Major Features and Benefits

The SEL-451-4 Bay Control, Automation, and Protection System integrates bay control for breakers and disconnect switches with full automation and protection in one device.

➤ **Commissioning.** Rapidly commission your Bay Control with preconfigured bay arrangements. Choose among different bus configurations, including single- and dual-busbar, transfer bus, tie breaker, breaker-and-a-half, ring-bus, double-bus/double-breaker, and source transfer configurations. These bus arrangements allow easy status and control of as many as five disconnect switches and two breakers. Additional user-selectable bay types are available via an SEL-5030 Quickset interface that can be downloaded at www.selinc.com.

➤ **Automation.** Take advantage of enhanced automation features that include 32 programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large format front-panel Liquid Crystal Display (LCD) eliminates the need for separate panel meters. Use serial and Ethernet links to efficiently transmit key information, including metering data, protection element and control I/O status, IEEE C37.118 Synchrophasors, IEC 61850 GOOSE messages, Sequential Events Recorder (SER) reports, breaker monitor, relay summary event reports, and time synchronization. Use expanded SELOGIC® control equations with math and comparison functions in control applications. High-isolation inputs have settable assertion levels to easily combine inputs from different systems. Incorporate up to 1000 lines of automation logic to speed and improve control actions.

➤ **Protection.** Use multiple instantaneous and time-overcurrent elements with SELOGIC control equations to customize distribution protection. Best Choice Ground Directional Element™ logic optimizes directional element performance and eliminates the need for many directional settings. Protect two breakers with one relay.

➤ **Synchrophasors.** Make informed load dispatch decisions based on actual real-time phasor measurements from across your power system. Use synchrophasors to determine actual stability margins with standard spreadsheet, graphics program, or data management system.

➤ **High-impedance Fault Detection.** The optional high-impedance fault (HIF) detection element operates for small current ground faults typically caused by downed conductors on ground surfaces such as earth, concrete or other poorly conductive materials. HIF event data are made available in standard COMTRADE format.

➤ **Ethernet Access.** Access all relay functions with the optional Ethernet Processor. Interconnect with automation systems using IEC 61850 or DNP3 protocol directly. Optionally connect to DNP3 networks through an SEL-2032 Communications Processor. Use file transfer protocol (FTP) for high-speed data collection. Connect to substation or corporate LANs to transmit synchrophasors in the IEEE C37.118-2005 format using TCP or UDP internet protocols.
➤ **Digital Relay-to-Relay Communications.** Use Enhanced MIRRORED BITS® communications to monitor internal element conditions between bays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel.

➤ **Monitoring.** Schedule breaker maintenance when accumulated breaker duty (independently monitored for each pole of two circuit breakers) indicates possible excess contact wear. Electrical and mechanical operating times are recorded for both the last operation and the average of operations since function reset. Alarm contacts provide notification of substation battery voltage problems (two independent battery monitors) even if voltage is low only during trip or close operations.

➤ **Breaker Failure.** Use high-speed (less than one cycle) open-pole detection logic to reduce coordination times for critical breaker failure applications. Apply the SEL-451-4 to supply breaker failure protection for one or two breakers. Logic for breaker failure retrip and initiation of transfer tripping is included.

➤ **Sequential Events Recorder (SER).** Record the last 1000 entries, including setting changes, power-ups, and selectable logic elements.

➤ **Dual CT Input.** Apply with ring bus, breaker-and-a-half, or other two-breaker schemes. Combine currents within the relay from two sets of CTs for protection functions, but keep them separately available for monitoring and station integration applications.

➤ **Comprehensive Metering.** Improve feeder loading by using built-in, high-accuracy metering functions. Use watt and VAR measurements to optimize feeder operation. Minimize equipment needs with full metering capabilities including rms, maximum/minimum, demand/peak, energy, and instantaneous values.

➤ **High-Accuracy Time-Stamping.** Time-tag binary COMTRADE event reports with real-time accuracy of better than 10 µs. View system state information to an accuracy of better than 1/4 of an electrical degree.

➤ **Oscillography and Event Reporting.** Record voltages, currents, and internal logic points at up to 8 kHz sampling rate. Off line phasor and harmonic analysis features allow investigation of bay and system performance.

➤ **Reclosing.** Incorporate programmable reclosing of one or two breakers into an integrated substation control system. Synchronism and voltage checks from multiple sources provide complete bay control.

➤ **Fault Locator.** Efficiently dispatch line crews to quickly isolate line problems and restore service faster.

➤ **Thermal Overload Modeling.** Use the SEL-451-4 with the SEL-2600A RTD Module for dynamic overload protection using SELOGIC control equations.

➤ **Rules-Based Settings Editor.** Communicate with and set the relay using an ASCII terminal, or use the PC-based ACSELERATOR® QuickSet™ SEL-5030 Software to configure the SEL-451-4 and analyze fault records with relay element response.

➤ **Auxiliary Trip/Close Pushbuttons.** These optional pushbuttons are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.
Product Overview

Bay Control

The SEL-451-4 Bay Control provides dynamic bay one-line diagrams on the front-panel screen with disconnect and breaker control capabilities for 25 predefined user-selectable bay types. Additional user-selectable bay types are available via an SEL-5030 Quickset interface that can be downloaded at www.selinc.com. The bay control is equipped to control as many as five disconnects and two breakers, depending on the one-line diagram selected. Certain one-line diagrams provide status for up to three breakers and five disconnect switches. Operate disconnects and breakers with ASCII commands, SELOGIC control equations, Fast Operation Messages, and from the one-line diagram. The one-line diagram includes user-configurable apparatus labels and as many as six user-definable Analog Quantities.

One-Line Bay Diagrams

The SEL-451-4 bay control offers a variety of preconfigured one-line diagrams for common bus configurations. Once a one-line diagram is selected, the user has the ability to customize the names for all of the breakers, disconnect switches, and buses. Most one-line diagrams contain analog display points. These display points can be set to any of the available analog quantities with labels, units, and scaling. These values are updated real-time along with the breakers and switch position to give instant status and complete control of a bay. The diagrams below demonstrate some of the preconfigured bay arrangements available in the SEL-451-4.

The operator can see all valuable information on a bay before making a critical control decision. Programmable interlocks help prevent operators from incorrectly opening or closing switches or breakers. The SEL-451-4 will not only prevent the operator from making an incorrect control decision, but can notify and/or alarm when an incorrect operation is initiated.
Circuit Breaker Operations From the Front Panel

Figure 2 through Figure 5 are examples of some of the 23 selectable one-line diagrams in the SEL-451-4. The one-line diagram is selectable from the Bay settings. Additional settings for defining labels and analog quantities are also found in the Bay settings. One-line diagrams are composed of the following:

➤ Bay Names and Bay Labels (Bay Labels available in one-line diagrams 14, 17, 18, and 23. All other one-line diagrams use the Bay Name.)
➤ Busbar and Busbar Labels
➤ Breaker and Breaker Labels
➤ Disconnect Switches and Disconnect Switch Labels
➤ Analog Display Points

Figure 6 shows the Breaker Control Screens available when the (ENT) pushbutton is pressed with the circuit breaker highlighted as shown in Figure 6 (a). After pressing the (ENT) pushbutton with the breaker highlighted and the LOCAL Relay Word bit asserted, the Breaker Control Screen in Figure 6 (b) is displayed. After entering the screen in Figure 6 (b), the relay performs the circuit breaker operations as outlined in the SEL-451 User’s Guide. If the LOCAL Relay Word bit is not asserted when the (ENT) pushbutton is pressed, the screen in Figure 6 (c) is displayed for three seconds, then the bay control displays again the screen in Figure 6 (a).
Rules-Based Settings Editor

Use ACSELERATOR QuickSet to develop settings off-line. The system automatically checks interrelated settings and highlights out-of-range settings. Settings created off-line can be transferred by using a PC communications link with the SEL-451-4. The ACSELERATOR QuickSet interface supports Windows® 98, 2000, XP, and NT® operating systems. Open COMTRADE files from SEL and other products. Convert binary COMTRADE files to ASCII format for portability and ease of use. View real-time phasors and harmonic values.

ACSELERATOR QuickSet Bay Control Settings Interface

There are two ways to enter Bay Control settings using the ACSELERATOR QuickSet settings interface. The standard style settings are displayed in traditional form under the Bay Control form. ACSELERATOR QuickSet also provides an interactive bay control setting entry method. The interactive method works by clicking on the one-line diagram labels. This action automatically displays all the settings for the device selected. This method provides an easy way of organizing and verifying all settings associated with the device.

Figure 6 illustrates the interactive bay control setting form in ACSELERATOR QuickSet. Click on an apparatus in the one-line diagram, and a form with apparatus-specific settings is displayed.
ACSELERATOR QuickSet Designer SEL-5031

Use the ACSELERATOR QuickSet Designer SEL-5031 to create custom views of settings, called Application Designs, to reduce complexity, decrease the chance of errors, and increase productivity.

➤ Lock and hide unused settings.
➤ Lock settings to match your standard for protection, I/O assignment, communications, and SELLLOGIC control equations.
➤ Enforce settings limits narrower than the device settings.
➤ Define input variables based on the equipment nameplate or manufacturer’s terminology or scaling and calculate settings from these “friendlier” inputs.
➤ Use settings comments to guide users and explain design reasoning.

Figure 7 Interactive Bay Control Setting Form

Front-Panel Display

The liquid crystal display (LCD) shows event, metering, settings, and relay self-test status information. The target LEDs display relay target information as described in Figure 8 and explained in Table 1.

Figure 8 Factory Default Status and Trip Target LEDs (8 Pushbutton, 16 Target Option)
The LCD is controlled by the navigation pushbuttons (Figure 10), automatic messages the relay generates, and user-programmed analog and digital display points. The rotating display scrolls through the bay screen, alarm points, display points, and metering screens. Each display remains for a user-programmed time (1–15 seconds) before the display continues scrolling. Any message generated by the relay because of an alarm condition takes precedence over the rotating display.

The SEL-451-4 includes programmable status and trip target LEDs, as well as programmable direct-action control pushbuttons/LEDs on the front panel. These targets are shown in Figure 8 and Figure 9 and explained in Table 1.

### Table 1 Description of Factory Default Target LEDs

<table>
<thead>
<tr>
<th>Target LED</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENABLED</td>
<td>Relay powered properly and self-tests okay</td>
</tr>
<tr>
<td>TRIP</td>
<td>Indication that a trip occurred</td>
</tr>
<tr>
<td>INST</td>
<td>High-speed rip</td>
</tr>
<tr>
<td>TIME</td>
<td>Time-delayed trip</td>
</tr>
<tr>
<td>COMM</td>
<td>Communications-assisted trip</td>
</tr>
<tr>
<td>SOTF</td>
<td>Switch-onto-fault trip</td>
</tr>
<tr>
<td>RECLOSE</td>
<td>Ready for reclose cycle</td>
</tr>
<tr>
<td>79 RESET</td>
<td>Control in cycle state</td>
</tr>
<tr>
<td>79 CYCLE</td>
<td>Control in lockout state</td>
</tr>
<tr>
<td>PHASE</td>
<td>Phases involved in fault</td>
</tr>
<tr>
<td>A, B, C</td>
<td>Ground involved in fault</td>
</tr>
<tr>
<td>GROUND</td>
<td>Loss-of-potential condition</td>
</tr>
<tr>
<td>VOLTAGES</td>
<td>VY phase filtered instantaneous voltages applied</td>
</tr>
<tr>
<td>VAY ON, VBY ON, VCY ON</td>
<td>VZ phase filtered instantaneous voltages applied</td>
</tr>
<tr>
<td>VAZ ON, VBZ ON, VCZ ON</td>
<td></td>
</tr>
<tr>
<td>BKR FAIL</td>
<td>Breaker Failure trip</td>
</tr>
<tr>
<td>BKR MAINT</td>
<td>Breaker maintenance needed</td>
</tr>
<tr>
<td>EXT TRIP</td>
<td>External trip detected</td>
</tr>
<tr>
<td>51 TIMING</td>
<td>51 element picked up and timing</td>
</tr>
<tr>
<td>IRIG LOCKED</td>
<td>IRIG synchronization detected</td>
</tr>
</tbody>
</table>

* Only available in 24-LED models.

The SEL-451-4 features a versatile front panel that you can customize to fit your needs. Use SElogic control equations and slide-in configurable front-panel labels to change the function and identification of target LEDs and operator control pushbuttons and LEDs. The blank slide-in label set is included with the SEL-451-4. Label sets can be printed from a laser printer using templates supplied with the relay or hand labeled on supplied blank labels.

### Advanced Display Points

Create custom screens showing metering values, special text messages, or a mix of analog and status information. Figure 11 shows an example of how display points can be used to show circuit breaker information and current metering. As many as 96 display points can be created. All display points occupy one, and only one, line on the display at all times. The height of the line is programmable as either single or double as shown in Figure 11. These screens become part of the autoscrolling display when the front panel times out.
Alarm Points

You can display messages on the SEL-451-4 front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 12 shows a sample alarm points screen. The relay is capable of displaying up to 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. The alarm points message is user-configurable through SER and can be triggered using inputs, communications, SEL-2600A, or conditional using powerful SELOGIC equations. The asterisk next to the alarm point indicates an active alarm. The inactive alarms can be cleared using the front-panel navigation buttons.

Auxiliary Trip/Close Pushbuttons and Indicating LEDs

Optional auxiliary trip and close pushbuttons (see Figure 13) and indicating LEDs allow breaker control independent of the relay. The auxiliary trip/close pushbuttons are electrically separate from the relay, operating even if the relay is powered down. Make the extra connections at terminals 201 through 208. See Figure 25 for a rear-panel view. Figure 14 shows one possible set of connections.

The auxiliary trip/close pushbuttons incorporate an arc suppression circuit for interrupting dc trip or close current. To use these pushbuttons with ac trip or close circuits, disable the arc suppression for either pushbutton by changing jumpers inside the SEL-451-4 Relay. The operating voltage ranges of the breaker CLOSED and breaker OPEN indicating LEDs are also jumper selectable.

Monitoring and Metering

Complete Metering Capabilities

The SEL-451-4 provides extensive metering capabilities as listed in Table 2.

Event Reporting and Sequential Events Recorder (SER)

Event Reports and Sequential Events Recorder 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 bay settings and control schemes. Oscillograms are available in binary COMTRADE and ASCII COMTRADE formats.

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. Decide how much detail is necessary when an event report is triggered:
8 kHz, 4 kHz, 2 kHz, or 1 kHz resolution analog data. The bay control stores from 5 seconds of data per fault at 1 kHz resolution to 2 seconds per fault at 8 kHz resolution. Reports are stored in nonvolatile memory. Bay settings operational in the bay at the time of the event are appended to each event report.

Event Summary
Each time the SEL-451-4 generates a standard event report, it also generates a corresponding Event Summary. This is a concise description of an event that includes bay/terminal identification, event date and time, fault location, phase voltages, fault type at time of trip, and trip and close times of day.

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

Sequential Events Recorder (SER)
Use this feature to gain a broad perspective of bay control element operation. Items that trigger an SER entry are selectable and can include input/output change of state, element pickup/dropout, recloser state changes, etc. The bay control SER stores the latest 1,000 entries.

High-Accuracy Time Keeping
Using a combination of IRIG-B and a global positioning satellite, the SEL-451-4 can time-tag oscillography to within 10 µs accuracy. This high accuracy can be combined with the high sampling rate of the relay to synchronize data from across the system with an accuracy of better than 1/4 electrical degree. This allows examination of the power system state at given times, including load angles, system swings, and other system-wide events. Triggering can be via external signal (contact or communications port), set time, or system event. Optimal calibration of this feature requires a knowledge of primary input component (VT and CT) phase delay and error.

A single IRIG-B time-code input synchronizes the SEL-451-4 time to within ±1 ms of the time-source input. A convenient source for this time code is the SEL-2032 Communications Processor (via Serial Port 1 on the SEL-451-4).

Substation Battery Monitor for DC Quality Assurance
The SEL-451-4 measures and reports the substation battery voltage for two battery systems. Two sets of programmable threshold comparators and associated logic provide alarm and control of two separate batteries and chargers. The bay control also provides dual ground detection. Monitor these thresholds with the SEL-2032 Communications Processor and trigger messages, telephone calls, or other actions.

The measured dc voltage is reported in the METER display via serial 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.

Table 2 Metering Capabilities

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous Quantities</td>
<td></td>
</tr>
<tr>
<td>Voltages</td>
<td>0–300 V with phase quantities for each of the six voltage sources available as a separate quantity.</td>
</tr>
<tr>
<td>Phase quantities</td>
<td></td>
</tr>
<tr>
<td>Currents</td>
<td></td>
</tr>
<tr>
<td>IA,B,C (W), IA,B,C (X)</td>
<td></td>
</tr>
<tr>
<td>IaL, IbL, IcL, (combined currents)</td>
<td></td>
</tr>
<tr>
<td>IGL, IIL, 3I2L (combined currents)</td>
<td></td>
</tr>
<tr>
<td>Power/Energy Metering Quantities</td>
<td>Available for each input set and as combined quantities for the line.</td>
</tr>
<tr>
<td>Demand/Peak Demand Metering</td>
<td></td>
</tr>
<tr>
<td>1A,B,C, 3I2, 3I0</td>
<td>Thermal or rolling interval demand and peak demand.</td>
</tr>
<tr>
<td>MW, MVAr, MVA, single-phase</td>
<td>Thermal or rolling interval demand and peak demand.</td>
</tr>
<tr>
<td>MW, MVAr, MVA, three-phase</td>
<td>Thermal or rolling interval demand and peak demand.</td>
</tr>
</tbody>
</table>
Breaker Monitor Feature Allows for Wear-Based Breaker Maintenance Scheduling

Circuit breakers experience mechanical and electrical wear at each operation. Effective scheduling of breaker maintenance takes into account the manufacturer’s published data of contact wear versus interruption levels and operation count. The SEL-451-4 dual breaker monitor feature compares the breaker manufacturer’s published data to the integrated actual interrupted current and number of operations.

- Every time the breaker trips, the relay integrates interrupted current. When the result of this integration exceeds the threshold set by the breaker wear curve (Figure 15), the bay can alarm via an output contact or the optional front-panel display. With this information, you can schedule breaker maintenance in a timely, economical fashion.

- The bay monitors last and average mechanical and electrical interruption time per pole. You can easily determine if operating time is increasing beyond reasonable tolerance to schedule proactive breaker maintenance. You can activate an alarm point if operation time goes beyond a preset value.

- Breaker motor run time and breaker inactivity are also monitored.

Figure 15 Breaker Contact Wear Curve and Settings

Automation

Flexible Control Logic and Integration Features

Use the SEL-451-4 control logic to do the following:
- Replace traditional panel control switches
- Eliminate RTU-to-bay wiring
- Replace traditional latching relays
- Replace 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 local control points for such functions as trip testing, enabling/disabling reclosing, and tripping/closing circuit breakers.

Eliminate RTU-to-bay wiring with 32 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, close, settings group selection).

Replace traditional latching relays for such functions as “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 latch control points retain states when the relay loses power.

Replace traditional indicating panel lights and switches with up to 24 latching target LEDs and up to 12 programmable pushbuttons with LEDs. Define custom messages (i.e., BREAKER OPEN, BREAKER CLOSED, RECLOSER ENABLED) to report power system or relay conditions on the large format LCD. Control which messages are displayed via SELOGIC control equations by driving the LCD display via any logic point in the relay.

Open Communications Protocols

The SEL-451-4 does not require special communications software. ASCII terminals, printing terminals, or a computer supplied with terminal emulation and a serial communications port are all that is required. Table 3 lists a brief description of the terminal protocols.

Table 3 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 communications. 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. Allows external devices to obtain bay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.</td>
</tr>
</tbody>
</table>
Expanded SEL-451-4 is factory set for use without additional logic in most situations. For complex or unique applications, these expanded SELOGIC functions allow superior flexibility.

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:

\[ \text{assign the alias “TAN” to math variable PMV02} \]

\[ \text{(assign the alias “THETA” to math variable PMV01) \vphantom{A} } \]

\[ \text{2: PMV02, TAN} \]

These expanded SELOGIC functions also provide programmable control functions to your bay control and automation systems. New functions and capabilities enable using analog values in conditional logic statements. The following are examples of possible applications of SELOGIC control equations with expanded capabilities.

- Emulate a motor-driven reclose timer, including stall, reset, and drive-to-lockout conditions (refer to Figure 16).
- Scale analog values for SCADA retrieval.
- Initiate remedial action sequence based on load flow before fault conditions.
- Interlock breakers and disconnect switches.
- Restrict breaker tripping in excessive duty situations without additional relays.
- Construct a compensated overvoltage element for open line overvoltage protection.
- Hold momentary change-of-state conditions for SCADA polling.
- Provide a combination of frequency or rate of change of frequency functions.

Table 3 Open Communications Protocol

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended Fast Meter, Fast Operate, and Fast SER</td>
<td>Binary protocol for machine-to-machine communication. Quickly updates SEL-2032 Communications Processors, RTUs, and other substation devices with metering information, bay element, I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines so that control operator metering information is not lost while a technician is transferring an event report.</td>
</tr>
<tr>
<td>Ymodem</td>
<td>Support for reading event, settings, and oscillography files.</td>
</tr>
<tr>
<td>Optional DNP3 Level 2 Slave</td>
<td>Distributed Network Protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SEL, relay summary event reports, and settings groups.</td>
</tr>
<tr>
<td>IEEE C37.118</td>
<td>Phasor measurement protocol.</td>
</tr>
<tr>
<td>IEC 61850</td>
<td>Ethernet-based international standard for interoperability between intelligent devices in a substation.</td>
</tr>
</tbody>
</table>

Table 4 SELogic Control Equation Operators

<table>
<thead>
<tr>
<th>Operator Type</th>
<th>Operators</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>AND, OR, NOT</td>
<td>Allows combination of measuring units.</td>
</tr>
<tr>
<td>Edge Detection</td>
<td>F_TRIG, R_TRIG</td>
<td>Operates at the change of state of an internal function.</td>
</tr>
<tr>
<td>Comparison</td>
<td>&gt;, &gt;=, =, &lt;=, &lt;, &lt;&gt;</td>
<td>Uses traditional math functions for analog quantities in an easily programmable equation.</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>+, -, *, /</td>
<td></td>
</tr>
<tr>
<td>Numerical</td>
<td>ABS, SIN, COS, LN, EXP, SQRT</td>
<td>Allows multiple and nested sets of parentheses.</td>
</tr>
<tr>
<td>Precedence Control</td>
<td>( )</td>
<td>Provides for easy documentation of control and protection logic.</td>
</tr>
<tr>
<td>Comment</td>
<td>#</td>
<td></td>
</tr>
</tbody>
</table>
The SEL patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication (Figure 17). In the SEL-451-4, MIRRORED BITS can operate simultaneously on any two serial ports for three-terminal power system operation.

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 bays through the local bay. These MIRRORED BITS can be used to transfer information between line terminals to enhance coordination and achieve faster tripping. MIRRORED BITS also help reduce total pilot scheme operating time by eliminating the need to close output contacts and debounce contact outputs. Use the dual-port MIRRORED BITS communications capabilities for high-speed communications-assisted schemes applied to three-terminal transmission lines.

**Communication**

The SEL-451-4 offers the following serial communication features:

- Four independent EIA-232 serial ports.
- Full access to event history, relay status, and meter information.
- Settings and group switching have strong password protection.
- DNP3 Level 2 Slave.
- Patented SEL Fast Message Interleaving of ASCII and binary data for SCADA communications, including access to SER, relay element targets, event data and more.

![Figure 16 Motor-Driven Reclose Timer](image)

**Figure 16** Motor-Driven Reclose Timer

**Figure 17** Integral Communication Provides Secure Protection, Monitoring, and Control, as Well as Terminal Access to Both Relays Through One Connection
Network Connection and Integration

Connect the SEL-451-4 to Local Area Networks (LANs) using the optional Ethernet card. The Ethernet card also allows connection of the SEL-2032 Communications Processor to a single or dual LAN (see Figure 18). The integrated Ethernet card supports both copper and/or fiber connections with fail-over protection.

Ethernet Card

The optional Ethernet card mounts directly in the SEL-451-4. Use popular Telnet applications for easy terminal communications with SEL relays and other devices. Transfer data at high speeds (10 Mbps or 100 Mbps) for fast HMI updates and file uploads. The Ethernet card communicates using File Transfer Protocol (FTP) applications for easy and fast file transfers.

Provide Operations with situational awareness of the power system using IEEE C37.118-2005 Standard for Synchrophasors for Power Systems. Communicate with SCADA and other substation IEDs using DNP3 or IEC 61850 Logical Nodes and GOOSE messaging.

Choose Ethernet connection media options for primary and standby connections:
- 10/100BASE-T Twisted Pair Network
- 100BASE FX Fiber-Optic Network

Telnet and FTP

Order the SEL-451-4 with Ethernet communications and use the built-in Telnet and FTP (File Transfer Protocol) that come standard with Ethernet to enhance relay communication sessions. Use Telnet to access relay settings, and metering and event reports remotely using the ASCII interface. Transfer settings files to and from the relay via the high-speed Ethernet port using FTP.

IEEE C37.118 Synchrophasors

The latest IEEE synchrophasor protocol provides a standard method for communicating synchronized phasor measurement data over Ethernet or serial media. The integrated Ethernet card in the SEL-451-4 provides two independent connections using either TCP/IP, UDP/IP, or a combination thereof. Each connection supports unicast data for serving data to a single client. Each data stream can support up to 60 frames per second.

DNP3 LAN/WAN

The DNP3 LAN/WAN option provides the SEL-451-4 with DNP3 Level 2 slave functionality over Ethernet. Custom DNP3 data maps can be configured for use with specific DNP3 masters.

IEC 61850 Ethernet Communications

IEC 61850 Ethernet-based communications provide interoperability between 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 between various manufacturers’ devices and simplify operating logic with IEC 61850. Eliminate system RTUs by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.

The SEL-451-4 can be ordered with embedded IEC 61850 protocol operating on 100 Mbps Ethernet. Use the IEC 61850 Ethernet protocol for relay monitoring and control functions, including:
➤ As many as 24 incoming GOOSE messages. The incoming GOOSE messages can be used to control up to 128 control bits in the relay with <3 ms latency from device to device. These messages provide binary control inputs to the relay for high-speed control functions and monitoring.

➤ As many as 8 outgoing GOOSE messages. Outgoing GOOSE messages can be configured for Boolean or analog data. Boolean data is provided with <3 ms latency from device to device. Use outgoing GOOSE messages for high-speed control and monitoring of external breakers, switches, and other devices.

➤ IEC 61850 Data Server. The SEL-451-4 Relay equipped with embedded IEC 61850 Ethernet protocol provides data according to pre-defined logical node objects. As many as six simultaneous client associations are supported by each relay. Relevant relay word bits are available within the logical node data, so status of relay elements, inputs, outputs or SELOGIC equations can be monitored using the IEC 61850 data server provided in the relay.

Use the ACCELERATOR Architect SEL-5032 software to manage the logical node data for all IEC 68150 devices on the network. This Microsoft Windows-based software provides easy-to-use displays for identifying and binding IEC 61850 network data between logical nodes using IEC 61850 compliant CID (Configured IED Description) files. CID files are used by the ACCELERATOR Architect to describe the data that will be provided by the IEC 61850 logical node within each relay.

Protection Features

Directional Elements Increase Sensitivity and Security

The SEL-451-4 provides multiple directional elements to optimize security and sensitivity. Use ground and negative-sequence directional overcurrent elements to detect high-resistance faults when using communications-assisted tripping schemes.

The SEL-451-4 includes a number of directional elements for supervision of overcurrent elements. The negative-sequence directional element uses the same patented principle proven in our SEL-351 Relay. This directional element can be applied in virtually any application, regardless of the amount of negative-sequence voltage available at the relay location.

Ground overcurrent elements are directionally controlled by three directional elements working together:

➤ Negative-sequence voltage-polarized directional element
➤ Zero-sequence voltage-polarized directional element
➤ Zero-sequence current-polarized directional element

Our patented Best Choice Ground Directional Element selects the best ground directional element for the system conditions and simplifies directional element settings (you can override this automatic setting feature for special applications).

Communications-Assisted Tripping Schemes

Use communications to improve tripping time for better customer service. The SEL-451-4 is the ideal relay for use in pilot-based tripping schemes. Use Enhanced MRORED BITS communications with SEL fiber-optic transceivers for 3–6 ms relay-to-relay transmission time. Among the schemes supported are:

➤ Permissive Overreaching Transfer Tripping (POTT)
➤ Directional Comparison Unblocking (DCUB)
➤ Directional Comparison Blocking (DCB)

Use the SELOGIC control equation TRCOMM to program specific elements, combinations of elements, inputs, etc., to perform communications scheme tripping and other scheme functions. The logic readily accommodates the following conditions:

➤ Current reversals
➤ Breaker open at one terminal
➤ Weak-infeed conditions at one terminal
➤ Switch-onto-fault conditions

Overcurrent Elements

The SEL-451-4 includes four phase, four negative-sequence, and four ground instantaneous overcurrent elements. The SEL-451-4 also includes six selectable operating quantity inverse-time overcurrent elements. You can select the operating quantities from the following:

|IA|, |IB|, |IC|, MAX(|IA|, |IB|, |IC|), |I1|, |3I2|, |IG|

where |IA|, |IB|, |IC| can be fundamental or rms quantities from either circuit breaker or combined currents.

The time-overcurrent curves (listed in Table 5) have two reset characteristic choices for each time-overcurrent element. One choice resets the elements if current drops below pickup for one cycle. The other choice emulates the reset characteristic of an electromechanical induction disc relay.
Breaker Failure Protection
Incorporated into the SEL-451-4 is a full function breaker failure system. Current can be individually monitored in two breakers. High-speed open-pole detection logic allows you to set the pickup current below minimum load for sensitivity without sacrificing high-speed dropout. Even in cases with delayed current zero in the secondary of the CT caused by trapped flux, high-speed detection of circuit breaker opening is achieved. This feature is essential if breaker failure is initiated on all circuit breaker trips. A reset of less than one cycle reduces coordination times, improving stability.

Thermal Overload Protection
The SEL-451-4 supports receipt of Fast Messages from the SEL-2600A RTD Module. Magnitude information from the SEL-2600A is placed in predefined analog values and status information is stored in predefined Relay Word bits. For more information, see SEL Application Guide AG2003-06, Implementation of the SEL-49 Relay Line Thermal Protection Using the SEL-421 Relay SEL-LOGIC Equations.

Loss-of-Potential (LOP) Logic Supervises Directional Elements
The SEL-451-4 includes logic to detect a loss-of-potential (LOP) caused by failures such as blown fuses, which can cause an incorrect operation in directional elements. Simple settings configure the LOP logic to either block or force forward ground and phase directional elements under these conditions. The logic checks for a sudden change in positive-sequence voltage without a corresponding change in positive- or zero-sequence current. Tests and field experience show that this principle is very secure and is faster than the tripping elements.

High-Impedance Fault Detection
High-impedance faults are short-circuit faults with fault currents smaller than what a traditional overcurrent protective relay can detect. The SEL-451 includes logic used to detect HIF signatures without being affected by loads and other system operation conditions. A running average provides a stable pre-fault reference and adaptive tuning learns and tunes out feeder ambient noise conditions. Decision logic differentiates an HIF condition from other system conditions such as switching operations and noisy loads. Up to 40 minutes of high-impedance fault activity is stored in high-resolution COMTRADE format and a summary of HIF activity is available using ASCII commands.

Six Independent Settings Groups Increase Operation Flexibility
The bay control 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 control contingencies. Selectable settings groups make the SEL-451-4 ideal for applications requiring frequent settings changes and for adapting the bay 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, emergency contingencies, loading, source changes, and adjacent relay settings changes.

Combined Current for Protection Flexibility
In traditional relays, when protecting a line fed from two breakers, such as a breaker-and-a-half system or double-breaker system, you needed to combine the CT inputs before connecting these inputs to the relay. The SEL-451-4 can accept separate inputs from two separate CTs (CTs must be the same ratio) and mathematically combine the currents. This allows collecting separate current metering and breaker monitor information for each breaker. Breaker monitoring functions for two breakers are done within one relay. Individual breaker currents allow for breaker failure functions on a per-breaker basis within the SEL-451-4. Breaker diagnostics are reported on a comparative basis allowing for advanced, proactive troubleshooting.

Custom Control Capabilities
Customize control capabilities, adding stability and security to your system.

➤ Use expanded SEL-LOGIC control equations to create advanced stability enhancements such as VAR-flow controlled time undervoltage load shedding.
➤ Combine frequency elements with voltage supervision for added security with underfrequency load-shedding systems.

### Table 5 Time-Overcurrent Curves

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

The standard SEL-451-4 includes five independent and two common inputs, two Form A and three Form C standard interrupting outputs, and three Form A high-current interrupting outputs. The following additional input/output (I/O) boards are currently available.

➤ Eight independent inputs, 13 standard Form A and two standard Form C contact outputs.
➤ Eight independent inputs, eight high-speed, high-current interrupting Form A contact outputs.
➤ Eight independent inputs, 13 high-current interrupting Form A outputs and two standard Form C contact outputs.
➤ Twenty-four inputs, six high-speed and two standard Form A contact outputs.

Assign the control inputs for control functions, monitoring logic, and general indication. Each control output is programmable using SELOGIC control equations. No additional I/O boards can be added to the 3U chassis; however, one board can be added to the 4U chassis, and two additional I/O boards can be added to the 5U chassis. Order standard and additional I/O as either the universal (15-265 Vdc settable pickup) or optoisolated type.

Multifunction Reclosing With Flexible Applications

The SEL-451-4 includes three-pole trip and reclose functions, for either one or two breakers (Figure 20). Synchronism check is included for breaker control. Synchronizing and polarizing voltage inputs are fully programmable with Dead Line/Dead Bus closing logic as well as zero-closing-angle logic to minimize system stress upon reclosing. Program up to four reclose attempts. Select Leader and Follower breakers directly, or use a SELOGIC control equation to determine reclosing order based on system conditions.

Two-Breaker Control

The SEL-451-4 contains analog voltage inputs for multiple sources and control inputs to indicate both breaker and disconnect position, as well as the logic required to provide full control for two breakers. This includes separate monitoring functions as well as separate elements for tripping and closing the two breakers to allow for leader/follower operation or other desired control schemes. All analog values are monitored on a per-breaker basis to allow station control access to complete information for individual components of the system.

Backup Protection

Add reliability and dependability by providing independent backup protection without increasing relay count. Use each SEL-451-4 to provide primary directional over-
current protection with backup nondirectional overcurrent protection on the adjacent feeder. For additional flexibility, use the available I/O or MIRRORED BITS to switch protection upon loss of one relay.

Guideform Specification

The microprocessor-based bay control shall provide control, automation, monitoring, fault locating, and protection. Bay control self-checking functions shall be included. Specific requirements are as follows.

➢ Bay Display. The bay control shall have the ability to display one-line bay diagrams on the front-panel display. The bay display shall be interactive to view the status and control of breakers and disconnect switches.

➢ Bay Control. The bay control shall have the ability to control as many as five disconnects and two breakers and status of as many as three breakers and five disconnect switches.

➢ Bay Control Logic. The bay control shall include programmable logic functions for a wide range of user-configurable protection, monitoring, and control schemes. Logic shall have the ability to use bay elements, math functions, comparison functions, and Boolean logic functions.

➢ Overcurrent Fault Protection. The bay control shall incorporate selectable operating quantity time-overcurrent elements. Torque control capability (internal and external) shall be provided.

➢ Voltage Transfer Capability. The bay control shall be able to change protection voltage source upon detection of loss of potential (LOP). Voltage shall be capable of changing to a second source connected to the bay.

➢ Breaker Failure Logic. The bay control shall incorporate dual breaker failure logic for three-pole tripping and reclosing. Retrip and transfer trip initiate contacts shall be provided. Dropout time of the current detection circuit shall be less than one cycle, even in cases with residual dc current in the CT secondary.

➢ Autoreclosing. The bay control shall incorporate three-pole reclosing with four separately-set open time intervals for reclosing. Separately-set reset times from reclose cycle and from lockout shall be available. Reclosing shall be selectable for one or two breakers.

➢ Synchronism Check. The bay control shall include two synchronism check elements with separate maximum angle settings. The synchronism check function shall incorporate slip frequency and close angle settings and allow different sources of synchronizing voltage (VA, VB, VC, VAB, VBC, VCA).

➢ Independent Trip/Close Pushbuttons. The relay shall include independently operated breaker trip/close switches and indicating lamps. The switches and breaker status lamps shall be functional regardless of the relay status.

➢ High Impedance Fault Detection. The relay shall include high-impedance fault detection algorithms capable of detecting HIF signatures without being affected by loads and other system operation conditions. The relay shall make high-impedance fault summary and history information available in ASCII format and up to forty minutes of fault data shall be stored in COMTRADE format.

➢ Automation. The bay control shall include 32 local control switches, 32 remote control switches, 32 latching switches, and programmable display messages in conjunction with a local display panel in the relay. The bay control shall be capable of displaying custom messages. Input signals to the bay shall have settable assertion levels.

➢ Communications. The bay control shall include four independent EIA-232 serial ports for external communications.

➢ Digital Relay-to-Relay Communications. The bay control shall have send and receive logic elements, and analog and virtual terminal elements in each of two communications ports for dedicated relay-to-relay communications.

➢ IEC 61850. The relay shall provide IEC 61850-compliant communications. The IEC 61850 capability shall include GOOSE messaging and defined logical node data points.

➢ Distributed Network Protocol (DNP). The bay control shall incorporate certified DNP3 Level 2 Slave protocol and Ethernet DNP3 LAN/WAN communications capability.

➢ IRIG-B Time Input. The bay control shall include an interface port for either a standard or high-accuracy demodulated IRIG-B time-synchronization input signal.

➢ High-Accuracy Timing. The bay control shall time-tag event reports to an absolute accuracy of 10 µs. Bay controls at different system locations shall have the same absolute timing accuracy.

➢ Synchrophasors. The bay control shall include operation as a phasor measurement and control unit (PMU) following the IEEE C37.118-2005 Standard for Synchrophasors for Power Systems.
Password Protection. The bay control shall have multilevel passwords to safeguard bay control, protection, and automation settings.

HMI Display. The bay control shall include custom configurable display information to display status, analog quantities with units, user-defined labels, and alarm information.

Bay Display. The bay control shall have the ability to display one-line bay diagrams on the front-panel display. The bay display shall be interactive to view the status and control of breakers and disconnect switches.

Operator Controls. The bay control shall include operator control pushbuttons on the relay front panel. Each pushbutton shall be programmable and accessible in the bay control logic.

Fault Locator. The bay control shall include a fault locating algorithm to provide an accurate estimate of fault location without communications channels or special instrument transformers.

Event Reporting and Sequential Events Recorder. The bay control shall automatically record disturbance events of up to 2 seconds at 8 kHz sampling rate and 5 seconds at 1 kHz sampling rate. Events shall be stored in nonvolatile memory. The relay shall also include a Sequential Events Recorder (SER) that stores the latest 1000 entries.

Dual Circuit Breaker Monitor. The bay control shall include a breaker wear monitor function for two circuit breakers with a programmable breaker monitor curve. Electrical and mechanical operating times, with comparison between last and average times, shall be monitored and reported.

Dual Substation Battery Monitor. The bay control shall measure and report the substation battery voltages both at steady-state conditions and during trip operations. Two sets of selectable threshold parameters shall be provided for alarm and control purposes at each battery voltage. DC ground detection for two systems shall be included.

Environment. The bay control shall be suitable for continuous operation over a temperature range of -40° to +85°C.

PC Interface. The bay control shall be capable of being set by Windows-based graphical and ASCII terminal interfaces.

Terminal Connectors. The bay control shall include the ability to remove the screw terminal block connectors from the back of the bay control to disconnect I/O, dc battery monitor, and power without removing each wire connection.

Configurable Labels. The bay control shall include configurable labels to customize the targets and operator control pushbuttons.

IEEE 37.90. The bay control output contacts shall be rated to pass the IEEE 37.90-1989 contact standard.

Conformal Coating. The device shall have optional conformal coating to protect the circuit boards from harsh environments.

Warranty. The relay shall have a minimum 10-year worldwide warranty.

Reliability. The manufacturer shall supply the actual measured Mean-Time Between Failures (MTBF) for the device upon request.

Manufacturer. This device shall be manufactured in the U.S.A.

Warranty Return. The manufacturer shall support a 72-hour turn-around on all warranty repairs.
Front- and Rear-Panel Diagrams

**3U Front Panel, Rack-Mount Option**

**4U Front Panel, Panel-Mount Option**

**5U Front Panel, Panel-Mount Option**

Figure 22  Typical SEL-451-4 Front-Panel Diagrams
Figure 23  3U Rear Panel, No Additional I/O Board

Figure 24  4U Rear Panel, Connectorized® Option, One Additional I/O Board

Figure 25  5U Rear Panel, Main Board A, INT4 and INT1 I/O Interface Board
Figure 26 5U Rear Panel, Main Board B, INT3 and INT1 I/O Interface Board

Figure 27 5U Rear Panel, Main Board B, INT2 and INT7 I/O Interface Board
Bay Control Dimensions

Figure 28  SEL-451-4 Dimensions for Rack- and Panel-Mount Models
(Horizontal Mounting Shown; Dimensions Also Apply to Vertical Mounting)
**Specifications**

**Important:** Do not use the following specification information to order an SEL-451-4. Refer to the actual ordering information sheets.

### General

**AC Current Inputs (Secondary Circuits)**

- **Note:** Current transformers are Measurement Category II.
- **5 A nominal**
  - 15 A continuous, linear to 100 A symmetrical
  - 500 A for 1 second
  - 1250 A for 1 cycle
- **Burden:**
  - 0.27 VA at 5 A
  - 2.51 VA at 15 A
- **1 A nominal**
  - 3 A continuous, linear to 20 A symmetrical
  - 100 A for 1 second
  - 250 A for 1 cycle
- **Burden:**
  - 0.13 VA at 1 A
  - 1.31 VA at 3 A

**AC Voltage Inputs**

- **300 V L-N continuous (connect any voltage up to 300 Vac)**
- **600 Vac for 10 seconds**
- **Burden:**
  - 0.03 VA at 67 V
  - 0.06 VA at 120 V
  - 0.8 VA at 300 V

**Power Supply**

- **125/250 Vdc or 120/230 Vac**
  - **Range:** 85–300 Vdc <35 W or 85–264 Vac
  - **VDC Input Ripple:** 15% per IEC 60255-11:2008
  - **Nominal Frequency:** 50/60 Hz
  - **Range:** 30–120 Hz
  - **Burden:** <120 VA

- **48/125 Vdc or 120 Vac**
  - **Range:** 38–140 Vdc <35W or 85–140 Vac
  - **VDC Input Ripple:** 15% per IEC 60255-11:2008
  - **Nominal Frequency:** 50/60 Hz
  - **Range:** 30–120 Hz
  - **Burden:** <120 VA

- **24/48 Vdc**
  - **Range:** 18–60 Vdc
  - **VDC Input Ripple:** 15% per IEC 60255-11:2008
  - **Burden:** <35 W

**Control Outputs**

- **Standard**
  - **Make:** 30 A
  - **Carry:** 6 A continuous carry at 70°C
  - **1s Rating:** 50 A
  - **MOV Protection**
    - **(maximum voltage):** 250 Vac/330 Vdc
  - **Pickup/ Dropout Time:** 6 ms, resistive load
  - **Update Rate:** 1/8 cycle
  - **Break Capacity (10000 operations):**
    - 48 Vdc 0.50 A L/R = 40 ms
    - 125 Vdc 0.30 A L/R = 40 ms
    - 250 Vdc 0.20 A L/R = 40 ms

- **Cyclic Capacity (2.5 cycle/second):**
  - 48 Vdc 0.50 A L/R = 40 ms
  - 125 Vdc 0.30 A L/R = 40 ms
  - 250 Vdc 0.20 A L/R = 40 ms

- **Note:** EA certified relays do not have MOV protected standard output contacts.

- **Hybrid (high current interrupting)**
  - **Make:** 30 A
  - **Carry:** 6 A continuous carry at 70°C
  - **1s Rating:** 50 A
  - **MOV Protection**
    - **(maximum voltage):** 330 Vdc
  - **Pickup/ Dropout Time:** 6 ms, resistive load
  - **Update Rate:** 1/8 cycle
  - **Break Capacity (10000 operations):**
    - 48 Vdc 10.0 A L/R = 40 ms
    - 125 Vdc 10.0 A L/R = 40 ms
    - 250 Vdc 10.0 A L/R = 20 ms

- **Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation)**
  - 48 Vdc 10.0 A L/R = 40 ms
  - 125 Vdc 10.0 A L/R = 40 ms
  - 250 Vdc 10.0 A L/R = 20 ms

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

- **Fast Hybrid (high-speed high current interrupting)**
  - **Make:** 30 A
  - **Carry:** 6 A continuous carry at 70°C
  - **1s Rating:** 50 A
  - **MOV Protection**
    - **(maximum voltage):** 250 Vac/330 Vdc
  - **Pickup Time:** 10 µs, resistive load
  - **Dropout Time:** 8 ms, resistive load
  - **Update Rate:** 1/8 cycle
  - **Break Capacity (10000 operations):**
    - 48 Vdc 10.0 A L/R = 40 ms
    - 125 Vdc 10.0 A L/R = 40 ms
    - 250 Vdc 10.0 A L/R = 20 ms

- **Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation)**
  - 48 Vdc 10.0 A L/R = 40 ms
  - 125 Vdc 10.0 A L/R = 40 ms
  - 250 Vdc 10.0 A L/R = 20 ms

- **Note:** Per IEC 60255-23:1994, using the simplified method of assessment.

- **Note:** Make rating per IEEE C37.90-1989.
Auxiliary Trip/Close Pushbuttons (Select Models Only)

Resistive DC or AC Outputs with Arc Suppression Disabled:
Make: 30 A
Carry: 6 A continuous carry
1 s Rating: 50 A
MOV Protection: 250 Vac/330 Vdc/130 J
Breaking Capacity (1000 operations):
48 V 0.50 A L/R = 40 ms
125 V 0.30 A L/R = 40 ms
250 V 0.20 A L/R = 40 ms

Note: Make per IEEE C37.90-1989.

High Interrupt DC Outputs with Arc Suppression Enabled:
Make: 30 A
Carry: 6 A continuous carry
1 s Rating: 50 A
MOV Protection: 330 Vdc/130 J
Breaking Capacity (10000 operations):
48 V 10 A L/R = 40 ms
125 V 10 A L/R = 40 ms
250 V 10 A L/R = 20 ms

Note: Make per IEEE C37.90-1989.

Breaker Open/Closed LEDs:
250 Vdc: on for 150–300 Vdc; 192–288 Vac
125 Vdc: on for 80–150 Vdc; 96–144 Vac
48 Vdc: on for 30–60 Vdc;
24 Vdc: on for 15–30 Vdc

Note: With nominal control voltage applied, each LED draws 8 mA (max.). Jumpers may be set to 125 Vdc for 110 Vdc input and set to 250 Vdc for 220 Vdc input.

Control Inputs

Direct Coupled (for use with dc signals)
Main Board A: 5 inputs with no shared terminals
2 inputs with shared terminals
INT1, INT5, and INT6 interface boards: 8 inputs with no shared terminals
Range: 15–265 Vdc, independently adjustable
Accuracy: ±5% plus ±3 Vdc
Maximum Voltage: 300 Vdc
Sampling Rate: 1/16 cycle
Typical Burden: 0.24 W at 125 Vdc

Optoisolated (use with ac or dc signals)
Main Board B: 5 inputs with no shared terminals
2 inputs with shared terminals
INT2, INT7, and INT8 interface boards: 8 inputs with no shared terminals
INT3 and INT4 interface boards: 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 V standard
48, 110, 125, 220, 250 V level sensitive

DC Thresholds (Dropout thresholds indicate level-sensitive option):
24 Vdc: Pickup 15.0–30.0 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;
220 Vdc: Pickup 176–264 Vdc;
250 Vdc: Pickup 200–300 Vdc

AC Thresholds (Ratings met only when recommended control input settings are used):
24 Vac: Pickup 12.8–30.0 Vac rms
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 150–264 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: 1/16 cycle

Frequency and Rotation

System Frequency: 50/60 Hz
Phase Rotation: ABC or ACB
Frequency Tracking Range: 40–65 Hz

Communications Ports

EIA-232: 1 Front & 3 Rear
Serial Data Speed: 300–57600 bps
Communications Card Slot for optional Ethernet Processor

Fiber Optic (Optional)

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

Time Inputs

IRIG Input–Serial Port 1
Input: Demodulated IRIG-B
Nominal Voltage: 5 Vdc ±10%
Maximum Voltage: 8 Vdc
Input Impedance: 333 ohms
Isolation: 500 Vdc

IRIG-B Input–BNC Connector
Input: Demodulated IRIG-B
Nominal Voltage: 5 Vdc ±10%
Maximum Voltage: 8 Vdc
Input Impedance: 2500 ohms
Operating Temperature
Without Ethernet: –40° to +85°C (–40° to +185°F)
With Ethernet: –40° to +70°C (–40° to +158°F)
Note: LCD contrast impaired for temperatures below –20° and above +70°C

Humidity
5% to 95% without condensation

Weight (Maximum)
3U Rack Unit: 17.5 lbs (8.0 kg)
4U Rack Unit: 21.5 lbs (9.8 kg)
5U Rack Unit: 25.5 lbs (11.6 kg)

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), current, voltage, 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>Minimum Wire Size</th>
<th>Maximum Wire Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grounding (Earthing)</td>
<td>18 AWG (0.8 mm²)</td>
<td>14 AWG (2.5 mm²)</td>
</tr>
<tr>
<td>Current Connection</td>
<td>16 AWG (1.5 mm²)</td>
<td>12 AWG (4 mm²)</td>
</tr>
<tr>
<td>Potential (Voltage)</td>
<td>18 AWG (0.8 mm²)</td>
<td>14 AWG (2.5 mm²)</td>
</tr>
<tr>
<td>Contact I/O</td>
<td>18 AWG (0.8 mm²)</td>
<td>14 AWG (2.5 mm²)</td>
</tr>
</tbody>
</table>

Use wire with 0.4 mm-thick insulation for high-voltage connections to allow for contact between adjacent wires. If possible, use 0.4 mm insulated wires for all connections.

Routine Dielectric Strength Tests
(Performed on Each Manufactured Relay)
AC Current Inputs, optoisolated inputs, and output contacts: 2500 Vac for 10 s
Power Supply: 3100 Vdc for 10 s

Type Tests
Electromagnetic Compatibility Emissions

Electromagnetic Compatibility Immunity
Conducted RF Immunity: IEC 60255-22-6:2001
Severlty Level: 10 Vrms
IEC 61000-4-6:2008
Severlty Level: 10 Vrms
Electrostatic Discharge Immunity:
IEC 60255-22-2:2008
Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
IEC 61000-4-2:2008
Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
IEEE C37.90.3-2001
Severity Level: 2, 4, 8 kV contact; 4, 8, 15 kV air

Fast Transient/Burst Immunity:
IEC 60255-22-4:2008
Severity Level: Class A: 4 kV, 5 kHz; 2 kV, 5 kHz on communication ports
IEC 61000-4-4:2011
Severity Level: 4 kV, 5 kHz

Magnetic Field Immunity:
IEC 61000-4-8:2009
Severity Level: 900 A/m for 3 seconds, 100 A/m for 1 minute
IEC 61000-4-9:2001
Severity Level: 1000 A/m

Power Supply Immunity:
IEC 60255-11:2008
IEC 61000-4-11:2004
IEC 61000-4-29:2000

Radiated Digital Radio Telephone RF Immunity:
Severity Level: 10 V/m at 900 MHz and 1.89 GHz
IEC 60255-22-3:2007
Frequency Immunity:
IEC 60255-22-3:2007
Severity Level: 10 V/m
IEC 61000-4-3:2010
Severity Level: 10 V/m
IEEE C37.90.2:2004
Severity Level: 35 V/m

Surge Immunity:
IEC 60255-22-5:2008
Severity Level: 1 kV Line-to-Line, 2 kV Line-to-Earth
IEC 61000-4-5:2005
Severity Level: 1 kV Line-to-Line, 2 kV Line-to-Earth

Surge Withstand Capability Immunity:
IEC 60255-22-1:2007
Severity Level: 2.5 kV peak common mode, 1.0 kV peak differential mode
IEEE C37.90.1:2002
Severity Level: 2.5 kV oscillatory, 4 kV fast transient waveform

Environmental
Cold:
IEC 60608-2-1:2007
Severity Level: 16 hours at –40°C

Damp Heat, Cyclic:
IEC 60608-2-30:2005
Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity: 95%

Dry Heat:
IEC 60608-2-2:2007
Severity Level: 16 hours at +85°C

Vibration:
IEC 60255-21-1:1988
Severity Level: Class 1 Endurance, Class 2 Response
IEC 60255-21-2:1988
Severity Level: Class 1–Shock withstand, Bump, and Class 2–Shock Response
IEC 60255-21-3:1993
Severity Level: Class 2 (Quake Response)

Schweitzer Engineering Laboratories, Inc.
Safety

Dielectric Strength: IEC 60255-5:2000
Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute.
IEEE C37.90:2005
Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute.

Impulse: IEC 60255-5:2000
Severity Level: 0.5 Joule, 5 kV
IEEE C37.90: 2005
Severity Level: 0.5 Joule, 5 kV

Severity Level: IP30

Laser Safety: ANSI Z136.1:2007, Class 1
IEC 60825-1:2007, Class 1

Safety Agency Certifications

Product Safety: C22.2 No. 14
cUL Listed Protective Relay, Product Category NRGU7
UL 508
UL Listed Protective Relay, Product Category NRGU

Certifications

ISO: Relay is designed and manufactured using ISO 9001:2000 certified quality program.

Product Safety: IEC 60255-6:1988

Reporting Functions

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

Note: Per IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111–1999

Event Reports
Storage: 35 quarter-second events or 24 half-second events
Maximum Duration: Record events as long as 5 seconds
Resolution: 8- or 4-samples/cycle

Event Summary
Storage: 100 summaries

Breaker History
Storage: 128 histories

Sequential Events Recorder
Storage: 1000 entries
Trigger elements: 250 relay elements

Processing Specifications

AC Voltage and Current Inputs
8000 samples per second, 3 dB low-pass analog filter cut-off frequency of 3000 Hz.

Digital Filtering

Full-cycle cosine and half-cycle Fourier filters after low-pass analog and digital filtering.

Protection and Control Processing

8 times per power system cycle

Synchronphasors

Maximum data rate in messages per second
IEEE C37.118 V7.3 protocol: 60 (nominal 60 Hz system) 50 (nominal 50 Hz system)
SEL Fast Message protocol: 20 (nominal 60 Hz system) 10 (nominal 50 Hz system)

Control Points

32 remote bits
32 local control bits
32 latch bits in protection logic
32 latch bits in automation logic

 Relay Element Pickup Ranges and Accuracies

Instantaneous/Definite-Time Overcurrent Elements

Phase, Residual Ground, and Negative-Sequence

Pickup 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 plus ±3% of setting
1 A Model: ±0.01 A plus ±3% of setting

Transmit Overreach: < 5% of pickup

Time: 0.000–1600.000 cycles, 0.125 cycle steps

Timer Accuracy: ±0.125 cycle plus ±0.1% of setting

Maximum Operating Time: 1.5 cycles

Time-Overcurrent Elements

Pickup Range
5 A Model: 0.25–16.00 A secondary, 0.01 A steps
1 A Model: 0.05–3.20 A secondary, 0.01 A steps

Accuracy (Steady State)
5 A Model: ±0.05 A plus ±3% of setting
1 A Model: ±0.01 A plus ±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 plus ±4% of curve time
(for current between 2 and 30 multiples of pickup)

Reset: 1 power cycle or Electromechanical Reset Emulation time

Ground Directional Elements

Neg.-Seq. Directional Impedance Threshold (Z2F, Z2R)
5 A Model: –64 to 64 Ω
1 A Model: –320 to 320 Ω
Zero-Seq. Directional Impedance Threshold (Z0F, Z0R)

5 A Model: –64 to 64 Ω
1 A Model: –320 to 320 Ω

Supervisory Overcurrent Pickup 50FP, 50RP

5 A Model: 0.25 to 5.00 A 3I0 secondary
0.25 to 5.00 A 3I2 secondary
1 A Model: 0.05 to 1.00 A 3I0 secondary
0.05 to 1.00 A 3I2 secondary

Undervoltage and Overvoltage Elements

Pickup Ranges: Phase elements: 1–200 V secondary, 1 V steps
Phase-to-Phase Elements: 1.0–300.0 V secondary, 0.1 V steps
Accuracy (Steady State): ±1 V plus ±5% of setting
Transient Overreach: < 5% of pickup

Optional RTD Elements

(Models Compatible With SEL-2600 Series RTD Module)

12 RTD Inputs via SEL-2600 Series RTD Module and SEL-2800 Fiber-Optic Transceiver
Monitor Ambient or Other Temperatures
PT 100, NI 100, NI 120, and CU 10 RTD-Types Supported, Field Selectable
Up to 500 m Fiber-Optic Cable to SEL-2600 Series RTD Module

Breaker Failure Instantaneous Overcurrent

Setting Range
5 A Model: 0.50–50.0 A, 0.01 A steps
1 A Model: 0.10–10.0 A, 0.01 A steps
Accuracy
5 A Model: ±0.05 A plus ±3% of setting
1 A Model: ±0.01 A plus ±3% of setting
Transient Overreach: < 5% of setting
Maximum Pickup Time: 1.5 cycles
Maximum Reset Time: 1 cycle
Timers Setting Range: 0–6000 cycles, 0.125 cycle steps
(All but BFIDOn, BFISPn)
0–1000 cycles, 0.125 cycle steps
(BFIDOn, BFISPn)
Time Delay Accuracy: 0.125 cycle plus ±0.1% of setting

Synchronism-Check Elements

Slip Frequency
Pickup Range: 0.005–0.500 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy: ±0.0025 Hz plus ±2% of setting
Close Angle Range: 3–80°, 1° steps
Close Angle Accuracy: ±3°

Load-Encroachment Detection

Setting Range
5 A Model: 0.05–64 Ω secondary, 0.01 Ω steps
1 A Model: 0.25–320 Ω secondary, 0.01 Ω steps
Forward Load Angle: –90° to +90°
Reverse Load Angle: +90° to +270°

Accuracy
Impedance Measurement: ±3%
Angle Measurement: ±2°

Timer Specifications

Setting Ranges
Breaker Failure: 0–6000 cycles, 0.125 cycle steps
(All but BFIDOn, BFISPn)
Communications-Assisted Tripping Schemes: 0.000–16000 cycles, 0.125 cycle steps
Pole Open Timer: 0.000–60 cycles, 0.125 cycle steps
Recloser: 1–999999 cycles, 1 cycle steps
Switch-On-Fault
CLOEND, 52AEND: OFF, 0.000–16000 cycles, 0.125 cycle steps
SOTFD: 0.500–16000 cycles, 0.125 cycle steps

Station DC Battery System Monitor Specifications

Operating Range: 0–350 Vdc
Input Sampling Rate: 2 kHz
Processing Rate: 1/8 cycle
Maximum Operating Time: ≤ 1.5 cycles
Setting Range
DC settings: 15–300 Vdc, 1 Vdc steps
AC ripple setting: 1–300 Vac, 1 Vac steps
Accuracy
Pickup Accuracy: ±3% plus ±2 Vdc (all elements but DC1RP and DC2RP)
±10% plus ±2 Vac (DC1RP and DC2RP)

Metering Accuracy

All metering accuracy is at 20°C, and nominal frequency unless otherwise noted.

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 A sec)
Phase Current Angle
All Models ±0.2° in the current range 0.5 • I nom to 3.0 • I nom
Sequence Currents Magnitude
5 A Model: ±0.3% plus ± 4 mA (2.5–15 A sec)
1 A Model: ±0.3% plus ± 0.8 mA (0.5–3 A sec)
Sequence Current Angle
All Models ±0.3° in the current range 0.5 • I nom to 3.0 • I nom
Voltages

Phase and Phase-to-Phase Voltage
Magnitude: ±0.1% (33.5–200 V_{L-N})
Phase and Phase-to-Phase Angle: ±0.05° (33.5–200 V_{L-N})
Sequence Voltage
Magnitude: ±0.15% (33.5–200 V_{L-N})
Sequence Voltage Angle: ±0.1° (33.5–200 V_{L-N})

Frequency (Input 40–65 Hz)
Accuracy: ±0.01 Hz

Power and Energy

Real Power, P (MW), Three Phase
At 0.1 \cdot I_{\text{nom}}
Power factor unity: ±0.4%
Power factor 0.5 lag, 0.5 lead: ±0.7%
At 1.0 \cdot I_{\text{nom}}
Power factor unity: ±0.4%
Power factor 0.5 lag, 0.5 lead: ±0.4%

Reactive Power, Q (MVAR), Three Phase
At 0.1 \cdot I_{\text{nom}}
Power factor 0.5 lag, 0.5 lead: ±0.5%
At 1.0 \cdot I_{\text{nom}}
Power factor 0.5 lag, 0.5 lead: ±0.4%

Energy (MWh), Three Phase
At 0.1 \cdot I_{\text{nom}}
Power factor unity: ±0.5%
Power factor 0.5 lag, 0.5 lead: ±0.7%
At 1.0 \cdot I_{\text{nom}}
Power factor unity: ±0.4%
Power factor 0.5 lag, 0.5 lead: ±0.4%

Synchrophasors

See the SEL-451 Instruction Manual for test exclusions and details
TVE (total vector error): ≤ 1%
Frequency Range: ±5 Hz of nominal (50 or 60 Hz)
Voltage Range: 30 V–150 V
Current Range: (0.1–2) \cdot I_{\text{nom}} (I_{\text{nom}} = 1A or 5A)
Phase Angle Range: −179.99° to 180°