SEL-651R Recloser Control

Advanced Recloser Control

Major Features and Benefits

- ➤ Connect to Traditional Retrofit, G&W Viper®-ST, ABB OVR-3/VR-3S (15 and 27 kV models), Control-Power Kyle® NOVA, Joslyn TriMod™ 600R, or Kyle® NOVA-TS or NOVA-STS Triple-Single reclosers. Retrofit existing recloser installations (plug compatible) or equip new recloser installations.
- ➤ Comply with the most recent IEEE C37.60 standard.
- ➤ Improve system reliability with automatic network reconfiguration. Isolate faulted line sections and restore service to unaffected areas of the system.
- ➤ Speed up system isolation and restoration with SEL-patented MIRRORED BITS® communications technology. This technology provides fast and secure recloser control-to-recloser control communications to realize advanced tripping and control schemes, such as automatic network reconfiguration.
- ➤ Determine power flow or VAR flow direction and magnitude with configurable power elements. Apply at locations like system intertie points or at capacitor bank installations.
- ➤ Reduce system and customer outage impacts due to faults, with single-phase tripping/reclosing. Keep customers in service who are not on the faulted phase.
- ➤ Reduce costs and save space with six 8-voltage maximum-type low energy analog (LEA) voltage inputs, which decrease the number of PTs needed on the load or source side of the recloser.
- ➤ Create and use custom application designs with ACSELERATOR® QuickSet SEL-5030 Software to conveniently set the SEL-651R, making only the minimum necessary settings.
- ➤ Quickly commission recloser controls by using just the settings you need. Design custom templates using the licensed version of QuickSet for your specific applications. Templates are stored on the recloser control for easy access when making settings changes.
- ➤ Easily configure multiple group settings to fit operational situations through use of eight settings groups. Use alternate settings for network reconfiguration applications.
- ➤ Monitor and take control/action based on total harmonic distortion (THD) with harmonic metering (up to the 15th harmonic).

(Continued)

- Easily power demanding 12 Vdc accessories (e.g., radios) with a built-in 40 W continuous (60 W surge) auxiliary power supply.
- Easily access the front-panel interface, wiring connections, fuses, and accessories with multiple enclosure options.
- Trip securely for forward or reverse faults with simultaneous phase and ground directional elements applied to overcurrent protection. SEL's Best Choice Ground Directional Element® selects the best ground directional element for system conditions and eliminates settings.
- Vary logic according to time of year/week/day. Such logic variations handle seasonal environment or load changes (e.g., fire season, pumping season, peak load time).

Compatibility Overview

Three-Phase Reclosers

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

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

Realize the new features of the SEL-651R by connecting to these reclosers. Learn the settings and operation of one recloser control and retrofit numerous existing recloser installations.

Three-Phase Reclosers With Single-Phase Tripping

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

- G&W Viper-ST
- ABB OVR-3/VR-3S (15 and 27 kV models)
- Joslyn TriMod 600R
- Kyle NOVA-TS or NOVA-STS Triple-Single (Cooper)

Realize all the new features of the SEL-651R by connecting to these reclosers. Learn the settings and operation of one recloser control and equip new recloser installations.

NOTE: A specific recloser interface is selected at ordering time.

New 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 1*, there is no direct communication between the recloser control sites and there is minimal voltage sensing. For the sample fault in *Figure 1*, system isolation and restoration is methodically accomplished with:

- Sectionalism 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 in *Figure 2* includes both source-side and load-side voltages into the SEL-651R Recloser Controls and MIRRORED BITS communications (via fiber-optics or radio) between the recloser sites. These enhancements greatly speed up automatic network reconfiguration operation. Apply automatic network reconfiguration especially to urban areas, and critical loads where there are tie points available to other feeders for system restoration.

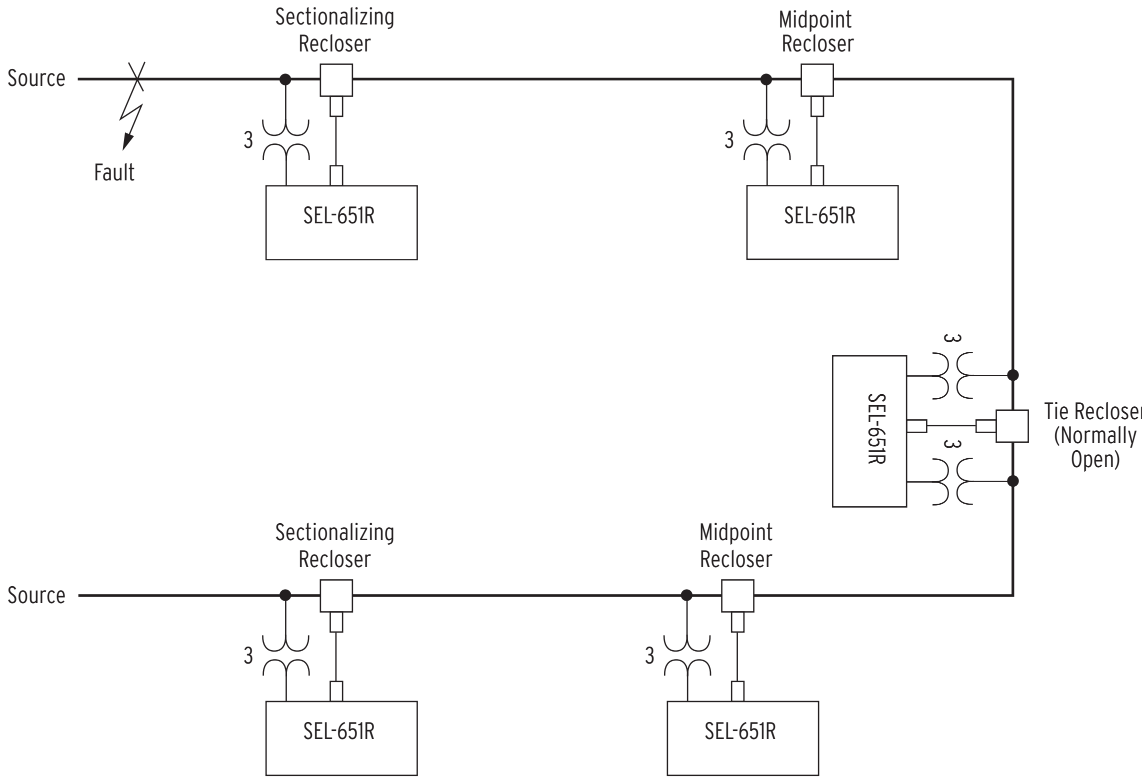


Figure 1 Simple Automatic Network Reconfiguration

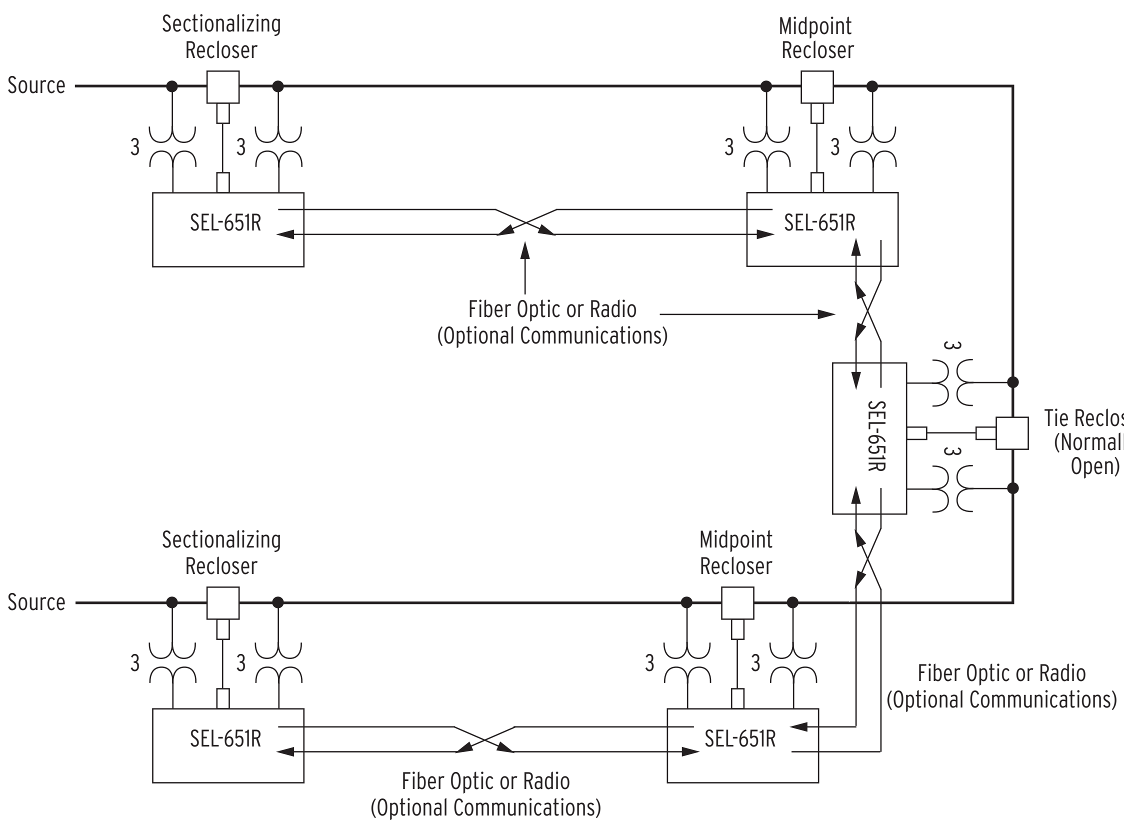


Figure 2 Advanced Automatic Network Reconfiguration

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 3*, a permanent fault occurs on the middle phase. Single-phase tripping/reclosing is enabled and only the middle pole of the recloser opens for the fault. Single-phase reclosing is unsuccessful because of the permanent fault and only the customers on the middle phase are left without power, rather than all three-phases locking out.

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

- 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 the preceding single-phase trip modes. Apply single-phase operation especially 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 on time of year (e.g., three-phase operation during pumping season because of three-phase motor loads).

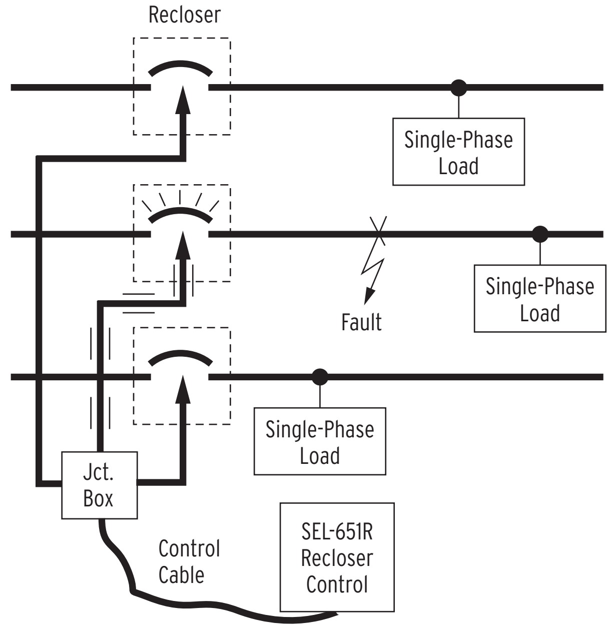


Figure 3 Single-Phase Tripping Isolates Only the Faulted Phase

Functional Overview and General Connections

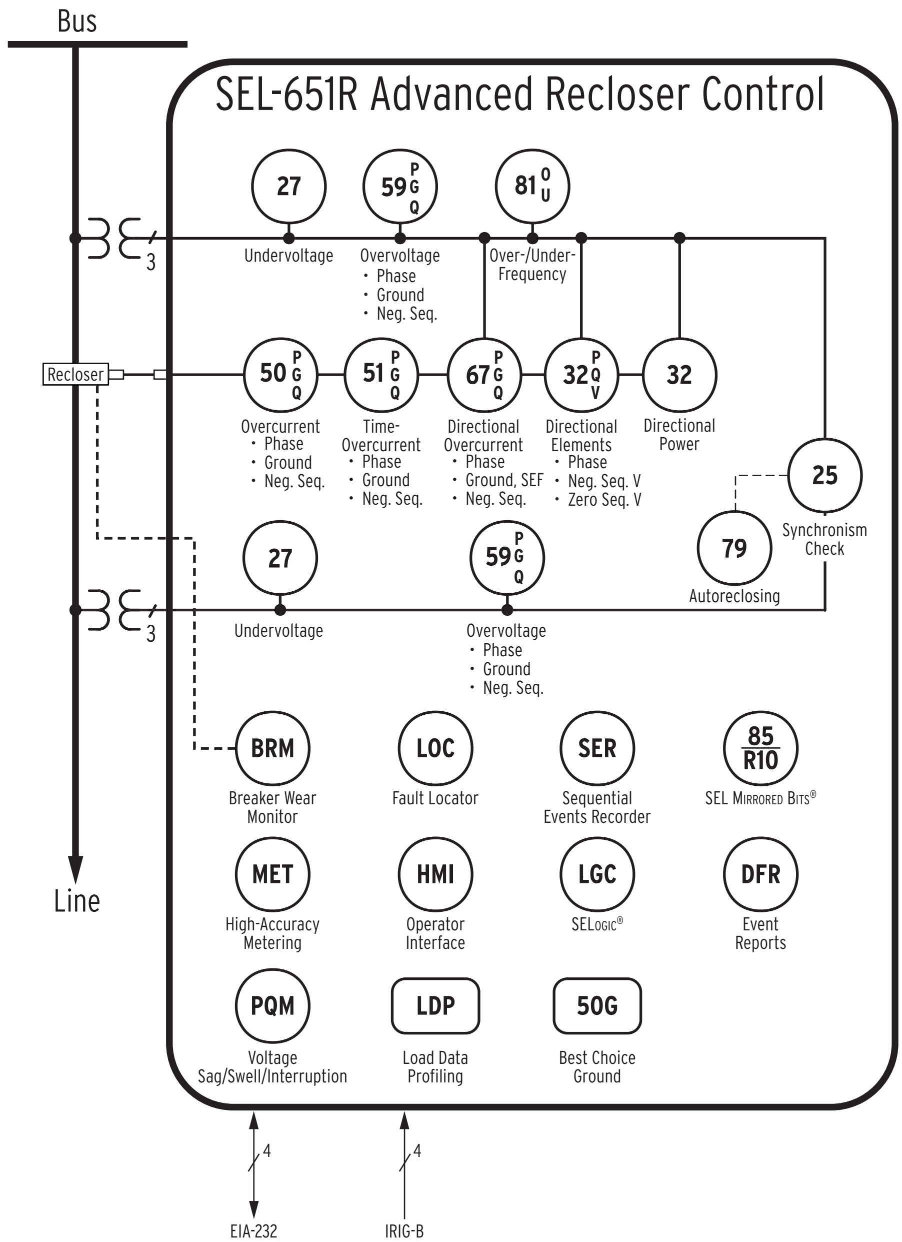


Figure 4 Functional Overview

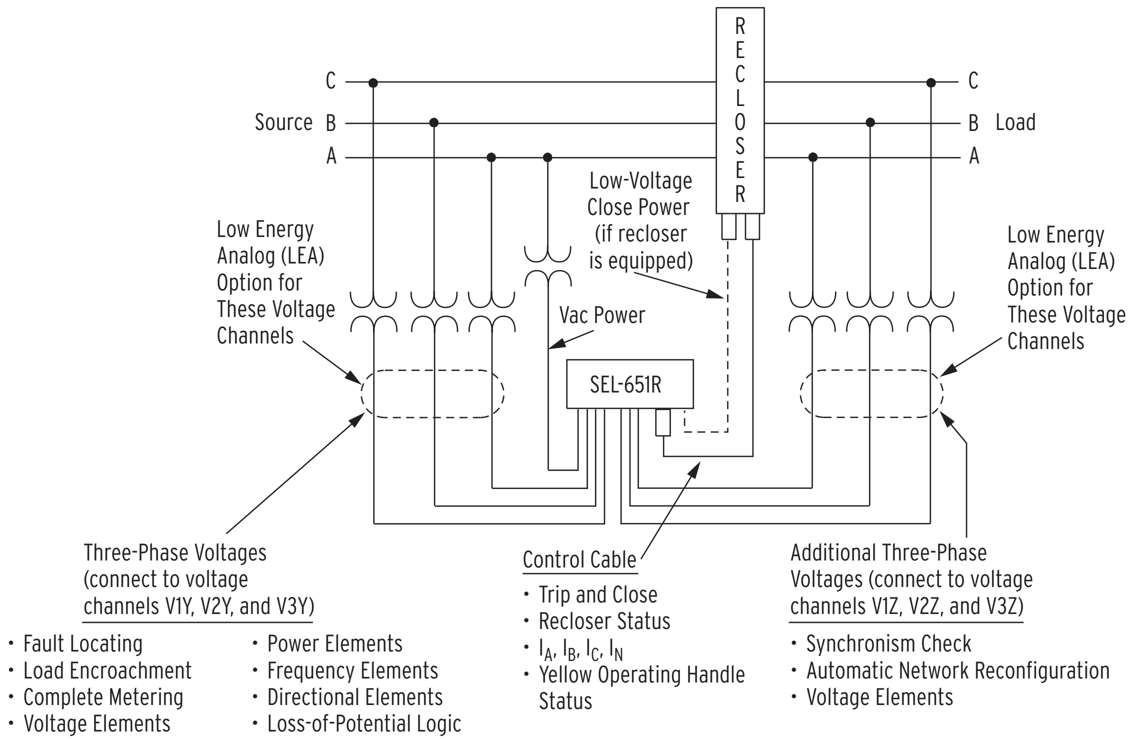


Figure 5 Connect Three-Phase Load and Source Voltages to SEL-651R

Voltage Inputs

Connect voltages on both sides of the recloser, as shown in *Figure 5*, for such schemes as automatic network reconfiguration in *Figure 2* and synchronism check. Select the three-phase voltage channel (VY or VZ) to operate features such as fault locating, load encroachment, power elements and voltage sag/swell/interrupt recording (features shown listed under the VY voltage channels in *Figure 5* example). The voltage channel frequency source for frequency elements can also be selected (again, feature shown listed under the VY voltage channels in *Figure 5* example).

The VY and VZ voltage channels can optionally be ordered as Low Energy Analog (LEA) voltage inputs. Connect the low-level voltage outputs from less-costly power system voltage transducers (8 Vac output or less) to three-phase LEA voltage inputs on the SEL-651R.

Control Power Input

Order the control power input (shown as the Vac Power connection in *Figure 5*) as either 120 Vac, 230 Vac, or 125 Vdc. Various accessories (e.g., fuse blocks, ac transfer switch, low-voltage close power) are available with the 120 Vac option. A Ground Fault Circuit Interrupter (GFCI) convenience outlet comes on front of the power module, when the 120 Vac option is ordered (see front cover photo).

Use ac transfer switches (see *Figure 6*) especially in automatic network reconfigurations (see *Figure 1* and *Figure 2*). The transfer switch switches to the alternate control power source when the primary control power source is unavailable/dead. The transfer switch mounts on the rear panel of the power module (see *Figure 15*).

The incoming control power to the power module is converted to:

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

If the incoming control power is unavailable/dead, then the 12 V battery provides energy for the capacitors in the power module and to run the relay module.

The 125 Vdc power input option does not include the 12 V auxiliary supply, battery charger, batteries, or GFCI convenience outlet.

Control Cable

The control cable, brings secondary current, recloser status, and yellow operating handle status to the SEL-651R Recloser Control and takes trip/close signals out to the recloser (see *Figure 6*). Control cable connection to the SEL-651R is made to a control cable receptacle/interface at the bottom of the enclosure.

NOTE: A single control cable interface is selected at ordering time.

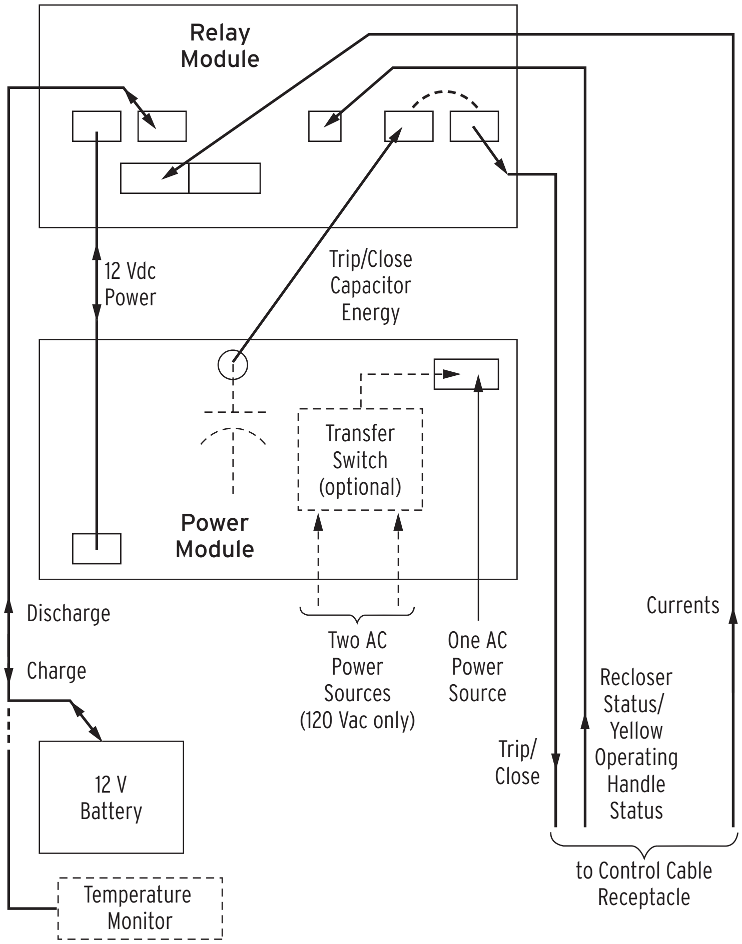


Figure 6 Major Interconnections Among SEL-651R Components (Rear View)

Protection Features

Overcurrent Protection

Use any combination of fast and delay curves (see *Figure 7*) for phase, ground, and negative-sequence overcurrent protection. For a nominal recloser CT ratio of 1000:1, these curves can be set as sensitive as 100 A primary for phase and 5 A primary for ground overcurrent protection.

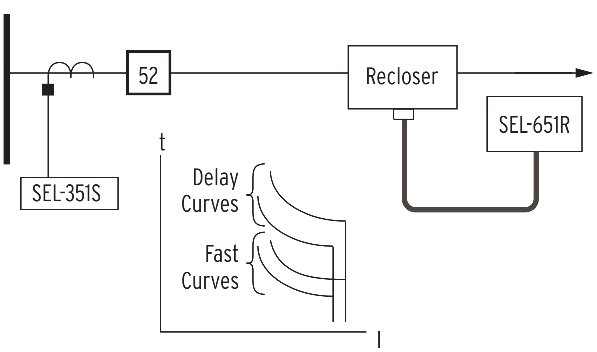


Figure 7 Coordinate the SEL-651R With Other Devices

Any fast or delay curve can be set with any of the curves in *Table 1*. 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 1* are listed using the older electronic control designations.

Table 1 Curve Choices Resident in the SEL-651R

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

The traditional recloser curves can also be specified in a curve setting using the newer microprocessor-based control designations; the SEL-651R works with either designation. For example, a given traditional recloser curve has the following two designations:

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

Traditional recloser curve A and 101 are the same curve. Use either designation in making curve settings in the SEL-651R.

Fast and delay curves (including U.S. or IEC curve choices) can be modified with the following 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 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 disc elements, where the reset time depends on the time dial setting, the percentage of disc travel, and the amount of current.

Load Encroachment

Load-encroachment logic (*Figure 8*) 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 8*) without causing a trip, even though load current is above phase minimum trip.

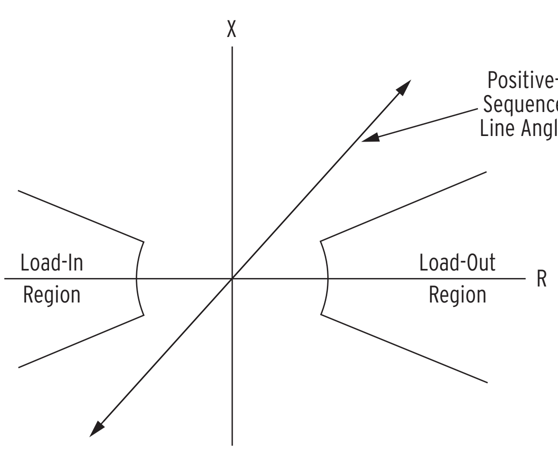


Figure 8 Load-Encroachment Logic Defines Load Zones (No Trip Zones)

Directional Elements Increase Sensitivity and Security

Phase and ground directional elements are standard. An automatic setting mode sets all directional threshold settings based on replica line impedance settings. Phase directional elements provide directional control to the phase- and negative-sequence overcurrent elements. Ground directional elements provide directional control to the ground overcurrent elements.

Phase directional characteristics include positive-sequence and negative-sequence directional elements that work together. The positive-sequence directional element memory provides a reliable output for close-in, 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 our SEL-321 Relay. Apply this directional element in virtually any application regardless of the amount of negative-sequence voltage available at the recloser control location.

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 may 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 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, as it only requires a nominal setting and is universally applicable.

Reclosing

The SEL-651R can reclose up to four (4) times. This allows for up to five operations of any combination of fast and delay curve overcurrent elements. The SEL-651R verifies that adequate close power is available before issuing an auto-reclose. The reset times are separately set for reset timing for an auto-reclose and reset timing for a manual/remote close from lockout. Traditionally, the reset time for a manual/remote close from lockout is set less than the reset time for an auto-reclose. Front-panel LEDs track the control state for autoreclosing: 79 RESET, 79 CYCLE, or 79 LOCKOUT (see

Figure 11 and *Table 4*). Sequence coordination logic is enabled to prevent the SEL-651R from tripping on its fast curves for faults beyond a downstream recloser. Customize reclosing logic 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. 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 are:

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

Fault Locating

The SEL-651R 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 dispatch of line crews and fast restoration of service. The fault locator requires three-phase voltage inputs.

Automation and Communication

Flexible Control Logic and Integration Features

Use the SEL-651R control logic to:

- ➤ 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 with:

- ➤ 12 programmable operator control pushbuttons
- ➤ 16 local control points

Program operator control pushbuttons to implement your control scheme via SELOGIC control equations. Change operator control pushbutton labeling to suit your control scheme (see *Figure 11*).

Local control points are accessed via the front-panel human-machine interface and display (see *Figure 11*). They are in a sense “hidden/extra” operator control pushbuttons. Set, clear, or pulse local control points with the front-panel human-machine interface pushbuttons and display. Program the local control points to implement your control scheme via SELOGIC control equations. Use the local control points for such extra functions as trip testing or scheme enabling/disabling.

Eliminate RTU-to-relay wiring with 32 remote control points. Set, clear, or pulse remote control points via serial port commands. Incorporate the remote control points into your control scheme via SELOGIC control equations. Use remote control points for SCADA-type control operations (e.g., trip, close, settings group selection).

Replace traditional latching relays for such functions as “remote control enable” with 32 latching control points. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the latching control points via operator control pushbuttons, control inputs, remote control points, local control points, or any programmable logic condition. The latching control points retain states when the relay loses power. In the factory settings, these latching control points are what 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 (see *Figure 11*). Note that the aforementioned 12 programmable operator control pushbuttons also have programmable LEDs associated with them.

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. Up to 32 programmable display messages can be set.

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 desired element (e.g., time qualify a voltage element). Assign the timer output to trip logic or other control scheme logic. The SEL-651R also features 16 general purpose up/down counters. Such counters can be used to emulate motor-driven timers, which can stall in place indefinitely and then continue timing when appropriate user-set conditions are present.

SELOGIC Control Equations With Expanded Capabilities

Expanded SELOGIC control equations puts relay logic in the hands of the protection engineer. Assign the relay inputs to suit your application, logically combine selected relay elements for various control functions, and assign outputs to your logic functions.

Programming SELOGIC control equations consists of combining relay elements, inputs, and outputs with SELOGIC control equation operators (see *Table 2*). Any element in the Relay Word can be used in these equations. The SEL-651R is factory set for use without additional logic in many situations. For complex or unique applications these expanded SELOGIC functions allow superior flexibility. Add programmable control functions to your protection and automation systems. New functions and capabilities enable you to use analog values in conditional logic statements.

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 Templates

Use the ACSELERATOR QuickSet SEL-5030 Software to develop settings off-line. The system automatically checks interrelated settings and highlights out-of-range settings. Settings created off-line can be transferred by using a PC communications link with the SEL-651R. The software converts event reports to oscillograms with time-coordinated element assertion and phasor/sequence element diagrams. The QuickSet interface supports Windows 95, 98, 2000, and NT operating systems. View real-time phasors via QuickSet.

QuickSet allows users to author personalized application designs. Use application designs within QuickSet to quickly implement advanced schemes such as automatic network reconfiguration and single-phase tripping/reclosing. Application Designs hide settings you do not want changed (e.g., SELOGIC control equations), while making visible just the minimum necessary settings (e.g., timer and pickup settings) to implement the scheme. All settings can be aliased and manipulated mathematically for simple end-user interfacing. Custom notes and settings ranges can also be defined. These Application Designs also enhance security, allowing access to only a specified group of settings. Create Application Designs that include the most commonly used relay features and settings (see *Figure 9*) and watch commissioning times drop drastically.

Quickly commission recloser controls by using just the settings you need. Design custom templates using the licensed version of QuickSet for your specific applications. Templates are stored on the recloser control for easy access when making settings changes.

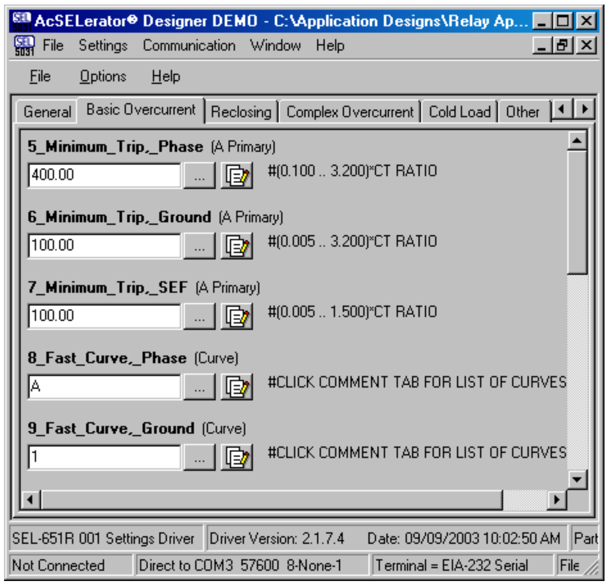


Figure 9 Example Application Designs

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 up to two EIA-232 serial ports on a single SEL-651R. With MIRRORED BITS operating on two serial ports, there is communication upstream and downstream from the SEL-651R site.

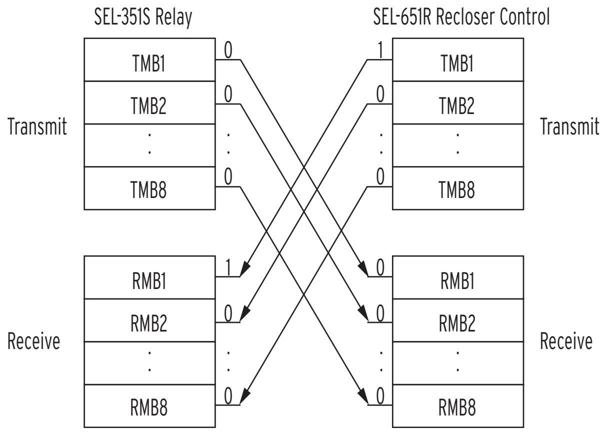


Figure 10 MIRRORED BITS Transmit and Receive Bits

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 10*). Use these MIRRORED BITS to transmit/receive information between upstream relays and 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.

Serial Port Communications

The SEL-651R is equipped with four independently operated serial ports: one EIA-232 port on the front and three EIA-232 ports on the rear. The recloser control does not require special communications software. Use any system that emulates a standard terminal system. Establish communication by connecting computers, modems, protocol converters, printers, an SEL-2020, SEL-2030, or SEL-2032 Communications Processor, SCADA serial port, and/or RTU for local or remote communication.

SEL manufactures a variety of standard cables for connecting this and other IEDs to a variety of external devices. Consult your SEL representative for more information on cable availability.

Table 3 Open Communications Protocols

Type	Description
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.
Extended Fast Meter and Fast Operate	Binary protocol for machine-to-machine communications. Quickly updates SEL Communications Processors, RTUs, and other substation devices with metering information, relay element, I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines so control operator metering information is not lost while a technician is transferring an event report.
DNP3 Level 2 Slave	Distributed Network Protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and setting groups. (Optional)

Additional Features

Status and Trip Target LEDs/Operator Controls

The SEL-651R Recloser Control 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 11* and explained in *Table 4*. The SEL-651R features a versatile front panel that you can customize to fit your needs—even LED colors can be changed (if tri-color LEDs are ordered). 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 software. Label sets can be printed from a laser printer using templates supplied with the relay or hand labeled on supplied blank labels.

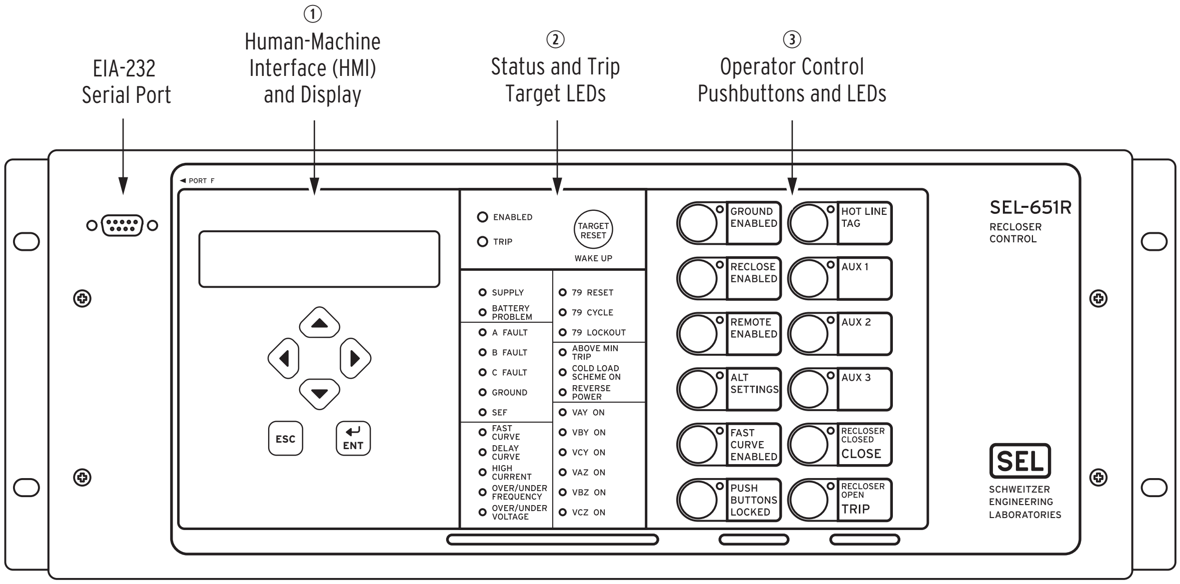


Figure 11 Front View of SEL-651R Relay Module (Dual-Door Enclosure)

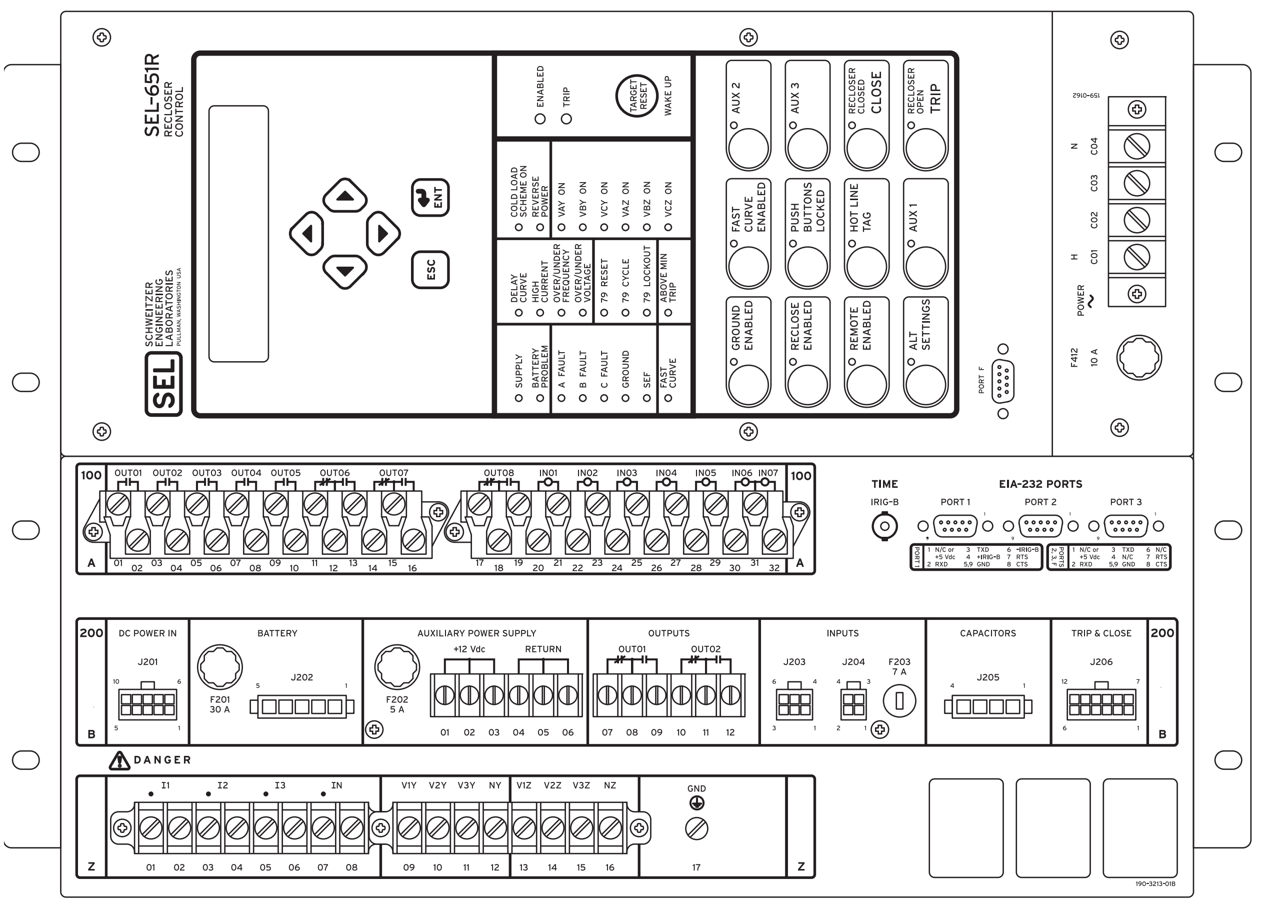


Figure 12 Front View of SEL-651R Modules (Single-Door Enclosure

Table 4 Factory-Default Front-Panel Interface Definitions (see Figure 11)

	Function	Definition
①	HMI Pushbuttons and Display	Navigate through the menu and various available functions (e.g., Metering, Event Summaries, Settings) using the HMI pushbuttons and 2 x 16 LCD.
②	ENABLED[a]	SEL-651R Recloser Control is powered correctly, functional, and has no self-test failures.
	TRIP[a]	Trip occurred.
	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/underfrequency element trip (not set from factory).
	OVER/UNDER VOLTAGE	Over/undervoltage element trip (not set from factory).
	TARGET REST/WAKE UP Pushbutton[a]	Reset latched-in target LEDs; wake up the control after it has been put to sleep.
	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 setpoint (not set from factory).
	VAY, VBY, VCY ON VAZ, VBZ, VCZ ON	VY voltage channels energized. VZ voltage channels energized (not set from factory).
③	GROUND ENABLED	Enable/disable ground overcurrent elements.
	RECLOSE ENABLED	Enable/disable auto-reclosing.
	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 auto-reclosing can take place via the control.
	AUX 1	User programmable; e.g., program to Trip Test—test auto-reclose 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

Besides the dedicated trip/close outputs that exit the SEL-651R on a control cable receptacle/interface at the bottom of the enclosure (see *Figure 6*), the basic SEL-651R includes two Form C (normally closed/normally open) standard-interrupting output contacts: OUT201 and OUT202 (row 200; see *Figure 14*). OUT201 is programmed as an alarm output from the factory.

The following additional input/output (I/O) can be ordered (row 100; see *Figure 14*):

- ➤ 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.

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. Access settings, events, and other data over a single communications link to increase availability of information.

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 samples/cycle or 32 samples/cycle resolution analog data. The relay stores:

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

Reports are stored in nonvolatile memory. Relay settings operational in the relay at the time of the event are appended to each event report.

The SEL-5601 Software and QuickSet software can read a Compressed ASCII version of the event report, which contains even more information than the standard ASCII event report. With this software, oscillographic traces and digital element traces can be produced on the PC display. A phasor analysis screen allows the protection engineer to analyze the prefault, fault, and postfault intervals, observing both 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. This is 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 amps primary measured at the largest phase current magnitude in the triggered event report

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

Sequential Events Recorder (SER)

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

Voltage Sag/Swell/Interrupt (SSI) Report

The voltage sag/swell/interrupt (SSI) report captures power quality data related to voltage disturbances over a long period of time. Data captured includes the magnitude of currents, one set of three-phase voltages, a reference voltage, and the status of the voltage sag/sell/interrupt (VSSI) elements (Relay Word bits).

SSI report information is useful for analyzing power quality disturbances, or protective device actions that last longer than the time window of a conventional event report. The SSI recording rate varies from fast to slow, depending on changes in the triggering elements. SSI data (a minimum of 3855 entries) is stored to nonvolatile memory just after it is 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 result of this integration exceeds the threshold set by the recloser wear curve (see *Figure 13*), the SEL-651R asserts a logic point for the affected phase. This logic point can be routed for alarming or to modify reclosing (e.g., shorten the number of reclosures). This method of monitoring recloser wear is solidly based on methods of breaker rating from switchgear manufacturers.

Figure 13 shows three setpoints needed to emulate a breaker wear curve. If the user wants to customize the recloser wear curve, the setpoints in *Figure 13* can be programmed. Predetermined setpoints are available for traditional reclosers, following recommendations for reclosers in ANSI C37.61-1973.

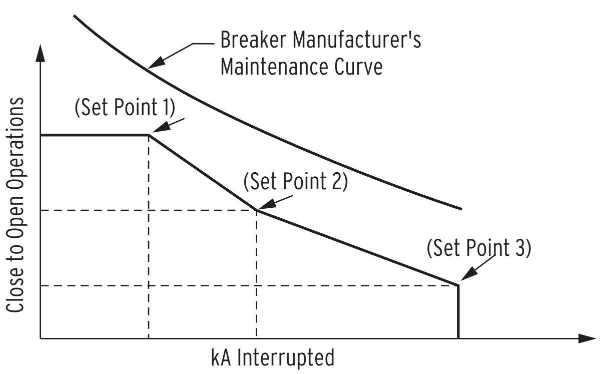


Figure 13 Recloser Contact Wear Curve and Settings

Metering

The SEL-651R provides extensive and accurate metering capabilities, as shown in *Table 5*. See *Specifications* for metering accuracies. The recloser control reports all metered quantities in primary quantities (current in A primary and voltage in kV primary). THD elements for the current and voltage channels are available 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 5 Available Metering Quantities (Sheet 1 of 3)

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-neutral and line-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-amps, 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-amps, 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

Table 5 Available Metering Quantities (Sheet 2 of 3)

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-neutral
Power	
MW_{3P}	Megawatts, three-phase
$MVAR_{3P}$	Megavars, three-phase
MVA_{3P}	Megavolt-amps, 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-neutral

Table 5 Available Metering Quantities (Sheet 3 of 3)

Power (average)	
$MW_{A,B,C,3P}$	Megawatts, single- and three-phase
Harmonic Quantities and Total Harmonic Distortion (THD)	**Through the 15th 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-neutral

Load Profile

The load profile recorder in the SEL-651R is capable of recording up to 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 5* (except peak demands). At a five-minute periodic recording rate and with 15 selected analog quantities, up to 26 days of load profile data can be stored. The greater the periodic recording rate or the lesser number of selected analog quantities, the greater the number of days of storage available.

Front- and Rear-Panel Diagrams

See *Figure 11* and *Figure 12* for the front views of the SEL-651R Relay Module.

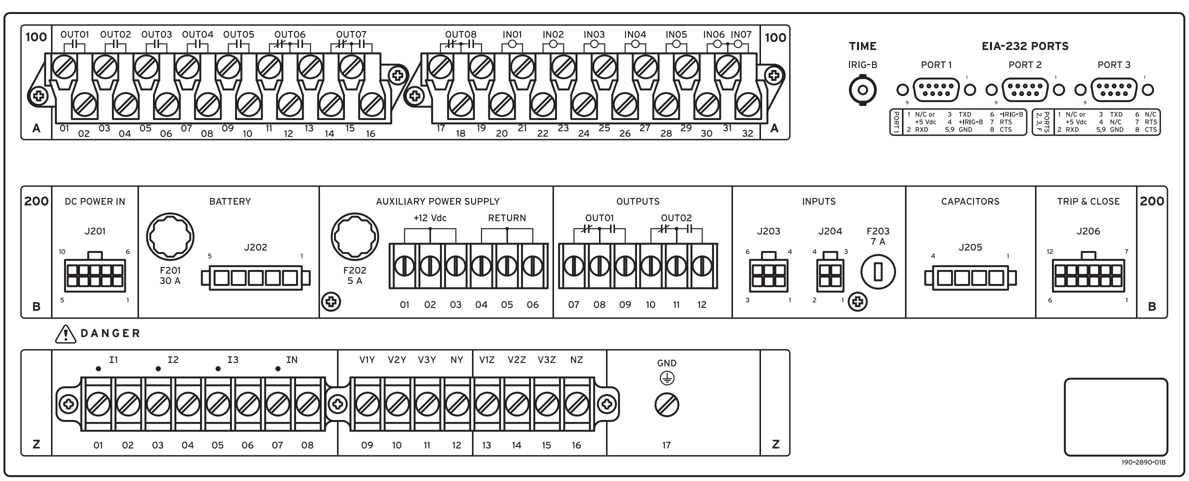
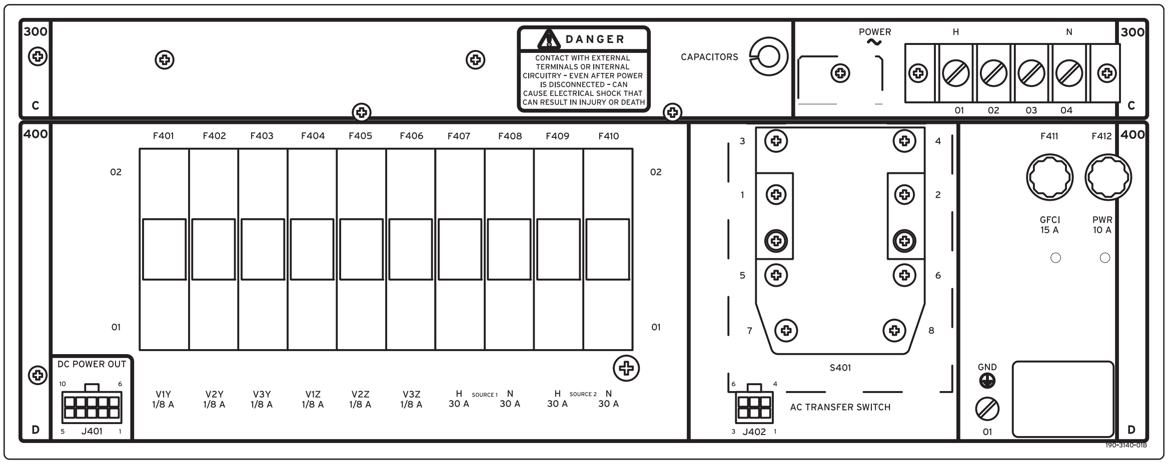


Figure 14 Rear View of SEL-651R Relay Module



Shown fully equipped with fuse blocks and ac transfer switch.

Figure 15 Rear View of SEL-651R Power Module (Dual-Door Enclosure)

Enclosure Dimensions

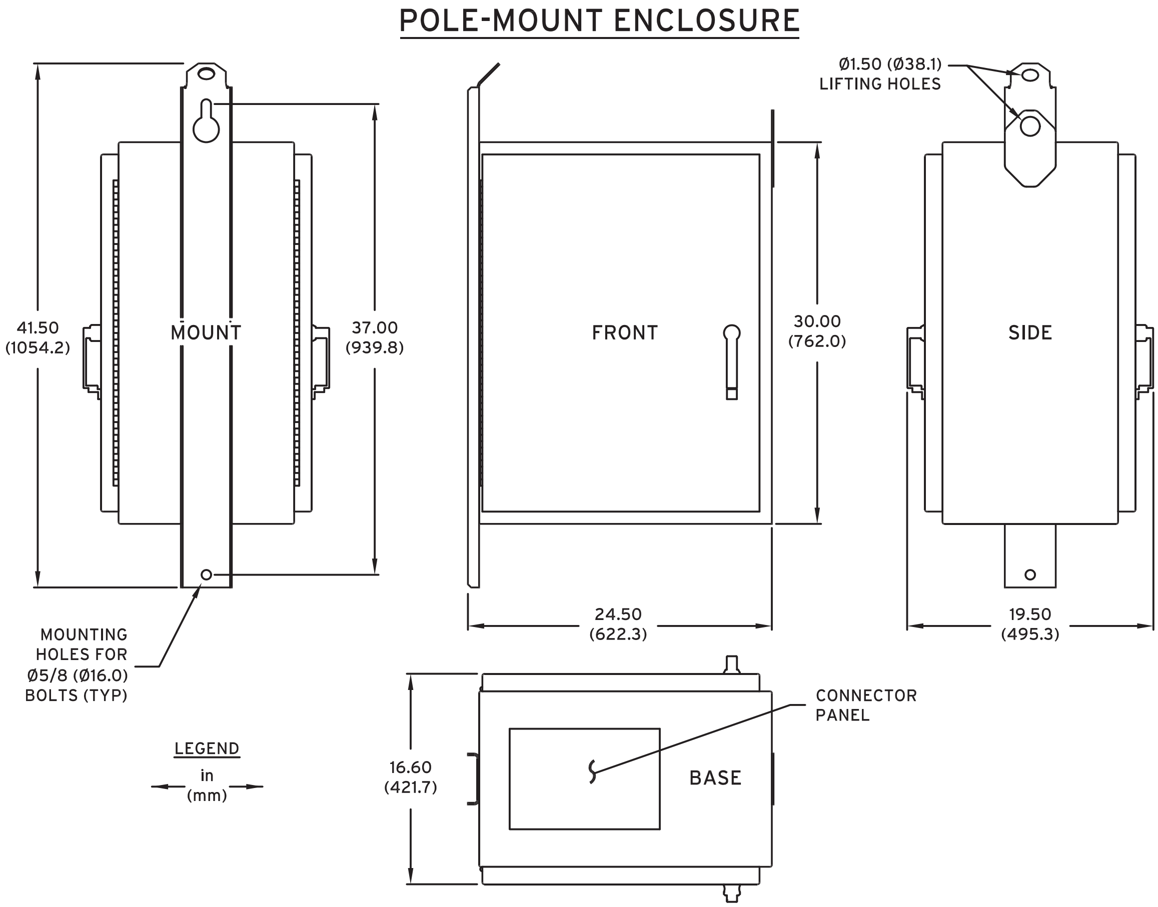


Figure 16 SEL-651R Dimensions and Mounting Drill Plan (Dual-Door Enclosure)

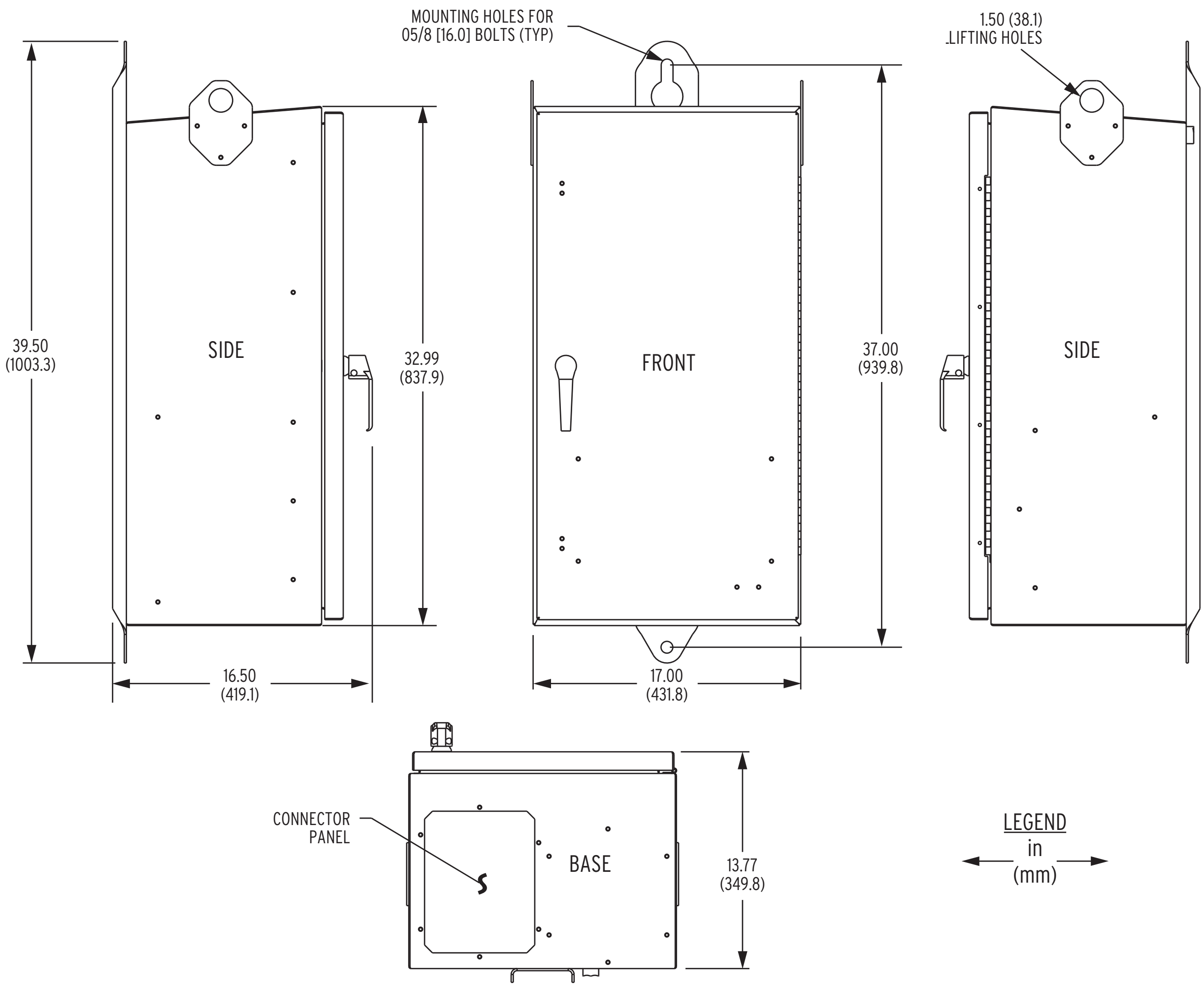


Figure 17 SEL-651R Dimensions and Mounting Drill Plan (Single-Door Enclosure)

Specifications

Important: Do not use the following specification information to order an SEL-651R. Refer to the actual ordering information sheets.

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; 500 A for 1 s; 1250 A for 1 cycle Burden: <0.5 VA @ 0.2 A

AC Voltage Inputs

300 V Maximum (PT):	300 V_{L-N} continuous (connect any voltage up to 240 Vac, with allowance for surge): 600 Vac for 10 seconds.
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 (connect any voltage up to 6.5 Vac, with allowance for surge): 300 Vac for 10 seconds.
Burden:	Relay Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	50 Vac
Kyle/Cooper NOVA LEA:	37 V_{L-N} continuous (connect any voltage up to 29.6 Vac with allowance for surge): 250 Vac for 10 seconds.
Burden:	Relay Input Z = 165 kΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	53 Vac
Lindsey SVMI LEA:	200 V_{L-N} continuous (connect any voltage up to 160 Vac with allowance for surge): 250 Vac for 10 seconds.
Burden:	Relay Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	25 Vac
Siemens LEA:	8.49 V_{L-N} continuous (connect any voltage up to 6.79 Vac with allowance for surge): 155 Vac for 10 seconds.
Burden:	Relay Input Z = 24.22 kΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	50 Vac

Frequency and Rotation

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

Note: V1Y or V1Z required for frequency tracking.

Power Supply

120 Vac Nominal	
Rated Range:	85–132 Vac
Frequency Range:	40–65 Hz
Maximum Burden:	250 VA average, 500 VA peak
Inrush:	< 100 A (I^2t < 24 A^2 – s)
230 Vac Nominal	
Rated Range:	170–265 Vac
Frequency Range:	40–65 Hz
Maximum Burden:	250 VA average, 500 VA peak
Inrush:	< 50 A (I^2t < 6 A^2 – s)
125 Vdc Nominal:	
Rated Range:	100–137.5 Vdc
Maximum Burden:	25 W continuous, 300 W for 1.5 seconds

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 C37.90:1989*
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

Break Capacity (10000 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.

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 Rating	
Coil Voltage:	155 +5, –3 Vdc
Coil Current:	12–17 A [Close], 4 A [Trip] (per phase)
Pulse Duration:	53–55 ms [Close], 28–30 ms [Trip]

ABB OVR-3/VR-3S (15 and 27 kV models) Rating

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

Control-Powered Kyle NOVA Rating

Coil Voltage:	48 +5, –3 Vdc

Joslyn TriMod 600R Rating

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

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

Coil Voltage:	48 +5, –3 Vdc

Tavrida OSM 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]

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

Optoisolated Inputs (Optional)

DC Pickup Range	9.6–14.4 Vdc

Note: Optoisolated inputs draw approximately 4–10 mA of current.

Status Inputs

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

For Kyle NOVA-TS or NOVA-STS Triple-Single Recloser applications, inputs IN204–IN206 are self-whetted (< 20 Vdc output; < 20 mA output).

Communications Ports

EIA-232:	1 Front, 3 Rear
Baud Rate:	300–57600 bps
DNP Response Time:	20 ms typical

Time-Code Input

Recloser control accepts demodulated IRIG-B time-code input at Port 1 and a BNC Connector, but not simultaneously. Recloser control time is synchronized to within ±0.5 ms of time-source input. Input impedance is 1.33 kΩ ±50 Ω.

Operating Temperature

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

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

Normal Capacity:	16 amp-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 Requirement:

Normal Capacity:	40 amp-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

AC Voltage and Current Inputs

32 samples per power system cycle, 3 dB low-pass filter cut-off frequency of 960 Hz.

Digital Filtering

One cycle cosine after low-pass analog filtering.

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

Protection and Control Processing

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

Relay 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 A, 0.001 A steps
Neutral:	0.005–2.5 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.:	0.10–3.20 A, 0.01 A steps
Ground:	0.005–3.200 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)

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

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[1]
Phase-to-Phase:	0.05–13.87 V[1]
Sequence:	0.05–8.00 V[1]
Kyle/Cooper NOVA LEA Inputs (37 Vac Max):	
Phase:	0.12–37.09 V[1]
Phase-to-Phase:	0.21–64.24 V[1]
Sequence:	0.25–37.09 V[1]
Lindsey SVMI LEA Inputs (200 Vac Max):	
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 Max):	
Phase:	0.03–8.49 V[1]
Phase-to-Phase:	0.05–14.72 V[1]
Sequence:	0.05–8.00 V[1]
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:[1]	
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
Kyle/Cooper NOVA LEA:[1]	
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:	
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:[1]	
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

Note 1: See *Table 9.18* in the *SEL-651R Recloser Control Instruction Manual (*and accompanying text) on how to set voltage elements when using these LEA inputs.

Synchronism-Check Elements (25)

Slip Frequency Pickup Range:	0.005–5.000 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-/Overfrequency Elements (81)[1]

Frequency Range:	40.00–65.00 Hz, 0.01 Hz steps
Frequency Accuracy:	±0.01 Hz
Time Delay Range:	2.00–16,000.00 cycles, 0.25-cycle steps
Time Delay Accuracy:	±0.25 cycle plus ±0.1%
Undervoltage Frequency Element Block Range:	
300 V Inputs:	12.50–300.00 V
8 V LEA Inputs:	0.33–8.00 V

Power Elements[2]

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[2]

Minimum Current:	0.1 A
Minimum Voltage:	12.5 Vac
Forward Load Impedance:	0.5–640 ohms secondary
Forward Positive Load Angle:	–90° to +90°
Forward Negative Load Angle:	–90° to +90°
Negative Load Impedance:	0.50–640 ohms secondary
Negative Positive Load Angle:	+90° to +270°
Negative Negative Load Angle:	+90° to +270°
Pickup Accuracy:	
Impedance:	±3%
Angle:	±2°

Note 2: Voltage, Power, and Impedance values listed for 300 Vbase (PT) inputs.

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°
VABY, VBCY, VCAY, VABZ, VBCZ, VCAZ:	±0.4% (50–300 V), ±1.0°
3V0Y, V1Y, V2Y, 3V0Z, V1Z, V2Z:	±0.6% (50–300 V), ±1.0°

Currents

IA, IB, IC:	±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}[5] > 50 Vac, I_{phase} > 0.1 A)
Real (MW) MWA, MWB, MWC, MW3P	±0.7% @ PF = 1, ±1.0% @ PF > 0.87 (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)
Reactive (MVAR) MVARA, MVARB, MVARC, MVAR3P:	±0.7% @ PF = 0, ±1.0% @ PF < 0.50 (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)

Energy

Megawatt Hours (In and Out): MWhA, MWhB, MWhC, MWh3P:	+1.2% @ PF=1, (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)
Megavar Hours (In and Out): MVARhA, MVARhB, MVARhC, MVARh3P:	+1.2% @ PF=0, (V_{phase}[5] > 50 Vac, 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)

Harmonic Metering

±5%

RMS Metering

Voltages

VAY, VBY, VCY, VAZ, VBZ, VCZ:	±1.2% V_{phase}[5] > 50 Vac

Currents

IA, IB, IC:	±0.5 mA plus ±0.2% (0.1–2 A)
IN (Measured):	±0.08 mA plus ±0.2% (0.005–4.5 A)

Average Real Power (MW)

MWA, MWB, MWC, MW3P:	±2.0% @ PF = 1 (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)

Note 5: Voltage threshold for 8 V LEA inputs is 0.67 Vac.
Voltage threshold for Kyle/Cooper NOVA LEA inputs is 1.7 Vac.
Voltage threshold for Lindsey SVMI LEA inputs is 14 Vac.

Recloser Type Tests

ANSI/IEEE C37.60: 1981, performed with the following reclosers:

G&W Viper-ST	27 kV, 12.5 kA interrupting, 800 A continuous

ANSI/IEEE C37.60: 2003, performed with the following reclosers:

Cooper NOVA	27 kV, 12.5 kA interrupting, 630 A continuous
Kyle® Recloser type "WVE-27"	27 kV, 8 kA interrupting, 560 A continuous
ABB OVR-3	27 kV, 12.5 kA interrupting, 630 A continuous
Cooper NOVA-TS	15.5 kV, 8 kA interrupting, 400 A continuous
Cooper NOVA (control powered)	27 kV, 12.5 kA interrupting, 630 A continuous

Section 6.12
Cable Charging Current Interrupting test for automatic circuit reclosers and fault interrupters for AC systems, 5 A rms charging current interrupted, 20 close-open operations, randomly timed.

Section 6.13
Transformer Magnetizing Current Interruption test for automatic circuit reclosers and fault interrupters for AC systems, magnetizing current interrupted equal to 3.5% of the continuous current rating of the recloser, 20 close-open operations, randomly timed.

Section 6.14
Control Elements, SWC tests for automatic circuit reclosers and fault interrupters for AC systems, 1.0–1.5 MHz oscillatory test wave of crest voltage of 2.5–3.0 kV occurring in the first half-cycle, decaying to 50% in not less than 6 µs.

Section 6.2
Insulation (Dielectric) tests for automatic circuit reclosers and fault interrupters for AC systems, 1.2 • 50 µs voltage impulse (positive and negative) of crest voltage of 125 kV, applied to recloser with control connected.

Section 6.3
Interruptions.

Notes

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