SEL-651R-2 Recloser Control

Advanced Recloser Control

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

- **Single-Phase Tripping/Reclosing.** Interrupt, then restore service on the faulted phase, rather than affecting all three phases. When load levels vary from phase to phase, set trip levels independently for each phase.
- **Multi-Recloser Interface.** Support a number of reclosers from different manufacturers with one common control cable interface.
- **Wide-Range Recloser Compatibility.** Use the SEL-651R-2 Advanced Recloser Control with control cable interfaces for many different reclosers. Learning the settings and operation of just the SEL-651R-2 enables you to operate a wide range of reclosers.
- **ACSELERATOR QuickSet® SEL-5030 Software.** Use the eight settings groups to easily configure multiple group settings to fit operational situations. Apply custom application designs and create design templates that can be stored on the recloser control for your specific applications.
- **Low-Energy Analog (LEA) Inputs.** Reduce costs and save space with as many as six LEA voltage inputs.
- **Enclosure Options.** Choose the extra space and easy access of the dual-door enclosure or the more compact size of the single-door option. For the dual- or single-door options, select the painted cold-rolled steel enclosure (NEMA 3R rated) for normal applications or the painted type 304 stainless steel enclosure (NEMA 3RX rated) to reduce corrosion in harsh environments. Both enclosure styles also achieve an IP45 rating for solids and water ingress resistance.
- **Ethernet Communications.** Provide DNP, Modbus®, IEC 61850, File Transfer Protocol (FTP), and Simple Network Time Protocol (SNTP) capabilities through use of single fiber, dual copper, or fiber-optic Ethernet ports. A built-in web server makes firmware upgrades over Ethernet quick and secure.
- **Communications Flexibility.** Order the SEL-651R-2 with one USB port, four serial ports (three EIA-232 and one EIA-485), one Ethernet port (fiber-optic), or two Ethernet ports (copper or fiber-optic). The front-panel USB port retrieves events, settings, and templates faster than traditional EIA-232 ports.
- **Automatic Network Reconfiguration (ANR).** Improve reliability with ANR by isolating faulted line sections and restoring service to unaffected areas of the system.
- **Configurable Power Elements.** Determine power flow or VAR flow direction and magnitude with configurable power elements. Apply at system intertie points or at capacitor bank installations.
- **Total Harmonic Distortion (THD).** Monitor the system power quality based on THD with harmonic metering as high as the 16th harmonic, following IEEE 519-2014.
- **Built-In Power Supply.** Power demanding 12 Vdc accessories easily with a built-in 40 W continuous (60 W surge) auxiliary power supply.
- **Digitally Signed Firmware Upgrade.** Upload digitally signed firmware over Ethernet or serial connection. Secure algorithms guarantee the validity of the firmware file.
- **Second-Harmonic Blocking.** Secure the recloser control during transformer energization.
- **Rate-of-Change-of-Frequency Elements.** Detect rapid frequency changes to initiate load shedding or network decoupling.
- **Event Data and Fast Sampling Rate.** See more pre-fault and post-fault data with 60-cycle-length event reports. Gain better resolution with 128-samples/cycle analog data.
- **COMTRADE Event Reports.** Capture standard and high-impedance event reports in COMTRADE standard file format.
- **Synchrophasors.** Gather power system information and monitor wide-area performance with IEEE C37.118 synchrophasors.
- **High-Impedance Fault Detection.** Apply SEL Arc Sense™ technology in detecting more high-impedance faults than conventional protection for more reliable operation of distribution systems.

Compatibility Overview

Multi-Recloser Interface

An SEL-651R-2 Recloser Control ordered with the Multi-Recloser Interface is compatible with the following reclosers on one common interface:

- G&W Viper-ST
- G&W Viper-LT
- ABB Elastimold MVR
- Tavrida OSM Al_4
- ABB Gridshield (32-pin and 42-pin versions)
- Eaton NOVA NX-T

Three-Phase Reclosers With Single-Phase Tripping Capability

An SEL-651R-2 Recloser Control connects to the following three-phase reclosers with single-phase tripping capability:

- G&W Viper-ST
- G&W Viper-LT
- ABB Elastimold MVR
- ABB OVR-3/VR-3S (24-pin, 15 and 27 kV models)
- ABB Joslyn TriMod 600R
- ABB Gridshield (32-pin and 42-pin versions)
- Eaton NOVA-TS or NOVA-STS Triple-Single
- Eaton NOVA NX-T
- Tavrida OSM Al_4
- Siemens SDR Triple-Single

Three-Phase Reclosers

The SEL-651R-2 Recloser Control connects to the following three-phase reclosers:

- G&W Viper-S
- G&W Control Power Viper-S
- Eaton
  - CXE
  - Auxiliary-Powered Eaton NOVA
  - RE
  - RVE
  - RXE
  - VSA
  - VSO
  - VWE
  - VWVE 27
  - VWVE 38X
  - WE
  - WVE 27
  - WVE 38X
  - Control-Powered Eaton NOVA
- Whipp & Bourne GVR (when equipped with interface module)
- Tavrida OSM Al_2
- Siemens SDR Three-Phase

Certification

The current IEEE C37.60 test certificates are available at selinc.com.

Product Overview or Functional Overview

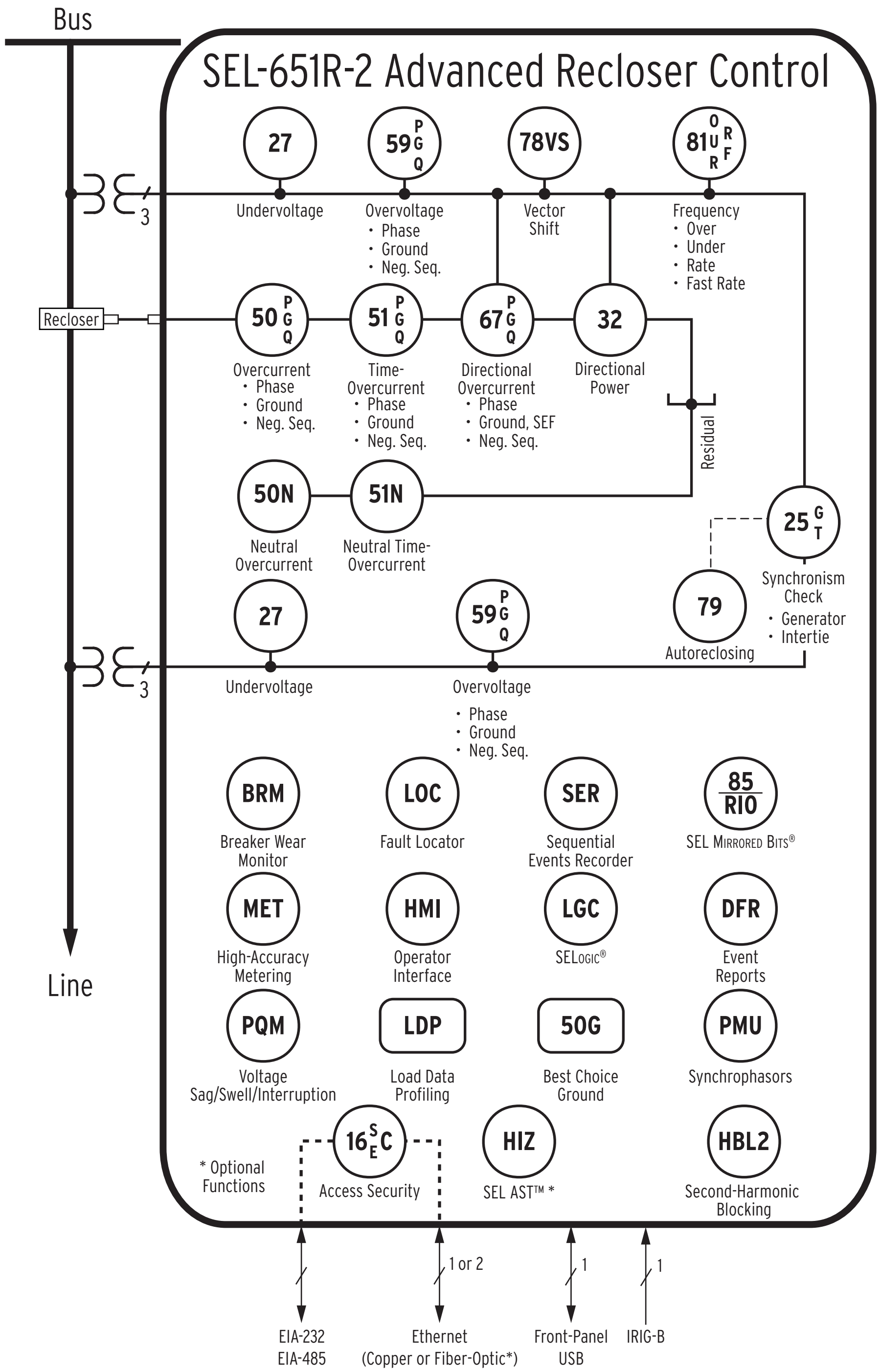


Figure 1 Functional Diagram

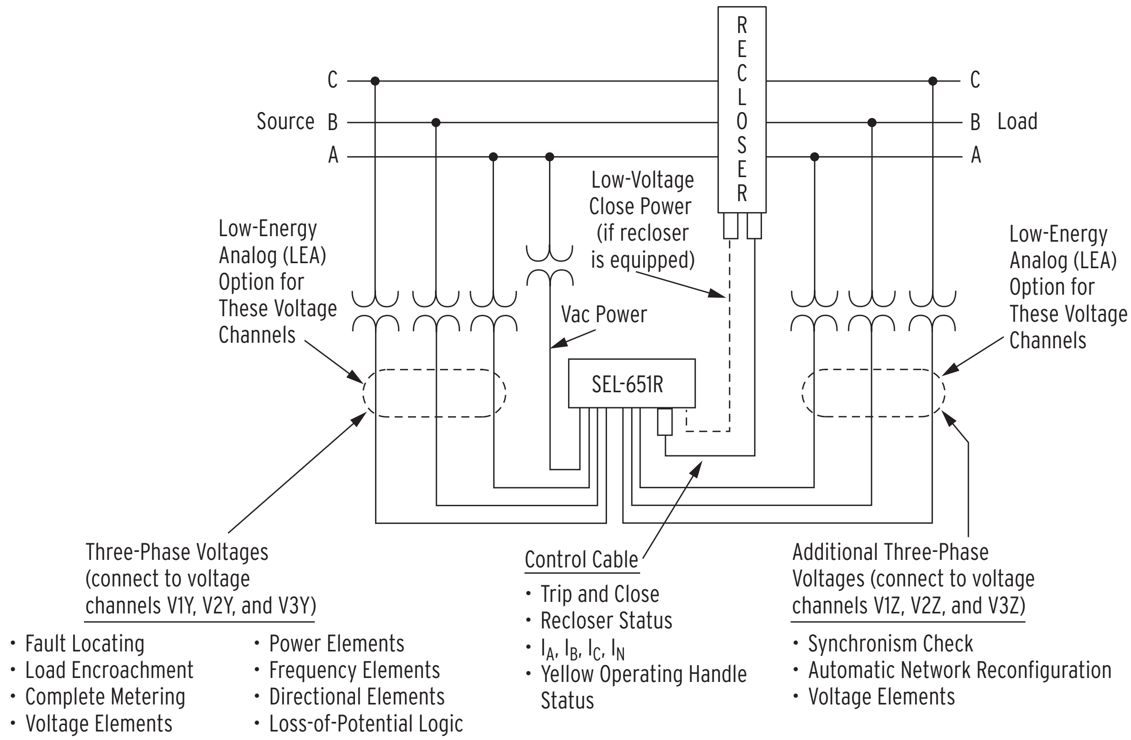


Figure 2 Connect Three-Phase Load and Source Voltages to SEL-651R-2

Control Cable

The control cable brings secondary current, recloser status, yellow operating handle status, and, in some cases, LEA voltages to the SEL-651R-2 and takes trip/close signals out to the recloser (see *Figure 3*). The control cable connects to the SEL-651R-2 via a control cable receptacle/interface at the bottom of the enclosure.

Note: Select the appropriate control cable interface when ordering.

Voltage Inputs

Connect voltages on both sides of the recloser, as shown in *Figure 2*, for such schemes as Automatic Network Reconfiguration (*Figure 12*) and synchronism check. Select the three-phase voltage channel (VY or VZ) to operate features such as the following (*Figure 2*):

- ➤ Fault locating
- ➤ Load encroachment
- ➤ Power elements
- ➤ Voltage sag/swell/interrupt 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-651R-2.

Control Power Input

Order the control power input (shown as the Vac Power connection in *Figure 2*) as either 120 Vac, 230 Vac, 125 Vdc, or 48 Vdc.

The 120 Vac option includes a ground-fault circuit interrupter (GFCI) convenience outlet.

Use ac transfer switches (see *Figure 3*) to change to the alternate control power source when the primary control power source is unavailable. This ability is especially valuable in Automatic Network Reconfigurations such as those in *Figure 11* and *Figure 12*.

The incoming control power is converted to the following:

- ➤ 12 Vdc to run the control electronics
- ➤ Stored energy in capacitors in the power module to provide energy for the trip/close outputs of the relay module

If the incoming control power is unavailable, the 12 V battery provides energy to charge the capacitors and to run the control electronics.

The 125 Vdc and 48 Vdc power input options include a reduced level 12 V auxiliary supply for use in wetting contact inputs, but not for powering communications devices. These options do not include the battery charger, batteries, or GFCI convenience outlet.

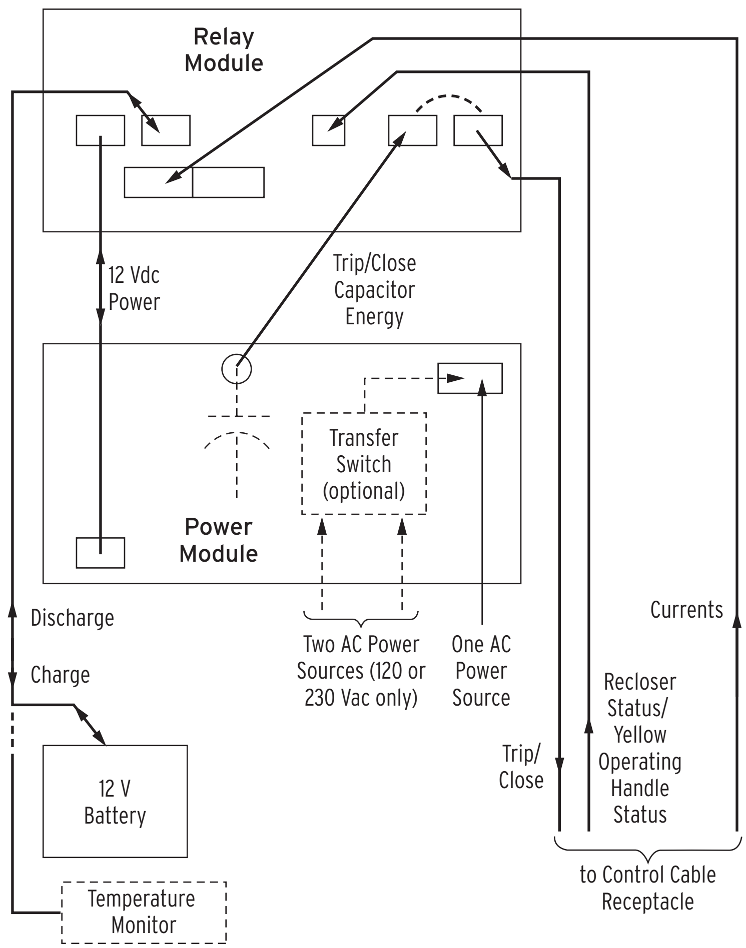


Figure 3 Major Interconnections Between SEL-651R-2 Components

Automation and Communication

Communications Connection Options

The base model SEL-651R-2 is equipped with one USB port, three independently operated EIA-232 serial ports, and one isolated EIA-485 port. Ethernet port ordering options include the following:

- Single 100BASE-FX optical Ethernet port
- Dual redundant 10/100BASE-T metallic Ethernet ports
- Dual redundant 100BASE-FX optical Ethernet ports

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, and communications processors. Connect multiple SEL-651R-2 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*).

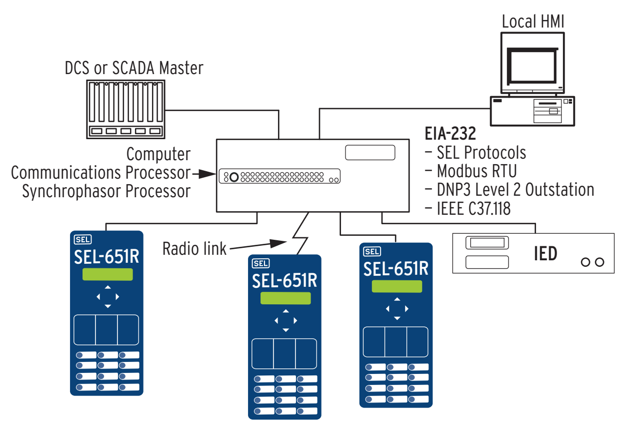


Figure 4 Typical Serial Communications Architecture

SEL manufactures a variety of standard cables for connecting SEL-651R-2 to many external devices. Consult your SEL representative for more information on cable availability. The SEL-651R-2 can communicate directly with SCADA systems, computers, and RTUs via serial or Ethernet port for local or remote communications (see *Figure 5*).

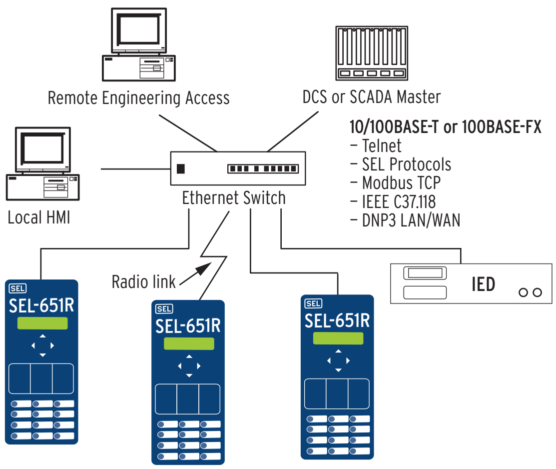


Figure 5 Typical Ethernet Communications Architecture

High-speed Ethernet ports are valuable for engineering access and control setup. Download a 60-cycle, 128 sample-per-cycle event report in as little as 40 seconds. Upgrade firmware in a scant 55 seconds from initiation to Relay Enabled.

Go beyond local engineering access and connect optional dual Ethernet ports to increase network reliability and availability (*Figure 6* and *Figure 7*). The configuration shown in *Figure 6* uses an Ethernet switch inside the control to bridge network connections and form a self-healing ring as part of a managed network. *Figure 7* shows how to connect the control for fully redundant fast-failover configuration. In either configuration, no single point of failure can prevent communication with the control. *Table 1* lists available protocols.

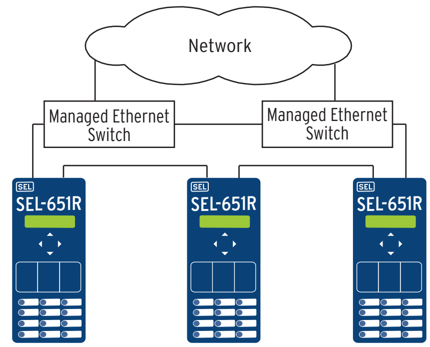


Figure 6 Self-Healing Ring Using Internal Ethernet Switch

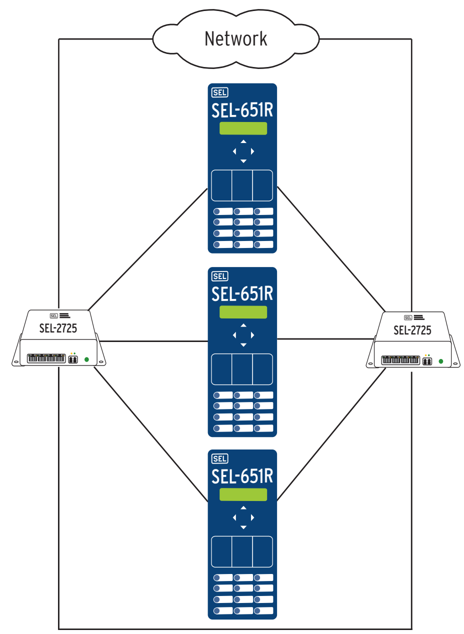


Figure 7 Failover Network Topology

Serial Communication

The SEL-651R-2 retains all the serial communications capability of previous SEL-651R models and adds an EIA-485 and Type B USB port for fast and convenient local access. Use any communications processor software that emulates a standard terminal system.

FTP

Provides the ability to read and write available settings files and read COMTRADE file format event reports from the recloser control over Ethernet.

Table 1 Open Communications Protocol

Type	Description
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation. Operates remote bits, breaker controls, and input/output (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 relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Fast SER Protocol	Provides serial or Ethernet SER data transfers with original time stamp to an automated data collection system.
Modbus RTU or TCP	Serial or Ethernet-based Modbus with point remapping. Includes access to metering data, protection elements, contact I/O, targets, relay summary events, and settings groups.
Extended Fast Meter and Fast Operate	Serial or Telnet binary protocol for machine-to-machine communications. Quickly updates SEL communications processors, RTUs, and other substation devices with metering information, relay 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 relay using ASCII communications through the same relay communications port.
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, relay 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-651R-2 control logic to provide the following improvements:

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

Eliminate traditional panel control switches:

- 12 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*).
- 16 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., SINGLE PHASE TRIP\ ENABLED) to report power system or relay conditions on the LCD.
  - Control which messages are displayed via SELOGIC control equations by driving the LCD display via any logic point in the relay. Set as many as 32 programmable display messages.

Replace RTU-to-Relay Wiring 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 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 relay 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.

- In the factory settings, these latching control points give many of the operator-control pushbuttons their ENABLE/DISABLE or ON/OFF mode of operation, where each press of the pushbutton toggles the latch to the opposite state.

Replace Traditional Indicating Panel Lights With 24 Status and Target LEDs

Change 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.
- Each timer has independent time-delay pickup and dropout settings.
- 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-651R-2 is factory set for use without additional logic in many situations. For complex or unique applications, expanded SELOGIC functions allow superior flexibility and put relay logic into the hands of the protection engineer.

With expanded SELOGIC control equations you can do the following:

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

To program SELOGIC control equations, combine relay 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. New functions and abilities enable you to 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

ACSELERATOR QuickSet SEL-5030 With Design Features

Use the ACSELERATOR QuickSet SEL-5030 Software 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-651R-2. The software also converts event reports to oscillograms with time-coordinated element assertion and phasor/sequence element diagrams. View real-time phasors via QuickSet.

With the licensed version of QuickSet, you can commission recloser controls using only the settings you need. This version allows users to create custom Application Designs. Use these designs to quickly implement advanced schemes, such as Automatic Network Reconfiguration and single-phase tripping/reclosing. 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 relay features and settings (*Figure 8*) and watch commissioning times drop drastically. Design custom templates using QuickSet for your specific applications and then store the templates on the recloser control for easy access when making settings changes.

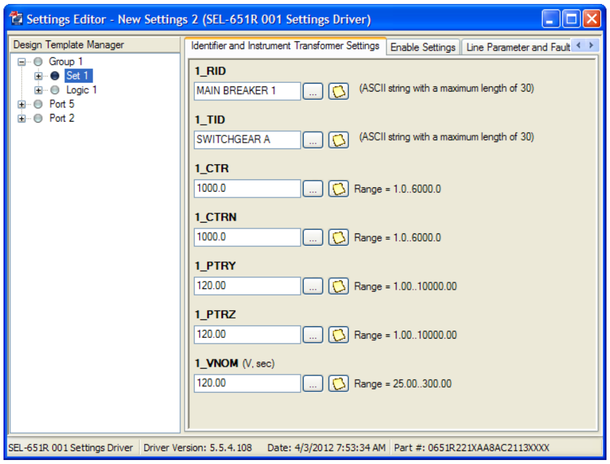


Figure 8 Example Application Designs

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-651R-2. With MIRRORED BITS operating on two serial ports, there is communication upstream and downstream from the SEL-651R-2 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 the MIRRORED BITS mode (see *Figure 9*). Use these MIRRORED BITS to transmit/receive information between upstream relays 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.

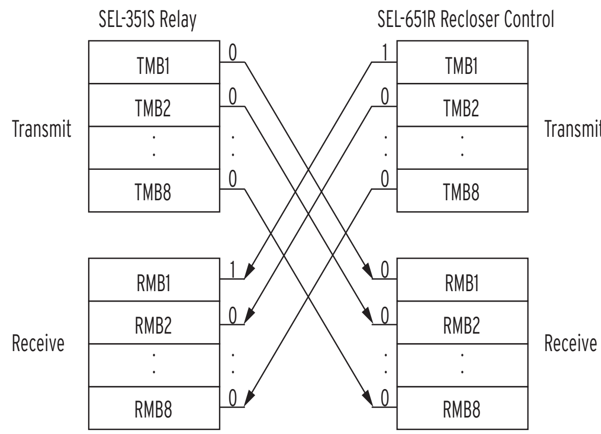


Figure 9 MIRRORED BITS Transmit and Receive Bits

Integrated Web Server

An embedded web server is included in every SEL-651R-2 recloser control. 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 allows no control or modification actions at Access Level 1 or lower, so users can be confident that an inadvertent button press will have no adverse effects. *Figure 10* 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-651R-2 firmware files contain cryptographic signatures that enable the SEL-651R-2 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 relay, the relay 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 relay. If the relay cannot verify the signature, it reverts to the previously installed firmware.

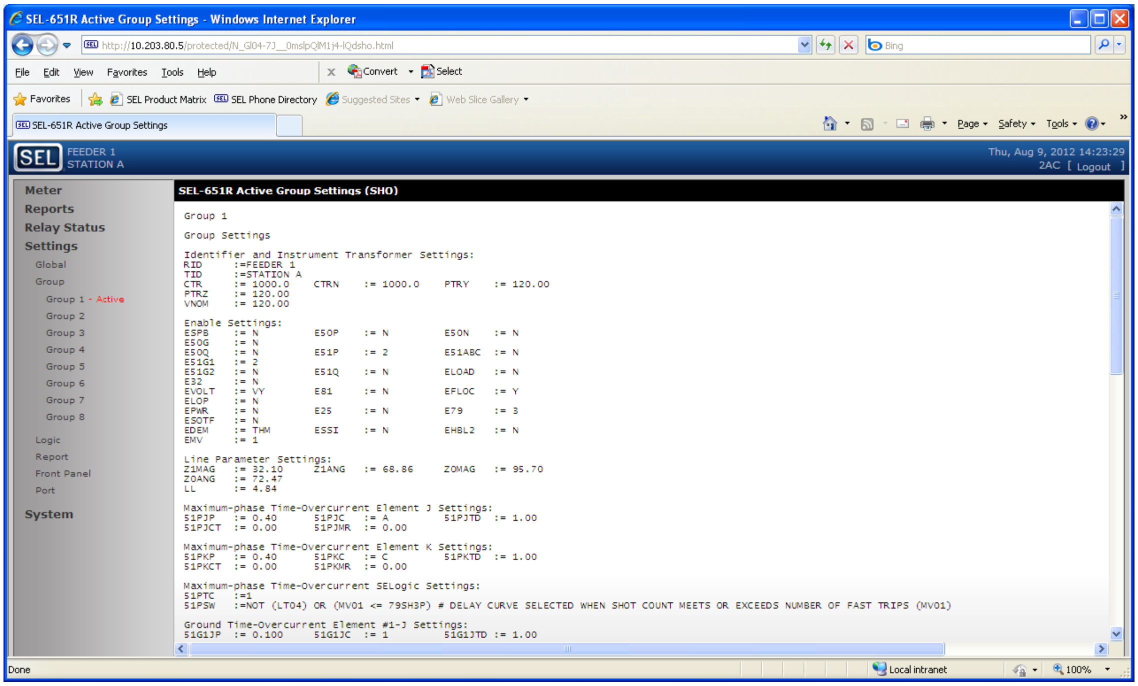


Figure 10 Settings Display Webpage

Applications

Automatic Network Reconfiguration

Automatic Network Reconfiguration augments system reliability by automatically isolating faulted line sections and restoring service to the unaffected areas of the system. In the simple Automatic Network Reconfiguration implementation in *Figure 11*, there is no direct communication between the recloser control sites and there is minimal voltage sensing. For the sample fault in *Figure 11*, system isolation and restoration is 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 12* includes both source-side and load-side voltages into the SEL-651R-2 Recloser Controls and Mirrored Bits communications (via fiber optics or radio) between the recloser sites. These enhancements greatly speed up 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.

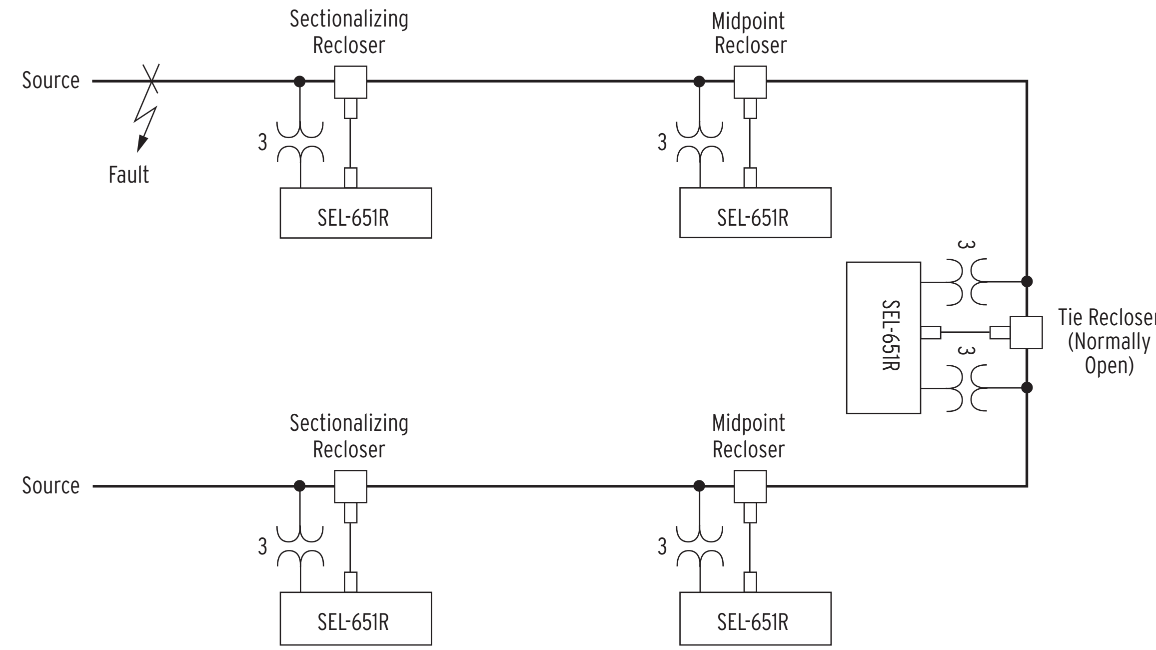


Figure 11 Simple Automatic Network Reconfiguration

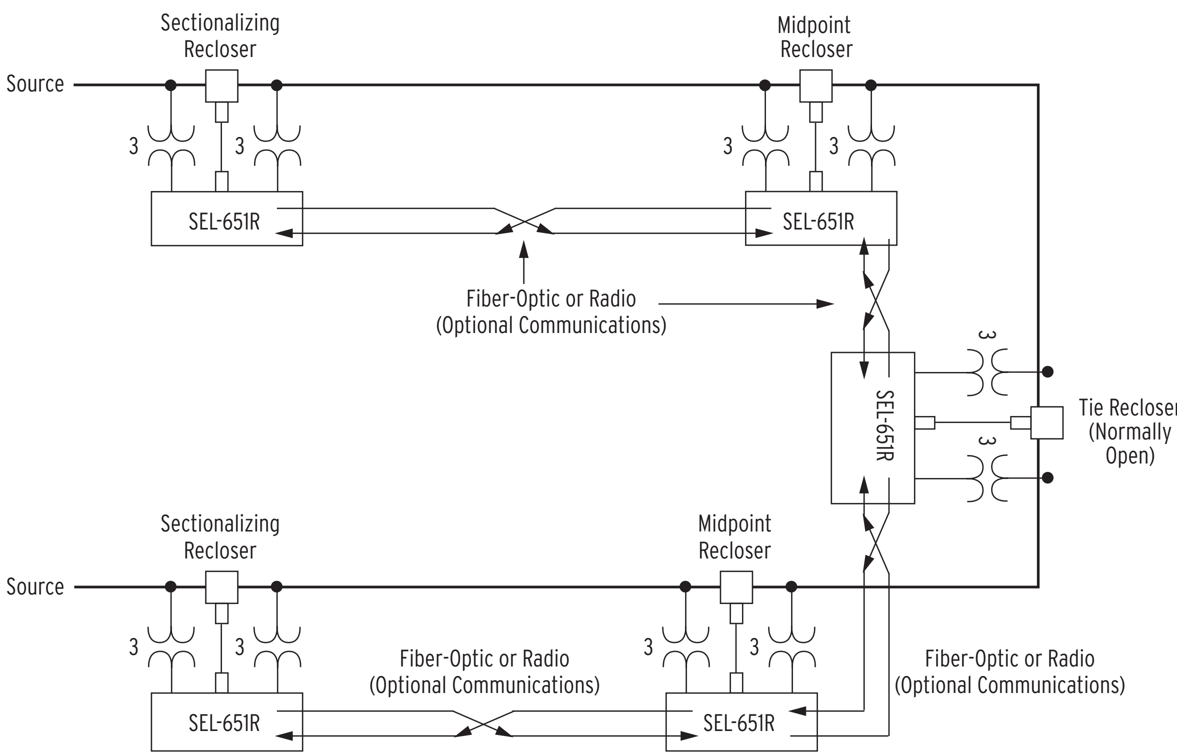


Figure 12 Advanced Automatic Network Reconfiguration

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 13* 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.

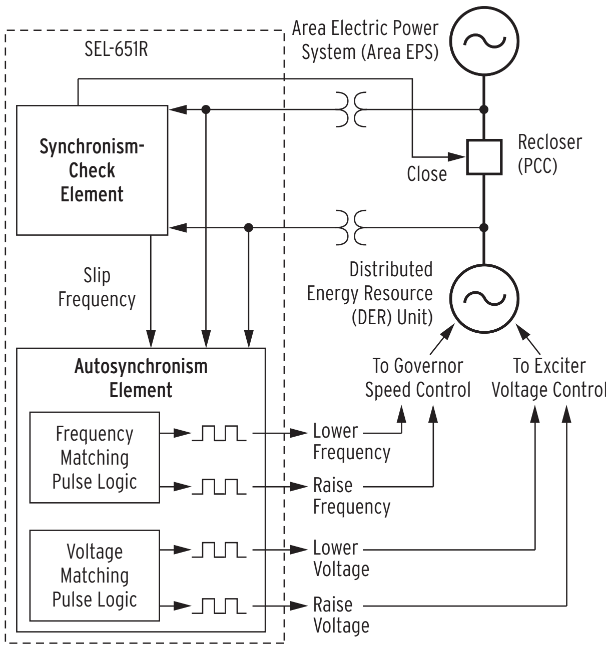


Figure 13 Distributed Energy Resource Intertie

Single-Phase Tripping/Reclosing

Single-phase tripping/reclosing also improves system reliability by keeping customers in service who are not on the faulted phase of a feeder. In *Figure 14*, a permanent fault occurs on the middle phase. Because single-phase tripping/reclosing is enabled, only the middle pole of the recloser opens for the fault. In this case, reclosing does not restore service because the fault is permanent, but only the customers on the middle phase are left without power, rather than customers on all three phases.

Available trip-reclose-lockout operation modes for the single-phase reclosers are as follows:

- Three-phase trip/reclose, three-phase lockout
- Single-phase trip/reclose, three-phase lockout
- Single-phase trip/reclose, single-phase lockout
- Single-phase trip/reclose, single-phase lockout (three-phase lockout if two or more phases involved)

Three-phase tripping is still available for all single-phase trip modes. Apply single-phase operation to rural areas where many loads are single-phase and restoration can take longer because of travel distance. Switch between single-phase and three-phase operation depending upon seasonal needs. When the load levels differ from phase to phase, set the trip levels for each phase independently.

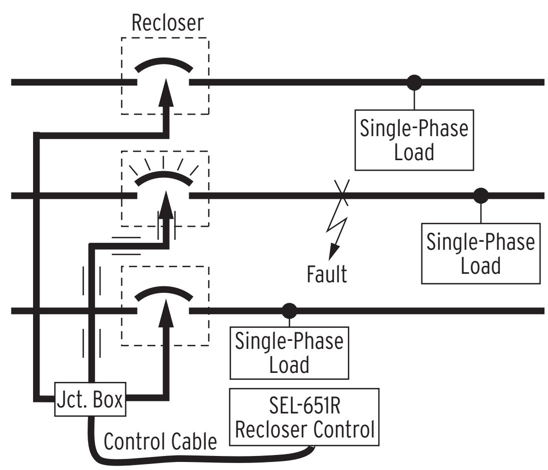


Figure 14 Single-Phase Tripping Isolates Only the Faulted Phase

Protection Features

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 100 A primary for phase-to-ground overcurrent protection and 5 A primary for ground overcurrent protection.

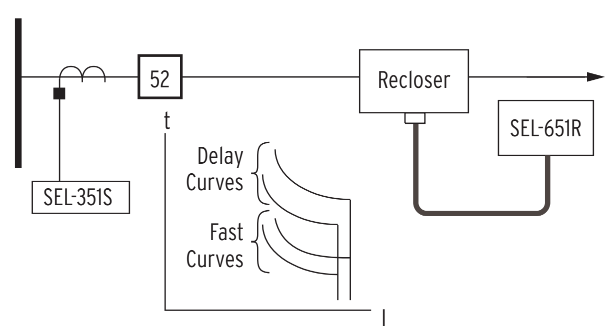


Figure 15 Coordinate the SEL-651R-2 With Other Devices

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 using the older electronic control designations.

Table 3 Curve Choices Resident in the SEL-651R-2

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 by using the newer microprocessor-based control designations (the SEL-651R-2 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-651R-2 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 disk 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 is above phase minimum trip.

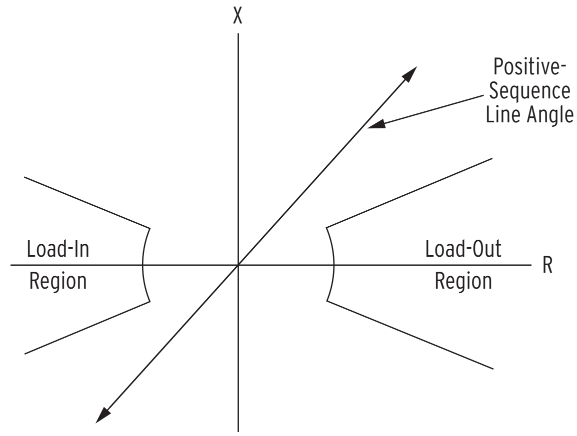


Figure 16 Load-Encroachment Logic Defines Load Zones (No Trip Zones)

Directional Elements Increase Sensitivity and Security

Phase and ground directional elements are standard. 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-651R-2 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-651R-2 can reclose as many as four (4) times. This allows for as many as five operations of any combination of fast and delay curve overcurrent elements. The SEL-651R-2 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-651R-2 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-651R-2. 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 Protection

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.

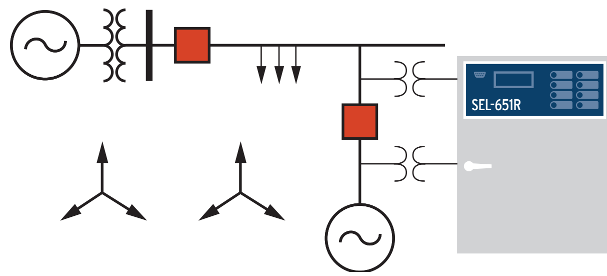


Figure 17 Fast Islanding Detection

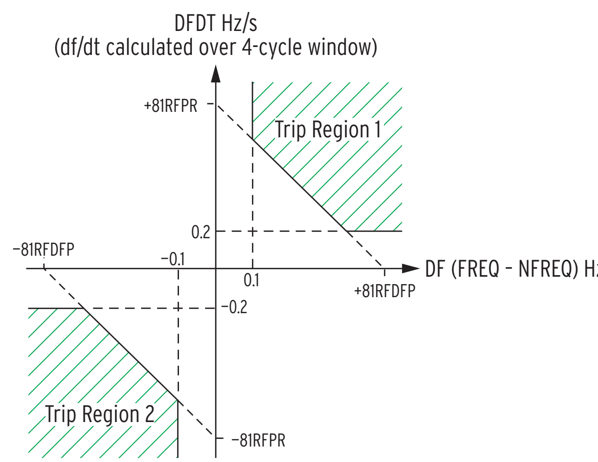


Figure 18 81RF Characteristics

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. 81RFDFP (in Hz) and 81RFRP (in Hz/sec) are the settings used 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 Locating

The SEL-651R-2 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 pre-fault 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 are short-circuit faults with fault currents smaller than what a traditional overcurrent element can detect.

The SEL-651R-2 with Arc Sense technology includes logic that can detect HIF signatures without being affected by loads or other system operation conditions. High-impedance fault event reports are stored in both Compressed ASCII and COMTRADE file format.

The SEL-651R-2 offers another method of detecting high-impedance faults. 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 relay asserts an alarm indicating a potential high-impedance fault.

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 relay 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 relay, 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/cycle resolution analog data. The relay 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 Standard ASCII, Compressed ASCII, and COMTRADE file format. Relay settings operational in the relay at the time of the event are appended to each event report.

High-impedance fault event reports are also available in Compressed ASCII and COMTRADE file formats. The information used to determine if a high-impedance fault is present on the system is included in the report. The relay 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 BNC 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-651R-2 for millisecond accurate time synchronization.

The recloser control also synchronizes the internal clock to an NTP server via SNTP with 5 ms accuracy. Connect all possible time sources (IRIG, SNTP, DNP) and the recloser control automatically selects the most accurate.

The ACSELERATOR Analytic Assistant® SEL-5601 Software and QuickSet can read a Compressed ASCII or COMTRADE file format version of the event report, which contains even more information than the standard ASCII 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 users to analyze the pre-fault, fault, and post-fault intervals, observing the directly measured inputs, as well as the calculated sequence component signals.

Event Summary

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

- Relay/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 relay 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 relay element operation. Select items that trigger an SER entry including I/O change of state, element pickup/dropout, recloser state changes, etc. The relay 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-651R-2 recloser controls and concentrates the result into a single-output data stream. The SEL-3378 SVP enables control applications based on synchrophasors, which allows users to do the following:

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

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

The data rate of SEL-651R-2 synchrophasors is selectable, with a range of 1–60 messages per second. This flexibility is important for efficient use of communications capacity. The SEL-651R-2 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-651R-2 in any application that otherwise would have required purchasing a separate dedicated phasor measurement unit (PMU).

Use the SEL-651R-2 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.

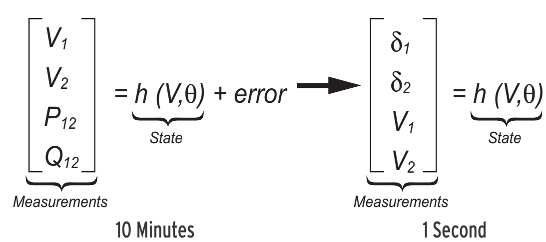


Figure 19 Synchrophasor Measurements Turn State Estimation Into State Measurement

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 users 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

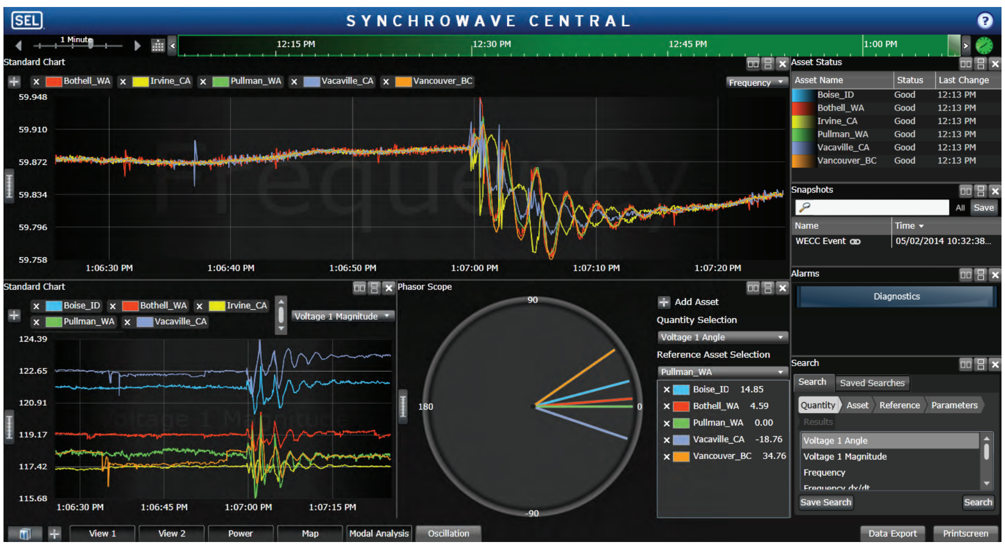


Figure 21 SEL-5078-2 SYNCHROWAVE Central Real-Time, Wide-Area Visualization Tool

Voltage Sag/Swell/Interrupt (VSSI) Report

The 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 just 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-651R-2 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.

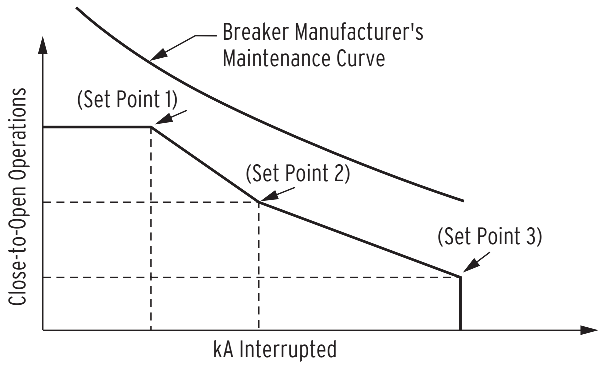


Figure 22 Recloser Contact Wear Curve and Settings

Load Profile

The load profile recorder in the SEL-651R-2 is capable of recording as many as 15 selectable analog quantities at a periodic rate (5, 10, 15, 30, or 60 minutes) and storing 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-651R-2 stores as many as 26 days of load profile data. More days of storage are available if you choose longer periodic recording rates or select fewer analog quantities.

Metering

The SEL-651R-2 provides extensive and accurate metering capabilities, as shown in *Table 4*. See *Specifications* for metering accuracies. The SEL-651R-2 reports all metered quantities in primary quantities (current in A primary and voltage in kV 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

Table 4 Available Metering Quantities (Sheet 2 of 2)

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
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-651R-2 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-651R-2 front panel to fit your needs. Optional tricolor LEDs even 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 using QuickSet. Print label sets using templates or write labels by hand.

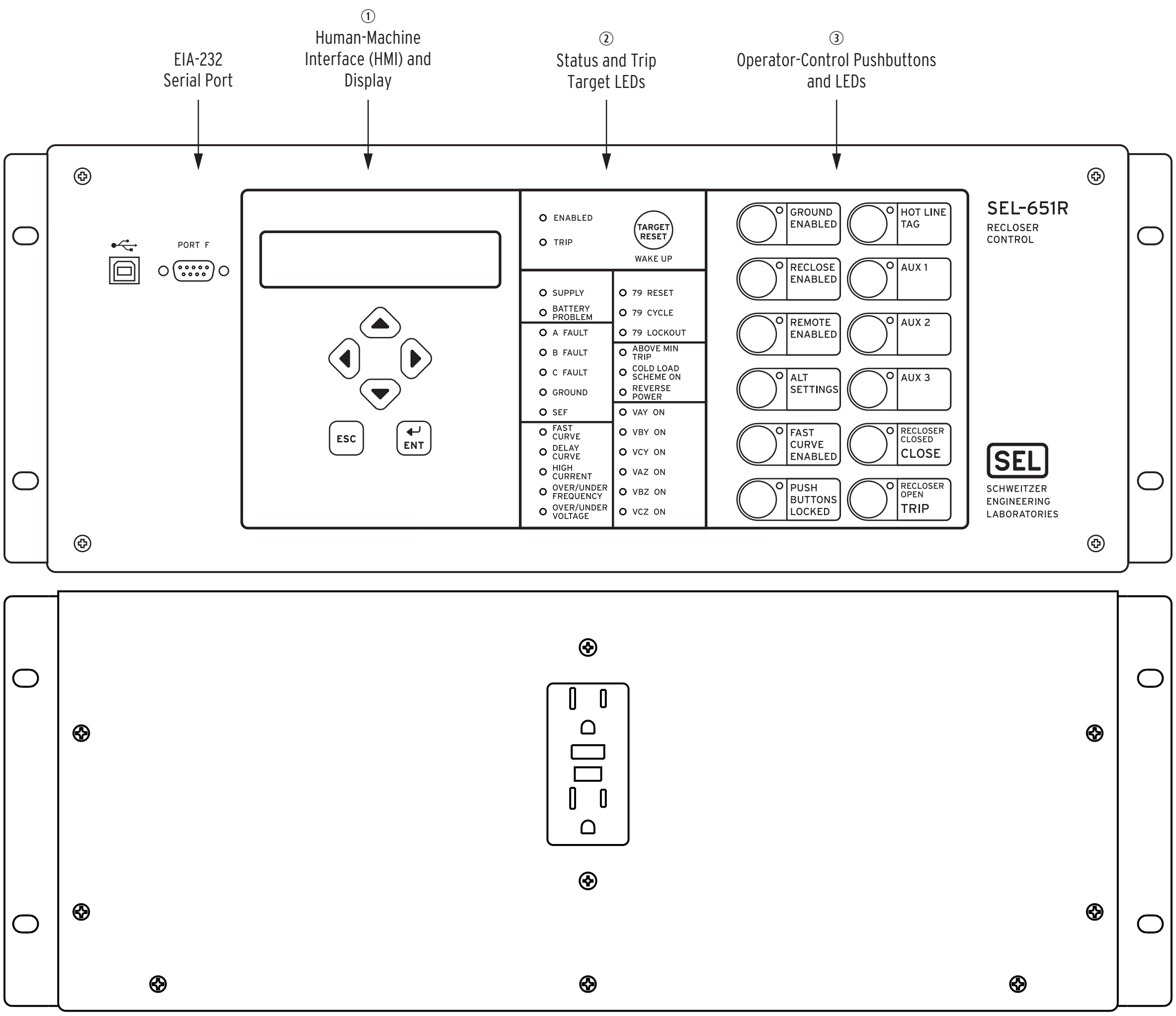


Figure 23 Front View of SEL-651R-2 Relay and Power Modules (Dual-Door Enclosure)

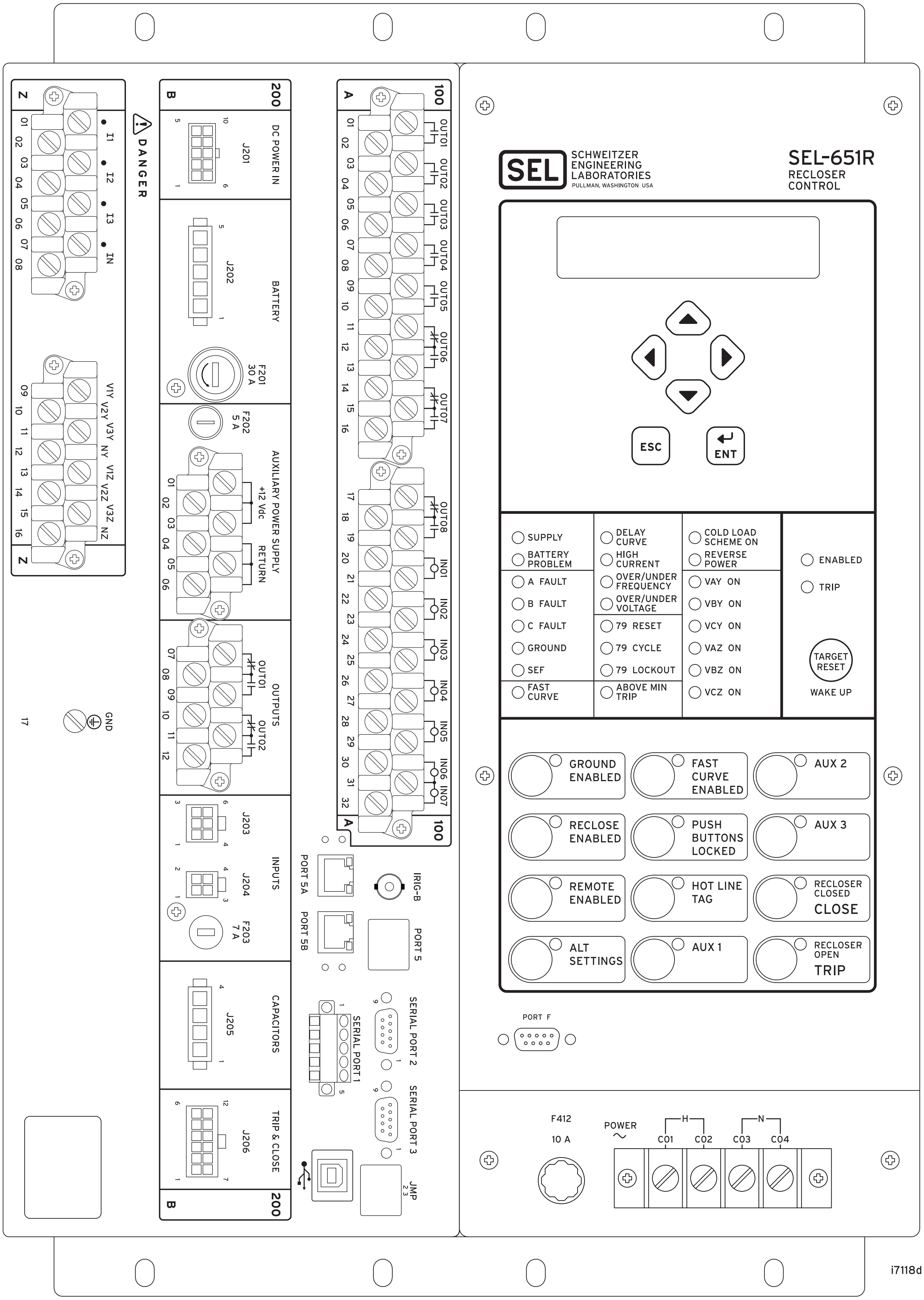


Figure 24 Front View of SEL-651R-2 Relay and Power Modules (Single-Door Enclosure)

Table 5 Factory-Default Front-Panel Interface Definitions (see *Figure 22*)

	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-651R-2 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/UNDER FREQUENCY	Over- and underfrequency element trip (not set from factory).
	OVER/UNDER VOLTAGE	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.
	ALTERNATE SETTINGS	Switch active setting group between main and alternate setting groups.
	FAST CURVE ENABLED	Enable/disable fast curve overcurrent element.
	PUSH BUTTONS 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.
	AUX 1	User programmable; e.g., program to Trip Test—test autoreclose logic without applying current.
	AUX 2	User programmable; e.g., program to enable/disable delay curve tripping.
	AUX 3	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-651R-2 includes the following control inputs and outputs:

- ➤ Dedicated trip/close outputs that exit the SEL-651R-2 on a control cable receptacle/ interface at the bottom of the enclosure (see *Figure 3*).
- ➤ Two Form C (normally closed/normally open) standard interrupting output contacts: OUT201 and OUT202 (row 200; *Figure 25*). OUT201 is factory-programmed as an alarm output.

Order the following additional I/O (row 100; *Figure 25*):

- ➤ Optoisolated inputs IN101–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–OUT108

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.

Rear-Panel Diagrams

See *Figure 23* and *Figure 24* for the front views of the SEL-651R-2 Relay module.

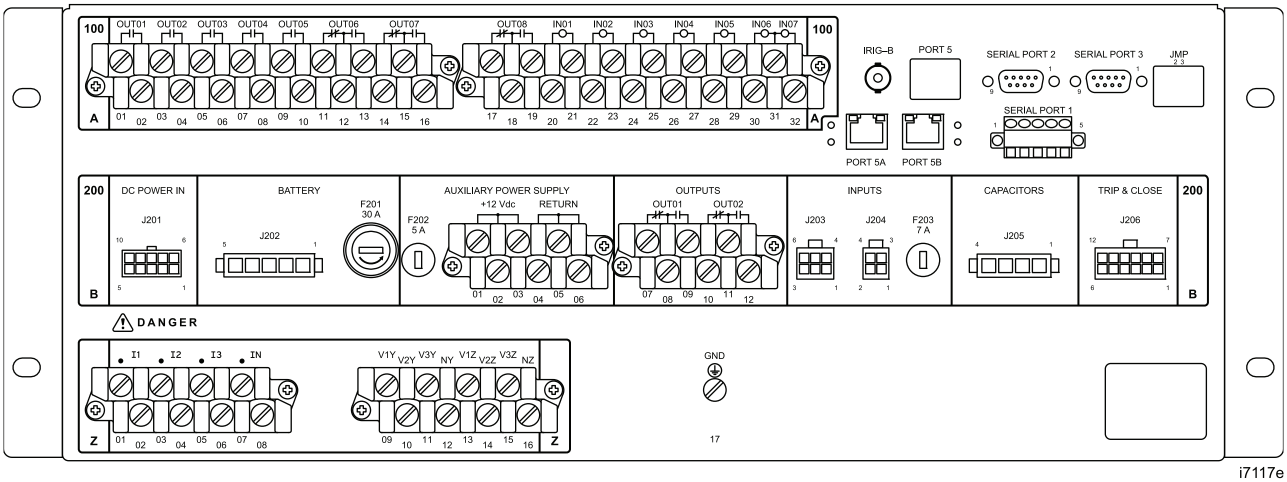


Figure 25 Rear View of the SEL-651R-2 Relay Module

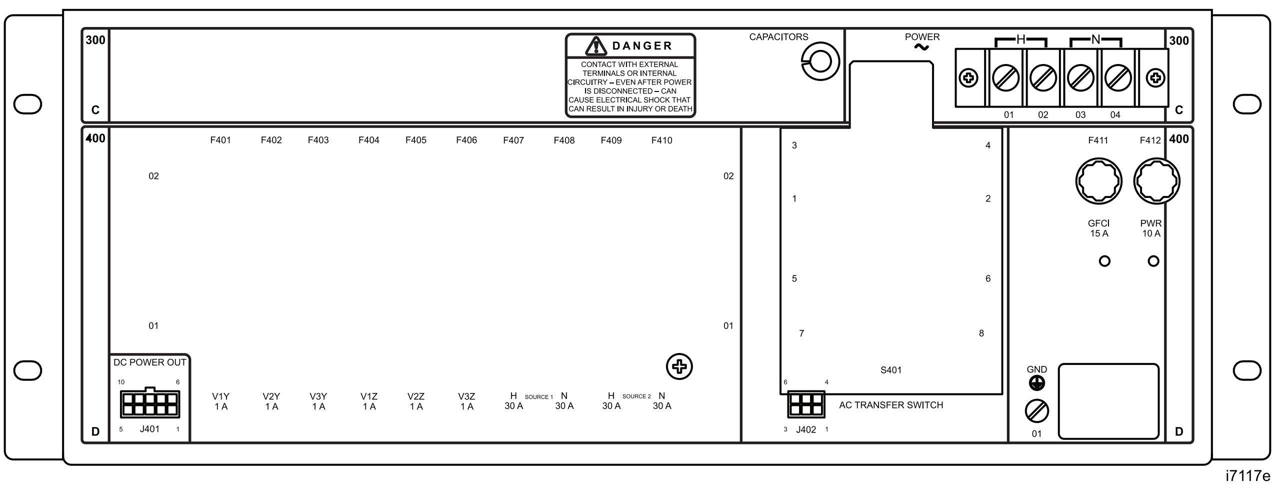
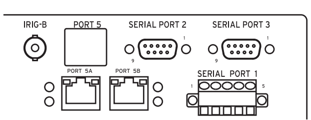
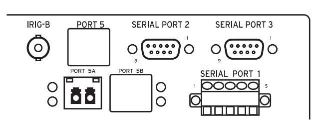


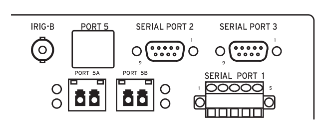
Figure 26 Rear View of the SEL-651R-2 Power Module (Dual-Door Enclosure)



Optional dual redundant 10/100BASE-T metallic Ethernet ports (5A and 5B) with EIA-485 serial Port 1



Optional single 100BASE-FX fiber Ethernet port (5A) with EIA-485 serial Port 1



Optional dual redundant 100BASE-FX Ethernet ports (5A and 5B) with EIA-485 serial Port 1

Figure 27 SEL-651R-2 Rear-Panel Communications Port Configurations

Enclosure Dimensions

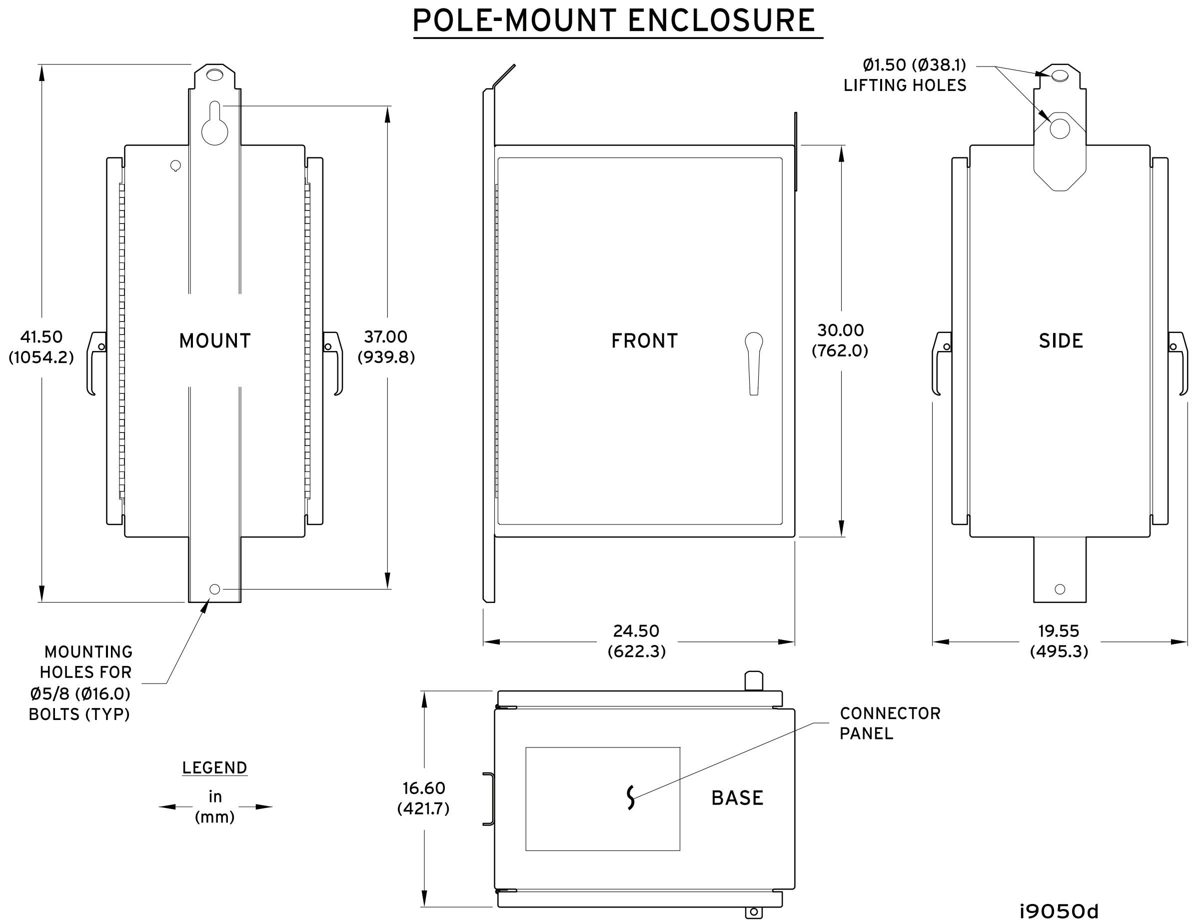


Figure 28 SEL-651R-2 Dimensions and Mounting Drill Plan (Dual-Door Enclosure)

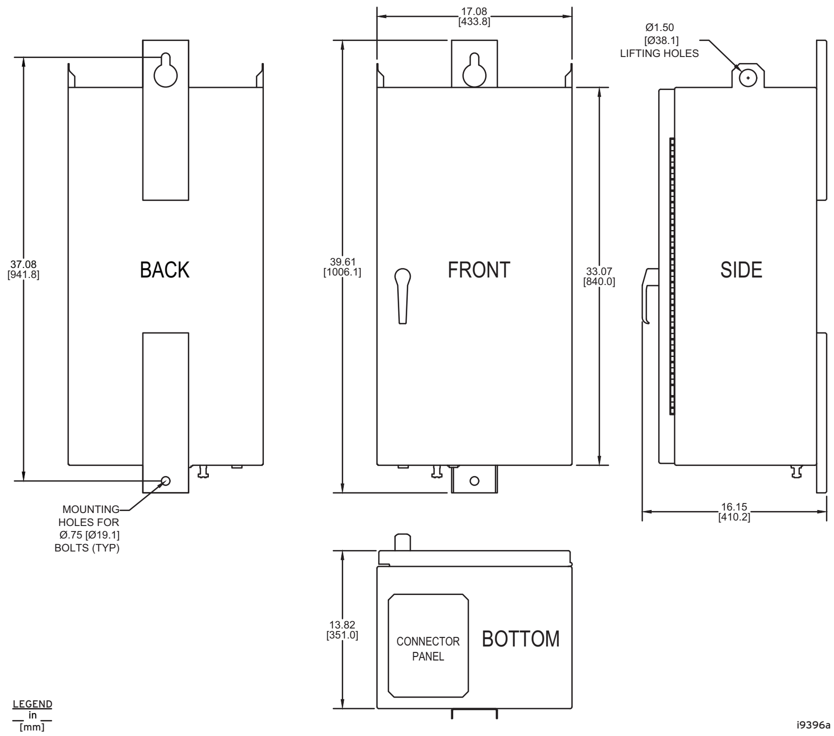


Figure 29 SEL-651R-2 Dimensions and Mounting Drill Plan (Single-Door Enclosure)

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 (4 A continuous at 55°C), 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 (PT):	300 $V_{L\text{-}N}$ 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:	8 $V_{L\text{-}N}$ 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:	Relay Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	50 Vac
Eaton NOVA LEA:	37 $V_{L\text{-}N}$ 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:	Relay Input Z = 165 kΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	53 Vac
Lindsey SVMI LEA:	200 $V_{L\text{-}N}$ 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:	Relay Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	25 Vac

Siemens LEA: $8.49 V_{L-N}$ continuous (ideally connect voltage no higher than 6.79 Vac nominal, thus providing 1.7 Vac margin for accurately measuring overvoltage conditions); 155 Vac for 10 s.

Burden: Relay Input Z = 24.22 kΩ

Common Mode Voltage

Operation: 3 Vac

Without Damage: 50 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 relay will not measure faster-changing frequencies and will revert to nominal frequency if the condition is maintained for longer 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

120 Vac Supply

Rated Voltage:	120 Vac
Rated Frequency:	50/60 Hz
Operational Range:	85–132 Vac
Operational Frequency Range:	40–65 Hz
Maximum Burden:	250 VA average, 500 VA peak
Inrush:	<100 A (I^2t < 24 A^2 – s)

230 Vac Supply

Rated Voltage:	230 Vac
Rated Frequency:	50/60 Hz
Operational Range:	170–265 Vac
Operational Frequency Range:	40–65 Hz
Maximum Burden:	250 VA average, 500 VA peak
Inrush:	<50 A (I^2t < 6 A^2 – s)

125 Vdc Supply

Rated Voltage:	125 Vdc
Operational Range:	100.0–137.5 Vdc
Maximum Burden:	25 W continuous, 300 W for 1.5 s

48 Vdc Supply

Rated Voltage:	48 Vdc
Operational Range:	40–65 Vdc
Maximum Burden:	25 W continuous, 300 W for 1.5 s

12 V Accessory Power Supply

For Models With AC Power Supply

12 Vdc ±10%, 40 W continuous, 60 W for 6 s every 60 s

For Models With DC Power Supply

12 Vdc ±10%, 3 W (0.25 A) continuous

Note: Some models momentarily dip to 9 Vdc during trip/close operations.

Output Contacts (Except Trip and Close)

Make:	30 A per IEEE C37.90-2005, Section 5.8
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
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: Per IEC 60255-0-20:1974, using the simplified assessment method.

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 ± 2.4 Vdc
Coil Current:	15.5 A (Close), 12.2 A (Trip)

G&W Viper-ST/-LT, ABB Elastimold MVR, and ABB Gridshield (32-Pin and 42-Pin Versions) Rating

Coil Voltage:	155 + 5, –3 Vdc
Coil Current:	12–17 A (Close), 4 A (Trip) (per phase)
Pulse Duration:	52–55 ms (Close), 27–30 ms (Trip)

ABB OVR-3/VR-3S (24-Pin, 15 and 27 kV Models) Rating

Coil Voltage:	48 + 5, –3 Vdc
Pulse Duration:	85 ms (Close), 45 ms (Trip)

Control-Powered Eaton NOVA Rating

Coil Voltage:	48 + 5, –3 Vdc

ABB Joslyn TriMod 600R Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	35 ms (Close), 14 ms (Trip)

Eaton NOVA-TS or NOVA-STS Triple-Single Rating

Coil Voltage:	48 + 5, –3 Vdc

Tavrida OSM AI_2 Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	60 ms (Close), 15 ms (Trip)

Tavrida OSM AI_4 Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	60 ms (Close), 15 ms (Trip)

Siemens SDR Triple-Single Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	65 ms (Close), 40 ms (Trip)

Siemens SDR Three-Phase Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	65 ms (Close), 40 ms (Trip)

Eaton NOVA NX-T Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	45 ms (Close), 10 ms (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 105–150 Vdc; off below 75 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

DC Dropout Range:	0–4 Vdc
DC Pickup Range:	8–28 Vdc
Current Draw:	1–10 mA

Communications Ports

EIA-232:	One front, two rear
EIA-485:	One rear with 2100 Vdc of isolation
Per Port Data Rate Selections:	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600
USB:	One front port (Type B connector, CDC class device)
Ethernet:	One 10/100BASE-T rear port (RJ45 connector) (discontinued option) Two 10/100BASE-T rear ports optional (RJ45 connector) One or two 100BASE-FX rear ports optional (LC connectors multimode) 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**, **EVE P**, **CEV P**):	±10 µs
All Other Reports:	±5 ms

Simple Network Time Protocol (SNTP) Accuracy

Internal Clock:	±5 ms

Unsynchronized Clock Drift

Relay Powered:	2 minutes per year typical

Operating Temperature

Relay Module:	–40° to +85°C (–40° to +185°F)
Batteries:	–40° to +80°C (–40° to +176°F)
Entire SEL-651R-2 unit:	–40° to +55°C (–40° to +131°F)

Note: LCD contrast impaired for temperatures below –20°C (–4°F). The entire SEL-651R-2 unit 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

<114 kg (<250 lb)

Battery Specifications

Base Version Requirements

Normal Capacity:	16 ampere-hours @ 25°C
Run Time (Relay Electronics Operate Plus One Trip/Close Cycle):	≥9.6 hours @ 25°C ≥3.2 hours @ –40°C
Recharge Time (Deep Discharge to Fully Charged):	≤9.6 hours @ 25°C
Estimated Life:	≥4 years @ 25°C ≥1 year @ +80°C

Extended Capacity Option Requirements

Normal Capacity:	40 ampere-hours @ 25°C
Run Time (Relay Electronics Operate Plus One Trip/Close Cycle):	≥24 hours @ 25°C ≥8 hours @ –40°C
Recharge Time (Deep Discharge to Fully Charged):	≤24 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 s 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:	ASCII and Compressed ASCII Binary COMTRADE (128 samples per cycle unfiltered)
Time-Stamp Resolution:	1 µs when high-accuracy time source is connected (**EVE P** or **CEV P** commands)
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:	0.00–16,000.00 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.:	0.5–15.0, 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% to 100% of fundamental, 1% steps
Steady-State Pickup Accuracy:	2.5 percentage points
Pickup/Dropout Time:	<1.25 cycles
Time Delay:	0.00–16,000.00 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
Siemens LEA Inputs (8.49 Vac Maximum)	
Phase:	0.03–8.49 V[a]
Phase-to-Phase:	0.05–14.72 V[a]
Sequence:	0.05–8.00 V[a]
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 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 Vac
Siemens LEA[a]	
Phase:	±10 mV plus ±1% of setting
Phase-to-Phase:	±20 mV plus ±2% of setting
Sequence:	±30 mVac plus ±3% of setting @ 0.33–8.49 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:	0–80°, 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-651R-2 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 Ω secondary
Forward Positive Load Angle:	–90° to +90°
Forward Negative Load Angle:	–90° to +90°
Negative Load Impedance:	0.50–640 Ω 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% (50–300 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% (25–200.00 V), ±0.5° for Lindsey SVMI LEAs ±0.2% (0.71–8.49 V), ±0.5° for Siemens SDR LEAs
VABY, VBCY, VCAY, VABZ, VBCZ, VCAZ:	±0.4% (50–300 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 ±0.4% (1.22–14.70 V), ±1.0° for Siemens SDR LEAs
3V0Y, V1Y, V2Y, 3V0Z, V1Z, V2Z:	±0.6% (50–300 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 ±0.6% (0.71–8.49 V), ±1.0° for Siemens SDR LEAs

Currents

IA, IB, IC[c]:	±0.5 mA plus ±0.1% of reading (0.1–2 A), ±0.5°
IN:	±0.08 mA plus ±0.1% of reading (0.005–4.5 A), ±1°
3I1, 3I0, 3I2:	±0.01 A plus ±3% of reading (0.1–2 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 A)
IN (Measured):	±0.25% (0.005–4.5 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:	(0.2–2.0) • I_{nom} (I_{nom} = 1 A phase, 0.2 A neutral)
Frequency Range:	±5 Hz of nominal (50 or 60 Hz)
Voltage Range:	30–250 V for PTs 0.8–8.0 V for 8 V LEA inputs 3.71–37.09 V for Eaton NOVA LEA inputs 30–300 V for Lindsey SVMI LEA inputs 0.85–8.49 V for Siemens SDR 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[e]

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[e]

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 ±0.20% (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)

Type Tests

Recloser Type Tests

IEEE C37.60-2003, Section 6.13 Control Electronic Elements Surge Withstand Capability (SWC) Tests

6.13.1 Oscillatory and fast transient surge tests (a control-only test, performed in accordance with IEEE C37.90.1-2002)

6.13.2 Simulated surge arrester operation test (performed with the control connected to the following reclosers)

G&W Viper-ST:	27 kV, 12.5 kA interrupting, 800 A continuous 38 kV, 12.5 kA interrupting, 800 A continuous
ABB Elastimold MVR:	15/17 kV, 12.5 kA interrupting, 800 A continuous 38 kV, 12.5 kA interrupting, 800 A continuous
Eaton NOVA:	27 kV, 12.5 kA interrupting, 630 A continuous
Eaton Recloser Type "WVE-27":	38 kV, 8 kA interrupting, 560 A continuous
ABB OVR-3:	27 kV, 12.5 kA interrupting, 630 A continuous
Eaton NOVA-TS:	15.5 kV, 8 kA interrupting, 400 A continuous
Eaton NOVA (Control Powered):	27 kV, 12.5 kA interrupting, 630 A continuous
Tavrida OSM Al_2:	27 kV, 12.5 kA interrupting, 600 A continuous
Tavrida OSM Al_4:	27 kV, 12.5 kA interrupting, 600 A continuous

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-ST, Solid Dielectric

Voltage Rating:	38 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	800 A

Eaton Type NOVA 15, Aux. Power

Voltage Rating:	15.5 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	630 A

Tavrida OSM25_Al_2(630_150_2)

Voltage Rating:	27 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	630 A

ABB Gridshield TS Recloser (32-Pin)

Voltage Rating:	27 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	1000 A

Electromagnetic Compatibility Emissions[f]

Radiated and Conducted 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[f]

Radiated RF Immunity:	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)
Conducted RF Immunity:	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:	EN/IEC 60255-26:2013, Section 7.2.3 IEC 61000-4-2:2008 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:	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
Surge Immunity[g, h]:	EN/IEC 60255-26:2013, Section 7.2.7 Severity Level: Zone A Severity Level: Zone B on 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 IRIG-B: 2 kV line-to-earth
Surge Withstand Capability:	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

Environmental

Cold[f]:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Damp Heat, Cyclic[f]:	IEC 60068-2-30:2005 Test Db: 25° to 55°C, 6 cycles, Relative Humidity: 95%
Dry Heat[f]:	IEC 60068-2-2:2007 Test Bd: Dry heat, 16 hours at +85°C
Vibration[f]:	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[i]:	IEC 60529:2001 + CRGD:2003 [BS EN 60529 Second Edition—1992 + REAF:2004] IP45

Safety[f]

Insulation Coordination

IEC 60255-27:2013, Section 10.6.4
EN 60255-27:2014, Section 10.6.4
IEEE C37.90-2005, Section 8
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

[a] See Section 9: Settings in the SEL-651R-2 Instruction Manual 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, 1.70 Vac for Eaton NOVA LEA inputs, 14.00 Vac for Lindsey SVMI LEA inputs, and 0.60 Vac for Siemens SDR LEA inputs.
[e] For example, for a particular harmonic value applied at 10% of fundamental, the harmonic value meters in the range of 5% to 15%.
[f] SEL enclosure excluded from test.
[g] Serial cable (non-fiber) lengths assumed to be <3 m.
[h] The following pickup/dropout delays are used:
Under- and overvoltage elements: 0.0/0.0 cycles
(Eaton NOVA and Lindsey LEAs required 6.0/6.0 cycles)
Phase instantaneous overcurrent elements: 0.5/1.0 cycles
Neutral instantaneous overcurrent elements: 0.0/4.0 cycles
Digital inputs: 0.5/0.5 cycles
[i] SEL enclosure included in test.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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