCK</td>
<td></td>
<td>Off=0, On=1</td>
</tr>
<tr>
<td>AUX UV1 SIGNAL SOURCE</td>
<td></td>
<td>SRC 1, SRC 2</td>
</tr>
<tr>
<td>AUX UV1 PICKUP</td>
<td></td>
<td>0.000 to 3.000 pu steps of 0.001</td>
</tr>
<tr>
<td>AUX UV1 CURVE</td>
<td></td>
<td>Definite Time, Inverse Time</td>
</tr>
<tr>
<td>AUX UV1 DELAY</td>
<td></td>
<td>0.00 to 600.00 s steps of 0.01</td>
</tr>
<tr>
<td>AUX UV1 MINIMUM</td>
<td></td>
<td>0.000 to 3.000 pu steps of 0.001</td>
</tr>
<tr>
<td>AUX UV1 BLOCK</td>
<td></td>
<td>FlexLogic™ operand</td>
</tr>
<tr>
<td>AUX UV1 TARGET</td>
<td></td>
<td>Self-reset, Latched, Disabled</td>
</tr>
<tr>
<td>AUX UV1 EVENTS</td>
<td></td>
<td>Disabled, Enabled</td>
</tr>
<tr>
<td>AUX UV1 VOLT Vx</td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>AUX UV1 DELAY t</td>
<td></td>
<td>FLEXLOGIC OPERAND</td>
</tr>
<tr>
<td>AUX UV1 PKP</td>
<td></td>
<td>AUX UV1 DP</td>
</tr>
<tr>
<td>AUX UV1 DPO</td>
<td></td>
<td>AUX UV1 OP</td>
</tr>
</tbody>
</table>

**MESSAGE**

- **AUX UV1 SIGNAL SOURCE**: SRC 1, SRC 2
- **AUX UV1 PICKUP**: 0.700 pu
- **AUX UV1 CURVE**: Definite Time
- **AUX UV1 DELAY**: 1.00 s
- **AUX UV1 MINIMUM**: Voltage: 0.100 pu
- **AUX UV1 BLOCK**: Off
- **AUX UV1 TARGET**: Self-reset
- **AUX UV1 EVENTS**: Disabled
This element is intended for monitoring overvoltage conditions of the auxiliary voltage. A typical application for this element is monitoring the zero-sequence voltage (3V₀) supplied from an open-corner-delta VT connection. The nominal secondary voltage of the auxiliary voltage channel entered under SYSTEM SETUP ➔ AC INPUTS ➔ VOLTAGE BANK X5 ➔ AUXILIARY VT X5 SECONDARY is the p.u. base used when setting the pickup level.
The Directional Power element responds to three-phase active power and is designed for reverse power and low forward power applications for synchronous machines or interconnections involving co-generation. The relay measures the three-phase power from either full set of wye-connected VTs or full-set of delta-connected VTs. In the latter case, the two-wattmeter method is used. Refer to the UR Metering Conventions section in Chapter 6 for conventions regarding the active and reactive powers used by the Directional Power element.

The element has an adjustable characteristic angle and minimum operating power as shown in the Directional Power Characteristic diagram. The element responds to the following condition:

\[ P \cos \theta + Q \sin \theta > SMIN \]  

(EQ 5.20)

where:  
- \( P \) and \( Q \) are active and reactive powers as measured per the UR convention,  
- \( \theta \) is a sum of the element characteristic (DIR POWER 1 RCA) and calibration (DIR POWER 1 CALIBRATION) angles, and  
- \( SMIN \) is the minimum operating power

The operating quantity is available for display as under ACTUAL VALUES ⇒ METERING ⇒ SENSITIVE DIRECTIONAL POWER 1(2). The element has two independent (as to the pickup and delay settings) stages for alarm and trip, respectively.
By making the characteristic angle adjustable and providing for both negative and positive values of the minimum operating power a variety of operating characteristics can be achieved as presented in the figure below. For example, Figure (a) below shows settings for reverse power application, while Figure (b) shows settings for low forward power application.
• **DIR POWER 1(2) RCA**: Specifies the relay characteristic angle (RCA) for the directional power function. Application of this setting is threefold:
  1. It allows the element to respond to active or reactive power in any direction (active overpower/underpower, etc.).
  2. Together with a precise calibration angle, it allows compensation for any CT and VT angular errors to permit more sensitive settings.
  3. It allows for required direction in situations when the voltage signal is taken from behind a delta-wye connected power transformer and the phase angle compensation is required.

For example, the active overpower characteristic is achieved by setting `DIR POWER 1(2) RCA` to “0°”, reactive overpower by setting `DIR POWER 1(2) RCA` to “90°”, active underpower by setting `DIR POWER 1(2) RCA` to “180°”, and reactive underpower by setting `DIR POWER 1(2) RCA` to “270°”.

• **DIR POWER 1(2) CALIBRATION**: This setting allows the RCA to change in small steps of 0.05°. This may be useful when a small difference in VT and CT angular errors is to be compensated to permit more sensitive settings. This setting virtually enables calibration of the Directional Power function in terms of the angular error of applied VTs and CTs. The element responds to the sum of the `DIR POWER 1(2) RCA` and `DIR POWER 1(2) CALIBRATION` settings.

• **DIR POWER 1(2) STG1 SMIN**: This setting specifies the minimum power as defined along the RCA angle for the stage 1 of the element. The positive values imply a shift towards the operate region along the RCA line. The negative values imply a shift towards the restrain region along the RCA line. Refer to the *Directional Power Sample Applications* figure for an illustration. Together with the RCA, this setting enables a wide range of operating characteristics. This setting applies to three-phase power and is entered in pu. The base quantity is $3 \times \text{VT pu base} \times \text{CT pu base}$.

For example, a setting of 2% for a 200 MW machine, is $0.02 \times 200 \text{ MW} = 4 \text{ MW}$. If 7.967 kV is a primary VT voltage and 10 kA is a primary CT current and a primary CT current, the source pu quantity is 239 MVA, and thus, SMIN should be set at $4 \text{ MW} / 239 \text{ MVA} = 0.0167 \text{ pu} = 0.017 \text{ pu}$. If the reverse power application is considered, $\text{RCA} = 180°$ and SMIN = 0.017 pu.

The element drops out if the magnitude of the positive-sequence current becomes virtually zero, that is, it drops below the cutoff level.

• **DIR POWER 1(2) STG1 DELAY**: This setting specifies a time delay for Stage 1. For reverse power or low forward power applications for a synchronous machine, Stage 1 is typically applied for alarming and Stage 2 for tripping.

---

**Figure 5–71: DIRECTIONAL POWER SCHEME LOGIC**
## 5.6 Control Elements

### 5.6.1 Overview

Control elements are generally used for control rather than protection. See the *Introduction to Elements* section at the beginning of this chapter for further information.

### 5.6.2 Setting Groups

The Setting Groups menu controls the activation/deactivation of up to six 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 n 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 Group n 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 Setting Group EVENTS setting allows you to assign a name to each of the six settings groups. Once programmed, this name will appear on the second line of the Grouped Elements ➔ Setting Group (1 to 6) menu display.

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.

**Table:**

<table>
<thead>
<tr>
<th>Setting Groups</th>
<th>Setting Groups Function: Disabled</th>
<th>Setting Groups BLK: Off</th>
<th>Group 2 Activate On: Off</th>
<th>Group 3 Activate On: Off</th>
<th>Group 6 Activate On: Off</th>
<th>Group 1 Name:</th>
<th>Group 2 Name:</th>
<th>Group 6 Name:</th>
<th>Setting Group EVENTS: Disabled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range: Disabled, Enabled</td>
<td>Range: FlexLogic™ operand</td>
<td>Range: FlexLogic™ operand</td>
<td>Range: FlexLogic™ operand</td>
<td>Range: FlexLogic™ operand</td>
<td>Range: up to 16 alphanumeric characters</td>
<td>Range: up to 16 alphanumeric characters</td>
<td>Range: up to 16 alphanumeric characters</td>
<td>Range: Disabled, Enabled</td>
</tr>
</tbody>
</table>
5.6 CONTROL ELEMENTS

5.6.3 SELECTOR SWITCH

PATH: SETTINGS ⇒ SELECTOR SWITCH ⇒ SELECTOR SWITCH 1(2)

<table>
<thead>
<tr>
<th>SELECTOR SWITCH 1</th>
<th>SELECTOR 1 FUNCTION: Disabled</th>
<th>Range: Disabled, Enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 FULL RANGE: 7</td>
<td>Range: 1 to 7 in steps of 1</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 TIME-OUT: 5.0 s</td>
<td>Range: 3.0 to 60.0 s in steps of 0.1</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 STEP-UP: Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 STEP-UP MODE: Time-out</td>
<td></td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 ACK: Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 3BIT A0: Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 3BIT A1: Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 3BIT A2: Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 3BIT MODE: Time-out</td>
<td>Range: Time-out, Acknowledge</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 3BIT ACK: Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 POWER-UP MODE: Restore</td>
<td>Range: Restore, Synchronize, Sync/Restore</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 TARGETS: Self-reset</td>
<td>Range: Self-reset, Latched, Disabled</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>SELECTOR 1 EVENTS: Disabled</td>
<td>Range: Disabled, Enabled</td>
</tr>
</tbody>
</table>
The Selector Switch element is intended to replace a mechanical selector switch. Typical applications include setting group control or control of multiple logic sub-circuits in user-programmable logic.

The element provides for two control inputs. The step-up control allows stepping through selector position one step at a time with each pulse of the control input, such as a user-programmable pushbutton. The 3-bit control input allows setting the selector to the position defined by a 3-bit word.

The element allows pre-selecting a new position without applying it. The pre-selected position gets applied either after time-out or upon acknowledgement via separate inputs (user setting). The selector position is stored in non-volatile memory. Upon power-up, either the previous position is restored or the relay synchronizes to the current 3-bit word (user setting). Basic alarm functionality alerts the user under abnormal conditions; e.g. the 3-bit control input being out of range.

- **SELECTOR 1 FULL RANGE**: This setting defines the upper position of the selector. When stepping up through available positions of the selector, the upper position wraps up to the lower position (Position 1). When using a direct 3-bit control word for programming the selector to a desired position, the change would take place only if the control word is within the range of 1 to the **SELECTOR FULL RANGE**. If the control word is outside the range, an alarm is established by setting the SELECTOR ALARM FlexLogic™ operand for 3 seconds.

- **SELECTOR 1 TIME-OUT**: This setting defines the time-out period for the selector. This value is used by the relay in the following two ways. When the **SELECTOR STEP-UP MODE** is “Time-out”, the setting specifies the required period of inactivity of the control input after which the pre-selected position is automatically applied. When the **SELECTOR STEP-UP MODE** is “Acknowledge”, the setting specifies the period of time for the acknowledging input to appear. The timer is re-started by any activity of the control input. The acknowledging input must come before the **SELECTOR 1 TIME-OUT** timer expires; otherwise, the change will not take place and an alarm will be set.

- **SELECTOR 1 STEP-UP**: This setting specifies a control input for the selector switch. The switch is shifted to a new position at each rising edge of this signal. The position changes incrementally, wrapping up from the last (SELECTOR 1 FULL RANGE) to the first (Position 1). Consecutive pulses of this control operand must not occur faster than every 50 ms. After each rising edge of the assigned operand, the time-out timer is restarted and the **SELECTOR SWITCH 1: POS Z CHNG INITIATED** target message is displayed, where Z the pre-selected position. The message is displayed for the time specified by the FLASH MESSAGE TIME setting. The pre-selected position is applied after the selector times out (“Time-out” mode), or when the acknowledging signal appears before the element times out (“Acknowledge” mode). When the new position is applied, the relay displays the **SELECTOR SWITCH 1: POSITION Z IN USE** message. Typically, a user-programmable pushbutton is configured as the stepping up control input.

- **SELECTOR 1 STEP-UP MODE**: This setting defines the selector mode of operation. When set to “Time-out”, the selector will change its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require any explicit confirmation of the intent to change the selector's position. When set to “Acknowledge”, the selector will change its position only after the intent is confirmed through a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector does not accept the change and an alarm is established by setting the SELECTOR STP ALARM output FlexLogic™ operand for 3 seconds.

- **SELECTOR 1 ACK**: This setting specifies an acknowledging input for the stepping up control input. The pre-selected position is applied on the rising edge of the assigned operand. This setting is active only under “Acknowledge” mode of operation. The acknowledging signal must appear within the time defined by the **SELECTOR 1 TIME-OUT** setting after the last activity of the control input. A user-programmable pushbutton is typically configured as the acknowledging input.

- **SELECTOR 1 3BIT A0, A1, and A2**: These settings specify a 3-bit control input of the selector. The 3-bit control word pre-selects the position using the following encoding convention:

<table>
<thead>
<tr>
<th>A2</th>
<th>A1</th>
<th>A0</th>
<th>POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>rest</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>
The “rest” position (0, 0, 0) does not generate an action and is intended for situations when the device generating the 3-bit control word is having a problem. When SELECTOR 1 3BIT MODE is “Time-out”, the pre-selected position is applied in SELECTOR 1 TIME-OUT seconds after the last activity of the 3-bit input. When SELECTOR 1 3BIT MODE is “Acknowledge”, the pre-selected position is applied on the rising edge of the SELECTOR 1 3BIT ACK acknowledging input.

The stepping up control input (SELECTOR 1 STEP-UP) and the 3-bit control inputs (SELECTOR 1 3BIT A0 through A2) lock-out mutually: once the stepping up sequence is initiated, the 3-bit control input is inactive; once the 3-bit control sequence is initiated, the stepping up input is inactive.

- **SELECTOR 1 3BIT MODE**: This setting defines the selector mode of operation. When set to “Time-out”, the selector changes its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require explicit confirmation to change the selector position. When set to “Acknowledge”, the selector changes its position only after confirmation via a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector rejects the change and an alarm established by invoking the SELECTOR BIT ALARM FlexLogic™ operand for 3 seconds.

- **SELECTOR 1 3BIT ACK**: This setting specifies an acknowledging input for the 3-bit control input. The pre-selected position is applied on the rising edge of the assigned FlexLogic™ operand. This setting is active only under the “Acknowledge” mode of operation. The acknowledging signal must appear within the time defined by the SELECTOR TIME-OUT setting after the last activity of the 3-bit control inputs. Note that the stepping up control input and 3-bit control input have independent acknowledging signals (SELECTOR 1 ACK and SELECTOR 1 3BIT ACK, accordingly).

- **SELECTOR 1 POWER-UP MODE**: This setting specifies the element behavior on power up of the relay.

  When set to “Restore”, the last position of the selector (stored in the non-volatile memory) is restored after powering up the relay. If the position restored from memory is out of range, position 0 (no output operand selected) is applied and an alarm is set (SELECTOR 1 PWR ALARM).

  When set to “Synchronize” selector switch acts as follows. For two power cycles, the selector applies position 0 to the switch and activates SELECTOR 1 PWR ALARM. After two power cycles expire, the selector synchronizes to the position dictated by the 3-bit control input. This operation does not wait for time-out or the acknowledging input. When the synchronization attempt is unsuccessful (i.e., the 3-bit input is not available (0,0,0) or out of range) then the selector switch output is set to position 0 (no output operand selected) and an alarm is established (SELECTOR 1 PWR ALARM).

  The operation of “Synch/Restore” mode is similar to the “Synchronize” mode. The only difference is that after an unsuccessful synchronization attempt, the switch will attempt to restore the position stored in the relay memory. The “Synch/Restore” mode is useful for applications where the selector switch is employed to change the setting group in redundant (two relay) protection schemes.

- **SELECTOR 1 EVENTS**: If enabled, the following events are logged:

<table>
<thead>
<tr>
<th>EVENT NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECTOR 1 POS Z</td>
<td>Selector 1 changed its position to Z.</td>
</tr>
<tr>
<td>SELECTOR 1 STP ALARM</td>
<td>The selector position pre-selected via the stepping up control input has not</td>
</tr>
<tr>
<td></td>
<td>been confirmed before the time out.</td>
</tr>
<tr>
<td>SELECTOR 1 BIT ALARM</td>
<td>The selector position pre-selected via the 3-bit control input has not been</td>
</tr>
<tr>
<td></td>
<td>confirmed before the time out.</td>
</tr>
</tbody>
</table>
The following figures illustrate the operation of the Selector Switch. In these diagrams, “T” represents a time-out setting.

Figure 5–73: TIME-OUT MODE
### 5.6 CONTROL ELEMENTS

#### 5 SETTINGS

**Figure 5–74: ACKNOWLEDGE MODE**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEP-UP</td>
<td>pre-existing position 2</td>
</tr>
<tr>
<td>ACK</td>
<td>changed to 4 with a pushbutton</td>
</tr>
<tr>
<td>3BIT A0</td>
<td>changed to 1 with a 3-bit input</td>
</tr>
<tr>
<td>3BIT A1</td>
<td>changed to 2 with a pushbutton</td>
</tr>
<tr>
<td>3BIT A2</td>
<td></td>
</tr>
<tr>
<td>3BIT ACK</td>
<td></td>
</tr>
<tr>
<td>POS 1</td>
<td></td>
</tr>
<tr>
<td>POS 2</td>
<td></td>
</tr>
<tr>
<td>POS 3</td>
<td></td>
</tr>
<tr>
<td>POS 4</td>
<td></td>
</tr>
<tr>
<td>POS 5</td>
<td></td>
</tr>
<tr>
<td>POS 6</td>
<td></td>
</tr>
<tr>
<td>POS 7</td>
<td></td>
</tr>
<tr>
<td>BIT 0</td>
<td></td>
</tr>
<tr>
<td>BIT 1</td>
<td></td>
</tr>
<tr>
<td>BIT 2</td>
<td></td>
</tr>
<tr>
<td>STP ALARM</td>
<td></td>
</tr>
<tr>
<td>BIT ALARM</td>
<td></td>
</tr>
<tr>
<td>ALARM</td>
<td></td>
</tr>
</tbody>
</table>
APPLICATION EXAMPLE

Consider an application where the selector switch is used to control Setting Groups 1 through 4 in the relay. The setting groups are to be controlled from both User-Programmable Pushbutton 1 and from an external device via Contact Inputs 1 through 3. The active setting group shall be available as an encoded 3-bit word to the external device and SCADA via output contacts 1 through 3. The pre-selected setting group shall be applied automatically after 5 seconds of inactivity of the control inputs. When the relay powers up, it should synchronize the setting group to the 3-bit control input.

Make the following changes to Setting Group Control in the \textit{SETTINGS \Rightarrow \CONTROL ELEMENTS \Rightarrow SETTING GROUPS} menu:

- \textbf{SETTING GROUPS FUNCTION:} “Enabled”
- \textbf{GROUP 4 ACTIVATE ON:} “SELECTOR 1 POS 4”
- \textbf{GROUP 5 ACTIVATE ON:} “SELECTOR 1 POS 2”
- \textbf{GROUP 6 ACTIVATE ON:} “SELECTOR 1 POS 3”

Make the following changes to Selector Switch element in the \textit{SETTINGS \Rightarrow \CONTROL ELEMENTS \Rightarrow SELECTOR SWITCH \Rightarrow SELECTOR SWITCH 1} menu to assign control to User Programmable Pushbutton 1 and Contact Inputs 1 through 3:

- \textbf{SELECTOR 1 FUNCTION:} “Enabled”
- \textbf{SELECTOR 1 FULL-RANGE:} “4”
- \textbf{SELECTOR 1 STEP-UP MODE:} “Time-out”
- \textbf{SELECTOR 1 TIME-OUT:} “5.0 s”
- \textbf{SELECTOR 1 3BIT A0:} “CONT IP 1 ON”
- \textbf{SELECTOR 1 3BIT A1:} “CONT IP 2 ON”
- \textbf{SELECTOR 1 3BIT A2:} “CONT IP 3 ON”
- \textbf{SELECTOR 1 3BIT MODE:} “Time-out”
- \textbf{SELECTOR 1 3BIT ACK:} “Off”
- \textbf{SELECTOR 1 POW UP MODE:} “Synchronize”

Now, assign the contact output operation (assume the H6E module) to the Selector Switch element by making the following changes in the \textit{SETTINGS \Rightarrow \INPUTS/OUTPUTS \Rightarrow CONTACT OUTPUTS} menu:

- \textbf{OUTPUT H1 OPERATE:} “SELECTOR 1 BIT 0”
- \textbf{OUTPUT H2 OPERATE:} “SELECTOR 1 BIT 1”
- \textbf{OUTPUT H3 OPERATE:} “SELECTOR 1 BIT 2”

Finally, assign configure User-Programmable Pushbutton 1 by making the following changes in the \textit{SETTINGS \Rightarrow PRODUCT SETUP \Rightarrow USER-PROGRAMMABLE PUSHBUTTONS \Rightarrow USER PUSHBUTTON 1} menu:

- \textbf{PUSHBUTTON 1 FUNCTION:} “Self-reset”
- \textbf{PUSHBUTTON 1 DROP-OUT TIME:} “0.10 s”

The logic for the selector switch is shown below:

\begin{figure}[h]
\includegraphics[width=\textwidth]{Figure5-75.png}
\caption{SELECTOR SWITCH LOGIC}
\end{figure}
There are six identical underfrequency elements, numbered from 1 through 6 inclusive.

The steady-state frequency of a power system is a certain indicator of the existing balance between the generated power and the load. Whenever this balance is disrupted through the loss of an important generating unit or the isolation of part of the system from the rest of the system, the effect will be a reduction in frequency. If the control systems of the system generators do not respond fast enough, the system may collapse. A reliable method to quickly restore the balance between load and generation is to automatically disconnect selected loads, based on the actual system frequency. This technique, called "load-shedding", maintains system integrity and minimize widespread outages. After the frequency returns to normal, the load may be automatically or manually restored.

The UNDERFREQ 1 SOURCE setting is used to select the source for the signal to be measured. The element first checks for a live phase voltage available from the selected Source. If voltage is not available, the element attempts to use a phase current. If neither voltage nor current is available, the element will not operate, as it will not measure a parameter above the minimum voltage/current setting.

The UNDERFREQ 1 MIN VOLT/AMP setting selects the minimum per unit voltage or current level required to allow the underfrequency element to operate. This threshold is used to prevent an incorrect operation because there is no signal to measure.

This UNDERFREQ 1 PICKUP setting is used to select the level at which the underfrequency element is to pickup. For example, if the system frequency is 60 Hz and the load shedding is required at 59.5 Hz, the setting will be 59.50 Hz.
There are four overfrequency elements, numbered 1 through 4.

A frequency calculation for a given source is made on the input of a voltage or current channel, depending on which is available. The channels are searched for the signal input in the following order: voltage channel A, auxiliary voltage channel, current channel A, ground current channel. The first available signal is used for frequency calculation.

The steady-state frequency of a power system is an indicator of the existing balance between the generated power and the load. Whenever this balance is disrupted through the disconnection of significant load or the isolation of a part of the system that has a surplus of generation, the effect will be an increase in frequency. If the control systems of the generators do not respond fast enough, to quickly ramp the turbine speed back to normal, the overspeed can lead to the turbine trip. The overfrequency element can be used to control the turbine frequency ramp down at a generating location. This element can also be used for feeder reclosing as part of the "after load shedding restoration".

The \texttt{OVERFREQ 1 SOURCE} setting selects the source for the signal to be measured. The \texttt{OVERFREQ 1 PICKUP} setting selects the level at which the overfrequency element is to pickup.
5.6 CONTROL ELEMENTS

5.6.6 FREQUENCY RATE OF CHANGE

PATH: SETTINGS ➔ CONTROL ELEMENTS ➔ FREQUENCY RATE OF CHANGE ➔ FREQUENCY RATE OF CHANGE 1(4)

<table>
<thead>
<tr>
<th>MESSAGE</th>
<th>FREQUENCY RATE OF CHANGE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE FUNCTION: Disabled</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 FUNCTION: Disabled</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 SOURCE: SRC 1</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 TREND: Decreasing</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 PICKUP: 0.50 Hz/sec</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 OV SUPV PICKUP: 0.700 pu</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 OC SUPV PICKUP: 0.200 pu</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 MIN FREQUENCY: 45.00 Hz</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 MAX FREQUENCY: 65.00 Hz</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 PICKUP DELAY: 0.000 s</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 RESET DELAY: 0.000 s</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 BLOCK: Off</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 TARGET: Self-Reset</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>FREQUENCY RATE 1 EVENTS: Disabled</td>
</tr>
</tbody>
</table>

Four (4) independent Rate of Change of Frequency elements are available. The element responds to rate of change of frequency with voltage, current and frequency supervision.

- **FREQ RATE 1 TREND:** This setting allows configuring the element to respond to increasing or decreasing frequency, or to frequency change in either direction.

- **FREQ RATE 1 PICKUP:** This setting specifies an intended \( \frac{df}{dt} \) pickup threshold. For applications monitoring a decreasing trend, set **FREQ RATE 1 TREND** to “Decreasing” and specify the pickup threshold accordingly. The operating condition is: \( -\frac{df}{dt} > \text{Pickup} \).

  For applications monitoring an increasing trend, set **FREQ RATE 1 TREND** to “Increasing” and specify the pickup threshold accordingly. The operating condition is: \( \frac{df}{dt} > \text{Pickup} \).

  For applications monitoring rate of change of frequency in any direction set **FREQ RATE 1 TREND** to “Bi-Directional” and specify the pickup threshold accordingly. The operating condition is: \( \text{abs}(\frac{df}{dt}) > \text{Pickup} \).

- **FREQ RATE 1 OV SUPV PICKUP:** This setting defines minimum voltage level required for operation of the element. The supervising function responds to the positive-sequence voltage. Overvoltage supervision should be used to prevent operation under specific system conditions such as faults.

- **FREQ RATE 1 OC SUPV PICKUP:** This setting defines minimum current level required for operation of the element. The supervising function responds to the positive-sequence current. Typical application includes load shedding. Set the pickup threshold to zero if no overcurrent supervision is required.
• **FREQ RATE 1 MIN FREQUENCY**: This setting defines minimum frequency level required for operation of the element. The setting may be used to effectively block the feature based on frequency. For example, if the intent is to monitor an increasing trend but only if the frequency is already above certain level, this setting should be set to the required frequency level.

• **FREQ RATE 1 MAX FREQUENCY**: This setting defines maximum frequency level required for operation of the element. The setting may be used to effectively block the feature based on frequency. For example, if the intent is to monitor a decreasing trend but only if the frequency is already below certain level (such as for load shedding), this setting should be set to the required frequency level.

![Figure 5–78: FREQUENCY RATE OF CHANGE SCHEME LOGIC](image-url)
5.6 CONTROL ELEMENTS

5.6.7 SYNCHROCHECK

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 that the two voltages remain within the admissible angle difference is determined by the setting of the phase angle difference $\Delta \Phi$ and the frequency difference $\Delta F$ (slip frequency). It can be defined as the time it would take the voltage phasor $V_1$ or $V_2$ to traverse an angle equal to $2 \times \Delta \Phi$ at a frequency equal to the frequency difference $\Delta F$. This time can be calculated by:

$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta \Phi \times \Delta F}}$$  \hspace{1cm} (EQ 5.21)

where: $\Delta \Phi = $ phase angle difference in degrees; $\Delta F = $ frequency difference in Hz.

<table>
<thead>
<tr>
<th>PATH: SETTINGS ➔ CONTROL ELEMENTS ➔ SYNCHROCHECK ➔ SYNCHROCHECK 1(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ SYNCHROCHECK 1</td>
</tr>
<tr>
<td>SYNCHK1 FUNCTION: .Disabled</td>
</tr>
<tr>
<td>Range: Disabled, Enabled</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 BLOCK:  Off</td>
</tr>
<tr>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 V1 SOURCE:  SRC 1</td>
</tr>
<tr>
<td>Range: SRC 1, SRC 2</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 V2 SOURCE:  SRC 2</td>
</tr>
<tr>
<td>Range: SRC 1, SRC 2</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 MAX VOLT DIFF:  10000 V</td>
</tr>
<tr>
<td>Range: 0 to 400000 V in steps of 1</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 MAX ANGLE DIFF:  30°</td>
</tr>
<tr>
<td>Range: 0 to 100° in steps of 1</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 MAX FREQ DIFF:  1.00 Hz</td>
</tr>
<tr>
<td>Range: 0.00 to 2.00 Hz in steps of 0.01</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 MAX FREQ HYSTERESIS:  0.06 Hz</td>
</tr>
<tr>
<td>Range: 0.00 to 0.10 Hz in steps of 0.01</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 DEAD SOURCE SELECT:  LV1 and DV2</td>
</tr>
<tr>
<td>Range: None, LV1 and DV2, DV1 and LV2, DV1 or DV2, DV1 Xor DV2, DV1 and DV2</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 DEAD V1 MAX VOLT:  0.30 pu</td>
</tr>
<tr>
<td>Range: 0.00 to 1.25 pu in steps of 0.01</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 DEAD V2 MAX VOLT:  0.30 pu</td>
</tr>
<tr>
<td>Range: 0.00 to 1.25 pu in steps of 0.01</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 LIVE V1 MIN VOLT:  0.70 pu</td>
</tr>
<tr>
<td>Range: 0.00 to 1.25 pu in steps of 0.01</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 LIVE V2 MIN VOLT:  0.70 pu</td>
</tr>
<tr>
<td>Range: 0.00 to 1.25 pu in steps of 0.01</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 TARGET:  Self-reset</td>
</tr>
<tr>
<td>Range: Self-reset, Latched, Disabled</td>
</tr>
<tr>
<td>MESSAGE SYNCHK1 EVENTS:  Disabled</td>
</tr>
<tr>
<td>Range: Disabled, Enabled</td>
</tr>
</tbody>
</table>
As an example; for the default values ($\Delta \Phi = 30^\circ$, $\Delta F = 0.1$ Hz), the time while the angle between the two voltages will be less than the set value is:

$$T = \frac{1}{\frac{360^\circ}{2} \times \Delta \Phi \times \Delta F} = \frac{1}{\frac{360^\circ}{2} \times 30^\circ \times 0.1 \text{ Hz}} = 1.66 \text{ sec.}$$  \hspace{1cm} (EQ 5.22)

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).

- **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 primary voltage difference in ‘kV’ between the two sources. A primary 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 MAX FREQ HYSTERESIS**: This setting specifies the required hysteresis for the maximum frequency difference condition. The condition becomes satisfied when the frequency difference becomes lower than $\text{SYNCHK1 MAX FREQ DIFF} + \text{SYNCHK1 MAX FREQ HYSTERESIS}$ sum to drop out (assuming the other two conditions, voltage and angle, remain satisfied).
- **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 1 ‘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 ON THE SYNCHROCHECK FUNCTION:

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.

<table>
<thead>
<tr>
<th>NO.</th>
<th>V1 OR V2 (SOURCE Y)</th>
<th>V2 OR V1 (SOURCE Z)</th>
<th>AUTO-SELECTED COMBINATION</th>
<th>AUTO-SELECTED VOLTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phase VTs and Auxiliary VT</td>
<td>Phase VTs and Auxiliary VT</td>
<td>Phase</td>
<td>Phase</td>
</tr>
<tr>
<td>2</td>
<td>Phase VTs and Auxiliary VT</td>
<td>Phase VT</td>
<td>Phase</td>
<td>Phase</td>
</tr>
<tr>
<td>3</td>
<td>Phase VT</td>
<td>Phase VT</td>
<td>Phase</td>
<td>Phase</td>
</tr>
<tr>
<td>4</td>
<td>Phase VT and Auxiliary VT</td>
<td>Auxiliary VT</td>
<td>Phase</td>
<td>Auxiliary</td>
</tr>
<tr>
<td>5</td>
<td>Auxiliary VT</td>
<td>Auxiliary VT</td>
<td>Auxiliary</td>
<td>Auxiliary</td>
</tr>
</tbody>
</table>

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.
Figure 5–79: SYNCHROCHECK SCHEME LOGIC
### 5.6 CONTROL ELEMENTS ➔ 5 SETTINGS ➔ 5.6.8 AUTORECLOSE

**PATH:** SETTINGS ➔ CONTROL ELEMENTS ➔ AUTORECLOSE ➔ AUTORECLOSE 1(2)

<table>
<thead>
<tr>
<th><strong>Message</strong></th>
<th><strong>Parameter</strong></th>
<th><strong>Values</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>AR1 FUNCTION</td>
<td>Disabled</td>
<td>Range: Disabled, Enabled</td>
</tr>
<tr>
<td>AR1 INITIATE</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 BLOCK</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 MAX NUMBER OF SHOTS</td>
<td>1</td>
<td>Range: 1, 2, 3, 4</td>
</tr>
<tr>
<td>AR1 REDUCE MAX TO 1</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 REDUCE MAX TO 2</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 REDUCE MAX TO 3</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 MANUAL CLOSE</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 MNL RST FRM LO</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 RESET LOCKOUT IF BREAKER CLOSED</td>
<td>Off</td>
<td>Range: Off, On</td>
</tr>
<tr>
<td>AR1 RESET LOCKOUT ON MANUAL CLOSE</td>
<td>Off</td>
<td>Range: Off, On</td>
</tr>
<tr>
<td>AR1 BKR CLOSED</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 BKR OPEN</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 BLK TIME UPON MNL CLS</td>
<td>10.000 s</td>
<td>Range: 0.00 to 655.35 s in steps of 0.01</td>
</tr>
<tr>
<td>AR1 DEAD TIME 1</td>
<td>1.000 s</td>
<td>Range: 0.00 to 655.35 s in steps of 0.01</td>
</tr>
<tr>
<td>AR1 DEAD TIME 2</td>
<td>2.000 s</td>
<td>Range: 0.00 to 655.35 s in steps of 0.01</td>
</tr>
<tr>
<td>AR1 DEAD TIME 3</td>
<td>3.000 s</td>
<td>Range: 0.00 to 655.35 s in steps of 0.01</td>
</tr>
<tr>
<td>AR1 DEAD TIME 4</td>
<td>4.000 s</td>
<td>Range: 0.00 to 655.35 s in steps of 0.01</td>
</tr>
<tr>
<td>AR1 ADD DELAY 1</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
<tr>
<td>AR1 ADD DELAY 2</td>
<td>Off</td>
<td>Range: FlexLogic™ operand</td>
</tr>
</tbody>
</table>
The maximum number of autoreclosure elements available is equal to the number of installed CT banks.

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.

The reclosure scheme is considered enabled when all of the following conditions are true:

- The AR1(2) FUNCTION is set to “Enabled”.
- The scheme is not in the 'Lockout' state.
- The 'Block' input is not asserted.
- The AR1(2) BLK TIME UPON MNL CLS timer is not active.

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.

The reclose-in-progress (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, or
- 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.

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(2) DELAY 1 or AR1(2) 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 AR1 SHOT CNT =n, SETTING GROUP ACT 1, etc. The autoreclose provides up to maximum 4 selectable shots. Maximum number of shots can be dynamically modified through the settings AR1(2) REDUCE MAX TO 1 (2, 3), using the appropriate FlexLogic™ operand.

Scheme lockout blocks all phases of the reclosing cycle, preventing automatic reclosure, if any of the following 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, or whenever the breaker has been closed and stays closed for a preset time.

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.

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.

SETTINGS:

• **AR1(2) INITIATE:** Selects the FlexLogic™ operand that initiates the scheme, typically the trip signal from protection.
• **AR1(2) BLOCK:** Selects the FlexLogic™ operand that blocks the autoreclosure initiate (it could be from the breaker failure, bus differential protection, etc.).
• **AR1(2) MAX NUMBER OF SHOTS:** Specifies the number of reclosures that can be attempted before reclosure goes to “Lockout” because the fault is permanent.
• **AR1(2) REDUCE MAX TO 1(3):** Selects the FlexLogic™ operand that changes the maximum number of shots from the initial setting to 1, 2, or 3, respectively.
• **AR1(2) MANUAL CLOSE:** Selects the logic input set when the breaker is manually closed.
• **AR1(2) 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(2) 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(2) RESET LOCKOUT ON MANUAL CLOSE**) should be disabled.
• **AR1(2) 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(2) RESET LOCKOUT IF BREAKER CLOSED**).
• **AR1(2) 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(2) DEAD TIME 1 to AR1(2) DEAD TIME 4:** These are the intentional delays before first, second, third, and fourth breaker automatic reclosures (1st, 2nd, and 3rd shots, respectively, and should be set longer than the estimated deionizing time following a three pole trip.
• **AR1(2) 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(2) DELAY 1:** This setting establishes the extent of the additional dead time Delay 1.
• **AR1(2) 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(2) DELAY 2:** This setting establishes the extent of the additional dead time Delay 2.
• **AR1(2) RESET LOCKOUT DELAY:** This setting establishes how long the breaker should stay closed after a manual close command, in order for the autorecloser to reset from Lockout.
• **AR1(2) 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(2) INCOMPLETE SEQ TIME:** This timer defines 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 5–80: AUTORECLOSURE SCHEME LOGIC (Sheet 1 of 2)
Figure 5–81: AUTORECLOSURE SCHEME LOGIC (Sheet 2 of 2)
Figure 5–82: SINGLE SHOT AUTORECLOSING SEQUENCE - PERMANENT FAULT

- **Breaker Status**
  - BKR CLOSED
  - BKR OPEN

- **Fault Occurs**

- **Trip Command**

- **Contacts Separate**

- **Arc Extinquishes**

- **Fault Duration**

- **Close Command**

- **Contacts Close**

- **Trip Command**

- **Contacts Separate**

- **Arc Extinquishes**

- **Fault Duration**

- **Auto Reclose**

- **Dead Time**

- **Incomplete Sequence Occurs**

- **Reset Time Occurs**
5.6 CONTROL ELEMENTS

5.6.9 DIGITAL ELEMENTS

There are 48 identical digital elements available, numbered 1 to 48. 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”.
- **DIGITAL ELEMENT 1 PICKUP LED**: This setting enables or disabled the digital element pickup LED. When set to “Disabled”, the operation of the pickup LED is blocked.

There are 48 identical digital elements available, numbered 1 to 48. 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.

There are 48 identical digital elements available, numbered 1 to 48. 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.

**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.

**EXAMPLE 1: BREAKER TRIP CIRCUIT INTEGRITY MONITORING**

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.

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:

<table>
<thead>
<tr>
<th><strong>DIGITAL ELEMENT 1</strong></th>
<th><strong>DIGITAL ELEMENT 1</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNCTION: Enabled</td>
<td>FUNCTION: Enabled</td>
</tr>
<tr>
<td>DIG ELEM 1 NAME:</td>
<td>DIG ELEM 1 NAME:</td>
</tr>
<tr>
<td>Bkr Trip Cct Out</td>
<td>Bkr Trip Cct Out</td>
</tr>
<tr>
<td>DIG ELEM 1 INPUT:</td>
<td>DIG ELEM 1 INPUT:</td>
</tr>
<tr>
<td>Cont Op 1 VOff</td>
<td>Cont Op 1 VOff</td>
</tr>
<tr>
<td>DIG ELEM 1 PICKUP</td>
<td>DIG ELEM 1 PICKUP</td>
</tr>
<tr>
<td>DELAY: 0.200 s</td>
<td>DELAY: 0.200 s</td>
</tr>
<tr>
<td>DIG ELEM 1 RESET</td>
<td>DIG ELEM 1 RESET</td>
</tr>
<tr>
<td>DELAY: 0.100 s</td>
<td>DELAY: 0.100 s</td>
</tr>
<tr>
<td>DIG ELEM 1 BLOCK:</td>
<td>DIG ELEM 1 BLOCK:</td>
</tr>
<tr>
<td>Cont Ip 1 Off</td>
<td>Cont Ip 1 Off</td>
</tr>
<tr>
<td>DIGITAL ELEMENT 1</td>
<td>DIGITAL ELEMENT 1</td>
</tr>
<tr>
<td>TARGET: Self-reset</td>
<td>TARGET: Self-reset</td>
</tr>
<tr>
<td>EVENTS: Enabled</td>
<td>EVENTS: Enabled</td>
</tr>
</tbody>
</table>

Figure 5–84: 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:
The PICKUP DELAY setting should be greater than the operating time of the breaker to avoid nuisance alarms.

**EXAMPLE 2: BREAKER TRIP CIRCUIT INTEGRITY MONITORING**

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 the figure below). This can be achieved by connecting a suitable resistor (see figure below) 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:

<table>
<thead>
<tr>
<th>DIGITAL ELEMENT 1</th>
<th>DIGITAL ELEMENT 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNCTION: Enabled</td>
<td>DIG ELEM 1 NAME: Bkr Trip Cct Out</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIG ELEM 1 INPUT: Cont Op 1 VOff</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIG ELEM 1 PICKUP DELAY: 0.200 s</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIG ELEM 1 RESET DELAY: 0.100 s</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIG ELEM 1 BLOCK: Off</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIGITAL ELEMENT 1 TARGET: Self-reset</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIGITAL ELEMENT 1 EVENTS: Enabled</td>
</tr>
</tbody>
</table>

**Table 5–20: VALUES OF RESISTOR ‘R’**

<table>
<thead>
<tr>
<th>POWER SUPPLY (V DC)</th>
<th>RESISTANCE (OHMS)</th>
<th>POWER (WATTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>1000</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>5000</td>
<td>2</td>
</tr>
<tr>
<td>48</td>
<td>10000</td>
<td>2</td>
</tr>
<tr>
<td>110</td>
<td>25000</td>
<td>5</td>
</tr>
<tr>
<td>125</td>
<td>25000</td>
<td>5</td>
</tr>
<tr>
<td>250</td>
<td>50000</td>
<td>5</td>
</tr>
</tbody>
</table>

**Figure 5–85: TRIP CIRCUIT EXAMPLE 2**
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.
5.6 CONTROL ELEMENTS

- **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** operand 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 5–86: DIGITAL COUNTER SCHEME LOGIC
### 5 SETTINGs

#### 5.6 CONTROL ELEMENTs

##### 5.6.11 MONITORING ELEMENTs

#### a) MAIN MENU

**PATH: SETTINGS ➔ CONTROL ELEMENTs ➔ MONITORING ELEMENTs**

<table>
<thead>
<tr>
<th>MONITORING ELEMENTs</th>
<th>HI-Z</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MESSAGE</strong></td>
<td>See page 5–153.</td>
</tr>
<tr>
<td><strong>BREAKER 1</strong></td>
<td>See page 5–159.</td>
</tr>
<tr>
<td><strong>ARCING CURRENT</strong></td>
<td>See page 5–159.</td>
</tr>
<tr>
<td><strong>BREAKER 2</strong></td>
<td>See page 5–161.</td>
</tr>
<tr>
<td><strong>ARCING CURRENT</strong></td>
<td>See page 5–161.</td>
</tr>
<tr>
<td><strong>BREAKER</strong></td>
<td>See page 5–161.</td>
</tr>
<tr>
<td><strong>FLASHOVER 1</strong></td>
<td>See page 5–161.</td>
</tr>
<tr>
<td><strong>BREAKER</strong></td>
<td>See page 5–164.</td>
</tr>
<tr>
<td><strong>FLASHOVER 2</strong></td>
<td>See page 5–164.</td>
</tr>
<tr>
<td><strong>VT FUSE FAILURE 1</strong></td>
<td>See page 5–164.</td>
</tr>
<tr>
<td><strong>VT FUSE FAILURE 2</strong></td>
<td>See page 5–164.</td>
</tr>
</tbody>
</table>

#### b) HI-Z

**PATH: SETTINGS ➔ CONTROL ELEMENTs ➔ HI-Z MONITORING ELEMENTs ➔ HI-Z**

<table>
<thead>
<tr>
<th>HI-Z FUNCTION:</th>
<th>Disabled, Enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MESSAGE</strong></td>
<td>Range: SRC 1, SRC 2</td>
</tr>
<tr>
<td><strong>SOURCE:</strong></td>
<td>SRC 1</td>
</tr>
<tr>
<td><strong>ARCING SENSITIVITY:</strong></td>
<td>5</td>
</tr>
<tr>
<td><strong>PHASE EVENT COUNT:</strong></td>
<td>30</td>
</tr>
<tr>
<td><strong>GROUND EVENT COUNT:</strong></td>
<td>30</td>
</tr>
<tr>
<td><strong>EVENT COUNT TIME:</strong></td>
<td>15 min</td>
</tr>
<tr>
<td><strong>OC PROTECTION COORD TIMEOUT:</strong></td>
<td>15 s</td>
</tr>
<tr>
<td><strong>PHASE OC MIN PICKUP:</strong></td>
<td>1.50 pu</td>
</tr>
<tr>
<td><strong>NEUTRAL OC MIN PICKUP:</strong></td>
<td>1.00 pu</td>
</tr>
<tr>
<td><strong>PHASE RATE OF CHANGE:</strong></td>
<td>150 A/2cycle</td>
</tr>
<tr>
<td><strong>NEUTRAL RATE OF CHANGE:</strong></td>
<td>150 A/2cycle</td>
</tr>
<tr>
<td><strong>LOSS OF LOAD THRESHOLD:</strong></td>
<td>15%</td>
</tr>
</tbody>
</table>

**MESSAGE** | Range: 5 to 100% in steps of 1 |
Some faults in overhead distribution feeders are characterized by low fault current due to high ground resistance. If the fault current is in the order of expected unbalance load or less, it cannot be reliably detected by overcurrent protection. These faults are classified as high-impedance (Hi-Z) faults. Since a Hi-Z fault is not accompanied by excessive current, it is generally not dangerous to the electrical installation except for some damage to the overhead conductor at the fault location. However, an undetected Hi-Z fault is a risk to people and property as well as having a potential to evolve into a full-blown fault.

The following event types are associated with Hi-Z faults. It is assumed that for all cases that ground is involved.

- High impedance fault: a fault with fault impedance sufficiently high such that it is not detected by overcurrent protection
- High impedance, downed conductor fault: a high impedance fault for which the primary conductor is no longer intact on pole top insulators, but instead is in contact with earth or a grounded object
- Arcing fault: any high impedance fault which exhibits arcing

Combinations of these events are possible: for example, an arcing high impedance, downed conductor fault. The Hi-Z element is intended to detect high impedance faults that arc and to differentiate those that are downed conductors from those that are not. It should be noted that no known technology can detect all Hi-Z faults.

The Hi-Z element was primarily designed for solidly grounded systems. The similar Hi-Z element in the DFM200 relay has been tested with some success on impedance grounded systems as well. However, there are no guarantees of certain operation of the high impedance fault detection element on non-solidly grounded systems.

The Hi-Z data collection consists of RMS Data Capture and Hi-Z Data capture:

- **RMS Data Capture**: The RMS data captures are triggered by two-cycle Hi-Z overcurrent conditions, loss of load conditions, and high arc confidence conditions. Captures triggered by loss of load and high arc confidence conditions are saved to a temporary capture table, and deleted if the event does not result in an Arcing or Downed Conductor condition. The relay maintains a history of four captures and utilizes a combination of age, priority and access for determining which capture to save.

The RMS data capture contains the two-cycle RMS values for the voltage and current for each of the phases and current for the neutral channel. The capture frequency is half the system frequency. Each capture contains 1800 points.

- **High-Z Data Capture**: Hi-Z Data Captures are triggered and maintained in an identical manner as RMS Data Captures. The relay maintains four captures of 300 records each. The capture frequency is 1 Hz and the data collected is defined in the following two tables.
**Table 5–21: HI-Z SPECIFIC DATA**

<table>
<thead>
<tr>
<th>#</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>EadCounts</td>
<td>Total number of EAD counts for the phase</td>
</tr>
<tr>
<td>1</td>
<td>ArcConfidence</td>
<td>ArcConfidence for the phase</td>
</tr>
<tr>
<td>2</td>
<td>AccumArcConf</td>
<td>Accumulated ArcConfidence for the phase</td>
</tr>
<tr>
<td>3</td>
<td>RmsCurrent</td>
<td>The 2-cycle RMS current for the phase</td>
</tr>
<tr>
<td>4</td>
<td>HighROC</td>
<td>Flag indicating a high rate of change was detected</td>
</tr>
<tr>
<td>5</td>
<td>IOC</td>
<td>Flag indicating an instantaneous 2-cycle overcurrent was detected</td>
</tr>
<tr>
<td>6</td>
<td>LossOfLoad</td>
<td>Flag indicating a loss of load was detected</td>
</tr>
<tr>
<td>7</td>
<td>EadZeroed</td>
<td>Flag indicating that this phase’s EAD table was cleared</td>
</tr>
<tr>
<td>8</td>
<td>HighZArmed</td>
<td>Flag indicating that this phase is armed for a high-Z detection</td>
</tr>
<tr>
<td>9</td>
<td>VoltageDip</td>
<td>Flag indicating that a voltage dip was detected on this phase</td>
</tr>
<tr>
<td>10</td>
<td>HighEad</td>
<td>Flag indicating that a high arc confidence occurred on this phase</td>
</tr>
<tr>
<td>11</td>
<td>ArcBurst</td>
<td>Flag indicating that an arc burst was identified on this phase</td>
</tr>
<tr>
<td>12</td>
<td>VDisturbanceCc</td>
<td>Cycle-to-cycle voltage disturbance</td>
</tr>
<tr>
<td>13</td>
<td>VDisturbanceAbs</td>
<td>Absolute voltage disturbance</td>
</tr>
<tr>
<td>14</td>
<td>HarmonicRestraint</td>
<td>Harmonic Restraint</td>
</tr>
</tbody>
</table>

**Table 5–22: HI-Z CAPTURE DATA**

<table>
<thead>
<tr>
<th>#</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>StatusMask</td>
<td>Bit-mask of the algorithm state (16 bits)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_ARCING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_DOWNED_COND</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_ARC_TREND</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_PHASE_A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_PHASE_B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_PHASE_C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_PHASE_N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_IOC_A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_IOC_B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_IOC_C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_IOC_N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_LOL_A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_LOL_B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_LOL_C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_I_DISTURBANCE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIT_V_DISTURBANCE</td>
</tr>
<tr>
<td>2</td>
<td>AlgorithmState</td>
<td>Present value of the High-Z output state machine: Normal = 0, Coordination Timeout = 1, Armed = 2, Arcing = 5, Downed Conductor = 9</td>
</tr>
<tr>
<td>3</td>
<td>EadZeroedFlag</td>
<td>Flag indicating the EAD table was cleared</td>
</tr>
<tr>
<td>4</td>
<td>SpectralFlag</td>
<td>Flag indicating the Spectral algorithm has found a match</td>
</tr>
<tr>
<td>5</td>
<td>ThreePhaseFlag</td>
<td>Flag indicating a three phase event was detected</td>
</tr>
<tr>
<td>6</td>
<td>PhaseInfo[4]</td>
<td>Phase specific information for the three phase currents and the neutral (see table below)</td>
</tr>
</tbody>
</table>

The algorithm is in “Normal” state when it detects no abnormal activity on the power system. While in the “Normal” state, any one of several power system events (a high output of the Expert Arc Detector, a significant loss of load, or a HI-Z overcurrent) cause the algorithm to move to the “Coordination Timeout” state, where it remains for the time specified by the OC PROTECTION COORD TIMEOUT setting. Following this interval, the algorithm moves into its “Armed” state. The criteria for detecting arcing or a downed conductor are:

1. the Expert Arc Detector Algorithm’s output reaches a high level enough times, and
2. its high level was last reached when the algorithm’s state was “Armed”.

The “Arcing Sensitivity” setting determines what level constitutes a “high” output from the Expert Arc Detector Algorithm, and the number that constitutes what “enough times” means. If these criteria are met, the algorithm temporarily moves to either the “Arcing” state or the “Downed Conductor” state, the difference being determined by whether or not there was a
The Hi-Z settings are described below:

- **HI-Z SOURCE**: Selects the source for the RMS currents and voltages used in Hi-Z algorithms. The source should include currents from the 8F/8G CT module and appropriate voltages. If the source does not include voltages, Voltage Supervision is disabled.

- **HI-Z ARCING SENSITIVITY**: This setting establishes the belief-in-arcing confidence level at which the Hi-Z element will recognize arcing and the number of times the algorithm must conform its belief in arcing before it produces an output. The range is 1 to 10, where 10 is the most sensitive and 1 is the least sensitive setting.

  A higher setting would be suitable for a very quiet, well-behaved power system. An initial setting of 5 is suggested if the user has no previous experience with the Hi-Z element.

- **HI-Z PHASE EVENT COUNT**: Specifies how many individual belief-in-arcing indications for a phase current must be counted in a specified time period before it is determined that an arcing-suspected event exists. These belief-in-arcing indications are detected by arc detection algorithms (energy and randomness) for a specific set of non-fundamental frequency component energies. This setting affects only the Hi-Z Arcing Suspected outputs.

- **HI-Z GROUND EVENT COUNT**: Specifies how many individual belief-in-arcing indications for a ground/neutral current must be counted in a specified time period before it is determined that an arcing-suspected event exists. These belief-in-arcing indications are detected by arc detection algorithms (energy and randomness) for a specific set of non-fundamental frequency component energies. This setting affects only the Hi-Z Arcing Suspected outputs.

- **HI-Z EVENT COUNT TIME**: Specifies the time (in minutes) over which the relay monitors long-term, sporadic, arcing events for determination of an arcing-suspected event. This setting affects only the Hi-Z Arcing Suspected outputs.

- **HI-Z OC PROTECTION COORD TIMEOUT**: This setting coordinates between the Hi-Z element and conventional feeder overcurrent protection. A downed conductor or an arcing, intact conductor will not be indicated before the expiration of this timeout, which begins when the Hi-Z element detects a trigger condition (i.e. loss of load, high rate of change, overcurrent, breaker open, or high belief-in-arcing confidence). Note that this is a minimum operating time; the actual operating time will depend on the fault characteristics and will likely be significantly longer than this setting.

  This value should be such that the conventional feeder overcurrent protection is given an opportunity to operate before the timeout expires. It is recommended that this timeout value not exceed 30 seconds, because arcing fault current often diminishes as the fault progresses, making the fault more difficult to detect with increasing time. After the timeout has expired, at least one additional arc burst must occur in order for the Hi-Z element to proceed with its analysis.

- **HI-Z PHASE OC MIN PICKUP**: Phase overcurrent minimum pickup indicates the level at which the Hi-Z element considers a phase current to be an overcurrent condition. The Hi-Z detection algorithms will ignore all data as long as an overcurrent condition exists on the system, because it is assumed that conventional feeder overcurrent protection will clear an overcurrent fault. It is recommended that this setting is above the maximum load current.

- **HI-Z NEUTRAL OC MIN PICKUP**: Neutral overcurrent minimum pickup indicates the level at which the Hi-Z element considers a neutral current to be an overcurrent condition. The Hi-Z detection algorithms will ignore all data as long as an overcurrent condition exists on the system, because it is assumed that conventional feeder overcurrent protection will clear an overcurrent fault. It is recommended that this setting is above the maximum 3Io (residual) current due to unbalanced loading.

- **HI-Z PHASE RATE OF CHANGE**: Establishes a threshold for determining when a high rate-of-change event occurs on a phase RMS current. An extremely high rate of change is not characteristic of most high impedance faults; it is more indicative of a low impedance fault or of the inrush of breaker closing. The inrush current produces substantial variations in the harmonics used by the high impedance algorithms. Therefore these algorithms ignore all data for several seconds following a high rate-of-change event that exceeds this setting.

  The RMS currents in the Hi-Z algorithms are calculated over a two-cycle time window. The rate-of-change is calculated as the difference between two consecutive two-cycle RMS readings. The recommended setting is 150 A per two-cycle interval. The setting is given in primary amperes.
• **HI-Z NEUTRAL RATE OF CHANGE**: Establishes a threshold for determining when a high rate-of-change event occurs on a neutral RMS current. An extremely high rate of change is not characteristic of most high impedance faults; it is more indicative of a breaker closing, causing associated inrush. The inrush current produces substantial variations in the harmonics used by the high impedance algorithms. Therefore, these algorithms ignore all data for several seconds following a high rate-of-change event exceeding this setting.

The RMS currents in the Hi-Z algorithms are calculated over a two-cycle time window. The rate-of-change is calculated as the difference between two consecutive two-cycle RMS readings. The recommended setting is 150 A per two-cycle interval. **The setting is given in primary amperes.**

• **HI-Z LOSS OF LOAD THRESHOLD**: Establishes the loss of load level used as an indication of a downed conductor. A Loss of Load flag is set if the Hi-Z algorithms detect a percentage drop in phase current between two successive two-cycle RMS values that equals or exceeds the Loss of Load Threshold. The amount the phase current must decrease between successive two-cycle RMS values is based on this setting times the recent average phase current level. The range is 5 to 100%; 5% being the most sensitive.

• **HI-Z 3-PHASE EVENT THRESHOLD**: Establishes the level at which the Hi-Z element characterizes a sudden three-phase current increase as a three-phase event. The Hi-Z detection algorithms ignore the data generated by a large three-phase event. The recommended setting is 25 A (primary).

• **HI-Z VOLTAGE SUPV THRESHOLD**: In the event that a fault simultaneously occurs on two adjacent feeders (line voltage from the same bus), the drop in line voltage will cause a subsequent drop in load current. This function will block the Loss of Load flag from being set while the voltage is depressed. Thus, if the voltage level drops by a percentage greater than this threshold in successive two-cycle RMS samples, the Loss of Load flag will be blocked. If the setting is "0", the voltage supervision function will be disabled.

• **HI-Z VOLTAGE SUPV DELAY**: This setting adds time delay to the voltage supervision function. Specifically, the Loss of Load flag will continue to be blocked for the number of cycles specified by this setting.

• **HI-Z EVEN HARMONIC RESTRAINT**: This setting determines the level of the even harmonic at which the setting of the overcurrent flags is inhibited. The even harmonic content is evaluated on each phase current as a percentage of that phase's RMS current. The intent is to inhibit the setting of the overcurrent flags if the overcurrent is simply a surge caused by cold-load pickup or other inrush event.

**IMPORTANT NOTE REGARDING INSTALLATION:** The F60 Hi-Z algorithm is adaptive in nature. The algorithm’s internal thresholds gradually adapt to background “noise” on circuits with a moderate to high level of transient activity. For the first three to five days after installation (or after being out-of-service for a significant period), the F60 may identify some of this noise as arcing. This should be taken into account when responding to alarms during these type of operating periods.
Figure 5–87: HI-Z SCHEME LOGIC
c) BREAKER ARCING CURRENT

PATH: SETTINGS ⇒ CONTROL ELEMENTS ⇒ MONITORING ELEMENTS ⇒ BREAKER 1(2) ARCING CURRENT

There is one Breaker Arcing Current element available per CT bank, with a minimum of 2 elements. 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 ms, which is expected to include the total arcing period.

The feature is programmed to perform fault duration calculations. Fault duration is defined as a time between operation of the disturbance detector occurring before initiation of this feature, and reset of an internal low-set overcurrent function. Correction is implemented to account for a non-zero reset time of the overcurrent function.

Breaker arcing currents and fault duration values are available under the ACTUAL VALUES ⇒ RECORDS ⇒ MAINTENANCE ⇒ BREAKER 1(2) menus.

- **BKR 1(2) ARC AMP INT-A(C):** Select the same output operands that are configured to operate the output relays used to trip the breaker. In three-pole tripping applications, the same operand should be configured to initiate arcing current calculations for poles A, B and C of the breaker. In single-pole tripping applications, per-pole tripping operands should be configured to initiate the calculations for the poles that are actually tripped.

- **BKR 1(2) 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(2) ARC AMP LIMIT:** Selects the threshold value above which the output operand is set.
5.6 CONTROL ELEMENTS

**Figure 5–88: ARcing CURRENT MEASUREMENT**

- **Initiate**
- **Breaker Contacts Part**
- **Arc Extinguished**

Total Area = Breaker Arcing Current (kA·cycle)

- Programmable Start Delay
- Start Integration
- Stop Integration

**Figure 5–89: BREAKER ARCING CURRENT SCHEME LOGIC**

- **Breaker 1 Arcing Amp Function**
- **Breaker 1 Arcing Amp Block**
- **Breaker 1 Arcing Amp Init A**
- **Breaker 1 Arcing Amp Init B**
- **Breaker 1 Arcing Amp Init C**
- **Breaker 1 Arcing Amp Limit**

- **Clear Breaker 1 Arcing Amps**
- **Set All To Zero**

- **Select Highest Value**
- **Add to Accumulator**
- **Set Value**

**Command**: Set All To Zero
**Actuator**: Arc Extinguisher

**Operands**:
- **BKR 1 Operating Time A**
- **BKR 1 Operating Time B**
- **BKR 1 Operating Time C**

**FLEXLOGIC OPERANDS**

- **Enabled = 1**
- **Disabled = 0**

- **AND**
- **OR**

**Settling Time**

- **100 ms**
- **2**
- **2**

- **CA Cycle**
- **AC Cycle**
- **DC Cycle**

- **KA Cycle Limit**

**Setting**: Breaker 1 Arcing Amp Delay: 100 ms

**ACTIVITY**:
- **Selecting Highest Value**
- **Add to Accumulator**
- **Set Value**

**F60 Feeder Management Relay**

GE MultiLin
The detection of the breaker flashover is based on the following condition:

1. Breaker open,
2. Voltage drop measured from either side of the breaker during the flashover period,
3. Voltage difference drop, and
4. Measured flashover current through the breaker.

Furthermore, the scheme is applicable for cases where either one or two sets of three-phase voltages are available across the breaker.
THREE VT BREAKER FLASHOVER APPLICATION

When only one set of VTs is available across the breaker, the **BRK FLSHOWR SIDE 2 SRC** setting should be “None”. To detect an open breaker condition in this application, the scheme checks if the per-phase voltages were recovered (picked up), the status of the breaker is open (contact input indicating the breaker status is off), and no flashover current is flowing. A contact showing the breaker status must be provided to the relay. The voltage difference will not be considered as a condition for open breaker in this part of the logic.

**NOTE**

Voltages must be present prior to flashover conditions. If the three VTs are placed after the breaker on the line (or feeder), and the downstream breaker is open, the measured voltage would be zero and the flashover element will not be initiated.

The flashover detection will reset if the current drops back to zero, the breaker closes, or the selected FlexLogic™ operand for supervision changes to high. Using supervision through the **BRK FLSHOWR SPV** setting is recommended by selecting a trip operand that will not allow the flashover element to pickup prior to the trip.

The flashover detection can be used for external alarm, re-tripping the breaker, or energizing the lockout relay.

Consider the following configuration:

![Diagram](image.png)

The source 1 (SRC1) phase currents are feeder CTs and phase voltages are bus VTs, and Contact Input 1 is set as Breaker 52a contact. The conditions prior to flashover detection are:

1. 52a status = 0
2. VAg, VBg, or VCg is greater than the pickup setting
3. IA, IB, IC = 0; no current flows through the breaker
4. \( \Delta VA \) is greater than pickup (not applicable in this scheme)

The conditions at flashover detection are:

1. 52a status = 0
2. VAg, VBg, or VCg is lower than the pickup setting
3. IA, IB, or IC is greater than the pickup current flowing through the breaker
4. \( \Delta VA \) is greater than pickup (not applicable in this scheme)

SIX VT BREAKER FLASHOVER APPLICATION

The per-phase voltage difference approaches zero when the breaker is closed. The is well below any typical minimum pickup voltage. Select the level of the **BRK 1(2) FLSHOWR DIFF V PKP** setting to be less than the voltage difference measured across the breaker when the close or open breaker resistors are left in service. Prior to flashover, the voltage difference is larger than **BRK 1(2) FLSHOWR DIFF V PKP** (applies to either the difference between two live voltages per phase or when the voltage from one side of the breaker has dropped to zero – line de-energized), at least one per-phase voltage is larger than the **BRK 1(2) FLSHOWR V PKP** setting, and no current flows through the breaker poles. During breaker flashover, the per-phase voltages from both sides of the breaker drops below the pickup value defined by the **BRK 1(2) FLSHOWR V PKP** setting, the voltage difference drops below the pickup setting, and flashover current is detected. These flashover conditions initiate FlexLogic™ pickup operands and start the **BRK 1(2) FLSHOWR PKP DELAY** timer.

This application do not require detection of breaker status via a 52a contact, as it uses a voltage difference larger than the **BRK 1(2) FLSHOWR DIFF V PKP** setting. However, monitoring the breaker contact will ensure scheme stability.
Consider the following configuration:

The source 1 (SRC1) phase currents are CTs and phase voltages are bus VTs. The source 2 (SRC2) phase voltages are line VTs. Contact Input 1 is set as Breaker 52a contact (optional).

The conditions prior to flashover detection are:
1. $\Delta V_A$ is greater than pickup
2. $V_{Ag}$, $V_{Bg}$, or $V_{Cg}$ is greater than the pickup setting
3. $I_A$, $I_B$, $I_C = 0$; no current flows through the breaker
4. 52a status = 0 (optional)

The conditions at flashover detection are:
1. $\Delta V_A$ is less than pickup
2. $V_{Ag}$, $V_{Bg}$, or $V_{Cg}$ is lower than the pickup setting
3. $I_A$, $I_B$, or $I_C$ is greater than the pickup current flowing through the breaker
4. 52a status = 0 (optional)

The element is operational only when phase-to-ground voltages are connected to relay terminals. The flashover element will not operate if delta voltages are applied.

The Breaker Flashover settings are described below.

- **BRK FLSHOVR SIDE 1 SRC**: This setting specifies a signal source used to provide three-phase voltages and three-phase currents from one side of the current breaker. The source selected as a setting and must be configured with breaker phase voltages and currents, even if only 3 VTs are available across the breaker.

- **BRK FLSHOVR SIDE 2 SRC**: This setting specifies a signal source used to provide another set of three-phase voltages whenever six (6) VTs are available across the breaker.

- **BRK STATUS CLSD A(C)**: These settings specify FlexLogic™ operands to indicate the open status of the breaker. A separate FlexLogic™ operand can be selected to detect individual breaker pole status and provide flashover detection. The recommended setting is 52a breaker contact or another operand defining the breaker poles open status.

- **BRK FLSHOVR V PKP**: This setting specifies a pickup level for the phase voltages from both sides of the breaker. If 6 VTs are available, opening the breaker leads to two possible combinations – live voltages from only one side of the breaker, or live voltages from both sides of the breaker. Either case will set the scheme ready for flashover detection upon detection of voltage above the selected value. Set **BRK FLSHOVR V PKP** to 85 to 90% of the nominal voltage.

- **BRK FLSHOVR DIFF V PKP**: This setting specifies a pickup level for the phase voltage difference when two VTs per phase are available across the breaker. The pickup voltage difference should be below the monitored voltage difference when close or open breaker resistors are left in service. The setting is selected as primary volts difference between the sources.

- **BRK FLSHOVR AMP PKP**: This setting specifies the normal load current which can flow through the breaker. Depending on the flashover protection application, the flashover current can vary from levels of the charging current when the line is de-energized (all line breakers open), to well above the maximum line (feeder) load (line/feeder connected to load).

- **BRK FLSHOVR SPV A(C)**: This setting specifies a FlexLogic™ operand (per breaker pole) that supervises the operation of the element per phase. Supervision can be provided by operation of other protection elements, breaker failure, and close and trip commands. A 6-cycle time delay applies after the selected FlexLogic™ operand resets.
• **BRK FLSHOVR PKP DELAY**: This setting specifies the time delay to operate after a pickup condition is detected.

**Figure 5–90: BREAKER FLASHOVER SCHEME LOGIC**

e) **VT FUSE FAILURE**

PATH: SETTINGS -> CONTROL ELEMENTS -> MONITORING ELEMENTS -> VT FUSE FAILURE 1(2)

**VT FUSE FAILURE 1**

**FUNCTION:** Disabled

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:

Class A: Loss of one or two phases.
Class B: Loss of all three phases.

Different means of detection are required for each class. An indication of Class A failures is a significant level of negative sequence voltage, whereas an indication of Class B failures is when positive sequence current is present and there is an insignificant amount of positive sequence voltage. These noted indications of fuse failure could also be present when faults are present on the system, so a means of detecting faults and inhibiting fuse failure declarations during these events is provided. Once the fuse failure condition is declared, it will be sealed-in until the cause that generated it disappears.

An additional condition is introduced to inhibit a fuse failure declaration when the monitored circuit is de-energized; positive sequence voltage and current are both below threshold levels.

The **VT FUSE FAILURE 1(2) FUNCTION** setting enables/disables the fuse failure feature for each source.
5 SETTINGS

5.6 CONTROL ELEMENTS

5.6.12 COLD LOAD PICKUP

There are two (2) identical Cold Load Pickup features available, numbered 1 and 2. This feature can be used to change protection element settings when (by changing to another settings group) a cold load condition is expected to occur. A cold load condition can be caused by a prolonged outage of the load, by opening of the circuit breaker, or by a loss of supply even if the breaker remains closed. Upon the return of the source, the circuit will experience inrush current into connected transformers, accelerating currents into motors, and simultaneous demand from many other loads because the normal load diversity has been lost. During the cold load condition, the current level can be above the pickup setting of some protection elements, so this feature can be used to prevent the tripping that would otherwise be caused by the normal settings.
Without historical data on a particular feeder, some utilities assume an initial cold load current of about 500% of normal load, decaying to 300% after 1 second, 200% after 2 seconds, and 150% after 3 seconds.

There are two methods of initiating the operation of this feature.

The first initiation method is intended to automatically respond to a loss of the source to the feeder, by detecting that all phase currents have declined to zero for some time. When zero current on all phases has been detected, a timer is started. This timer is set to an interval after which it is expected the normal load diversity will have been lost, so setting groups are not changed for short duration outages. After the delay interval, the output operand is set.

The second initiation method is intended to automatically respond to an event that will set an operand, such as an operator-initiated virtual input. This second method of initiation sets the output operand immediately.

Both initiating inputs can be inhibited by a blocking input. Once cold load pickup is in operation, the output operand will remain set until at least one phase of the load has returned to a level above 2% of CT nominal for the interval programmed by the **ON-LOAD TIME BEFORE RESET** setting has expired. The reset delay interval is intended to be set to a period until the feeder load has decayed to normal levels, after which other features may be used to switch setting groups.
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 IP X Off corresponds to contact input “X” being open. The CONTACT INPUT DEBNECE 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 F60 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 5–94: INPUT CONTACT DEBOUNCING MECHANISM AND TIME-STAMPING SAMPLE TIMING](image)

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.
There are 64 virtual inputs that can be individually programmed to respond to input signals from the keypad (Commands menu) and communications protocols. 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.

If the VIRTUAL INPUT x FUNCTION is 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 operates as shown on the logic diagram and generates output FlexLogic™ operands in response to received input signals and the applied settings.

There are two types of operation: Self-Reset and Latched. If VIRTUAL INPUT x TYPE is “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.

The “Self-Reset” operating mode 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 likely have to be lengthened in time. A FlexLogic™ timer with a delayed reset can perform this function.

Figure 5–95: VIRTUAL INPUTS SCHEME LOGIC
### 5.7.3 CONTACT OUTPUTS

#### a) DIGITAL OUTPUTS

**PATH: SETTINGS ➔ INPUTS/OUTPUTS ➔ CONTACT OUTPUTS ➔ CONTACT OUTPUT H1**

<table>
<thead>
<tr>
<th>CONTACT OUTPUT H1 ID</th>
<th>Range: Up to 12 alphanumeric characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cont Op 1</td>
<td></td>
</tr>
</tbody>
</table>

**OUTPUT H1 OPERATE:** Off  
**OUTPUT H1 SEAL-IN:** Off  
**CONTACT OUTPUT H1 EVENTS:** Enabled

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.

For 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 the 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 F60 using the ‘Cont Op 1 IOn’ FlexLogic™ operand to seal-in the contact output as follows:

- CONTACT OUTPUT H1 ID: “Cont Op 1”
- OUTPUT H1 OPERATE: any suitable FlexLogic™ operand
- OUTPUT H1 SEAL-IN: “Cont Op 1 IOn”
- CONTACT OUTPUT H1 EVENTS: “Enabled”

#### b) LATCHING OUTPUTS

**PATH: SETTINGS ➔ INPUTS/OUTPUTS ➔ CONTACT OUTPUTS ➔ CONTACT OUTPUT H1a**

<table>
<thead>
<tr>
<th>OUTPUT H1a ID</th>
<th>Range: Up to 12 alphanumeric characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-Cont Op 1</td>
<td></td>
</tr>
</tbody>
</table>

**OUTPUT H1a OPERATE:** Off  
**OUTPUT H1a RESET:** Off  
**OUTPUT H1a TYPE:** Operate-dominant  
**OUTPUT H1a EVENTS:** Disabled

MESSAGE

MESSAGE

MESSAGE

MESSAGE

MESSAGE
The F60 latching output contacts are mechanically bi-stable and controlled by two separate (open and close) coils. As such they retain their position even if the relay is not powered up. The relay recognizes all latching output contact cards and populates the setting menu accordingly. On power up, the relay reads positions of the latching contacts from the hardware before executing any other functions of the relay (such as protection and control features or FlexLogic™).

The latching output modules, either as a part of the relay or as individual modules, are shipped from the factory with all latching contacts opened. It is highly recommended to double-check the programming and positions of the latching contacts when replacing a module.

Since the relay asserts the output contact and reads back its position, it is possible to incorporate self-monitoring capabilities for the latching outputs. If any latching outputs exhibits a discrepancy, the LATCHING OUTPUT ERROR self-test error is declared. The error is signaled by the LATCHING OUT ERROR FlexLogic™ operand, event, and target message.

• OUTPUT H1a OPERATE: This setting specifies a FlexLogic™ operand to operate the ‘close coil’ of the contact. The relay will seal-in this input to safely close the contact. Once the contact is closed and the RESET input is logic 0 (off), any activity of the OPERATE input, such as subsequent chattering, will not have any effect. With both the OPERATE and RESET inputs active (logic 1), the response of the latching contact is specified by the OUTPUT H1A TYPE setting.

• OUTPUT H1a RESET: This setting specifies a FlexLogic™ operand to operate the ‘trip coil’ of the contact. The relay will seal-in this input to safely open the contact. Once the contact is opened and the OPERATE input is logic 0 (off), any activity of the RESET input, such as subsequent chattering, will not have any effect. With both the OPERATE and RESET inputs active (logic 1), the response of the latching contact is specified by the OUTPUT H1A TYPE setting.

• OUTPUT H1a TYPE: This setting specifies the contact response under conflicting control inputs; that is, when both the OPERATE and RESET signals are applied. With both control inputs applied simultaneously, the contact will close if set to “Operate-dominant” and will open if set to “Reset-dominant”.

Application Example 1:

A latching output contact H1a is to be controlled from two user-programmable pushbuttons (buttons number 1 and 2). The following settings should be applied.

Program the Latching Outputs by making the following changes in the SETTINGS ➔ INPUTS/OUTPUTS ➔ CONTACT OUTPUTS ➔ CONTACT OUTPUT H1a menu (assuming an H4L module):

OUTPUT H1a OPERATE: “PUSHBUTTON 1 ON”
OUTPUT H1a RESET: “PUSHBUTTON 2 ON”

Program the pushbuttons by making the following changes in the PRODUCT SETUP ➔ USER-PROGRAMMABLE PUSHBUTTONS ➔ USER PUSHBUTTON 1 and USER PUSHBUTTON 2 menus:

PUSHBUTTON 1 FUNCTION: “Self-reset”
PUSHBTN 1 DROP-OUT TIME: “0.00 s”
PUSHBUTTON 2 FUNCTION: “Self-reset”
PUSHBTN 2 DROP-OUT TIME: “0.00 s”

Application Example 2:

A relay, having two latching contacts H1a and H1c, is to be programmed. The H1a contact is to be a Type-a contact, while the H1c contact is to be a Type-b contact (Type-a means closed after exercising the operate input; Type-b means closed after exercising the reset input). The relay is to be controlled from virtual outputs: VO1 to operate and VO2 to reset.

Program the Latching Outputs by making the following changes in the SETTINGS ➔ INPUTS/OUTPUTS ➔ CONTACT OUTPUTS ➔ CONTACT OUTPUT H1a and CONTACT OUTPUT H1c menus (assuming an H4L module):

OUTPUT H1a OPERATE: “VO1”
OUTPUT H1a RESET: “VO2”
OUTPUT H1c OPERATE: “VO2”
OUTPUT H1c RESET: “VO1”

Since the two physical contacts in this example are mechanically separated and have individual control inputs, they will not operate at exactly the same time. A discrepancy in the range of a fraction of a maximum operating time may occur. Therefore, a pair of contacts programmed to be a multi-contact relay will not guarantee any specific sequence of operation (such as make before break). If required, the sequence of operation must be programmed explicitly by delaying some of the control inputs as shown in the next application example.

Application Example 3:

A make before break functionality must be added to the preceding example. An overlap of 20 ms is required to implement this functionality as described below:
Write the following FlexLogic™ equation (EnerVista UR Setup example shown):

![FlexLogic Equation Editor]

Both timers (Timer 1 and Timer 2) should be set to 20 ms pickup and 0 ms dropout.

Program the Latching Outputs by making the following changes in the SETTINGS ➔ INPUTS/OUTPUTS ➔ CONTACT OUTPUTS ➔ CONTACT OUTPUT H1a and CONTACT OUTPUT H1c menus (assuming an H4L module):

OUTPUT H1a OPERATE: "VO1"
OUTPUT H1a RESET: "VO4"
OUTPUT H1c OPERATE: "VO2"
OUTPUT H1c RESET: "VO3"

Application Example 4:
A latching contact H1a is to be controlled from a single virtual output VO1. The contact should stay closed as long as VO1 is high, and should stay opened when VO1 is low. Program the relay as follows.

Write the following FlexLogic™ equation (EnerVista UR Setup example shown):

![FlexLogic Equation Editor]

Program the Latching Outputs by making the following changes in the SETTINGS ➔ INPUTS/OUTPUTS ➔ CONTACT OUTPUTS ➔ CONTACT OUTPUT H1a menu (assuming an H4L module):

OUTPUT H1a OPERATE: "VO1"
OUTPUT H1a RESET: "VO2"

5.7.4 VIRTUAL OUTPUTS

**PATH: SETTINGS ➔ INPUTS/OUTPUTS ➔ VIRTUAL OUTPUTS ➔ VIRTUAL OUTPUT 1 (96)**

- **VIRTUAL OUTPUT 1 ID**: Virt Op 1
- **VIRTUAL OUTPUT 1 EVENTS**: Disabled

There are 96 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:

VIRTUAL OUTPUT 1 ID: "Trip"
VIRTUAL OUTPUT 1 EVENTS: "Disabled"
5 SETTINGS

5.7 INPUTS/OUTPUTS

5.7.5 REMOTE DEVICES

a) REMOTE INPUTS/OUTPUTS OVERVIEW

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

The IEC 61850 specification requires that communications between devices be implemented on Ethernet. For UR-series relays, Ethernet communications is provided only all CPU modules except type 9E.

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

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

Both GSSE and GOOSE messages are designed to be short, reliable, and high priority. GOOSE messages have additional advantages over GSSE messages due to their support of VLAN (virtual LAN) and Ethernet priority tagging functionality. The GSSE message structure contains space for 128 bit pairs representing digital point state information. The IEC 61850 specification provides 32 “DNA” bit pairs that represent the state of two pre-defined events and 30 user-defined events. All remaining bit pairs are “UserSt” bit pairs, which are status bits representing user-definable events. The F60 implementation provides 32 of the 96 available UserSt bit pairs.

The IEC 61850 specification includes features that are used to cope with the loss of communication between transmitting and receiving devices. Each transmitting device will send a GSSE/GOOSE message upon a successful power-up, when the state of any included point changes, or after a specified interval (the default update time) if a change-of-state has not occurred. The transmitting device also sends a ‘hold time’ which is set greater than three times the programmed default time required by the receiving device.

Receiving devices are constantly monitoring the communications network for messages they require, as recognized by the identification of the originating device carried in the message. Messages received from remote devices include the message time allowed to live. The receiving relay sets a timer assigned to the originating device to this time interval, and if it has not received another message from this device at time-out, the remote device is declared to be non-communicating, so it will use the programmed default state for all points from that specific remote device. If a message is received from a remote device before the time allowed to live expires, all points for that device are updated to the states contained in the message and the hold timer is restarted. The status of a remote device, where “Offline” indicates non-communicating, can be displayed.

The remote input/output facility provides for 32 remote inputs and 64 remote outputs.

b) LOCAL DEVICES: ID OF DEVICE FOR TRANSMITTING GSSE MESSAGES

In a F60 relay, the device ID that identifies the originator of the message is programmed in the SETTINGS ⇒ PRODUCT SETUP ⇒ INSTALLATION ⇒ RELAY NAME setting.

c) REMOTE DEVICES: ID OF DEVICE FOR RECEIVING GSSE MESSAGES

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ REMOTE DEVICES ⇒ REMOTE DEVICE 1(16)

- Remote Device 1 ID: Remote Device 1
  - Range: up to 20 alphanumeric characters
- VLAN ID: 0
  - Range: 0 to 4095 in steps of 1
- ETENP ID: 0
  - Range: 0 to 16383 in steps of 1
Sixteen remote devices, numbered from 1 to 16, can be selected for setting purposes. A receiving relay must be programmed to capture messages from only those originating remote devices of interest. This setting is used to select specific remote devices by entering (bottom row) the exact identification (ID) assigned to those devices.

The `REMOTE DEVICE 1(16) VLAN ID` and `REMOTE DEVICE 1(16) ETYP APPID` settings are only used with GOOSE messages; they are not applicable to GSSE messages. The `REMOTE DEVICE 1(16) VLAN ID` setting identifies the virtual LAN on which the remote device is sending the GOOSE message. The `REMOTE DEVICE 1(16) ETYP APPID` setting identifies the Ethernet application identification in the GOOSE message. These settings should match the corresponding settings on the sending device.

### 5.7.6 REMOTE INPUTS

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

The `REMOTE INPUT 1 ID` setting allows the user to assign descriptive text to the remote input. The `REMOTE IN 1 DEVICE` setting selects the number (1 to 16) of the remote device which originates the required signal, as previously assigned to the remote device via the setting `REMOTE DEVICE NN ID` (see the Remote Devices section). `REMOTE IN 1 BIT PAIR` selects the specific bits of the GSSE/GOOSE message required.

The `REMOTE IN 1 DEFAULT STATE` setting selects the logic state for this point if the local relay has just completed startup or the remote device sending the point is declared to be non-communicating. The following choices are available:

- Setting `REMOTE IN 1 DEFAULT STATE` to “On” value defaults the input to Logic 1.
- Setting `REMOTE IN 1 DEFAULT STATE` to "Off" value defaults the input to Logic 0.
- Setting `REMOTE IN 1 DEFAULT STATE` to “Latest/On” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to Logic 1. When communication resumes, the input becomes fully operational.
- Setting `REMOTE IN 1 DEFAULT STATE` to “Latest/Off” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to Logic 0. When communication resumes, the input becomes fully operational.

For additional information on GSSE/GOOSE messaging, refer to the Remote Devices section in this chapter.
5 SETTINGS

5.7 INPUTS/OUTPUTS

5.7.7 REMOTE OUTPUTS

a) DNA BIT PAIRS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ REMOTE OUTPUTS DNA BIT PAIRS ⇒ REMOTE OUTPUTS DNA-1(32) BIT PAIR

<table>
<thead>
<tr>
<th>DNA-1 BIT PAIR</th>
<th>DNA-1 OPERAND: Off</th>
<th>DNA-1 EVENTS: Disabled</th>
</tr>
</thead>
</table>

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

Table 5–23: IEC 61850 DNA ASSIGNMENTS

<table>
<thead>
<tr>
<th>DNA</th>
<th>IEC 61850 DEFINITION</th>
<th>FLEXLOGIC™ OPERAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Test</td>
<td>IEC 61850 TEST MODE</td>
</tr>
<tr>
<td>2</td>
<td>ConfRev</td>
<td>IEC 61850 CONF REV</td>
</tr>
</tbody>
</table>

b) USERST BIT PAIRS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ REMOTE OUTPUTS USERST BIT PAIRS ⇒ REMOTE OUTPUTS USERST-1(32) BIT PAIR

<table>
<thead>
<tr>
<th>USERST-1 BIT PAIR</th>
<th>USERST-1 OPERAND: Off</th>
<th>USERST-1 EVENTS: Disabled</th>
</tr>
</thead>
</table>

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

The following setting represents the time between sending GSSE/GOOSE messages when there has been no change of state of any selected digital point. This setting is located in the PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ IEC 61850 PROTOCOL ⇒ GSSE/GOOSE CONFIGURATION settings menu.

| DEFAULT GSSE/GOOSE UPDATE TIME: 60 s |

Range: 1 to 60 s in steps of 1

The following setting determines whether remote input/output data is transported using IEC 61850 GSSE or IEC 61850 GOOSE messages. If GOOSE is selected, the VLAN and APPID settings should be set accordingly. If GSSE is selected, the VLAN and APPID settings are not relevant. This setting is located in the PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ IEC 61850 PROTOCOL ⇒ GSSE/GOOSE CONFIGURATION menu.

| REMOTE I/O TRANSFER METHOD: GSSE |

Range: GOOSE, GSSE, None

For more information on GSSE/GOOSE messaging, refer to Remote Inputs/Outputs Overview in the Remote Devices section.
5.7 INPUTS/OUTPUTS

5.7.8 RESETTING

PATH: SETTINGS ➔ INPUTS/OUTPUTS ➔ RESETTING

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 RESET OP FlexLogic™ operand. 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.

5.7.9 DIRECT INPUTS/OUTPUTS

a) DIRECT INPUTS

PATH: SETTINGS ➔ INPUTS/OUTPUTS ➔ DIRECT INPUTS ➔ DIRECT INPUT 1(32)

 These settings specify how the direct input information is processed. The DIRECT INPUT 1 NAME setting allows the user to assign a descriptive name to the direct input. The DIRECT INPUT DEVICE ID represents the source of this direct input. The specified direct input is driven by the device identified here.

The DIRECT INPUT 1 BIT NUMBER is the bit number to extract the state for this direct input. Direct Input x is driven by the bit identified here as DIRECT INPUT 1 BIT NUMBER. This corresponds to the direct output number of the sending device.

The DIRECT INPUT 1 DEFAULT STATE represents the state of the direct input when the associated direct device is offline. The following choices are available:

- Setting DIRECT INPUT 1 DEFAULT STATE to “On” value defaults the input to Logic 1.
- Setting DIRECT INPUT 1 DEFAULT STATE to “Off” value defaults the input to Logic 0.
- Setting DIRECT INPUT 1 DEFAULT STATE to “Latest/On” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to Logic 1. When communication resumes, the input becomes fully operational.
- Setting DIRECT INPUT 1 DEFAULT STATE to “Latest/Off” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to Logic 0. When communication resumes, the input becomes fully operational.
**b) DIRECT OUTPUTS**

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ DIRECT OUTPUTS ⇒ DIRECT OUTPUT 1(32)

- **DIRECT OUTPUT 1**
  - **DIRECT OUT 1 NAME:** Dir Out 1
  - **DIRECT OUT 1 OPERAND:** Off
  - **DIRECT OUTPUT 1 EVENTS:** Disabled

The **DIRECT OUT 1 NAME** setting allows the user to assign a descriptive name to the direct output. The **DIR OUT 1 OPERAND** determines the state of this direct output.

**c) APPLICATION EXAMPLES**

The examples introduced in the earlier *Direct Inputs/Outputs* section (part of the *Product Setup* section) direct inputs/outputs are continued below to illustrate usage of the direct inputs and outputs.

**EXAMPLE 1: EXTENDING INPUT/OUTPUT CAPABILITIES OF A F60 RELAY**

Consider an application that requires additional quantities of digital inputs and/or output contacts and/or lines of programmable logic that exceed the capabilities of a single UR-series chassis. The problem is solved by adding an extra UR-series IED, such as the C30, to satisfy the additional inputs/outputs and programmable logic requirements. The two IEDs are connected via single-channel digital communication cards as shown below.

**Figure 5–96: INPUT/OUTPUT EXTENSION VIA DIRECT INPUTS/OUTPUTS**

Assume Contact Input 1 from UR IED 2 is to be used by UR IED 1. The following settings should be applied (Direct Input 5 and bit number 12 are used, as an example):

- **UR IED 1:** DIRECT INPUT 5 DEVICE ID = “2”
  - DIRECT INPUT 5 BIT NUMBER = “12”
- **UR IED 2:** DIRECT OUT 12 OPERAND = “Cont Ip 1 On”

The Cont Ip 1 On operand of UR IED 2 is now available in UR IED 1 as DIRECT INPUT 5 ON.

**EXAMPLE 2: INTERLOCKING BUSBAR PROTECTION**

A simple interlocking busbar protection scheme can be accomplished by sending a blocking signal from downstream devices, say 2, 3 and 4, to the upstream device that monitors a single incomer of the busbar, as shown in the figure below.

**Figure 5–97: SAMPLE INTERLOCKING BUSBAR PROTECTION SCHEME**
5.7 INPUTS/OUTPUTS

Assume that Phase Instantaneous Overcurrent 1 is used by Devices 2, 3, and 4 to block Device 1. If not blocked, Device 1 would trip the bus upon detecting a fault and applying a short coordination time delay.

The following settings should be applied (assume Bit 3 is used by all 3 devices to sent the blocking signal and Direct Inputs 7, 8, and 9 are used by the receiving device to monitor the three blocking signals):

UR IED 2:  DIRECT OUT 3 OPERAND: "PHASE IOC1 OP"
UR IED 3:  DIRECT OUT 3 OPERAND: "PHASE IOC1 OP"
UR IED 4:  DIRECT OUT 3 OPERAND: "PHASE IOC1 OP"
 UR IED 1:  DIRECT INPUT 7 DEVICE ID: "2"
             DIRECT INPUT 7 BIT NUMBER: "3"
             DIRECT INPUT 7 DEFAULT STATE: select "On" for security, select "Off" for dependability
             DIRECT INPUT 8 DEVICE ID: "3"
             DIRECT INPUT 8 BIT NUMBER: "3"
             DIRECT INPUT 8 DEFAULT STATE: select "On" for security, select "Off" for dependability
             DIRECT INPUT 9 DEVICE ID: "4"
             DIRECT INPUT 9 BIT NUMBER: "3"
             DIRECT INPUT 9 DEFAULT STATE: select "On" for security, select "Off" for dependability

Now the three blocking signals are available in UR IED 1 as DIRECT INPUT 7 ON, DIRECT INPUT 8 ON, and DIRECT INPUT 9 ON. Upon losing communications or a device, the scheme is inclined to block (if any default state is set to "On"), or to trip the bus on any overcurrent condition (all default states set to "Off").

EXAMPLE 2: PILOT-AIDED SCHEMES

Consider a three-terminal line protection application shown in the figure below.

**Figure 5–98: THREE-TERMINAL LINE APPLICATION**

Assume the Hybrid Permissive Overreaching Transfer Trip (Hybrid POTT) scheme is applied using the architecture shown below. The scheme output operand HYB POTT TX1 is used to key the permission.

**Figure 5–99: SINGLE-CHANNEL OPEN-LOOP CONFIGURATION**
In the above architecture, Devices 1 and 3 do not communicate directly. Therefore, Device 2 must act as a ‘bridge’. The following settings should be applied:

**UR IED 1:**
- **DIRECT OUT 2 OPERAND:** "HYB POTT TX1"
- **DIRECT INPUT 5 DEVICE ID:** "2"
- **DIRECT INPUT 5 BIT NUMBER:** "2" (this is a message from IED 2)
- **DIRECT INPUT 6 DEVICE ID:** "2"
- **DIRECT INPUT 6 BIT NUMBER:** "4" (effectively, this is a message from IED 3)

**UR IED 3:**
- **DIRECT OUT 2 OPERAND:** "HYB POTT TX1"
- **DIRECT INPUT 5 DEVICE ID:** "2"
- **DIRECT INPUT 5 BIT NUMBER:** "2" (this is a message from IED 2)
- **DIRECT INPUT 6 DEVICE ID:** "2"
- **DIRECT INPUT 6 BIT NUMBER:** "3" (effectively, this is a message from IED 1)

**UR IED 2:**
- **DIRECT INPUT 5 DEVICE ID:** "1"
- **DIRECT INPUT 5 BIT NUMBER:** "2"
- **DIRECT INPUT 6 DEVICE ID:** "3"
- **DIRECT INPUT 6 BIT NUMBER:** "2"
- **DIRECT OUT 2 OPERAND:** "HYB POTT TX1"
- **DIRECT OUT 3 OPERAND:** "DIRECT INPUT 5" (forward a message from 1 to 3)
- **DIRECT OUT 4 OPERAND:** "DIRECT INPUT 6" (forward a message from 3 to 1)

Signal flow between the three IEDs is shown in the figure below:

![Signal Flow Diagram](image-url)

**Figure 5–100: SIGNAL FLOW FOR DIRECT INPUT/OUTPUT EXAMPLE 3**

In three-terminal applications, both the remote terminals must grant permission to trip. Therefore, at each terminal, Direct Inputs 5 and 6 should be ANDed in FlexLogic™ and the resulting operand configured as the permission to trip (HYB POTT RX1 setting).
a) OVERVIEW

The relay provides sixteen teleprotection inputs on communications channel 1 (numbered 1-1 through 1-16) and sixteen teleprotection inputs on communications channel 2 (on two-terminals two-channel and three-terminal systems only, numbered 2-1 through 2-16). The remote relay connected to channels 1 and 2 of the local relay is programmed by assigning FlexLogic™ operands to be sent via the selected communications channel. This allows the user to create distributed protection and control schemes via dedicated communications channels. Some examples are directional comparison pilot schemes and direct transfer tripping. It should be noted that failures of communications channels will affect teleprotection functionality. The teleprotection function must be enabled to utilize the inputs.

b) TELEPROTECTION INPUTS

### PATH: SETTINGS ➔ INPUTS/OUTPUTS ➔ TELEPROTECTION ➔ TELEPROT INPUTS

<table>
<thead>
<tr>
<th>TELEPROT INPUT 1-1</th>
<th>DEFAULT: Off</th>
<th>Range: Off, On, Latest/Off, Latest/On</th>
</tr>
</thead>
<tbody>
<tr>
<td>TELEPROT INPUT 1-16</td>
<td>DEFAULT: Off</td>
<td>Range: Off, On, Latest/Off, Latest/On</td>
</tr>
<tr>
<td>TELEPROT INPUT 2-1</td>
<td>DEFAULT: Off</td>
<td>Range: Off, On, Latest/Off, Latest/On</td>
</tr>
<tr>
<td>TELEPROT INPUT 2-16</td>
<td>DEFAULT: Off</td>
<td>Range: Off, On, Latest/Off, Latest/On</td>
</tr>
</tbody>
</table>

Setting the TELEPROT INPUT ➔ DEFAULT setting to “On” defaults the input to logic 1 when the channel fails. A value of “Off” defaults the input to logic 0 when the channel fails.

The “Latest/On” and “Latest/Off” values freeze the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, then the input defaults to logic 1 for “Latest/On” and logic 0 for “Latest/Off”.

---

**MESSAGE**

The relay provides sixteen teleprotection inputs on communications channel 1 (numbered 1-1 through 1-16) and sixteen teleprotection inputs on communications channel 2 (on two-terminals two-channel and three-terminal systems only, numbered 2-1 through 2-16). The remote relay connected to channels 1 and 2 of the local relay is programmed by assigning FlexLogic™ operands to be sent via the selected communications channel. This allows the user to create distributed protection and control schemes via dedicated communications channels. Some examples are directional comparison pilot schemes and direct transfer tripping. It should be noted that failures of communications channels will affect teleprotection functionality. The teleprotection function must be enabled to utilize the inputs.
c) TELEPROTECTION OUTPUTS

As the following figure demonstrates, processing of the teleprotection inputs/outputs is dependent on the number of communication channels and terminals. On two-terminal two-channel systems, they are processed continuously on each channel and mapped separately per channel. Therefore, to achieve redundancy, the user must assign the same operand on both channels (teleprotection outputs at the sending end or corresponding teleprotection inputs at the receiving end). On three-terminal two-channel systems, redundancy is achieved by programming signal re-transmittal in the case of channel failure between any pair of relays.

---

**Figure 5–101: TELEPROTECTION INPUT/OUTPUT PROCESSING**
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 Chapter 3.

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 above for the first channel of a type 5F transducer module installed in slot H.

The function of the channel may be either “Enabled” or “Disabled”. If “Disabled”, no actual values are created for the channel. An alphanumeric “ID” is assigned to each channel; this ID will be included in the channel actual value, along with the programmed units associated with the parameter measured by the transducer, such as volts, °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 DCMA INPUT H1 RANGE setting specifies the mA DC range of the transducer connected to the input channel.

The DCMA INPUT H1 MIN VALUE and DCMA INPUT H1 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 DCMA INPUT H1 MIN VALUE value is “0” and the DCMA INPUT H1 MAX VALUE value is “250”. Another example would be a watts transducer with a span from –20 to +180 MW; in this case the DCMA INPUT H1 MIN VALUE value would be “–20” and the DCMA INPUT H1 MAX VALUE value “180”. Intermediate values between the min and max values are scaled linearly.
5 SETTINGS

5.8 TRANSDUCER INPUTS/OUTPUTS

5.8.2 RTD INPUTS

PATH: SETTINGS ➔ TRANSDUCER I/O ➔ RTD INPUTS ➔ RTD INPUT H1(W8)

- RTD INPUT H1
- RTD INPUT H1
  FUNCTION: Disabled
  Range: Disabled, Enabled

- RTD INPUT H1 ID:
- RTD Input 1

- RTD INPUT H1 TYPE:
  100Ω Nickel
  Range: 100Ω Nickel, 10Ω Copper, 100Ω Platinum, 120Ω Nickel

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 Chapter 3.

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 configure generation 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 above for the first channel of a type 5C transducer module installed in slot H.

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 channel actual values. It 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.

Actions based on RTD overtemperature, such as trips or alarms, are done in conjunction with the FlexElements™ feature. In FlexElements™, the operate level is scaled to a base of 100°C. For example, a trip level of 150°C is achieved by setting the operate level at 1.5 pu. FlexElement™ operands are available to FlexLogic™ for further interlocking or to operate an output contact directly.

5.8.3 DCMA OUTPUTS

PATH: SETTINGS ➔ TRANSDUCER I/O ➔ DCMA OUTPUTS ➔ DCMA OUTPUT H1(W8)

- DCMA OUTPUT H1
- DCMA OUTPUT H1
  SOURCE: Off
  Range: Off, any analog actual value parameter

- DCMA OUTPUT H1
  RANGE: –1 to 1 mA
  Range: –1 to 1 mA, 0 to 1 mA, 4 to 20 mA

- DCMA OUTPUT H1
  MIN VAL: 0.000 pu
  Range: –90.000 to 90.000 pu in steps of 0.001

- DCMA OUTPUT H1
  MAX VAL: 1.000 pu
  Range: –90.000 to 90.000 pu in steps of 0.001

Hardware and software is provided to generate dcmA signals that allow interfacing with external equipment. Specific hardware details are contained in Chapter 3. The dcmA output channels are arranged in a manner similar to transducer input or CT and VT channels. The user configures individual channels with the settings shown below.

The channels are arranged in sub-modules of two channels, numbered 1 through 8 from top to bottom. On power-up, the relay automatically generates configuration settings for every channel, based on the order code, in the same manner 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.

Both the output range and a signal driving a given output are user-programmable via the following settings menu (an example for channel M5 is shown).
5.8 TRANSDUCER INPUTS/OUTPUTS

The relay checks the driving signal \(x\) in equations below) for the minimum and maximum limits, and subsequently re-scales so the limits defined as \(\text{MIN VAL}\) and \(\text{MAX VAL}\) match the output range of the hardware defined as \(\text{RANGE}\). The following equation is applied:

\[
I_{\text{out}} = \begin{cases} 
I_{\text{min}} & \text{if } x < \text{MIN VAL} \\
I_{\text{max}} & \text{if } x > \text{MAX VAL} \\
k(x - \text{MIN VAL}) + I_{\text{min}} & \text{otherwise}
\end{cases}
\]

(EQ 5.23)

where:
- \(x\) is a driving signal specified by the \(\text{SOURCE}\) setting
- \(I_{\text{min}}\) and \(I_{\text{max}}\) are defined by the \(\text{RANGE}\) setting
- \(k\) is a scaling constant calculated as:

\[
k = \frac{I_{\text{max}} - I_{\text{min}}}{\text{MAX VAL} - \text{MIN VAL}}
\]

(EQ 5.24)

The feature is intentionally inhibited if the \(\text{MAX VAL}\) and \(\text{MIN VAL}\) settings are entered incorrectly, e.g. when \(\text{MAX VAL} - \text{MIN VAL} < 0.1\) pu. The resulting characteristic is illustrated in the following figure.

The \(\text{DCMA OUTPUT H1 MIN VAL}\) and \(\text{DCMA OUTPUT H1 MAX VAL}\) settings are ignored for power factor base units (i.e. if the \(\text{DCMA OUTPUT H1 SOURCE}\) is set to FlexAnalog value based on power factor measurement).

Three application examples are described below.

---

**NOTE**
EXAMPLE 1:
A three phase active power on a 13.8 kV system measured via UR-series relay source 1 is to be monitored by the dcmA H1 output of the range of –1 to 1 mA. The following settings are applied on the relay: CT ratio = 1200:5, VT secondary 115, VT connection is delta, and VT ratio = 120. The nominal current is 800 A primary and the nominal power factor is 0.90. The power is to be monitored in both importing and exporting directions and allow for 20% overload compared to the nominal. The nominal three-phase power is:

\[ P = \sqrt{3} \times 13.8 \, \text{kV} \times 0.8 \, \text{kA} \times 0.9 = 17.21 \, \text{MW} \]  

(EQ 5.25)

The three-phase power with 20% overload margin is:

\[ P_{\text{max}} = 1.2 \times 17.21 \, \text{MW} = 20.65 \, \text{MW} \]  

(EQ 5.26)

The base unit for power (refer to the FlexElements section in this chapter for additional details) is:

\[ P_{\text{BASE}} = 115 \, \text{V} \times 120 \times 1.2 \, \text{kA} = 16.56 \, \text{MW} \]  

(EQ 5.27)

The minimum and maximum power values to be monitored (in pu) are:

\[ \text{minimum power} = \frac{-20.65 \, \text{MW}}{16.56 \, \text{MW}} = -1.247 \, \text{pu}, \quad \text{maximum power} = \frac{20.65 \, \text{MW}}{16.56 \, \text{MW}} = 1.247 \, \text{pu} \]  

(EQ 5.28)

The following settings should be entered:

- DCMA OUTPUT H1 SOURCE: "SRC 1 P"
- DCMA OUTPUT H1 RANGE: "–1 to 1 mA"
- DCMA OUTPUT H1 MIN VAL: "–1.247 pu"
- DCMA OUTPUT H1 MAX VAL: "1.247 pu"

With the above settings, the output will represent the power with the scale of 1 mA per 20.65 MW. The worst-case error for this application can be calculated by superimposing the following two sources of error:

- ±0.5% of the full scale for the analog output module, or \( \pm 0.005 \times (20 \text{–} 1) \times 20.65 \, \text{MW} = \pm 0.207 \, \text{MW} \)
- ±1% of reading error for the active power at power factor of 0.9

For example at the reading of 20 MW, the worst-case error is 0.01 \times 20 \, \text{MW} + 0.207 \, \text{MW} = 0.407 \, \text{MW}.

EXAMPLE 2:

The phase A current (true RMS value) is to be monitored via the H2 current output working with the range from 4 to 20 mA. The CT ratio is 5000:5 and the maximum load current is 4200 A. The current should be monitored from 0 A upwards, allowing for 50% overload.

The phase current with the 50% overload margin is:

\[ I_{\text{max}} = 1.5 \times 4.2 \, \text{kA} = 6.3 \, \text{kA} \]  

(EQ 5.29)

The base unit for current (refer to the FlexElements section in this chapter for additional details) is:

\[ I_{\text{BASE}} = 5 \, \text{kA} \]  

(EQ 5.30)

The minimum and maximum power values to be monitored (in pu) are:

\[ \text{minimum current} = \frac{0 \, \text{kA}}{5 \, \text{kA}} = 0 \, \text{pu}, \quad \text{maximum current} = \frac{6.3 \, \text{kA}}{5 \, \text{kA}} = 1.26 \, \text{pu} \]  

(EQ 5.31)

The following settings should be entered:

- DCMA OUTPUT H2 SOURCE: "SRC 1 Ia RMS"
- DCMA OUTPUT H2 RANGE: "4 to 20 mA"
- DCMA OUTPUT H2 MIN VAL: "0.000 pu"
- DCMA OUTPUT H2 MAX VAL: "1.260 pu"

The worst-case error for this application could be calculated by superimposing the following two sources of error:

- ±0.5% of the full scale for the analog output module, or \( \pm 0.005 \times (20 \text{–} 4) \times 6.3 \, \text{kA} = \pm 0.504 \, \text{kA} \)
- ±0.25% of reading or ±0.1% of rated (whichever is greater) for currents between 0.1 and 2.0 of nominal.
For example, at the reading of 4.2 kA, the worst-case error is \(\max(0.0025 \times 4.2 \text{ kA}, 0.001 \times 5 \text{ kA}) + 0.504 \text{ kA} = 0.515 \text{ kA}\).

**EXAMPLE 3:**

A positive-sequence voltage on a 400 kV system measured via Source 2 is to be monitored by the dcmA H3 output with a range of 0 to 1 mA. The VT secondary setting is 66.4 V, the VT ratio setting is 6024, and the VT connection setting is “Delta”. The voltage should be monitored in the range from 70% to 110% of nominal.

The minimum and maximum positive-sequence voltages to be monitored are:

\[
V_{\text{min}} = 0.7 \times \frac{400 \text{ kV}}{\sqrt{3}} = 161.66 \text{ kV}, \quad V_{\text{max}} = 1.1 \times \frac{400 \text{ kV}}{\sqrt{3}} = 254.03 \text{ kV}
\]  

(EQ 5.32)

The base unit for voltage (refer to the FlexElements section in this chapter for additional details) is:

\[
V_{\text{BASE}} = 0.0664 \text{ kV} \times 6024 = 400 \text{ kV}
\]  

(EQ 5.33)

The minimum and maximum voltage values to be monitored (in pu) are:

\[
\frac{161.66 \text{ kV}}{400 \text{ kV}} = 0.404 \text{ pu}, \quad \frac{254.03 \text{ kV}}{400 \text{ kV}} = 0.635 \text{ pu}
\]  

(EQ 5.34)

The following settings should be entered:

- **DCMA OUTPUT H3 SOURCE**: “SRC 2 V_1 mag”
- **DCMA OUTPUT H3 RANGE**: “0 to 1 mA”
- **DCMA OUTPUT H3 MIN VAL**: “0.404 pu”
- **DCMA OUTPUT H3 MAX VAL**: “0.635 pu”

The limit settings differ from the expected 0.7 pu and 1.1 pu because the relay calculates the positive-sequence quantities scaled to the phase-to-ground voltages, even if the VTs are connected in “Delta” (refer to the Metering Conventions section in Chapter 6), while at the same time the VT nominal voltage is 1 pu for the settings. Consequently the settings required in this example differ from naturally expected by the factor of \(\sqrt{3}\).

The worst-case error for this application could be calculated by superimposing the following two sources of error:

- \(\pm 0.5\% \text{ of the full scale for the analog output module, or } \pm 0.005 \times (1 - 0) \times 254.03 \text{ kV} = \pm 1.27 \text{ kV}\)
- \(\pm 0.5\% \text{ of reading}\)

For example, under nominal conditions, the positive-sequence reads 230.94 kV and the worst-case error is 0.005 \times 230.94 kV + 1.27 kV = 2.42 kV.
The relay provides test settings to verify that functionality using simulated conditions for contact inputs and outputs. The Test Mode is indicated on the relay faceplate by a flashing Test Mode LED indicator.

To initiate the Test mode, the **TEST MODE FUNCTION** setting must be “Enabled” and the **TEST MODE INITIATE** setting must be set to Logic 1. In particular:

- To initiate Test Mode through relay settings, set **TEST MODE INITIATE** to “On”. The Test Mode starts when the **TEST MODE FUNCTION** setting is changed from “Disabled” to “Enabled”.
- To initiate Test Mode through a user-programmable condition, such as FlexLogic™ operand (pushbutton, digital input, communication-based input, or a combination of these), set **TEST MODE FUNCTION** to “Enabled” and set **TEST MODE INITIATE** to the desired operand. The Test Mode starts when the selected operand assumes a Logic 1 state.

When in Test Mode, the F60 remains fully operational, allowing for various testing procedures. In particular, the protection and control elements, FlexLogic™, and communication-based inputs and outputs function normally.

The only difference between the normal operation and the Test Mode is the behavior of the input and output contacts. The former can be forced to report as open or closed or remain fully operational; the latter can be forced to open, close, freeze, or remain fully operational. The response of the digital input and output contacts to the Test Mode is programmed individually for each input and output using the Force Contact Inputs and Force Contact Outputs test functions described in the following sections.

### 5.9.2 FORCE CONTACT INPUTS

The relay digital inputs (contact inputs) could be pre-programmed to respond to the Test Mode in the following ways:

- If set to “Disabled”, the input remains fully operational. It is controlled by the voltage across its input terminals and can be turned on and off by external circuitry. This value should be selected if a given input must be operational during the test. This includes, for example, an input initiating the test, or being a part of a user pre-programmed test sequence.
- If set to “Open”, the input is forced to report as opened (Logic 0) for the entire duration of the Test Mode regardless of the voltage across the input terminals.
- If set to “Closed”, the input is forced to report as closed (Logic 1) for the entire duration of the Test Mode regardless of the voltage across the input terminals.

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 TESTING

5.9.3 FORCE CONTACT OUTPUTS

The relay contact outputs can be pre-programmed to respond to the Test Mode. If set to “Disabled”, the contact output remains fully operational. If operates when its control operand is Logic 1 and will resets when its control operand is Logic 0. If set to “Energize”, the output will close and remain closed for the entire duration of the Test Mode, regardless of the status of the operand configured to control the output contact. If set to “De-energize”, the output will open and remain opened for the entire duration of the Test Mode regardless of the status of the operand configured to control the output contact. If set to “Freeze”, the output retains its position from before entering the Test Mode, regardless of the status of the operand configured to control the output contact.

These settings are applied two ways. First, external circuits may be tested by energizing or de-energizing contacts. Second, by controlling the output contact state, relay logic may be tested and undesirable effects on external circuits avoided.

Example 1: Initiating a Test from User-Programmable Pushbutton 1

The Test Mode should be initiated from User-Programmable Pushbutton 1. The pushbutton will be programmed as “Latched” (pushbutton pressed to initiate the test, and pressed again to terminate the test). During the test, Digital Input 1 should remain operational, Digital Inputs 2 and 3 should open, and Digital Input 4 should close. Also, Contact Output 1 should freeze, Contact Output 2 should open, Contact Output 3 should close, and Contact Output 4 should remain fully operational. The required settings are shown below.

To enable User-Programmable Pushbutton 1 to initiate the Test mode, make the following changes in the SETTINGS \(\rightarrow\) TESTING \(\rightarrow\) TEST MODE menu:

   **TEST MODE FUNCTION:** “Enabled” and **TEST MODE INITIATE:** “PUSHBUTTON 1 ON”

Make the following changes to configure the Contact I/Os. In the SETTINGS \(\rightarrow\) TESTING \(\rightarrow\) FORCE CONTACT INPUTS and FORCE CONTACT OUTPUTS menus, set:

- **FORCE Cont Ip 1:** “Disabled”, **FORCE Cont Ip 2:** “Open”, **FORCE Cont Ip 3:** “Open”, and **FORCE Cont Ip 4:** “Closed”
- **FORCE Cont Op 1:** “Freeze”, **FORCE Cont Op 2:** “De-energized”, **FORCE Cont Op 3:** “Open”, and **FORCE Cont Op 4:** “Disabled”

Example 2: Initiating a Test from User-Programmable Pushbutton 1 or through Remote Input 1

The Test should be initiated locally from User-Programmable Pushbutton 1 or remotely through Remote Input 1. Both the pushbutton and the remote input will be programmed as “Latched”. The required settings are shown below.

Write the following FlexLogic™ equation (EnerVista UR Setup example shown):

```
Set the User Programmable Pushbutton as latching by changing SETTINGS \(\rightarrow\) PRODUCT SETUP \(\rightarrow\) USER-PROGRAMMABLE PUSHBUTTONS \(\rightarrow\) USER PUSHBUTTON 1 \(\rightarrow\) PUSHBUTTON 1 FUNCTION to “Latched”. To enable either Pushbutton 1 or Remote Input 1 to initiate the Test mode, make the following changes in the SETTINGS \(\rightarrow\) TESTING \(\rightarrow\) TEST MODE menu:

**TEST MODE FUNCTION:** “Enabled” and **TEST MODE INITIATE:** “VO1”
```
6 ACTUAL VALUES

6.1 OVERVIEW

6.1.1 ACTUAL VALUES MAIN MENU

- CONTACT INPUTS
  - See page 6-3.
- VIRTUAL INPUTS
  - See page 6-3.
- REMOTE INPUTS
  - See page 6-3.
- TELEPROTECTION
  - 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.
- TELEPROTECTION
  - INPUTS
  - See page 6-4.
- CONTACT OUTPUTS
  - See page 6-4.
- VIRTUAL OUTPUTS
  - See page 6-4.
- REMOTE DEVICES
  - STATUS
  - See page 6-5.
- TELEPROTECTION
  - INPUTS
  - See page 6-4.
- DIGITAL COUNTERS
  - See page 6-6.
- SELECTOR SWITCHES
  - See page 6-6.
- FLEX STATES
  - See page 6-6.
- ETHERNET
  - See page 6-6.
- HIZ STATUS
  - See page 6-7.
- DIRECT INPUTS
  - See page 6-7.
- DIRECT DEVICES
  - STATUS
  - See page 6-8.
- EGD PROTOCOL
  - STATUS
  - See page 6-8.
- TELEPROT CH TESTS
  - See page 6-9.

- SOURCE SRC 1
  - See page 6-13.
- SOURCE SRC 2
  - See page 6-13.
- SENSITIVE
  - DIRECTIONAL POWER
  - See page 6-17.
# 6.1 OVERVIEW

## SYNCHROCHECK
- See page 6-18.

## TRACKING FREQUENCY
- See page 6-18.

## FREQUENCY RATE OF CHANGE
- See page 6-18.

## FLEXELEMENTS
- See page 6-19.

## TRANSDUCER I/O
- See page 6-19.

## DCMA INPUTS
- See page 6-19.

## TRANSDUCER I/O RTD INPUTS
- See page 6-19.

## FAULT REPORTS
- See page 6-20.

## EVENT RECORDS
- See page 6-22.

## OSCILLOGRAPHY
- See page 6-22.

## DATA LOGGER
- See page 6-22.

## MAINTENANCE
- See page 6-23.

## HIZ RECORDS
- See page 6-23.

## MODEL INFORMATION
- See page 6-24.

## FIRMWARE REVISIONS
- See page 6-24.
For status reporting, ‘On’ represents Logic 1 and ‘Off’ represents Logic 0.

### 6.2.1 CONTACT INPUTS

**PATH: ACTUAL VALUES** ➔ **STATUS** ➔ **CONTACT INPUTS**

<table>
<thead>
<tr>
<th>CONTACT INPUTS</th>
<th>Cont Ip 1</th>
<th>Off</th>
</tr>
</thead>
</table>

**MESSAGE**

| Cont Ip xx | Off |

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**

<table>
<thead>
<tr>
<th>VIRTUAL INPUTS</th>
<th>Virt Ip 1</th>
<th>Off</th>
</tr>
</thead>
</table>

**MESSAGE**

| Virt Ip 64 | Off |

The present status of the 64 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. 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**

<table>
<thead>
<tr>
<th>REMOTE INPUTS</th>
<th>Range: On, Off</th>
</tr>
</thead>
</table>

**MESSAGE**

<table>
<thead>
<tr>
<th>REMOTE INPUT 1</th>
<th>Range: On, Off</th>
</tr>
</thead>
</table>

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 STATUS

6.2.4 TELEPROTECTION INPUTS

The present state of teleprotection inputs from communication channels 1 and 2 are shown here. The state displayed will be that of corresponding remote output unless the channel is declared failed.

6.2.5 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.

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

The present state of up to 96 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 ACTUAL VALUES

6.2 STATUS

6.2.7 AUTORECLOSE

PATH: ACTUAL VALUES ⇤ STATUS ⇤ AUTORECLOSE ⇤ AUTORECLOSE 1

The automatic reclosure shot count is shown here.

6.2.8 REMOTE DEVICES

a) 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.

b) 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 GSSE message is sent. This number will rollover to zero when a count of 4,294,967,295 is incremented.
6.2 STATUS

6.2.9 DIGITAL COUNTERS

PATH: ACTUAL VALUES ⇒ STATUS ⇒ 8 DIGITAL COUNTERS ⇒ DIGITAL COUNTERS Counter 1(8)

<table>
<thead>
<tr>
<th>Digital Counters</th>
<th>Counter 1</th>
<th>Accum: 0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Counter 1</td>
<td>Frozen: 0</td>
</tr>
<tr>
<td></td>
<td>Counter 1</td>
<td>Frozen: YYYY/MM/DD HH:MM:SS</td>
</tr>
<tr>
<td></td>
<td>Counter 1</td>
<td>Micros: 0</td>
</tr>
</tbody>
</table>

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.

6.2.10 SELECTOR SWITCHES

PATH: ACTUAL VALUES ⇒ STATUS ⇒ 8 SELECTOR SWITCHES

<table>
<thead>
<tr>
<th>Selector Switches</th>
<th>Selector Switch 1</th>
<th>Position: 0/7</th>
<th>Range: Current Position / 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Selector Switch 2</td>
<td>Position: 0/7</td>
<td>Range: Current Position / 7</td>
</tr>
</tbody>
</table>

The display shows both the current position and the full range. The current position only (an integer from 0 through 7) is the actual value.

6.2.11 FLEX STATES

PATH: ACTUAL VALUES ⇒ STATUS ⇒ 8 FLEX STATES

<table>
<thead>
<tr>
<th>Flex States</th>
<th>Param 1: Off</th>
<th>Range: Off, On</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Param 256: Off</td>
<td>Range: Off, On</td>
</tr>
</tbody>
</table>

There are 256 FlexState bits available. The second line value indicates the state of the given FlexState bit.

6.2.12 ETHERNET

PATH: ACTUAL VALUES ⇒ STATUS ⇒ ETHERNET

<table>
<thead>
<tr>
<th>Ethernet</th>
<th>Primary Link Status: OK</th>
<th>Range: Fail, OK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Secondary Link Status: OK</td>
<td>Range: Fail, OK</td>
</tr>
</tbody>
</table>

These values indicate the status of the primary and secondary Ethernet links.
6 ACTUAL VALUES

6.2 STATUS

6.2.13 HI-Z STATUS

PATH: ACTUAL VALUES \(\rightarrow\) STATUS \(\rightarrow\) HI-Z STATUS

<table>
<thead>
<tr>
<th>HIZ STATUS</th>
<th>HIZ STATUS: NORMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESSAGE</td>
<td>ARC CONFIDENCE A:100</td>
</tr>
<tr>
<td></td>
<td>B:100 C:100 N:100 %</td>
</tr>
</tbody>
</table>

6.2.14 DIRECT INPUTS

PATH: ACTUAL VALUES \(\rightarrow\) STATUS \(\rightarrow\) DIRECT INPUTS

<table>
<thead>
<tr>
<th>DIRECT INPUTS</th>
<th>AVG MSG RETURN TIME CH1: 0 ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESSAGE</td>
<td>UNRETURNED MSG COUNT CH1: 0</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>CRC FAIL COUNT CH1: 0</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>AVG MSG RETURN TIME CH2: 0 ms</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>UNRETURNED MSG COUNT CH2: 0</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>CRC FAIL COUNT CH2: 0</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIRECT INPUT 1: On</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>DIRECT INPUT 32: On</td>
</tr>
</tbody>
</table>

The AVERAGE MSG RETURN TIME is the time taken for direct output messages to return to the sender in a direct input/output ring configuration (this value is not applicable for non-ring configurations). This is a rolling average calculated for the last 10 messages. There are two return times for dual-channel communications modules.

The UNRETURNED MSG COUNT values (one per communications channel) count the direct output messages that do not make the trip around the communications ring. The CRC FAIL COUNT values (one per communications channel) count the direct output messages that have been received but fail the CRC check. High values for either of these counts may indicate a problem with wiring, the communication channel, or the relay(s). The UNRETURNED MSG COUNT and CRC FAIL COUNT values can be cleared using the CLEAR DIRECT I/O COUNTERS command.

The DIRECT INPUT x values represent the state of the x-th direct input.

The UNRETURNED MSG COUNT values (one per communications channel) count the direct output messages that do not make the trip around the communications ring. The CRC FAIL COUNT values (one per communications channel) count the direct output messages that have been received but fail the CRC check. High values for either of these counts may indicate a problem with wiring, the communication channel, or the relay(s). The UNRETURNED MSG COUNT and CRC FAIL COUNT values can be cleared using the CLEAR DIRECT I/O COUNTERS command.

The DIRECT INPUT x values represent the state of the x-th direct input.
6.2 STATUS

6.2.15 DIRECT DEVICES STATUS

DIRECT DEVICES

STATUS

DIRECT DEVICE 1

STATUS: Offline

MESSAGE

DIRECT DEVICE 2

STATUS: Offline

MESSAGE

DIRECT DEVICE 16

STATUS: Offline

These actual values represent the state of direct devices 1 through 16.

6.2.16 EGD PROTOCOL STATUS

a) FAST EXCHANGE

FAST EXCHANGE 1

SIGNATURE: 0

MESSAGE

DATA LENGTH: 0

These values provide information that may be useful for debugging an EGD network. The EGD signature and packet size for the fast EGD exchange is displayed.

b) SLOW EXCHANGE

SLOW EXCHANGE 1

SIGNATURE: 0

MESSAGE

DATA LENGTH: 0

These values provide information that may be useful for debugging an EGD network. The EGD signature and packet size for the slow EGD exchanges are displayed.
### TELEPROTECTION CHANNEL TESTS

**PATH: ACTUAL VALUES ➔ STATUS ➔ TELEPROT CH TESTS**

<table>
<thead>
<tr>
<th>MESSAGE</th>
<th>CHANNEL 1</th>
<th>STATUS: n/a</th>
<th>Range: n/a, FAIL, OK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CHANNEL 1 LOST</td>
<td>PACKETS: 1</td>
<td>Range: 1 to 65535 in steps of 1</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>CHANNEL 2</td>
<td>STATUS: n/a</td>
<td>Range: n/a, FAIL, OK</td>
</tr>
<tr>
<td></td>
<td>CHANNEL 2 LOST</td>
<td>PACKETS: 1</td>
<td>Range: 1 to 65535 in steps of 1</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>VALIDITY OF CHANNEL CONFIGURATION: FAIL</td>
<td></td>
<td>Range: n/a, FAIL, OK</td>
</tr>
</tbody>
</table>

The status information for two channels is shown here.

- **CHANNEL 1(2) STATUS**: This represents the receiver status of each channel. If the value is “OK”, teleprotection is enabled and data is being received from the remote terminal; if the value is “FAIL”, teleprotection enabled and data is not being received from the remote terminal. If “n/a”, teleprotection is disabled.

- **CHANNEL 1(2) LOST PACKETS**: Data is transmitted to the remote terminals in data packets at a rate of 2 packets per cycle. The number of lost packets represents data packets lost in transmission; this count can be reset to 0 through the **COMMANDS ➔ CLEAR RECORDS** menu.

- **VALIDITY OF CHANNEL CONFIGURATION**: This value displays the current state of the communications channel identification check, and hence validity. If a remote relay ID does not match the programmed ID at the local relay, the “FAIL” message will be displayed. The “N/A” value appears if the local relay ID is set to a default value of “0”, the channel is failed, or if the teleprotection inputs/outputs are not enabled.
6.3 METERING

6.3.1 METERING CONVENTIONS

a) UR CONVENTION FOR MEASURING POWER AND ENERGY

The following figure illustrates the conventions established for use in UR-series 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-series 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.

![Diagram of phase angle measurement convention]

Figure 6–2: UR PHASE ANGLE MEASUREMENT CONVENTION

c) UR CONVENTION FOR SYMMETRICAL COMPONENTS

The UR-series of 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:**
  
  \[
  \begin{align*}
  V_0 &= \frac{1}{3}(V_{AG} + V_{BG} + V_{CG}) \\
  V_1 &= \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG}) \\
  V_2 &= \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})
  \end{align*}
  \]

- **ACB phase rotation:**
  
  \[
  \begin{align*}
  V_0 &= \frac{1}{3}(V_{AG} + V_{BG} + V_{CG}) \\
  V_1 &= \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG}) \\
  V_2 &= \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})
  \end{align*}
  \]

The above equations apply to currents as well.
DELTA-CONNECTED INSTRUMENT TRANSFORMERS:

- ABC phase rotation:
  \[
  V_0 = \frac{1\angle-30^\circ}{3\sqrt{3}} (V_{AB} + aV_{BC} + a^2V_{CA}) \\
  V_1 = \frac{1\angle-30^\circ}{3\sqrt{3}} (V_{AB} + aV_{BC} + a^2V_{CA}) \\
  V_2 = \frac{1\angle-30^\circ}{3\sqrt{3}} (V_{AB} + a^2V_{BC} + aV_{CA})
  \]

- ACB phase rotation:
  \[
  V_0 = \frac{1\angle30^\circ}{3\sqrt{3}} (V_{AB} + aV_{BC} + a^2V_{CA}) \\
  V_1 = \frac{1\angle30^\circ}{3\sqrt{3}} (V_{AB} + aV_{BC} + a^2V_{CA}) \\
  V_2 = \frac{1\angle30^\circ}{3\sqrt{3}} (V_{AB} + a^2V_{BC} + aV_{CA})
  \]

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: SYMMETRICAL COMPONENTS CALCULATION EXAMPLE**

<table>
<thead>
<tr>
<th>SYSTEM VOLTAGES, SEC. V *</th>
<th>VT CONN.</th>
<th>RELAY INPUTS, SEC. V</th>
<th>SYMM. COMP. SEC. V</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{AG} ) ( \angle 0^\circ )</td>
<td>WYE</td>
<td>F5AC</td>
<td>( V_0 )</td>
</tr>
<tr>
<td>( V_{BG} ) ( \angle 125^\circ )</td>
<td></td>
<td>F6AC</td>
<td>( V_1 )</td>
</tr>
<tr>
<td>( V_{CG} ) ( \angle 250^\circ )</td>
<td></td>
<td>F7AC</td>
<td>( V_2 )</td>
</tr>
<tr>
<td>( V_{AB} ) ( \angle -313^\circ )</td>
<td>( 13.9 )</td>
<td>( 13.9 ) ( \angle 0^\circ )</td>
<td>( 76.2 ) ( \angle -125^\circ )</td>
</tr>
<tr>
<td>( V_{BC} ) ( \angle -97^\circ )</td>
<td>( 138.3 )</td>
<td>( 138.3 ) ( \angle -144^\circ )</td>
<td>( 79.7 ) ( \angle -144^\circ )</td>
</tr>
<tr>
<td>( V_{CA} ) ( \angle -241^\circ )</td>
<td>( 85.4 )</td>
<td>( 85.4 ) ( \angle -288^\circ )</td>
<td>( 19.5 ) ( \angle -288^\circ )</td>
</tr>
</tbody>
</table>

* The power system voltages are phase-referenced – for simplicity – to \( V_{AG} \) and \( V_{AB} \), respectively. This, however, is a relative matter. It is important to remember that the F60 displays are always referenced as specified under SETTINGS \( \Rightarrow \) SYSTEM SETUP \( \Rightarrow \) POWER SYSTEM \( \Rightarrow \) FREQUENCY AND PHASE REFERENCE.

The example above is illustrated in the following figure.

![Figure 6–3: MEASUREMENT CONVENTION FOR SYMMETRICAL COMPONENTS](827844A1.CDR)
Because energy values are accumulated, these values should be recorded and then reset immediately prior to changing CT or VT characteristics.

**PHASE CURRENT**

**SRC 1**

- **SRC 1 RMS Ia:** 0.000 A
- **SRC 1 RMS Ib:** 0.000 A
- **SRC 1 RMS Ic:** 0.000 A
- **SRC 1 RMS In:** 0.000 A
- **SRC 1 PHASOR Ia:** 0.000 A 0.0°
- **SRC 1 PHASOR Ib:** 0.000 A 0.0°
- **SRC 1 PHASOR Ic:** 0.000 A 0.0°
- **SRC 1 PHASOR In:** 0.000 A 0.0°

**GROUND CURRENT**

**SRC 1**

- **SRC 1 RMS Ig:** 0.000 A
- **SRC 1 PHASOR Ig:** 0.000 A 0.0°
- **SRC 1 PHASOR Igd:** 0.000 A 0.0°

**PHASE VOLTAGE**

**SRC 1**

- **SRC 1 RMS Vag:** 0.00 V
- **SRC 1 RMS Vbg:** 0.00 V
- **SRC 1 RMS Vcg:** 0.00 V
- **SRC 1 PHASOR Vag:** 0.00 V 0.0°
### 6.3 Metering

<table>
<thead>
<tr>
<th>Message</th>
<th>SRC 1 Phasor Vbg: 0.000 V 0.0°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message</td>
<td>SRC 1 Phasor Vcg: 0.000 V 0.0°</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 RMS Vab: 0.00 V</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 RMS Vbc: 0.00 V</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 RMS Vca: 0.00 V</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Phasor Vab: 0.000 V 0.0°</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Phasor Vbc: 0.000 V 0.0°</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Phasor Vca: 0.000 V 0.0°</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Zero Seq V0: 0.000 V 0.0°</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Pos Seq V1: 0.000 V 0.0°</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Neg Seq V2: 0.000 V 0.0°</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 RMS Vx: 0.00 V</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Phasor Vx: 0.000 V 0.0°</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Real Power 3φ: 0.000 W</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Real Power φa: 0.000 W</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Real Power φb: 0.000 W</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Real Power φc: 0.000 W</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Reactive Pwr 3φ: 0.000 var</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Reactive Pwr φa: 0.000 var</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Reactive Pwr φb: 0.000 var</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Reactive Pwr φc: 0.000 var</td>
</tr>
</tbody>
</table>

### Auxiliary Voltage

### Power

<table>
<thead>
<tr>
<th>Message</th>
<th>SRC 1 Real Power 3φ: 0.000 W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message</td>
<td>SRC 1 Real Power φa: 0.000 W</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Real Power φb: 0.000 W</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Real Power φc: 0.000 W</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Reactive Pwr 3φ: 0.000 var</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Reactive Pwr φa: 0.000 var</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Reactive Pwr φb: 0.000 var</td>
</tr>
<tr>
<td>Message</td>
<td>SRC 1 Reactive Pwr φc: 0.000 var</td>
</tr>
</tbody>
</table>
### 6 ACTUAL VALUES

#### 6.3 METERING

- **MESSAGE**
  - SRC 1 APPARENT PWR
    - $\Phi$: 0.000 VA
  - SRC 1 APPARENT PWR
    - $\phi_a$: 0.000 VA
  - SRC 1 APPARENT PWR
    - $\phi_b$: 0.000 VA
  - SRC 1 APPARENT PWR
    - $\phi_c$: 0.000 VA
  - SRC 1 POWER FACTOR
    - $\Phi$: 1.000
  - SRC 1 POWER FACTOR
    - $\phi_a$: 1.000
  - SRC 1 POWER FACTOR
    - $\phi_b$: 1.000
  - SRC 1 POWER FACTOR
    - $\phi_c$: 1.000

### ENERGY

- **MESSAGE**
  - SRC 1 POS WATTHOUR: 0.000 Wh
  - SRC 1 NEG WATTHOUR: 0.000 Wh
  - SRC 1 POS VARHOUR: 0.000 varh
  - SRC 1 NEG VARHOUR: 0.000 varh

### DEMAND

- **MESSAGE**
  - SRC 1 DMD IA: 0.000 A
  - SRC 1 DMD IA MAX: 0.000 A
  - SRC 1 DMD IA DATE: 2001/07/31 16:30:07
  - SRC 1 DMD IB: 0.000 A
  - SRC 1 DMD IB MAX: 0.000 A
  - SRC 1 DMD IB DATE: 2001/07/31 16:30:07
  - SRC 1 DMD IC: 0.000 A
  - SRC 1 DMD IC MAX: 0.000 A
  - SRC 1 DMD IC DATE: 2001/07/31 16:30:07
Two identical Source menus are available. The "SRC 1" text 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 **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 the **SYSTEM SETUP ⇄ POWER SYSTEM** settings). 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.

**CURRENT HARMONICS** are measured for each Source for the THD and 2nd to 25th harmonics per phase.

The technique used to extract the 2nd to 25th **VOLTAGE HARMONICS** is as follows. Each harmonic is computer per-phase, where:

- $N = 64$ is the number of samples per cycle
- $\omega_0 = 2\pi f$ is the angular frequency based on the system frequency (50 or 60 Hz)
- $k = 1, 2, ..., N – 1$ is the index over one cycle for the FFT
- $m$ is the last sample number for the sliding window
- $h = 1, 2, ..., 25$ is the harmonic number

The short-time Fourier transform is applied to the unfiltered signal:

$$F_{\text{real}}(m, h) = \frac{2}{N} \sum_{k} (f(m - k) \cdot \cos(\omega_0 \cdot t(k)))$$

$$F_{\text{imag}}(m, h) = \frac{2}{N} \sum_{k} (f(m - k) \cdot \sin(\omega_0 \cdot t(k)))$$

$$F_{\text{amp}}(m, h) = \sqrt{F_{\text{real}}(m, h)^2 + F_{\text{imag}}(m, h)^2}$$

(EQ 6.1)

The harmonics are a percentage of the fundamental signal obtained by multiplying the amplitudes obtained above 100%.

The total harmonic distortion (THD) is the ratio of the total harmonic content to the fundamental:

$$\text{THD} = \sqrt{F_2^2 + F_3^2 + \ldots + F_{25}^2}$$

(EQ 6.2)

**Voltage harmonics are not available on F60 relays configured with the high-impedance fault detection (Hi-Z) feature.**

**Voltage harmonics are calculated only for Wye connected phase VTs. Ensure the **SYSTEM SETUP ⇄ AC INPUTS ⇄ VOLTAGE BANK F5 ⇄ PHASE VT XX CONNECTION** setting is “Wye” for voltage harmonics metering.**

### 6.3.3 SENSITIVE DIRECTIONAL POWER

**PATH: ACTUAL VALUES ⇄ METERING ⇄ SENSITIVE DIRECTIONAL POWER**

<table>
<thead>
<tr>
<th>SENSITIVE</th>
<th>DIRECTIONAL POWER 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Ø: 0.000 W</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DIRECTIONAL POWER 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Ø: 0.000 W</td>
</tr>
</tbody>
</table>

The effective operating quantities of the sensitive directional power elements are displayed here. The display may be useful to calibrate the feature by compensating the angular errors of the CTs and VTs with the use of the **RCA** and **CALIBRATION** settings.
The Actual Values menu for Synchrocheck 2 is identical to that of Synchrocheck 1. If a synchrocheck function setting is "Disabled", the corresponding actual values menu item will not be displayed.

6.3.5 TRACKING FREQUENCY

The tracking frequency is displayed here. The frequency is tracked based on configuration of the reference source. The TRACKING FREQUENCY is based upon positive sequence current phasors from all line terminals and is synchronously adjusted at all terminals. If currents are below 0.125 pu, then the NOMINAL FREQUENCY is used.

6.3.6 FREQUENCY RATE OF CHANGE

The metered frequency rate of change for the four elements is shown here.
6 ACTUAL VALUES

6.3 METERING

6.3.7 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BREAKER ARCING AMPS (Brk X Arc Amp A, B, and C)</td>
<td>BASE = 2000 kA² × cycle</td>
</tr>
<tr>
<td>dcmA</td>
<td>BASE = maximum value of the DCMA INPUT MAX setting for the two transducers configured under the +IN and –IN inputs.</td>
</tr>
<tr>
<td>FREQUENCY</td>
<td>f_BASE = 1 Hz</td>
</tr>
<tr>
<td>FREQUENCY RATE OF CHANGE</td>
<td>df/dt_BASE = 1 Hz/s</td>
</tr>
<tr>
<td>PHASE ANGLE</td>
<td>θ_BASE = 360 degrees (see the UR angle referencing convention)</td>
</tr>
<tr>
<td>POWER FACTOR</td>
<td>PF_BASE = 1.00</td>
</tr>
<tr>
<td>RTDs</td>
<td>BASE = 100°C</td>
</tr>
<tr>
<td>SENSITIVE DIR POWER (Sns Dir Power)</td>
<td>P_BASE = maximum value of 3 × V_BASE × I_BASE for the +IN and –IN inputs of the sources configured for the sensitive power directional element(s).</td>
</tr>
<tr>
<td>SOURCE CURRENT</td>
<td>I_BASE = maximum nominal primary RMS value of the +IN and –IN inputs</td>
</tr>
<tr>
<td>SOURCE ENERGY (SRC X Positive and Negative Watthours; (SRC X Positive and Negative Varhours)</td>
<td>E_BASE = 10000 MWh or MVAh, respectively</td>
</tr>
<tr>
<td>SOURCE POWER</td>
<td>P_BASE = maximum value of V_BASE × I_BASE for the +IN and –IN inputs</td>
</tr>
<tr>
<td>SOURCE THD &amp; HARMONICS</td>
<td>BASE = 100% of fundamental frequency component</td>
</tr>
<tr>
<td>SOURCE VOLTAGE</td>
<td>V_BASE = maximum nominal primary RMS value of the +IN and –IN inputs</td>
</tr>
<tr>
<td>SYNCHROCHECK (Max Delta Volts)</td>
<td>V_BASE = maximum primary RMS value of all the sources related to the +IN and –IN inputs</td>
</tr>
</tbody>
</table>

6.3.8 TRANSDUCER INPUTS/OUTPUTS

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.
6.4 RECORDS

6.4.1 FAULT REPORTS

The latest 15 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 ➔ 6 FAULT REPORTS ➔ FAULT REPORT 1 menu for assigning the source and trigger for fault calculations. Refer to the COMMANDS ➔ 6 CLEAR RECORDS menu for manual clearing of the fault reports and to the SETTINGS ➔ PRODUCT SETUP ➔ 6 CLEAR RELAY RECORDS menu for automated clearing of the fault reports.

The fault locator does not report fault type or location if the source VTs are connected in the Delta configuration.

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](image)

The following equations hold true for this equivalent system.

\[
V_A = m \cdot Z \cdot I_A + R_F \cdot (I_A + I_B)
\]

where: \[m = \text{sought pu distance to fault}, \ Z = \text{positive sequence impedance of the line.}\]

The currents from the local and remote systems can be parted between their fault (F) and pre-fault load (pre) components:

\[
I_A = I_AF + I_{A\text{pre}}
\]
and neglecting shunt parameters of the line:

\[ I_B = I_{BF} - I_{A,pre} \]  
(EQ 6.5)

Inserting the \( I_A \) and \( I_B \) equations into the \( V_A \) equation and solving for the fault resistance yields:

\[ R_F = \frac{V_A - m \cdot Z \cdot I_A}{I_{AF} \left( 1 + \frac{I_{BF}}{I_{AF}} \right)} \]  
(EQ 6.6)

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:

\[ \text{Im} \left( \frac{V_A - m \cdot Z \cdot I_A}{I_{AF}} \right) = 0 \]  
(EQ 6.7)

where: \( \text{Im()} \) represents the imaginary part of a complex number. Solving the above equation for the unknown \( m \) creates the following fault location algorithm:

\[ m = \frac{\text{Im}(V_A \cdot I_{AF}^*)}{\text{Im}(Z \cdot I_A \cdot I_{AF}^*)} \]  
(EQ 6.8)

where * denotes the complex conjugate and \( I_{AF} = I_A^* - I_{A,pre}^* \).

Depending on the fault type, appropriate voltage and current signals are selected from the phase quantities before applying the two equations above (the superscripts denote phases, the subscripts denote stations):

- For AG faults: \( V_A = V_A^A \), \( I_A = I_A^A + K_0 \cdot I_{DA} \)
- For BG faults: \( V_A = V_A^B \), \( I_A = I_A^B + K_0 \cdot I_{DA} \)
- For CG faults: \( V_A = V_A^C \), \( I_A = I_A^C + K_0 \cdot I_{DA} \)
- For AB and ABG faults: \( V_A = V_A^A - V_A^B \), \( I_A = I_A^A - I_A^B \)
- For BC and BCG faults: \( V_A = V_A^B - V_A^C \), \( I_A = I_A^B - I_A^C \)
- For CA and CAG faults: \( V_A = V_A^C - V_A^A \), \( I_A = I_A^C - I_A^A \)

where \( K_0 \) is the zero sequence compensation factor (for the first six equations above)

- 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.
6.4 RECORDS

6.4.2 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 \( \rightarrow \) CLEAR RECORDS menu for clearing event records.

6.4.3 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 for further details.

A trigger can be forced here at any time by setting “Yes” to the FORCE TRIGGER? command. Refer to the COMMANDS \( \rightarrow \) CLEAR RECORDS menu for clearing the oscillography records.

6.4.4 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 \( \rightarrow \) CLEAR RECORDS menu for clearing data logger records.
6.4.5 BREAKER MAINTENANCE

There is an identical menu for each of the breakers. The BKR 1 ARCING AMP values are in units of kA2-cycles. Refer to the COMMANDS ⇒ CLEAR RECORDS menu for clearing breaker arcing current records. The BREAKER OPERATING TIME is defined as the slowest operating time of breaker poles that were initiated to open.

6.4.6 HI-Z RECORDS

There is an identical menu for each of the breakers. The BKR 1 ARCING AMP values are in units of kA2-cycles. Refer to the COMMANDS ⇒ CLEAR RECORDS menu for clearing breaker arcing current records. The BREAKER OPERATING TIME is defined as the slowest operating time of breaker poles that were initiated to open.
6.5 PRODUCT INFORMATION

6.5.1 MODEL INFORMATION

**ORDER CODE LINE 1:**
F60-E00-HCH-F8F-H6A

**ORDER CODE LINE 2:**

**ORDER CODE LINE 3:**

**ORDER CODE LINE 4:**

**SERIAL NUMBER:**

**ETHERNET MAC ADDRESS:**
000000000000

**MANUFACTURING DATE:**
0

**OPERATING TIME:**
0:00:00

The product order code, serial number, Ethernet MAC address, date/time of manufacture, and operating time are shown here.

6.5.2 FIRMWARE REVISIONS

**F60 Feeder Relay**

**REVISION:** 4.40

**MODIFICATION FILE NUMBER:** 0

**BOOT PROGRAM REVISION:** 1.13

**FRONT PANEL PROGRAM REVISION:** 0.08

**COMPILE DATE:**
2004/09/15 04:55:16

**BOOT DATE:**
2004/09/15 16:41:32

The shown data is illustrative only. A modification file number of 0 indicates that, currently, no modifications have been installed.
7.1 COMMANDS

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 section of Chapter 5 for details. The following flash message appears after successfully command entry:

![Command Executed]

7.1.2 VIRTUAL INPUTS

PATH: COMMANDS \rightarrow VIRTUAL INPUTS

The states of up to 64 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).

![Virtual Inputs]

7.1.3 CLEAR RECORDS

PATH: COMMANDS \rightarrow CLEAR RECORDS

![Clear Records]

GE Multilin  
F60 Feeder Management Relay  
7-1
7.1 COMMANDS

This menu contains commands for clearing historical data such as the Event Records. Data is cleared by changing a command setting to “Yes” and pressing the $\text{ENT}$ key. After clearing data, the command setting automatically reverts to “No”.

### 7.1.4 SET DATE AND TIME

**PATH:** COMMANDS $\Rightarrow$ SET DATE AND TIME

- **SET DATE AND TIME:** (YYYY/MM/DD HH:MM:SS)
  - **SET DATE AND TIME:** 2000/01/14 13:47:03

The date and time can be entered here via the faceplate keypad only if the IRIG-B or SNTP signal is not in use. 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 $\text{ENT}$ key is clicked.

### 7.1.5 RELAY MAINTENANCE

**PATH:** COMMANDS $\Rightarrow$ RELAY MAINTENANCE

- **PERFORM LAMPTTEST?** Range: No, Yes
  - **PERFORM LAMPTTEST?** No

- **UPDATE ORDER CODE?** Range: No, Yes
  - **UPDATE ORDER CODE?** No

This menu contains commands for relay maintenance purposes. Commands are activated by changing a command setting to “Yes” and pressing the $\text{ENT}$ key. The command setting will then automatically revert to “No”.

The **PERFORM LAMPTTEST** 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.

- **UPDATING...**
- **PLEASE WAIT**

There is no impact if there have been no changes to the hardware modules. When an update does not occur, the **ORDER CODE NOT UPDATED** message will be shown.
7.2 TARGETS

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:

7.2.2 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

<table>
<thead>
<tr>
<th>PRIORITY</th>
<th>ACTIVE STATUS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OP</td>
<td>element operated and still picked up</td>
</tr>
<tr>
<td>2</td>
<td>PKP</td>
<td>element picked up and timed out</td>
</tr>
<tr>
<td>3</td>
<td>LATCHED</td>
<td>element had operated but has dropped out</td>
</tr>
</tbody>
</table>

If a self test error is detected, a message appears indicating the cause of the error. For example UNIT NOT PROGRAMMED indicates that the minimal relay settings have not been programmed.

7.2.3 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 LED 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 LED indicator is turned off
- a RELAY OUT OF SERVICE event is recorded

Most of the minor self-test errors can be disabled. Refer to the settings in the User-Programmable Self-Tests section in Chapter 5 for additional details.
## Table 7–2: MAJOR SELF-TEST ERROR MESSAGES

<table>
<thead>
<tr>
<th>SELF-TEST ERROR MESSAGE</th>
<th>LATCHED TARGET MESSAGE?</th>
<th>DESCRIPTION OF PROBLEM</th>
<th>HOW OFTEN THE TEST IS PERFORMED</th>
<th>WHAT TO DO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DSP ERRORS:</strong> A/D Calibration, A/D Interrupt, A/D Reset, Inter DSP Rx, Sample Int, Rx Interrupt, Tx Interrupt, Rx Sample Index, Invalid Settings, Rx Checksum</td>
<td>Yes</td>
<td>CT/VT module with digital signal processor may have a problem.</td>
<td>Every 1/8th of a cycle.</td>
<td>Cycle the control power (if the problem recurs, contact the factory).</td>
</tr>
<tr>
<td><strong>DSP ERROR: INVALID REVISION</strong></td>
<td>Yes</td>
<td>One or more DSP modules in a multiple DSP unit have Rev. C hardware.</td>
<td>Rev. C DSP needs to be replaced with a Rev. D DSP.</td>
<td>Contact the factory</td>
</tr>
<tr>
<td><strong>EQUIPMENT MISMATCH with 2nd-line detail</strong></td>
<td>No</td>
<td>Configuration of modules does not match the order code stored in the CPU.</td>
<td>On power up; thereafter, the backplane is checked for missing cards every 5 seconds.</td>
<td>Check all modules against the order code, ensure they are inserted properly, and cycle control power (if problem persists, contact factory).</td>
</tr>
<tr>
<td><strong>FLEXLOGIC ERR TOKEN with 2nd-line detail</strong></td>
<td>No</td>
<td>FlexLogic™ equations do not compile properly.</td>
<td>Event driven; whenever FlexLogic™ equations are modified.</td>
<td>Finish all equation editing and use self test to debug any errors.</td>
</tr>
<tr>
<td><strong>LATCHING OUTPUT ERROR</strong></td>
<td>No</td>
<td>Discrepancy in the position of a latching contact between firmware and hardware has been detected.</td>
<td>Every 1/8th of a cycle.</td>
<td>The latching output module failed. Replace the Module.</td>
</tr>
<tr>
<td><strong>PROGRAM MEMORY Test Failed</strong></td>
<td>Yes</td>
<td>Error was found while checking Flash memory.</td>
<td>Once flash is uploaded with new firmware.</td>
<td>Contact the factory.</td>
</tr>
<tr>
<td><strong>UNIT NOT CALIBRATED</strong></td>
<td>No</td>
<td>Settings indicate the unit is not calibrated.</td>
<td>On power up.</td>
<td>Contact the factory.</td>
</tr>
<tr>
<td><strong>UNIT NOT PROGRAMMED</strong></td>
<td>No</td>
<td>PRODUCT SETUP INSTALLATION setting indicates relay is not in a programmed state.</td>
<td>On power up and whenever the RELAY PROGRAMMED setting is altered.</td>
<td>Program all settings (especially those under PRODUCT SETUP INSTALLATION).</td>
</tr>
</tbody>
</table>

## Table 7–3: MINOR SELF-TEST ERROR MESSAGES

<table>
<thead>
<tr>
<th>SELF-TEST ERROR MESSAGE</th>
<th>LATCHED TARGET MESSAGE</th>
<th>DESCRIPTION OF PROBLEM</th>
<th>HOW OFTEN THE TEST IS PERFORMED</th>
<th>WHAT TO DO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BATTERY FAIL</strong></td>
<td>Yes</td>
<td>Battery is not functioning.</td>
<td>Monitored every 5 seconds.</td>
<td>Replace the battery located in the power supply module (1H or 1L).</td>
</tr>
<tr>
<td><strong>DIRECT RING BREAK</strong></td>
<td>No</td>
<td>Direct input/output settings configured for a ring, but the connection is not in a ring.</td>
<td>Every second.</td>
<td>Check direct input/output configuration and/or wiring.</td>
</tr>
<tr>
<td><strong>DIRECT DEVICE OFF</strong></td>
<td>No</td>
<td>A direct device is configured but not connected.</td>
<td>Every second.</td>
<td>Check direct input/output configuration and/or wiring.</td>
</tr>
<tr>
<td><strong>EEPROM DATA ERROR</strong></td>
<td>Yes</td>
<td>The non-volatile memory has been corrupted.</td>
<td>On power up only.</td>
<td>If this message appears after an order code update is performed, press the RESET key to clear target message. In other cases, contact the factory.</td>
</tr>
<tr>
<td><strong>IRIG-B FAILURE</strong></td>
<td>No</td>
<td>A bad IRIG-B input signal has been detected.</td>
<td>Monitored whenever an IRIG-B signal is received.</td>
<td>Ensure the IRIG-B cable is connected, check cable functionality (i.e. look for physical damage or perform continuity test), ensure IRIG-B receiver is functioning, and check input signal level (it may be less than specification). If none of these apply, contact the factory.</td>
</tr>
<tr>
<td><strong>LATCHING OUTPUT ERROR</strong></td>
<td>Yes</td>
<td>Latching output failure.</td>
<td>Event driven.</td>
<td>Contact the factory.</td>
</tr>
<tr>
<td><strong>LOW ON MEMORY</strong></td>
<td>Yes</td>
<td>Memory is close to 100% capacity.</td>
<td>Monitored every 5 seconds.</td>
<td>Contact the factory.</td>
</tr>
<tr>
<td><strong>PRI ETHERNET FAIL</strong></td>
<td>Yes</td>
<td>Primary Ethernet connection failed.</td>
<td>Monitored every 2 seconds</td>
<td>Check connections.</td>
</tr>
<tr>
<td><strong>PROTOTYPE Firmware</strong></td>
<td>Yes</td>
<td>A prototype version of the firmware is loaded.</td>
<td>On power up only.</td>
<td>Contact the factory.</td>
</tr>
<tr>
<td><strong>REMOTE DEVICE OFF</strong></td>
<td>No</td>
<td>One or more GOOSE devices are not responding.</td>
<td>Event driven – occurs when a device programmed to receive GOOSE messages stops receiving. Every 1 to 60 s, depending on GOOSE packets.</td>
<td>Check GOOSE setup.</td>
</tr>
<tr>
<td><strong>SEC ETHERNET FAIL</strong></td>
<td>Yes</td>
<td>Sec. Ethernet connection failed.</td>
<td>Monitored every 2 seconds</td>
<td>Check connections.</td>
</tr>
<tr>
<td><strong>SNTP FAILURE</strong></td>
<td>No</td>
<td>SNTP server not responding.</td>
<td>10 to 60 seconds.</td>
<td>Check SNTP configuration and/or network connections.</td>
</tr>
<tr>
<td><strong>SYSTEM EXCEPTION</strong></td>
<td>Yes</td>
<td>Abnormal restart from modules being removed/inserted when powered-up, abnormal DC supply, or internal relay failure.</td>
<td>Event driven.</td>
<td>Contact the factory.</td>
</tr>
<tr>
<td><strong>WATCHDOG ERROR</strong></td>
<td>No</td>
<td>Some tasks are behind schedule.</td>
<td>Event driven.</td>
<td>Contact the factory.</td>
</tr>
</tbody>
</table>

---

7-4 F60 Feeder Management Relay

GE Multilin
The Hi-Z element accomplishes high-impedance fault detection using a variety of algorithms, all coordinated by an expert system. At the heart of the high-impedance fault-detection system is the identification of arcing on a feeder. If the Hi-Z element detects arcing, it then determines whether or not the arcing persists for a significant period of time. If it does, the Hi-Z element determines whether the persistent arcing is from a downed conductor or from an intact conductor and then generates an output to indicate either the detection of a downed conductor or the detection of arcing, respectively.

Distinction between an arcing intact conductor and an arcing downed conductor is determined by looking at patterns in the load current at the beginning of the fault. A downed conductor is indicated only when a precipitous loss of load or an overcurrent condition precedes arcing detection. Otherwise, the Hi-Z element assumes that the line is intact, even if arcing is present. In such a case, if the detected arcing can be classified as persistent, and an output contact is configured for 'arcing detected', the Hi-Z element will close that contact.

In some cases, arcing is determined to be present, but not persistent. For example, if it is caused by tree limb contact or insulator degradation, arcing will typically be present intermittently with relatively long periods of inactivity (e.g. minutes) interspersed. In such cases, arcing may be affected by such factors as the motion of a tree limb or the moisture and contamination on an insulator. Conditions such as these, characterized by a high number of brief occurrences of arcing over an extended period of time (e.g. from a fraction of an hour to one or two hours), lead the Hi-Z element to recognize and flag an “arcing suspected” event. None of these brief occurrences of arcing, if taken individually, are sufficient to indicate detection of a downed conductor or to set off an alarm indicating that persistent arcing has been detected. When considered cumulatively, however, they do indicate a need for attention. If an output contact is configured to indicate ‘arcing suspected’, the Hi-Z element will recognize such sporadic arcing and close that contact and appropriate actions can be taken.

If the Hi-Z element determines that a downed conductor exists, oscillography and fault data are captured. In addition, target messages and appropriate LEDs are activated on the relay faceplate.

The detection of a downed conductor or arcing condition is accomplished through the execution of the following algorithms:

- Energy Algorithm
- Randomness Algorithm
- Expert Arc Detector Algorithm
- Load Event Detector Algorithm
- Load Analysis Algorithm
- Load Extraction Algorithm
- Arc Burst Pattern Analysis Algorithm
- Spectral Analysis Algorithm
- Arcing-Suspected Identifier Algorithm
- Even Harmonic Restraint Algorithm
- Voltage Supervision Algorithm

### 8.1.2 ENERGY ALGORITHM

The Energy algorithm monitors a specific set of non-fundamental frequency component energies of phase and neutral current. After establishing an average value for a given component energy, the algorithm indicates arcing if it detects a sudden, sustained increase in the value of that component. The Hi-Z element runs the Energy algorithm on each of the following parameters for each phase current and for the neutral:

- even harmonics
- odd harmonics
- non-harmonics

On a 60 Hz system, the non-harmonic component consists of a sum of the 30, 90, 150, ..., 750 Hz components, while on a 50 Hz system, it consists of a sum of the 25, 75, 125, ..., 625 Hz components. If the Energy Algorithm detects a sudden, sustained increase in one of these component energies, it reports this to the Expert Arc Detector algorithm, resets itself, and continues to monitor for another sudden increase.
8.1 HIGH-IMPEDANCE (HI-Z) FAULT DETECTION

8.1.3 RANDOMNESS ALGORITHM

The Randomness algorithm monitors the same set of component energies as the Energy algorithm. However, rather than checking for a sudden, sustained increase in the value of the monitored component energy, it looks for a sudden increase in a component followed by highly erratic behavior. This type of highly erratic behavior is indicative of many arcing faults. Just as with the Energy algorithm, if the Randomness algorithm detects a suspicious event in one of its monitored components, it reports it to the Expert Arc Detector algorithm, resets itself, and continues to monitor for another suspicious event.

8.1.4 EXPERT ARC DETECTER ALGORITHM

The purpose of the Expert Arc Detector Algorithm is to assimilate the outputs of the basic arc detection algorithms into one “arching confidence” level per phase. Note that there are actually 24 independent basic arc detection algorithms, since both the Energy Algorithm and the Randomness Algorithm are run for the even harmonics, odd harmonics, and non-harmonics for each phase current and for the neutral. The assimilation performed by the Expert Arc Detector Algorithm, then, is accomplished by counting the number of arcing indications determined by any one of the twenty-four algorithms over a short period of time (e.g. the last 30 seconds). Also taken into account is the number of different basic algorithms that indicate arcing.

In the Expert Arc Detector Algorithm, the arcing confidence level for each phase increases as the number of basic algorithms that indicate arcing (per phase) increases. It also increases with increasing numbers of indications from any one basic algorithm. These increases in confidence levels occur because multiple, consecutive indications from a given algorithm and indications from multiple independent algorithms are more indicative of the presence of arcing than a single algorithm giving a single indication.

8.1.5 SPECTRAL ANALYSIS ALGORITHM

The Spectral Analysis algorithm is the third and final confirmation algorithm performed only when a high impedance condition is suspected.

The Spectral Analysis algorithm receives five seconds of averaged non-harmonic residual current spectrum data and compares it to an ideal 1/f curve. Depending on the result, three percent can be added to the arcing confidence level generated by the Expert Arc Detector Algorithm.

8.1.6 LOAD EVENT DETECTOR ALGORITHM

The Load Event Detector Algorithm examines, on a per-phase basis, one reading of RMS values per two-cycle interval for each phase current and the neutral. It then sets flags for each phase current and for the neutral based on the following events:

- an overcurrent condition
- a precipitous loss of load
- a high rate-of-change
- a significant three-phase event
- a breaker open condition.

These flags are examined by the Load Analysis Algorithm. Their states contribute to that algorithm's differentiation between arcing downed conductors and arcing intact conductors, and inhibit the Expert Arc Detector Algorithm from indicating the need for an arcing alarm for a limited time following an overcurrent or breaker open condition.

Any of the above five flags will zero the Expert Arc Detector buffer, since the power system is in a state of change and the values being calculated for use by the Energy and Randomness algorithms are probably not valid.

An extremely high rate of change is not characteristic of most high impedance faults and is more indicative of a breaker closing, causing associated inrush. Since this type of inrush current causes substantial variations in the harmonics used by the high impedance algorithms, these algorithms ignore all data for several seconds following a high rate-of-change event that exceeds the associated rate-of-change threshold, in order to give the power system a chance to stabilize.
8 THEORY OF OPERATION

8.1 HIGH-IMPEDANCE (HI-Z) FAULT DETECTION

8.1.7 LOAD ANALYSIS ALGORITHM

The purpose of the Load Analysis algorithm is to differentiate between arcing downed conductors and arcing intact conductors by looking for a precipitous loss of load and/or an overcurrent disturbance at the beginning of an arcing episode. The presence of arcing on the system is determined based on the output of the Expert Arc Detector algorithm. If the Hi-Z element finds persistent arcing on the power system, the Load Analysis algorithm then considers the type of incident that initiated the arcing and classifies the arcing conductor as either downed or intact. Another function of the algorithm is to provide coordination between the Hi-Z element and the power system's conventional overcurrent protection by observing a timeout, via the **HI-Z OC PROTECTION COORD TIMEOUT** setting from the beginning of the arcing before giving an indication of arcing.

If the Load Analysis algorithm determines that a downed conductor or arcing exists, it attempts to determine the phase on which the high impedance fault condition exists. It does this in a hierarchical manner. First, if a significant loss of load triggered the Load Analysis algorithm, and if there was a significant loss on only one phase, that phase is identified. If there was not a single phase loss of load, and if an overcurrent condition on only one phase triggered the algorithm, that phase is identified. If both of these tests fail to identify the phase, the phase with a significantly higher confidence level (e.g. higher than the other two phases by at least 25%) is identified. Finally, if none of these tests provides phase identification, the result of the Arc Burst Pattern Analysis algorithm is checked. If that test fails, the phase is not identified.

8.1.8 LOAD EXTRACTION ALGORITHM

The Load Extraction Algorithm attempts to find a quiescent period during an arcing fault so that it can determine the background load current level in the neutral current. If it is successful in doing so, it then removes the load component from the total measured current, resulting in a signal which consists only of the fault component of the neutral current. This information is then provided as input to the Arc Burst Pattern Analysis Algorithm.

8.1.9 ARC BURST PATTERN ANALYSIS ALGORITHM

The Arc Burst Pattern Analysis algorithm attempts to provide faulted phase identification information based on a correlation between the fault component of the measured neutral current and the phase voltages. The phase identified will be the one whose phase voltage peak lines up with the neutral current burst. The fault component is received from the Load Extraction algorithm. The result of the analysis is checked by the Load Analysis algorithm if its other phase identification methods prove unsuccessful.

8.1.10 ARcing Suspected ALGORITHM

The purpose of the Arcing Suspected Algorithm is to detect multiple, sporadic arcing events. If taken individually, such events are not sufficient to warrant an arcing alarm. When taken cumulatively, however, these events do warrant an alarm to system operators so that the cause of the recurrent arcing can be investigated.

8.1.11 OVERCURRENT DISturBANCE MONITORING

This function is part of High Impedance Fault Detection and should not be confused with conventional overcurrent protection. The Hi-Z element monitors for an overcurrent condition on the feeder by establishing overcurrent thresholds for the phases and for the neutral and then checking for a single two-cycle RMS current that exceeds those thresholds. Oscillography and fault data are captured if it is determined that an overcurrent condition exists.

8.1.12 HI-Z EVEN HARMONIC RESTRAINT ALGORITHM

Every two-cycle interval the algorithm evaluates the even harmonic content of each phase current. The even harmonic content is evaluated as a percentage of the phase RMS current. If for any phase the percentage is greater than the **HI-Z EVEN HARMONIC RESTRAINT** setting, the algorithm will inhibit setting of the overcurrent flags. This is to prevent a cold-load pickup event from starting the Hi-Z logic sequence (which requires the overcurrent flag or the loss-of-load flag to be set at the beginning of an arcing event). The duration over which the algorithm inhibits the setting of the overcurrent flag(s) is from the time the even-harmonic level (as a percentage of RMS) increases above the threshold until one second after it falls back below the threshold.
8.1.13 HI-Z VOLTAGE SUPERVISION ALGORITHM

This algorithm was implemented to minimize the probability of a false Hi-Z indication due to bus voltage dips (e.g. from parallel feeder faults). A fault on a parallel line can cause voltage dips that will produce a decrease in the line load which can be mistaken by Hi-Z element as Loss of Load.

Every two cycle the voltage on each phase is checked against the HI-Z V SUPV THRESHOLD. If the voltage on any phase has dropped by a percentage greater than or equal to this setting, the Loss of Load flag will be blocked. The blocking is not done on a per-phase basis. If one phase voltage shows a dip, the block is applied for all phases. Also the High Impedance Oscillography will record that a voltage dip was experienced. The Oscillography record is phase specific.
### Table A–1: FLEXANALOG DATA ITEMS (Sheet 1 of 12)

<table>
<thead>
<tr>
<th>ADDR</th>
<th>DATA ITEM</th>
<th>FLEXANALOG NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>5760</td>
<td>Sens Dir Power 1 Actual</td>
<td>Sns Dir Power 1</td>
</tr>
<tr>
<td>5762</td>
<td>Sens Dir Power 2 Actual</td>
<td>Sns Dir Power 2</td>
</tr>
<tr>
<td>5856</td>
<td>Frequency Rate of Change 1 Actual</td>
<td>Freq Rate 1 Value</td>
</tr>
<tr>
<td>5860</td>
<td>Frequency Rate of Change 2 Actual</td>
<td>Freq Rate 2 Value</td>
</tr>
<tr>
<td>5864</td>
<td>Frequency Rate of Change 3 Actual</td>
<td>Freq Rate 3 Value</td>
</tr>
<tr>
<td>5868</td>
<td>Frequency Rate of Change 4 Actual</td>
<td>Freq Rate 4 Value</td>
</tr>
<tr>
<td>6144</td>
<td>SRC 2 Phase A Current RMS</td>
<td>SRC 2 Ia RMS</td>
</tr>
<tr>
<td>6146</td>
<td>SRC 2 Phase B Current RMS</td>
<td>SRC 2 Ib RMS</td>
</tr>
<tr>
<td>6148</td>
<td>SRC 2 Phase C Current RMS</td>
<td>SRC 2 Ic RMS</td>
</tr>
<tr>
<td>6150</td>
<td>SRC 2 Neutral Current RMS</td>
<td>SRC 2 In RMS</td>
</tr>
<tr>
<td>6152</td>
<td>SRC 2 Phase A Current Magnitude</td>
<td>SRC 2 Ia Mag</td>
</tr>
<tr>
<td>6154</td>
<td>SRC 2 Phase A Current Angle</td>
<td>SRC 2 Ia Angle</td>
</tr>
<tr>
<td>6155</td>
<td>SRC 2 Phase B Current Magnitude</td>
<td>SRC 2 Ib Mag</td>
</tr>
<tr>
<td>6157</td>
<td>SRC 2 Phase B Current Angle</td>
<td>SRC 2 Ib Angle</td>
</tr>
<tr>
<td>6158</td>
<td>SRC 2 Phase C Current Magnitude</td>
<td>SRC 2 Ic Mag</td>
</tr>
<tr>
<td>6160</td>
<td>SRC 2 Phase C Current Angle</td>
<td>SRC 2 Ic Angle</td>
</tr>
<tr>
<td>6161</td>
<td>SRC 2 Neutral Current Magnitude</td>
<td>SRC 2 In Mag</td>
</tr>
<tr>
<td>6163</td>
<td>SRC 2 Neutral Current Angle</td>
<td>SRC 2 In Angle</td>
</tr>
<tr>
<td>6164</td>
<td>SRC 2 Neutral Current RMS</td>
<td>SRC 2 In RMS</td>
</tr>
<tr>
<td>6166</td>
<td>SRC 2 Neutral Current Magnitude</td>
<td>SRC 2 In Mag</td>
</tr>
<tr>
<td>6168</td>
<td>SRC 2 Neutral Current Angle</td>
<td>SRC 2 In Angle</td>
</tr>
<tr>
<td>6169</td>
<td>SRC 2 Zero Seq. Current Magnitude</td>
<td>SRC 2 I_0 Mag</td>
</tr>
<tr>
<td>6171</td>
<td>SRC 2 Zero Sequence Current Angle</td>
<td>SRC 2 I_0 Angle</td>
</tr>
<tr>
<td>6172</td>
<td>SRC 1 Pos. Seq. Current Magnitude</td>
<td>SRC 1 I_1 Mag</td>
</tr>
<tr>
<td>6174</td>
<td>SRC 1 Pos. Seq. Current Angle</td>
<td>SRC 1 I_1 Angle</td>
</tr>
<tr>
<td>6175</td>
<td>SRC 1 Neg. Seq. Current Magnitude</td>
<td>SRC 1 I_2 Mag</td>
</tr>
<tr>
<td>6177</td>
<td>SRC 1 Neg. Seq. Current Angle</td>
<td>SRC 1 I_2 Angle</td>
</tr>
<tr>
<td>6178</td>
<td>SRC 1 Differential Gnd Current Magn.</td>
<td>SRC 1 Igd Mag</td>
</tr>
<tr>
<td>6180</td>
<td>SRC 1 Diff. Gnd. Current Angle</td>
<td>SRC 1 Igd Angle</td>
</tr>
<tr>
<td>6208</td>
<td>SRC 2 Phase A Current RMS</td>
<td>SRC 2 Ia RMS</td>
</tr>
<tr>
<td>6210</td>
<td>SRC 2 Phase B Current RMS</td>
<td>SRC 2 Ib RMS</td>
</tr>
<tr>
<td>6212</td>
<td>SRC 2 Phase C Current RMS</td>
<td>SRC 2 Ic RMS</td>
</tr>
<tr>
<td>6214</td>
<td>SRC 2 Neutral Current RMS</td>
<td>SRC 2 In RMS</td>
</tr>
<tr>
<td>6216</td>
<td>SRC 2 Neutral Current Magnitude</td>
<td>SRC 2 In Mag</td>
</tr>
<tr>
<td>6218</td>
<td>SRC 2 Phase A Current Angle</td>
<td>SRC 2 Ia Angle</td>
</tr>
<tr>
<td>6219</td>
<td>SRC 2 Phase B Current Magnitude</td>
<td>SRC 2 Ib Mag</td>
</tr>
<tr>
<td>6221</td>
<td>SRC 2 Phase B Current Angle</td>
<td>SRC 2 Ib Angle</td>
</tr>
<tr>
<td>6222</td>
<td>SRC 2 Phase C Current Magnitude</td>
<td>SRC 2 Ic Mag</td>
</tr>
<tr>
<td>6224</td>
<td>SRC 2 Phase C Current Angle</td>
<td>SRC 2 Ic Angle</td>
</tr>
<tr>
<td>6225</td>
<td>SRC 2 Neutral Current Magnitude</td>
<td>SRC 2 In Mag</td>
</tr>
<tr>
<td>6227</td>
<td>SRC 2 Neutral Current Angle</td>
<td>SRC 2 In Angle</td>
</tr>
<tr>
<td>6228</td>
<td>SRC 2 Ground Current RMS</td>
<td>SRC 2 Ig RMS</td>
</tr>
<tr>
<td>6230</td>
<td>SRC 2 Ground Current Magnitude</td>
<td>SRC 2 Ig Mag</td>
</tr>
<tr>
<td>6232</td>
<td>SRC 2 Ground Current Angle</td>
<td>SRC 2 Ig Angle</td>
</tr>
<tr>
<td>6233</td>
<td>SRC 2 Zero Seq. Current Magnitude</td>
<td>SRC 2 I_0 Mag</td>
</tr>
<tr>
<td>6235</td>
<td>SRC 2 Zero Sequence Current Angle</td>
<td>SRC 2 I_0 Angle</td>
</tr>
<tr>
<td>6236</td>
<td>SRC 2 Pos. Seq. Current Magnitude</td>
<td>SRC 2 I_1 Mag</td>
</tr>
<tr>
<td>6238</td>
<td>SRC 2 Positive Seq. Current Angle</td>
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### Table A–1: FLEXANALOG DATA ITEMS (Sheet 2 of 12)

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## Table A–1: FLEXANALOG DATA ITEMS (Sheet 9 of 12)

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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 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 Chapter 5 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>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAVE ADDRESS</td>
<td>1 byte</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>1 byte</td>
</tr>
<tr>
<td>DATA</td>
<td>N bytes</td>
</tr>
<tr>
<td>CRC</td>
<td>2 bytes</td>
</tr>
<tr>
<td>DEAD TIME</td>
<td>3.5 bytes transmission time</td>
</tr>
</tbody>
</table>

- **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 slave address 0 indicates a broadcast command. All slaves on the communication link take action based on the packet, but none 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.
B.1 MODBUS RTU PROTOCOL

- **FUNCTION CODE:** This is one of the supported function 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 details on calculating 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 (11000000000000101B). 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.

A C programming language implementation of the CRC algorithm will be provided upon request.

#### Table B–2: CRC-16 ALGORITHM

<table>
<thead>
<tr>
<th>SYMBOLS:</th>
<th>--&gt;</th>
<th>data transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16 bit working register</td>
<td></td>
</tr>
<tr>
<td>Alow</td>
<td>low order byte of A</td>
<td></td>
</tr>
<tr>
<td>Ahigh</td>
<td>high order byte of A</td>
<td></td>
</tr>
<tr>
<td>CRC</td>
<td>16 bit CRC-16 result</td>
<td></td>
</tr>
<tr>
<td>i,j</td>
<td>loop counters</td>
<td></td>
</tr>
<tr>
<td>(+)</td>
<td>logical EXCLUSIVE-OR operator</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>total number of data bytes</td>
<td></td>
</tr>
<tr>
<td>Di</td>
<td>i-th data byte (i = 0 to N-1)</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>16 bit characteristic polynomial = 1010000000000001 (binary) with MSbit dropped and bit order reversed</td>
<td></td>
</tr>
<tr>
<td>shr (x)</td>
<td>right shift operator (th LSB 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)</td>
<td></td>
</tr>
</tbody>
</table>

#### 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
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.

<table>
<thead>
<tr>
<th>FUNCTION CODE</th>
<th>MODBUS DEFINITION</th>
<th>GE MULTILIN DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEX</td>
<td>DEC</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>3</td>
<td>Read Holding Registers</td>
</tr>
<tr>
<td>04</td>
<td>4</td>
<td>Read Holding Registers</td>
</tr>
<tr>
<td>05</td>
<td>5</td>
<td>Force Single Coil</td>
</tr>
<tr>
<td>06</td>
<td>6</td>
<td>Preset Single Register</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>Preset Multiple Registers</td>
</tr>
</tbody>
</table>

**B.2.2 READ ACTUAL VALUES OR SETTINGS (FUNCTION CODE 03/04H)**

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 Modbus Memory Map table 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**

<table>
<thead>
<tr>
<th>MASTER TRANSMISSION</th>
<th>EXAMPLE (HEX)</th>
<th>SLAVE RESPONSE</th>
<th>EXAMPLE (HEX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
<td>SLAVE ADDRESS</td>
<td>11</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>04</td>
<td>FUNCTION CODE</td>
<td>04</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - high</td>
<td>40</td>
<td>BYTE COUNT</td>
<td>06</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - low</td>
<td>50</td>
<td>DATA #1 - high</td>
<td>00</td>
</tr>
<tr>
<td>NUMBER OF REGISTERS - high</td>
<td>00</td>
<td>DATA #1 - low</td>
<td>28</td>
</tr>
<tr>
<td>NUMBER OF REGISTERS - low</td>
<td>03</td>
<td>DATA #2 - high</td>
<td>01</td>
</tr>
<tr>
<td>CRC - low</td>
<td>A7</td>
<td>DATA #2 - low</td>
<td>2C</td>
</tr>
<tr>
<td>CRC - high</td>
<td>4A</td>
<td>DATA #3 - high</td>
<td>00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DATA #3 - low</td>
<td>00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CRC - low</td>
<td>0D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CRC - high</td>
<td>60</td>
</tr>
</tbody>
</table>
B.2 MODBUS FUNCTION CODES

B.2.3 EXECUTE OPERATION (FUNCTION CODE 05H)

This function code allows the master to perform various operations in the relay. Available operations are shown in the Summary of Operation Codes table below.

The following table shows the format of the master and slave packets. The example shows a master device requesting the slave device 11h (17 decimal) to perform a reset. The high and low 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

<table>
<thead>
<tr>
<th>MASTER TRANSMISSION</th>
<th>EXAMPLE (HEX)</th>
<th>SLAVE RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PACKET FORMAT</td>
<td></td>
<td>PACKET FORMAT</td>
</tr>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
<td>SLAVE ADDRESS</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>05</td>
<td>FUNCTION CODE</td>
</tr>
<tr>
<td>OPERATION CODE - high</td>
<td>00</td>
<td>OPERATION CODE - high</td>
</tr>
<tr>
<td>OPERATION CODE - low</td>
<td>01</td>
<td>OPERATION CODE - low</td>
</tr>
<tr>
<td>CODE VALUE - high</td>
<td>FF</td>
<td>CODE VALUE - high</td>
</tr>
<tr>
<td>CODE VALUE - low</td>
<td>00</td>
<td>CODE VALUE - low</td>
</tr>
<tr>
<td>CRC - low</td>
<td>DF</td>
<td>CRC - low</td>
</tr>
<tr>
<td>CRC - high</td>
<td>6A</td>
<td>CRC - high</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRC - high</td>
<td>6A</td>
<td></td>
</tr>
</tbody>
</table>

Table B–5: SUMMARY OF OPERATION CODES FOR FUNCTION 05H

<table>
<thead>
<tr>
<th>OPERATION CODE (HEX)</th>
<th>DEFINITION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>NO OPERATION</td>
<td>Does not do anything.</td>
</tr>
<tr>
<td>0001</td>
<td>RESET</td>
<td>Performs the same function as the faceplate RESET key.</td>
</tr>
<tr>
<td>0005</td>
<td>CLEAR EVENT RECORDS</td>
<td>Performs the same function as the faceplate CLEAR EVENT RECORDS menu command.</td>
</tr>
<tr>
<td>0006</td>
<td>CLEAR OSCILLOGRAPHY</td>
<td>Clears all oscillography records.</td>
</tr>
<tr>
<td>1000 to 103F</td>
<td>VIRTUAL IN 1 to 64 ON/OFF</td>
<td>Sets the states of Virtual Inputs 1 to 64 either “ON” or “OFF”.</td>
</tr>
</tbody>
</table>

B.2.4 STORE SINGLE SETTING (FUNCTION CODE 06H)

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

<table>
<thead>
<tr>
<th>MASTER TRANSMISSION</th>
<th>EXAMPLE (HEX)</th>
<th>SLAVE RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PACKET FORMAT</td>
<td></td>
<td>PACKET FORMAT</td>
</tr>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
<td>SLAVE ADDRESS</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>06</td>
<td>FUNCTION CODE</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - high</td>
<td>40</td>
<td>DATA STARTING ADDRESS - high</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - low</td>
<td>51</td>
<td>DATA STARTING ADDRESS - low</td>
</tr>
<tr>
<td>DATA - high</td>
<td>00</td>
<td>DATA - high</td>
</tr>
<tr>
<td>DATA - low</td>
<td>C8</td>
<td>DATA - low</td>
</tr>
<tr>
<td>CRC - low</td>
<td>CE</td>
<td>CRC - low</td>
</tr>
<tr>
<td>CRC - high</td>
<td>DD</td>
<td>CRC - high</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CRC - high</td>
</tr>
</tbody>
</table>
APPENDIX B

B.2 MODBUS FUNCTION CODES

B.2.5 STORE MULTIPLE SETTINGS (FUNCTION CODE 10H)

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 decimal).

Table B–7: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

<table>
<thead>
<tr>
<th>MASTER TRANSMISSION</th>
<th>SLAVE RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PACKET FORMAT</td>
<td>EXAMPLE (HEX)</td>
</tr>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>10</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - hi</td>
<td>40</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - lo</td>
<td>51</td>
</tr>
<tr>
<td>NUMBER OF SETTINGS - hi</td>
<td>00</td>
</tr>
<tr>
<td>NUMBER OF SETTINGS - lo</td>
<td>02</td>
</tr>
<tr>
<td>BYTE COUNT</td>
<td>04</td>
</tr>
<tr>
<td>DATA #1 - high order byte</td>
<td>00</td>
</tr>
<tr>
<td>DATA #1 - low order byte</td>
<td>C8</td>
</tr>
<tr>
<td>DATA #2 - high order byte</td>
<td>00</td>
</tr>
<tr>
<td>DATA #2 - low order byte</td>
<td>01</td>
</tr>
<tr>
<td>CRC - low order byte</td>
<td>12</td>
</tr>
<tr>
<td>CRC - high order byte</td>
<td>62</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SLAVE RESPONSE</th>
<th>PACKET FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>10</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - hi</td>
<td>40</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - lo</td>
<td>51</td>
</tr>
<tr>
<td>NUMBER OF SETTINGS - hi</td>
<td>00</td>
</tr>
<tr>
<td>NUMBER OF SETTINGS - lo</td>
<td>02</td>
</tr>
<tr>
<td>CRC - lo</td>
<td>07</td>
</tr>
<tr>
<td>CRC - hi</td>
<td>64</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>MASTER TRANSMISSION</th>
<th>SLAVE RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PACKET FORMAT</td>
<td>EXAMPLE (HEX)</td>
</tr>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>39</td>
</tr>
<tr>
<td>CRC - low order byte</td>
<td>CD</td>
</tr>
<tr>
<td>CRC - high order byte</td>
<td>F2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SLAVE RESPONSE</th>
<th>PACKET FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>89</td>
</tr>
<tr>
<td>ERROR CODE</td>
<td>01</td>
</tr>
<tr>
<td>CRC - low order byte</td>
<td>93</td>
</tr>
<tr>
<td>CRC - high order byte</td>
<td>95</td>
</tr>
</tbody>
</table>
a) DESCRIPTION

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.

b) OTHER PROTOCOLS

All the files available via Modbus may also be retrieved using the standard file transfer mechanisms in other protocols (e.g., TFTP or MMS).

c) 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.

d) READING OSCILLOGRAPHY FILES

Familiarity with the oscillography feature is required to understand the following description. Refer to the Oscillography section in Chapter 5 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 register 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 and OSCnnn.DAT

Replace “nnn” with the desired oscillography trigger number. For ASCII format, use the following file names

OSCAnnnn.CFG and OSCAann.DAT
APPENDIX B

B.3 FILE TRANSFERS

e) 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` and `datalog.dat`

To read the entire data logger in ASCII COMTRADE format, read the following files:

- `dataloga.cfg` and `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.

f) 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)

To read from a specific record to another specific record, use the following filename:

- `EVT.TXT xxxxx yyyyy` (replace `xxxxx` with the starting record number and `yyyyy` with the ending record number)

g) READING FAULT REPORT FILES

Fault report data has been available via the F60 file retrieval mechanism since UR 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.4 MEMORY MAPPING

#### B.4.1 MODBUS MEMORY MAP

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
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<td></td>
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<td></td>
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<td>&quot;Order Code x&quot;</td>
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## Table B–9: MODBUS MEMORY MAP (Sheet 2 of 47)

<table>
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<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
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**Digital Counter States (Read Only Non-Volatile) (8 modules)**

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<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
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**FlexStates (Read Only)**

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**Element States (Read Only)**

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### Table B–9: MODBUS MEMORY MAP (Sheet 3 of 47)

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### Table B–9: MODBUS MEMORY MAP (Sheet 4 of 47)

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<td>seconds</td>
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<td>1814</td>
<td>Source 3 Line Voltage Magnitude</td>
<td>-359.9 to 0</td>
<td>degrees</td>
<td>0.1</td>
<td>F002</td>
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### Table B–9: MODBUS MEMORY MAP (Sheet 5 of 47)

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<tbody>
<tr>
<td>1A0F</td>
<td>Source 1 Phase AB or AC Voltage RMS</td>
<td>0 to 9999999.999</td>
<td>V</td>
<td>0.001</td>
<td>F060</td>
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<td>1A11</td>
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<td>0 to 9999999.999</td>
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<td>F060</td>
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<td>1A13</td>
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<td>V</td>
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<td>1A15</td>
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<td>V</td>
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**Source Power (Read Only) (6 modules)**

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<td>1C00</td>
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<td>F060</td>
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<td>F060</td>
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### APPENDIX B

#### B.4 MEMORY MAPPING

**Table B–9: MODBUS MEMORY MAP (Sheet 6 of 47)**

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**Source Energy (Read Only Non-Volatile) (6 modules)**

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<td>Source 1 Positive Watthour</td>
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<td>...Repeated for Source 2</td>
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<tr>
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**Energy Commands (Read/Write Command)**

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**Source Frequency (Read Only) (6 modules)**

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**Source Demand (Read Only) (6 modules)**

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<td>F060</td>
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**Source Demand Peaks (Read Only Non-Volatile) (6 modules)**

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<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
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<tr>
<td>1E94</td>
<td>Source 1 Demand Va Maximum</td>
<td>0 to 999999.999 VA</td>
<td>0.001</td>
<td>F060</td>
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<td>1E96</td>
<td>Source 1 Demand Va Maximum Date</td>
<td>0 to 4294967295</td>
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<td>1</td>
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<tr>
<td>1E98</td>
<td>Reserved (8 items)</td>
<td>---</td>
<td>---</td>
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<tr>
<td>1EA0</td>
<td>...Repeated for Source 2</td>
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<td></td>
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<td>1EC0</td>
<td>...Repeated for Source 3</td>
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<td>1EE0</td>
<td>...Repeated for Source 4</td>
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<td>1F00</td>
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<td>1F20</td>
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### Table B–9: MODBUS MEMORY MAP (Sheet 7 of 47)

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<td>1F80</td>
<td>Source 1 Va THD</td>
<td>0 to 99.9</td>
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<td>0.1</td>
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<tr>
<td>1F81</td>
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<td>0 to 99.9</td>
<td></td>
<td>0.1</td>
<td>F001</td>
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<td>1F99</td>
<td>Source 1 Vb THD</td>
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**Breaker Flashover (Read/Write Setting) (2 modules)**

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<td>21A6</td>
<td>Breaker 1 Flashover Function</td>
<td>0 to 1</td>
<td></td>
<td>1</td>
<td>F102</td>
<td>0 (Disabled)</td>
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<tr>
<td>21A7</td>
<td>Breaker 1 Flashover Side 1 Source</td>
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<td></td>
<td>1</td>
<td>F167</td>
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<tr>
<td>21A8</td>
<td>Breaker 1 Flashover Side 2 Source</td>
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<td>F211</td>
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<td>21A9</td>
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<td>0 to 65535</td>
<td></td>
<td>1</td>
<td>F300</td>
<td>0</td>
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<td>21AA</td>
<td>Breaker 1 Flashover Status Closed B</td>
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<td>F300</td>
<td>0</td>
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<tr>
<td>21AB</td>
<td>Breaker 1 Flashover Status Closed C</td>
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<tr>
<td>21AC</td>
<td>Breaker 1 Flashover Voltage Pickup Level</td>
<td>0 to 1.5</td>
<td>pu</td>
<td>0.001</td>
<td>F001</td>
<td>850</td>
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<td>21AD</td>
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<td>0 to 100000</td>
<td>V</td>
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<td>F060</td>
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<td>s</td>
<td>0.001</td>
<td>F001</td>
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<td>21B6</td>
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<td>0 to 2</td>
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<td>1</td>
<td>F109</td>
<td>0 (Self-Reset)</td>
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<td>21BB</td>
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<td>kA²-cyc</td>
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**Breaker Arcing Current Actuals (Read Only Non-Volatile) (2 modules)**

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<td>F001</td>
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**Breaker Arcing Current Commands (Read/Write Command) (2 modules)**

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<td>Breaker 1 Arcing Current Clear Command</td>
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<td></td>
<td>1</td>
<td>F126</td>
<td>0 (No)</td>
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<td>2225</td>
<td>Breaker 2 Arcing Current Clear Command</td>
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**Passwords Unauthorized Access (Read/Write Command)**

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<td>Reset Unauthorized Access</td>
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**Hi-Z (High Impedance Fault Detection) Commands (Read/Write Command)**

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<td>2240</td>
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<td>2241</td>
<td>Hi-Z Oscillography Force Trigger</td>
<td>0 to 1</td>
<td></td>
<td>1</td>
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<tr>
<td>2242</td>
<td>Hi-Z Oscillography Force Algorithm Capture</td>
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<td>2243</td>
<td>Hi-Z Reset Sigma Values</td>
<td>0 to 1</td>
<td></td>
<td>1</td>
<td>F126</td>
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**Hi-Z (High Impedance Fault Detection) Status (Read Only)**

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<td>Hi-Z Phase B Arc Confidence</td>
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## APPENDIX B

### B.4 MEMORY MAPPING

#### Hi-Z (High Impedance Fault Detection) Records (Read Only) (4 modules)

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<tbody>
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<td>2253</td>
<td>Hi-Z Phase C Arc Confidence</td>
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<td>2254</td>
<td>Hi-Z Neutral Arc Confidence</td>
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#### Hi-Z (High Impedance Fault Detection) RMS Records (Read Only) (4 modules)

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<td>Hi-Z RMS Capture 1 Trigger Type</td>
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#### Fault Location (Read Only) (5 modules)

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<tr>
<td>2340</td>
<td>Fault 1 Prefault Phase A Current Magnitude</td>
<td>0 to 999999.999</td>
<td>A</td>
<td>0.001</td>
<td>F060</td>
<td>0</td>
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<tr>
<td>2342</td>
<td>Fault 1 Prefault Phase A Current Angle</td>
<td>-359.9 to 0</td>
<td>degrees</td>
<td>0.1</td>
<td>F002</td>
<td>0</td>
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<tr>
<td>2343</td>
<td>Fault 1 Prefault Phase B Current Magnitude</td>
<td>0 to 999999.999</td>
<td>A</td>
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<td>0 to 999999.999</td>
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<td>F060</td>
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<td>234B</td>
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<td>0.1</td>
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<td>0 to 999999.999</td>
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#### Synchrocheck Actuals (Read Only) (2 modules)

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<td>Hz</td>
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#### Autoreclose Status (Read Only) (6 modules)

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<td>2411</td>
<td>Autoreclose 2 Count</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
</tbody>
</table>

---

Table B–9: MODBUS MEMORY MAP (Sheet 8 of 47)
### Table B–9: MODBUS MEMORY MAP (Sheet 9 of 47)

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2412</td>
<td>Autoreclose 3 Count</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>2413</td>
<td>Autoreclose 4 Count</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>2414</td>
<td>Autoreclose 5 Count</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>2415</td>
<td>Autoreclose 6 Count</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
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</tr>
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**Source Current THD And Harmonics (Read Only) (6 modules)**

<table>
<thead>
<tr>
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<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2800</td>
<td>Ia THD for Source 1</td>
<td>0 to 99.9</td>
<td>---</td>
<td>0.1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>2801</td>
<td>Ia Harmonics for Source 1 - 2nd to 25th (24 items)</td>
<td>0 to 99.9</td>
<td>---</td>
<td>0.1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>2821</td>
<td>Ib THD for Source 1</td>
<td>0 to 99.9</td>
<td>---</td>
<td>0.1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>2822</td>
<td>Ib Harmonics for Source 1 - 2nd to 25th (24 items)</td>
<td>0 to 99.9</td>
<td>---</td>
<td>0.1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>283A</td>
<td>Reserved (8 items)</td>
<td>0 to 0.1</td>
<td>---</td>
<td>0.1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>2842</td>
<td>Ic THD for Source 1</td>
<td>0 to 99.9</td>
<td>---</td>
<td>0.1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>2843</td>
<td>Ic Harmonics for Source 1 - 2nd to 25th (24 items)</td>
<td>0 to 99.9</td>
<td>---</td>
<td>0.1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>285B</td>
<td>Reserved (8 items)</td>
<td>0 to 0.1</td>
<td>---</td>
<td>0.1</td>
<td>F001</td>
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...Repeated for Source 2

**Expanded FlexStates (Read Only)**

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<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2B00</td>
<td>FlexStates, one per register (256 items)</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F108</td>
<td>0</td>
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**Expanded Digital Input/Output states (Read Only)**

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D00</td>
<td>Contact input States, one per register (96 items)</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F108</td>
<td>0</td>
</tr>
<tr>
<td>2D80</td>
<td>Contact Output States, one per register (64 items)</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F108</td>
<td>0</td>
</tr>
<tr>
<td>2E00</td>
<td>Virtual Output States, one per register (96 items)</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F108</td>
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**Expanded Remote Input/Output Status (Read Only)**

<table>
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<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2F00</td>
<td>Remote Device States, one per register (16 items)</td>
<td>0 to 1</td>
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<td>1</td>
<td>F155</td>
<td>0</td>
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<tr>
<td>2F80</td>
<td>Remote Input States, one per register (64 items)</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F108</td>
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**Oscillography Values (Read Only)**

<table>
<thead>
<tr>
<th>ADDR</th>
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<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000</td>
<td>Oscillography Number of Triggers</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>3001</td>
<td>Oscillography Available Records</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>3002</td>
<td>Oscillography Last Cleared Date</td>
<td>0 to 400000000</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3004</td>
<td>Oscillography Number Of Cycles Per Record</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
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</table>

**Oscillography Commands (Read/Write Command)**

<table>
<thead>
<tr>
<th>ADDR</th>
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<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3005</td>
<td>Oscillography Force Trigger</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F126</td>
<td>0</td>
</tr>
<tr>
<td>3011</td>
<td>Oscillography Clear Data</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F126</td>
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**Fault Report Indexing (Read Only Non-Volatile)**

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<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3020</td>
<td>Number of Fault Reports</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
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</tr>
</tbody>
</table>

**Fault Report Actuals (Read Only Non-Volatile) (15 modules)**

<table>
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<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3030</td>
<td>Fault Report 1 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3032</td>
<td>Fault Report 2 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3034</td>
<td>Fault Report 3 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3036</td>
<td>Fault Report 4 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3038</td>
<td>Fault Report 5 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>303A</td>
<td>Fault Report 6 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>303C</td>
<td>Fault Report 7 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>303E</td>
<td>Fault Report 8 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3040</td>
<td>Fault Report 9 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3042</td>
<td>Fault Report 10 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3044</td>
<td>Fault Report 11 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3046</td>
<td>Fault Report 12 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3048</td>
<td>Fault Report 13 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>304A</td>
<td>Fault Report 14 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>304C</td>
<td>Fault Report 15 Time</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F050</td>
<td>0</td>
</tr>
</tbody>
</table>
# MODBUS MEMORY MAP

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3100</td>
<td>Name of file to read</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>(none)</td>
</tr>
<tr>
<td>3200</td>
<td>Character position of current block within file</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>3203</td>
<td>Size of currently-available data block</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>3204</td>
<td>Block of data from requested file (122 items)</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>3400</td>
<td>Events Since Last Clear</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F003</td>
<td>0</td>
</tr>
<tr>
<td>3402</td>
<td>Number of Available Events</td>
<td>0 to 4294967295</td>
<td>---</td>
<td>1</td>
<td>F003</td>
<td>0</td>
</tr>
<tr>
<td>3404</td>
<td>Event Recorder Last Cleared Date</td>
<td>0 to 4294967295</td>
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<td>F050</td>
<td>0</td>
</tr>
<tr>
<td>3406</td>
<td>Event Recorder Clear Command</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F126</td>
<td>0 (No)</td>
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<tr>
<td>34C0</td>
<td>DCMA Inputs 1 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<tr>
<td>34C2</td>
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<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<tr>
<td>34C4</td>
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<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
<tr>
<td>34C6</td>
<td>DCMA Inputs 4 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<tr>
<td>34C8</td>
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<td>F004</td>
<td>0</td>
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<td>-9999999 to 9999999</td>
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<td>F004</td>
<td>0</td>
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<tr>
<td>34CC</td>
<td>DCMA Inputs 7 Value</td>
<td>-9999999 to 9999999</td>
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<td>1</td>
<td>F004</td>
<td>0</td>
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<td>34CE</td>
<td>DCMA Inputs 8 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<tr>
<td>34D0</td>
<td>DCMA Inputs 9 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
<tr>
<td>34D2</td>
<td>DCMA Inputs 10 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
<tr>
<td>34D4</td>
<td>DCMA Inputs 11 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
<tr>
<td>34D6</td>
<td>DCMA Inputs 12 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
<tr>
<td>34D8</td>
<td>DCMA Inputs 13 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<td>34DA</td>
<td>DCMA Inputs 14 Value</td>
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<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<td>34DE</td>
<td>DCMA Inputs 16 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<tr>
<td>34E0</td>
<td>DCMA Inputs 17 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
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<td>34E2</td>
<td>DCMA Inputs 18 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
<tr>
<td>34E4</td>
<td>DCMA Inputs 19 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
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<td>34E6</td>
<td>DCMA Inputs 20 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
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<td>F004</td>
<td>0</td>
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<td>34E8</td>
<td>DCMA Inputs 21 Value</td>
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<td>1</td>
<td>F004</td>
<td>0</td>
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<td>DCMA Inputs 22 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<td>DCMA Inputs 23 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
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<td>34EE</td>
<td>DCMA Inputs 24 Value</td>
<td>-9999999 to 9999999</td>
<td>---</td>
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<td>F004</td>
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<td>34F0</td>
<td>RTD Input 1 Value</td>
<td>-32768 to 32767</td>
<td>°C</td>
<td>1</td>
<td>F002</td>
<td>0</td>
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<td>34F1</td>
<td>RTD Input 2 Value</td>
<td>-32768 to 32767</td>
<td>°C</td>
<td>1</td>
<td>F002</td>
<td>0</td>
</tr>
<tr>
<td>34F2</td>
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<td>-32768 to 32767</td>
<td>°C</td>
<td>1</td>
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<td>0</td>
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<td>°C</td>
<td>1</td>
<td>F002</td>
<td>0</td>
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<tr>
<td>34F4</td>
<td>RTD Input 5 Value</td>
<td>-32768 to 32767</td>
<td>°C</td>
<td>1</td>
<td>F002</td>
<td>0</td>
</tr>
<tr>
<td>34F5</td>
<td>RTD Input 6 Value</td>
<td>-32768 to 32767</td>
<td>°C</td>
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<td>0</td>
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<tr>
<td>34F6</td>
<td>RTD Input 7 Value</td>
<td>-32768 to 32767</td>
<td>°C</td>
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<td>F002</td>
<td>0</td>
</tr>
<tr>
<td>34F7</td>
<td>RTD Input 8 Value</td>
<td>-32768 to 32767</td>
<td>°C</td>
<td>1</td>
<td>F002</td>
<td>0</td>
</tr>
<tr>
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### Table B–9: MODBUS MEMORY MAP (Sheet 11 of 47)

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**Expanded Direct Input/Output Status (Read Only)**

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<td>3560</td>
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**Passwords (Read/Write Command)**

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<tr>
<td>4000</td>
<td>Command Password Setting</td>
<td>0 to 4294967295</td>
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<td>4002</td>
<td>Setting Password Setting</td>
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**Passwords (Read/Write)**

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**Passwords (Read Only)**

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**User Display Invoke (Read/Write Setting)**

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<td>4040</td>
<td>Invoke and Scroll Through User Display Menu Operand</td>
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**LED Test (Read/Write Setting)**

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<td>4046</td>
<td>LED Test Function</td>
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<td>4049</td>
<td>LED Test Control</td>
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**Preferences (Read/Write Setting)**

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<td>404F</td>
<td>Language</td>
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<td>Flash Message Time</td>
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<td>0.1</td>
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## Table B–9: MODBUS MEMORY MAP (Sheet 12 of 47)

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<td>COM2 minimum response time</td>
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<td>DNP Unsolicited Responses Function</td>
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<td>DNP Unsolicited Responses Destination Address</td>
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<td>40AD</td>
<td>Ethernet Operation Mode</td>
<td>0 to 1</td>
<td>---</td>
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<td>F192</td>
<td>0 (Half-Duplex)</td>
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<td>40AE</td>
<td>DNP Current Scale Factor</td>
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<td>40B3</td>
<td>DNP Current Default Deadband</td>
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<td>40B8</td>
<td>DNP INI Time Sync Bit Period</td>
<td>1 to 10080</td>
<td>min</td>
<td>1</td>
<td>F001</td>
<td>1440</td>
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<td>40B9</td>
<td>DNP Message Fragment Size</td>
<td>30 to 2048</td>
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<td>DNP Client Address 3</td>
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<td>40C0</td>
<td>DNP Number of Paired Binary Output Control Points</td>
<td>0 to 16</td>
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<td>Reserved (31 items)</td>
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<td>40E0</td>
<td>TCP Port Number for the IEC 60870-5-104 Protocol</td>
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<td>IEC 60870-5-104 Protocol Function</td>
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<td>IEC 60870-5-104 Protocol Common Address of ASDU</td>
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<td>IEC 60870-5-104 Protocol Cyclic Data Trans. Period</td>
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### B.4 MEMORY MAPPING

**Table B–9: MODBUS MEMORY MAP (Sheet 13 of 47)**

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<td>40E4</td>
<td>IEC 60870-5-104 Current Default Threshold</td>
<td>0 to 65535</td>
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<td>IEC 60870-5-104 Voltage Default Threshold</td>
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<td>30000</td>
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<td>IEC 60870-5-104 Energy Default Threshold</td>
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<td>4140</td>
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<td>4142</td>
<td>DNP Object 20 Default Variation</td>
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<td>0 (1)</td>
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<td>DNP Object 21 Default Variation</td>
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<td>4145</td>
<td>DNP Object 23 Default Variation</td>
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**Simple Network Time Protocol (Read/Write Setting)**

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<tr>
<td>4168</td>
<td>Simple Network Time Protocol Function</td>
<td>0 to 1</td>
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<td>4169</td>
<td>Simple Network Time Protocol Server IP Address</td>
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**Data Logger Commands (Read/Write Command)**

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<tr>
<td>4170</td>
<td>Data Logger Clear</td>
<td>0 to 1</td>
<td></td>
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<td>F126</td>
<td>0 (No)</td>
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**Data Logger (Read/Write Setting)**

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<tr>
<td>4181</td>
<td>Data Logger Channel Settings (16 items)</td>
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<td>4191</td>
<td>Data Logger Mode</td>
<td>0 to 1</td>
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<td>F260</td>
<td>0 (continuous)</td>
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<tr>
<td>4192</td>
<td>Data Logger Trigger</td>
<td>0 to 65535</td>
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<td>1</td>
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<tr>
<td>4193</td>
<td>Data Logger Rate</td>
<td>15 to 3600000</td>
<td>ms</td>
<td>1</td>
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<td>60000</td>
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**Clock (Read/Write Command)**

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<tr>
<td>41A0</td>
<td>Real Time Clock Set Time</td>
<td>0 to 235959</td>
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**Clock (Read/Write Setting)**

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<td>SR Date Format</td>
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<td>41A6</td>
<td>IRIG-B Signal Type</td>
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<td>0 (None)</td>
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<td>41A7</td>
<td>Clock Events Enable / Disable</td>
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<td>1</td>
<td>F102</td>
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**Fault Report Commands (Read/Write Command)**

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<tr>
<td>41B2</td>
<td>Fault Reports Clear Data Command</td>
<td>0 to 1</td>
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<td>F126</td>
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**Oscillography (Read/Write Setting)**

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<tbody>
<tr>
<td>41C0</td>
<td>Oscillography Number of Records</td>
<td>1 to 64</td>
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<td>F001</td>
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<td>41C1</td>
<td>Oscillography Trigger Mode</td>
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<td>F118</td>
<td>0 (Auto. Overwrite)</td>
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<td>41C2</td>
<td>Oscillography Trigger Position</td>
<td>0 to 100</td>
<td>%</td>
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<td>41C4</td>
<td>Oscillography AC Input Waveforms</td>
<td>0 to 4</td>
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<td>2 (16 samples/cycle)</td>
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<td>41D0</td>
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**Trip and Alarm LEDs (Read/Write Setting)**

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<td>4260</td>
<td>Trip LED Input FlexLogic Operand</td>
<td>0 to 65535</td>
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<td>4261</td>
<td>Alarm LED Input FlexLogic Operand</td>
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**User Programmable LEDs (Read/Write Setting) (48 modules)**

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<td>4280</td>
<td>FlexLogic™ Operand to Activate LED</td>
<td>0 to 65535</td>
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<td>4281</td>
<td>User LED type (latched or self-resetting)</td>
<td>0 to 1</td>
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<td>F127</td>
<td>1 (Self-Reset)</td>
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### Table B–9: MODBUS MEMORY MAP (Sheet 14 of 47)

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#### Installation (Read/Write Setting)
- **43E0** Relay Programmed State
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F133
  - DEFAULT: 0 (Not Programmed)

- **43E1** Relay Name
  - RANGE: ---
  - UNITS: ---
  - STEP: ---
  - FORMAT: F202
  - DEFAULT: "Relay-1"

#### User Programmable Self Tests (Read/Write Setting)
- **4441** User Programmable Detect Ring Break Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 1 (Enabled)

- **4442** User Programmable Direct Device Off Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 1 (Enabled)

- **4443** User Programmable Remote Device Off Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 1 (Enabled)

- **4444** User Programmable Primary Ethernet Fail Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 0 (Disabled)

- **4445** User Programmable Secondary Ethernet Fail Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 0 (Disabled)

- **4446** User Programmable Battery Fail Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 1 (Enabled)

- **4447** User Programmable SNTP Fail Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 1 (Enabled)

- **4448** User Programmable IRIG-B Fail Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 1 (Enabled)
### Table B–9: MODBUS MEMORY MAP (Sheet 15 of 47)

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
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### Table B–9: MODBUS MEMORY MAP (Sheet 16 of 47)

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<th>ADDR</th>
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<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
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<td>Synchrocheck 1 V1 Source</td>
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<td>Synchrocheck 1 Maximum Voltage Difference</td>
<td>0 to 400000</td>
<td>V</td>
<td>1</td>
<td>F060</td>
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<td>Synchrocheck 1 Dead Source Select</td>
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### Table B–9: MODBUS MEMORY MAP (Sheet 17 of 47)

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**Flexlogic (Read/Write Setting)**

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**Flexlogic Timers (Read/Write Setting) (32 modules)**

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**Phase Time Overcurrent (Read/Write Grouped Setting) (6 modules)**

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**Phase Instantaneous Overcurrent (Read/Write Grouped Setting) (12 modules)**

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**Neutral Time Overcurrent (Read/Write Grouped Setting) (6 modules)**

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### Table B–9: MODBUS MEMORY MAP (Sheet 19 of 47)

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#### Ground Time Overcurrent (Read/Write Grouped Setting) (6 modules)

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#### Ground Instantaneous Overcurrent (Read/Write Grouped Setting) (12 modules)

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# APPENDIX B

## B.4 MEMORY MAPPING

### Table B–9: MODBUS MEMORY MAP (Sheet 20 of 47)

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<td>0 to 5</td>
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#### Setting Groups (Read/Write Setting)

- **5F80** Setting Group for Modbus Comms (0 means group 1) 0 to 5 --- 1 F001 0
- **5F81** Setting Groups Block 0 to 65535 --- 1 F300 0
- **5F82** FlexLogic to Activate Groups 2 through 6 (5 items) 0 to 65535 --- 1 F300 0
- **5F89** Setting Group Function 0 to 1 --- 1 F102 0 (Disabled)
- **5F9A** Setting Group Events 0 to 1 --- 1 F102 0 (Disabled)

#### Setting Groups (Read Only)

- **5F8B** Current Setting Group 0 to 5 --- 1 F001 0

#### Setting Group Names (Read/Write Setting)

- **5F8C** Setting Group 1 Name --- --- --- F203 (none)
- **5F94** Setting Group 2 Name --- --- --- F203 (none)
- **5F9C** Setting Group 3 Name --- --- --- F203 (none)
- **5FA4** Setting Group 4 Name --- --- --- F203 (none)
- **5FAC** Setting Group 5 Name --- --- --- F203 (none)
- **5FB4** Setting Group 6 Name --- --- --- F203 (none)

#### Autoreclose (Read/Write Setting) (6 modules)

- **6240** Autoreclose 1 Function 0 to 1 --- 1 F102 0 (Disabled)
- **6241** Autoreclose 1 Initiate 0 to 65535 --- 1 F300 0
- **6242** Autoreclose 1 Block 0 to 65535 --- 1 F300 0
- **6243** Autoreclose 1 Max Number of Shots 1 to 4 --- 1 F001 1
- **6244** Autoreclose 1 Manual Close 0 to 65535 --- 1 F300 0
- **6245** Autoreclose 1 Manual Reset from LO 0 to 65535 --- 1 F300 0
- **6246** Autoreclose 1 Reset Lockout if Breaker Closed 0 to 1 --- 1 F108 0 (Off)
- **6247** Autoreclose 1 Reset Lockout On Manual Close 0 to 1 --- 1 F108 0 (Off)
- **6248** Autoreclose 1 Breaker Closed 0 to 65535 --- 1 F300 0
- **6249** Autoreclose 1 Breaker Open 0 to 65535 --- 1 F300 0
- **624A** Autoreclose 1 Block Time Upon Manual Close 0 to 655.35 s 0.01 F001 1000
- **624B** Autoreclose 1 Dead Time Shot 1 0 to 655.35 s 0.01 F001 100
- **624C** Autoreclose 1 Dead Time Shot 2 0 to 655.35 s 0.01 F001 200
- **624D** Autoreclose 1 Dead Time Shot 3 0 to 655.35 s 0.01 F001 300
- **624E** Autoreclose 1 Dead Time Shot 4 0 to 655.35 s 0.01 F001 400
- **624F** Autoreclose 1 Reset Lockout Delay 0 to 655.35 s 0.01 F001 6000
- **6250** Autoreclose 1 Reset Time 0 to 655.35 s 0.01 F001 6000
- **6251** Autoreclose 1 Incomplete Sequence Time 0 to 655.35 s 0.01 F001 500
- **6252** Autoreclose 1 Events 0 to 1 --- 1 F102 0 (Disabled)
- **6253** Autoreclose 1 Reduce Max 1 0 to 65535 --- 1 F300 0
- **6254** Autoreclose 1 Reduce Max 2 0 to 65535 --- 1 F300 0
- **6255** Autoreclose 1 Reduce Max 3 0 to 65535 --- 1 F300 0
- **6256** Autoreclose 1 Add Delay 1 0 to 65535 --- 1 F300 0
- **6257** Autoreclose 1 Delay 1 0 to 655.35 s 0.01 F001 0
- **6258** Autoreclose 1 Add Delay 2 0 to 65535 --- 1 F300 0
- **6259** Autoreclose 1 Delay 2 0 to 655.35 s 0.01 F001 0
- **625A** Reserved (4 items) 0 to 0.001 --- 0.001 F001 0
- **625E** ...Repeated for Autoreclose 2
- **627C** ...Repeated for Autoreclose 3
- **629A** ...Repeated for Autoreclose 4
- **62B8** ...Repeated for Autoreclose 5
- **62D6** ...Repeated for Autoreclose 6
### Table B–9: MODBUS MEMORY MAP (Sheet 21 of 47)

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
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<tr>
<td>6300</td>
<td>Negative Sequence Time Overcurrent 1 Function</td>
<td>0 to 1</td>
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<td>0 (Disabled)</td>
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<tr>
<td>6301</td>
<td>Negative Sequence Time Overcurrent 1 Signal Source</td>
<td>0 to 5</td>
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<td>0 (SRC 1)</td>
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<tr>
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<td>Negative Sequence Time Overcurrent 1 Pickup</td>
<td>0 to 30</td>
<td>pu</td>
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<td>Negative Sequence Time Overcurrent 1 Curve</td>
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<td>6304</td>
<td>Negative Sequence Time Overcurrent 1 Multiplier</td>
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<td>Negative Sequence Time Overcurrent 1 Reset</td>
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<td>6309</td>
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<td>Negative Sequence Instantaneous OC 1 Source</td>
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<td>1</td>
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<td>0 (SRC 1)</td>
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<td>Negative Sequence Instantaneous Current 1 Pickup</td>
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<td>0 (Disabled)</td>
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### Table B–9: MODBUS MEMORY MAP (Sheet 22 of 47)

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Load Encroachment (Read/Write Grouped Setting)

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<th>UNITS</th>
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<td>1</td>
<td>F167</td>
<td>0 (SRC 1)</td>
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<tr>
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<td>F001</td>
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<td>0.02 to 250</td>
<td>ohms</td>
<td>0.01</td>
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<td>degrees</td>
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Phase Undervoltage (Read/Write Grouped Setting) (2 modules)

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<td>0 (SRC 1)</td>
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<td>F111</td>
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<td>---</td>
<td>1</td>
<td>F109</td>
<td>0 (Self-reset)</td>
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<tr>
<td>7008</td>
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<td>7009</td>
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Phase Overvoltage (Read/Write Grouped Setting)

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Breaker Failure (Read/Write Grouped Setting) (2 modules)

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**Phase Directional Overcurrent (Read/Write Grouped Setting) (2 modules)**

**Neutral Directional Overcurrent (Read/Write Grouped Setting) (2 modules)**

**Negative Sequence Directional Overcurrent (Read/Write Grouped Setting) (2 modules)**
## Table B–9: MODBUS MEMORY MAP (Sheet 24 of 47)

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<td>72A3</td>
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<td>0 to 90</td>
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<td>0.05 to 30</td>
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### Breaker Arcing Current Settings (Read/Write Setting) (2 modules)

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### DCMA Inputs (Read/Write Setting) (24 modules)

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...Repeated for dcmA Inputs 2

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...Repeated for dcmA Inputs 4

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...Repeated for dcmA Inputs 6

...Repeated for dcmA Inputs 7

...Repeated for dcmA Inputs 8

...Repeated for dcmA Inputs 9

...Repeated for dcmA Inputs 10

...Repeated for dcmA Inputs 11

...Repeated for dcmA Inputs 12

...Repeated for dcmA Inputs 13

...Repeated for dcmA Inputs 14

...Repeated for dcmA Inputs 15

...Repeated for dcmA Inputs 16

...Repeated for dcmA Inputs 17

...Repeated for dcmA Inputs 18

...Repeated for dcmA Inputs 19

...Repeated for dcmA Inputs 20

...Repeated for dcmA Inputs 21

...Repeated for dcmA Inputs 22
### B.4 MEMORY MAPPING

#### Table B–9: MODBUS MEMORY MAP (Sheet 25 of 47)

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### High Impedance Fault Detection (Hi-Z) Settings (Read/Write Setting)

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### Underfrequency (Read/Write Setting) (6 modules)

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### Neutral Overvoltage (Read/Write Grouped Setting) (3 modules)

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### Auxiliary Overvoltage (Read/Write Grouped Setting) (3 modules)

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Table B–9: MODBUS MEMORY MAP (Sheet 27 of 47)

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### Table B–9: MODBUS MEMORY MAP (Sheet 28 of 47)

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**FlexElement (Read/Write Setting) (16 modules)**

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Table B–9: MODBUS MEMORY MAP (Sheet 30 of 47)

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Direct Input/Output Names (Read/Write Setting) (96 modules)

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FlexElement Actuals (Read Only) (16 modules)

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### Table B–9: MODBUS MEMORY MAP (Sheet 31 of 47)

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#### Teleprotection Inputs/Outputs (Read/Write Settings)

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<tbody>
<tr>
<td>9B00</td>
<td>Teleprotection Function</td>
<td>0 to 1</td>
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<td>1</td>
<td>F102</td>
<td>0</td>
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<tr>
<td>9B01</td>
<td>Teleprotection Number of Terminals</td>
<td>2 to 3</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>2</td>
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<tr>
<td>9B02</td>
<td>Teleprotection Number of Channels</td>
<td>1 to 2</td>
<td>---</td>
<td>1</td>
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<tr>
<td>9B03</td>
<td>Teleprotection Local Relay ID</td>
<td>0 to 255</td>
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<td>F001</td>
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<tr>
<td>9B04</td>
<td>Teleprotection Terminal 1 ID</td>
<td>0 to 255</td>
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<td>Teleprotection Terminal 2 ID</td>
<td>0 to 255</td>
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<tr>
<td>9B06</td>
<td>Reserved (10 items)</td>
<td>0 to 1</td>
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<td>F001</td>
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<td>9B10</td>
<td>Teleprotection Input 1-n Default States</td>
<td>0 to 3</td>
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<td>F086</td>
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<td>9B30</td>
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<td>---</td>
<td>1</td>
<td>F086</td>
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<td>9B50</td>
<td>Teleprotection Output 1-n Operand</td>
<td>0 to 65535</td>
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<td>F300</td>
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<td>9B70</td>
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#### Teleprotection Inputs/Outputs Commands (Read/Write Command)

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<tbody>
<tr>
<td>9B90</td>
<td>Teleprotection Clear Lost Packets</td>
<td>0 to 1</td>
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<td>F126</td>
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#### Teleprotection Channel Tests (Read Only)

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<tr>
<td>9B91</td>
<td>Teleprotection Channel 1 Status</td>
<td>0 to 2</td>
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<td>1</td>
<td>F134</td>
<td>1 (OK)</td>
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<tr>
<td>9B92</td>
<td>Teleprotection Channel 1 Number of Lost Packets</td>
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<td>F001</td>
<td>0</td>
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<td>Teleprotection Channel 2 Status</td>
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<td>F134</td>
<td>1 (OK)</td>
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<td>9B94</td>
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<td>9B95</td>
<td>Teleprotection Network Status</td>
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<td>F134</td>
<td>2 (via)</td>
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<td>9B96</td>
<td>Teleprotection Channel 1 Input States</td>
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<td>Teleprotection Channel 2 Input States</td>
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<td>9BB0</td>
<td>Teleprotection Input 1 States, 1 per register (16 items)</td>
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#### Cold Load Pickup (Read/Write Setting) (2 modules)

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<td>A010</td>
<td>Cold Load Pickup 1 Function</td>
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<td>A011</td>
<td>Cold Load Pickup 1 Initiate</td>
<td>0 to 65535</td>
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<td>A012</td>
<td>Cold Load Pickup 1 Block</td>
<td>0 to 65535</td>
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<td>A013</td>
<td>Outage Time Before Cold Load Pickup 1</td>
<td>0 to 1000</td>
<td>s</td>
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<td>On Load Time Before Reset 1</td>
<td>0 to 10000000</td>
<td>s</td>
<td>0.001</td>
<td>F003</td>
<td>1000000</td>
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<td>A016</td>
<td>Cold Load Pickup 1 Source</td>
<td>0 to 5</td>
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<td>A017</td>
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#### VT Fuse Failure (Read/Write Setting) (6 modules)

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#### Selector Switch Actuals (Read Only)

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<tbody>
<tr>
<td>A400</td>
<td>Selector 1 Position</td>
<td>1 to 7</td>
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<td>A401</td>
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#### Selector Switch (Read/Write Setting) (2 modules)

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<td>F102</td>
<td>0 (Disabled)</td>
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<td>A411</td>
<td>Selector 1 Range</td>
<td>1 to 7</td>
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<td>Selector 1 Timeout</td>
<td>3 to 60</td>
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<td>Selector 1 Step Up</td>
<td>0 to 65535</td>
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<td>F083</td>
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<td>Selector 1 Acknowledge</td>
<td>0 to 65535</td>
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<td>1</td>
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### APPENDIX B

#### B.4 MEMORY MAPPING

**Table B–9: MODBUS MEMORY MAP (Sheet 32 of 47)**

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<td>Selector 1 Bit0</td>
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<td>(Time-out)</td>
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<td>Selector 1 Power Up Mode</td>
<td>0 to 2</td>
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<td>F084</td>
<td>(Restore)</td>
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<td>A422</td>
<td>Selector 1 Target</td>
<td>0 to 2</td>
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<td>1</td>
<td>F109</td>
<td>(Self-reset)</td>
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<tr>
<td>A423</td>
<td>Selector 1 Events</td>
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**DNP/IEC Points (Read/Write Setting)**

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<tbody>
<tr>
<td>A500</td>
<td>DNP/IEC 60870-5-104 Analog Input Points (256 items)</td>
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**Flexcurves C and D (Read/Write Setting)**

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<tbody>
<tr>
<td>A900</td>
<td>FlexCurve D (120 items)</td>
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**Non Volatile Latches (Read/Write Setting) (16 modules)**

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<th>Non-Volatile Latch 1 Function</th>
<th>RANGE</th>
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<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A00</td>
<td>Non-Volatile Latch 1 Type</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F519</td>
<td>(Reset Dominant)</td>
</tr>
<tr>
<td>A01</td>
<td>Non-Volatile Latch 1 Set</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>A02</td>
<td>Non-Volatile Latch 1 Reset</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>A03</td>
<td>Non-Volatile Latch 1 Target</td>
<td>0 to 2</td>
<td>---</td>
<td>1</td>
<td>F109</td>
<td>(Self-reset)</td>
</tr>
<tr>
<td>A04</td>
<td>Non-Volatile Latch 1 Events</td>
<td>0 to 1</td>
<td>---</td>
<td>1</td>
<td>F102</td>
<td>(Disabled)</td>
</tr>
<tr>
<td>A05</td>
<td>Reserved (4 items)</td>
<td>---</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>A06</td>
<td>...Repeated for Non-Volatile Latch 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A07</td>
<td>...Repeated for Non-Volatile Latch 3</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>A08</td>
<td>...Repeated for Non-Volatile Latch 4</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A09</td>
<td>...Repeated for Non-Volatile Latch 5</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A0A</td>
<td>...Repeated for Non-Volatile Latch 6</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>A0B</td>
<td>...Repeated for Non-Volatile Latch 7</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>A0C</td>
<td>...Repeated for Non-Volatile Latch 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A0D</td>
<td>...Repeated for Non-Volatile Latch 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A0E</td>
<td>...Repeated for Non-Volatile Latch 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A0F</td>
<td>...Repeated for Non-Volatile Latch 11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A0G</td>
<td>...Repeated for Non-Volatile Latch 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>A0H</td>
<td>...Repeated for Non-Volatile Latch 13</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A0I</td>
<td>...Repeated for Non-Volatile Latch 14</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>A0J</td>
<td>...Repeated for Non-Volatile Latch 15</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>A0K</td>
<td>...Repeated for Non-Volatile Latch 16</td>
<td></td>
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</tr>
</tbody>
</table>

**Digital Counter (Read/Write Setting) (8 modules)**

<table>
<thead>
<tr>
<th>ADDR</th>
<th>Digital Counter 1 Function</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB0</td>
<td>Digital Counter 1 Name</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>F205</td>
<td>&quot;Counter 1&quot;</td>
</tr>
<tr>
<td>AB1</td>
<td>Digital Counter 1 Units</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>F206</td>
<td>(none)</td>
</tr>
<tr>
<td>AB2</td>
<td>Digital Counter 1 Block</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>AB3</td>
<td>Digital Counter 1 Up</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>AB4</td>
<td>Digital Counter 1 Down</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>AB5</td>
<td>Digital Counter 1 Preset</td>
<td>-2147483647 to 2147483647</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
<tr>
<td>AB6</td>
<td>Digital Counter 1 Compare</td>
<td>-2147483647 to 2147483647</td>
<td>---</td>
<td>1</td>
<td>F004</td>
<td>0</td>
</tr>
<tr>
<td>AB7</td>
<td>Digital Counter 1 Clear</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>AB8</td>
<td>Digital Counter 1 Freeze/Reset</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>AB9</td>
<td>Digital Counter 1 Freeze/Count</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>AB10</td>
<td>Digital Counter 1 Set To Preset</td>
<td>0 to 65535</td>
<td>---</td>
<td>1</td>
<td>F300</td>
<td>0</td>
</tr>
<tr>
<td>AB11</td>
<td>Reserved (11 items)</td>
<td>---</td>
<td>---</td>
<td>1</td>
<td>F001</td>
<td>0</td>
</tr>
<tr>
<td>AB12</td>
<td>...Repeated for Digital Counter 2</td>
<td></td>
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</tr>
</tbody>
</table>
### B.4 MEMORY MAPPING

**Table B–9: MODBUS MEMORY MAP (Sheet 33 of 47)**

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB40</td>
<td>...Repeated for Digital Counter 3</td>
<td></td>
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</tr>
<tr>
<td>AB60</td>
<td>...Repeated for Digital Counter 4</td>
<td></td>
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</tr>
<tr>
<td>AB80</td>
<td>...Repeated for Digital Counter 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABA0</td>
<td>...Repeated for Digital Counter 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABC0</td>
<td>...Repeated for Digital Counter 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABE0</td>
<td>...Repeated for Digital Counter 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Frequency Rate of Change (Read/Write Setting) (4 modules)**

- **AC00** Frequency Rate of Change 1 Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 0 (Disabled)

- **AC01** Frequency Rate of Change 1 OC Supervision
  - RANGE: 0 to 30
  - UNITS: pu
  - STEP: 0.001
  - FORMAT: F001
  - DEFAULT: 200

- **AC02** Frequency Rate of Change 1 Min
  - RANGE: 20 to 80
  - UNITS: Hz
  - STEP: 0.01
  - FORMAT: F001
  - DEFAULT: 4500

- **AC03** Frequency Rate of Change 1 Max
  - RANGE: 20 to 80
  - UNITS: Hz
  - STEP: 0.01
  - FORMAT: F001
  - DEFAULT: 6500

- **AC04** Frequency Rate of Change 1 Pickup Delay
  - RANGE: 0 to 65,535
  - UNITS: s
  - STEP: 0.001
  - FORMAT: F001
  - DEFAULT: 0

- **AC05** Frequency Rate of Change 1 Reset Delay
  - RANGE: 0 to 65,535
  - UNITS: s
  - STEP: 0.001
  - FORMAT: F001
  - DEFAULT: 0

- **AC06** Frequency Rate of Change 1 Block
  - RANGE: 0 to 65,535
  - UNITS: ---
  - STEP: 1
  - FORMAT: F300
  - DEFAULT: 0

- **AC07** Frequency Rate of Change 1 Target
  - RANGE: 0 to 2
  - UNITS: ---
  - STEP: 1
  - FORMAT: F109
  - DEFAULT: 0 (Self-reset)

- **AC08** Frequency Rate of Change 1 Events
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 0 (Disabled)

- **AC09** Frequency Rate of Change 1 Source
  - RANGE: 0 to 5
  - UNITS: ---
  - STEP: 1
  - FORMAT: F167
  - DEFAULT: 0 (SRC 1)

- **AC0A** Frequency Rate of Change 1 Trend
  - RANGE: 0 to 2
  - UNITS: ---
  - STEP: 1
  - FORMAT: F224
  - DEFAULT: 0 (Increasing)

- **AC0B** Frequency Rate of Change 1 Pickup
  - RANGE: 0.1 to 15
  - UNITS: Hz/s
  - STEP: 0.01
  - FORMAT: F001
  - DEFAULT: 50

- **AC0C** Frequency Rate of Change 1 OV Supervision
  - RANGE: 0.1 to 3
  - UNITS: pu
  - STEP: 0.001
  - FORMAT: F001
  - DEFAULT: 700

**IEC 61850 GSSE Configuration (Read/Write Setting)**

- **AD80** Default GSSE Update Time
  - RANGE: 1 to 60
  - UNITS: s
  - STEP: 1
  - FORMAT: F001
  - DEFAULT: 60

- **AD81** Remote Input/Output Transfer Method
  - RANGE: 0 to 2
  - UNITS: ---
  - STEP: 1
  - FORMAT: F226
  - DEFAULT: 1 (GSSE)

- **AD82** IEC 61850 GOOSE VLAN Transmit Priority
  - RANGE: 0 to 7
  - UNITS: ---
  - STEP: 1
  - FORMAT: F001
  - DEFAULT: 4

- **AD83** IEC 61850 GOOSE VLAN ID
  - RANGE: 0 to 4095
  - UNITS: ---
  - STEP: 1
  - FORMAT: F001
  - DEFAULT: 0

- **AD84** IEC 61850 GOOSE ETYP APPID
  - RANGE: 0 to 16,383
  - UNITS: ---
  - STEP: 1
  - FORMAT: F001
  - DEFAULT: 0

- **AD85** Reserved (22 items)
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F001
  - DEFAULT: 0

**IEC 61850 Server Configuration (Read/Write Settings/Commands)**

- **ADA0** TCP Port Number for the IEC 61850 Protocol
  - RANGE: 1 to 65,535
  - UNITS: ---
  - STEP: 1
  - FORMAT: F001
  - DEFAULT: 102

- **ADA1** IEC 61850 Logical Device Name
  - RANGE: ---
  - UNITS: ---
  - STEP: ---
  - FORMAT: F213
  - DEFAULT: "IECDevice"

- **ADB1** Include Non-IEC 61850 Data
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 1 (Enabled)

- **ADB2** Number of Status Indications in GGIO1
  - RANGE: 8 to 128
  - UNITS: ---
  - STEP: 8
  - FORMAT: F001
  - DEFAULT: 8

- **ADB3** IEC 61850 Server Data Scanning Function
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F102
  - DEFAULT: 0 (Disabled)

- **ADB4** Command to Clear XCBR1 OpCnt Counter
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F126
  - DEFAULT: 0 (No)

- **ADB5** Command to Clear XCBR2 OpCnt Counter
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F126
  - DEFAULT: 0 (No)

- **ADB6** Reserved (10 items)
  - RANGE: 0 to 1
  - UNITS: ---
  - STEP: 1
  - FORMAT: F001
  - DEFAULT: 0

**IEC 61850 Logical Node Name Prefixes (Read/Write Setting)**

- **AE00** IEC 61850 Logical Node PIOCx Name Prefix (72 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AE08** IEC 61850 Logical Node PTOCx Name Prefix (24 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AF20** IEC 61850 Logical Node PTUVx Name Prefix (12 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AF44** IEC 61850 Logical Node PTOVx Name Prefix (8 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AF5C** IEC 61850 Logical Node PDISx Name Prefix (10 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AF7A** IEC 61850 Logical Node RRBFx Name Prefix (24 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AFC2** IEC 61850 Logical Node RPSBx Name Prefix
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AFC5** IEC 61850 Logical Node RRRECx Name Prefix (6 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AFD7** IEC 61850 Logical Node MMXUx Name Prefix (24 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AEF9** IEC 61850 Logical Node GGIox Name Prefix (2 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AFE9** IEC 61850 Logical Node RFLOx Name Prefix (5 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **AFFE** IEC 61850 Logical Node XCBRx Name Prefix (2 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)

- **BO04** IEC 61850 Logical Node PTRCx Name Prefix (2 items)
  - RANGE: 0 to 65,534
  - UNITS: ---
  - STEP: 1
  - FORMAT: F206
  - DEFAULT: (None)
### Table B–9: MODBUS MEMORY MAP (Sheet 34 of 47)

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>B00A</td>
<td>IEC 61850 Logical Node PDIFx Name Prefix (4 items)</td>
<td>0 to 65534</td>
<td>---</td>
<td>1</td>
<td>F206</td>
<td>(None)</td>
</tr>
<tr>
<td>B016</td>
<td>IEC 61850 Logical Node MMXNx Name Prefix (37 items)</td>
<td>0 to 65534</td>
<td>---</td>
<td>1</td>
<td>F206</td>
<td>(None)</td>
</tr>
</tbody>
</table>

#### IEC 61850 MMXU Deadbands (Read/Write Setting) (6 modules)

<table>
<thead>
<tr>
<th>ADDR</th>
<th>REGISTER NAME</th>
<th>RANGE</th>
<th>UNITS</th>
<th>STEP</th>
<th>FORMAT</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>B100</td>
<td>IEC 61850 MMXU T0tW Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B102</td>
<td>IEC 61850 MMXU T0tVA Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B104</td>
<td>IEC 61850 MMXU T0tPF Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B106</td>
<td>IEC 61850 MMXU Hz Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B108</td>
<td>IEC 61850 MMXU PpV.phsAB Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B110</td>
<td>IEC 61850 MMXU PpV.phsBC Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B112</td>
<td>IEC 61850 MMXU PpV.phsCA Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B114</td>
<td>IEC 61850 MMXU PhV.phsADeadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B116</td>
<td>IEC 61850 MMXU PhV.phsB Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B118</td>
<td>IEC 61850 MMXU PhV.phsC Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B120</td>
<td>IEC 61850 MMXU PVar.phsA Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B122</td>
<td>IEC 61850 MMXU PVar.phsB Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B124</td>
<td>IEC 61850 MMXU PVar.phsC Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B126</td>
<td>IEC 61850 MMXU PVA.phsA Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B128</td>
<td>IEC 61850 MMXU PVA.phsB Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B130</td>
<td>IEC 61850 MMXU PF.phsA Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B132</td>
<td>IEC 61850 MMXU PF.phsB Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
<tr>
<td>B134</td>
<td>IEC 61850 MMXU PF.phsC Deadband 1</td>
<td>0.001 to 100</td>
<td>%</td>
<td>0.001</td>
<td>F003</td>
<td>10000</td>
</tr>
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#### IEC 61850 GGIO2 Control Configuration (Read/Write Setting) (64 modules)

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### Table B–9: MODBUS MEMORY MAP (Sheet 35 of 47)

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**Contact Inputs (Read/Write Setting) (96 modules)**

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Table B–9: MODBUS MEMORY MAP (Sheet 37 of 47)

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Contact Input Thresholds (Read/Write Setting)

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Virtual Inputs (Read/Write Setting) (64 modules)

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**Mandatory (Read/Write Setting)**

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**Mandatory (Read/Write Command)**

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**Contact Outputs (Read/Write Setting) (64 modules)**

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## Table B-9: MODBUS MEMORY MAP (Sheet 41 of 47)

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## APPENDIX B

### B.4 MEMORY MAPPING

#### Table B–9: MODBUS MEMORY MAP (Sheet 42 of 47)

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**Reset (Read/Write Setting)**

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**Control Pushbuttons (Read/Write Setting) (7 modules)**

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**Clear Records (Read/Write Setting)**

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**Force Contact Inputs/Outputs (Read/Write Settings)**

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**Direct Inputs/Outputs (Read/Write Setting)**

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**Direct input/output commands (Read/Write Command)**

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**Direct inputs (Read/Write Setting) (96 modules)**

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### B.4 MEMORY MAPPING

#### Table B–9: MODBUS MEMORY MAP (Sheet 43 of 47)

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### Platform Direct Outputs (Read/Write Setting) (96 modules)

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### Table B–9: MODBUS MEMORY MAP (Sheet 44 of 47)

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### Direct Input/Output Alarms (Read/Write Setting)

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### Remote Devices (Read/Write Setting) (16 modules)

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### Remote Inputs (Read/Write Setting) (64 modules)

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Table B–9: MODBUS MEMORY MAP (Sheet 45 of 47)

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### Remote Output DNA Pairs (Read/Write Setting) (32 modules)

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### Remote Output UserSt Pairs (Read/Write Setting) (32 modules)

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### B.4 MEMORY MAPPING

#### B.4.2 DATA FORMATS

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#### 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 |

#### F007

| UR_UINT8 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.
APPENDIX B

B.4 MEMORY MAPPING

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 (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,...,59.999=59.999s)

F060
FLOATING_POINT IEEE 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

F080
ENUMERATION: AUTORECLOSE MODE
0 = 1 & 3 Pole, 1 = 1 Pole, 2 = 3 Pole-A, 3 = 3 Pole-B

F083
ENUMERATION: SELECTOR MODES
0 = Time-Out, 1 = Acknowledge

F084
ENUMERATION: SELECTOR POWER UP
0 = Restore, 1 = Synchronize, 2 = Sync/Restore

F086
ENUMERATION: DIGITAL INPUT DEFAULT STATE
0 = Off, 1 = On, 2= Latest/Off, 3 = Latest/On

F090
ENUMERATION: LATCHING OUTPUT TYPE
0 = Operate-dominant, 1 = Reset-dominant

F100
ENUMERATION: VT CONNECTION TYPE
0 = Wye; 1 = Delta

F101
ENUMERATION: MESSAGE DISPLAY INTENSITY
0 = 25%, 1 = 50%, 2 = 75%, 3 = 100%
### B.4 MEMORY MAPPING

<table>
<thead>
<tr>
<th><strong>B.4 MEMORY MAPPING</strong></th>
<th><strong>APPENDIX B</strong></th>
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</thead>
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#### F102
**ENUMERATION: DISABLED/ENABLED**

0 = Disabled; 1 = Enabled

---

#### F103
**ENUMERATION: CURVE SHAPES**

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<td>IAC Short Inv</td>
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<td>8</td>
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#### F111
**ENUMERATION: UNDERVERTAGE CURVE SHAPES**

0 = Definite Time, 1 = Inverse Time

---

#### F112
**ENUMERATION: RS485 BAUD RATES**

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<td>19200</td>
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#### 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

---

#### F116
**ENUMERATION: NEUTRAL OVERVOLTAGE CURVES**

0 = Definite Time, 1 = FlexCurve™ A, 2 = FlexCurve™ B, 3 = FlexCurve™ C

---

#### 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

---
### F119
**Enumeration: FlexCurve™ Pickup Ratios**

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### 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**

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### B.4 MEMORY MAPPING

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<tr>
<td>733</td>
<td>Digital Element 42</td>
</tr>
<tr>
<td>734</td>
<td>Digital Element 43</td>
</tr>
<tr>
<td>735</td>
<td>Digital Element 44</td>
</tr>
<tr>
<td>736</td>
<td>Digital Element 45</td>
</tr>
<tr>
<td>737</td>
<td>Digital Element 46</td>
</tr>
<tr>
<td>738</td>
<td>Digital Element 47</td>
</tr>
<tr>
<td>739</td>
<td>Digital Element 48</td>
</tr>
</tbody>
</table>

**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 = 17 V DC, 1 = 33 V DC, 2 = 84 V DC, 3 = 166 V DC

**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

**F132 ENUMERATION: DEMAND INTERVAL**
0 = 5 min, 1 = 10 min, 2 = 15 min, 3 = 20 min, 4 = 30 min, 5 = 60 min

**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

F139
ENUMERATION: DEMAND CALCULATIONS
0 = Thermal Exponential, 1 = Block Interval, 2 = Rolling Demand

F140
ENUMERATION: CURRENT, SENS CURRENT, VOLTAGE, DISABLED
0 = Disabled, 1 = Current 46 A, 2 = Voltage 280 V,
3 = Current 4.6 A, 4 = Current 2 A, 5 = Notched 4.6 A,
6 = Notched 2 A

F141
ENUMERATION: SELF TEST ERROR
<table>
<thead>
<tr>
<th>bitmask</th>
<th>error</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Any Self Tests</td>
</tr>
<tr>
<td>1</td>
<td>IRIG-B Failure</td>
</tr>
<tr>
<td>2</td>
<td>DSP Error</td>
</tr>
<tr>
<td>4</td>
<td>No DSP Interrupts</td>
</tr>
<tr>
<td>5</td>
<td>Unit Not Calibrated</td>
</tr>
<tr>
<td>9</td>
<td>Prototype Firmware</td>
</tr>
<tr>
<td>10</td>
<td>Flexlogic Error Token</td>
</tr>
<tr>
<td>11</td>
<td>Equipment Mismatch</td>
</tr>
<tr>
<td>13</td>
<td>Unit Not Programmed</td>
</tr>
<tr>
<td>14</td>
<td>System Exception</td>
</tr>
<tr>
<td>15</td>
<td>Latching Out Error</td>
</tr>
<tr>
<td>18</td>
<td>SNTP Failure</td>
</tr>
<tr>
<td>19</td>
<td>Battery Failure</td>
</tr>
<tr>
<td>20</td>
<td>Primary Ethernet Failure</td>
</tr>
<tr>
<td>21</td>
<td>Secondary Ethernet Failure</td>
</tr>
<tr>
<td>22</td>
<td>EEPROM Data Error</td>
</tr>
<tr>
<td>23</td>
<td>SRAM Data Error</td>
</tr>
<tr>
<td>24</td>
<td>Program Memory</td>
</tr>
<tr>
<td>25</td>
<td>Watchdog Error</td>
</tr>
</tbody>
</table>

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

F146
ENUMERATION: MISCELLANEOUS EVENT CAUSES
<table>
<thead>
<tr>
<th>bitmask</th>
<th>definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Events Cleared</td>
</tr>
<tr>
<td>1</td>
<td>Oscillography Triggered</td>
</tr>
<tr>
<td>2</td>
<td>Date/time Changed</td>
</tr>
<tr>
<td>3</td>
<td>Default Settings Loaded</td>
</tr>
<tr>
<td>4</td>
<td>Test Mode On</td>
</tr>
<tr>
<td>5</td>
<td>Test Mode Off</td>
</tr>
<tr>
<td>6</td>
<td>Power On</td>
</tr>
<tr>
<td>7</td>
<td>Power Off</td>
</tr>
<tr>
<td>8</td>
<td>Relay In Service</td>
</tr>
<tr>
<td>9</td>
<td>Relay Out Of Service</td>
</tr>
<tr>
<td>10</td>
<td>Watchdog Reset</td>
</tr>
<tr>
<td>11</td>
<td>Oscillography Clear</td>
</tr>
<tr>
<td>12</td>
<td>Reboot Command</td>
</tr>
<tr>
<td>13</td>
<td>Led Test Initiated</td>
</tr>
<tr>
<td>14</td>
<td>Flash Programming</td>
</tr>
<tr>
<td>15</td>
<td>Fault Report Trigger</td>
</tr>
</tbody>
</table>
APPENDIX B

B.4 MEMORY MAPPING

F147
ENUMERATION: LINE LENGTH UNITS
0 = km, 1 = miles

F148
ENUMERATION: FAULT TYPE

<table>
<thead>
<tr>
<th>bitmask</th>
<th>fault type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>1</td>
<td>AG</td>
</tr>
<tr>
<td>2</td>
<td>BG</td>
</tr>
<tr>
<td>3</td>
<td>CG</td>
</tr>
<tr>
<td>4</td>
<td>AB</td>
</tr>
<tr>
<td>5</td>
<td>BC</td>
</tr>
</tbody>
</table>

F151
ENUMERATION: RTD SELECTION

<table>
<thead>
<tr>
<th>bitmask</th>
<th>RTD#</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NONE</td>
</tr>
<tr>
<td>1</td>
<td>RTD 1</td>
</tr>
<tr>
<td>2</td>
<td>RTD 2</td>
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<tr>
<td>3</td>
<td>RTD 3</td>
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<tr>
<td>4</td>
<td>RTD 4</td>
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<tr>
<td>5</td>
<td>RTD 5</td>
</tr>
<tr>
<td>6</td>
<td>RTD 6</td>
</tr>
<tr>
<td>7</td>
<td>RTD 7</td>
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<tr>
<td>8</td>
<td>RTD 8</td>
</tr>
<tr>
<td>9</td>
<td>RTD 9</td>
</tr>
<tr>
<td>10</td>
<td>RTD 10</td>
</tr>
<tr>
<td>11</td>
<td>RTD 11</td>
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<tr>
<td>12</td>
<td>RTD 12</td>
</tr>
<tr>
<td>13</td>
<td>RTD 13</td>
</tr>
<tr>
<td>14</td>
<td>RTD 14</td>
</tr>
<tr>
<td>15</td>
<td>RTD 15</td>
</tr>
<tr>
<td>16</td>
<td>RTD 16</td>
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<tr>
<td>17</td>
<td>RTD 17</td>
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<tr>
<td>18</td>
<td>RTD 18</td>
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<tr>
<td>19</td>
<td>RTD 19</td>
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<tr>
<td>20</td>
<td>RTD 20</td>
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<tr>
<td>21</td>
<td>RTD 21</td>
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<tr>
<td>22</td>
<td>RTD 22</td>
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<tr>
<td>23</td>
<td>RTD 23</td>
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<tr>
<td>24</td>
<td>RTD 24</td>
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<tr>
<td>25</td>
<td>RTD 25</td>
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<tr>
<td>26</td>
<td>RTD 26</td>
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<tr>
<td>27</td>
<td>RTD 27</td>
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<tr>
<td>28</td>
<td>RTD 28</td>
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<td>29</td>
<td>RTD 29</td>
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<tr>
<td>30</td>
<td>RTD 30</td>
</tr>
<tr>
<td>31</td>
<td>RTD 31</td>
</tr>
<tr>
<td>32</td>
<td>RTD 32</td>
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F156
ENUMERATION: REMOTE INPUT BIT PAIRS

<table>
<thead>
<tr>
<th>bitmask</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NONE</td>
</tr>
<tr>
<td>1</td>
<td>DNA-1</td>
</tr>
<tr>
<td>2</td>
<td>DNA-2</td>
</tr>
<tr>
<td>3</td>
<td>DNA-3</td>
</tr>
<tr>
<td>4</td>
<td>DNA-4</td>
</tr>
<tr>
<td>5</td>
<td>DNA-5</td>
</tr>
<tr>
<td>6</td>
<td>DNA-6</td>
</tr>
<tr>
<td>7</td>
<td>DNA-7</td>
</tr>
<tr>
<td>8</td>
<td>DNA-8</td>
</tr>
<tr>
<td>9</td>
<td>DNA-9</td>
</tr>
<tr>
<td>10</td>
<td>DNA-10</td>
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<tr>
<td>11</td>
<td>DNA-11</td>
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<tr>
<td>12</td>
<td>DNA-12</td>
</tr>
<tr>
<td>13</td>
<td>DNA-13</td>
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<tr>
<td>14</td>
<td>DNA-14</td>
</tr>
<tr>
<td>15</td>
<td>DNA-15</td>
</tr>
<tr>
<td>16</td>
<td>DNA-16</td>
</tr>
<tr>
<td>17</td>
<td>DNA-17</td>
</tr>
<tr>
<td>18</td>
<td>DNA-18</td>
</tr>
<tr>
<td>19</td>
<td>DNA-19</td>
</tr>
<tr>
<td>20</td>
<td>DNA-20</td>
</tr>
<tr>
<td>21</td>
<td>DNA-21</td>
</tr>
</tbody>
</table>

F157
ENUMERATION: BREAKER MODE
0 = 3-Pole, 1 = 1-Pole

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 = Adapt. 2nd, 2 = Trad. 2nd
B.4 MEMORY MAPPING

F170
ENUMERATION: LOW/HIGH OFFSET and GAIN
TRANSUDER INPUT/OUTPUT SELECTION
0 = LOW, 1 = HIGH

F171
ENUMERATION: TRANSUDER CHANNEL INPUT TYPE
0 = dcmA IN, 1 = Ohms IN, 2 = RTD IN, 3 = dcmA OUT

F172
ENUMERATION: SLOT LETTERS

<table>
<thead>
<tr>
<th>bitmask</th>
<th>slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>F</td>
</tr>
<tr>
<td>1</td>
<td>G</td>
</tr>
<tr>
<td>2</td>
<td>H</td>
</tr>
<tr>
<td>3</td>
<td>J</td>
</tr>
</tbody>
</table>

F173
ENUMERATION: DCMA INPUT/OUTPUT RANGE

<table>
<thead>
<tr>
<th>bitmask</th>
<th>dcma input/output range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0 to –1 mA</td>
</tr>
<tr>
<td>1</td>
<td>0 to 1 mA</td>
</tr>
<tr>
<td>2</td>
<td>–1 to 1 mA</td>
</tr>
<tr>
<td>3</td>
<td>0 to 5 mA</td>
</tr>
<tr>
<td>4</td>
<td>0 to 10 mA</td>
</tr>
<tr>
<td>5</td>
<td>0 to 20 mA</td>
</tr>
<tr>
<td>6</td>
<td>4 to 20 mA</td>
</tr>
</tbody>
</table>

F174
ENUMERATION: TRANSUDER 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

<table>
<thead>
<tr>
<th>bitmask</th>
<th>synchrocheck dead source</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>LV1 and DV2</td>
</tr>
<tr>
<td>2</td>
<td>DV1 and LV2</td>
</tr>
<tr>
<td>3</td>
<td>DV1 or DV2</td>
</tr>
<tr>
<td>4</td>
<td>DV1 Xor DV2</td>
</tr>
<tr>
<td>5</td>
<td>DV1 and DV2</td>
</tr>
</tbody>
</table>

F177
ENUMERATION: COMMUNICATION PORT
0 = None, 1 = COM1-RS485, 2 = COM2-RS485,
3 = Front Panel-RS232, 4 = Network - TCP, 5 = Network - UDP

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, 8 = 15 ms, 9 = 30 ms,
10 = 100 ms, 11 = 500 ms

F179
ENUMERATION: NEGATIVE SEQUENCE DIRECTIONAL
OVERCURRENT TYPE
0 = Neg Sequence, 1 = Zero Sequence

F180
ENUMERATION: PHASE/GROUND
0 = PHASE, 1 = GROUND

F181
ENUMERATION: ODD/EVEN/NONE
0 = ODD, 1 = EVEN, 2 = NONE

F182
ENUMERATION: LOSS OF LOAD / ARCING SUSPECTED /
ARCING / OVERCURRENT DOWND CONDUCTOR /
EXTERNAL

<table>
<thead>
<tr>
<th>bitmask</th>
<th>definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>LOSS OF LOAD</td>
</tr>
<tr>
<td>1</td>
<td>ARCING SUSPECTED</td>
</tr>
<tr>
<td>2</td>
<td>ARCING</td>
</tr>
<tr>
<td>3</td>
<td>OVERCURRENT</td>
</tr>
<tr>
<td>4</td>
<td>DOWND CONDUCTOR</td>
</tr>
<tr>
<td>5</td>
<td>EXTERNAL</td>
</tr>
</tbody>
</table>

F183
ENUMERATION: AC INPUT WAVEFORMS

<table>
<thead>
<tr>
<th>bitmask</th>
<th>definition</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>Off</td>
</tr>
<tr>
<td>1</td>
<td>8 samples/cycle</td>
</tr>
<tr>
<td>2</td>
<td>16 samples/cycle</td>
</tr>
<tr>
<td>3</td>
<td>32 samples/cycle</td>
</tr>
<tr>
<td>4</td>
<td>64 samples/cycle</td>
</tr>
</tbody>
</table>

F185
ENUMERATION: PHASE A,B,C, GROUND SELECTOR
0 = A, 1 = B, 2 = C, 3 = G
APPENDIX B

B.4 MEMORY MAPPING

F186
ENUMERATION: MEASUREMENT MODE
0 = Phase to Ground, 1 = Phase to Phase

F187
ENUMERATION: HI-Z STATES

<table>
<thead>
<tr>
<th>bitmask</th>
<th>Hi-Z State</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NORMAL</td>
</tr>
<tr>
<td>1</td>
<td>COORDINATION TIMEOUT</td>
</tr>
<tr>
<td>2</td>
<td>ARMED</td>
</tr>
<tr>
<td>5</td>
<td>ARCING</td>
</tr>
<tr>
<td>9</td>
<td>DOWNED CONDUCTOR</td>
</tr>
</tbody>
</table>

F188
ENUMERATION: HI-Z CAPTURE TRIGGER TYPES

<table>
<thead>
<tr>
<th>bitmask</th>
<th>trigger type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Loss Of Load</td>
</tr>
<tr>
<td>2</td>
<td>Arc Suspected</td>
</tr>
<tr>
<td>3</td>
<td>Arcing</td>
</tr>
<tr>
<td>4</td>
<td>Overcurrent</td>
</tr>
<tr>
<td>5</td>
<td>Down Conductor</td>
</tr>
<tr>
<td>6</td>
<td>External</td>
</tr>
</tbody>
</table>

F190
ENUMERATION: SIMULATED KEYPRESS

<table>
<thead>
<tr>
<th>bitmask</th>
<th>keypress</th>
<th>bitmask</th>
<th>keypress</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>--- use between real keys</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>21</td>
<td>Escape</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>22</td>
<td>Enter</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>23</td>
<td>Reset</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>24</td>
<td>User 1</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>25</td>
<td>User 2</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>26</td>
<td>User 3</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>27</td>
<td>User-programmable key 1</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>28</td>
<td>User-programmable key 2</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>29</td>
<td>User-programmable key 3</td>
</tr>
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<td>0</td>
<td>30</td>
<td>User-programmable key 4</td>
</tr>
<tr>
<td>11</td>
<td>Decimal Pt</td>
<td>31</td>
<td>User-programmable key 5</td>
</tr>
<tr>
<td>12</td>
<td>Plus/Minus</td>
<td>32</td>
<td>User-programmable key 6</td>
</tr>
<tr>
<td>13</td>
<td>Value Up</td>
<td>33</td>
<td>User-programmable key 7</td>
</tr>
<tr>
<td>14</td>
<td>Value Down</td>
<td>34</td>
<td>User-programmable key 8</td>
</tr>
<tr>
<td>15</td>
<td>Message Up</td>
<td>35</td>
<td>User-programmable key 9</td>
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<tr>
<td>16</td>
<td>Message Down</td>
<td>36</td>
<td>User-programmable key 10</td>
</tr>
<tr>
<td>17</td>
<td>Message Left</td>
<td>37</td>
<td>User-programmable key 11</td>
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<tr>
<td>18</td>
<td>Message Right</td>
<td>38</td>
<td>User-programmable key 12</td>
</tr>
<tr>
<td>19</td>
<td>Menu</td>
<td>39</td>
<td>User 4 (control pushbutton)</td>
</tr>
<tr>
<td>20</td>
<td>Help</td>
<td>40</td>
<td>User 5 (control pushbutton)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41</td>
<td>User 6 (control pushbutton)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>42</td>
<td>User 7 (control pushbutton)</td>
</tr>
</tbody>
</table>

F191
ENUMERATION: HI-Z ENERGY/RANDOM STATE

<table>
<thead>
<tr>
<th>bitmask</th>
<th>Hi-Z Energy/RANDOM State</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>REINSTATE</td>
</tr>
<tr>
<td>1</td>
<td>INITSTATE</td>
</tr>
<tr>
<td>2</td>
<td>NORMALSTATE</td>
</tr>
<tr>
<td>3</td>
<td>EVENTSTATE</td>
</tr>
<tr>
<td>4</td>
<td>SERIOUSSTATE</td>
</tr>
</tbody>
</table>

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, 6 = 10000, 7 = 100000, 8 = 0.001

F196
ENUMERATION: NEUTRAL DIRECTIONAL OVERCURRENT OPERATING CURRENT
0 = Calculated 3I0, 1 = Measured IG

F199
ENUMERATION: DISABLED/ENABLED/CUSTOM
0 = Disabled, 1 = Enabled, 2 = Custom

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
B.4 MEMORY MAPPING

F206
TEXT6: 6-CHARACTER ASCII TEXT

F207
TEXT4: 4-CHARACTER ASCII TEXT

F208
TEXT2: 2-CHARACTER ASCII TEXT

F211
ENUMERATION: SOURCE SELECTION
0 = None, 1 = SRC 1, 2 = SRC 2, 3 = SRC 3, 4 = SRC 4,
5 = SRC 5, 6 = SRC 6

F222
ENUMERATION: TEST ENUMERATION
0 = Test Enumeration 0, 1 = Test Enumeration 1

F224
ENUMERATION: RATE TREND FOR FREQ RATE OF CHANGE
0 = Increasing, 1 = Decreasing, 2 = Bidirectional

F226
ENUMERATION: REMOTE INPUT/OUTPUT TRANSFER METHOD
0 = None, 1 = GSSE, 2 = GOOSE

F227
ENUMERATION: RELAY SERVICE STATUS
0 = Unknown, 1 = Relay In Service, 2 = Relay Out Of Service

F230
ENUMERATION: DIRECTIONAL POLARIZING
0 = Voltage, 1 = Current, 2 = Dual

F231
ENUMERATION: POLARIZING VOLTAGE
0 = Calculated V0, 1 = Measured VX

F260
ENUMERATION: DATA LOGGER MODE
0 = Continuous, 1 = Trigger

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: PTTTTTTTDDDDDDDD,

F400
UR_UINT16: CT/VT BANK SELECTION

<table>
<thead>
<tr>
<th>bitmask</th>
<th>bank selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Card 1 Contact 1 to 4</td>
</tr>
<tr>
<td>1</td>
<td>Card 1 Contact 5 to 8</td>
</tr>
<tr>
<td>2</td>
<td>Card 2 Contact 1 to 4</td>
</tr>
<tr>
<td>3</td>
<td>Card 2 Contact 5 to 8</td>
</tr>
<tr>
<td>4</td>
<td>Card 3 Contact 1 to 4</td>
</tr>
<tr>
<td>5</td>
<td>Card 3 Contact 5 to 8</td>
</tr>
</tbody>
</table>

F500
UR_UINT16: PACKED BITFIELD
First register indicates input/output state with bits 0 (MSB) to 15 (LSB) corresponding to input/output state 1 to 16. The second register indicates input/output state with bits 0 to 15 corresponding to input/output state 17 to 32 (if required) The third register indicates input/output state with bits 0 to 15 corresponding to input/output state 33 to 48 (if required). The fourth register indicates input/output state with bits 0 to 15 corresponding to input/output state 49 to 64 (if required).

The number of registers required is determined by the specific data item. A bit value of 0 = Off and 1 = On.


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 [PTTTTTTT] 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 to 96)
[3] CONTACT INPUTS OFF (1 to 96)
[4] VIRTUAL INPUTS (1 to 64)
[6] VIRTUAL OUTPUTS (1 to 96)
[10] CONTACT OUTPUTS VOLTAGE DETECTED (1 to 64)
[11] CONTACT OUTPUTS VOLTAGE OFF DETECTED (1 to 64)
[12] CONTACT OUTPUTS CURRENT DETECTED (1 to 64)
[13] CONTACT OUTPUTS CURRENT OFF DETECTED (1 to 64)
[14] REMOTE INPUTS (1 to 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 to 16 inputs)
[42] AND (2 to 16 inputs)
[44] NOR (2 to 16 inputs)
[46] NAND (2 to 16 inputs)
[48] TIMER (1 to 32)
[50] ASSIGN VIRTUAL OUTPUT (1 to 96)
[52] SELF-TEST ERROR (see F141 for range)
[56] ACTIVE SETTING GROUP (1 to 6)
[62] MISCELLANEOUS EVENTS (see F146 for range)
[64 to 127] ELEMENT STATES
APPENDIX B

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

<table>
<thead>
<tr>
<th>bitmask</th>
<th>element state</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Pickup</td>
</tr>
<tr>
<td>1</td>
<td>Operate</td>
</tr>
<tr>
<td>2</td>
<td>Pickup Phase A</td>
</tr>
<tr>
<td>3</td>
<td>Pickup Phase B</td>
</tr>
<tr>
<td>4</td>
<td>Pickup Phase C</td>
</tr>
<tr>
<td>5</td>
<td>Operate Phase A</td>
</tr>
<tr>
<td>6</td>
<td>Operate Phase B</td>
</tr>
<tr>
<td>7</td>
<td>Operate Phase C</td>
</tr>
</tbody>
</table>

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

F511
BITFIELD: 3-PHASE SIMPLE ELEMENT STATE

0 = Operate, 1 = Operate A, 2 = Operate B, 3 = Operate C

F512
ENUMERATION: HARMONIC NUMBER

<table>
<thead>
<tr>
<th>bitmask</th>
<th>harmonic</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>2ND</td>
</tr>
<tr>
<td>1</td>
<td>3RD</td>
</tr>
<tr>
<td>2</td>
<td>4TH</td>
</tr>
<tr>
<td>3</td>
<td>5TH</td>
</tr>
<tr>
<td>4</td>
<td>6TH</td>
</tr>
<tr>
<td>5</td>
<td>7TH</td>
</tr>
<tr>
<td>6</td>
<td>8TH</td>
</tr>
<tr>
<td>7</td>
<td>9TH</td>
</tr>
<tr>
<td>8</td>
<td>10TH</td>
</tr>
<tr>
<td>9</td>
<td>11TH</td>
</tr>
<tr>
<td>10</td>
<td>12TH</td>
</tr>
<tr>
<td>11</td>
<td>13TH</td>
</tr>
<tr>
<td>12</td>
<td>14TH</td>
</tr>
<tr>
<td>13</td>
<td>15TH</td>
</tr>
<tr>
<td>14</td>
<td>16TH</td>
</tr>
<tr>
<td>15</td>
<td>17TH</td>
</tr>
<tr>
<td>16</td>
<td>18TH</td>
</tr>
<tr>
<td>17</td>
<td>19TH</td>
</tr>
<tr>
<td>18</td>
<td>20TH</td>
</tr>
<tr>
<td>19</td>
<td>21ST</td>
</tr>
<tr>
<td>20</td>
<td>22ND</td>
</tr>
<tr>
<td>21</td>
<td>23RD</td>
</tr>
<tr>
<td>22</td>
<td>24TH</td>
</tr>
<tr>
<td>23</td>
<td>25TH</td>
</tr>
</tbody>
</table>

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

F519
ENUMERATION: NON-VOLATILE LATCH

0 = Reset-Dominant, 1 = Set-Dominant

F522
ENUMERATION: TRANSDUCER DCMA OUTPUT RANGE

0 = –1 to 1 mA; 1 = 0 to 1 mA; 2 = 4 to 20 mA

F523
ENUMERATION: DNP OBJECTS 20, 22, AND 23 DEFAULT VARIATION

<table>
<thead>
<tr>
<th>bitmask</th>
<th>default variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
### F524  
**ENUMERATION: DNP OBJECT 21 DEFAULT VARIATION**

<table>
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<tr>
<th>bitmask</th>
<th>Default Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
</tr>
</tbody>
</table>

### F525  
**ENUMERATION: DNP OBJECT 32 DEFAULT VARIATION**

<table>
<thead>
<tr>
<th>bitmask</th>
<th>Default Variation</th>
</tr>
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</tr>
<tr>
<td>1</td>
<td>2</td>
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<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

### F530  
**ENUMERATION: FRONT PANEL INTERFACE KEYPRESS**

<table>
<thead>
<tr>
<th>bitmask</th>
<th>Keypress</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Menu</td>
</tr>
<tr>
<td>2</td>
<td>Message Up</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>Help</td>
</tr>
<tr>
<td>7</td>
<td>Message Left</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>Escape</td>
</tr>
<tr>
<td>12</td>
<td>Message Right</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>Enter</td>
</tr>
<tr>
<td>17</td>
<td>Message Down</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>Decimal</td>
</tr>
<tr>
<td>20</td>
<td>+/-</td>
</tr>
<tr>
<td>21</td>
<td>Value Up</td>
</tr>
</tbody>
</table>

### F531  
**ENUMERATION: LANGUAGE**

0 = English, 1 = French, 2 = Chinese, 3 = Russian

### F600  
**UR_UINT16: FLEXANALOG PARAMETER**

Corresponds to the modbus address of the value used when this parameter is selected. Only certain values may be used as Flex-Analogs (basically all metering quantities used in protection).
C.1.1 OVERVIEW

The IEC 61850 standard is the result of years of work by electric utilities and vendors of electronic equipment to produce standardized communications systems. IEC 61850 is a series of standards describing client/server and peer-to-peer communications, substation design and configuration, testing, environmental and project standards. The complete set includes:

- IEC 61850-1: Introduction and overview
- IEC 61850-2: Glossary
- IEC 61850-3: General requirements
- IEC 61850-4: System and project management
- IEC 61850-5: Communications and requirements for functions and device models
- IEC 61850-6: Configuration description language for communication in electrical substations related to IEDs
- IEC 61850-7-1: Basic communication structure for substation and feeder equipment - Principles and models
- IEC 61850-7-2: Basic communication structure for substation and feeder equipment - Abstract communication service interface (ACSI)
- IEC 61850-7-3: Basic communication structure for substation and feeder equipment – Common data classes
- IEC 61850-7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes
- IEC 61850-8-1: Specific Communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
- IEC 61850-9-1: Specific Communication Service Mapping (SCSM) – Sampled values over serial unidirectional multi-drop point to point link
- IEC 61850-9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3
- IEC 61850-10: Conformance testing

These documents can be obtained from the IEC (http://www.iec.ch). It is strongly recommended that all those involved with any IEC 61850 implementation obtain this document set.

C.1.2 COMMUNICATION PROFILES

The F60 relay supports IEC 61850 server services over both TCP/IP and TP4/CLNP (OSI) communication protocol stacks. The TP4/CLNP profile requires the F60 to have a network address or Network Service Access Point (NSAP) to establish a communication link. The TCP/IP profile requires the F60 to have an IP address to establish communications. These addresses are located in the SETTINGS → PRODUCT SETUP → COMMUNICATIONS → NETWORK menu. Note that the F60 supports IEC 61850 over the TP4/CLNP or TCP/IP stacks, and also operation over both stacks simultaneously. It is possible to have up to four simultaneous connections (in addition to DNP and Modbus/TCP (non-IEC 61850) connections).

C.1.3 MMS PROTOCOL

IEC 61850 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. Actual MMS protocol services are mapped to IEC 61850 abstract services in IEC 61850-8-1.

C.1.4 PEER-TO-PEER COMMUNICATION

Peer-to-peer communication of digital state information (remote inputs/outputs) is supported using the IEC 61850 GSSE and GOOSE services. This feature allows digital points to be exchanged between IEC 61850 conforming devices.

C.1.5 FILE SERVICES

MMS file services are supported to allow transfer of oscillography, event record, or other files from a F60 relay.
The exact structure and values of the supported IEC 61850 logical nodes can be seen by connecting to a F60 relay with an MMS browser, such as the “MMS Object Explorer and AXS4-MMS” DDE/OPC server from Sisco Inc.

C.1.7 NON-IEC 61850 DATA

The F60 relay makes available a number of non-IEC 61850 data items. These data items can be accessed through the “UR” MMS domain. IEC 61850 data can be accessed through the “IECDevice” MMS domain (IEC 61850 logical device).

C.1.8 TCP CONNECTION TIMING

A built-in TCP/IP connection timeout of two minutes is employed by the F60 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 F60. This frees up the connection to be used by other clients. Therefore, when using IEC 61850 reporting, clients should configure report control block items such that an integrity report will be issued at least every 2 minutes (120000 ms). This ensures that the F60 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.

C.1.9 LOGICAL NODE MMXU DATA MAPPING

The mapping of F60 relay data to IEC 61850 MMXU data is performed on a per-source basis. MMXU1 data originates from F60 source 1, MMXU2 data originates from F60 source 2, etc.

C.1.10 LOGICAL NODE GGIO DATA MAPPING

Logical node GGIO1 data is mapped using the F60 Flexstate parameters. Each single point indication in GGIO1 can be selected using the corresponding Flexstate parameter setting. For example, the value of GGIO1 point “Ind3” is determined from the FlexLogic™ operand selected in the Flexstate parameter 3 setting. Thus, GGIO1 data can originate as any FlexLogic™ parameter.

Logical node GGIO2 data is mapped to the F60 virtual inputs. Each single point control in GGIO2 is mapped to a virtual input. For example, GGIO2 control point SPCSO3 is mapped to virtual input 3.

C.1.11 OTHER LOGICAL NODE MAPPING

All other IEC 61850 logical nodes (with the exception of PTRC) are associated with standard UR-series relay protection elements and features. The following mapping is used (for applicable elements):

- PIOC: phase instantaneous overcurrent, neutral instantaneous overcurrent, ground instantaneous overcurrent, negative sequence instantaneous overcurrent
- PTOC: phase time overcurrent, neutral time overcurrent, ground time overcurrent, negative sequence time overcurrent, neutral directional overcurrent, negative sequence directional overcurrent
- PTUV: phase undervoltage, auxiliary undervoltage, third harmonic neutral undervoltage
- PTOV: phase overvoltage, neutral overvoltage, auxiliary overvoltage, negative sequence overvoltage
- RBRF: breaker failure
- RREC: autoreclosure
- RFLO: fault locator
- XCBR: breaker control
## C.2 ACSI CONFORMANCE

### C.2.1 ACSI BASIC CONFORMANCE STATEMENT

<table>
<thead>
<tr>
<th>SERVICES</th>
<th>SERVER/PUBLISHER</th>
<th>UR-FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLIENT-SERVER ROLES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B11</td>
<td>Server side (of two-party application-association)</td>
<td>c1</td>
</tr>
<tr>
<td>B12</td>
<td>Client side (of two-party application-association)</td>
<td>---</td>
</tr>
<tr>
<td><strong>SCSMS SUPPORTED</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B21</td>
<td>SCSM: IEC 61850-8-1 used</td>
<td></td>
</tr>
<tr>
<td>B22</td>
<td>SCSM: IEC 61850-9-1 used</td>
<td></td>
</tr>
<tr>
<td>B23</td>
<td>SCSM: IEC 61850-9-2 used</td>
<td></td>
</tr>
<tr>
<td>B24</td>
<td>SCSM: other</td>
<td></td>
</tr>
<tr>
<td><strong>GENERIC SUBSTATION EVENT MODEL (GSE)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B31</td>
<td>Publisher side</td>
<td>O</td>
</tr>
<tr>
<td>B32</td>
<td>Subscriber side</td>
<td>---</td>
</tr>
<tr>
<td><strong>TRANSMISSION OF SAMPLED VALUE MODEL (SVC)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B41</td>
<td>Publisher side</td>
<td>O</td>
</tr>
<tr>
<td>B42</td>
<td>Subscriber side</td>
<td>---</td>
</tr>
</tbody>
</table>

**NOTE**

- c1: shall be "M" if support for LOGICAL-DEVICE model has been declared
- O: Optional
- M: Mandatory

### C.2.2 ACSI MODELS CONFORMANCE STATEMENT

<table>
<thead>
<tr>
<th>SERVICES</th>
<th>SERVER/PUBLISHER</th>
<th>UR-FAMILY</th>
</tr>
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<tbody>
<tr>
<td><strong>IF SERVER SIDE (B11) SUPPORTED</strong></td>
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<td></td>
</tr>
<tr>
<td>M1</td>
<td>Logical device</td>
<td>c2</td>
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<tr>
<td>M2</td>
<td>Logical node</td>
<td>c3</td>
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<td>M3</td>
<td>Data</td>
<td>c4</td>
</tr>
<tr>
<td>M4</td>
<td>Data set</td>
<td>c5</td>
</tr>
<tr>
<td>M5</td>
<td>Substitution</td>
<td>O</td>
</tr>
<tr>
<td>M6</td>
<td>Setting group control</td>
<td>O</td>
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<tr>
<td><strong>REPORTING</strong></td>
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</tr>
<tr>
<td>M7</td>
<td>Buffered report control</td>
<td>O</td>
</tr>
<tr>
<td>M7-1</td>
<td>sequence-number</td>
<td></td>
</tr>
<tr>
<td>M7-2</td>
<td>report-time-stamp</td>
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<tr>
<td>M7-3</td>
<td>reason-for-inclusion</td>
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<td>data-set-name</td>
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<td>data-reference</td>
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### C.2 ACSI CONFORMANCE

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<thead>
<tr>
<th>SERVICES</th>
<th>SERVER/ PUBLISHER</th>
<th>UR-FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>M8-4</td>
<td>data-set-name</td>
<td></td>
</tr>
<tr>
<td>M8-5</td>
<td>data-reference</td>
<td></td>
</tr>
<tr>
<td>M8-6</td>
<td>BufTm</td>
<td></td>
</tr>
<tr>
<td>M8-7</td>
<td>IntgPd</td>
<td></td>
</tr>
<tr>
<td>M8-8</td>
<td>GI</td>
<td></td>
</tr>
<tr>
<td>M9</td>
<td>Logging</td>
<td>O</td>
</tr>
<tr>
<td>M9-1</td>
<td>Log control</td>
<td>O</td>
</tr>
<tr>
<td>M10</td>
<td>Log</td>
<td>O</td>
</tr>
<tr>
<td>M11</td>
<td>Control</td>
<td>M</td>
</tr>
<tr>
<td>IF GSE (B31/32) IS SUPPORTED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M12-1</td>
<td>GOOSE</td>
<td>O</td>
</tr>
<tr>
<td>M12-2</td>
<td>GSSE</td>
<td>O</td>
</tr>
<tr>
<td>IF SVC (B41/B42) IS SUPPORTED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M14</td>
<td>Multicast SVC</td>
<td>O</td>
</tr>
<tr>
<td>M15</td>
<td>Unicast SVC</td>
<td>O</td>
</tr>
<tr>
<td>M16</td>
<td>Time</td>
<td>M</td>
</tr>
<tr>
<td>M17</td>
<td>File transfer</td>
<td>O</td>
</tr>
</tbody>
</table>

**NOTE:**
- c2: shall be "M" if support for LOGICAL-NODE model has been declared
- c3: shall be "M" if support for DATA model has been declared
- c4: shall be "M" if support for DATA-SET, Substitution, Report, Log Control, or Time models has been declared
- c5: shall be "M" if support for Report, GSE, or SMV models has been declared
- M: Mandatory

### C.2.3 ACSI SERVICES CONFORMANCE STATEMENT

In the table below, the acronym AA refers to Application Associations (TP: Two Party / MC: Multicast). The c6 to c10 entries are defined in the notes following the table.

<table>
<thead>
<tr>
<th>SERVICES</th>
<th>AA: TP/MC</th>
<th>SERVER/ PUBLISHER</th>
<th>UR FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERVER (CLAUSE 6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1 ServerDirectory</td>
<td>TP</td>
<td>M</td>
<td>Yes</td>
</tr>
<tr>
<td>APPLICATION ASSOCIATION (CLAUSE 7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2 Associate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3 Abort</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4 Release</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LOGICAL DEVICE (CLAUSE 8)

<table>
<thead>
<tr>
<th>SERVICES</th>
<th>SERVER/ PUBLISHER</th>
<th>UR FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>S5 LogicalDeviceDirectory</td>
<td>TP</td>
<td>M</td>
</tr>
<tr>
<td>LOGICAL NODE (CLAUSE 9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S6 LogicalNodeDirectory</td>
<td>TP</td>
<td>M</td>
</tr>
</tbody>
</table>

DATA (CLAUSE 10)

<table>
<thead>
<tr>
<th>SERVICES</th>
<th>SERVER/ PUBLISHER</th>
<th>UR FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>S8 GetDataValues</td>
<td>TP</td>
<td>M</td>
</tr>
<tr>
<td>S9 SetDataValues</td>
<td>TP</td>
<td>O</td>
</tr>
<tr>
<td>S10 GetDataDirectory</td>
<td>TP</td>
<td>M</td>
</tr>
<tr>
<td>S11 GetDataDefinition</td>
<td>TP</td>
<td>M</td>
</tr>
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</table>
### APPENDIX C

#### C.2 ACSI CONFORMANCE

<table>
<thead>
<tr>
<th>SERVICES</th>
<th>AA: TP/MC</th>
<th>SERVER/PUBLISHER</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>DATA SET (CLAUSE 11)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S12 GetDataSetValues</td>
<td>TP</td>
<td>M</td>
<td>Yes</td>
</tr>
<tr>
<td>S13 SetDataSetValues</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S14 CreateDataSet</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S15 DeleteDataSet</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S16 GetDataSetDirectory</td>
<td>TP</td>
<td>O</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>SUBSTITUTION (CLAUSE 12)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S17 SetDataValues</td>
<td>TP</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td><strong>SETTING GROUP CONTROL (CLAUSE 13)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S18 SelectActiveSG</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S19 SelectEditSG</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S20 SetSGValues</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S21 ConfirmEditSGValues</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S22 GetSGValues</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S23 GetSGCBValues</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td><strong>REPORTING (CLAUSE 14)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BUFFERED REPORT CONTROL BLOCK (BRCB)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S24 Report</td>
<td>TP</td>
<td>c6</td>
<td>Yes</td>
</tr>
<tr>
<td>S24-1 data-change (dchg)</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>S24-2 qchg-change (qchg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S24-3 data-update (dupd)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S25 GetBRCBValues</td>
<td>TP</td>
<td>c6</td>
<td>Yes</td>
</tr>
<tr>
<td>S26 SetBRCBValues</td>
<td>TP</td>
<td>c6</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>UNBUFFERED REPORT CONTROL BLOCK (URCB)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S27 Report</td>
<td>TP</td>
<td>c6</td>
<td>Yes</td>
</tr>
<tr>
<td>S27-1 data-change (dchg)</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>S27-2 qchg-change (qchg)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>S27-3 data-update (dupd)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S28 GetURCBValues</td>
<td>TP</td>
<td>c6</td>
<td>Yes</td>
</tr>
<tr>
<td>S29 SetURCBValues</td>
<td>TP</td>
<td>c6</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>LOGGING (CLAUSE 14)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LOG CONTROL BLOCK</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>S30 GetLCBValues</td>
<td>TP</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>S31 SetLCBValues</td>
<td>TP</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td><strong>LOG</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S32 QueryLogByTime</td>
<td>TP</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>S33 QueryLogByEntry</td>
<td>TP</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>S34 GetLogStatusValues</td>
<td>TP</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td><strong>GENERIC SUBSTATION EVENT MODEL (GSE) (CLAUSE 14.3.5.3.4)</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>GOOSE-CONTROL-BLOCK</strong></td>
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</tr>
<tr>
<td>S35 SendGOOSEMessage</td>
<td>MC</td>
<td>c8</td>
<td>Yes</td>
</tr>
<tr>
<td>S36 GetReference</td>
<td>TP</td>
<td>c9</td>
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</tr>
<tr>
<td>S37 GetGOOSEElementNumber</td>
<td>TP</td>
<td>c9</td>
<td></td>
</tr>
<tr>
<td>S38 GetGoCBValues</td>
<td>TP</td>
<td>O</td>
<td>Yes</td>
</tr>
<tr>
<td>S39 SetGoCBValues</td>
<td>TP</td>
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<td>Yes</td>
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<tr>
<td><strong>GSSE-CONTROL-BLOCK</strong></td>
<td></td>
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</tr>
<tr>
<td>S40 SendGSSEMessage</td>
<td>MC</td>
<td>c8</td>
<td>Yes</td>
</tr>
<tr>
<td>S41 GetReference</td>
<td>TP</td>
<td>c9</td>
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</table>
**C.2 ACSI CONFORMANCE**

<table>
<thead>
<tr>
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<th>AA: TP/MC</th>
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<tbody>
<tr>
<td>S42 GetGSSEElementNumber</td>
<td>TP</td>
<td>c9</td>
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</tr>
<tr>
<td>S43 GetGsCBValues</td>
<td>TP</td>
<td>O</td>
<td>Yes</td>
</tr>
<tr>
<td>S44 SetGsCBValues</td>
<td>TP</td>
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</table>

**TRANSMISSION OF SAMPLE VALUE MODEL (SVC) (CLAUSE 16)**

**MULTICAST SVC**

<table>
<thead>
<tr>
<th>SERVICES</th>
<th>AA: TP/MC</th>
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</tr>
</thead>
<tbody>
<tr>
<td>S45 SendMSVMessage</td>
<td>MC</td>
<td>c10</td>
<td></td>
</tr>
<tr>
<td>S46 GetMSVCBValues</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S47 SetMSVCBValues</td>
<td>TP</td>
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**UNICAST SVC**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>S48 SendUSVMessage</td>
<td>MC</td>
<td>c10</td>
<td></td>
</tr>
<tr>
<td>S49 GetUSVCBValues</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S50 SetUSVCBValues</td>
<td>TP</td>
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**CONTROL (CLAUSE 16.4.8)**

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>S51 Select</td>
<td></td>
<td>O</td>
<td>Yes</td>
</tr>
<tr>
<td>S52 SelectWithValue</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S53 Cancel</td>
<td>TP</td>
<td>O</td>
<td>Yes</td>
</tr>
<tr>
<td>S54 Operate</td>
<td>TP</td>
<td>M</td>
<td>Yes</td>
</tr>
<tr>
<td>S55 Command-Termination</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S56 TimeActivated-Operate</td>
<td>TP</td>
<td>O</td>
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</tr>
</tbody>
</table>

**FILE TRANSFER (CLAUSE 20)**

<table>
<thead>
<tr>
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<th>AA: TP/MC</th>
<th>SERVER/ PUBLISHER</th>
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</tr>
</thead>
<tbody>
<tr>
<td>S57 GetFile</td>
<td>TP</td>
<td>M</td>
<td>Yes</td>
</tr>
<tr>
<td>S58 SetFile</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S59 DeleteFile</td>
<td>TP</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>S60 GetFileAttributeValues</td>
<td>TP</td>
<td>M</td>
<td>Yes</td>
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</table>

**TIME (CLAUSE 5.5)**

<table>
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<th>UR FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 Time resolution of internal clock (nearest negative power of 2 in seconds)</td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>T2 Time accuracy of internal clock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3 supported TimeStamp resolution (nearest value of 2⁻ⁿ in seconds, according to 5.5.3.7.3.3)</td>
<td></td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE**

- c6: shall declare support for at least one (BRCB or URCB)
- c7: shall declare support for at least one (QueryLogByTime or QueryLogAfter)
- c8: shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage)
- c9: shall declare support if TP association is available
- c10: shall declare support for at least one (SendMSVMessage or SendUSVMessage)
The UR-series of relays supports IEC 61850 logical nodes as indicated in the following table. Note that the actual instantiation of each logical node is determined by the product order code. For example, the logical node “PDIS” (distance protection) is available only in the D60 Line Distance Relay.

<table>
<thead>
<tr>
<th>NODES</th>
<th>UR-FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L: SYSTEM LOGICAL NODES</strong></td>
<td></td>
</tr>
<tr>
<td>LPHD: Physical device information</td>
<td>Yes</td>
</tr>
<tr>
<td>LLN0: Logical node zero</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>P: LOGICAL NODES FOR PROTECTION FUNCTIONS</strong></td>
<td></td>
</tr>
<tr>
<td>PDIF: Differential</td>
<td>Yes</td>
</tr>
<tr>
<td>PDIR: Direction comparison</td>
<td>---</td>
</tr>
<tr>
<td>PDIS: Distance</td>
<td>Yes</td>
</tr>
<tr>
<td>PDOP: Directional overpower</td>
<td>---</td>
</tr>
<tr>
<td>PDUP: Directional underpower</td>
<td>---</td>
</tr>
<tr>
<td>PFRC: Rate of change of frequency</td>
<td>---</td>
</tr>
<tr>
<td>PHAR: Harmonic restraint</td>
<td>---</td>
</tr>
<tr>
<td>PHIZ: Ground detector</td>
<td>---</td>
</tr>
<tr>
<td>PIOC: Instantaneous overcurrent</td>
<td>Yes</td>
</tr>
<tr>
<td>PMRI: Motor restart inhibition</td>
<td>---</td>
</tr>
<tr>
<td>PMSS: Motor starting time supervision</td>
<td>---</td>
</tr>
<tr>
<td>POFP: Over power factor</td>
<td>---</td>
</tr>
<tr>
<td>PPAM: Phase angle measuring</td>
<td>---</td>
</tr>
<tr>
<td>PSCH: Protection scheme</td>
<td>---</td>
</tr>
<tr>
<td>PSDE: Sensitive directional earth fault</td>
<td>---</td>
</tr>
<tr>
<td>PTEF: Transient earth fault</td>
<td>---</td>
</tr>
<tr>
<td>PTOC: Time overcurrent</td>
<td>Yes</td>
</tr>
<tr>
<td>PTOF: Overfrequency</td>
<td>---</td>
</tr>
<tr>
<td>PTOV: Overtorque</td>
<td>---</td>
</tr>
<tr>
<td>PTRC: Protection trip conditioning</td>
<td>Yes</td>
</tr>
<tr>
<td>PTTR: Thermal overload</td>
<td>---</td>
</tr>
<tr>
<td>PTUC: Undercurrent</td>
<td>---</td>
</tr>
<tr>
<td>PTUV: Undervoltage</td>
<td>Yes</td>
</tr>
<tr>
<td>PUFF: Underpower factor</td>
<td>---</td>
</tr>
<tr>
<td>PTUF: Underfrequency</td>
<td>---</td>
</tr>
<tr>
<td>PVOC: Voltage controlled time overcurrent</td>
<td>---</td>
</tr>
<tr>
<td>PVPH: Volts per Hz</td>
<td>---</td>
</tr>
<tr>
<td>PZSU: Zero speed or underspeed</td>
<td>---</td>
</tr>
<tr>
<td><strong>R: LOGICAL NODES FOR PROTECTION RELATED FUNCTIONS</strong></td>
<td></td>
</tr>
<tr>
<td>RDRE: Disturbance recorder function</td>
<td>---</td>
</tr>
<tr>
<td>RADR: Disturbance recorder channel analogue</td>
<td>---</td>
</tr>
<tr>
<td>RBDR: Disturbance recorder channel binary</td>
<td>---</td>
</tr>
<tr>
<td>RDRS: Disturbance record handling</td>
<td>---</td>
</tr>
<tr>
<td>RBFR: Breaker failure</td>
<td>Yes</td>
</tr>
<tr>
<td>RDIR: Directional element</td>
<td>---</td>
</tr>
<tr>
<td>RFLO: Fault locator</td>
<td>Yes</td>
</tr>
<tr>
<td>RPSB: Power swing detection/blocking</td>
<td>Yes</td>
</tr>
<tr>
<td>RREC: Autoreclosing</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NODES</th>
<th>UR-FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C: LOGICAL NODES FOR CONTROL</strong></td>
<td></td>
</tr>
<tr>
<td>CALH: Alarm handling</td>
<td>---</td>
</tr>
<tr>
<td>CCGR: Cooling group control</td>
<td>---</td>
</tr>
<tr>
<td>CILO: Interlocking</td>
<td>---</td>
</tr>
<tr>
<td>CPOW: Point-on-wave switching</td>
<td>---</td>
</tr>
<tr>
<td>CSWI: Switch controller</td>
<td>---</td>
</tr>
<tr>
<td><strong>G: LOGICAL NODES FOR GENERIC REFERENCES</strong></td>
<td></td>
</tr>
<tr>
<td>GAPC: Generic automatic process control</td>
<td>---</td>
</tr>
<tr>
<td>GGIO: Generic process I/O</td>
<td>Yes</td>
</tr>
<tr>
<td>GSAL: Generic security application</td>
<td>---</td>
</tr>
<tr>
<td><strong>I: LOGICAL NODES FOR INTERFACING AND ARCHIVING</strong></td>
<td></td>
</tr>
<tr>
<td>IARC: Archiving</td>
<td>---</td>
</tr>
<tr>
<td>IHMI: Human machine interface</td>
<td>---</td>
</tr>
<tr>
<td>ITCI: Telecontrol interface</td>
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</tr>
<tr>
<td>ITMI: Telemonitoring interface</td>
<td>---</td>
</tr>
<tr>
<td><strong>A: LOGICAL NODES FOR AUTOMATIC CONTROL</strong></td>
<td></td>
</tr>
<tr>
<td>ANCR: Neutral current regulator</td>
<td>---</td>
</tr>
<tr>
<td>ARCO: Reactive power control</td>
<td>---</td>
</tr>
<tr>
<td>ATCC: Automatic tap changer controller</td>
<td>---</td>
</tr>
<tr>
<td>AVCO: Voltage control</td>
<td>---</td>
</tr>
<tr>
<td><strong>M: LOGICAL NODES FOR METERING AND MEASUREMENT</strong></td>
<td></td>
</tr>
<tr>
<td>MDIF: Differential measurements</td>
<td>---</td>
</tr>
<tr>
<td>MHAI: Harmonics or interharmonics</td>
<td>---</td>
</tr>
<tr>
<td>MHAN: Non phase related harmonics or interharmonics</td>
<td>---</td>
</tr>
<tr>
<td>MMTR: Metering</td>
<td>---</td>
</tr>
<tr>
<td>MMXN: Non phase related measurement</td>
<td>---</td>
</tr>
<tr>
<td>MMXU: Measurement</td>
<td>Yes</td>
</tr>
<tr>
<td>MSQI: Sequence and imbalance</td>
<td>---</td>
</tr>
<tr>
<td>MSTA: Metering statistics</td>
<td>---</td>
</tr>
<tr>
<td><strong>S: LOGICAL NODES FOR SENSORS AND MONITORING</strong></td>
<td></td>
</tr>
<tr>
<td>SARC: Monitoring and diagnostics for arcs</td>
<td>---</td>
</tr>
<tr>
<td>SIMG: Insulation medium supervision (gas)</td>
<td>---</td>
</tr>
<tr>
<td>SIML: Insulation medium supervision (liquid)</td>
<td>---</td>
</tr>
<tr>
<td>SPDC: Monitoring and diagnostics for partial discharges</td>
<td>---</td>
</tr>
<tr>
<td><strong>X: LOGICAL NODES FOR SWITCHGEAR</strong></td>
<td></td>
</tr>
<tr>
<td>XCBR: Circuit breaker</td>
<td>Yes</td>
</tr>
<tr>
<td>XSWI: Circuit switch</td>
<td>---</td>
</tr>
<tr>
<td><strong>T: LOGICAL NODES FOR INSTRUMENT TRANSFORMERS</strong></td>
<td></td>
</tr>
<tr>
<td>TCTR: Current transformer</td>
<td>---</td>
</tr>
<tr>
<td>TVTR: Voltage transformer</td>
<td>---</td>
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</tbody>
</table>
## C.3 LOGICAL NODES

<table>
<thead>
<tr>
<th>NODES</th>
<th>UR-FAMILY</th>
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<tbody>
<tr>
<td><strong>Y: LOGICAL NODES FOR POWER TRANSFORMERS</strong></td>
<td></td>
</tr>
<tr>
<td>YEFN: Earth fault neutralizer (Peterson coil)</td>
<td>---</td>
</tr>
<tr>
<td>YLTC: Tap changer</td>
<td>---</td>
</tr>
<tr>
<td>YPSH: Power shunt</td>
<td>---</td>
</tr>
<tr>
<td>YPTR: Power transformer</td>
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</tr>
<tr>
<td><strong>Z: LOGICAL NODES FOR FURTHER POWER SYSTEM EQUIPMENT</strong></td>
<td></td>
</tr>
<tr>
<td>ZAXN: Auxiliary network</td>
<td>---</td>
</tr>
<tr>
<td>ZBAT: Battery</td>
<td>---</td>
</tr>
<tr>
<td>ZBSH: Bushing</td>
<td>---</td>
</tr>
<tr>
<td>ZCAB: Power cable</td>
<td>---</td>
</tr>
<tr>
<td>ZCAP: Capacitor bank</td>
<td>---</td>
</tr>
<tr>
<td>ZCON: Converter</td>
<td>---</td>
</tr>
<tr>
<td>ZGEN: Generator</td>
<td>---</td>
</tr>
<tr>
<td>ZGIL: Gas insulated line</td>
<td>---</td>
</tr>
<tr>
<td>ZLIN: Power overhead line</td>
<td>---</td>
</tr>
<tr>
<td>ZMOT: Motor</td>
<td>---</td>
</tr>
<tr>
<td>ZREA: Reactor</td>
<td>---</td>
</tr>
<tr>
<td>ZRRC: Rotating reactive component</td>
<td>---</td>
</tr>
<tr>
<td>ZSAR: Surge arrester</td>
<td>---</td>
</tr>
<tr>
<td>ZTCF: Thyristor controlled frequency converter</td>
<td>---</td>
</tr>
<tr>
<td>ZTRC: Thyristor controlled reactive component</td>
<td>---</td>
</tr>
</tbody>
</table>
This document is adapted from the IEC 60870-5-104 standard. For this 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
- Multipoint
- Multiple Point-to-Point
- Multipoint-Star

3. PHYSICAL LAYER

Transmission Speed (control direction):

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>100 bits/sec.</td>
<td>2400 bits/sec.</td>
<td>2400 bits/sec.</td>
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<tr>
<td>200 bits/sec.</td>
<td>4800 bits/sec.</td>
<td>4800 bits/sec.</td>
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<tr>
<td>300 bits/sec.</td>
<td>9600 bits/sec.</td>
<td>9600 bits/sec.</td>
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<tr>
<td>600 bits/sec.</td>
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<td>49200 bits/sec.</td>
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<tr>
<td>1200 bits/sec.</td>
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<td>38400 bits/sec.</td>
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<tr>
<td></td>
<td></td>
<td>56000 bits/sec.</td>
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<tr>
<td></td>
<td></td>
<td>64000 bits/sec.</td>
</tr>
</tbody>
</table>

Transmission Speed (monitor direction):

<table>
<thead>
<tr>
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<th></th>
<th></th>
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<tbody>
<tr>
<td>100 bits/sec.</td>
<td>2400 bits/sec.</td>
<td>2400 bits/sec.</td>
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<tr>
<td>200 bits/sec.</td>
<td>4800 bits/sec.</td>
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<td>300 bits/sec.</td>
<td>9600 bits/sec.</td>
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<td>600 bits/sec.</td>
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<td>49200 bits/sec.</td>
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<td>1200 bits/sec.</td>
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<td>38400 bits/sec.</td>
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<td></td>
<td></td>
<td>56000 bits/sec.</td>
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<tr>
<td></td>
<td></td>
<td>64000 bits/sec.</td>
</tr>
</tbody>
</table>

4. LINK LAYER

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<thead>
<tr>
<th>Link Transmission Procedure:</th>
<th>Address Field of the Link:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balanced Transmission</td>
<td>Not Present (Balanced Transmission-Only)</td>
</tr>
<tr>
<td>Unbalanced Transmission</td>
<td>One-Octet</td>
</tr>
<tr>
<td></td>
<td>Two-Octets</td>
</tr>
<tr>
<td></td>
<td>Structured</td>
</tr>
<tr>
<td></td>
<td>Unstructured</td>
</tr>
</tbody>
</table>

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 standard.

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_ME_TA_1
□ <11> := Measured value, scaled value M_ME_NB_1
□ <12> := Measured value, scaled value with time tag M_ME_TB_1
□ <13> := Measured value, short floating point value M_ME_NC_1
□ <14> := Measured value, short floating point value with time tag M_ME_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
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

Either the ASDUs of the set <45> to <51> or of the set <58> to <64> are used.

System information in monitor direction

System information in control direction
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

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<thead>
<tr>
<th>TYPE IDENTIFICATION</th>
<th>CAUSE OF TRANSMISSION</th>
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<tbody>
<tr>
<td></td>
<td>PERIODIC, CYCLIC</td>
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<tr>
<td></td>
<td>BACKGROUND SCAN</td>
</tr>
<tr>
<td></td>
<td>SPONTANEOUS</td>
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<td>REQUEST OR REQUESTED</td>
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<td>INITIAL</td>
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<td>ACTIVATION</td>
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<td>ACTIVATION CONFIRMATION</td>
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<td>DEACTIVATION</td>
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<td>DEACTIVATION CONFIRMATION</td>
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<td>RETURN INFO CAUSED BY LOCAL CMD</td>
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<td>FILE TRANSFER</td>
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<td>INTERROGATED BY GROUP &lt;NUMBER&gt;</td>
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<table>
<thead>
<tr>
<th>NO.</th>
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<th>20 to 36</th>
<th>37 to 41</th>
<th>44</th>
<th>45</th>
<th>46</th>
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<tbody>
<tr>
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<td>&lt;103&gt;</td>
<td>C_CS_NA_1</td>
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<td>X</td>
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<td>&lt;104&gt;</td>
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<td>&lt;106&gt;</td>
<td>C_CD_NA_1</td>
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<td>&lt;107&gt;</td>
<td>C_TS_TA_1</td>
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<td>&lt;110&gt;</td>
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<td>&lt;112&gt;</td>
<td>P_ME_NC_1</td>
<td>X</td>
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<td>&lt;113&gt;</td>
<td>P_AC_NA_1</td>
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<td>&lt;120&gt;</td>
<td>F_FR_NA_1</td>
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<td>&lt;122&gt;</td>
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<tr>
<td>&lt;123&gt;</td>
<td>F_LS_NA_1</td>
<td></td>
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<tr>
<td>&lt;124&gt;</td>
<td>F_AF_NA_1</td>
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<tr>
<td>&lt;125&gt;</td>
<td>F_SG_NA_1</td>
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<tr>
<td>&lt;126&gt;</td>
<td>F_DR_TA_1*</td>
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</tr>
</tbody>
</table>

**TYPE IDENTIFICATION**
- PERIODIC, CYCLIC
- BACKGROUND SCAN
- SPONTANEOUS
- INITIALIZED
- REQUEST OR REQUESTED
- ACTIVATION
- ACTIVATION CONFIRMATION
- DEACTIVATION
- DEACTIVATION CONFIRMATION
- RETURN INFO CAUSED BY LOCAL CMD
- FILE TRANSFER
- INTERROGATED BY GROUP <NUMBER>
- REQUEST BY GROUP <NUMBER> COUNTER REQ

**CAUSE OF TRANSMISSION**
- TYPICAL CALL IDENTIFICATION
- UNKNOWN TYPE IDENTIFICATION
- UNKNOWN CAUSE OF TRANSMISSION
- UNKNOWN COMMON ADDRESS OF ADSU
- UNKNOWN INFORMATION OBJECT ADDR
- UNKNOWN INFORMATION OBJECT ADDR
- DEACTIVATION
- DEACTIVATION CONFIRMATION
- ACTIVATION TERMINATION
- RETURN INFO CAUSED BY LOCAL CMD
- FILE TRANSFER
- INTERROGATED BY GROUP <NUMBER>
- REQUEST BY GROUP <NUMBER> COUNTER REQ
- TYPICAL CALL IDENTIFICATION
- UNKNOWN TYPE IDENTIFICATION
- UNKNOWN CAUSE OF TRANSMISSION
- UNKNOWN COMMON ADDRESS OF ADSU
- UNKNOWN INFORMATION OBJECT ADDR
- UNKNOWN INFORMATION OBJECT ADDR
- DEACTIVATION
- DEACTIVATION CONFIRMATION
- ACTIVATION TERMINATION
- RETURN INFO CAUSED BY LOCAL CMD
- FILE TRANSFER
- INTERROGATED BY GROUP <NUMBER>
- REQUEST BY GROUP <NUMBER> COUNTER REQ
- TYPICAL CALL IDENTIFICATION
- UNKNOWN TYPE IDENTIFICATION
- UNKNOWN CAUSE OF TRANSMISSION
- UNKNOWN COMMON ADDRESS OF ADSU
- UNKNOWN INFORMATION OBJECT ADDR
- UNKNOWN INFORMATION OBJECT ADDR
- DEACTIVATION
- DEACTIVATION CONFIRMATION
- ACTIVATION TERMINATION
- RETURN INFO CAUSED BY LOCAL CMD
- FILE TRANSFER
- INTERROGATED BY GROUP <NUMBER>
- REQUEST BY GROUP <NUMBER> COUNTER REQ
- TYPICAL CALL IDENTIFICATION
- UNKNOWN TYPE IDENTIFICATION
- UNKNOWN CAUSE OF TRANSMISSION
- UNKNOWN COMMON ADDRESS OF ADSU
- UNKNOWN INFORMATION OBJECT ADDR
- UNKNOWN INFORMATION OBJECT ADDR

* Indicates additional cause of transmission
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 2
- Group 3
- Group 4
- Group 5
- Group 6
- Group 7
- Group 8
- Group 9
- Group 10
- Group 11
- Group 12
- Group 13
- Group 14
- Group 15
- 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:

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DEFAULT VALUE</th>
<th>REMARKS</th>
<th>SELECTED VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_0 )</td>
<td>30 s</td>
<td>Timeout of connection establishment</td>
<td>120 s</td>
</tr>
<tr>
<td>( t_1 )</td>
<td>15 s</td>
<td>Timeout of send or test APDUs</td>
<td>15 s</td>
</tr>
<tr>
<td>( t_2 )</td>
<td>10 s</td>
<td>Timeout for acknowledgements in case of no data messages ( t_2 &lt; t_1 )</td>
<td>10 s</td>
</tr>
<tr>
<td>( t_3 )</td>
<td>20 s</td>
<td>Timeout for sending test frames in case of a long idle state</td>
<td>20 s</td>
</tr>
</tbody>
</table>

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 \( w \):

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DEFAULT VALUE</th>
<th>REMARKS</th>
<th>SELECTED VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k )</td>
<td>12 APDUs</td>
<td>Maximum difference receive sequence number to send state variable</td>
<td>12 APDUs</td>
</tr>
<tr>
<td>( w )</td>
<td>8 APDUs</td>
<td>Latest acknowledge after receiving ( w ) I-format APDUs</td>
<td>8 APDUs</td>
</tr>
</tbody>
</table>

Maximum range of values \( k \): 1 to \( 2^{15} - 1 \) 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:

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portnumber</td>
<td>2404</td>
<td>In all cases</td>
</tr>
</tbody>
</table>

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)

The IEC 60870-5-104 data points are configured through the SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ DNP / IEC104 POINT LISTS menu. Refer to the Communications section of Chapter 5 for additional details.
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)

<table>
<thead>
<tr>
<th>Vendor Name: General Electric Multilin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device Name: UR Series Relay</td>
</tr>
<tr>
<td><strong>Highest DNP Level Supported:</strong></td>
</tr>
<tr>
<td>For Requests: Level 2</td>
</tr>
<tr>
<td>For Responses: Level 2</td>
</tr>
<tr>
<td><strong>Device Function:</strong></td>
</tr>
<tr>
<td>[ ] Master</td>
</tr>
<tr>
<td>[x] Slave</td>
</tr>
</tbody>
</table>

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)
- File Transfer (Object 70)

| 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 |
| [x] Fixed at 2 |
| [ ] Configurable |

| Maximum Application Layer Re-tries: |
| [x] None |
| [ ] Configurable |

| Requires Data Link Layer Confirmation: |
| [x] Never |
| [ ] Always |
| [ ] Sometimes |
| [ ] Configurable |
### Requires Application Layer Confirmation:
- □ Never
- □ Always
- ☒ When reporting Event Data
- ☒ When sending multi-fragment responses
- □ Sometimes
- □ Configurable

### Timeouts while waiting for:

<table>
<thead>
<tr>
<th>Timeout Type</th>
<th>Option Options</th>
<th>Option Options</th>
<th>Option Options</th>
<th>Option Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Link Confirm</td>
<td>None</td>
<td>□ Fixed at 3 s</td>
<td>□ Variable</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Complete Appl. Fragment</td>
<td>None</td>
<td>□ Fixed at ____</td>
<td>□ Variable</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Application Confirm</td>
<td>None</td>
<td>☒ Fixed at 4 s</td>
<td>□ Variable</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Complete Appl. Response</td>
<td>None</td>
<td>□ Fixed at ____</td>
<td>□ Variable</td>
<td>□ Configurable</td>
</tr>
</tbody>
</table>

### 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:

<table>
<thead>
<tr>
<th>Operation Type</th>
<th>Option Options</th>
<th>Option Options</th>
<th>Option Options</th>
<th>Option Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRITE Binary Outputs</td>
<td>☒ Never</td>
<td>□ Always</td>
<td>□ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>SELECT/OPERATE</td>
<td>□ Never</td>
<td>☒ Always</td>
<td>□ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>DIRECT OPERATE</td>
<td>□ Never</td>
<td>☒ Always</td>
<td>□ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>DIRECT OPERATE – NO ACK</td>
<td>□ Never</td>
<td>☒ Always</td>
<td>□ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Count &gt; 1</td>
<td>☒ Never</td>
<td>□ Always</td>
<td>□ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Pulse On</td>
<td>□ Never</td>
<td>□ Always</td>
<td>☒ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Pulse Off</td>
<td>□ Never</td>
<td>□ Always</td>
<td>☒ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Latch On</td>
<td>□ Never</td>
<td>□ Always</td>
<td>☒ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Latch Off</td>
<td>□ Never</td>
<td>□ Always</td>
<td>☒ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Queue</td>
<td>☒ Never</td>
<td>□ Always</td>
<td>□ Sometimes</td>
<td>□ Configurable</td>
</tr>
<tr>
<td>Clear Queue</td>
<td>☒ Never</td>
<td>□ Always</td>
<td>□ Sometimes</td>
<td>□ Configurable</td>
</tr>
</tbody>
</table>

### 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)

<table>
<thead>
<tr>
<th>Reports Binary Input Change Events when no specific variation requested:</th>
<th>Reports time-tagged Binary Input Change Events when no specific variation requested:</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Never</td>
<td>□ Never</td>
</tr>
<tr>
<td>☒ Only time-tagged</td>
<td>☒ Binary Input Change With Time</td>
</tr>
<tr>
<td>□ Only non-time-tagged</td>
<td>□ Binary Input Change With Relative Time</td>
</tr>
<tr>
<td>□ Configurable</td>
<td>□ Configurable (attach explanation)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sends Unsolicited Responses:</th>
<th>Sends Static Data in Unsolicited Responses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Never</td>
<td>☒ Never</td>
</tr>
<tr>
<td>☒ Configurable</td>
<td>☒ When Device Restarts</td>
</tr>
<tr>
<td>□ Only certain objects</td>
<td>□ When Status Flags Change</td>
</tr>
<tr>
<td>□ Sometimes (attach explanation)</td>
<td>No other options are permitted.</td>
</tr>
<tr>
<td>☒ ENABLE/DISABLE unsolicited Function codes supported</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Default Counter Object/Variation:</th>
<th>Counters Roll Over at:</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ No Counters Reported</td>
<td>□ No Counters Reported</td>
</tr>
<tr>
<td>□ Configurable (attach explanation)</td>
<td>□ Configurable (attach explanation)</td>
</tr>
<tr>
<td>☒ Default Object: 20</td>
<td>☒ 16 Bits (Counter 8)</td>
</tr>
<tr>
<td>Default Variation: 1</td>
<td>☒ 32 Bits (Counters 0 to 7, 9)</td>
</tr>
<tr>
<td>☒ Point-by-point list attached</td>
<td>□ Other Value: _____</td>
</tr>
<tr>
<td></td>
<td>☒ Point-by-point list attached</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sends Multi-Fragment Responses:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>☒ Yes</td>
<td></td>
</tr>
<tr>
<td>□ No</td>
<td></td>
</tr>
</tbody>
</table>

Point-by-point list attached
The following table identifies the variations, function codes, and qualifiers supported by the F60 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)

<table>
<thead>
<tr>
<th>OBJECT NO.</th>
<th>VARIATION NO.</th>
<th>VARIATION</th>
<th>DESCRIPTION</th>
<th>REQUEST</th>
<th>QUALIFIER CODES (DEC)</th>
<th>FUNCTION CODES (DEC)</th>
<th>QUALIFIER CODES (HEX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Binary Input (Variation 0 is used to request default variation)</td>
<td>1 (read) 22 (assign class)</td>
<td>00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited quantity) 17, 28 (index)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Binary Input</td>
<td>1 (read) 22 (assign class)</td>
<td>00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited quantity) 17, 28 (index)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>Binary Input Change (Variation 0 is used to request default variation)</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Binary Input Change without Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>Binary Input Change with Time</td>
<td>1 (read)</td>
<td>07, 08 (limited quantity)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>Binary Input Change with Relative Time</td>
<td>1 (read)</td>
<td>07, 08 (limited quantity)</td>
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</tr>
<tr>
<td>10</td>
<td>0</td>
<td>Binary Output Status (Variation 0 is used to request default variation)</td>
<td>1 (read)</td>
<td>00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited quantity) 17, 28 (index)</td>
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</tr>
<tr>
<td>2</td>
<td>0</td>
<td>Binary Output Status</td>
<td>1 (read)</td>
<td>00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited quantity) 17, 28 (index)</td>
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<tr>
<td>12</td>
<td>1</td>
<td>Control Relay Output Block</td>
<td>3 (select) 4 (operate) 5 (direct op) 6 (dir. op, noack)</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
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</tr>
<tr>
<td>20</td>
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<td>Binary Counter (Variation 0 is used to request default variation)</td>
<td>1 (read)</td>
<td>00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited quantity) 17, 28 (index)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>32-Bit Binary Counter</td>
<td>1 (read)</td>
<td>00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited quantity) 17, 28 (index)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. Refer to the Communications section in Chapter 5 for details. 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 F60 is not restarted, but the DNP process is restarted.
Table E–2: IMPLEMENTATION TABLE (Sheet 2 of 4)

<table>
<thead>
<tr>
<th>OBJECT NO.</th>
<th>VARIATION NO.</th>
<th>DESCRIPTION</th>
<th>REQUEST</th>
<th>RESPONSE</th>
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<td></td>
</tr>
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<td>2</td>
<td>16-Bit Binary Counter</td>
<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>129 (response)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 (freeze)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 (freeze noack)</td>
<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 (freeze clear)</td>
<td>17, 28 (index)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 (frz. cl. noack)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 (assign class)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>32-Bit Binary Counter without Flag</td>
<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>129 (response)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 (freeze)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 (freeze noack)</td>
<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 (freeze clear)</td>
<td>17, 28 (index)</td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 (assign class)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16-Bit Binary Counter without Flag</td>
<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>129 (response)</td>
</tr>
<tr>
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<td>7 (freeze)</td>
<td>06 (no range, or all)</td>
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<tr>
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<td></td>
<td>8 (freeze noack)</td>
<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 (freeze clear)</td>
<td>17, 28 (index)</td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
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<td></td>
<td>22 (assign class)</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0 Frozen Counter (Variation 0 is used to request default variation)</td>
<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>129 (response)</td>
</tr>
<tr>
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<td></td>
<td>22 (assign class)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td>07, 08 (limited quantity)</td>
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</tr>
<tr>
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<td></td>
<td>17, 28 (index)</td>
<td></td>
</tr>
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<td>1</td>
<td>32-Bit Frozen Counter</td>
<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>129 (response)</td>
</tr>
<tr>
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<td></td>
<td>22 (assign class)</td>
<td>06 (no range, or all)</td>
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<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
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<td>17, 28 (index)</td>
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<td>16-Bit Frozen Counter</td>
<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>129 (response)</td>
</tr>
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<td></td>
<td></td>
<td>22 (assign class)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
<tr>
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<td>17, 28 (index)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>32-Bit Frozen Counter without Flag</td>
<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>129 (response)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 (assign class)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17, 28 (index)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>16-Bit Frozen Counter without Flag</td>
<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>129 (response)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 (assign class)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td>07, 08 (limited quantity)</td>
<td></td>
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<td>17, 28 (index)</td>
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</tr>
<tr>
<td>22</td>
<td>0 Counter Change Event (Variation 0 is used to request default variation)</td>
<td>1 (read)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>07, 08 (limited quantity)</td>
<td></td>
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<td>32-Bit Counter Change Event</td>
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<td>06 (no range, or all)</td>
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<tr>
<td></td>
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<td></td>
<td>07, 08 (limited quantity)</td>
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<td>16-Bit Counter Change Event</td>
<td>1 (read)</td>
<td>06 (no range, or all)</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>32-Bit Counter Change Event with Time</td>
<td>1 (read)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16-Bit Counter Change Event with Time</td>
<td>1 (read)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>0 Frozen Counter Event (Variation 0 is used to request default variation)</td>
<td>1 (read)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>07, 08 (limited quantity)</td>
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<td>32-Bit Frozen Counter Event</td>
<td>1 (read)</td>
<td>06 (no range, or all)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td>07, 08 (limited quantity)</td>
<td></td>
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<tr>
<td>2</td>
<td>16-Bit Frozen Counter Event</td>
<td>1 (read)</td>
<td>06 (no range, or all)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>07, 08 (limited quantity)</td>
<td></td>
</tr>
</tbody>
</table>

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. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. Refer to the Communications section in Chapter 5 for details. 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 F60 is not restarted, but the DNP process is restarted.
Table E–2: IMPLEMENTATION TABLE (Sheet 3 of 4)

<table>
<thead>
<tr>
<th>OBJECT NO.</th>
<th>VARIATION NO.</th>
<th>DESCRIPTION</th>
<th>FUNCTION CODES (DEC)</th>
<th>QUALIFIER CODES (HEX)</th>
<th>FUNCTION CODES (DEC)</th>
<th>QUALIFIER CODES (HEX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 cont’d</td>
<td>5</td>
<td>32-Bit Frozen Counter Event with Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>16-Bit Frozen Counter Event with Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>Analog Input (Variation 0 is used to request default variation)</td>
<td>1 (read) 22 (assign class)</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>32-Bit Analog Input</td>
<td>1 (read) 22 (assign class)</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
<td>129 (response) 00, 01 (start-stop) 17, 28 (index) (see Note 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>16-Bit Analog Input</td>
<td>1 (read) 22 (assign class)</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
<td>129 (response) 00, 01 (start-stop) 17, 28 (index) (see Note 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>32-Bit Analog Input without Flag</td>
<td>1 (read) 22 (assign class)</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
<td>129 (response) 00, 01 (start-stop) 17, 28 (index) (see Note 2)</td>
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<td></td>
</tr>
<tr>
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<td>16-Bit Analog Input without Flag</td>
<td>1 (read) 22 (assign class)</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
<td>129 (response) 00, 01 (start-stop) 17, 28 (index) (see Note 2)</td>
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<td></td>
</tr>
<tr>
<td>5</td>
<td>short floating point</td>
<td>1 (read) 22 (assign class)</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
<td>129 (response) 00, 01 (start-stop) 17, 28 (index) (see Note 2)</td>
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<td></td>
</tr>
<tr>
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<td>Analog Change Event (Variation 0 is used to request default variation)</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>32-Bit Analog Change Event without Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
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</tr>
<tr>
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<td>2</td>
<td>16-Bit Analog Change Event without Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
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<tr>
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<td>3</td>
<td>32-Bit Analog Change Event with Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
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<tr>
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<td>4</td>
<td>16-Bit Analog Change Event with Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>short floating point Analog Change Event without Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
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</tr>
<tr>
<td></td>
<td>7</td>
<td>short floating point Analog Change Event with Time</td>
<td>1 (read)</td>
<td>06 (no range, or all) 07, 08 (limited quantity)</td>
<td>129 (response) 17, 28 (index)</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>0</td>
<td>Analog Input Reporting Deadband (Variation 0 is used to request default variation)</td>
<td>1 (read)</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
<td>129 (response) 00, 01 (start-stop) 17, 28 (index) (see Note 2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>16-bit Analog Input Reporting Deadband (default – see Note 1)</td>
<td>1 (read)</td>
<td>00, 01 (start-stop) 08 (no range, or all) 07, 08 (limited quantity) 17, 28 (index)</td>
<td>129 (response) 00, 01 (start-stop) 17, 28 (index) (see Note 2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>write</td>
<td>00, 01 (start-stop) 07, 08 (limited quantity) 17, 28 (index)</td>
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</tr>
</tbody>
</table>

**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. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. Refer to the Communications section in Chapter 5 for details. 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 F60 is not restarted, but the DNP process is restarted.
### Table E-2: IMPLEMENTATION TABLE (Sheet 4 of 4)

<table>
<thead>
<tr>
<th>OBJECT NO.</th>
<th>VARIATION NO.</th>
<th>DESCRIPTION</th>
<th>REQUEST</th>
<th>FUNCTION CODES (DEC)</th>
<th>QUALIFIER CODES (HEX)</th>
<th>RESPONSE</th>
<th>FUNCTION CODES (DEC)</th>
<th>QUALIFIER CODES (HEX)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1 (read)</td>
<td>00, 01 (start-stop)</td>
<td>06 (no range, or all)</td>
<td>17, 28 (index)</td>
<td>129 (response)</td>
<td>00, 01 (start-stop)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 (write)</td>
<td>00, 01 (start-stop)</td>
<td>07, 08 (limited quantity)</td>
<td>17, 28 (index)</td>
<td>129 (response)</td>
<td>00, 01 (start-stop)</td>
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<td>Short floating point Analog Input Reporting Deadband</td>
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<td>00, 01 (start-stop)</td>
<td>06 (no range, or all)</td>
<td>17, 28 (index)</td>
<td>129 (response)</td>
<td>00, 01 (start-stop)</td>
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<td>00, 01 (start-stop)</td>
<td>06 (no range, or all)</td>
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<td>07 (limited quantity)</td>
<td>(quantity = 1)</td>
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<td>20 (enable unsol)</td>
<td>21 (disable unsol)</td>
<td>22 (assign class)</td>
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<td>---</td>
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<td>14 (warm restart)</td>
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<td>---</td>
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**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. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. Refer to the Communications section in Chapter 5 for details. 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 F60 is not restarted, but the DNP process is restarted.
The DNP binary input data points are configured through the PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ DNP / IEC104 POINT LISTS ⇒ BINARY INPUT / MSP POINTS menu. Refer to the Communications section of Chapter 5 for additional details. 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
E.2.2 BINARY AND CONTROL RELAY OUTPUT

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)

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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–4: BINARY AND FROZEN COUNTERS

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A counter freeze command has no meaning for counters 8 and 9. F60 Digital Counter values are represented as 32-bit integers. The DNP 3.0 protocol defines counters to be unsigned integers. Care should be taken when interpreting negative counter values.
The DNP analog input data points are configured through the PRODUCT SETUP ☢️ COMMUNICATIONS ☢️ DNP / IEC104 POINT LISTS ☢️ ANALOG INPUT / MME POINTS menu. Refer to the Communications section of Chapter 5 for additional details.

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 for 16-bit values and 2147483647 for 32-bit values. 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.

| 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 without Time) |
| Change Event Scan Rate: defaults to | 500 ms |
| Change Event Buffer Size: | 800 |
| Default Class for all Points: | 1 |
## F.1.1 REVISION HISTORY

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### Table F–2: MAJOR UPDATES FOR F60 MANUAL REVISION M1

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### Table F–3: MAJOR UPDATES FOR F60 MANUAL REVISION L1 (Sheet 1 of 2)

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## APPENDIX F

### Table F–3: MAJOR UPDATES FOR F60 MANUAL REVISION L1 (Sheet 2 of 2)

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### Table F–4: MAJOR UPDATES FOR F60 MANUAL REVISION K1

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### F.2.1 STANDARD ABBREVIATIONS

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<td>ADC</td>
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<td>AE</td>
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<td>Ampere</td>
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<td>Angle</td>
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<td>AR</td>
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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 GE Multilin Standard Conditions of Sale.
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