Major Features and Benefits

The SEL-401 Merging Unit provides a reduction in cable and labor costs while improving the overall safety of the substation. The SEL-401 publishes IEC 61850-9-2 Sampled Values (SV) data streams according to the UCA 61850-9-2LE (9-2LE) guideline for use by compliant substation relays and provides phase overcurrent and breaker-failure backup protection in the absence of substation network communication.

➤ **Protection.** Use the SEL-401 to support breaker failure and phase overcurrent elements to provide protection during a loss of communication to a main substation relay.

➤ **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 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 Edition 2 GOOSE messages and MMS reporting, Sequential Events Recorder (SER) reports, breaker monitoring, relay summary event reports, and time synchronization. Use expanded SELOGIC® control equations with math and comparison functions in control applications. Incorporate as many as 100 lines of automation logic to speed and improve control actions.

➤ **IEC 61850-9-2 Sampled Values Merging Unit.** Publishes current and voltage information that is provided to subscribing remote relays instead of the relay by using standard PT and CT inputs to reduce cable lengths, labor costs, and improve the overall safety of the substation.

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

➤ **Digital Relay-to-Relay Communications.** Use MIRRORED BITS® communications to monitor internal element conditions between relays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel. The SEL-401 time correlates the data for use in SELOGIC control equations.
➤ **Parallel Redundancy Protocol (PRP).** Use PRP 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, with the exception of SV.

➤ **IEEE 1588-2008 Precision Time Protocol (PTP).** Provide high-accuracy timing over an Ethernet network.

➤ **Dual CT Input.** Combine currents within the relay from two sets of current transformers (CTs) for protection functions, but keep them separately available for monitoring and station integration applications.

➤ **Monitoring.** Schedule breaker maintenance when accumulated breaker duty 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 the voltage is low only during trip or close operations.

➤ **Breaker Failure.** Use high-speed (5/8-cycle) open-pole detection logic to reduce coordination times for critical breaker failure applications. Use the SEL-401 to supply three-pole breaker failure detection for one or two breakers. Necessary logic for three-pole breaker failure retrip and initiation of transfer tripping is included.

➤ **Oscillography.** Record voltages, currents, and internal logic points at as high as 8 kHz sampling rate. Phasor and harmonic analysis features allow investigation of relay and system performance.

➤ **Rules-Based Settings Editor.** In addition to communicating and setting the relay by using an ASCII terminal, use the PC-based ACSELERATOR QuickSet® SEL-5030 Software to configure the SEL-401 and analyze fault records with relay element response. View real-time phasors and harmonic levels.

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

➤ **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 root-mean-square (rms), maximum/minimum, and instantaneous values.

➤ **Synchrophasors.** Make informed load dispatch decisions based on actual real-time phasor measurements from SEL-401 Merging Units across your power system. Record streaming synchrophasor data from SEL-401 Merging Units for system-wide disturbance recording. Control the power system by using local and remote synchrophasor data.
Functional Overview

Figure 1  SEL-401 Functional Overview

The SEL-401 can provide basic overcurrent and breaker failure protection. Using the process bus, the SEL-401 provides voltage and current information to multiple relays that subscribe to SV. The data can be synchronized using IEEE 1588-2008 PTP or IRIG-B time input.
**Protection Features**

The SEL-401 publishes SV data streams to relays that can subscribe to these data. The SEL-401 publishes as many as seven outgoing data streams. The default Configured IED Description (CID) file will be configured for four publications but can be configured for as many as seven by using ACSELERATOR Architect® SEL-5032 Software.

**Overcurrent Elements**

The SEL-401 includes four phase instantaneous overcurrent elements. You can select the operating quantities from the following:

- |IA|, |IB|, |IC|, MAX (|IA|, |IB|, |IC|)

**Breaker Failure Protection**

A full-function breaker failure system is incorporated into the SEL-401. Current can be individually monitored in two breakers. High-speed open-pole detection logic allows you to set the pickup current below the minimum load for sensitivity without sacrificing high-speed drop-out. Even in cases with delayed current zeros in the secondary of the CT caused by trapped flux, high-speed detection of circuit breaker opening occurs. If breaker failure is initiated on all circuit breaker trips, this feature is essential. A 5/8-cycle reset reduces coordination times, improving stability.

**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-401 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, emergency contingencies, loading, source changes, and adjacent relay settings changes.
Control Inputs and Outputs

The basic SEL-401 does not include main-board input/output (I/O). The SEL-401 supports a 4U chassis (1 additional I/O board), 5U chassis (2 additional I/O boards), and 6U chassis (3 additional I/O boards). The following additional I/O boards are currently available:

➤ Eight optoisolated, independent, level-sensitive inputs; thirteen standard Form A and two standard Form C contact outputs
➤ Eight optoisolated, independent, level-sensitive inputs; thirteen high-current interrupting Form A outputs and two standard Form C contact outputs
➤ Twenty-four optoisolated, independent, level-sensitive inputs; six high-speed, high-current interrupting, Form A contact outputs and two standard Form A outputs
➤ Twenty-four optoisolated, independent, level-sensitive inputs and eight standard Form A outputs
➤ Twenty-four optoisolated, independent, level-sensitive inputs and eight high-speed, high-current interrupting, 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.

Two-Breaker Control

The SEL-401 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. All analog values are monitored on a per-breaker basis to allow station control access to complete information for individual components of the system.

Network Connection and Integration

Ethernet Card

The Ethernet card mounts directly in the SEL-401. The Ethernet card provides PTP for data time synchronization. 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 by using the IEEE C37.118-2005, Standard for Synchrophasors for Power Systems. Communicate with SCADA and other substation IEDs by using DNP3 or IEC 61850 Logical Nodes and GOOSE messaging.

Choose Ethernet connection media options for primary and stand-by connections:

➤ 10/100BASE-T twisted-pair network
➤ 100BASE FX fiber-optic network

Telnet and FTP

The SEL-401 is equipped with an Ethernet communications card that supports Telnet and FTP that enhance communications 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 by using FTP.

DNP3 LAN/WAN

The DNP3 LAN/WAN option provides the SEL-401 with DNP3 Level 2 Outstation functionality over Ethernet. Custom DNP3 data maps can be configured for use with specific DNP3 masters.

HTTP Web Server

When equipped with Ethernet communications, 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 Ethernet Communications

IEC 61850 Edition 2 Ethernet-based communications provide interoperability between intelligent electronic devices within the substation. Logical nodes using IEC 61850 Edition 2 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. Eliminate system remote terminal units (RTUs) by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.
The SEL-401 supports embedded IEC 61850 Edition 2 protocols operating on 100 Mbps Ethernet. Use the Ethernet protocol for relay monitoring and control functions, including the following.

➤ The SEL-401 supports self-monitoring of the Ethernet links and validates the data quality, which reduces the need for periodic testing of the communications network.

➤ The SEL-401 can publish as many as four data streams of SV data and provide basic backup overcurrent and breaker failure protection in the absence of substation network communication.

➤ As many as 128 incoming GOOSE messages, which 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 to the relay for high-speed control functions and monitoring.

➤ As many as eight outgoing GOOSE messages, which can be configured for Boolean or analog data. Boolean data are 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 Edition 2 Data Server: The SEL-401 is equipped with embedded Ethernet protocol and provides data according to predefined logical node objects. As many as seven 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 data server provided in the relay.

Use Architect 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 network data between logical nodes by using IEC 61850-compliant CID files. CID files are used by Architect to describe the data that will be provided by the logical node within each relay.

**Metering and Monitoring**

**Metering Capabilities**

The SEL-401 provides metering capabilities, as listed in Table 1.

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instantaneous Quantities</strong></td>
<td></td>
</tr>
<tr>
<td>Voltages</td>
<td>$V_{A,B,C} (Y), V_{A,B,C} (Z), V_{\phi \phi}, V_{0}, V_{1}, V_{3}$</td>
</tr>
<tr>
<td></td>
<td>0–300 V with phase quantities for each of the six voltage sources available as a separate quantity.</td>
</tr>
<tr>
<td>Currents</td>
<td>$I_{A,B,C} (W), I_{A,B,C} (X)$</td>
</tr>
<tr>
<td></td>
<td>$I_{L}, I_{L}, I_{3L}$ (combined currents)</td>
</tr>
<tr>
<td></td>
<td>Phase quantities for each of the two current sources are available as a separate quantity or combined as line quantities.</td>
</tr>
<tr>
<td><strong>Power/Energy Metering Quantities</strong></td>
<td></td>
</tr>
<tr>
<td>MW, MVAR, MVA, PF, single-phase and three-phase</td>
<td>Available for each input set and as combined quantities for the line.</td>
</tr>
<tr>
<td><strong>Synchronphasors</strong></td>
<td></td>
</tr>
<tr>
<td>Voltages (Primary Magnitude, Angle)</td>
<td>$V_{A,B,C} (Y), V_{A,B,C} (Z)$</td>
</tr>
<tr>
<td></td>
<td>Primary phase quantities (kV) for each of the six voltage sources available.</td>
</tr>
<tr>
<td>Currents (Primary Magnitude, Angle)</td>
<td>$I_{A,B,C} (W), I_{A,B,C} (X)$</td>
</tr>
<tr>
<td></td>
<td>Primary phase quantities (A) for each of the six current sources available.</td>
</tr>
<tr>
<td>Frequency</td>
<td>FREQ</td>
</tr>
<tr>
<td></td>
<td>Frequency (Hz) as measured by frequency source potential inputs.</td>
</tr>
<tr>
<td></td>
<td>Rate-of-change in frequency (Hz/s).</td>
</tr>
</tbody>
</table>
Event Reporting and SER

Event reports and Sequential Events Recorder (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 merging unit and relay settings and protection schemes. Oscillograms are available in binary COMTRADE and ASCII COMTRADE formats.

SV Reporting

The SEL-401 includes a comprehensive report of the SV communication stream. The ASCII command COM SV displays statistics information from the SV stream to aid in troubleshooting.

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 merging unit, 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 merging unit 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. Relay settings that are operational in the relay at the time of the event are appended to each event report.

Event Summary

Each time the SEL-401 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:

- Merging unit/terminal identification
- Event date and time
- Event type
- System frequency at time of trigger
- Phase voltages
- Prefault and faulted phase current levels
- Prefault and fault-calculated zero- and negative-sequence currents
- Active group targets
- Status of all MIRRORED BITS channels
- Trip and close times of day
- Breaker status (open/close)

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

SER

Use this feature to gain a broad perspective of merging unit and relay element operation. Items that trigger an SER entry are selectable and can include input/output change of state, element pickup/dropout, etc. The merging unit SER stores the latest 1,000 entries.

High-Accuracy Timekeeping

Using high-accuracy IRIG-B or IEEE 1588 from a global positioning satellite clock, the SEL-401 can time-tag oscillography to within 10 µs accuracy. This high accuracy can be combined with the high sampling rate of the merging unit 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 standard-accuracy IRIG-B time-code input synchronizes the SEL-401 time to within ±1 µs of the time-source input. A convenient source for this time code is an SEL communications processor (via serial Port 1 on the SEL-401).

Substation Battery Monitor for DC Quality Assurance

The SEL-401 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 merging unit also provides dual ground detection. Monitor these thresholds with an SEL communications processor and trigger messages, telephone calls, or other actions.

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

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 con-
tact wear versus interruption levels and operation count. The SEL-401 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 merging unit integrates interrupted current. When the result of this integration exceeds the threshold set by the breaker wear curve (Figure 3), the relay can alarm via an output contact or the front-panel display. With this information, you can schedule breaker maintenance in a timely, economical fashion.

➤ The merging unit monitors the last and the average mechanical and electrical interruption time. 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, pole scatter, pole discrepancy, and breaker inactivity are also monitored.

![Breaker Contact Wear Curve and Settings](image)

**Figure 3** Breaker Contact Wear Curve and Settings

---

**Automation**

**Flexible Control Logic and Integration Features**

Use the SEL-401 control logic to do the following:

➤ Replace traditional panel control switches
➤ Eliminate RTU-to-relay 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-relay 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 (for example, trip, close, or 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 as many as 24 latching target LEDs and as many as 12 programmable pushbuttons with LEDs. Define custom messages (such as BREAKER OPEN or BREAKER CLOSED) 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-401 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 2 lists a synopsis of the terminal protocols.

---

**Table 2** Open Communications Protocol (Sheet 1 of 2)

<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 relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.</td>
</tr>
</tbody>
</table>
Use QuickSet to develop settings offline. The system automatically checks interrelated settings and highlights out-of-range settings. Settings created offline can be transferred by using a PC communications link with the SEL-401. The relay converts event reports to oscillograms with time-coordinated element assertion and phasor/sequence element diagrams. The QuickSet interface supports Windows 95, 98, 2000, 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.

### QuickSet Templates

Use the fully licensed version of QuickSet to create custom views of settings, called Application Designs, to reduce complexity, decrease the chance of errors, and increase productivity, such as in the following ways:

- Lock and hide unused settings.
- Lock settings to match your standard for protection, I/O assignment, communication, and SELOGIC 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.

### SELOGIC Control Equations With Expanded Capabilities and Aliases

Expanded SELOGIC control equations 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 (see Table 3). Any element in the Relay Word can be used in these equations. The SEL-401 is factory-set for use without additional logic in most situations. For complex or unique applications, these expanded SELOGIC functions allow superior flexibility.

### Rules-Based Settings Editor

Use QuickSet to develop settings offline. The system automatically checks interrelated settings and highlights out-of-range settings. Settings created offline can be transferred by using a PC communications link with the SEL-401. The relay converts event reports to oscillograms with time-coordinated element assertion and phasor/sequence element diagrams. The QuickSet interface supports Windows 95, 98, 2000, 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.

### Table 2 Open Communications Protocol (Sheet 2 of 2)

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended Fast Meter, Fast Oper-</td>
<td>Binary protocol for machine-to-machine communication. Quickly updates SEL-2032 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. 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>ate, and Fast SER</td>
<td></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>IEEE C37.118</td>
<td>Phasor measurement protocol.</td>
</tr>
<tr>
<td>IEC 61850 Edition 2</td>
<td>Ethernet-based international standard for interoperability between intelligent devices in a substation.</td>
</tr>
</tbody>
</table>

### Table 3 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;, ≥, =, ≤, &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></td>
</tr>
<tr>
<td>Precedence Control</td>
<td>( )</td>
<td>Allows multiple and nested sets of parentheses.</td>
</tr>
<tr>
<td>Comment</td>
<td>#</td>
<td>Provides for easy documentation of control and protection logic.</td>
</tr>
</tbody>
</table>

<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;, ≥, =, ≤, &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></td>
</tr>
<tr>
<td>Precedence Control</td>
<td>( )</td>
<td>Allows multiple and nested sets of parentheses.</td>
</tr>
<tr>
<td>Comment</td>
<td>#</td>
<td>Provides for easy documentation of control and protection logic.</td>
</tr>
</tbody>
</table>
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 that use aliases:

```
>>> SET T <Enter>
1: PMV01,THETA
   (assign the alias "THETA" to math variable PMV01)
2: PMV02,TAN
   (assign the alias "TAN" to math variable PMV02)
   >>> SET L <Enter>
   1: # CALCULATE THE TANGENT OF THETA
      TAN:=SIN(THETA)/COS(THETA)
      (use the aliases in an equation)
```

Add programmable control functions to your protection and automation systems. New functions and capabilities enable the use of analog values in conditional logic statements. The following are examples of possible applications of SELOGIC control equations with expanded capabilities:

- Hold momentary change-of-state conditions for SCADA polling.
- Provide a combination of frequency or rate-of-change-of-frequency functions.

### Relay-to-Relay Digital Communication (MIRRORED BITS)

The SEL-patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication. In the SEL-401, MIRRORED BITS can operate simultaneously on any two serial ports for three-terminal power system operation.

The SEL-401 offers the following serial communication features:

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

### Advanced Front-Panel Operation

#### Front-Panel Display

The LCD shows event, metering, settings, and relay self-test status information.

The LCD is controlled by the navigation pushbuttons (Figure 5), automatic messages the relay generates, and user-programmed analog and digital display points. The rotating display scrolls through alarm points, display points, and metering screens. If none are active, the relay scrolls through displays of the fundamental and rms 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.

![Figure 4 Factory-Default Status and Trip Target LEDs (12-Pushbutton, 24-Target LED Option)](image-url)
control functions. The asserted and deasserted colors for the LEDs are programmable. Configure any of the direct-acting pushbuttons to navigate directly to any HMI menu item. Quickly view events, alarm points, display points, or the SER.

**Bay Control**

The SEL-401 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 the QuickSet interface that can be downloaded at selinc.com. The bay control is equipped to control as many as ten disconnects and two breakers, depending on the one-line diagram selected. Certain one-line diagrams provide status for as many as three breakers and five disconnect switches. Operate disconnects and breakers with ASCII commands, SELOGIC control equations, Fast Operate 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-401 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 in real-time along with the breakers and switch position to give instant status and complete control of a bay. Figure 6 through Figure 9 demonstrate some of the preconfigured bay arrangements available in the SEL-401.

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-401 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 6—Figure 9 are examples of some of the selectable one-line diagrams in the SEL-401. 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
- Busbar and Busbar Labels
- Breaker and Breaker Labels
- Disconnect Switches and Disconnect Switch Labels
- Analog Display Points
Rack-Type Breakers Mosaics

The SEL-401 supports the display of rack-type (also referred to as truck-type) circuit breakers. The rack-type breakers have three positions: racked out, test, and racked in. When in the test or racked-in positions, the breaker can be displayed as open or closed. When racked out, there is no breaker open/close display. The rack-type breakers are a display-only functionality and do not impact any circuit breaker control capabilities.

Status and Trip Target LEDs

The SEL-401 includes programmable status and trip target LEDs, as well as programmable direct-action control pushbuttons on the front panel.

The SEL-401 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, operator control pushbuttons, and LEDs. The blank slide-in label set is included with the SEL-401. Functions are simple to configure using QuickSet software. Label sets can be printed from a laser printer by using templates supplied with the merging unit or hand labeled on supplied blank labels.

Alarm Points

You can display messages on the SEL-401 front-panel LCD that indicate alarm conditions in the power system. The merging unit uses alarm points to place these messages on the LCD.

*Figure 11* shows a sample alarm points screen. The merging unit is capable of displaying as many as 66 alarm points. The merging unit automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. The alarm points message is user-configurable and can be triggered using inputs, communication, or the SEL-2600 or be conditional by using powerful SELOGIC control equations. The asterisk next to the alarm point indicates an active alarm. The inactive alarms can be cleared using the front-panel navigation pushbuttons.
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.

Front- and Rear-Panel Diagrams

![4U Front Panel, Rack-Mount Option](image1.png)

![4U Rear Panel, High-Speed INTC (200 Slot) Interface Board](image2.png)
Figure 14  6U Rear Panel, Connectorized Terminal Block, Three (INC, INT7, and INTE) I/O Board Option
Dimensions

**RACK-MOUNT CHASSIS**

- Rack Mount
- Projection Rack Mount
- Top: 4.15 (105.9) in
- Side: 1.12 (28.4) in
- Front:
  - A: 16.31 (465.1) in
  - B: 19.00 (482.6) in
- Dimensions: A, B, C, D, E

**PANEL-MOUNT CHASSIS**

- Top: 4.15 (105.9) in
- Front:
  - E: 18.31 (465.1) in
- Side:
  - D: 17.63 (447.8) in
- Panel Cutout
- Numbers: A, B, C, D, E

*ADD 0.30 (7.6) FOR CONNECTORIZED RELAYS*

---

**Figure 15** SEL-401 Dimensions for Rack- and Panel-Mount Models

---

Schweitzer Engineering Laboratories, Inc.  SEL-401 Data Sheet
Specifications

Note: The SEL-401 has a processing delay of about 1 ms. Protection and control operating times of an SV relay that receives SV messages from an SEL-401 are delayed by the total network delays, which includes the processing delay. Use caution when setting the SV relay coordination times to account for the total network delay.

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

AC Analog Inputs
Sampling Rate: 8 kHz

AC Current Input (Secondary Circuit)
Current Range Rating (With DC Offset at X/R = 10, 1.5 Cycles)
1 A Nominal: 0.1–18.2 A
5 A Nominal: 0.5–91 A
Continuous Thermal Rating
1 A Nominal: 3 A
5 A Nominal: 15 A
Saturation Current (Linear) Rating
1 A Nominal: 20 A
5 A Nominal: 100 A
A/D Current Limit (peak)
1 A Nominal: 49.5 A
5 A Nominal: 247.5 A
Note: Signal clipping can occur beyond this limit.

One-Second Thermal Rating
1 A Nominal: 100 A
5 A Nominal: 500 A

One-Cycle Thermal Rating
1 A Nominal: 250 A peak
5 A Nominal: 1250 A peak

Burden Rating
1 A Nominal: ≤0.1 VA @ 1 A
5 A Nominal: ≤0.5 VA @ 5 A

AC Voltage Inputs
Three-phase, four-wire (wye) connections are supported.
Rated Voltage Range: 67–250 V_LN
Operation Voltage Range: 0–300 V_LN
Ten-Second Thermal Rating: 600 Vac
Burden: ≤0.1 VA @ 125 V

Frequency and Rotation
Nominal Frequency: 50 ± 5 Hz
Rating: 60 ± 5 Hz
Phase Rotation: ABC or ACB
Frequency Tracking Range: ≤60 Hz = 40 Hz
>65 Hz = 65 Hz
Maximum slew rate: 15 Hz/s

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 Vdc
Rated Frequency: 50/60 Hz
Vdc Input Ripple: 15% per IEC 60255-26:2013
Interruption: 14 ms at 48 Vdc, 160 ms at 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: 85–264 Vac
Rated Frequency: 50/60 Hz
Vdc Input Ripple: 15% per IEC 60255-26:2013
Interruption: 46 ms at 125 Vdc, 250 ms at 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 A
Limit Making Capacity: 1000 W at 250 Vdc (L/R = 40 ms)
Mechanical Endurance: 10,000 operations

Standard
Rated Voltage: 24–250 Vdc
Operational Voltage Range: 0–300 Vdc
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
264 Vrms continuous voltage
300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance: 10,000 operations
10 operations in 4 seconds, 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>0.75 Adc</td>
<td>0.75 Adc</td>
</tr>
<tr>
<td>48 Vdc</td>
<td>0.63 Adc</td>
<td>0.63 Adc</td>
</tr>
<tr>
<td>125 Vdc</td>
<td>0.30 Adc</td>
<td>0.30 Adc</td>
</tr>
<tr>
<td>250 Vdc</td>
<td>0.20 Adc</td>
<td>0.20 Adc</td>
</tr>
<tr>
<td>110 Vrms</td>
<td>0.30 Arms</td>
<td>0.30 Arms</td>
</tr>
<tr>
<td>240 Vrms</td>
<td>0.20 Arms</td>
<td>0.20 Arms</td>
</tr>
</tbody>
</table>

Rated Voltage
Resistive Break
Inductive Break L/R = 40 ms (DC) PF = 0.4 (AC)
24 Vdc 10 Adc 10 Adc (L/R = 40 ms)
48 Vdc 10 Adc 10 Adc (L/R = 40 ms)
125 Vdc 10 Adc 10 Adc (L/R = 40 ms)
250 Vdc 10 Adc 10 Adc (L/R = 20 ms)

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)
Main Board: No I/O
INT2, INT7, INT8, and INTE Interface Boards: 8 inputs with no shared terminals
INT4, INTC, and INTD Interface Boards: 18 inputs with shared terminals
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; Dropout <14.4 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 Vac: Pickup 16.4–30.0 Vac rms; Dropout <10.1 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 150.3–264.0 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

Communications Ports
EIA-232: 1 front and 3 rear
Serial Data Speed: 300–57600 bps
Ethernet Card Slot for Optional 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-B Input—Serial Port 1
Input: Demodulated IRIG-B
Rated I/O Voltage: 5 Vdc
Operating Voltage Range: 0–8 Vdc
Logic High Threshold: ≤2.8 Vdc
Logic Low Threshold: ≥0.8 Vdc
Input Impedance: 2.5 k\( \Omega \)
Dielectric Test Voltage 0.5 kVac

IRIG-B Input—BNC Connector
Input: Demodulated IRIG-B
Rated I/O Voltage: 5 Vdc
Operating Voltage Range: 0–8 Vdc
Logic High Threshold: ≤2.2 Vdc
Logic Low Threshold: ≥0.8 Vdc
Input Impedance: 50 \( \Omega \) or >1 k\( \Omega \)

Operating Temperature
–40° to +85°C (–40° to +185°F)
Note: LCD contrast impaired for temperatures below –20° and above +70°C. Stated temperature ranges not applicable to UL applications.

Humidity
5% to 95% without condensation

Weight (Maximum)
4U Rack Unit: 10.2 kg (22.5 lb)
5U Rack Unit: 11.8 kg (26 lb)
6U Rack Unit: 13.5 kg (30 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), 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) Connection</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) Connection</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>

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 M\( \Omega \) @ 500 Vdc

Protective Bonding:
IEC 60255-27:2013, Section 10.6.4.5.2
<0.1 \( \Omega \) @ 12 Vdc, 30 A for 1 min

Object Penetration:
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
IEEE C37.90-2005

Surge Withstand Capability (SWC):
IEC 61000-4-18:2006 + A:2010
IEEE C37.90.1-2012
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:
IEC 61000-4-2:2004
20 V/m (≥15 V/m, 80% AM, 1 kHz)
Sweep: 80 MHz to 1 GHz
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<sub>L-L</sub>
    - ±4 kV<sub>L-E</sub>
    - ±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

Surge Immunity:
- **IEC 61000-4-4:2012**
- **Zone A:**
  - ±2 kV: Communication ports
  - ±4 kV: All other 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<sub>RMS</sub>
    - Common Mode: 300 V<sub>RMS</sub>

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

Power Supply Immunity:
- **IEC 61000-4-11:2004**
- **IEC 61000-4-17:1999/A1:2001/A2:2008**
- **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

Environmental
- **Product Standards:**
  - **IEC 60255-27-2013**
- **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
- **Dry Heat, Operational:**
  - **IEC 60068-2-2:2007**
  - Test Bd: 16 hours at +85°C
- **Dry Heat, Storage:**
  - **IEC 60068-2-2:2007**
  - 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 60068-2-78:2013**
  - Severity: 93% RH, +40°C, 10 days

Vibration Resistance:
- **IEC 60255-21-1:1988**
- **Class 2 Endurance, Class 2 Response**

Shock Resistance:
- **IEC 60255-21-2:1988**
- **Class 1 Shock Withstand, Class 1 Bump Withstand, Class 2 Shock Response**

Seismic:
- **IEC 60255-21-3:1993**
- **Class 2 Quake Response**

Event Reports

High-Resolution Data
- **Rate:**
  - 8000 samples/second
  - 4000 samples/second
  - 2000 samples/second
  - 1000 samples/second

**Output Format:** Binary COMTRADE

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

Event Reports
- **Storage:**
  - 35 quarter-second events or 24 half-second events

**Maximum Duration:**
- Five records of 24 seconds each of 4000 samples/second

Event Summary
- **Storage:**
  - 128 histories

Breaker History
- **Storage:**
  - 100 summaries

Sequential Events Recorder (SER)
- **Storage:**
  - 1000 entries

Trigger Elements:
- 250 relay elements

Resolution:
- 0.5 ms for contact inputs
- 1/8 cycle for all elements

Processing Specifications

AC Voltage and Current Inputs
- 8000 samples per second, 3 dB low-pass analog filter cutoff 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
- Reclosing logic runs once per power system cycle.

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

Phase Instantaneous/Definite-Time Overcurrent Elements

**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

**Transient Overreach:**
- <5% of pickup

**Time Delay:**
- 0.00–16000.00 cycles, 0.125 cycle steps
**Timer Accuracy:** ±0.125 cycle plus ±0.1% of setting

**Maximum Operating Time:** 1.5 cycles

*Operate time is relay processing time only and does not include SV delay, 1.5 ms minimal.

**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 BFIDO, BFISPn)

0–1000 cycles, 0.125 cycle steps (BFIDO, BFISPn)

**Time-Delay Accuracy:** 0.125 cycle plus ± 0.1% of setting

**Bay Control**

- **Breakers:** 2 (control), 3rd indication
- **Disconnects (Isolators):** 10 (maximum)

**Timers Setting Range:** 1–99999 cycles, 1-cycle steps

**Time-Delay Accuracy:** ±0.1% of setting, ± 0.125 cycle

**Station DC Battery System Monitor Specifications**

**Rated Voltage:** 24–250 Vdc

**Operational Voltage Range:** 0–300 Vdc

**Sampling Rate:** DC1: 2 kHz
DC2: 1 kHz

**Processing Rate:** 1/8 cycle

**Operating Time:** Less than 1.5 cycles (all elements except ac ripple)
Less than 1.5 seconds (ac ripple element)

**Setting Range**

- 15–300 Vdc, 1 Vdc steps (all elements except ac ripple)
- 1–300 Vac, 1 Vac steps (ac ripple element)

**Accuracy**

- **Pickup Accuracy:** ±3% ± 2 Vdc (all elements except ac ripple)
- ±10% ± 2 Vac (ac ripple element)

**Metering Accuracy**

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

**Currents**

**Phase Current 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 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 • INOM to 3.0 • INOM

**Voltage**

**Phase and Phase-to-Phase Voltage Magnitude:** ±0.1% (33.5–300 V L-N)

**Phase and Phase-to-Phase Voltage Angle:** ±0.5° (33.5–300 V L-N)

**Sequence Voltage Magnitude:** ±0.1% (33.5–300 V L-N)

**Sequence Voltage Angle:** ±0.5° (33.5–300 V L-N)

**Frequency (40–65 Hz)**

**Accuracy:** ±0.01 Hz

**Power**

- **MW (P), Per Phase (Wye), 3φ (Wye or Delta) Per Terminal**
  ±1% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
  ±0.7% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)

- **MVA (S), Per Phase (Wye), 3φ (Wye or Delta) Per Terminal**
  ±1% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
  ±0.7% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)

- **PF, Per Phase (Wye), 3φ (Wye or Delta) Per Terminal**
  ±1% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
  ±0.7% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)

**Synchrophasors**

**Number of Synchrophasor Data Streams:** 5

**Number of Synchrophasors for Each Stream:**
- 15 phase synchrophasors (6 voltage and 9 currents)
- 5 positive-sequence synchrophasors (2 voltage and 3 currents)

**Number of User Analogs for Each Stream:** 16 (any analog quantity)

**Number of User Digitals for Each Stream:** 64 (any Relay Word bit)

**Synchrophasor Data Rate:** As many as 60 messages per second

**Synchrophasor Accuracy**

- **Voltage Accuracy:** ±1% Total Vector Error (TVE)
  Range 30–150 V, INOM ±5 Hz
- **Current Accuracy:** ±1% Total Vector Error (TVE)
  Range (0.1–20) • INOM A, INOM ± 5 Hz

**Synchrophasor Data Recording:** Records as much as 120 s

IEEE C37.232 File Naming Convention
We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com