SEL-651RA Recloser Control

Traditional Retrofit (14-Pin) Recloser Control With Ethernet

New Features

The following features were added for intertie protection and control, compliant with IEEE Standard 1547-2018 "IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power System Interfaces."

- **Fast Rate-of-Change-of-Frequency and Vector Shift Elements.** Swiftly detect islanding conditions and disconnect distributed energy resources (DER) before any possible autoreclosing of the electric power system (EPS).
- **Longer Seconds-Based Time Delays for Frequency Elements.** Frequency elements have adequate time-delay setting range for qualifying tripping for abnormal EPS frequency. Similarly, return of normal EPS frequency is qualified before the intertie (recloser) is closed. Seconds-based timing is immune to frequency changes and allows tripping time to be absolute.
- **Additional Voltage Elements.** Adequate number of voltage elements allows for qualifying tripping for abnormal EPS voltage. Similarly, return of normal EPS voltage is qualified before the intertie (recloser) is closed.
- **Autosynchronism Element Works in Tandem With Synchronism-Check Element.** Autosynchronism element frequency and voltage control outputs automatically bring DER (versus EPS) slip frequency, phase angle, and voltage magnitude differences within allowable limits for synchronism-check closing of the intertie (recloser).

Key Features and Benefits

- **Six Voltage Inputs.** Make better switching decisions and execute complex automatic network reconfiguration schemes. Optional six voltage inputs provide information about voltage on both sides of the recloser for each phase.
- **Low-Energy Analog (LEA) Voltage Inputs.** Reduce costs and save space with optional three or six LEA voltage inputs. Several versions of LEAs are supported, including those that are integral to popular reclosers as well as externally installed.
- **Ethernet and USB Ports.** Provide DNP3, Modbus®, IEC 61850, FTP, and SNTP capabilities by using single fiber, dual copper, dual fiber, or a combination of one copper and one fiber-optic Ethernet ports. You can use the front-panel USB port to retrieve events, settings, and templates quickly.
- **Secure Ethernet Communication.** Use Media Access Control Security (MACsec) to provide confidential communications and maintain message integrity among devices.
- **Built-in Power Supply.** Power accessories such as a radio with the 12 Vdc (15 W continuous) auxiliary power supply.
- **Arc Sense™ Technology.** Detect downed conductors and high-impedance faults with the optional Arc Sense technology.
- **Second-Harmonic Blocking.** Detect transformer energization with the second-harmonic blocking elements. Use the output of the harmonic detection elements to block selected tripping elements until the inrush conditions subside.
- **Rate-of-Change-of-Frequency Elements.** Detect rapid frequency changes to initiate load shedding or network decoupling.
- **Harmonic and RMS Metering.** Monitor the system power quality based on Total Harmonic Distortion (THD) with harmonic metering as high as the 16th harmonic, following IEEE 519-2014, and root-mean-square (rms) metering.
- **Configurable Power Elements.** Determine the real or reactive power flow direction and magnitude. Apply the elements at system intertie points, capacitor bank installations, and similar locations.
- **Comprehensive SELOGIC Capabilities.** Take advantage of 64 SELOGIC control equation variables, 64 Math Variables, 32 SELOGIC Latches, and 16 SELOGIC counters. Account for time of year, week, or day by using Analog Comparators and Analog Quantities in SELOGIC to adapt to seasonal environment or load changes (e.g., fire season, pumping season, peak load time, etc.).
- **IEC 61850 Communications Protocol.** Apply optional IEC 61850 communications protocol for guaranteed performance of substation automation and control. Streamline configurations of IEC 61850 enabled controls with ACSELERATOR Architect® SEL-5032 Software.
- **Simple Network Time Protocol (SNTP).** Simplify wiring and installation by receiving a time signal over existing Ethernet networks. SNTP can be used as a backup to more accurate IRIG-B time synchronization. The 5 ms accuracy is ideal for basic time synchronization.
- **Built-in Web Server.** Access basic control module information on a standard Ethernet network with the built-in web server. View control module status, Sequential Events Recorder (SER) data, metering information, and settings for easy access within a local network. Web server access requires a password and is limited to read-only viewing of information or to secure remote firmware upgrades requiring an additional login level.
- **Digitally Signed Firmware Upgrade.** Upload digitally signed firmware over Ethernet or serial connection. Secure algorithms guarantee the validity of the firmware file.
- **Built-in IEEE C37.118 Synchrophasors.** Apply synchrophasors in distribution applications to improve interconnection of distributed generation, optimize Volts/VAR control, expedite event analysis, and identify phasing.
- **Extensive Event Data and Fast Sampling Rate.** See more pre-fault and post-fault data with 60-cycle-long event reports. High-resolution, 128-samples-per-cycle analog data allow detailed event analysis.
- **COMTRADE Event Reports.** Capture standard and high-impedance event reports in COMTRADE standard file format.
- **Eight Settings Groups.** Use the eight settings groups to easily configure multiple applications in one settings file and to fit operational situations.
- **EZ Settings.** Use EZ settings to make configuration of traditional recloser control functions quick and simple.
- **Design Templates.** Quickly commission recloser controls by using just the settings you need. Design custom templates using the licensed version of ACSELERATOR QuickSet® SEL-5030 Software for your specific applications. Templates are stored on the recloser control for easy access when making settings changes.

- **MIRRORED BITS® Communications.** Provide fast and reliable control-to-control (or control-to-relay) communication for advanced communications-assisted protection, network reconfiguration, pilot protection, and restoration schemes.
- **Modbus®, DNP3, and ASCII Protocols.** Integrate into new or existing networks. SCADA links, local HMI, and dial-in modems can access important control data with these popular protocols.
- **Fault Location.** Take advantage of accurate distance-to-fault measurements by using the impedance-based fault locator.
- **Recloser Wear Monitoring.** Monitor breaker or recloser contact wear for each phase to assist in efficient maintenance planning and troubleshooting.
- **Metering and Monitoring.** Eliminate the need for external meters with included accurate metering. The control reports fundamental, power factor, rms, energy, maximum/minimum, and instantaneous/peak demand metering data.

Compatibility Overview: Three-Phase Reclosers

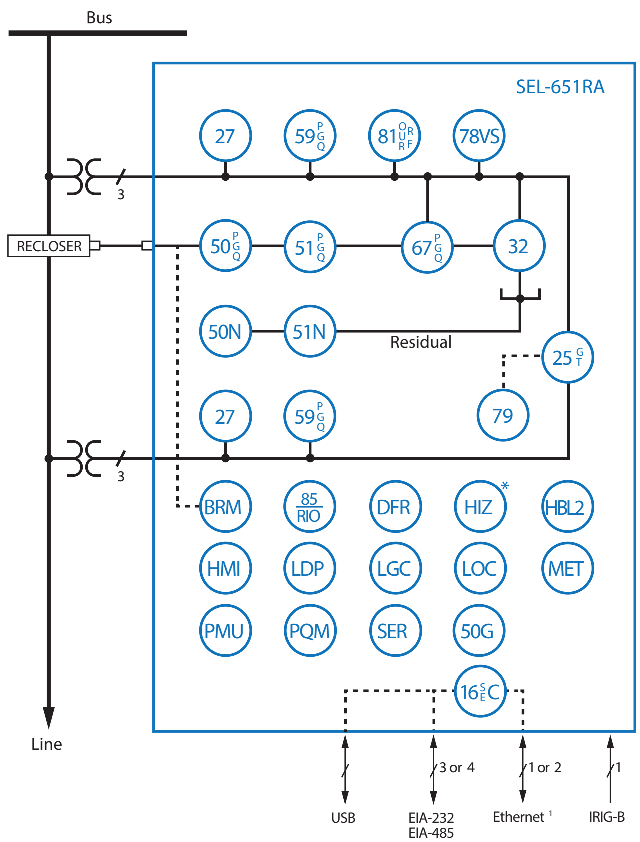
The SEL-651RA Recloser Control connects to the following three-phase reclosers:

- Traditional Retrofit (Eaton): CXE, RE, RVE, RXE, VSA, VSO, VWE, VWVE 27, VWVE 38X, WE, WVE 27, WVE 38X, Auxiliary-Powered Eaton NOVA™
- G&W Viper®-S
- Whipp & Bourne GVR (when equipped with interface module)

Certification

The current IEEE C37.60 test certificates are available on the SEL website at selinc.com.

Functional Overview and General Connections



ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
16 SEC	Access Security (Serial, Ethernet)
25 (G, T)	Synchronism Check (Generator, Intertie)
27	Undervoltage
32	Directional Power
50G	Best Choice Ground
50N	Inst./Def.-Time Neutral Overcurrent
50 (P, G, Q)	Inst./Def.-Time Overcurrent (Phase, Ground, Neg. Seq.)
51 (P, G, Q)	Time-Overcurrent (Phase, Ground, Neg. Seq.)
51N	Neutral Time-Overcurrent
59 (P, G, Q)	Overvoltage (Phase, Zero Seq., Neg. Seq.)
67 (P, G, Q)	Directional Overcurrent (Phase, Ground, Neg. Seq.)
78VS	Vector Shift
79	Autoreclosing
81 (O, U, R, RF)	Frequency (Over, Under, Rate, Fast Rate)
85 RIO	SEL MIRRORED BITS Communications
DFR	Event Reports
HIZ*	SEL Arc Sense Technology (AST)
HMI	Operator Interface
LGC	SELOGIC Control Equations
MET	High-Accuracy Metering
PMU	Synchrophasors
PQM	Voltage Sag, Swell, and Interruption
SER	Sequential Events Recorder
ADDITIONAL FUNCTIONS	
BRM	Breaker Wear Monitor
HBL2	Second-Harmonic Blocking
LDP	Load Data Profiling
LOC	Fault Locator

[1] Copper or Fiber Optic * Optional Feature

Figure 1 Functional Overview

EZ Settings Compatible With SEL-351R Recloser Controls

There is one-to-one correspondence of EZ settings in the SEL-651RA and SEL-351R. EZ settings of SEL-351R can be translated to SEL-651RA easily.

For traditional recloser functions, the SEL-651RA is easy to set. Only settings such as minimum trip pickup, curve type, and reclose interval are necessary. These settings are made at an EZ (easy) access level. SELOGIC control equations cannot be changed at this access level.

Control logic is preconfigured at the factory. To customize the logic for advanced functions, the SELOGIC control equations must be reprogrammed.

Control Cable

The standard 14-pin control cable from the recloser attaches at the bottom of the SEL-651RA enclosure to a standard receptacle. The control cable brings secondary current and recloser status to the SEL-651RA, and takes trip/close signals out to the recloser (see *Figure 2*).

Voltage Inputs

Connect voltages on both sides of the recloser, as shown in *Figure 3*, for such schemes as automatic network reconfiguration (*Figure 13*) and synchronism check. Select the three-phase voltage channel (VY or VZ) to operate features such as the following:

- ➤ Fault locating
- ➤ Load encroachment
- ➤ Power elements
- ➤ Voltage sag, swell, and interruption recording

Order the VY and VZ voltage channels as optional LEA voltage inputs. This option allows you to connect the low-level voltage outputs from less-costly power system voltage transducers, including those built into many of the popular reclosers, to LEA voltage inputs on the SEL-651RA.

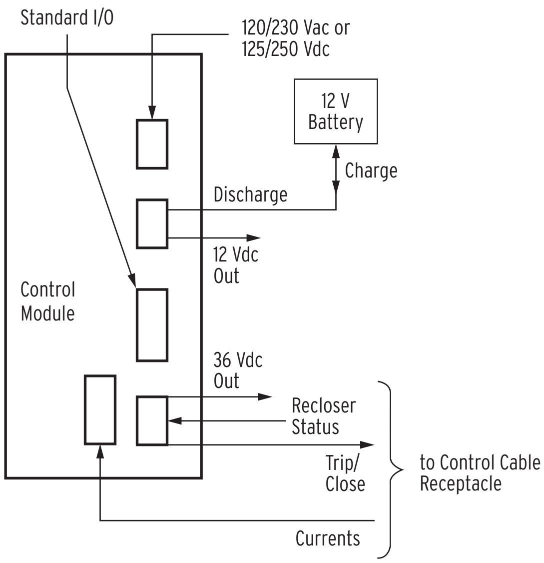


Figure 2 Major Connections to and From SEL-651RA

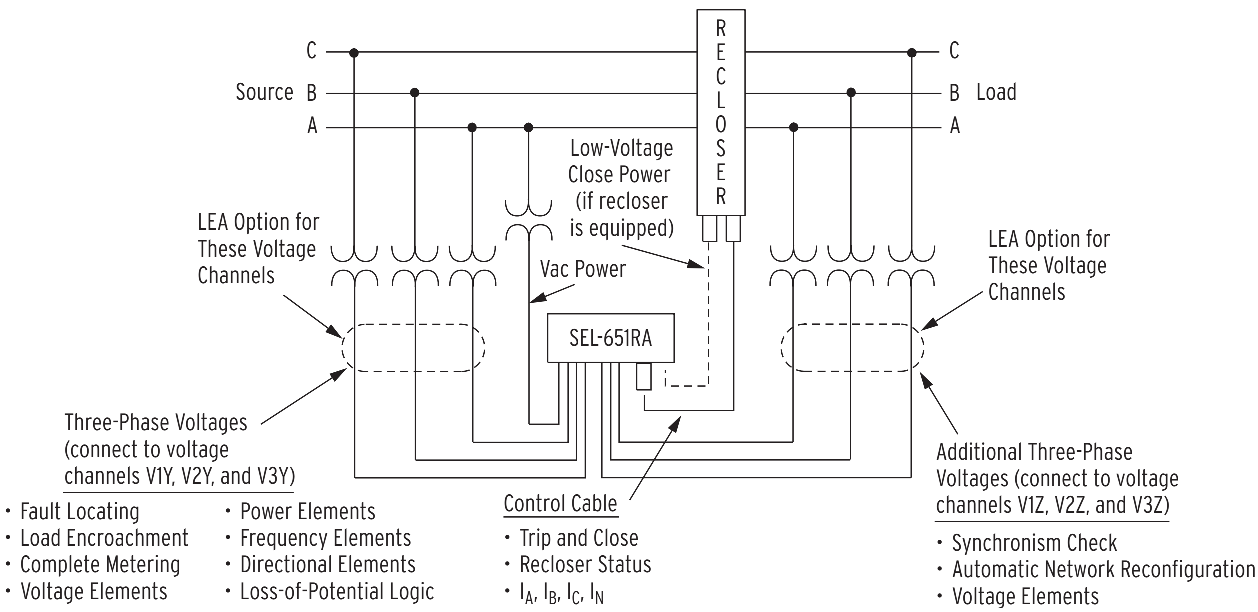


Figure 3 Connect Three-Phase Load and Source Voltages to the SEL-651RA

Control Power Input

The SEL-651RA can be powered with 120/230 Vac or 125/250 Vdc. A ground fault circuit interrupter (GFCI) convenience outlet is available as an orderable option.

The control module, its 12 Vdc auxiliary supply, and its internal trip/close capacitors are powered by the incoming control power. A 12 V battery, optional with an SEL enclosure, provides power when the incoming control power is unavailable.\

Automation and Communication

Communications Connection Options

The base model SEL-651RA is equipped with one USB Type-B port, three independently operated EIA-232 serial ports, and one EIA-485 port. Ethernet port ordering options include the following:

- ➤ Single 100BASE-FX optical Ethernet port
- ➤ Dual redundant 10/100BASE-T copper Ethernet ports
- ➤ Dual redundant 100BASE-FX optical Ethernet ports
- ➤ Single 10/100BASE-T copper and single 100BASE-FX optical Ethernet ports (not available with the EIA-485 port)

NOTE: The special driver required for USB communication is available for download at selinc.com.

Establish communication by connecting computers, modems, protocol converters, data concentrators, port switchers, or communications processors. Connect multiple SEL-651RA controls to an SEL communications processor, an SEL real-time automation controller (RTAC), an SEL computing platform, or to an SEL synchrophasor vector processor for advanced data collection, protection, and control schemes (see *Figure 4*).

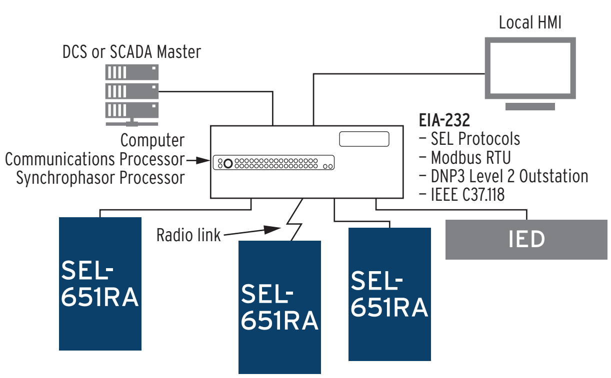


Figure 4 Typical Serial Communications Architecture

SEL manufactures a variety of standard cables for connecting SEL-651RA to many external devices. Consult your SEL representative for more information on cable availability. The SEL-651RA can communicate directly with SCADA systems, computers, and RTUs via serial or Ethernet port for local or remote communications (see *Figure 5*).

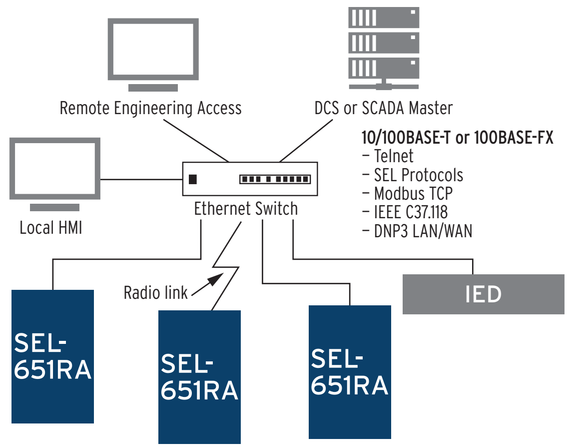


Figure 5 Typical Ethernet Communications Architecture

Serial Communication

The SEL-651RA retains all of the serial communications capabilities of the SEL-351R model and adds one USB Type-B port for fast and convenient local access. Use any communications processor software that emulates a standard terminal system.

Ethernet Communication

Use the Ethernet ports for local and remote engineering access, SCADA, real-time protection and control, loop restoration, islanding detection, blocking and fast bus-tripping schemes, and firmware upgrades. High-speed Ethernet ports are valuable for engineering access and control setup. Download a 60-cycle, 128-sample-per-cycle event report in as fast as 40 seconds. Upgrade firmware in as fast as 55 seconds from initiation to Control Enabled.

Go beyond local engineering access and connect optional dual Ethernet ports to increase network reliability and availability (*Figure 7* and *Figure 8*). The configuration shown in *Figure 7* uses an Ethernet switch inside the control to bridge network connections and form a self-healing ring as part of a managed network. *Figure 8* shows how to connect the control for fully redundant fast-failover configuration. In either configuration, no single point of failure will prevent communication with the control. *Table 1* lists available protocols.

The SEL-651RA secures Ethernet traffic by using MACsec (*Figure 6*). MACsec is a nonroutable "hop-by-hop" cryptographic protocol that protects Ethernet frames starting at the data-link layer (OSI Layer 2). When MACsec is enabled, a bidirectional secure link is established after an exchange and verification of security keys between the two connected devices. The MACsec protocol provides integrity, authenticity, replay prevention, and optional confidentiality to communications. The automated key management system is the MACsec Key Agreement (MKA protocol). The goal of the MKA protocol is to facilitate and automate the commissioning, management, and scalability of MACsec on an LAN.

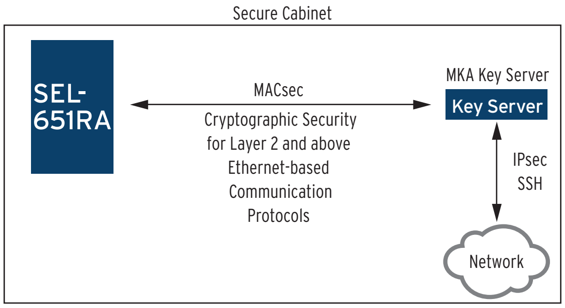


Figure 6 MACsec Secure Cabinet

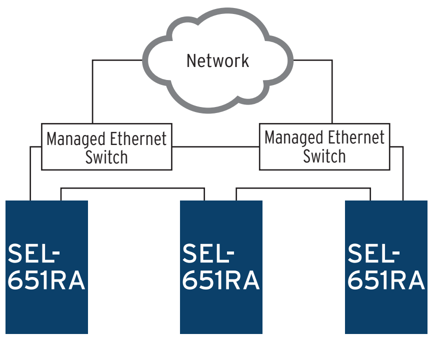


Figure 7 Self-Healing Ring Using Internal Ethernet Switch

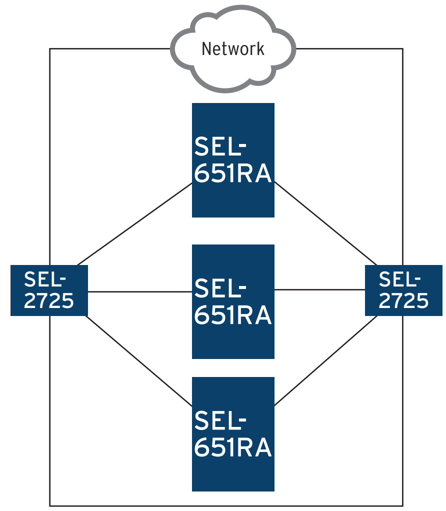


Figure 8 Failover Network Topology

Table 1 Available Communications Protocols (Sheet 1 of 2)

Type	Description
IEC 61850	Ethernet-based international standard for interoperability among intelligent devices in a substation. Operates remote bits, breaker controls, and inputs and outputs (I/O). Monitors Relay Word bits and analog quantities. Use MMS file transfer to retrieve COMTRADE file format event reports.
Simple ASCII	Plain language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain control data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
File Transfer Protocol (FTP)	Provides the ability to read and write available settings files and read COMTRADE file format event reports from the recloser control over Ethernet.
Fast SER Protocol	Provides serial or Ethernet SER data transfers with original time stamps to an automated data collection system.
Extended Fast Meter and Fast Operate	Serial or Telnet binary protocol for machine-to-machine communication. Quickly updates SEL communications processors, remote terminal units (RTUs), and other substation devices with metering information, control element and 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 binary SCADA metering information is not lost while an engineer or technician is transferring an event report or communicating with the control by using ASCII communications through the same communications port.
Modbus RTU or TCP	Serial or Ethernet-based Modbus with point remapping. Includes access to metering data, protection elements, contact I/O, targets, summary events, and settings groups.

Table 1 Available Communications Protocols (Sheet 2 of 2)

Type	Description
DNP3 Serial or LAN/WAN	Serial or Ethernet-based Distributed Network Protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, summary event reports, and settings groups.
IEEE C37.118	Serial or Ethernet Phasor Measurement Protocol. Streams synchrophasor data to archiving historian for post-disturbance analysis, to visualization software for real-time monitoring, or to synchrophasor data processor for real-time control.

Flexible Control Logic and Integration Features

Use the SEL-651RA control logic to provide the following improvements:

- Replace traditional panel control switches
- Eliminate RTU-to-control wiring
- Replace traditional latching relays
- Replace traditional indicating panel lights
- Replace external timers

Eliminate Traditional Panel Control Switches

- Twelve programmable operator control pushbuttons.
  - Use to implement your control scheme via SELOGIC control equations.
- Change operator control pushbutton labeling to suit your control scheme (*Figure 23*).
- Sixteen local control points.
  - Set, clear, or pulse local control points via the front-panel human-machine interface and display (*Figure 23*).
  - Program the local control points to implement your control scheme via SELOGIC control equations.
  - Use the local control points for extra functions such as trip testing or scheme enabling/ disabling.
  - Define custom messages (e.g., `COLD LOAD PICKUP ENABLED`) to report power system or control module conditions on the liquid crystal display (LCD).
  - Control which messages are displayed via SELOGIC control equations by driving the LCD display via any logic point in the control module. Set as many as 32 programmable display messages.

Replace RTU-to-Control Wiring by Using 32 Remote Control Points

- Set, clear, or pulse remote control points via serial port commands.
- Incorporate these points into your control scheme via SELOGIC control equations.
- Use them for SCADA-type control operations such as trip, close, and settings group selection.

Replace Traditional Latching Relays by Using 32 Latching Control Points

- Use these points for functions such as remote control enable.
- Program latch set and latch reset conditions with SELOGIC control equations. The latching control points retain states when the control loses power.
- Set or reset the latching control points via operator control pushbuttons, control inputs, remote control points, local control points, or any programmable logic condition.
- Toggle latches to the opposite state with each press of the operator control pushbutton. In the factory settings, the latching control points give many of the operator control pushbuttons their enable/ disable or on/off mode of operation.

Replace Traditional Indicating Panel Lights With 24 Status and Target LEDs

Change light-emitting diode (LED) labeling to suit your control scheme (*Figure 23*). Note that the aforementioned 12 programmable operator control pushbuttons also have programmable LEDs associated with them.

Replace External Timers With 64 General Purpose Timers and 16 General Purpose Up/Down Counters

- Eliminate external timers for custom protection or control schemes with 64 general purpose SELOGIC control equation timers.
- Set time-delay pickup and dropout settings independently for each timer.
- Program each timer input with any element (e.g., time qualify a voltage element).
- Assign the timer output to trip logic or other control scheme logic.
- Use the 16 general purpose up/down counters to emulate the features of motor-driven timers, which can stall in place indefinitely and then continue timing when appropriate user-set conditions exist.

SELOGIC Control Equations With Expanded Capabilities

The SEL-651RA is factory-set for use in many situations without requiring additional logic. For complex or unique applications, expanded SELOGIC functions allow superior flexibility and put control logic into the hands of the protection engineer.

With expanded SELOGIC control equations you can do the following:

- ➤ Assign the control inputs to suit your application
- ➤ Logically combine selected control elements for various control functions
- ➤ Assign outputs to your logic functions

To program SELOGIC control equations, combine control elements, inputs, and outputs with SELOGIC control equation operators (see *Table 2*). You can use any element in the Relay Word in these equations. Add programmable control functions to your protection and automation systems, and use analog values in conditional logic statements.

Table 2 SELOGIC Control Equation Operators

Operator Type	Operators	Comments
Boolean	AND, OR, NOT	Allows combination of measuring units.
Edge Detection	F_TRIG, R_TRIG	Operates at the change of state of an internal function.
Comparison	>, >=, =, <=, <, < >	
Precedence Control	( )	Allows multiple and nested sets of parentheses.
Comment	#	Provides for easy documentation of control and protection logic.

QuickSet With Design Features

Use QuickSet to develop settings offline. The system automatically checks interrelated settings and highlights out-of-range settings. You can transfer settings created offline by using a PC communications link with the SEL-651RA. The software also converts event reports to oscillograms with time-coordinated element assertion and phasor/sequence element diagrams. View real-time phasors via QuickSet. The QuickSet interface supports Microsoft® Windows® 7 and Windows Server® 2008 operating systems.

With the licensed version of QuickSet, you can commission recloser controls by using only the settings you need. This version allows you to create custom Application Designs to quickly implement advanced schemes such as automatic network reconfiguration. Application Designs hide settings you do not want changed (such as SELOGIC control equations), while making visible just the minimum necessary settings (such as timer and pickup settings) to implement the scheme.

All settings can be aliased and manipulated mathematically for simple end-user interfacing. You can also define custom notes and settings ranges. The Application Designs enhance security by allowing access to only a specified group of settings. Create Application Designs that include the most commonly used control features and settings (see *Figure 9* for example) and watch commissioning times drop drastically. Design custom templates by using QuickSet for your specific applications and then store the templates on the recloser control for easy access when making settings changes.

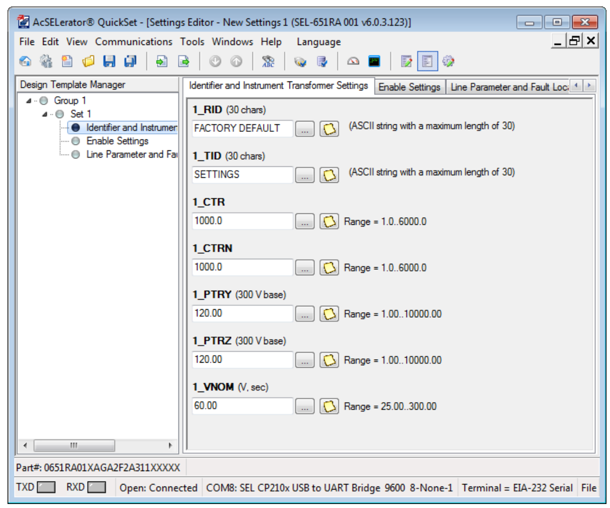


Figure 9 Example Application Designs

MIRRORED BITS Communications

The SEL-patented MIRRORED BITS communications technology provides bidirectional recloser control-to-recloser control digital communications. MIRRORED BITS can operate independently on one or two EIA-232 serial ports on a single SEL-651RA. With MIRRORED BITS operating on two serial ports, there is communication upstream and downstream from the SEL-651RA site.

This bidirectional digital communication creates eight additional virtual outputs (transmitted MIRRORED BITS) and eight additional virtual inputs (received MIRRORED BITS) for each serial port operating in MIRRORED BITS mode (see *Figure 10*). Use these MIRRORED BITS to transmit/receive information between an upstream recloser control (or relay) and a downstream recloser control to enhance coordination and achieve faster tripping for downstream faults. MIRRORED BITS technology also helps reduce total scheme operating time by eliminating the need to assert output contacts to transmit information.

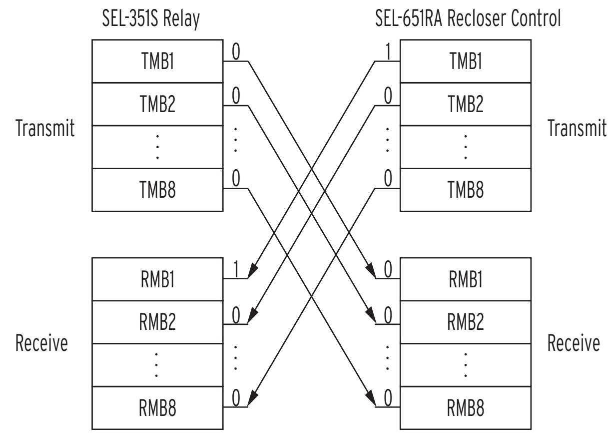


Figure 10 **Mirrored Bits Transmit and Receive Bits**

Integrated Web Server

An embedded web server is included in every SEL-651RA. Browse to the recloser control with any standard web browser to safely read settings, verify recloser control self-test status, inspect meter reports, and read recloser control configuration and event history. The web server does not allow control or modification actions at Access Level 1 and lower, so you can be confident that an inadvertent button press will have no adverse effects. *Figure 11* shows the settings display webpage.

The web server allows users with the appropriate engineering access level (2AC) to upgrade the firmware over an Ethernet connection. An Ethernet port setting enables or disables this feature, with the option of requiring front-panel confirmation when the file is completely uploaded.

The SEL-651RA firmware files contain cryptographic signatures that enable the SEL-651RA to recognize official SEL firmware. A digital signature, computed using the SHA-256 Secure Hash Algorithm, is appended to the compressed firmware file. Once the firmware is fully uploaded to the control, the control verifies the signature by using a Digital Signature Algorithm security key that SEL stored on the device. If the signature is valid, the firmware is upgraded in the control. If the control cannot verify the signature, it reverts back to the previously installed firmware.

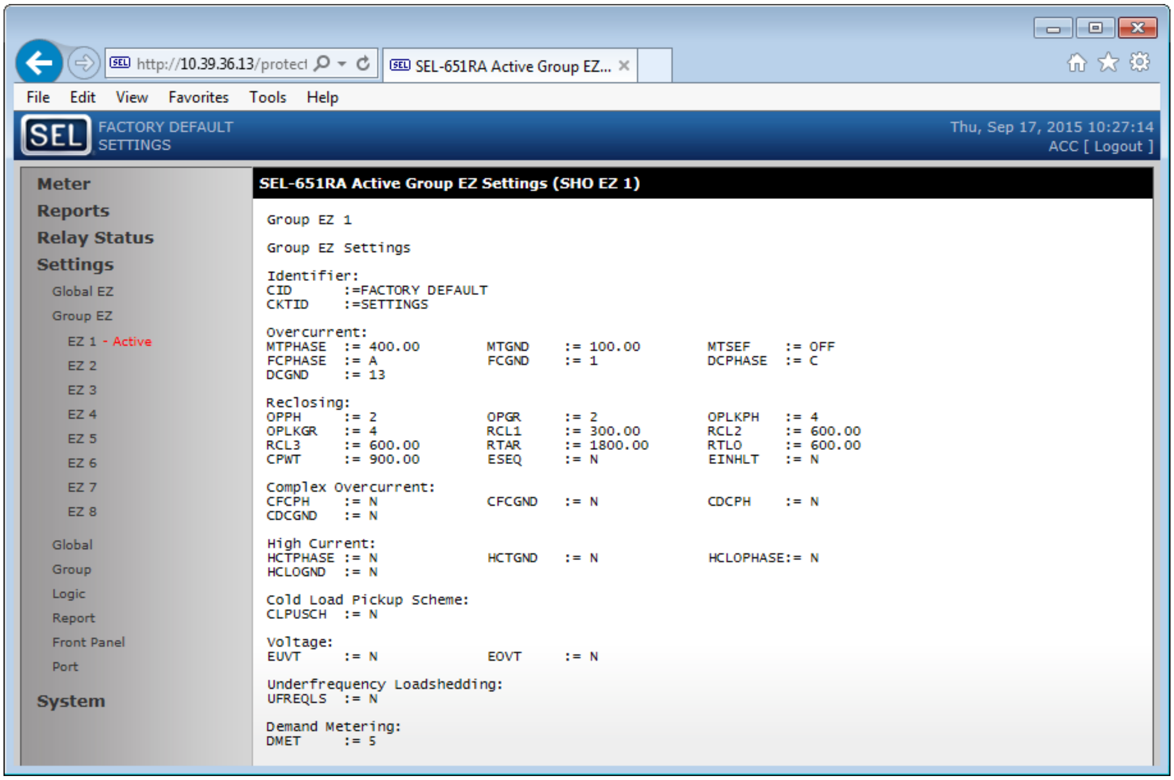


Figure 11 Settings Display Webpage

Applications

Automatic Network Reconfiguration

Automatic network reconfiguration augments system reliability by automatically isolating faulted line sections and restoring service to unaffected areas of the system. In the simple automatic network reconfiguration implementation in *Figure 12*, there is no direct communication between the recloser control sites and there is minimal voltage sensing. For the sample fault in *Figure 12*, system isolation and restoration are methodically accomplished with the following:

- ➤ Sectionalizing recloser tripping on sensed dead feeder (for line section isolation).
- ➤ Midpoint recloser control changing settings (for better backfeed coordination).
- ➤ Tie recloser closing into dead-line sections (for restoration of unfaulted line sections from adjacent feeder).

The advanced automatic network reconfiguration shown in *Figure 13* includes both source-side and load-side voltages into the SEL-651RA recloser controls and MIRRORED BITS communications (via fiber optics or radio) between the recloser sites. These enhancements greatly expedite automatic network reconfiguration. Automatic network reconfiguration is especially valuable in urban areas and for critical loads where there are tie points available to other feeders for system restoration.

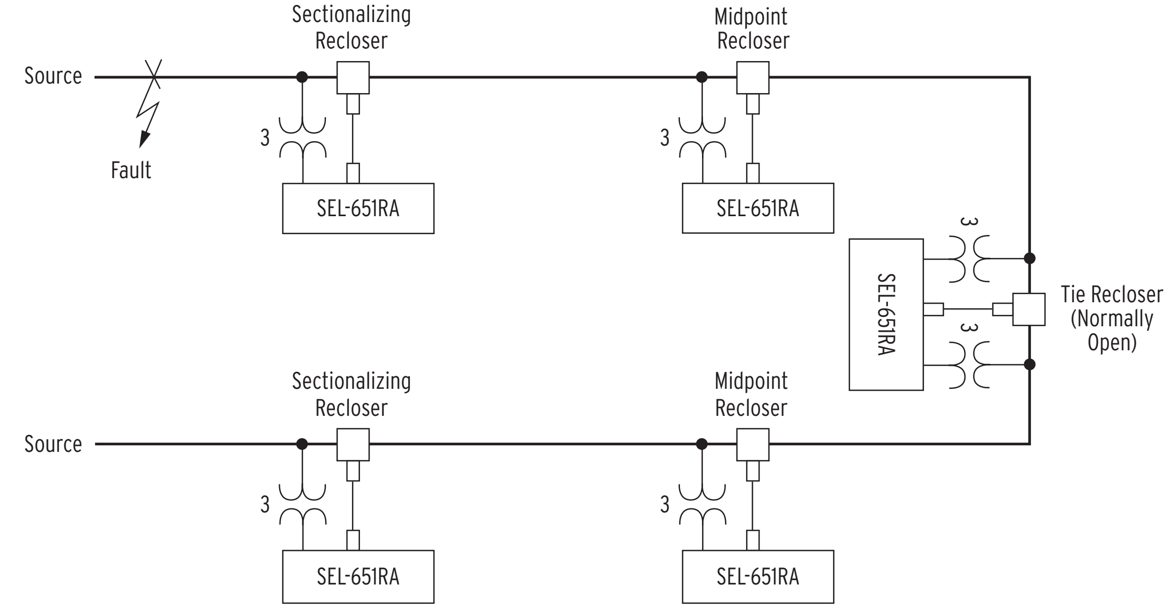


Figure 12 Simple Automatic Network Reconfiguration

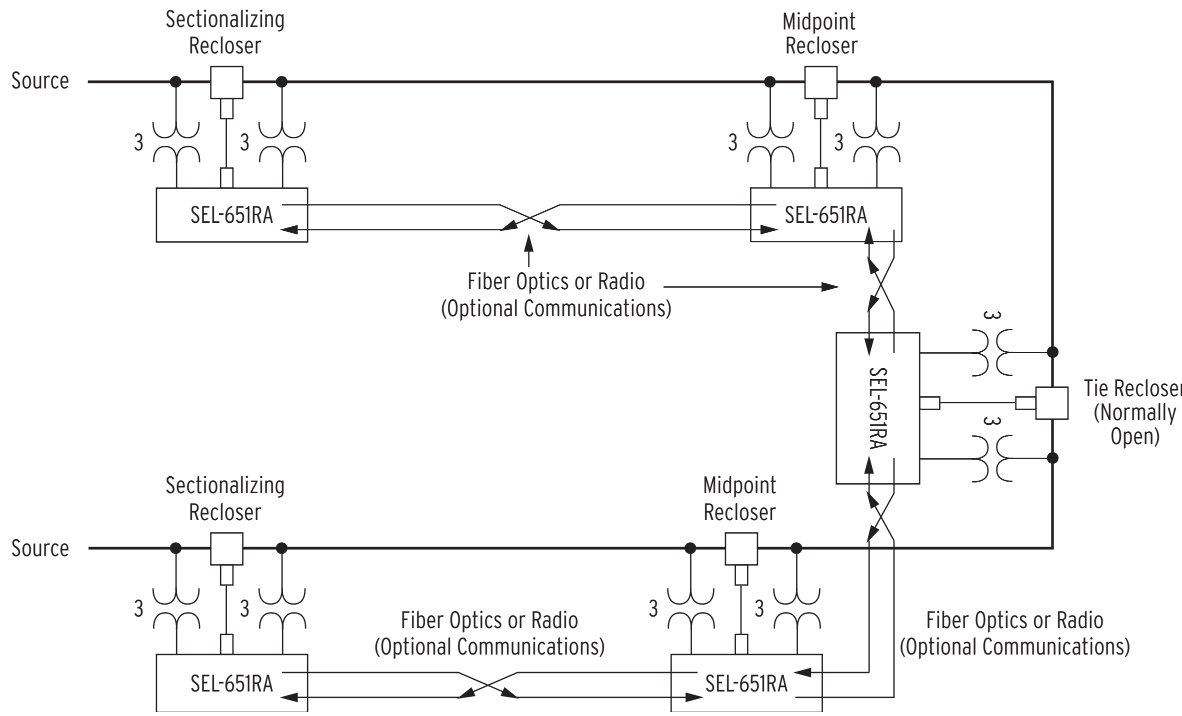


Figure 13 Advanced Automatic Network Reconfiguration

Distributed Energy Resource Interconnection

Reclosers are ideal for interconnecting microgrids and DER to area electric power systems (Area EPS). In these applications, they are commonly specified with six LEA voltage sensors built into the recloser. Utilities, consultants, microgrid owners, and DER owners use these turnkey recloser solutions at the Point of Common Coupling (PCC) as defined in IEEE 1547. *Figure 14* demonstrates autosynchronism control of the DER, resulting in eventual synchronism-check closing of the recloser when slip frequency, phase angle, and voltage magnitude differences are all within allowable limits.

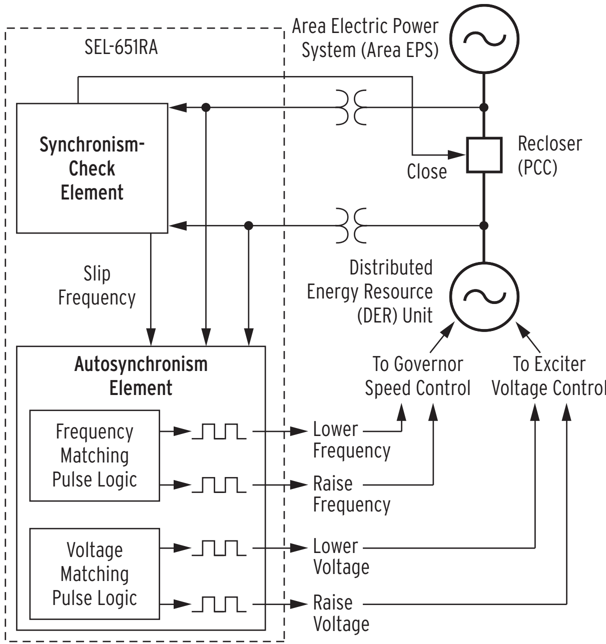


Figure 14 Distributed Energy Resource Intertie

Overcurrent Protection

Use any combination of fast and delay curves (see *Figure 15*) for phase, ground, and negative-sequence overcurrent protection. For a nominal recloser CT ratio of 1000:1, these curves can be set to levels as sensitive as 50 A primary for phase overcurrent protection and 5 A primary for ground overcurrent protection.

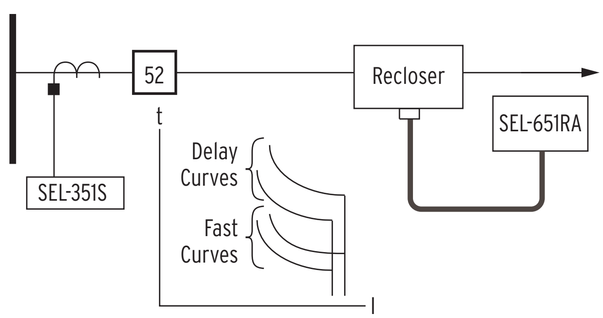


Figure 15 Coordinate the SEL-651RA With Other Devices

Any fast or delay curve can be set with any of the curves in *Table 3*. The U.S. and IEC curves conform to IEEE C37.112-1996, IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays. The traditional recloser curve choices in *Table 3* are listed with the older electronic control designations.

Table 3 Curve Choices Resident in the SEL-651RA

Curve Type	Curve Choices
All Traditional Recloser Curves	A, B, C, D, E, F, G, H, J, KP, L, M, N, P, R, T, V, W, Y, Z, 1, 2, 3, 4, 5, 6, 7, 8, 8PLUS, 9, KG, 11, 13, 14, 15, 16, 17, 18
U.S. Curves	Moderately inverse, inverse, very inverse, extremely inverse, short-time inverse
IEC Curves	Class A (standard inverse), class B (very inverse), class C (extremely inverse), long-time inverse, short-time inverse

You can also specify traditional recloser curves in a curve setting, using the newer microprocessor-based control designations. The SEL-651RA works with either designation. For example, a given traditional recloser curve has these two designations:

- Older electronic control designation: A
- Newer microprocessor-based control designation: 101

Traditional Recloser Curve A and 101 are the same curve.

Fast and delay curves (including U.S. or IEC curve choices) can be modified with these traditional recloser control curve modifiers:

- Constant time adder—adds time to curve
- Vertical multiplier (time dial)—shifts whole curve up or down in time
- Minimum response time—holds off curve tripping for minimum time

Instantaneous overcurrent trip, definite-time overcurrent trip, and high-current lockout variations are also available.

The SEL-651RA has two reset characteristic choices for each time-overcurrent element. One choice resets the elements if current drops below pickup for at least one cycle. The other choice emulates electromechanical induction disk elements, where the reset time depends on the time-dial setting, the percentage of disc travel, and the amount of post-fault load current.

Load Encroachment

Load-encroachment logic (*Figure 16*) prevents operation of phase overcurrent elements under high load conditions. This unique SEL feature permits load to enter a predefined area (shown in the impedance plane in *Figure 16*) without causing a trip, even though load current exceeds phase minimum trip.

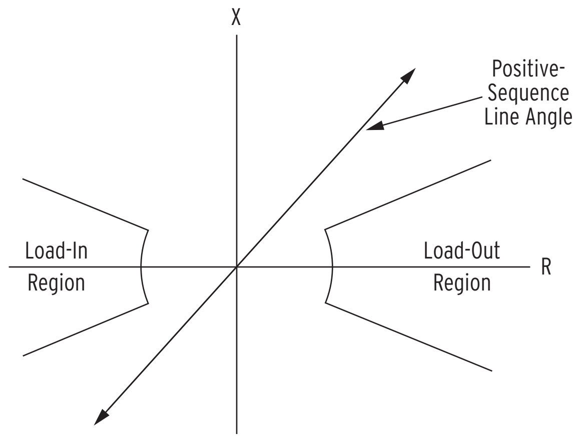


Figure 16 Load-Encroachment Logic Defines Load Zones (No Trip Zones)

Directional Elements Increase Sensitivity and Security

Phase and ground directional elements are included standard in the SEL-651RA. An automatic setting mode sets all directional thresholds based on replica line-impedance settings. Phase directional elements provide directional control to the phase-overcurrent and negative-sequence overcurrent elements. Positive-sequence and negative-sequence directional elements work together. The positive-sequence directional element memory provides a reliable output for close-in and forward- or reverse-bolted three-phase faults where each phase voltage is zero. The negative-sequence directional element uses the same patented principle proven in the SEL-351 Relay. Apply this directional element in virtually any application regardless of the amount of negative-sequence voltage available at the recloser control location.

Ground directional elements provide directional control to the ground overcurrent elements. The following directional elements work together to provide ground directionality:

- Negative-sequence voltage-polarized element
- Zero-sequence voltage-polarized element

Our patented Best Choice Ground Directional Element® logic selects the best ground directional element for the system conditions. This scheme eliminates directional element settings. You can also override this automatic setting feature for special applications.

Loss-of-Potential Logic Supervises Directional Elements

Voltage-polarized directional elements rely on valid input voltages to make correct decisions. The SEL-651RA includes loss-of-potential logic that detects one, two, or three blown potential fuses and disables the directional elements. For example, in a loss-of-potential condition, you can enable forward-set overcurrent elements to operate nondirectionally. This patented loss-of-potential logic is unique because it only requires a nominal setting and is universally applicable.

Reclosing

The SEL-651RA can reclose as many as four times. This allows for as many as five operations of any combination of fast and delay curve overcurrent elements. The SEL-651RA verifies that adequate close power is available before issuing an autoreclose. Reset timings for an autoreclose and for a manual/remote close from lockout are set separately. Traditionally, the reset time for a manual/remote close from lockout is set less than the reset time for an autoreclose. Front-panel LEDs track the control state for autoreclosing: **79 RESET**, **79 CYCLE**, or **79 LOCKOUT** (see *Figure 23* and *Table 5*). Sequence coordination logic is enabled to prevent the SEL-651RA from tripping on its fast curves for faults beyond a downstream recloser. Customize reclosing logic by using SELOGIC control equations. Use programmable timers, counters, latches, logic functions, and analog compare functions to optimize control actions.

Power Elements

Four independent directional three-phase power elements are available in the SEL-651RA. Each enabled power element can be set to detect real power or reactive power. With SELOGIC control equations, the power elements provide a wide variety of protection and control applications. Typical applications include the following:

- Overpower and/or underpower protection and control
- Reverse power protection and control
- VAR control for capacitor banks

Harmonic Blocking Elements Secure Protection During Transformer Energization

Transformer inrush can cause sensitive protection to operate. Use the second-harmonic blocking feature to detect an inrush condition and block selected tripping elements until the inrush subsides. Select the blocking threshold as a percentage of fundamental current, and optimize security and dependability with settable pickup and dropout times. Use the programmable torque-control equation to only enable the blocking element immediately after closing the breaker.

Fast Rate-of-Change-of-Frequency Protection for Fast Islanding Detection

The fast rate-of-change-of-frequency protection, 81RF, provides a faster response compared to frequency (81) and rate-of-change-of-frequency (81R) elements. Fast operating speed makes the 81RF element suitable for detecting islanding conditions. The element uses a characteristic (see *Figure 18*) based on the frequency deviation from nominal frequency (DF = FREQ – NFREQ) and the rate-of-change of frequency (DFDT) to detect islanding conditions.

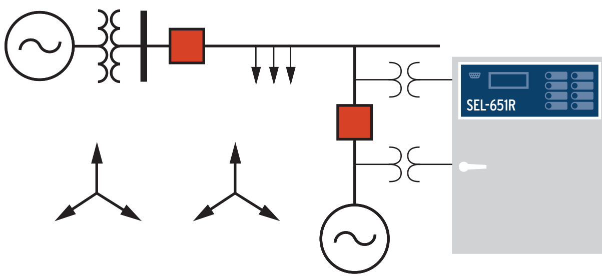


Figure 17 Fast Islanding Detection

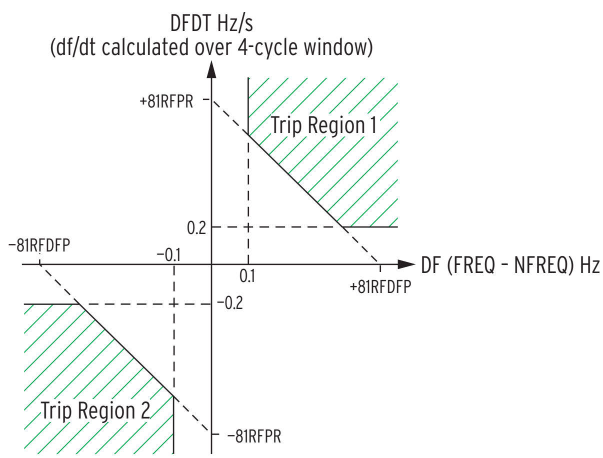


Figure 18 81RF Characteristics

Under steady-state conditions, the operating point is close to the origin. During islanding conditions, depending on the islanded system acceleration, the operating point enters Trip Region 1 or Trip Region 2 of the characteristic. Use settings 81RFDFP (in Hz) and 81RFRP (in Hz/s) to configure the characteristic.

Vector Shift (78VS) Protection

When distributed generators (DG) are connected in the utility network, the vector shift (78VS) element is used to detect islanding conditions and trip the DG. Failure to trip islanded generators can lead to problems such as personnel safety, out-of-synchronization reclosing, and degradation of power quality. Based on the change in the angle of the voltage waveform, the islanding condition can be detected by the vector shift function.

Use the vector shift element with the 81RF element as a backup for fast and secure islanding detection. The vector shift element operates within three cycles, which is fast enough to prevent reclosing out-of-synchronism with the network feeders to avoid generator damage.

Fault Location

The SEL-651RA provides an accurate estimate of fault location even during periods of substantial load flow. The fault locator uses fault type, replica line-impedance settings, and fault conditions to develop an estimate of fault location without communications channels, special instrument transformers, or prefault information. This feature contributes to efficient line crew dispatch and fast service restoration. The fault locator requires three-phase voltage inputs.

High-Impedance Fault Detection

High-impedance faults (HIF) are short-circuit faults with fault currents smaller than what a traditional overcurrent element can detect.

The SEL-651RA with optional Arc Sense technology includes logic that can detect HIF signatures without being affected by loads or other system operation conditions. HIF event reports are stored in both compressed ASCII and COMTRADE file format.

The SEL-651RA offers another method of detecting HIFs. A ground overcurrent element is used to count the number of times the ground current exceeds a threshold in a given amount of time. If the count exceeds a set threshold, the control asserts an alarm indicating a potential HIF.

Monitoring and Metering

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 control settings and protection schemes. Increase the availability of information by accessing settings, events, and other data over a single communications link.

Event Reporting and Oscillography

In response to a user-selected internal or external trigger, the voltage, current, and element status information contained in each event report confirms control, scheme, and system performance for every fault. Decide how much detail is necessary when an event report is triggered: 4-, 16-, 32-, or 128-samples-per-cycle resolution analog data. The control stores the following:

- 40 event reports (when event report length is 15 cycles)
- 25 event reports (when event report length is 30 cycles)
- 15 event reports (when event report length is 60 cycles)

Reports are stored in nonvolatile memory and are available in Compressed ASCII and COMTRADE file format. Settings operational in the control at the time of the event are appended to each event report.

HIF event reports are also available in compressed ASCII and COMTRADE file formats. The information used to determine if an HIF is present on the system is included in the report. The control stores the following:

- 28 event reports (when event report length is 2 minutes)
- 14 event reports (when event report length is 5 minutes)
- 7 event reports (when event report length is 10 minutes)
- 3 event reports (when event report length is 20 minutes)

Demodulated IRIG-B time code can be input into either the IRIG-B BNC connector or serial Port 2. Connect a high-quality time source such as the SEL-2401 Satellite-Synchronized Clock to the IRIG-B connector to enable microsecond-accurate time synchronization. Connect an SEL communications processor (combining data and IRIG signals) to serial Port 2 on the SEL-651RA for millisecond-accurate time synchronization.

The recloser control also synchronizes the internal clock to an NTP server via SNTP with 5 ms accuracy. If multiple time sources are connected, the recloser control automatically selects the most accurate source.

The ACSELERATOR Analytic Assistant® SEL-5601 Software and QuickSet can read a Compressed ASCII or COMTRADE file format version of the event report. Using Analytic Assistant and QuickSet, you can produce oscillographic traces and digital element traces on the PC display. A phasor analysis screen allows you to analyze the prefault, fault, and post-fault intervals and observe the directly measured inputs and calculated sequence component signals.

Event Summary

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

- Control/terminal identification
- Event date and time
- Event type
- Fault location
- Recloser shot count at time of trigger
- System frequency at the start of the event report
- Front-panel fault targets at the time of trip
- Phase (IA, IB, IC), ground (IG = 3I0), and negative-sequence (3I2) current magnitudes in amperes primary measured at the largest phase current magnitude in the triggered event report

Set the control to 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 on control element operation. To trigger an SER entry, choose such items as input/output change of state, element pickup/dropout, recloser state changes, etc. The control module SER stores the latest 1,024 entries.

Synchrophasor Measurements

Use the IEEE C37.118-2005 protocol to send synchrophasor data to SEL synchrophasor applications. These include the SEL-3373 Station Phasor Data Concentrator (PDC), SEL-3378 Synchrophasor Vector Processor (SVP), SEL-3530 Real-Time Automation Controller

(RTAC), and SEL SYNCHROWAVE® software suite. The SEL-3373 Station PDC time correlates data from multiple SEL-651RA recloser controls and concentrates the result into a single-output data stream. The SEL-3378 SVP enables control applications based on synchrophasors, which allows you to do the following:

- ➤ Directly measure the oscillation modes
- ➤ Act on the results
- ➤ Properly control islanding of distributed generation through use of wide-area phase-angle slip and acceleration measurements
- ➤ Customize synchrophasor control applications based on unique power system requirements

You can then use SEL SYNCHROWAVE software to archive and display wide-area system measurements, which are precisely time-aligned by using synchrophasor technology.

The data rate of SEL-651RA synchrophasors is user-configurable, with a range of 1–60 messages per second. This flexibility is important for efficient use of communications capacity. The SEL-651RA phasor measurement accuracy meets the highest IEEE C37.118-2005 Level 1 requirement of 1 percent total vector error (TVE). Use the low-cost SEL-651RA in any application that otherwise would have required purchasing a separate dedicated phasor measurement unit (PMU).

Use the SEL-651RA with the SEL communications processors, or the SEL-3530 RTAC, to change nonlinear state estimation into linear state estimation. If all necessary lines include synchrophasor measurements, state estimation is no longer necessary because the system state is directly measured.

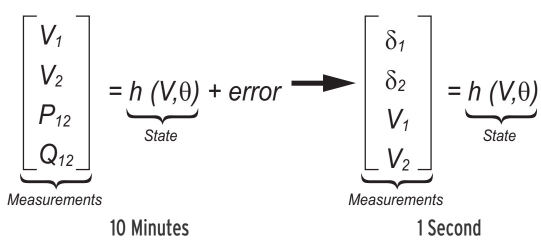


Figure 19 Synchrophasor Measurements Turn State Estimation Into State Measurement

Improve Situational Awareness

Improve information for system operators by using advanced synchrophasor-based tools to provide a real-time view of system conditions. Use system trends, alarm points, and preprogrammed responses to help operators prevent a cascading system collapse and maximize system stability. Awareness of system trends helps operators more accurately set system protection levels based on measured data.

Figure 20 Visualization of Phase Angle Measurements Across a Power System

Better information helps you do the following:

- ➤ Increase system loading while maintaining adequate stability margins
- ➤ Improve operator response to system contingencies such as overload conditions, transmission outages, or generator shutdown
- ➤ Increase system knowledge with correlated event reporting and real-time system visualization
- ➤ Validate planning studies to improve system load balance and station optimization

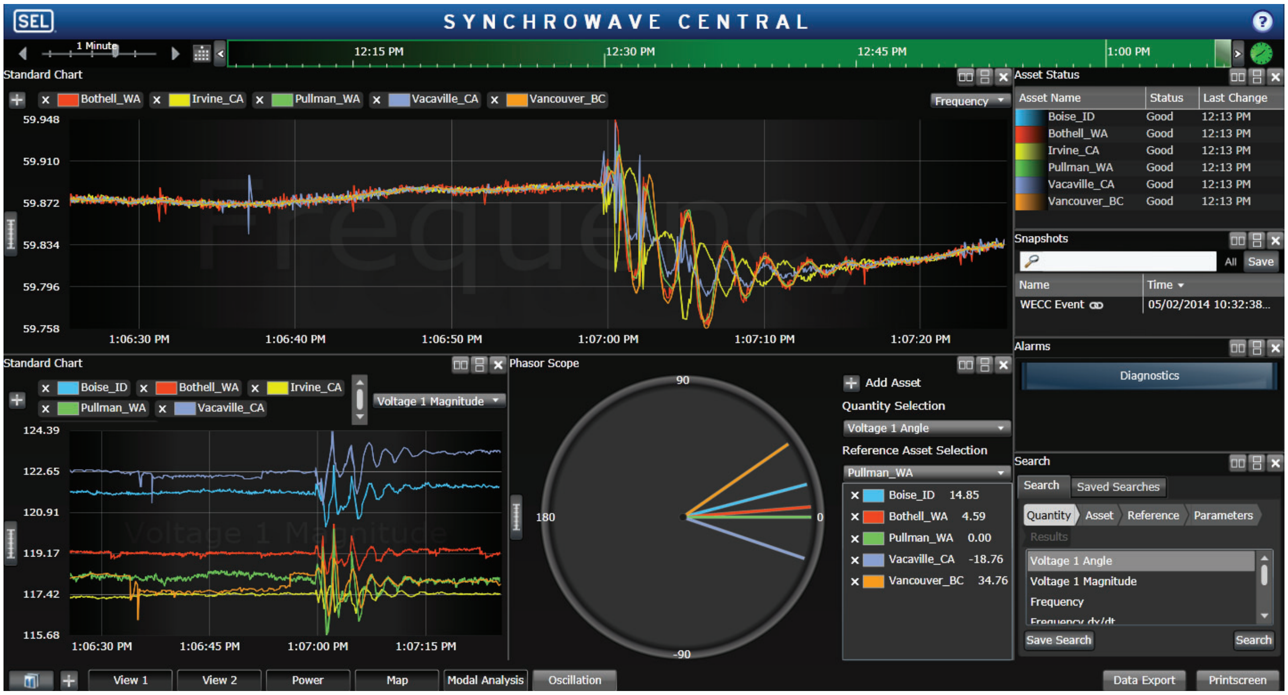


Figure 21 SEL-5078-2 SYNCHROWAVE Central Real-Time, Wide-Area Visualization Tool

Voltage Sag, Swell, and Interruption (VSSI) Report

The voltage sag, swell, and interruption (VSSI) report captures power quality data related to voltage disturbances over a long period. Captured data include the magnitude of currents, one set of three-phase voltages, a reference voltage, and the status of the VSSI elements (Relay Word bits).

Use VSSI report information to analyze power quality disturbances or protective device actions that last longer than the time window of a conventional event report. The VSSI recording rate varies from fast to slow, depending on changes in the triggering elements. VSSI data (a minimum of 3855 entries) are stored to nonvolatile memory after they are generated.

Recloser Wear Monitor

Reclosers experience mechanical and electrical wear every time they operate. The recloser wear monitor measures unfiltered ac current at the time of trip and the number of close-to-open operations as a means of monitoring this wear. Every time the recloser trips, the recloser control records the magnitude of the raw current in each phase. This current information is integrated on a per-phase basis.

When the integration exceeds the threshold set by the recloser wear curve (see *Figure 22*), the SEL-651RA asserts a logic point for the affected phase. Use the logic point for alarming or to modify reclosing. This method of monitoring recloser wear is based on breaker rating methods from switchgear manufacturers.

Figure 22 shows three set points needed to emulate a breaker wear curve. The set points in *Figure 22* can be programmed to customize the recloser wear curve. Predetermined set points are available for traditional reclosers, following recommendations for reclosers in ANSI C37.61-1973.

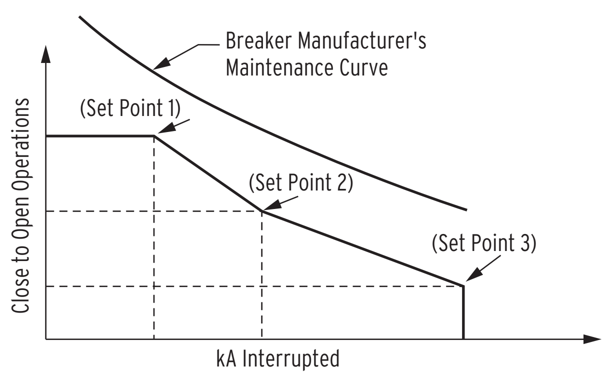


Figure 22 Recloser Contact Wear Curve and Settings

Load Profile

The load profile recorder in the SEL-651RA can record as many as 15 selectable analog quantities at a periodic rate (5, 10, 15, 30, or 60 minutes) and store the data in a report in nonvolatile memory. Choose any of the analog quantities listed in *Table 4* (except peak demands). At a five-minute periodic recording rate and with 15 selected analog quantities, the SEL-651RA stores as many as 26 days of load profile data. Longer periods of storage are available if you choose longer periodic recording rates or select fewer analog quantities.

Metering

The SEL-651RA provides extensive and accurate metering capabilities, as shown in *Table 4*. See *Specifications* for metering accuracies. The SEL-651RA reports all metered quantities in primary quantities (current in amperes primary and voltage in kilovolts primary). Use the THD elements for the current and voltage channels for harmonics-based decisions or operations.

The phantom voltage feature creates balanced three-phase voltage values for metering from a single-phase voltage connection. These derived three-phase voltage values are also used in three-phase power and energy metering.

Table 4 Available Metering Quantities (Sheet 1 of 2)

Instantaneous Quantities	**Fundamental Values**
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
I_G	Ground (residual current)
I_1, $3I_2$, $3I_0$	Positive-, negative-, and zero-sequence
Voltages	Values for both VY and VZ three-phase voltage channels
$V_{A, B, C, AB, BC, CA}$	Line-to-neutral and line-to-line
V_1, V_2, $3V_0$	Positive-, negative-, and zero-sequence
Power	
$MW_{A, B, C, 3P}$	Megawatts, single- and three-phase
$MVAR_{A, B, C, 3P}$	Megavars, single- and three-phase
$MVA_{A, B, C, 3P}$	Megavolt-amperes, single- and three-phase
$PF_{A, B, C, 3P}$	Power factor, single- and three-phase (with leading or lagging indication)
Demand Quantities	**Present and Peak (Fundamental Values)**
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
I_G	Ground (residual current)
$3I_2$	Negative-sequence

Table 4 Available Metering Quantities (Sheet 2 of 2)

Power	
$MW_{A, B, C, 3P}$	Megawatts, single- and three-phase (in and out)
$MVAR_{A, B, C, 3P}$	Megavars, single- and three-phase (in and out)
$MVA_{A, B, C, 3P}$	Megavolt-amperes, single- and three-phase
Energy Quantities	**In and Out (Fundamental Values)**
$MWh_{A, B, C, 3P}$	Megawatt hours, single- and three-phase
$MVARh_{A, B, C, 3P}$	Megavar hours, single- and three-phase
Maximum/Minimum Quantities	**Fundamental Values**
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
I_G	Ground (residual current)
Voltages	Values for both VY and VZ three-phase voltage channels
$V_{A, B, C}$	Line-to-neutral
Power	
MW_{3P}	Megawatts, three-phase
$MVAR_{3P}$	Megavars, three-phase
MVA_{3P}	Megavolt-amperes, three-phase
RMS Quantities	
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
Voltages	Values for both VY and VZ three-phase voltage channels
$V_{A, B, C}$	Line-to-neutral
Power (average)	
$MW_{A, B, C, 3P}$	Megawatts, single- and three-phase
Harmonic Quantities and Total Harmonic Distortion (THD)	**Through the 16th Harmonic**
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
Voltages	Values for both VY and VZ three-phase voltage channels
$V_{A, B, C}$	Line-to-neutral

Additional Features

Status and Trip Target LEDs/Operator Controls

The SEL-651RA includes 24 programmable status and trip target LEDs, as well as 12 programmable direct-action operator control pushbuttons on the front panel. These targets are shown in *Figure 23* and explained in *Table 5*. Customize the versatile SEL-651RA front panel to fit your needs. Optional tricolor LEDs allow you to customize color. 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. Functions are simple to configure through the use of QuickSet. Print label sets by using the included template, or write labels by hand.

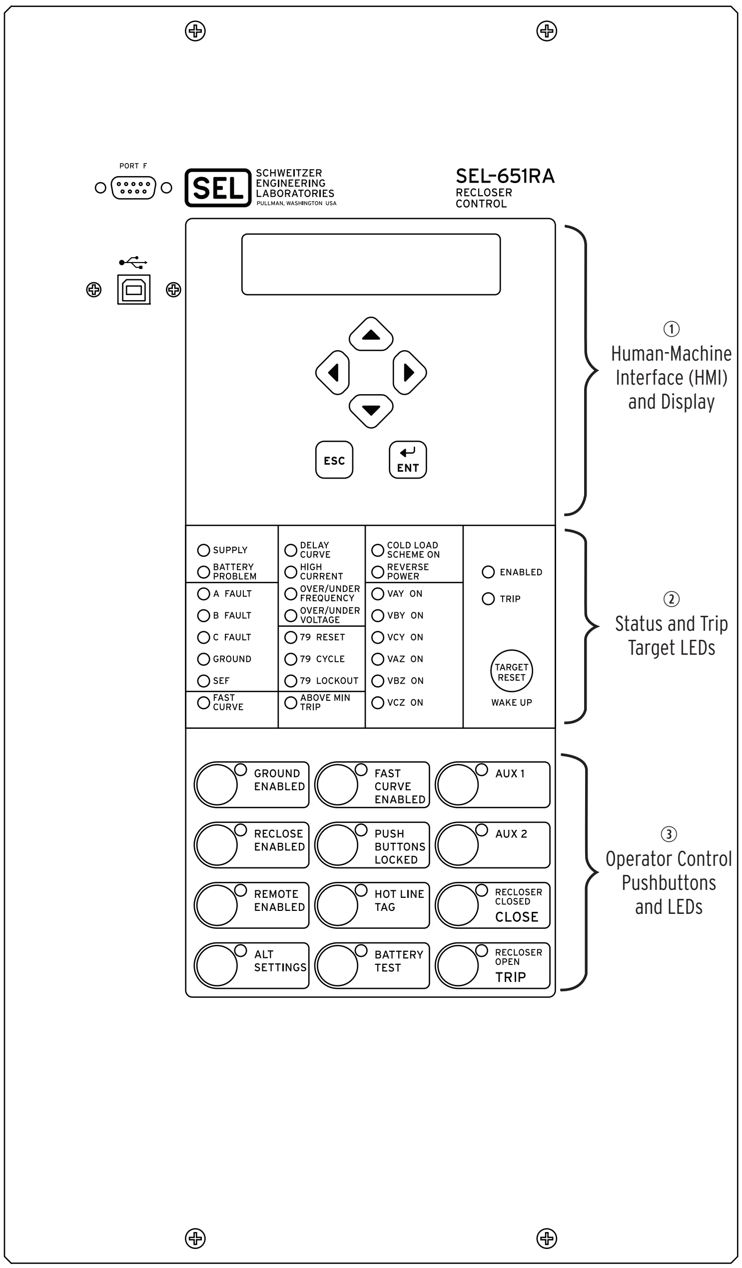


Figure 23 SEL-651RA Front Panel

Table 5 Factory-Default Front-Panel Interface Definitions (see *Figure 23*)

	Function	Definition
1	HMI Pushbuttons and Display	Navigate through the menu and various available functions (e.g., Metering, Event Summaries, Settings) by using the HMI pushbuttons and 2 x 16 LCD.
2	ENABLED[a]	SEL-651RA is powered correctly, functional, and has no self-test failures.
	TRIP[a]	Trip occurred.
	TARGET REST/WAKE UP Pushbutton[a]	Reset latched-in target LEDs; wake up the control after it has been put to sleep.
	SUPPLY	Supply power is present and OK.
	BATTERY PROBLEM	Indicates battery problems.
	A FAULT, B FAULT, C FAULT	Phases A, B, or C involved in fault.
	GROUND	Ground involved in fault.
	SEF	Sensitive earth fault overcurrent element trip (not set from factory).
	FAST CURVE	Fast curve overcurrent element trip.
	DELAY CURVE	Delay curve overcurrent element trip.
	HIGH CURRENT	High-set overcurrent element trip (not set from factory).
	OVER/UNDERFREQUENCY	Over- and underfrequency element trip (not set from factory).
	OVER/UNDERVOLTAGE	Over- and undervoltage element trip (not set from factory).
	79 RESET	The control is in the Reset State, ready for a reclose cycle.
	79 CYCLE	The control is actively in the trip/reclose cycle mode.
	79 LOCKOUT	All reclose attempts were unsuccessful.
	ABOVE MIN TRIP	Current levels above minimum set overcurrent element pickup (not set from factory).
	COLD LOAD SCHEME ON	Cold Load Scheme active (not set from factory).
	REVERSE POWER	Reverse Power flow exceeds power element set point (not set from factory).
	VAY, VBY, VCY ON	VY voltage channels energized.
	VAZ, VBZ, VCZ ON	VZ voltage channels energized (not set from factory).
3	GROUND ENABLED	Enable/disable ground overcurrent elements.
	RECLOSE ENABLED	Enable/disable autoreclosing.
	REMOTE ENABLED	Enable/disable remote control.
	ALT SETTINGS	Switch active setting group between main and alternate setting groups.
	FAST CURVE ENABLED	Enable/disable fast curve overcurrent element.
	PUSHBUTTONS LOCKED	Block the function of other operator controls (except WAKE UP and TRIP). Three-second delay to engage/disengage.
	HOT LINE TAG	No closing or autoreclosing can take place via the control.
	BATTERY TEST	Initiates a battery test. The corresponding LED flashes to indicate a battery test is in progress.
	AUX 1	User programmable; e.g., program to enable/disable delay curve tripping.
	AUX 2	User programmable.
	RECLOSER CLOSED/CLOSE	Recloser status/close recloser.
	RECLOSER OPEN/TRIP	Recloser status/trip recloser (go to lockout).

[a] These indicated LEDs and the operator control have fixed functions. All other LEDs and operator controls (with corresponding status LEDs) can change function by programming at a higher logic level.

Control Inputs and Outputs

The basic SEL-651RA includes the following control inputs and outputs:

- Dedicated trip/close outputs that exit the SEL-651RA on a control cable receptacle/interface at the bottom of the enclosure (see *Figure 2*).
- Two Form C (normally closed/normally open) standard-interrupting output contacts: OUT201 and OUT202 (see *Figure 24*). OUT201 is factory-programmed as an alarm output.

Order the following additional input/output (I/O) (see *Figure 24*):

- Optoisolated inputs IN101–IN102 (125 Vdc rating) IN103–IN107 (12 Vdc rating; IN106 and IN107 share a common terminal)
- Form A (normally open) standard-interrupting output contacts OUT101–OUT105
- Form C (normally closed/normally open) standard-interrupting output contacts OUT106–OUT107

Assign the optoisolated inputs for control functions, monitoring logic, and general indication. Set input debounce time independently for each input. Each output contact is programmable using SELOGIC control equations.

Panel Diagrams

The SEL-651RA front panel is shown in *Figure 23*.

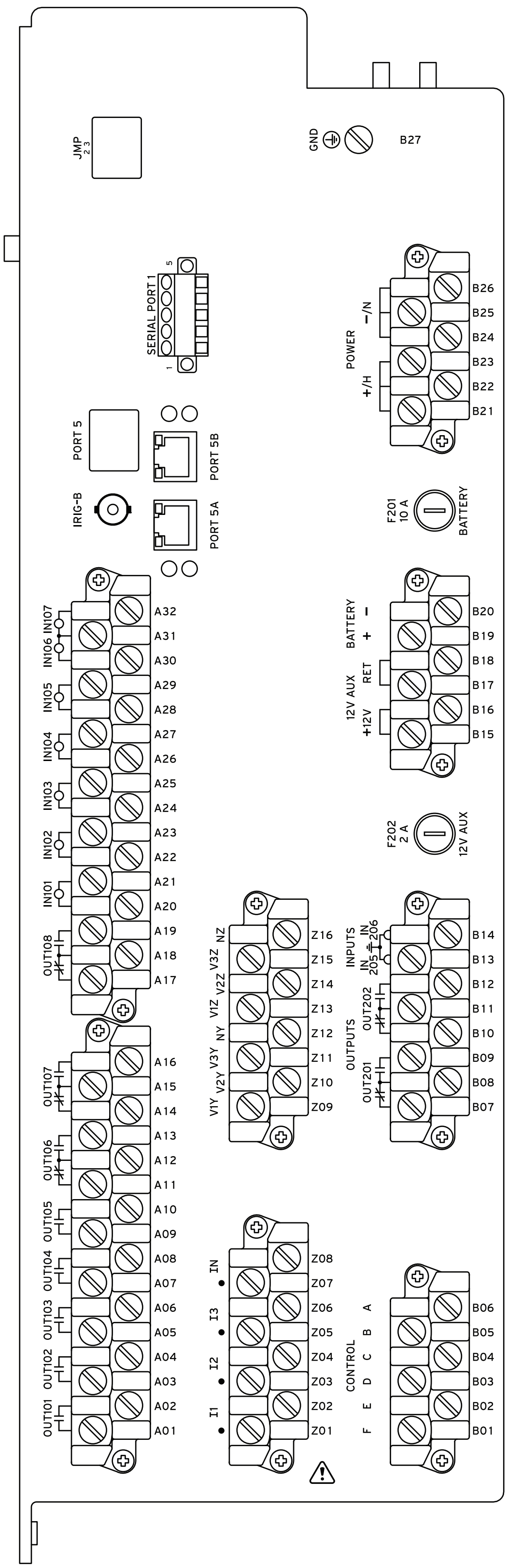


Figure 24 SEL-651RA Side Panel

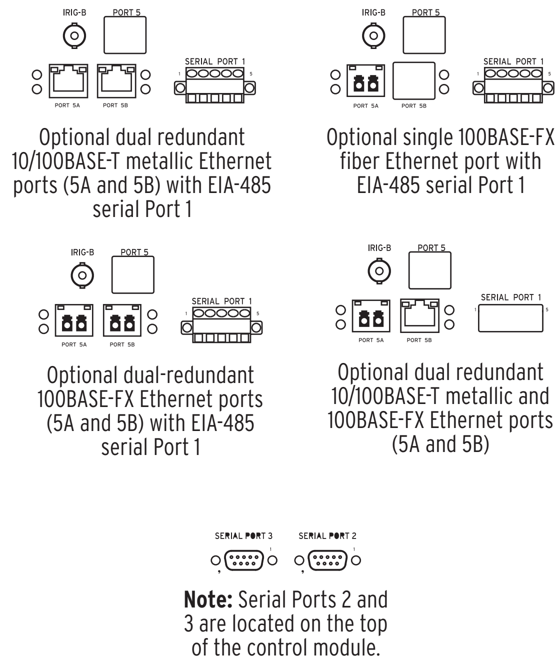


Figure 25 SEL-651RA Side-Panel Communications Port Configurations

SEL Enclosure Dimensions

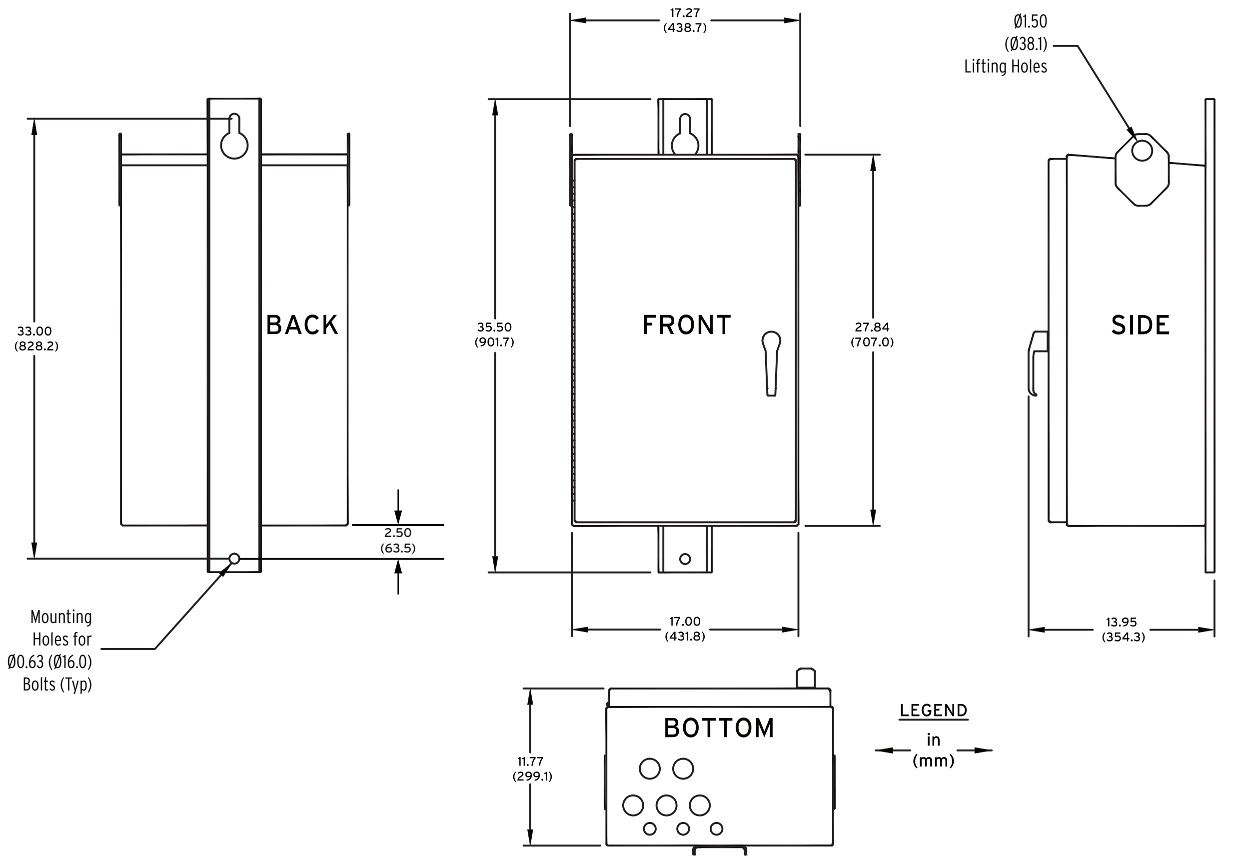


Figure 26 SEL-651RA Dimensions and Mounting Drill Plan

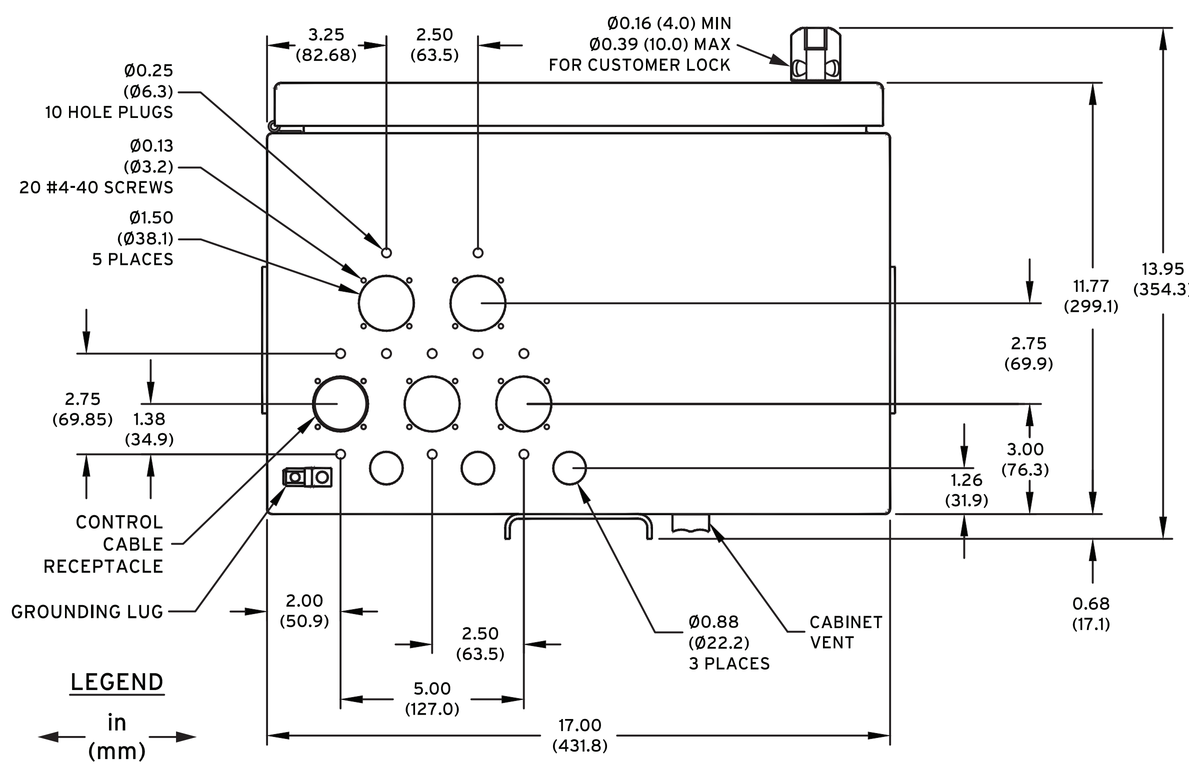


Figure 27 SEL-651RA Grounding Lug Location and Other Dimensional Information (Bottom View)

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

General

AC Current Inputs

Channels IA, IB, IC

1 A Nominal:	3 A continuous, linear to 20 A symmetrical; 100 A for 1 s; 250 A for 1 cycle
Burden:	0.13 VA @ 1 A, 1.31 VA @ 3 A

Channel IN

0.2 A Nominal:	15 A continuous, linear to 5.5 A symmetrical; 100 A for 1 s; 250 A for 1 cycle
Burden:	<0.5 VA @ 0.2 A

AC Voltage Inputs

300 V Maximum (PT):	300 V_{L-N} continuous (ideally connect voltage no higher than 240 Vac nominal, thus providing 60 Vac margin for accurately measuring overvoltage conditions); 600 Vac for 10 s.
Burden:	<0.03 VA @ 67 V <0.06 VA @ 120 V <0.80 VA @ 300 V
8 V LEA Maximum:	8 V_{L-N} continuous (ideally connect voltage no higher than 6.5 Vac nominal, thus providing 1.5 Vac margin for accurately measuring overvoltage conditions); 300 Vac for 10 s.
Burden:	Control Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	50 Vac
Eaton NOVA LEA:	37 V_{L-N} continuous (ideally connect voltage no higher than 29.6 Vac nominal, thus providing 7.4 Vac margin for accurately measuring overvoltage conditions); 250 Vac for 10 s.
Burden:	Control Input Z = 165 kΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	53 Vac
Lindsey SVMI LEA:	200 V_{L-N} continuous (ideally connect voltage no higher than 160 Vac nominal, thus providing 40 Vac margin for accurately measuring overvoltage conditions); 250 Vac for 10 s.
Burden:	Control Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	25 Vac

Frequency and Rotation

Note: 60/50 Hz system frequency and ABC/ACB phase rotation are user-settable.

Frequency Tracking Range:	40–66 Hz
Maximum Rate of Change:	~20 Hz/s (The control will not measure faster-changing frequencies and will revert to nominal frequency if the condition is maintained for more than 0.25 s)

Note: Voltage V*n*Y or V*n*Z (where *n* = 1, 2, or 3) required for frequency tracking, depending upon Global setting FSELECT.

Power Supply

Rated Range:	85–264 Vac 100–350 Vdc
Frequency Range:	40.1–65.0 Hz
Burden:	<90 VA

12 V Accessory Power Supply

With AC Present:	12 Vdc ±10%
Without AC Present:	10.2–18.0 Vdc (battery voltage)
Power:	15 W continuous

Output Contacts (Except Trip and Close)

DC Output Ratings

Make:	30 A per IEEE C37.90-2005
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection:	270 Vac, 360 Vdc, 40 J
Pickup Time:	<5 ms
Dropout Time:	<5 ms
Update Rate:	1/8 cycle

Breaking Capacity (10,000 Operations):

24 V	0.75 A	L/R = 40 ms
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

Cyclic Capacity (1 Cycle/Second):

24 V	0.75 A	L/R = 40 ms
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: Breaking and Cyclic Capacity per IEC 60255-0-20:1974.

AC Output Ratings

Maximum Operational Voltage (U_E) Rating:	240 Vac
Insulation Voltage (U_I) Rating (Excluding EN 61010-1):	300 Vac
Utilization Category:	AC-15 (control of electromagnetic loads >72 VA)
Contact Rating Designation:	B300 (B = 5 A, 300 = rated insulation voltage)
Voltage Protection Across Open Contacts:	270 Vac, 40 J
Rated Operational Current (I_E):	3 A @ 120 Vac 1.5 A @ 240 Vac
Conventional Enclosed Thermal Current (I_{THE}) Rating:	5 A
Rated Frequency:	50/60 ±5 Hz

Electrical Durability Make VA Rating:	3600 VA, cos φ = 0.3
Electrical Durability Break VA Rating:	360 VA, cos φ = 0.3

Trip and Close Outputs

Traditional Interface Rating

Coil Voltage:	24.0–36.0 Vdc
Coil Current:	15.5 A (Close), 12.2 A (Trip)

Note: Supports an entire trip-close-trip-close-trip-close-trip-close-trip-lockout sequence every minute.

Optoisolated Inputs (Optional)

When Used With DC Control Signals

125 Vdc:	On for 105.0–150.0 Vdc; off below 75.0 Vdc
12 Vdc:	On for 9.6–27 Vdc

When Used With AC Control Signals

125 Vdc:	On for 89.6–150.0 Vac; off below 53.0 Vac

Note: AC mode is selectable for inputs IN101 and IN102 when ordered with 125 Vdc options via Global settings IN101D and IN102D. AC input recognition delay from time of switching: 0.75 cycles maximum pickup, 1.25 cycles maximum dropout.

Note: All optoisolated inputs draw less than 10 mA of current at nominal voltage or ac rms equivalent.

Status Inputs

IN205, IN206

DC Dropout Range:	0.0–4.0 Vdc
DC Pickup Range:	9.0–28.0 Vdc
Current Draw:	1.0–10.0 mA

IN201–IN204

DC Dropout Range:	0.0–9.0 Vdc
DC Pickup Range:	20.0–40.5 Vdc
Current Draw:	0.5–1.5 mA

Communications Ports

EIA-232:	One front, two side
EIA-485:	One side port with 2100 Vdc of isolation
Per Port Data Rate Selections:	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600
USB:	One front (Type-B connector, CDC class device)
Ethernet:	One 10/100BASE-T side port (RJ45 connector) (discontinued option) Two 10/100BASE-T side port optional (RJ45 connector) One or two 100BASE-FX side ports optional (LC connectors) One 10/100BASE-T (RJ45 connector) and one 100BASE-FX (LC connector multimode) rear ports optional Internal Ethernet switch included with second Ethernet port

Time-Code Inputs

Recloser Control accepts demodulated IRIG-B time-code input at Port 2 or the BNC input.

Port 2, Pin 4 Input Current:	1.8 mA typical at 4.5 V (2.5 kΩ resistive)
BNC Input Current:	4 mA typical at 4.5 V (750 Ω resistive when input voltage is greater than 2 V)

Synchronization Accuracy

Internal Clock:	±1 µs
Synchrophasor Reports (e.g., **MET PM**, **CEV P**):	±10 µs
All Other Reports:	±5 ms

Simple Network Time Protocol (SNTP) Accuracy

Internal Clock:	±5 ms

Unsynchronized Clock Drift

Control Powered:	2 minutes per year typical

Operating Temperature

Control Module:	–40° to +85°C (–40° to +185°F)
Batteries:	–40° to +80°C (–40° to +176°F)
Entire Enclosure With Battery:	–40° to +55°C (–40° to +131°F)

Note: LCD contrast impaired for temperatures below –20°C (–4°F). The SEL-651RA enclosure with battery is operationally tested to +70°C (+158°F). The 15°C (27°F) difference between the +55°C rating and +70°C is for direct sunlight temperature rise.

Weight

<45 kg (<100 lb) with battery, without accessories

Battery Specifications

Base Version Requirement

Normal Capacity:	16 amp-hours @ 25°C
Run Time (Control Electronics Operate Plus One Trip/Close Cycle):	≥25 hours @ +25°C ≥8 hours @ –40°C
Recharge Time (Deep Discharge to Fully Charged):	≤23 hours @ 25°C
Estimated Life:	≥4 years @ 25°C ≥1 year @ 80°C

Extended Capacity Option Requirement

Normal Capacity:	40 amp-hours @ 25°C
Run Time (Control Electronics Operate Plus One Trip/Close Cycle):	≥83 hours @ +25°C ≥27 hours @ –40°C
Recharge Time (Deep Discharge to Fully Charged):	≤48 hours @ 25°C
Estimated Life:	≥4 years @ 25°C ≥1 year @ 80°C

Processing Specifications and Oscillography

AC Voltage and Current Inputs

128 samples per power system cycle, 3 dB low-pass filter cut-off frequency of 3 kHz

Digital Filtering

Digital low-pass filter then decimate to 32 samples per cycle followed by one-cycle cosine filter.

Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.

Protection and Control Processing

Most Elements:	Four times per power system cycle
Time-Overcurrent Elements:	Two times per power system cycle

Oscillography

Length:	15, 30, or 60 cycles
Total Storage:	11 seconds of analog and binary
Sampling Rate:	128 samples per cycle unfiltered 32 and 16 samples per cycle unfiltered and filtered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	Compressed ASCII Binary COMTRADE (128 samples per cycle unfiltered)
Time-Stamp Resolution:	1 µs when high-accuracy time source is connected (**CEV P** command)
Time-Stamp Accuracy:	See *Time-Code Inputs* in these specifications

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (With Respect to Time Source):	±5 ms

Control Element Settings Ranges and Accuracies

Instantaneous/Definite-Time Overcurrent Elements (50)

Current Pickup Range (A Secondary)

Phase and Neg.-Seq.:	0.05–20.00 A, 0.01 A steps
Ground:	0.005–20.000 A, 0.001 A steps
Neutral:	0.005–2.500 A

Steady-State Pickup Accuracy

Phase and Neg.-Seq.:	±0.01 A plus ±3% of setting
Ground:	±0.001 A plus ±3% of setting (IN <4.7 A) ±0.010 A plus ±3% of setting (IN ≥4.7 A)
Neutral:	±0.001 A plus ±3% of setting
Transient Overreach:	±5% of pickup

Pickup/Dropout Time:	1.25 cycles
Time Delay Range:	0.00–16000.00 cycles, 0.25-cycle steps
Time Delay Accuracy:	±0.25 cycle plus ±0.1% of setting

Time-Overcurrent Elements (51)

Current Pickup Range (A Secondary)

Phase and Neg.-Seq.:	0.05–3.20 A, 0.01 A steps
Ground:	0.005–3.200 A, 0.001 A steps
Neutral:	0.005–0.640 A, 0.001 A steps

Steady-State Pickup Accuracy

Phase and Neg.-Seq.:	±0.01 A plus ±3% of setting
Ground:	±0.001 A plus ±3% of setting (IN <4.7 A) ±0.010 A plus ±3% of setting (IN ≥4.7 A)
Neutral:	±0.001 A plus ±3% of setting

Time Dials

U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Recloser Curves:	0.10–2.00, 0.01 steps

Curve Timing Accuracy:	±1.50 cycles plus ±4% of setting, between 2 and 30 multiples of pickup

Second-Harmonic Blocking Elements

Pickup Range:	5–100% of fundamental, 1% steps
Steady-State Pickup Accuracy:	2.5 percentage points
Pickup/Dropout Time:	<1.25 cycles
Time Delay:	0.00–16000.00 cycles, 0.25-cycle steps
Timer Accuracy:	±0.25 cycle and ±0.1% of setting

Undervoltage (27) and Overvoltage (59)

Pickup Ranges (V Secondary)

300 V Maximum Inputs

Phase:	1.00–300.00 V, 0.01 V steps
Phase-to-Phase:	1.76–520.00 V, 0.02 V steps
Sequence:	2.00–300.00 V, 0.02 V steps

8 V LEA Maximum Inputs

Phase:	0.03–8.00 V[a]
Phase-to-Phase:	0.05–13.87 V[a]
Sequence:	0.05–8.00 V[a]

Eaton NOVA LEA Inputs (37 Vac Maximum)

Phase:	0.12–37.09 V[a]
Phase-to-Phase:	0.21–64.24 V[a]
Sequence:	0.25–37.09 V[a]

Lindsey SVMI LEA Inputs (200 Vac Maximum)

Phase:	1.00–200.00 V
Phase-to-Phase:	1.76–346.00 V
Sequence:	2.00–200.00 V

Steady-State Pickup Accuracy

300 V Maximum

Phase:	±0.5 V plus ±1% of setting
Phase-to-Phase:	±1 V plus ±2% of setting
Sequence:	±1.5 Vac plus ±3% of setting @ 12.5–300.0 Vac

8 V LEA Maximum[a]

Phase:	±10 mV plus ±1% of setting
Phase-to-Phase:	±20 mV plus ±2% of setting
Sequence:	±30 mVac plus ±3% of setting @ 0.33–8.00 Vac

Eaton NOVA LEA[a]

Phase:	±60 mV plus ±1% of setting
Phase-to-Phase:	±120 mV plus ±2% of setting
Sequence:	±180 mVac plus ±3% of setting @ 1.55–37.09 Vac

Lindsey SVMI LEA[a]

Phase:	±0.5 V plus ±1% of setting
Phase-to-Phase:	±1 V plus ±2% of setting
Sequence:	±1.5 Vac plus ±3% of setting @ 12.5–200.0 Vac

Transient Overreach:	±5%
Pickup/Dropout Time:	<1.25 cycles

Vector Shift (78VS)

Pickup Range:	2.0°–30.0°, 0.1-degree increment
Accuracy:	±1.5°, ±10% of setting
Pickup Time:	<3 cycles

Synchronism-Check Elements (25)

Slip Frequency Pickup Range:	0.005–0.500 Hz, 0.001-Hz steps
Slip Frequency Pickup Accuracy:	±0.003 Hz
Phase Angle Range:	0.00–80.00°, 0.01° steps
Phase Angle Accuracy:	±4°

Under- and Overfrequency Elements (81)

Frequency Range:	40.00–66.00 Hz, 0.01-Hz steps
Frequency Accuracy:	±0.01 Hz
Cycle-Based Delay Timers	
Time Delay Range:	2.00–16,000.00 cycles, 0.25-cycle steps
Time Delay Accuracy:	±0.25 cycle plus ±0.1%
Seconds-Based Delay Timers	
Time Delay Range:	0.10–1000.00 s, 0.01 s steps
Time Delay Accuracy:	±6 ms plus ±0.1% of setting
Undervoltage Frequency Element Block Range	
300 V Inputs:	12.50–300.00 V[a]

Rate-of-Change-of-Frequency Element (81R)

Pickup Range:	0.10–15.00 Hz/s, 0.01-Hz/s steps
Dropout:	95% of pickup
Pickup Accuracy:	±100 mHz/s and ±3.33% of pickup
Pickup Time:	See *Equation 4.7* in the *SEL-651RA Instruction Manual.*
Pickup Time Delay:	0.10–60.00 s, 0.01-second steps
Dropout Time Delay:	0.00–60.00 s, 0.01-second steps
Timer Accuracy:	±6 ms and ±0.1% of setting

Autosynchronizing

Frequency Matching	
Speed (Frequency) Control Outputs	
Raise:	Digital output, adjustable pulse duration and interval
Lower:	Digital output, adjustable pulse duration and interval
Frequency Synchronism	
Timer:	5–3600 s, 1 s increments
Frequency Adjustment Rate:	0.01–10.00 Hz/s, 0.01 Hz/s increment
Frequency Pulse Interval:	1–120 s, 1 s increment
Frequency Pulse Minimum:	0.02–60.00 s, 0.01 s increment
Frequency Pulse Maximum:	0.10–60.00 s, 0.01 s increment
Kick Pulse Interval:	1–120 s, 1 s increments
Kick Pulse Minimum:	0.02–2.00 s, 0.01 s increments
Kick Pulse Maximum:	0.02–2.00 s, 0.01 s increments
Voltage Matching	
Voltage Control Outputs	
Raise:	Digital output, adjustable pulse duration and interval
Lower:	Digital output, adjustable pulse duration and interval
Voltage Synchronized Timer:	5–3600 s, 1 s increments
Voltage Adjustment Rate (Control System):	0.01–30.00 V/s, 0.01 V/s increment
Voltage Pulse Interval:	1–120 s, 1 s increment
Voltage Control Pulse Minimum:	0.02–60.00 s, 0.01 s increment
Voltage Control Pulse Maximum:	0.10–60.00 s, 0.01 s increment
Timing Accuracy:	±0.5% plus ±1/4 cycle

Power Elements[b]

Minimum Current:	0.01 A
Minimum Voltage:	40 V
Steady-State Pickup Accuracy:	0.58 W plus ±5% of setting at unity power factor
Pickup/Dropout Time:	<3.75 cycles
Time Delay Accuracy:	±0.25 cycle plus ±0.1% of setting

Load Encroachment[b]

Minimum Current:	0.1 A
Minimum Voltage:	12.5 Vac
Forward Load Impedance:	0.5–640.0 ohms secondary
Forward Positive Load Angle:	–90° to +90°
Forward Negative Load Angle:	–90° to +90°
Negative Load Impedance:	0.50–640.00 ohms secondary
Negative Positive Load Angle:	+90° to +270°
Negative Negative Load Angle:	+90° to +270°
Pickup Accuracy	
Impedance:	±3%
Angle:	±2°

SELogic Control Equation Variable Timers

Pickup Ranges	
0.00–999,999.00 cycles:	0.25-cycle steps (programmable timers)
Pickup/Dropout Accuracy:	±0.25 cycle plus ±0.1% of setting

Metering Accuracies

Accuracies specified at 20°C and at nominal system frequency unless noted otherwise.

Instantaneous and Maximum/Minimum Metering

Voltages	
VAY, VBY, VCY, VAZ, VBZ, VCZ:	±0.2% (50.00–300.00 V), ±0.5° for PTs ±0.2% (0.67–8.00 V), ±0.5° for 8 V LEAs ±0.2% (3.09–37.09 V), ±0.5° for Eaton NOVA LEAs ±0.2% (25.00–200.00 V), ±0.5° for Lindsey SVMI LEAs
VABY, VBCY, VCAY, VABZ, VBCZ, VCAZ:	±0.4% (50.00–300.00 V), ±1.0° for PTs ±0.4% (1.16–13.86 V), ±1.0° for 8 V LEAs ±0.4% (5.35–64.28 V), ±1.0° for Eaton NOVA LEAs ±0.4% (43.30–346.41 V), ±1.0° for Lindsey SVMI LEAs

3V0Y, V1Y, V2Y, 3V0Z, V1Z, V2Z:	±0.6% (50.00–300.00 V), ±1.0° for PTs ±0.6% (0.67–8.00 V), ±1.0° for 8 V LEAs ±0.6% (3.09–37.09 V), ±1.0° for Eaton NOVA LEAs ±0.6% (25.00–200.00 V), ±1.0° for Lindsey SVMI LEAs

Currents

IA, IB, IC[c]:	±0.5 mA plus ±0.1% of reading (0.1–2.0 A), ±0.5°
IN:	±0.08 mA plus ±0.1% of reading (0.005–4.500 A), ±1°
3I1, 3I0, 3I2:	±0.01 A plus ±3% of reading (0.1–2.0 A), ±1°

Power

Apparent (MVA)

MVAA, MVAB, MVAC, MVA3P:	±1.2% (V_{phase} >50 Vac[d], I_{phase} >0.1 A)

Real (MW)

MWA, MWB, MWC,MW3P:	±0.7% @ PF = 1, ±1.0% @ PF >0.87 (V_{phase} >50 Vac[d], I_{phase} >0.1 A)

Reactive (MVAR)

MVARA, MVARB, MVARC, MVAR3P:	±0.7% @ PF = 0, ±1.0% @ PF < 0.50 (V_{phase} >50 Vac[d], I_{phase} >0.1 A)

Energy

Megawatt Hours (In and Out)

MWhA, MWhB, MWhC, MWh3P:	+1.2% @ PF = 1, (V_{phase} >50 Vac[d], I_{phase} >0.1 A)

Megavar Hours (In and Out)

MVARhA, MVARhB, MVARhC, MVARh3P:	+1.2% @ PF = 0, (V_{phase} >50 Vac[d], I_{phase} >0.1 A)

Demand Metering

Currents

IA, IB, IC:	±0.25% (0.1–2.0 A)
IN (Measured):	±0.25% (0.005–4.500 A)
3I2, 3I0 (IG):	±3% ±0.01 A, (0.1–20.0 A)

Synchrophasor Accuracy

Maximum Data Rate in Messages per Second

IEEE C37.118 Protocol:	60 (nominal 60 Hz system) 50 (nominal 50 Hz system)
SEL Fast Message Protocol:	1
IEEE C37.118-2005 Accuracy:	Level 1 at maximum message rate when phasor has the same frequency as A-phase voltage, frequency-based phasor compensation is enabled (PHCOMP := Y), and the narrow band filter is selected (PMAPP := N). Out-of-band interfering frequency (Fs) test, 10 Hz ≤ Fs ≤ (2 • NFREQ).
Current Range:	(0.1–2.0) • I_{nom} (I_{nom} = 1 A phase, 0.2 A neutral)
Frequency Range:	±5 Hz of nominal (50 or 60 Hz)
Voltage Range:	30.00–250.00 V for PTs 0.80–8.00 V for 8 V LEA inputs 3.71–37.09 V for Eaton NOVA LEA inputs 30.00–300.00 V for Lindsey SVMI LEA inputs
Phase Angle Range:	–179.99° to +180.00°

Harmonic Metering

Voltages

VAY, VBY, VCY, VAZ, VBZ, VCZ:	Accuracies valid for THD <100%, 30 V <fundamental <200 V sec, 50 Hz or 60 Hz
Fundamental Magnitude:	±5%
02–16 Harmonic Percentage:	±5 percentage points

Currents

IA, IB, IC:	Accuracies valid for THD <100%, fundamental voltage <200 V, 50 Hz or 60 Hz
1 A and 0.2 A Nominal:	0.02 A <fundamental current <1 A sec
Fundamental Magnitude:	±5%
02–16 Harmonic Percentage:	±5 percentage points

RMS Metering

Voltages

VAY, VBY, VCY, VAZ, VBZ, VCZ:	±1.2% V_{phase} > 50 Vac[d] for PTs

Currents

IA, IB, IC:	±0.5 mA plus ±0.2% (0.1–2.0 A)
IN (Measured):	±0.08 mA plus ±0.2% (0.005–4.500 A)

Average Real Power (MW)

MWA, MWB, MWC, MW3P:	±2.0% @ PF = 1 (V_{phase} > 50 Vac[c], I_{phase} > 0.1 A)

Product Standards

Measuring Relays and Protection Equipment:	IEC 60255-26:2013 Severity Level: Zone A Port 1 (EIA-485) and IRIG-B: Zone B

Type Tests

Recloser Type Tests

IEC 62271-111:2012/IEEE C37.60-2012, Section 6.111 Control electronic elements surge withstand capability (SWC) tests

6.111.2 Oscillatory and fast transient surge tests
6.111.3 Simulated surge arrester operation test
Both performed with the control connected to the following reclosers:

G&W Electric Viper-S, Solid Dielectric

Model:	VIP398ER-12S
Voltage Rating:	38 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	800 A

Eaton NOVA

Model:	NOVA 15, Aux. Power
Voltage Rating:	15.5 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	630 A

Electromagnetic Compatibility Emissions

Radiated[e] and Conducted[f] Emissions:	EN/IEC 60255-26:2013; Section 7.1 CISPR 22:2008 EN 55022:2010 + AC:2011 CISPR 11:2009 + A1:2010 EN 55011:2009 + A1:2010 FCC 47 CFR:2014; Part 15.107 FCC 47 CFR:2014; Part 15.109 Severity Level: Class A Canada ICES-001 (A) / NMB-001 (A)

Electromagnetic Compatibility Immunity

Conducted RF Immunity[e]:	EN/IEC 60255-26:2013; Section 7.2.8 IEC 61000-4-6:2008 EN 61000-4-6:2009 Severity Level: 10 Vrms
Electrostatic Discharge Immunity[f]:	EN/IEC 60255-26:2013; Section 7.2.3 IEC 61000-4-2:2008 EN 61000-4-2:2009 Levels 2, 4, 6, and 8 kV contact Levels 2, 4, 8, and 15 kV air IEEE C37.90.3-2001 Levels 2, 4, and 8 kV contact Levels 4, 8, and 15 kV air
Electrical Fast Transient Burst Immunity[f,g]:	EN/IEC 60255-26:2013; Section 7.2.5 EN/IEC 61000-4-4:2012 4 kV, 5 kHz on power supply, I/O, and ground; 2 kV, 5 kHz on communications ports
Radiated RF Immunity[f]:	EN/IEC 60255-26:2013; Section 7.2.4 IEC 61000-4-3:2006 + A1:2007+ A2:2010 EN 61000-4-3:2006 + A1:2008 + A2:2010 Severity Level: 10 V/m IEEE C37.90.2-2004 Severity Level: 20 V/m (average) 35 V/m (peak)
Surge Immunity[e,g,h]:	EN/IEC 60255-26:2013; Section 7.2.7 Severity Level: Zone A Severity Level: Zone B on Port 1 (485) and IRIG-B IEC 61000-4-5:2005 EN 61000-4-5:2006 Severity Level 4: 2 kV line-to-line 4 kV line-to-earth Severity Level 3 on Port 1 (485) and IRIG-B: 2 kV line-to-earth
Surge Withstand Capability[f]:	EN/IEC 60255-26:2013; Section 7.2.6 IEC 61000-4-18:2006 + A1:2010 EN 61000-4-18:2007 + A1:2010 Severity Level: Power supply and I/O 2.5 kV common mode 1.0 kV differential mode Communications ports 1.0 kV common mode IEEE C37.90.1-2012 2.5 kV oscillatory 4.0 kV fast transient

Power Supply Immunity[i]

Voltage Dips and Interruptions:	EN/IEC 60255-26:2013; Section 7.2.11 EN/IEC 61000-4-11:2004 EN/IEC 61000-4-29:2000
Voltage Ripple:	EN/IEC 60255-26:2013; Section 7.2.12 IEC 61000-4-17:1999 + A1:2001 + A2:2008 EN 61000-4-17:1999 + A1:2004 + A2:2009
Gradual Shutdown and Startup:	EN/IEC 60255-26:2013; Section 7.2.13

Environmental

Cold[e]:	IEC 60068-2-1:2007 Test Ab and Ad: 16 hours at –40°C
Damp Heat, Cyclic[f]:	EN/IEC 60068-2-30:2005 Test Db: 25° to 55°C, 6 cycles, Relative Humidity: 95%
Dry Heat:	EN/IEC 60068-2-2:2007 Test Bb and Bd: 16 hours at +85°C[i] Test Bd: 16 hours at +65°C[f]
Vibration[i]:	IEC 60255-21-1:1988 EN 60255-21-1:1995 Severity Level: Endurance Class 1 Response Class 2 IEC 60255-21-2:1988 EN 60255-21-2:1995 Severity Level: Shock Withstand, Bump Class 1 Shock Response Class 2 IEC 60255-21-3:1993 EN 60255-21-3:1995 Severity Level: Quake Response Class 2
Enclosure Ingress Protection[f]:	IEC 60529:1989 + A1:1999 + A2:2013 EN 60529:1989 + A1:2002 + A2:2013 IP45

Safety

Insulation Coordination[i]:	IEC 60255-27:2013; Section 10.6.4 EN 60255-27:2014; Section 10.6.4 IEEE C37.90-2005 Severity Level—Hipot: 2.5 kVac on optoisolated inputs, contact outputs, CTs, and PTs 0.75 kVdc on IRIG-B, EIA-485, and Ethernet ports 3.6 kVdc on power supply Type tested for one minute Severity Level—Impulse: 5.0 kV on optoisolated inputs, contact outputs, CTs, PTs, and power supply 0.8 kV on IRIG-B, EIA-485, and Ethernet ports

Power Supply[i]

Discharge of Capacitors:	IEC 60255-27:2013; Section 5.1.3 EN 60255-27:2014; Section 5.1.3
Reverse Polarity and Slow Ramp Tests:	IEC 60255-27:2013; Section 10.6.6 EN 60255-27:2014; Section 10.6.6

[a] See Section 9: Settings for details on how to set voltage elements when using LEA inputs.

[b] Voltage, Power, and Impedance values listed for 300 Vbase (PT) inputs.

[c] Accuracies specified with balanced phase voltages at 120 Vac.

[d] Voltage threshold for given accuracy is 0.67 Vac for 8 V LEA inputs, 1.7 Vac for Eaton NOVA LEA inputs, and 14 Vac for Lindsey SVMI LEA inputs.

[e] Test conducted both with and without SEL enclosure.

[f] SEL enclosure included in test.

[g] Serial cable (non-fiber) lengths assumed to be <3 m.

[h] The following pickup/dropout delays are used:
Under- and overvoltage elements 1.5/1.5 cycles
Phase instantaneous overcurrent elements 0/0.5 cycles
Neutral instantaneous overcurrent elements 0.5/2.5 cycles
Digital inputs 0.75/0.75 cycles

[i] SEL enclosure excluded from test.

Technical Support

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

Notes

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.332.1890 • Fax: +1.509.332.7990
selinc.com • info@selinc.com

PDS651RA-01