Bus Differential and Breaker Failure Relay
With Sampled Values

Major Features and Benefits

The SEL-487B-2 Sampled Values (SV) Relay provides bus-current differential protection, circuit-breaker failure protection, and backup overcurrent protection through the use of SV to acquire current and voltage information. The SEL-487B SV Subscriber Relay subscribes to 21 analog current inputs and 3 analog voltage inputs from as many as seven SV streams for protection of as many as seven terminals. For buses with no more than seven terminals, use one SEL-487B in a single-relay application. For buses with eight to ten terminals, use two SEL-487B Relays. For buses with as many as 21 terminals, use three SEL-487B Relays; each relay provides as many as six independent and adaptable zones of protection. Contact SEL Research and Development for methods of protecting larger systems. The SEL-487B SV Subscriber Relay subscribes to current and voltage SV (IEC 61850-9-2LE) information that is published by remote merging units instead of the standard PT and CT inputs. This reduces cable lengths, labor costs, and improve the overall safety of the substation.

➤ Busbar differential protection operates in less than one cycle to increase system stability margins and reduce equipment damage.

➤ The relay supports as many as seven SV subscriptions. SV message subscription complies with UCA 61850-9-2LE guidelines. The SEL-487B only accepts 9-2LE-compliant SV messages with 1 application service data unit (ASDU). Each subscription includes four current and four voltage channels. The supported SV subscription message rate is 4.8 kHz for a 60 Hz power system and 4 kHz for a 50 Hz power system.

➤ The relay supports IEC 61850 standard operating modes such as Test, Blocked, On, and Off.

➤ The relay includes flexible zone selection and six differential zones provide protection for multiple busbar applications.

➤ Failed CT detection elements reliably indicate open and shorted CTs for alarming and/or blocking.

➤ Differential protection accommodates up to 10:1 CT ratio mismatch without auxiliary CTs.
➤ Differential protection is secure for external faults with minimal CT requirements.
➤ The relay uses breaker failure protection for each terminal integrates bus and breaker failure protection.
➤ Instantaneous and inverse-time overcurrent elements provide backup protection for each terminal.
➤ Negative- and zero-sequence over- and undervoltage elements provide for differential element supervision.
➤ Three dedicated check zones are available in each relay to supervise complex bus differential schemes.
➤ The relay can interconnect with automation systems using IEC 61850 or DNP3 protocols directly or DNP3 through a communications processor. Use File Transfer Protocol (FTP) for high-speed data collection.
➤ The relay can record a wide range of system events with as fast as 8 kHz sampling rates, and as much as 24 seconds of data per COMTRADE compliant event report.
➤ Parallel Redundancy Protocol (PRP) provides seamless recovery from any single Ethernet network failure, in accordance with IEC 62439-3:2010. The station bus Ethernet network and traffic are fully duplicated with both copies operating in parallel.
➤ IEEE 1588-2008, Precision Time Protocol (PTP) provides high-accuracy timing over an Ethernet network.

Functional Overview

Figure 1  SEL-487B Functional Overview

<table>
<thead>
<tr>
<th>ANSI NUMBERS/ACRONYMS AND FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 SEC Access Security (Serial, Ethernet)</td>
</tr>
<tr>
<td>27/59 Over- and Undervoltage</td>
</tr>
<tr>
<td>50 Overcurrent</td>
</tr>
<tr>
<td>50BF Breaker Failure Overcurrent</td>
</tr>
<tr>
<td>51 Time-Overcurrent</td>
</tr>
<tr>
<td>85 RIO SEL MIRRORED BITS Communications</td>
</tr>
<tr>
<td>87 Current Differential</td>
</tr>
<tr>
<td>DFR Event Reports</td>
</tr>
<tr>
<td>HMI Operator Interface</td>
</tr>
<tr>
<td>LGC Expanded SELOGIC Control Equations</td>
</tr>
<tr>
<td>MET High-Accuracy Metering</td>
</tr>
<tr>
<td>RTU Remote Terminal Unit</td>
</tr>
<tr>
<td>SER Sequential Events Recorder</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADDITIONAL FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMB Station Battery Monitor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADDITIONAL FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open CT Detection</td>
</tr>
<tr>
<td>Three Independent Check Zones</td>
</tr>
<tr>
<td>Disconnect Status and Monitoring Logic for as many as 7 Disconnects</td>
</tr>
<tr>
<td>Single-Relay Application: 2 Three-Phase Zones for as many as 7 Terminals</td>
</tr>
<tr>
<td>Two-Relay Application: 3 Three-Phase Zones for as many as 10 Terminals</td>
</tr>
<tr>
<td>Three-Relay Application: 6 Single-Phase Zones for as many as 12 Terminals</td>
</tr>
</tbody>
</table>

Note: Both copper and fiber-optic Ethernet ports are available.
The SEL-487B subscribes to as many as seven IEC 61850-9-2LE data streams that are published by merging units, such as the SEL-421-7 Protection, Automation, and Control System with Sampled Values or SEL-401 Protection, Automation, and Control Merging Unit. The SEL-421-7 provides full backup protection while the SEL-401 can provide basic phase overcurrent and breaker-failure protection in the absence of communication. The data may be synchronized via IRIG-B time input or IEEE 1588-2008 PTP. As shown with blue lines in Figure 1, the SEL-487B performs breaker control through GOOSE communications.

Protection Features

The SEL-487B SV Subscriber Relay offers a comprehensive busbar protection feature. The relay supports one interface board which can be configured for different options of digital inputs and outputs.

With the flexibility of the expanded SELOGIC control equations, you need no external auxiliary relays to configure the relay for complex busbar arrangements. The SEL-487B provides station-wide protection through the use of as many as six zones of differential protection, advanced zone selection algorithms, and per-terminal breaker failure and overcurrent protection.

Dynamic Zone Configuration

The SEL-487B dynamically assigns the input currents to the correct differential elements without the need for auxiliary relays. SELOGIC control equations and zone selection logic will correctly assign the currents to the differential elements, even for complex bus arrangements.

Zone Selection Logic

Busbar protection requires the assignment of the correct current values to the appropriate differential elements as a function of user-defined conditions. To achieve this, the SEL-487B employs a two-step process:

➤ Evaluates the user-defined conditions.
➤ Assigns the currents to the differential element of the appropriate zone.

Current assignment conditions vary from simple to complex. A simple condition would be a statement such as “always include this terminal in the differential calculations.” A more complex condition statement could be “when Disconnect 2 is closed, and the transfer disconnect is open.”

SELOGIC control equations provide the mechanism by which the user enters the conditions for assigning the currents to the differential elements when these conditions are met. When a SELOGIC control equation becomes true (e.g., the disconnect is closed), the relay dynamically assigns the current to the differential elements. Conversely, when the SELOGIC control equation is false (the disconnect is open), the relay dynamically removes the currents from the differential elements. This is also true for the trip output. When the SELOGIC control equation of a terminal is false, the relay issues no trip signal to that terminal. Table 1 shows a simple case where the disconnect status is the only condition for the relay to consider.

Table 1 Conditions for Automatic Terminal Assignment

<table>
<thead>
<tr>
<th>Example of Condition</th>
<th>SELOGIC Control Equation Result</th>
<th>Consider Terminal in Protection Calculations?</th>
<th>Issue Trip?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disconnect is open</td>
<td>False</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Disconnect is closed</td>
<td>True</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

End-Zone Protection

To illustrate the flexibility of use of SELOGIC control equations for user-defined conditions, consider the ease of achieving end-zone protection with the SEL-487B.

Figure 2 shows fault F1 between an open circuit breaker and CT of a feeder at a substation. This area is a “dead” zone because neither busbar protection nor local line protection can clear this fault; the remote end of the feeder must clear this fault. Because the feeder circuit breaker is already open, operation of the busbar protection serves no purpose. The busbar protection must not operate for this fault.

By including the circuit breaker auxiliary contact in one of the SELOGIC control equations (Figure 3), we can cause the value of the SELOGIC control equation to be false when the circuit breaker is open, removing the current from the differential element calculations. This capability ensures the stability of the busbar protection. By our use of SELOGIC control equations and normal
communications channels to configure the protection system, the relay sends a trip signal to the remote end of the feeder.

Check Zones

The SEL-487B provides three completely independent check zones, each with its own adaptive differential element. Supervise zone differential elements by using the independent check zones to monitor all incoming sources and outgoing feeders on a per-phase basis. During an internal fault, the check zone differential element will assert. During an external fault, the check zone element will remain deasserted.

Differential Protection

The SEL-487B includes six independent current differential elements. Operating time for internal faults, including high-speed output contact closure, is less than one cycle. Figure 4 shows an example of an internal fault and differential element operation.

CT saturation is one of the main factors to address when considering relay security. Because of the high sampling rate, the fault detection logic detects external faults in less than 2 ms by comparing the rate of change of the restraint and operating currents. Following the detection of an external fault, the relay enters a high-security mode, during which it dynamically selects a higher slope

Figure 3 Bus Protection Is Not Affected by Fault, F1; Use Transfer Trip to Clear the Fault

Figure 4 Differential Element Operation in Less Than One Cycle for Internal Faults

Each of the differential elements provides the following:

➤ Fast operating times for all busbar faults
➤ Security for external faults with heavy CT saturation
➤ Security with subsidence current present
➤ High sensitivity for busbar faults
➤ Minimum delay for faults evolving from external to internal faults

Figure 5 shows a block diagram of one of the six differential protection elements.
for the differential elements (see Figure 5). Figure 6 shows an external fault with heavy CT saturation, without differential element operation.

Figure 6  Differential Element Does Not Operate for an External Fault With Heavy CT Saturation

CT Supervision
Open or shorted CTs produce equal and opposite changes in restraint and operate current. The advanced CT supervision in the SEL-487B monitors differential zone restraint and operating current for these changes, to provide rapid and dependable detection of open or shorted CT conditions. Use the CT supervision logic in zone trip equations.

Voltage Elements
Voltage elements consist of two levels of phase under-(27) and overvoltage (59) elements and two levels of negative- (59Q) and zero-sequence (59N) overvoltage elements, based on one set of three analog voltage quantities. Table 2 provides a summary of the voltage elements.

Table 2  Voltage Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Quantity</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undervoltage</td>
<td>Phase</td>
<td>Two levels</td>
</tr>
<tr>
<td>Overvoltage</td>
<td>Phase, negative-, and zero-sequence</td>
<td>Two levels</td>
</tr>
</tbody>
</table>

Breaker Failure Protection
The SEL-487B includes complete breaker failure protection, including retrip, for each of the 21 terminals. Because some applications require external breaker failure protection, set the SEL-487B to external breaker fail and connect the input from any external breaker failure relay to the SEL-487B; you can set any terminal to either internal or external breaker failure protection.

Figure 7  Open-Phase Detection Reduces Breaker Failure Coordination Time

High-speed, open-pole detection logic detects open-pole conditions in less than 0.75 cycle, reducing breaker failure coordination times as in Figure 7.

Overcurrent Elements
Choose from 10 time-overcurrent curves (Table 3) for each of the 21 current inputs. Each torque-controlled time-overcurrent element has two reset characteristics. One choice resets the elements if current drops below pickup for one cycle, while the other choice emulates the reset characteristic of an electromechanical induction disk relay.

Each terminal also includes instantaneous and definite-time overcurrent elements. These overcurrent elements are summarized in Table 4.

Table 3  Time-Overcurrent Curves

<table>
<thead>
<tr>
<th></th>
<th>US</th>
<th>IEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately Inverse</td>
<td>Standard Inverse</td>
<td></td>
</tr>
<tr>
<td>Inverse</td>
<td>Very Inverse</td>
<td></td>
</tr>
<tr>
<td>Very Inverse</td>
<td>Extremely Inverse</td>
<td></td>
</tr>
<tr>
<td>Extremely Inverse</td>
<td>Long-Time Inverse</td>
<td></td>
</tr>
<tr>
<td>Short-Time Inverse</td>
<td>Short-Time Inverse</td>
<td></td>
</tr>
</tbody>
</table>

Table 4  Overcurrent Elements per Terminal

<table>
<thead>
<tr>
<th>Element</th>
<th>Quantity</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous Overcurrent</td>
<td>Phase</td>
<td>One level</td>
</tr>
<tr>
<td>Definite-Time Overcurrent</td>
<td>Phase</td>
<td>One level</td>
</tr>
</tbody>
</table>
Disconnect Status Monitor

*Figure 8* shows the disconnect open and close contact relationship. During the open-to-close operation, the 89b contact must open (disconnect is CLOSED) during the transition zone before the main contact arcing starts. The 89a contact must close in this transition zone.

During the close-to-open operation, the 89b contact must close during the transition zone after the main contact arcing is extinguished (disconnect is OPEN), as shown in *Figure 8*. The 89a contact must open in this transition zone.

*Table 5* shows the four possible disconnect auxiliary contact combinations and how the relay interprets each combination.

**Table 5 Disconnect Status as a Function of the Auxiliary Contacts**

<table>
<thead>
<tr>
<th>89a</th>
<th>89b</th>
<th>Relay 89 Status Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>closed</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>open</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>closed</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>closed</td>
</tr>
</tbody>
</table>

**Six Independent Settings Groups Increase Operation Flexibility**

The relay stores six settings groups. Select the active settings group by control input, command, or other programmable conditions. Use these settings groups to cover a wide range of protection and control contingencies.

Selectable settings groups make the SEL-487B ideal for applications requiring frequent settings changes and for adapting the protection to changing system conditions.

Selecting a group also selects logic settings. Program group logic to adjust settings for different operating conditions, such as station maintenance, seasonal operations, and emergency contingencies.

**Applications**

*Figure 9* shows a station with a single bus and a bus tie breaker. *Figure 10* shows a station with a double-bus configuration.
Figure 9  Single Bus With Tie Breaker Application
For stations with 10 to 21 terminals, use three separate SEL-487B Relays. Each of the 21 analog current inputs in each relay measures only one phase, with six dedicated zones of protection available. Each relay operates independently. In this application, operators have complete flexibility because they can close any disconnect at any time without compromising the busbar protection. This is possible because the relay dynamically computes the station connection replica by using the patented zone-selection algorithm.

**Figure 10  Double-Breaker Double-Bus Application**

A high-accuracy IEEE C37.118 IRIG-B time-code input synchronizes the SEL-487B time to be within ±1 µs of the time-source input when the time-source input jitter is less than 500 ns and the time error is less than 1 µs. A convenient source for this time code is an SEL communications processor (via Serial Port 1 on the SEL-487B).

**PTP Time Synchronization**

In addition to IRIG-B, the relay can be time synchronized through the Ethernet network using IEEE 1588-2008 PTP. When connected directly to a grandmaster clock providing PTP at 1-second sync intervals, the relay can be synchronized to an accuracy of ±100 ns. The relay is capable of receiving as many as 32 sync messages per second. PTP support includes both the Default and the Power System (IEEE C37.238-2011) PTP Profiles.
SNTP Time Synchronization

Use SNTP to cost-effectively synchronize SEL-487B relays equipped with Ethernet communication to within ±1 ms over standard Ethernet networks without any time source delay. Use SNTP as a primary time source, or as a backup to a higher accuracy IRIG-B time input to the relay.

Automation
Flexible Control Logic and Integration Features

Use the SEL-487B control logic to replace the following:

- Traditional panel control switches
- RTU-to-relay wiring
- Traditional latching relays

- Traditional indicating panel lights

Eliminate traditional panel control switches with 32 local control points. Set, clear, or pulse local control points with the front-panel pushbuttons and display. Program the local control points to implement your control scheme via SELOGIC control equations. Use the same local control points for functions such as taking a terminal out of service for testing.

Eliminate RTU-to-relay wiring with 96 remote control points. Set, clear, or pulse remote control points via serial port commands. Incorporate the remote control points into your control scheme via SELOGIC control equations. Use remote control points for SCADA-type control operations (e.g., trip, settings group selection).

Replace traditional latching relays for such functions as the remote control enable with 32 latching control points. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the latch control points via control inputs, remote control points, local control points, or any programmable logic condition. The relay retains the states of the latch control points after powering up following a power interruption.

Replace traditional indicating panel lights and switches with 24 tricolor latching target LEDs and 12 programmable pushbuttons.

Define custom messages to report analog and Boolean power system or relay conditions on the large format LCD. Control displayed messages via SELOGIC control equations by driving the LCD display via any logic point in the relay. Use any of the dozens of measured or calculated analog values in the relay to create display messages for system metering on the front-panel LCD.

SELOGIC Control Equations With Expanded Capabilities and Aliases

Expanded SELOGIC control equations (Table 6) put relay logic in the hands of the protection engineer. Assign the relay inputs to suit your application, logically combine selected relay elements for various control functions, and assign outputs to your logic functions. Programming SELOGIC control equations consists of combining relay elements, inputs, and outputs with SELOGIC control equation operators. You can use any of the relay internal variables (Relay Word bits) in these equations. For complex or unique applications, these expanded SELOGIC control equation functions allow superior flexibility. Add programmable control functions to your protection and automation systems. New functions and capabilities enable you to use analog values in conditional logic statements. Use the new alias capability to assign more meaningful relay variable names. This improves the readability of customized programming. Use as many as
200 aliases to rename any digital or analog quantity. The following is an example of possible applications of SELOGIC control equations using aliases:

| SET T <Enter> | PMV01, THETA |
| SET L <Enter> | # CALCULATE THE TANGENT OF THETA |

```
1: PMV01, THETA
   (assign the alias "THETA" to math variable PMV01)
2: PMV02, TAN
   (assign the alias "TAN" to math variable PMV02)
```

```
1: # CALCULATE THE TANGENT OF THETA
2: TAN:= SIN(THETA)/COS(THETA)
   (use the aliases in an equation)
```

<table>
<thead>
<tr>
<th>Table 6 Expanded SELOGIC Control Equation Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator Type</td>
</tr>
<tr>
<td>Edge Trigger</td>
</tr>
<tr>
<td>Math Functions</td>
</tr>
<tr>
<td>Arithmetic</td>
</tr>
<tr>
<td>Comparison</td>
</tr>
<tr>
<td>Boolean</td>
</tr>
<tr>
<td>Precedence Control</td>
</tr>
<tr>
<td>Comment</td>
</tr>
</tbody>
</table>

**ACSELERATOR QuickSet SEL-5030 Software**

Use the ACSELERATOR QuickSet® SEL-5030 Software to develop settings and busbar configurations offline. The system automatically checks interrelated settings and highlights out-of-range settings. You can transfer settings you create offline by using a PC communications link with the SEL-487B. The relay converts event reports to oscillograms with time-coordinated element assertion and phasor diagrams. The QuickSet interface supports Server 2008, Microsoft Windows 7 and Windows 8 operating systems, and can be used to open COMTRADE files from SEL and other products. You can also use QuickSet to design application-specific settings templates and then store the templates in non-volatile memory within the relay for trouble-free retrieval.

**MIRRORED BITS Communications**

The SEL patented MIRRORED BITS® technology provides bidirectional relay-to-relay digital communication. This bidirectional digital communication creates additional outputs (transmitted MIRRORED BITS) and additional inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS communications mode.

Communicated information can include digital, analog, and virtual terminal data. Virtual terminal allows operator access to remote relays through the local relay. You can use this MIRRORED BITS protocol to transfer information between stations to enhance coordination and achieve faster tripping.

**Communications Features**

The SEL-487B offers the following communications features:

- Four independent EIA-232 serial ports
- Full access to event history, relay status, and meter information from the communications ports
➤ Settings and group switching password control
➤ SCADA interface capability including FTP, IEC 61850, and DNP3 LAN/WAN, and DNP3 Level 2 Outstation (via serial port)

The relay does not require special communications software. You need only ASCII terminals, printing terminals, or a computer supplied with terminal emulation and a serial communications port. Table 7 provides a synopsis of the communications protocols in the SEL-487B.

**Ethernet Communications**

The Ethernet card mounts directly in the SEL-487B. Use Telnet applications for easy terminal communication with SEL relays and other devices. Transfer data at high speeds (10 Mbps or 100 Mbps) for fast file uploads. The Ethernet card communicates using FTP applications for easy and fast file transfers. Choose Ethernet connection media options for primary and standby connections:

➤ 10/100BASE-T Twisted Pair Network
➤ 100BASE-FX Fiber-Optic Network

Communicate using IEC 61850 Logical Nodes and GOOSE Messages, or DNP3 LAN/WAN.

**Telnet and FTP**

The SEL-487B is equipped with an Ethernet communications card that supports Telnet and FTP communication. Use Telnet with the ASCII interface to access relay settings, and metering and event reports remotely. Use FTP to transfer settings files to and from the relay via the high-speed Ethernet port.

**DNP3 LAN/WAN**

DNP3 LAN/WAN provides the SEL-487B with DNP3 Level 2 Outstation functionality over Ethernet. You can configure custom DNP3 data maps for use with specific DNP3 masters.

**PTP**

The Ethernet card provides the ability to accept IEEE 1588-2008 PTP for data time synchronization. PTP support includes both the Default and Power System (IEEE C37.238-2011) PTP Profiles.

**PRP**

This protocol is used to provide seamless recovery from any single Ethernet network failure, in accordance with IEC 62439-3:2010. The station bus Ethernet network traffic is fully duplicated with both copies operating in parallel.

---

**HTTP Web Server**

The relay can serve read-only webpages displaying certain settings, metering, and status reports. As many as four users can access the embedded HTTP server simultaneously.

**IEC 61850-9-2LE Sampled Values**

The SEL-487B supports IEC 61850-9-2 SV protocol. The SEL-487B SV Subscriber Relay can subscribe to as many as seven SV streams from any source that conforms to the IEC 61850-9-2LE guideline. Self-monitoring of the Ethernet links validates the data quality and reduces the need for periodic testing of the communication network.

**IEC 61850 Ethernet Communications**

IEC 61850 Edition 2 Ethernet-based communications provides interoperability among intelligent devices within the substation. Logical nodes using IEC 61850 allow standardized interconnection of intelligent devices from different manufacturers for monitoring and control of the substation. Reduce wiring among various manufacturers’ devices and simplify operating logic with IEC 61850.

Eliminate system remote terminal units (RTUs) by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.

The SEL-487B supports embedded IEC 61850 Edition 2 protocol operating on 100 Mbps Ethernet. IEC 61850 Ethernet protocol provides relay monitoring and control functions including:

➤ As many as 128 incoming GOOSE messages. The incoming GOOSE messages can be used to control as many as 256 control bits in the relay with <3 ms latency from device to device. These messages provide binary control inputs and analog values to the relay for high-speed control functions and monitoring.

➤ As many as eight outgoing GOOSE messages. You can configure outgoing GOOSE messages for Boolean or analog data. Boolean data and designated remote analog outputs are provided with <3 ms latency from device to device. Apply outgoing GOOSE messages for high-speed control and monitoring of external breakers, switches, and other devices.
IEC 61850 Data Server. The SEL-487B, equipped with embedded IEC 61850 Ethernet protocol, provides data according to predefined logical node objects. Each relay supports as many as seven simultaneous client associations. Relevant Relay Word bits are available within the logical node data, so you can use the IEC 61850 data server in the relay to monitor the status of relay elements, inputs, outputs, or SELOGIC control equations.

Configuration of as many as 256 Virtual Bits within GOOSE messaging to represent a variety of Boolean values available within the relay. The Virtual Bits the relay receives are available for use in SELOGIC control equations.

As many as 64 remote analog outputs that you can assign to virtually any analog quantity available in the relay. You can also use SELOGIC math variables to develop custom analog quantities for assignment as remote analog outputs. Remote analog outputs using IEC 61850 provide peer-to-peer transmission of analog data. Each relay can receive as many as 256 remote analog inputs and use those inputs as analog quantities within SELOGIC control equations.

Table 7 Open Communications Protocol

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCII</td>
<td>Plain-language commands for human and simple machine communication. Use for metering, setting, self-test status, event reporting, and other functions.</td>
</tr>
<tr>
<td>Compressed ASCII</td>
<td>Comma-delimited ASCII data reports allow external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.</td>
</tr>
<tr>
<td>Extended SEL Fast Meter, SEL Fast Operate, and SEL Fast SER</td>
<td>Binary protocol for machine-to-machine communication. Quickly updates SEL communications processors, RTUs, and other substation devices with metering information, relay element, I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected.</td>
</tr>
<tr>
<td>Ymodem</td>
<td>Support for reading event, settings, and oscillography files.</td>
</tr>
<tr>
<td>Optional DNP3 Level 2 Outstation</td>
<td>Distributed Network Protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and settings groups.</td>
</tr>
<tr>
<td>MIRRORED BITS</td>
<td>SEL protocol for exchanging digital and analog information among SEL relays and for use as low-speed terminal connection.</td>
</tr>
<tr>
<td>FTP and Telnet</td>
<td>Available with the optional Ethernet card. Use Telnet to establish a terminal-to-relay connection over Ethernet. Use FTP to move files in and out of the relay over Ethernet.</td>
</tr>
<tr>
<td>IEC 61850</td>
<td>Ethernet-based international standard for interoperability among intelligent devices in a substation.</td>
</tr>
<tr>
<td>SNTP</td>
<td>Ethernet-based simple network time protocol for time synchronization among relays.</td>
</tr>
</tbody>
</table>

Additional Features

Front-Panel Display

The SEL-487B front panel includes a 128 x 128 pixel (76.2 mm x 76.2 mm or 3 in x 3 in) LCD screen; 24 LED target indicators; and 12 direct-action control pushbuttons with indicating LEDs for local control functions. Target and pushbutton identification can be custom-configured with easily changed slide-in labels. Use the capabilities of the SEL-487B front panel to integrate a wide range of control and system annunciation functions.
The LCD is controlled by the navigation pushbuttons, automatic messages the relay generates, and user-programmable display points.

The rotating display scrolls through any active, non-blank display points. If none are active, the relay scrolls through displays of the differential operating and restraint quantities and the primary current and voltage values. Metering screens can be enabled and displayed in an order defined by the user. Each display remains for a user-settable period of time before the display continues scrolling. Any message generated by the relay because of an alarm condition takes precedence over the rotating display.

Status and Trip Target LEDs

The SEL-487B front panel provides 24 programmable tricolor LED indicators and 12 direct-action control pushbuttons.

Configurable Front-Panel Labels

Customize the SEL-487B front panel to fit your needs. Use SELOGIC control equations and slide-in configurable front-panel labels to change the function and identification of target LEDs, operator control pushbuttons, and pushbutton LEDs. The blank slide-in label set is included with the SEL-487B. Functions are simple to configure using QuickSet.

You can use templates supplied with the relay or handwritten on blank labels supplied with the relay to print labels.

Control Inputs and Outputs

Select one interface board with a variety of contact input and output configurations, including the following:

- Optoisolated, level-sensitive contact inputs
- High-current interrupting contact outputs
- High-speed, high-current interrupting contact outputs

The relay is available in 4U chassis height. The 4U chassis requires the selection of one expansion I/O board. Assign the control inputs for disconnect auxiliary contact status and breaker auxiliary contact status. Set the input debounce time independently for each input or as a group. Each control output is programmable through the use of SELOGIC control equations.

Monitoring and Metering

Access a range of useful information in the relay with the metering function. Metered quantities include fundamental primary and secondary current and voltage magnitudes and angles for each terminal. Secondary quantities also include the PT ratio and CT ratio of each terminal. Zone information displays primary current and voltage magnitudes and angles for each terminal and also includes the polarity of each CT and the bus-zones in each of the protective zones at the station. The same information is available in secondary quantities and includes both the CT ratio and polarity. Differential metering shows the operating and restraint currents, as well as the reference current, for each zone.

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V01, V02, V03</td>
<td>Fundamental phase voltage magnitude and angle in primary and secondary values</td>
</tr>
<tr>
<td>I01, I02, . . . , I21</td>
<td>Fundamental phase current magnitude and angle in primary and secondary values</td>
</tr>
<tr>
<td>IOP, IRT, IREF</td>
<td>Operating and restraint currents for each zone, check zone, and the reference current</td>
</tr>
<tr>
<td>Bus Zones in Protection Zone n</td>
<td>Names of the bus-zones in Protection Zone n (where n = 1 to 6)</td>
</tr>
<tr>
<td>PTR, CTR</td>
<td>PT ratio and CT ratio for each terminal</td>
</tr>
<tr>
<td>POL</td>
<td>Polarity of each CT</td>
</tr>
</tbody>
</table>
Event Reporting and Sequential Events Recorder (SER)

Event Reports and SER features simplify post-fault analysis and help improve your understanding of both simple and complex protective scheme operations. These features also aid in testing and troubleshooting relay settings and protection schemes.

Oscillography and Event Reporting

In response to a user-selected internal or external trigger, the voltage, current, and element status information contained in each event report confirms relay, scheme, and system performance for every fault. The SEL-487B provides as fast as 8 kHz sampling rates for analog quantities in a COMTRADE file format. It also provides 12 sample-per cycle and 4 sample-per-cycle event reports that sample filtered analog quantities. The relay stores in nonvolatile memory as much as 5 seconds of 8 kHz event data and 24 seconds of 1 kHz event data. Relay settings operational in the relay at the time of the event display at the end of each filtered event report.

Use event report settings in the relay to assign as many as 20 analog quantities for inclusion in the filtered event reports. Use relay-calculated values such as check zone operate and restraint current, or use SELOGIC automation or protection math variables.

Each SEL-487B provides event reports for analysis with software such as SYNCHROWAVE® Event SEL-5601 Software. With SYNCHROWAVE Event, you can display events within the same time stamp range from as many as three different relays in one window to make the fault analysis easier and more meaningful. Because the different relays time-stamp the events with values from their individual clocks, be sure to time-synchronize the SEL-487B with an IRIG-B or PTP clock input to use this feature.

Event Summary

Each time the relay generates a standard event report, it also generates a corresponding Event Summary. This is a concise description of an event that includes the following information:

- Relay/terminal identification
- Event date and time
- Event type
- Event number
- Time source
- Active settings group
- Targets asserted during the fault
- Current magnitudes and angles for each terminal
- Voltage magnitudes and angles
- Terminals tripped for this fault
- Bus-zones in Protection Zone n (n = 1–6)

With an appropriate setting, the relay will send an Event Summary in ASCII text automatically to one or more serial ports for each triggering of an event report.

SER

Use this feature to gain a broad perspective of relay element operation. Items that trigger an SER entry are selectable and can include as many as 250 monitoring points such as I/O change of state and element pickup/dropout. The relay SER stores the latest 1000 events.

Substation Battery Monitor for DC Quality Assurance

The SEL-487B measures and reports the substation battery voltage for one battery system. The relay provides alarm, control, and dual ground detection for one battery and charger. The battery monitor includes warning and alarm thresholds that you can monitor with the SEL-3530 Real-Time Automation Controller (RTAC) and use to trigger messages, telephone calls, or other actions. The relay reports measured dc voltage in the display via serial or Ethernet port communications, on the LCD, and in the Event Report. Use the event report data to see an oscillographic display of the battery voltage. Monitor the substation battery voltage drops during trip, close, and other control operations.
Front- and Rear-Panel Diagrams

Figure 14  SEL-487B Front Panel

Figure 15  SEL-487B Rear Panel
Relay Dimensions

![Dimensions for Rack- and Panel-Mount Models](image)

**Specifications**

**Note:** The SEL-487B SV Subscriber Relay uses a SV-based remote data acquisition system. Operating times will be delayed by the configured channel delay, CH_DLY. Use caution when setting the relay coordination times to account for this added delay. See SV Network Delays on page 17.19 in the SEL-400 Series Relays Instruction Manual for more details on this setting.

**Note:** The metering and protection element accuracies specified for the SEL-487B SV Subscriber Relay are valid only when using SEL SV publisher relays. Third-party SV publisher devices are supported, but hardware accuracies and analog filtering need to be considered to determine the effect on SEL-487B performance.

### Compliance

- Designed and manufactured under an ISO 9001 certified quality management system
- 47 CFR 15B Class A
  - This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference in which case the user will be required to correct the interference at his own expense.

**UL Listed to U.S. and Canadian safety standards**
(File E212775; NRGU, NRGU7)

**CE Mark**

**RCM Mark**

#### General

**Power Supply**

- **24–48 Vdc**
  - Rated Voltage: 24–48 Vdc
  - Operational Voltage Range: 18–60 Vdc
  - Vdc Input Ripple: 15% per IEC 60255-26:2013
  - Interruption: 20 ms at 24 Vdc, 100 ms at 48 Vdc per IEC 60255-26:2013
  - Burden: <35 W
- **48–125 Vdc or 110–120 Vac**
  - Rated Voltage: 48–125 Vdc, 110–120 Vac
  - Operational Voltage Range: 38–140 Vac
  - 85–140 Vac
  - Rated Frequency: 50/60 Hz
Operational Frequency
Range: 30–120 Hz
Vdc Input Ripple: 15% per IEC 60255-26:2013
Interruption: 14 ms @ 48 Vdc, 160 ms @ 125 Vdc per IEC 60255-26:2013
Burden: <35 W, <90 VA
125–250 Vdc or 110–240 Vac
Rated Voltage: 125–250 Vdc, 110–240 Vac
Operational Voltage Range: 85–300 Vdc
85–264 Vac
Rated Frequency: 50/60 Hz
Operational Frequency Range: 30–120 Hz
Vdc Input Ripple: 15% per IEC 60255-26:2013
Interruption: 46 ms @ 125 Vdc, 250 ms @ 250 Vdc per IEC 60255-26:2013
Burden: <35 W, <90 VA

Control Outputs
Update Rate: 1/8 cycle
Make (Short Duration Contact Current): 30 Adc
1,000 operations at 250 Vdc
2,000 operations at 125 Vdc
Limiting Making Capacity: 1000 W at 250 Vdc (L/R = 40 ms)
Mechanical Endurance: 10,000 operations
Standard
Rated Voltage: 24–250 Vdc
110–240 Vrms
Operational Voltage Range: 0–300 Vdc
0–264 Vrms
Operating Time: Pickup ≤6 ms (resistive load)
Dropout ≤6 ms (resistive load)
Short-Time Thermal Withstand: 50 A for 1 s
Continuous Contact Current: 6 A at 70°C
4 A at 85°C
Contact Protection: MOV protection across open contacts
300 Vdc continuous voltage
Limiting Breaking Capacity: 10,000 operations
Electrical Endurance: 4 operations in 1 second, followed by 2 minutes idle

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Resistive Break</th>
<th>Inductive Break</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resistive Break</td>
<td>Inductive Break</td>
</tr>
<tr>
<td>24 Vdc</td>
<td>0.75 Adc</td>
<td>10 Adc</td>
</tr>
<tr>
<td>48 Vdc</td>
<td>0.63 Adc</td>
<td>10 Adc</td>
</tr>
<tr>
<td>125 Vdc</td>
<td>0.30 Adc</td>
<td>10 Adc</td>
</tr>
<tr>
<td>250 Vdc</td>
<td>0.20 Adc</td>
<td>10 Adc</td>
</tr>
<tr>
<td>110 Vrms</td>
<td>0.30 Arms</td>
<td>10 Adc</td>
</tr>
<tr>
<td>240 Vrms</td>
<td>0.20 Arms</td>
<td>10 Adc</td>
</tr>
</tbody>
</table>

Fast Hybrid (High-Speed High-Current Interrupting)
Rated Voltage: 48–250 Vdc
Operational Voltage Range: 0–300 Vdc
Operating Time: Pickup ≤0 µs (resistive load)
Dropout ≤8 ms (resistive load)

Short-Time Thermal Withstand: 50 Adc for 1 s
Continuous Contact Current: 6 Adc at 70°C
4 Adc at 85°C
Contact Protection: MOV protection across open contacts
300 Vdc continuous voltage
Limiting Breaking Capacity: 10,000 operations
Electrical Endurance: 4 operations in 1 second, followed by 2 minutes idle

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Resistive Break</th>
<th>Inductive Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>48 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>125 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>250 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 20 ms)</td>
</tr>
</tbody>
</table>

Note: Do not use hybrid control outputs to switch ac control signals. These outputs are polarity-dependent.

Control Inputs
Optoisolated (For Use With AC or DC Signals)
INT2 Interface Board: 8 inputs with no shared terminals
INT4 Interface Board: 6 inputs with no shared terminals
18 inputs with shared terminals
(2 groups of 9 inputs with each group sharing one terminal)
Voltage Options: 24, 48, 110, 125, 220, 250 V
Current Draw: <5 mA at nominal voltage
<8 mA for 110 V option
Sampling Rate: 2 kHz
DC Thresholds (Dropout thresholds indicate level-sensitive option)
24 Vdc: Pickup 19.2–30.0 Vdc
48 Vdc: Pickup 38.4–60.0 Vdc;
Dropout <28.8 Vdc
110 Vdc: Pickup 88.0–132.0 Vdc;
Dropout < 66.0 Vdc
125 Vdc: Pickup 105–150 Vdc;
Dropout <75 Vdc
220 Vdc: Pickup 176–264 Vdc;
Dropout <132 Vdc
250 Vdc: Pickup 200–300 Vdc;
Dropout <150 Vdc
AC Thresholds (Ratings met only when recommended control input settings are used)
24 Vdc: Pickup 16.4–30.0 Vdc
48 Vac: Pickup 32.8–60.0 Vac rms;
Dropout <20.3 Vac rms
110 Vac: Pickup 75.1–132.0 Vac rms;
Dropout <46.6 Vac rms
125 Vac: Pickup 89.6–150.0 Vac rms;
Dropout <53.0 Vac rms
220 Vac: Pickup 150.3–264.0 Vac rms;
Dropout <93.2 Vac rms
250 Vac: Pickup 170.6–300 Vac rms;
Dropout <106 Vac rms
Current Drawn: <5 mA at nominal voltage
<8 mA for 110 V option
Sampling Rate: 2 kHz

Schweitzer Engineering Laboratories, Inc. SEL-487B-2 Data Sheet
Communications Ports

EIA-232: 1 Front and 3 Rear
Serial Data Speed: 300–57600 bps

Communications Card Slot for the Ethernet Card

Ordering Options: 100BASE-FX fiber-optic Ethernet
Mode: Multi
Wavelength (nm): 1300
Source: LED
Connector Type: LC
Min. TX Pwr. (dBm): –19
Max. TX Pwr. (dBm): –14
RX Sens. (dBm): –32
Sys. Gain (dB): 13

Time Inputs

IRIG Time Input—Serial Port 1
Input: Demodulated IRIG-B
Rated I/O Voltage: 5 Vdc
Operational Voltage Range: 0–8 Vdc
Logic High Threshold: ≥2.2 Vdc
Logic Low Threshold: ≤0.8 Vdc
Input Impedance: 2.5 kΩ
Dielectric Test Voltage: 0.5 kVac

IRIG-B Input—BNC Connector
Input: Demodulated IRIG-B
Rated I/O Voltage: 5 Vdc
Operational Voltage Range: 0–8 Vdc
Logic High Threshold: ≥2.2 Vdc
Logic Low Threshold: ≤0.8 Vdc
Input Impedance: 50 Ω or >1 kΩ

PTP—Ethernet Port 5A, 5B
Input: IEEE 1588 PTPv2
Profiles: Default, IEEE C37.238-2011 (Power Profile)
Synchronization Accuracy: ±100 ns @ 1-second synchronization intervals when communicating directly with master clock

Operating Temperature

–40° to +85°C (–40° to +185°F)
Note: LCD contrast impaired for temperatures below –20° and above +70°C.

Humidity

5% to 95% without condensation

Weight (Maximum)

4U Rack Unit: 6.5 kg (14.5 lb)

Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug
Minimum: 1.0 Nm (9 in-lb)
Maximum: 2.0 Nm (18 in-lb)
User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Sizes and Insulation

Wire sizes for grounding (earthing) and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes:

<table>
<thead>
<tr>
<th>Connection Type</th>
<th>Min. Wire Size</th>
<th>Max. Wire Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grounding (Earthing)</td>
<td>14 AWG (2.5 mm²)</td>
<td>N/A</td>
</tr>
<tr>
<td>Contact I/O</td>
<td>18 AWG (0.8 mm²)</td>
<td>10 AWG (5.3 mm²)</td>
</tr>
<tr>
<td>Other Connection</td>
<td>10 AWG (5.3 mm²)</td>
<td>10 AWG (5.3 mm²)</td>
</tr>
</tbody>
</table>

Type Tests

Installation Requirements

Overvoltage Category: 3
Pollution Degree: 2

Safety

Product Standards: IEC 60255-27-2013
IEEE C37.90-2005
21 CFR 1040.10

Dielectric Strength: IEC 60255-27-2013, Section 10.6.4.3
2.5 kVac, 50/60 Hz for 1 min: Analog Inputs, Contact Outputs, Digital Inputs
3.6 kVdc for 1 min: Power Supply, Battery Monitors
2.5 kVdc for 1 min: IRIG-B
1.1 kVdc for 1 min: Ethernet

Impulse Withstand: IEC 60255-27-2013, Section 10.6.4.2
IEEE C37.90-2005
Common Mode:
±1.0 kV: Ethernet
±2.5 kV: IRIG-B
±5.0 kV: All other ports
Differential Mode:
0 kV: Analog Inputs, Ethernet, IRIG-B, Digital Inputs
±5.0 kV: Standard Contact Outputs, Power Supply Battery Monitors
+5.0 kV: Hybrid Contact Outputs

Insulation Resistance: IEC 60255-27-2013, Section 10.6.4.4
>100 MΩ @ 500 Vdc

Protection Class: IP30

Max Temperature of Parts and Materials: IEC 60255-27-2013, Section 7.3
Flammability of Insulating Materials: IEC 60255-27-2013, Section 7.6
Compliant

Electromagnetic (EMC) Immunity

Product Standards: IEC 60255-26-2013
IEC 60255-27-2013
IEEE C37.90-2005

Surge Withstand Capability (SWC):
IEEE C37.90-2012
Slow Damped Oscillatory, Common and Differential Mode:
±1.0 kV
±2.5 kV
Fast Transient, Common and Differential Mode:
±4.0 kV
Electrostatic Discharge (ESD):
- IEC 61000-4-2:2008
- IEEE C37.90.3-2001
  - Contact: ±8 kV
  - Air Discharge: ±15 kV

Radiated RF Immunity:
  - 20 V/m (>35 V/m, 80% AM, 1 kHz)
  - Spot: 80, 160, 450, 900 MHz
  - 10 V/m (>15 V/m, 80% AM, 1 kHz)
  - Sweep: 80 MHz to 1 GHz
  - Sweep: 1.4 GHz to 2.7 GHz
  - Spot: 80, 160, 380, 450, 900, 1850, 2150 MHz

Electrical Fast Transient Burst (EFTB):
- IEC 61000-4-4:2012
  - Zone A:
    - ±2 kV: Communication ports
    - ±4 kV: All other ports

Surge Immunity:
- IEC 61000-4-5:2005
  - Zone A:
    - ±2 kV$_{L,L}$
    - ±4 kV$_{L,E}$
    - ±4 kV: Communication Ports
  - Note: Cables connected to IRIG-B ports shall be less than 10 m in length for Zone A compliance.
  - Zone B:
    - ±2 kV: Communication Ports

Conducted Immunity:
- IEC 61000-4-6:2013
  - 20 V/m; (>35 V/m, 80% AM, 1 kHz)
  - Sweep: 150 kHz–80 MHz
  - Spot: 27, 68 MHz

Power Frequency Immunity (DC Inputs):
- IEC 61000-4-16:2015
  - Zone A:
    - Differential: 150 V$_{RMS}$
    - Common Mode: 300 V$_{RMS}$

Power Frequency Magnetic Field:
- IEC 61000-4-8:2009
  - Level 5:
    - 100 A/m; ±260 Seconds; 50/60 Hz
    - 1000 A/m 1 to 3 Seconds; 50/60 Hz
  - Note: 50G1P ±0.05 (ESS = N, 1, 2)
    - 50G1P ±0.1 (ESS = 3, 4)

Power Supply Immunity:
- IEC 61000-4-11:2004
- IEC 61000-4-29:2000
  - AC Dips & Interruptions
  - Ripple on DC Power Input
  - DC Dips & Interruptions
  - Gradual Shutdown/Startup (DC only)
  - Discharge of Capacitors
  - Slow Ramp Down/Up
  - Reverse Polarity (DC only)

Damped Oscillatory Magnetic Field:
- IEC 61000-4-10:2016
  - Level 5:
    - 100 A/m

EMC Compatibility
- Product Standards: IEC 60255-26:2013
  - 47 CFR
  - ICES-003
- Emissions: IEC 60255-26:2013, Section 7.1
  - 47 CFR Part 15.109
  - 47 CFR Part 15.107
  - ICES-003, Issue 6
  - Radiated: Class A
  - Conducted: Class A

Environmental
- Cold, Operational: IEC 60068-2-1:2007
  - Test Ad: 16 hours at −40°C
- Cold, Storage: IEC 60068-2-1:2007
  - Test Ad: 16 hours at −40°C
  - Test Bd: 16 hours at +85°C
  - Test Bd: 16 hours at +85°C
- Damp Heat, Cyclic: IEC 60068-2-30:2005
  - Test Db: +25°C to +55°C, 6 cycles (12 + 12-hour cycle), 95% RH
- Damp Heat, Steady State: IEC 60068-2-7:2013
  - Severity: 93% RH, +40°C, 10 days
  - Class 2 Endurance, Class 2 Response
  - Class 1 Shock Withstand, Class 1 Bump Withstand, Class 2 Shock Response
- Seismic: EC 60255-21-3:1993
  - Class 2 Quake Response

Reporting Functions

High-Resolution Data
- Rate: 8000 samples/second
  - 4000 samples/second
  - 2000 samples/second
  - 1000 samples/second
- Output Format: Binary COMTRADE

Event Reports
- Length: 0.25–24 seconds (depending on LER setting)
- Volatile Memory: 3 seconds of back-to-back event reports sampled at 8 kHz
- Nonvolatile Memory: At least 4 event reports of a 3-second duration sampled at 8 kHz
- Resolution: 4 and 12 samples/cycle

Event Summary
- Storage: 100 summaries

Sequential Events Recorder
- Storage: 1000 entries
- Trigger Elements: 250 relay elements
- Resolution: 0.5 ms for contact inputs
- Resolution: 1/12 cycle for all elements

Processing Specifications

AC Voltage and Current Inputs
- 8000 samples per second
- Full-cycle cosine filtering

Protection and Control Processing
- 12 times per power system cycle

Control Points
- 96 remote bits
- 32 local control bits
- 32 latch bits in protection logic
- 32 latch bits in automation logic
Frequency and Rotation
System Frequency: 50/60 Hz
Phase Rotation: ABC or ACB

Relay Element Pickup Ranges and Accuracies

Differential Elements
Number of Zones: 6
Number of Check Zones: 3
Number of Terminals:
  Three-Relay Application: 21
  Single-Relay Application: 7
Slope 1
  Setting Range: 15–90%
  Accuracy: ±5% ± 0.02 \* I_{NOM}
Slope 2
  Setting Range: 50–90%
  Accuracy: ±5% ± 0.02 \* I_{NOM}

Supervising Differential Element
Quantity: 9 total, 1 per zone (6 standard zones, 3 check zones)
Setting Range: 0.10–4.00 pu
Accuracy: ±5% ± 0.02 \* I_{NOM}

Incremental Restraint and Operating Threshold Current Supervision
Setting Range: 0.1–10.0 pu
Accuracy: ±5% ± 0.02 \* I_{NOM}

Sensitive Differential Current Alarm
Quantity: 9 total, 1 per zone (6 standard zones, 3 check zones)
Setting Range: 0.05–1.00 pu
Accuracy: ±5% ± 0.02 \* I_{NOM}
Timer Setting Range: 50–6000 cycles

Instantaneous/Definite-Time Overcurrent Elements
Phase Current Setting Range
  5 A Model: OFF, 0.25–100.00 A secondary, 0.01 A steps
  1 A Model: OFF, 0.05–20.00 A secondary, 0.01 A steps
Accuracy (Steady State)
  5 A Model: ±0.05 A, ±3% of setting
  1 A Model: ±0.01 A, ±3% of setting
Transmit Overreach:
  Timer Setting Range: 0.00–99999.00 cycles, 1/6-cycle steps
  Timer Accuracy: ±0.1% of settings ±1/6 cycle
Maximum Operating Time: 1.5 cycles

Time-Overcurrent Elements
Pickup Range
  5 A Model: 0.50–16.00 A secondary, 0.01 A steps
  1 A Model: 0.10–3.20 A secondary, 0.01 A steps
Accuracy (Steady State)
  5 A Model: ±0.05 A, ±3% of setting
  1 A Model: ±0.01 A, ±3% of setting

Time Dial Range
US: 0.50–15.00, 0.01 steps
IEC: 0.05–1.00, 0.01 steps

Curve Timing Accuracy:
±1.50 cycles, ±4% of curve time (for current between 2 and 30 multiples of pickup)
Reset: 1 power cycle or Electromechanical Reset Emulation time

Under- and Overvoltage Elements (27, 59)
Processing Rate: 1/6 cycle
Phase Under- and Overvoltage (2 Level/Phase)
Setting Range: 2.00–200 V_{LN} in 0.01 steps
Accuracy: ±5% of setting, ±0.5 V
Transmit Overreach: <5% of pickup
Maximum Delay: 1.5 cycles

Zero- and Negative-Sequence Overvoltage Elements
Setting Range: 1.0–200 V in 0.1 steps
Accuracy: ±5% of setting, ±1 V
Transmit Overreach: <5% of setting
Maximum Delay: 1.5 cycles

Breaker Failure Instantaneous Overcurrent
Setting Range
  5 A Model: 0.50–50 A, 0.01 A steps
  1 A Model: 0.10–10.0 A, 0.01 A steps
Accuracy
  5 A Model: ±0.05 A, ±3% of setting
  1 A Model: ±0.01 A, ±3% of setting
Transmit Overreach:
  Maximum Pickup Time: 1.5 cycles
  Maximum Reset Time: <1 cycle
Timers Setting Range:
  BFU\_nn: 0–6000 cycles, 1/12-cycle steps
  BFISP\_nn, RFP\_nn: 0–1000 cycles, 1/12-cycle steps
  BFISP\_nn, BFIDO\_nn: 0–1000 cycles, 1/12-cycle steps
Time Delay Accuracy: ±0.1% of setting

Disconnect Monitor
Number: 60
Timer Setting Range: 0–99999 cycles, 1 cycle step

Breaker Status Monitor
Number: 21
Timer Setting Range: 0–1000 cycles, 1/12 cycle step

Coupler Security Logic
Number: 4
Timer Setting Range: 0–1000 cycles, 1/12 cycle step

Control Input Timers
Setting Range
  Pickup: 0.00–30 ms
  Dropout: 0.00–30 ms
## Station DC Battery System Monitor Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Voltage</td>
<td>24–250 Vdc</td>
</tr>
<tr>
<td>Operational Voltage Range</td>
<td>0–300 Vdc</td>
</tr>
<tr>
<td>Sampling Rate</td>
<td>2 kHz</td>
</tr>
<tr>
<td>Processing Rate</td>
<td>1/8 cycle</td>
</tr>
<tr>
<td>Operating Time</td>
<td>Less than 1.5 cycles (all elements except ac ripple)</td>
</tr>
<tr>
<td></td>
<td>Less than 1.5 seconds (ac ripple element)</td>
</tr>
<tr>
<td>Setting Range</td>
<td></td>
</tr>
<tr>
<td>15–300 Vdc, 1 Vdc steps (all elements except ac ripple)</td>
<td></td>
</tr>
<tr>
<td>1–300 Vac, 1 Vac steps (ac ripple element)</td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td></td>
</tr>
<tr>
<td>Pickup Accuracy</td>
<td>±3% ± 2 Vdc (all elements except ac ripple)</td>
</tr>
<tr>
<td></td>
<td>±10% ± 2 Vac (ac ripple element)</td>
</tr>
</tbody>
</table>

### Metering Accuracy

All metering accuracies are based on an ambient temperature of 20°C and nominal frequency.

#### Currents

- **Phase Current Magnitude**
  - 5 A Model: ±0.2% plus ± 4 mA (2.5–15 A sec)
  - 1 A Model: ±0.2% plus ± 0.8 mA (0.5–3.0 A sec)

- **Phase Current Angle**
  - All Models: ±0.2° in the current range (0.5–3.0) • INOM

- **Differential Currents per Zone (Steady State)**
  - IOP, IRT: ±5.0% ± 0.02 • INOM
  - IOPCZ, IRTCA: ±5.0% ± 0.02 • INOM

#### Voltages

- **Phase Voltage Magnitude**
  - 300 V Maximum Inputs: ±2.5% ± 1 V (5–33.5 V)
  - ±0.1% (33.5–300 V)

- **Phase Angle**
  - 300 V Maximum Inputs: ±1.0° (5–33.5 V)
  - ±0.5° (33.5–300 V)