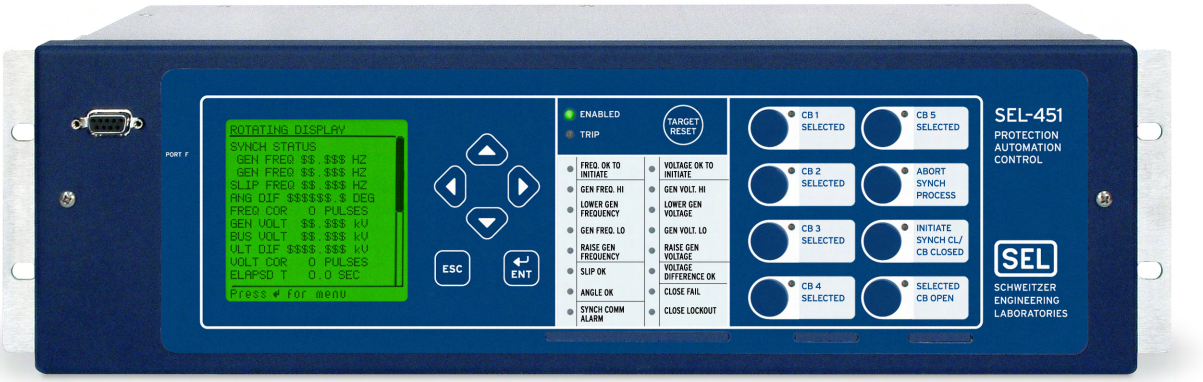
SEL-451-5-Based Autosynchronizer

A custom-engineered solution for safe, secure autosynchronization of generation onto the power system



Major Features and Benefits

SEL combines engineering services with the field-proven SEL-451-5 Feeder Protection Relay for Advanced Autosynchronizing (A25A) systems with the features and flexibility that customers have come to expect from SEL products and systems. The SEL-451-5-based A25A is sold as a configuration and documentation disc. The user separately purchases the SEL-451-5 Feeder Protection Relay per the Model Option Table requirements detailed in this data sheet. Alternatively, the user can contact SEL Engineering Services to obtain a fully engineered customized solution. Please refer to the SEL-451-5 data sheet for complete information on the standard features available in this powerful device.

The voltage on the generator side of the breaker is called the incoming signal. The voltage on the bus side of the breaker is called the running signal.

The pre-engineered A25A includes the following features:

- **Generator Frequency and Voltage Matching Control.** Pulse governor and exciter reference points to bring a generator into synchronism acceptance criteria. Pulse interval and pulse width parameters are configurable for multiple synchronization situations. The control supports either fixed or proportional pulse width control characteristics.
- **Breaker Close Delay Compensation.** Issue a close signal in advance of zero degrees phase coincidence so that the main contacts make as the generator phase angle difference reaches zero degrees.
- **Incoming Frequency Greater Than Running Frequency (IF > RF) (Antimotoring) Control.** Apply in situations with prime movers with extremely sensitive reverse power protection. The system requires incoming frequency greater than running frequency to cause initial power flow to be out of the generator to prevent trip of reverse power protection upon initial synchronization of the generator.
- **Dead-Scope Control.** Generate a frequency raise pulse to prevent a near-zero slip-rate condition in which two systems move very slowly relative to one another and take a long time to rotate into phase.

- **Incoming Voltage Greater Than Running Voltage (IV > RV) Control.** Apply in situations where it is necessary to prevent the generator from absorbing VARs from the system and pulling down the system voltage on initial synchronization.
- **Three-Close Conditions.** Close the controlled circuit breaker under three conditions with specific close acceptance criteria: autosynchronize close (phase angle is slipping), parallel close (zero slip conditions), and live generator/dead-bus close.
- **Autosynchronize Acceptance Criteria.** Initiate an autosynchronizing close when the generator frequency difference, generator voltage difference, rate-of-change of frequency, and rate-of-change of voltage are within user-defined parameters. Enable rate-of-change permissives separately to prevent initiating an autosynchronize close operation when the frequency and voltage are still changing.
- **Parallel Close Acceptance Criteria.** Initiate a parallel close when zero slip is detected and the angle, voltage, and frequency are within acceptable limits. This is often used in dual breaker applications to close the second synchronizing breaker after the generator has already been synchronized. This permissive can be disabled.
- **Dead-Bus Close Acceptance Criteria.** Energize a dead bus from the generator in black-start applications. When the dead-bus close permissive input on the autosynchronizer is energized, the control checks that the generator voltage and frequency are within acceptable limits and that the bus is dead and then closes the synchronizing circuit breaker. This permissive can be disabled.
- **Operator Close Permissive.** Implement multiple-level close supervision schemes by using the operator close permissive function. When operator close permissive is enabled, the operator must close the operator close permissive contact inside the operator close permissive window in addition to meeting all other close acceptance criteria. This permissive can be disabled.
- **Two Synchronizing Process Initiation Modes.** Start and stop the autosynchronization process by one of two modes: by selecting and deselecting the circuit breaker or by using initiate and abort controls.
- **Easy-to-Tune Settings.** Simply set an interval for correction pulses and set slope or duration based upon observed response rate of generator controls.
- **Digital Relay-to-Relay Communications.** Use MIRRORED BITS® communications over fiber-optic links to control breakers remote from the A25A device or to locate the A25A device remote from the generator control room. The standard control features Port 3 configured for MIRRORED BITS with generator control pulse output contacts so that the control can be located remotely from the generator control room. Add an SEL-2505 Remote I/O Module (or other MIRRORED BITS-capable device with the appropriate fiber-optic adapter and fiber cable) to locate the synchronizer close to the controlled synchronizing breaker and synchronizing PTs. The remote I/O (RIO) can be located at the generator exciter and governor. This feature is ideal for cogeneration applications where the cogenerator can operate with critical load islanded from the grid and needs to be synchronized back to the grid after a disturbance. Many other configurations are possible with customization. See the SEL-451-5 Data Sheet for more information on MIRRORED BITS.
- **Advanced Communications Options.** Easily integrate into your existing control system with serial or optional Ethernet communications by using SEL, DNP3, and/or IEC 61850 protocols.
- **Oscillography and Sequence of Events Recording.** Record current and voltage waveforms to analyze operation of each autosynchronization operation. Record sequence of events for binary status points for fine-tuning autosynchronization system operation and getting to the root cause of disturbances.
- **Close Fail Alarm.** Alert personnel if the controlled circuit breaker fails to close, within a user-configurable time and angle window, when a close command is issued.
- **Close Lockout Alarm.** Alert personnel if the controlled circuit breaker opens within a user-configurable time after a close.
- **Too Much Time Alarm.** Automatically abort the synchronizing process if a close does not occur within a maximum allowed time to synchronize. This function can be disabled.
- **Synchronization Operational Parameters Displayed.** Troubleshoot and optimize the autosynchronization operation, using generator frequency and voltage data recorded for the most recent eight correction pulses. The elapsed time of autosynchronization operation is also displayed.

- **Optional Second I/O Board.** When the optional second I/O board is ordered, the control includes high-current interrupting contacts for generator frequency and voltage raise and lower contacts. It also includes contacts for remote annunciation of front-panel indications such as SLIP OK, VOLTAGE OK, and ANGLE OK and remote annunciation of Close Fail and Close Lockout alarms.
- **Custom ACSELERATOR QuickSet® SEL-5030 Software Settings Interface.** Easily set the autosynchronizer by using the provided settings template, which hides all of the settings for unused features of the SEL-451-5 Relay and organizes all the user settings required to configure autosynchronizer features.
- **Settings Groups for Five Generator/Breakers.** Use in applications requiring as many as five independent generator/breaker combinations.
- **Unprecedented Flexibility.** With SEL Engineering Services customization, control multiple generators and/or multiple synchronizing breakers without the need for complicated synchronizing switch circuits to route voltage transformer and control signals. Six independent single-phase voltage inputs with two selectable master frequency-tracking inputs and multiple settings groups allow flexibility.

Ordering Information

Configuration and Documentation Disc

The pre-engineered system configuration and documentation disc can be ordered using part number 9163X451ASCD. The disc shown in *Figure 1* includes a QuickSet template that provides a customized user interface for setting up the SEL-451-5 Relay as an A25A. It also includes a detailed instruction manual and logic diagrams documenting the features, application, and programming of the A25A.

Figure 1 Configuration and Documentation Disc

End users who purchase a configuration and documentation disc can use it to configure as many SEL-451-5 relays as needed for use on their power system facilities. Use of the disc to configure advanced autosynchronizers for other end users without permission from SEL is prohibited.

SEL-451-5 Model Option Table

The autosynchronizer system requires an SEL-451-5, purchased separately. The pre-engineered system is configured as a fixed, single-function device with all inputs and outputs (I/O) preassigned as described in *Typical Connections on page 10*.

The SEL-451-5 is available in two standard configurations: a three-rack unit version with standard I/O or a four-rack unit version with a second I/O board. The standard autosynchronizer configuration requires a part number per the model option table (MOT) indicated in *Table 1*. See *Typical Connections on page 10* for more information on the features the optional I/O board provides.

Custom Engineered Systems

The power and flexibility of the SEL-451-5 allow SEL Engineering Services to customize the programming to build advanced synchronizing systems. In many cases, this can be more economical than designing and testing complex synchronizing switching circuits. In other cases, customization can create synchronizing systems that are simply not possible to obtain from conventional technology. See *Application Examples on page 14* for more information on possibilities. Contact SEL Engineering Services to discuss whether the pre-engineered system is right for your application or for a proposal on a custom engineered system.

Table 1 Pre-Engineered Autosynchronizer Model Option Table Requirements

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Selection	0	4	5	1	5				X			X						X	X		X
Notes						1	1	2		3	3		1	1	4	4	1			1	

Note 1: Select option per requirements of the installation.
Note 2: Select Option 1 or 5 per requirements of the installation.
Note 3: The pre-engineered automatic synchronizer does not include configuration of these communications protocols.
Note 4: Select Option 1X if standard I/O is required. Select Option 27 if the second I/O board is required. See *Table 3* for additional features provided with the second I/O board.

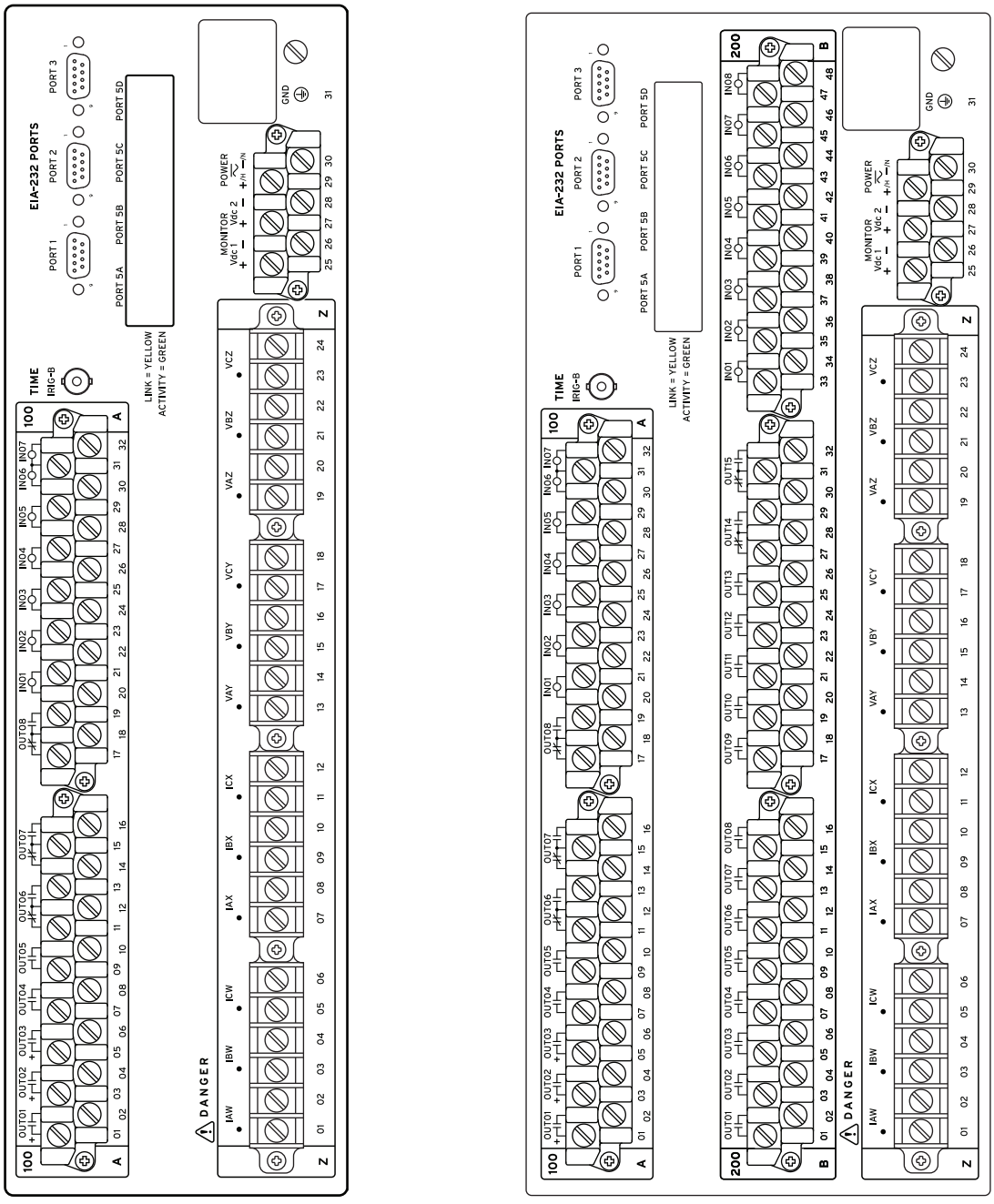


Figure 2 Rear Panel of SEL-451-5 With Standard I/O (a) and With Optional Second I/O Board (b)

Control Functions

Successfully synchronizing a generator requires that three parameters be within close acceptance criteria.

- Slip (frequency difference) in acceptance band
- Voltage difference in acceptance band
- Angle difference near zero

The heart of an autosynchronizer is the slip-compensated advanced angle close function that compensates for the breaker mechanism delay and energizes the synchronizing breaker close coil at the precise instant to cause the main contacts to make contact at zero degrees angle difference.

Additionally, the A25A has features to control the generator to match frequency and voltage by pulsing the reference points of the governor and voltage regulator controls, respectively, to bring these parameters into the synchronizing acceptance bands.

Start Sync Process Mode

Before a circuit breaker can be closed, the circuit breaker must be selected by asserting one of the circuit breaker selection inputs on the back of the control. Selecting a breaker loads all the settings associated with that breaker. One of two modes can be used to initiate the synchronizing process.

Start/Stop on Initiate and Abort Mode

When Start/Stop on Initiate and Abort mode is enabled, the operator must select a circuit breaker for autosynchronization. The synchronizing close process can be initiated, or the circuit breaker can be closed by initiating the autosynchronizer when one of the three close permissive conditions is asserted (synchronizing close, parallel close, dead-bus close).

Start/Stop on Circuit Breaker Selected Mode

When Start/Stop on Circuit Breaker Selected mode is enabled, the operator must select a circuit breaker for autosynchronization. The circuit breaker will close immediately, or the autosynchronizing process will start when one of the three close permissive conditions asserts.

Frequency Matching

The A25A can adjust the incoming (generator) frequency to match the frequency of the running (bus). When isolated from the system, the governor control typically operates in isosynchronous (frequency control) mode. The control raises or lowers the frequency reference point on the governor control via pulsing contacts. The user can select between OFF, Fixed Pulse Mode, and Proportional Pulse Mode.

Figure 3 shows the proportional pulse control characteristic when the IF > RF (antimotoring) feature is enabled. *Figure 4* shows the control characteristic when the IF > RF feature is disabled.

At zero slip, the generator angle will not rotate into phase with the power system and a close cannot occur. When IF > RF is not enabled, zero slip is inside the control dead band, and no correction pulses will be sent to the governor to change the slip rate off of zero. *Figure 4* shows that the proportional pulse characteristic is modified by addition of a dead-scope band. If the frequency is within the dead-scope band of ±20 mHz, a frequency raise correction pulse will be output to move the slip rate off of zero.

The following user settings define the control characteristic:

- Slip allowed (hertz)
- Pulse width (seconds) (fixed pulse mode)
- Proportional pulse slope (seconds/hertz) (proportional pulse mode)
- Pulse interval (seconds)
- Enable/disable IF > RF

The pulse interval defines the time between the rising edges of consecutive correction pulses. This time should be greater than the settle time of the generator frequency after each correction pulse.

The width of each correction pulse is proportional to the deviation of the frequency from the center of the correction dead band when Proportional Pulse Mode is enabled. As the frequency approaches the center of the dead band, the correction pulses become shorter to prevent hunting.

When IF > RF is enabled, the control ensures that the allowable slip is positive (generator frequency greater than bus frequency) so that power flow is out of the generator upon initial synchronization. This feature is recommended for applications that have prime movers with extremely sensitive reverse power protection. The center of the dead band is offset in the positive direction from zero slip by one half of the slip allowed setting.

The correction dead band is fixed with a 20 percent margin inside the slip allowed synchronism acceptance setting.

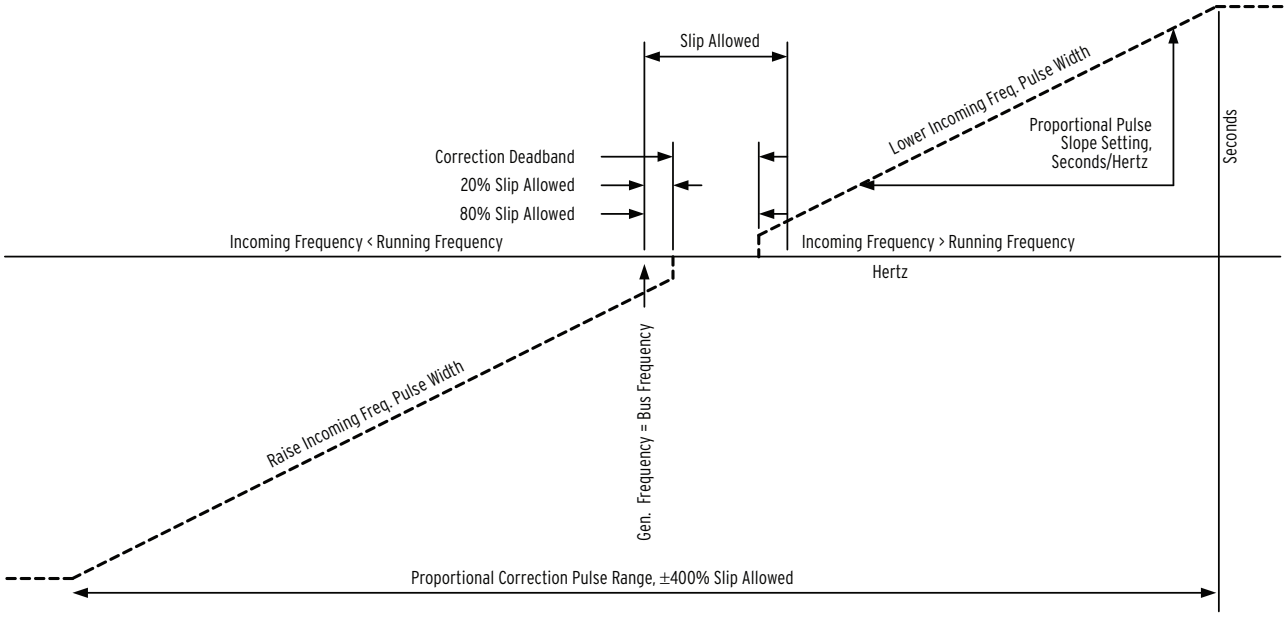


Figure 3 Proportional Frequency Correction Pulse Characteristic With IF > RF Enabled

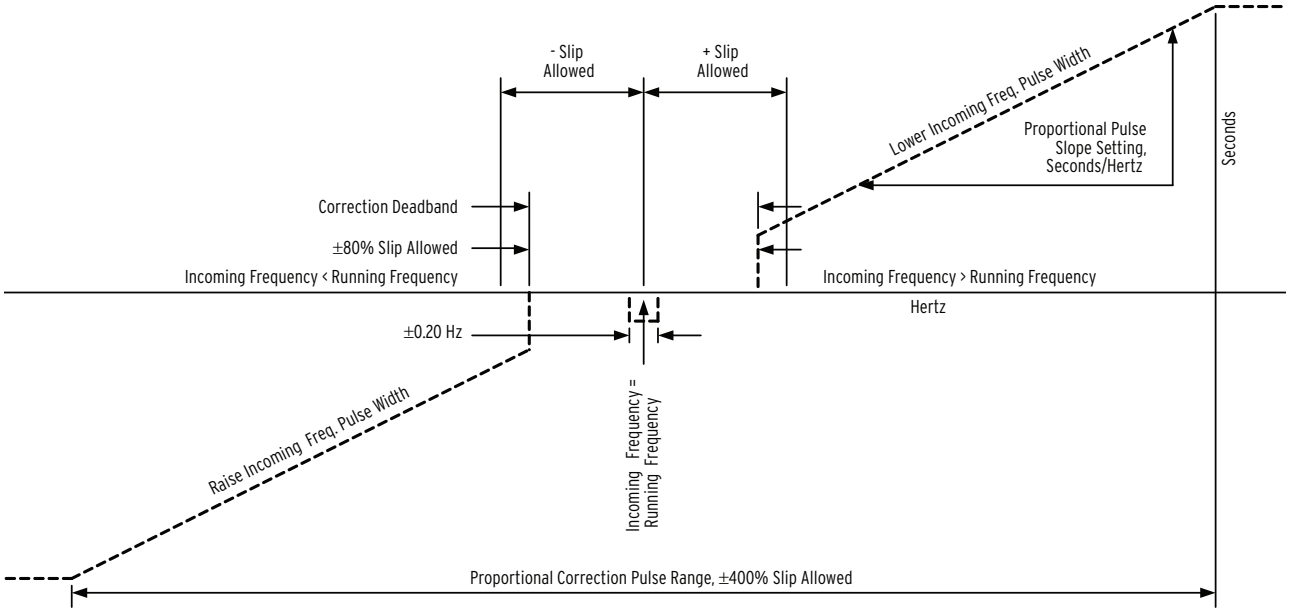


Figure 4 Proportional Frequency Correction Pulse Characteristic With IF > RF Disabled

Voltage Matching

The A25A can adjust the generator voltage to match the voltage of the bus. When isolated from the system, the voltage regulator control operates in voltage control mode. The control raises or lowers the voltage reference point on the exciter control via pulsing contacts. The user can select between OFF, Fixed Pulse Mode, and Proportional Pulse Mode.

Figure 6 shows the proportional pulse control characteristic when the IV > RV feature is enabled. *Figure 5* shows the control characteristic when the IV > RV feature is disabled. The IV > RV control is used when you want to ensure that the generator does not draw VARs from the system upon initial synchronization to the bus.

The following user settings define the control characteristic:

- Voltage difference allowed (per-unit volts)
- Pulse width (seconds) (fixed pulse mode)
- Proportional pulse slope (seconds/per-unit volts) (proportional pulse mode)
- Pulse interval (seconds)
- Enable/disable IV > RV

The pulse interval defines the time between the rising edges of consecutive correction pulses. This time should be greater than the settle time of the generator voltage after each correction pulse.

The width of each correction pulse is proportional to deviation of the voltage from the center of the correction dead band when Proportional Pulse Mode is enabled. As the voltage approaches the center of the dead band, the correction pulses become shorter to prevent hunting. The correction dead band is fixed with a 20 percent margin inside the voltage difference allowed synchronism acceptance setting.

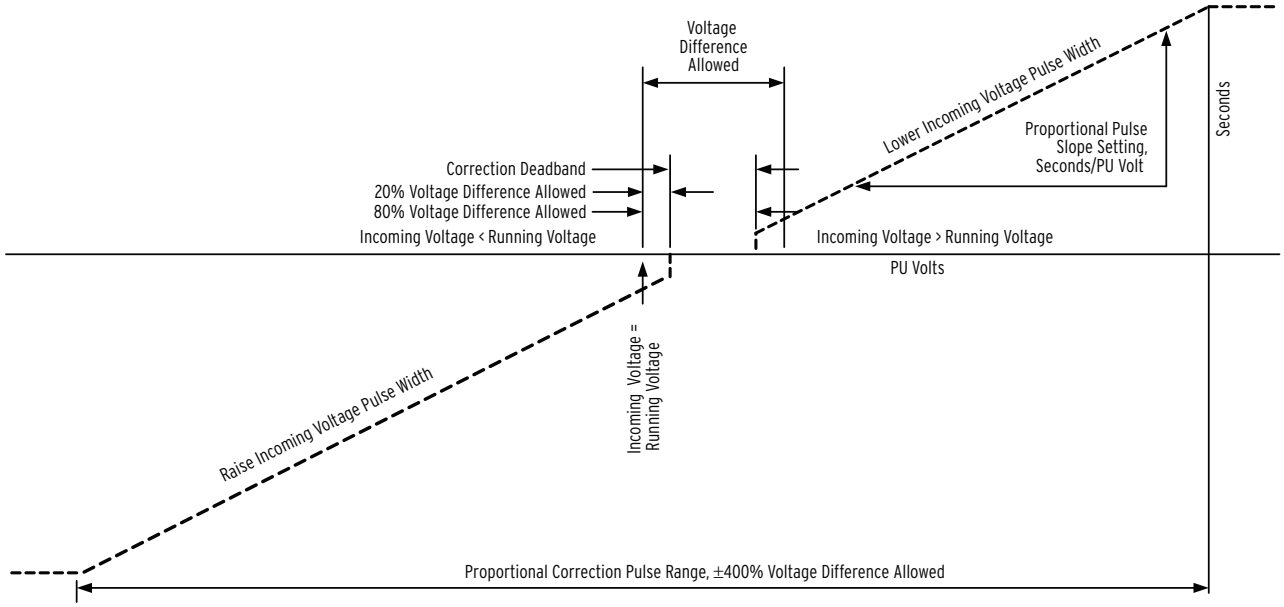


Figure 5 Proportional Voltage Correction Pulse Characteristic With IV > RV Enabled

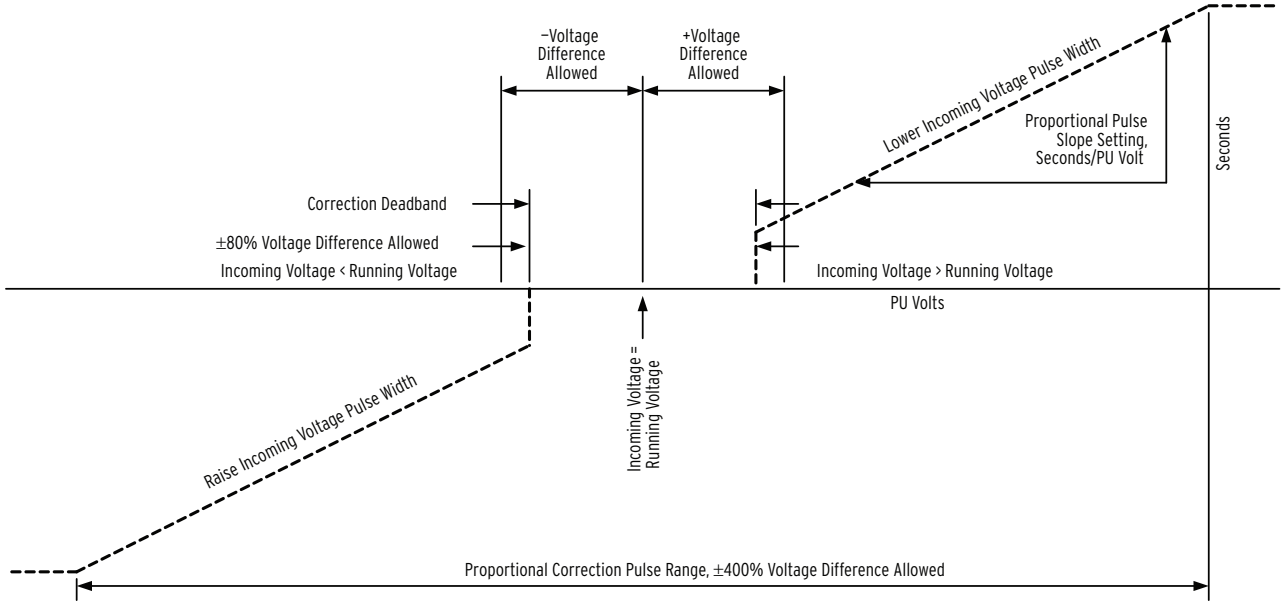


Figure 6 Proportional Voltage Correction Pulse Characteristic With IV > RV Disabled

Synchronism Acceptance Criteria

Synchronizing close acceptance criteria include the following:

- Slip allowed (Hz)
- dF/dt allowed (Hz/second or OFF)
- Voltage difference allowed (per-unit volts)
- dV/dt allowed (per-unit V/second or OFF)

The system initiates a close at the slip-compensated advanced angle as soon as the acceptance criteria are satisfied. The optional rate-of-change checks prevent the system from initiating a close operation when the frequency and voltage are still changing.

Parallel Close Acceptance Criteria

For a parallel close scenario, the generator is already synchronized to the system as determined by the absence of a detectable slip. Often, a parallel close scenario occurs when you want to close a second synchronizing breaker via the autosynchronizer in a double-breaker bus arrangement (ring bus, breaker-and-a-half bus, or double bus double breaker) after the generator has already been synchronized.

For a parallel close scenario, the breaker can be closed immediately without waiting for frequency and voltage matching processes to occur and the angle to slip towards zero. So, the breaker is closed immediately if the parallel close acceptance criteria are satisfied.

- Incoming and running frequency are within the healthy acceptance band
- Incoming and running voltage are within the healthy acceptance band
- Angle is within the parallel close permissive window

This permissive can be disabled if parallel closing via the A25A is not required.

Dead-Bus Close Acceptance Criteria

Dead-bus close acceptance criteria include the following:

- Incoming frequency is within the healthy acceptance band
- Incoming voltage is within the healthy acceptance band
- Running voltage is within the dead acceptance band
- Operator dead-bus permissive input is asserted

The autosynchronizer monitors single-phase voltage transformer (VT) inputs for incoming and running voltage sensing. Thus, it cannot discern between a dead bus and a blown VT fuse. To prevent an out-of-synchronization close via the dead-bus permissive path when a VT fuse blows, the dead-bus close acceptance criteria require an operator to assert the dead-bus close enable input to confirm that a dead-bus close is necessary.

This permissive can be disabled if dead-bus closing via the A25A is not required.

Operator Close Permissive

In some applications, a human operator should also agree that it is safe to close the breaker before the synchronizing close output is asserted. When operator close permissive is enabled, the operator must close the operator close permissive contact inside the operator close permissive window in addition to meeting all other close acceptance criteria. This option requires either the optional second I/O board or a remote I/O module to provide the operator close permissive input to the A25A.

The characteristic of the operator close permissive is shown in *Figure 7*. The slip-compensated advance angle for a generator fast condition is the hatched area shown in *Figure 7*. The operator close window is the black area shown in *Figure 7*. The advanced angle and the operator close window would be on the opposite side of zero degrees for a generator slow condition.

If the operator closes the permissive contact outside of the operator close permissive window, the close output is locked out until the generator angle passes through and back out of the synchronism-check angle window. This feature prevents operators from taking themselves out of the control loop by simply holding the control switch in the closed position and letting the A25A perform the close.

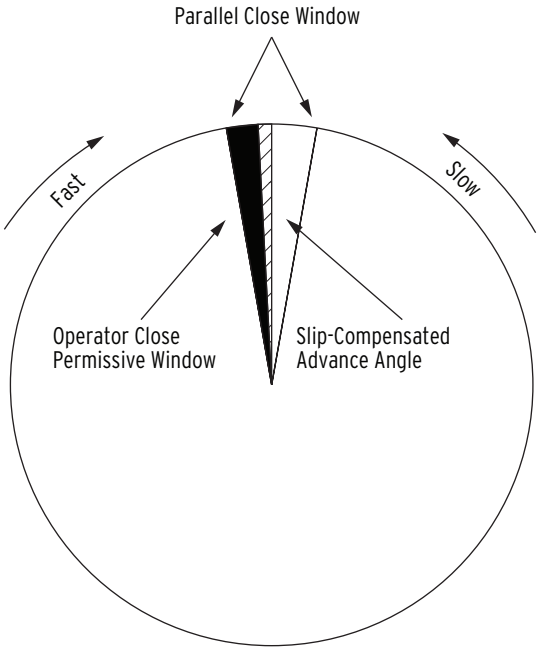


Figure 7 Operator Close Permissive Window

Compensated Close Control

Independently configure the close mechanism delay for as many as five controlled circuit breakers. As the phase angle difference between the two systems closes toward 0 degrees, the close signal asserts in advance of 0 degrees according to the measured slip rate and the breaker close mechanism delay, so that the main contacts make contact at precisely the instant when the phase angle between the two systems is zero.

Close Success Monitoring

Once the automatic synchronizer is initiated, the synchronizing process continues until one of the following things happens:

- The selected circuit breaker closes
- The process is manually aborted by the operator
- The breaker is deselected
- The maximum time allowed to synchronize the timer expires (if the function is enabled)
- A close is attempted and the breaker fails to close, asserting the Close Fail alarm

There are three close failure alarm functions.

Close Fail Alarm

A Close Fail alarm asserts if the system attempts an automatic close and the selected circuit breaker fails to close. The system latches this alarm in nonvolatile memory; you must reset this alarm before you can attempt another automatic close of that circuit breaker.

Close Lockout Alarm

A Close Lockout alarm asserts if a circuit breaker opens within a time you define after an automatic close occurs. The system latches this alarm in nonvolatile memory; you must reset this alarm before you can attempt another automatic close of that circuit breaker.

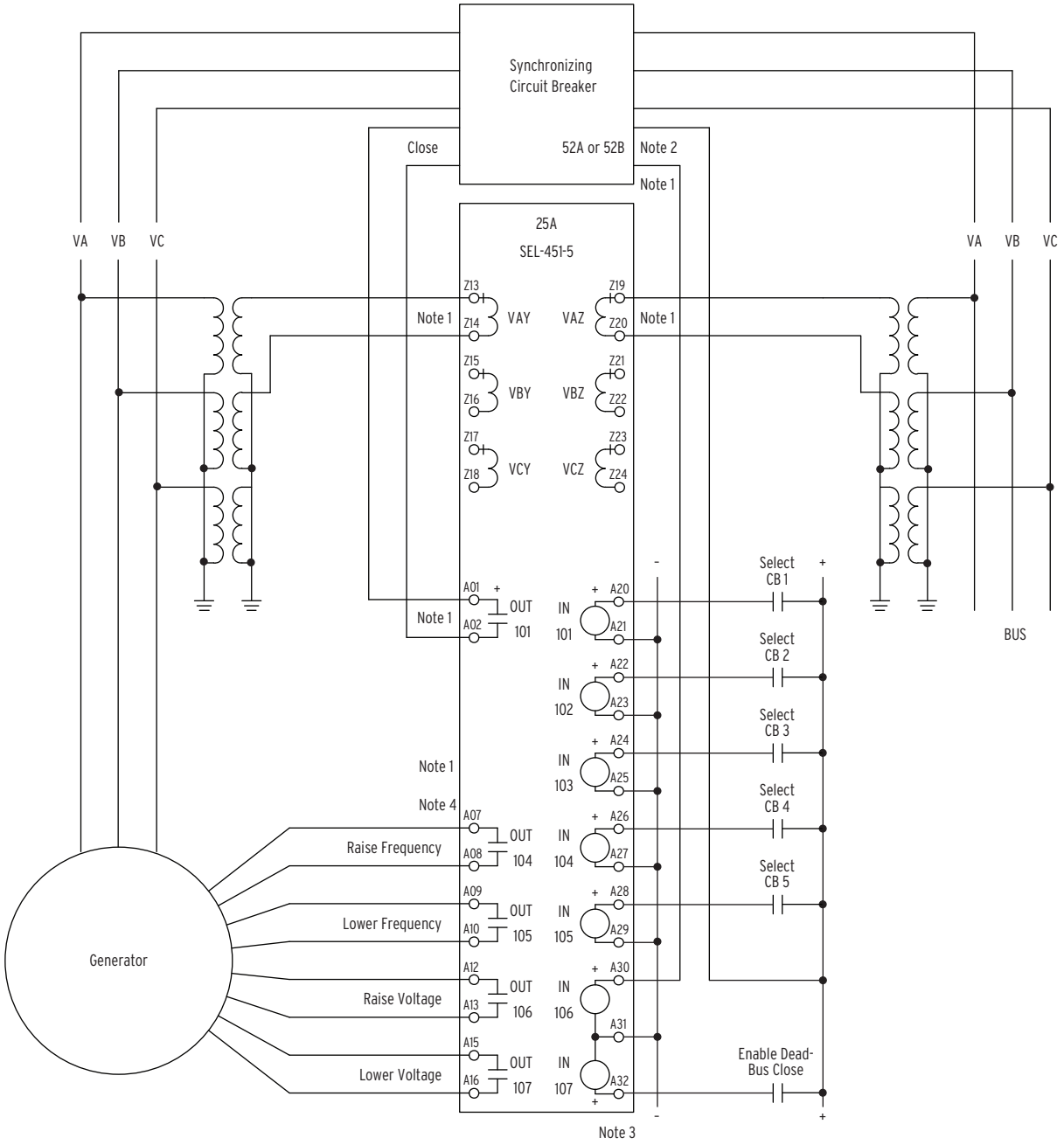
Maximum Time Allowed Alarm

The Maximum Time Allowed to Synchronize alarm asserts if the close acceptance criteria are not met, meaning that a close attempt can be initiated within the allowed time. The system latches this alarm in nonvolatile memory; you must reset this alarm before you can attempt another automatic close of that circuit breaker. This alarm can be disabled.

Antipump (One Close Attempt Allowed) Logic

Once an automatic close has been initiated, a latch is set that blocks any additional close attempts. The latch is automatically reset when the breaker is deselected.

Typical Connections



Note 1: Synchronizing switch contacts for switching VT and I/O connections for the five circuit breakers/generators are not shown for simplicity.

Note 2: A user setting defines whether CB Status contact is 52A or 52B.

Note 3: The contact sensing input debounce parameters are configured for application with either ac or dc wetting voltage. When using dc wetting voltage, observe polarity marks.

Note 4: If the optional second I/O board is ordered and high-current interrupting contacts are required for Raise and Lower outputs, the terminal numbers change from starting with "A" to starting with "B" and the output contact numbers change from 1xx series to 2xx series. The optional high-current interrupting contacts are polarity-sensitive, with the lower number terminal as the "+" terminal.

Figure 8 A25A Typical Connection Diagram

Table 2 shows a complete listing of input and output functions for the standard I/O board.

Table 2 I/O for Standard I/O Board

Outputs	Function	Inputs	Function
OUT101[a]	Close	IN101	Select Circuit Breaker 1
OUT102[a]		IN102	Select Circuit Breaker 2
OUT103[a]	Fail to Synchronize Alarm	IN103	Select Circuit Breaker 3
OUT104	Raise Frequency	IN104	Select Circuit Breaker 4
OUT105	Lower Frequency	IN105	Select Circuit Breaker 5
OUT106	Raise Voltage	IN106	CB Status 52A or 52B
OUT107	Lower Voltage	IN107	Enable Dead Bus Close
OUT108	Self-Test Fail Alarm		

[a] High-current interrupting contact.

Table 3 shows a complete listing of input and output functions for the optional second I/O board.

Table 3 I/O for Optional Second I/O Board

Outputs	Function	Inputs	Function
OUT201[a]	Too Much Time Alarm	IN201	Alarm Reset
OUT202[a]		IN202	
OUT203[a]		IN203	
OUT204[a]	Raise Frequency	IN204	
OUT205[a]	Lower Frequency	IN205	
OUT206[a]	Raise Voltage	IN206	Abort Synchronizing Process
OUT207[a]	Lower Voltage	IN207	Initiate Synchronizing Process
OUT208[a]		IN208	Operator Close Permissive
OUT209[a]	Voltage OK to initiate		
OUT210[a]	Frequency OK to initiate		
OUT211[a]	Slip OK		
OUT212[a]	Voltage OK		
OUT213[a]	Angle OK		
OUT214	Close Fail		
OUT215	Close Lockout		

[a] High-current interrupting contact.

Table 4 shows a complete listing of input and output functions for the optional Remote I/O module connected via MIRRORED BITS. See the SEL-451-5 Data Sheet for more information on MIRRORED BITS.

Table 4 I/O for MIRRORED BITS When Optional RIO Device Used

TMB	Function	RMB	Function
TMB1A	Voltage OK to initiate	RMB1A	Alarm Reset
TMB2A	Frequency OK to initiate	RMB2A	
TMB3A	Fail to Synchronize Alarm	RMB3A	
TMB4A	Raise Frequency	RMB4A	
TMB5A	Lower Frequency	RMB5A	Enable Dead Bus Close
TMB6A	Raise Voltage	RMB6A	Abort Synchronizing Process
TMB7A	Lower Voltage	RMB7A	Initiate Synchronizing Process
TMB8A		RMB8A	Operator Close Permissive

User Interface

The user interface allows system operators to monitor the autosynchronization process locally via the front panel of the device. The control can be customized by SEL Engineering Services to provide remote control and monitoring via a communications interface or local control via the front-panel pushbuttons.

Front-Panel HMI

The functionality of the front-panel LEDs and liquid crystal display (LCD) indications are pre-engineered to the functions shown in *Figure 9* and *Figure 10*. The labels are completely user-configurable. The configuration and documentation disc includes label template files that match the labeling shown in *Figure 9* and *Figure 10*. Users can easily modify these label files to provide application-specific labels.

Figure 9 shows the front-panel layout of the control pushbuttons and indicating LEDs when users enable Start/Stop on Initiate/Abort mode for Start Synchronizing Process mode.

Figure 10 shows the front-panel layout of the control pushbuttons and indicating LEDs when users enable Start/Stop on CB Selected mode for Start Synchronizing Process mode.

The control can be customized by SEL Engineering Services to use the optional 12-pushbutton front panel, SEL Fast Message communications, or any of the other available communications protocols to obtain remote access to all control functions, metering, and status indications.

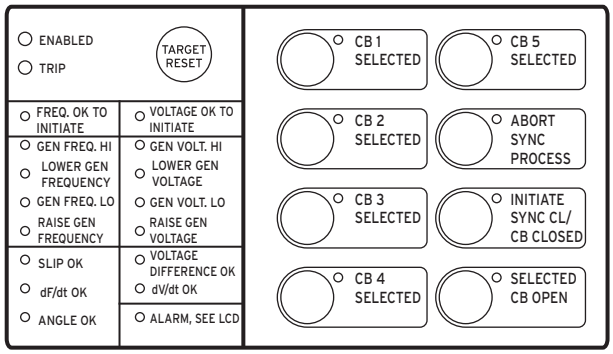


Figure 9 Front-Panel HMI Start Synchronizing Process Mode Start/Stop on Initiate/Abort

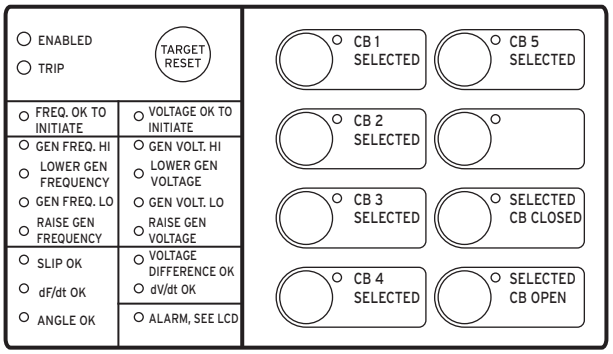


Figure 10 Front-Panel HMI Start Synchronizing Process Mode Start/Stop on CB Selected

The programmable LCD provides a summary of all critical parameters during the synchronizing process. *Figure 11* shows the information the 11-line LCD provides.

```
ROTATING DISPLAY
SYNC STATUS
 GEN FREQ XX.XXX HZ
 BUX FREQ XX.XXX HZ
SLIP FREQ XX.XXX HZ
ANG DIF XXXX.X DEG
FREQ COR XXX PULSES
GEN VOLT XXX.XXX kV
BUS VOLT XXX.XXX kV
VLT DIF XXXX.XXX kV
VOT COR XXX PULSES
ELAPSD T XXX.X SEC
Press ↵ for menu
```

Figure 11 Synchronizing Process Status Summary Screen

The programmable LCD also provides a summary of the generator frequency and voltage that the system recorded for the most recent eight correction pulses. *Figure 12* and *Figure 13* show the information the 11-line LCD provides. You can access these displays by pressing the pushbuttons on the front of the control.

```
ROTATING DISPLAY
FREQ MATCHING DETAIL
FREQ COR XXX PULSES
    dF/dt X.XXX HZ/s
G F N-0 XXX.XXX kV
G F N-1 XXX.XXX kV
G F N-2 XXX.XXX kV
G F N-3 XXX.XXX kV
G F N-4 XXX.XXX kV
G F N-5 XXX.XXX kV
G F N-6 XXX.XXX kV
G F N-7 XXX.XXX kV
Press ↵ for menu
```

Figure 12 Frequency Matching Screen

```
ROTATING DISPLAY
VOLT MATCHING DETAIL
VOLT COR XXX PULSES
    dV/dt X.XXX HZ/s
G V N-0 XXX.XXX kV
G V N-1 XXX.XXX kV
G V N-2 XXX.XXX kV
G V N-3 XXX.XXX kV
G V N-4 XXX.XXX kV
G V N-5 XXX.XXX kV
G V N-6 XXX.XXX kV
G V N-7 XXX.XXX kV
Press ↵ for menu
```

Figure 13 Voltage Matching Screen

Customized QuickSet Settings Template

A QuickSet template is provided with the autosynchronizer system that gives the user a custom settings interface, as shown in *Figure 14*. The template works inside the QuickSet settings environment. This template organizes the settings for the autosynchronizer functionality and hides most SEL-451-5 settings unused in the autosynchronizer control application.

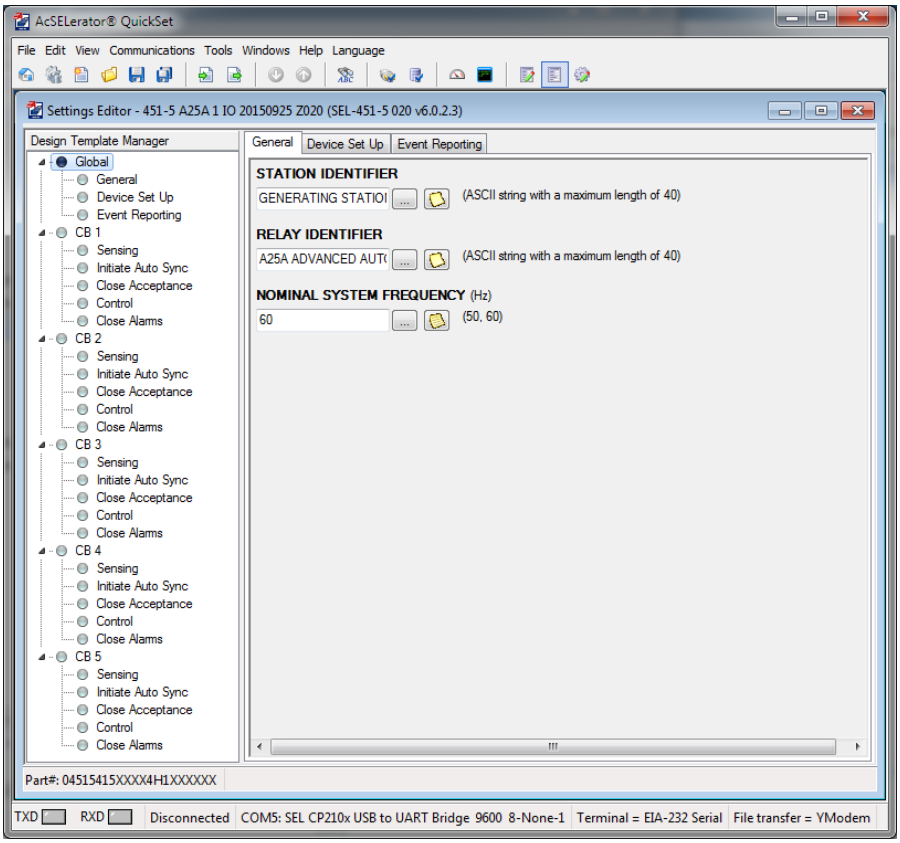


Figure 14 QuickSet Template

Application Examples

SEL autosynchronization systems measure voltage and frequency on both the generator and the power system, send correction pulses to adjust the governor and exciter as necessary, and automatically close the breaker, separating the two systems once synchronization acceptance criteria are met. This process ensures safe, secure autosynchronization of generation onto the power system.

Autosynchronization can reduce risk over manual synchronization operations by ensuring that voltage difference and frequency difference (slip) are less than maximum acceptance criteria and by closing the breaker at the exact moment that the slipping systems come into phase. Smooth synchronization reduces torsional stresses to the generator and prime mover that cause accumulated damage over the life of the generation system.

SEL autosynchronization systems are extremely flexible. In addition to synchronizing a generator to the power system, the system can also synchronize an islanded power system back to the grid.

The following application examples are just a few of the many configurations possible with SEL Engineering Services customization. Contact the synchronizing experts in SEL Engineering Services to discuss your application requirements and get a proposal for an advanced synchronizing system to improve reliability, reduce cost and complexity, and improve operational flexibility.

Application Example 1: Synchronizing Multiple Generators

Figure 15 shows a conventional autosynchronization (25A) application example that uses the SEL system to synchronize multiple generators. In this example, three generators, two combustion-turbine generators (CT1 and CT2), and one steam-turbine generator (ST1) in a combined cycle power plant are connected to a collector bus. Device A25A provides automatic close control of circuit breakers G1, G2, and G3.

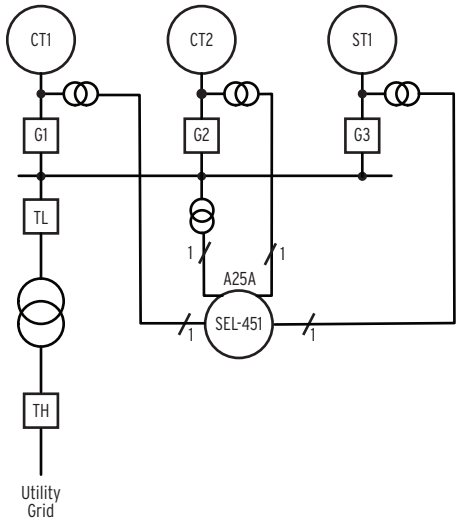


Figure 15 Synchronizing Multiple Generators

Output contacts connected to the governor system raise and lower frequency. Output contacts connected to the exciter system raise and lower voltage. The advance angle-compensated autosynchronized close contacts are connected to the close circuit of the circuit breakers.

While the pre-engineered scheme can be used in this application, the VT signals and control signals would have to be routed through synchronizing switch or selector contacts. With SEL Engineering Services customization, the synchronizing switching circuits can be eliminated. The application is unconventional in that SELOGIC® control equations provide all switching of VT circuits, governor and exciter correction pulse outputs, and circuit breaker close outputs, eliminating the need for complicated and unreliable synchronizing switch wiring.

In this application, you would select the correct VT signals for measurement of the generator and system frequency and voltage in programmable logic from the six available single-phase inputs. You can then add optional I/O boards to the SEL-451-5 to control as many generators and generator breakers as necessary via separate output contacts. This functionality, combined with the extensive communications capabilities available with the SEL-451-5, simplifies implementation of operation via a computerized integration system.

Application Example 2: Synchronizing at Multiple Locations

Figure 16 shows a custom application that uses a cogeneration system to ensure reliable power supply to a critical industrial load bus, where loss of power can result in severe safety issues or severe economic losses. In this application, we simplify the diagram by not showing CT connections.

Device 67-SEP, located at the critical load bus, includes voltage and frequency elements as well as directional overcurrent elements that separate the critical load bus from the utility when the device detects a disturbance on the utility supply. Device 25A-L (local), located in the cogeneration control room, provides autosynchronization control for circuit breaker (CB) G and CB TIE. Device 25A-R (remote), located at the utility tie substation some distance away, provides autosynchronization control and directional overcurrent protection for CB U.

To synchronize the generator to the system via CB G, device 25A-L, located in the cogeneration control room, measures the generator and system frequency and voltage from the generator voltage transformer (VT) and the auxiliary bus VT, respectively. The device uses software to select the appropriate VT inputs from the six available single-phase inputs on the SEL-451-5 relay. No external switching of VT signals is necessary. Output contacts for raising and lowering frequency are connected to the governor system. Output contacts for raising and lowering voltage are connected to the exciter system. The advance angle-compensated autosynchronizing close command is directly connected to the close circuit of CB G.

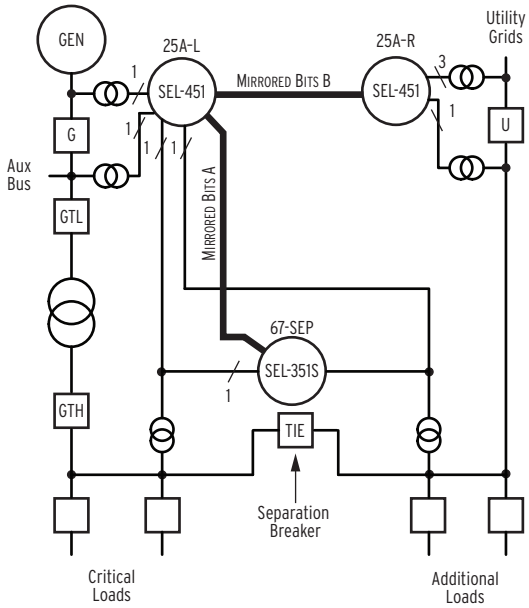


Figure 16 Synchronizing at Multiple Locations

To synchronize the islanded critical load bus to the system via CB TIE, device 25A-L measures the generator and system voltages at the critical load bus VT and the additional load bus VT, respectively. These signals are connected to two single-phase VT inputs on the SEL-451-5 relay. Device 67-SEP on CB TIE receives the advance angle-compensated autosynchronization close command via MIRRORED BITS Channel A. Alternatively, you could use an SEL-2505 or SEL-2506 Remote I/O Module for the remote close command if a MIRRORED BITS-capable relay is not used at CB TIE.

Device 25A-R provides both directional overcurrent protection and autosynchronization functionality for CB U. Thus, it measures three-phase voltage on the utility side of CB U and single-phase voltage on the cogeneration side of CB U. It sends frequency and voltage correction pulses to device 25A-L via MIRRORED BITS Channel B when you select CB U for autosynchronizing close.

Application Example 3: Dual Breaker Synchronizer With RIO

Figure 17 shows a custom application where the high-voltage substation and the generating station are physically separated and you want to maximize isolation of the protection and control systems between the two facilities. The A25A (SEL-451-5) is configured to autosynchronize two breakers. The RIO (SEL-2505) is configured to pass voltage and frequency correction pulses from the A25A to the generator and pass operator controls from the control room to the A25A.

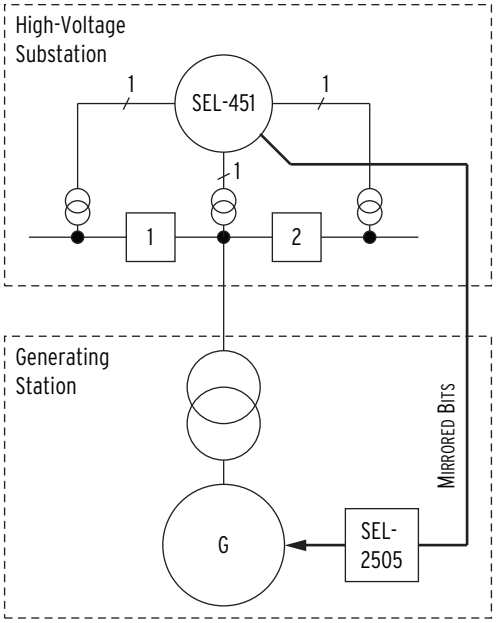


Figure 17 Dual-Breaker Synchronizer With Fiber-Optic Link Between High-Voltage Yard and Control Room

Guideform Specification

The SEL Advanced Autosynchronization System, based on the SEL-451-5 microprocessor-based relay, shall provide control, protection, monitoring, and automation. Relay self-checking functions shall be included. Specific requirements are as follows:

- **Frequency Matching.** The system shall provide fixed or proportional pulse width frequency matching outputs to bring the slip frequency within the acceptance criteria.
- **Voltage Matching.** The system shall provide fixed and proportional pulse-width voltage matching outputs to bring the incoming voltage within the acceptance criteria.
- **Easy Control Characteristic Parameters.** The system shall include independent settings for pulse interval, proportional pulse slope or duration, and synchronism acceptance band to configure the frequency matching and voltage matching control characteristics.
- **Antimotoring.** The system shall have the capability to optionally only allow synchronization when the frequency of the generator is greater than the frequency of the system.
- **Generator Voltage Greater Than Bus Voltage.** The system shall have the capability to optionally only allow synchronization when the voltage of the generator is greater than the voltage of the system.
- **Dead Scope.** The system shall have the capability to send a frequency correction pulse to the governor when a dead-scope (near zero slip) condition is detected.
- **Operator Close Permissive.** The system shall have the capability to optionally restrict synchronizing close unless an operator asserts a close command within a operator close permissive angle window.
- **VT Sensing Selection.** The system shall have the capability of measuring six individual single-phase voltage signals and of being programmed by SEL Engineering Services to select appropriate synchronizing sources and references from these signals via programmable logic equations without external switching of VT circuits. The control can be used with one incoming signal and five running signals or two incoming signals and four running signals.
- **Control Binary I/O Selection.** The system shall have the capability of isolated control I/O for each generator and breaker and of being programmed by SEL Engineering Services to select appropriate I/O without external switching of I/O circuits.
- **Control Characteristic and Synchronism Acceptance Settings.** The system shall be capable of storing separate sets of settings for as many as five generator and breaker combinations.
- **Synchronism Acceptance Criteria.** The system shall be capable of ensuring that the voltage difference, frequency difference, and optionally, the rate-of-change of voltage and rate-of-change of frequency meet acceptance criteria before an automatic close operation is initiated.
- **Slip Compensated Advanced Angle Close Control.** The system shall be capable of compensating for breaker close mechanism delay and measured slip rate to issue a close command so that the main contacts of the circuit breaker make at the moment that the two voltages come into phase.
- **Parallel Closing Control**. The system shall be capable of optionally closing a generator breaker under zero slip conditions after the generator has been synchronized to the system.
- **Dead-Bus Closing Control.** The system shall be capable of optionally closing a live generator onto a dead bus.
- **Two Modes of Start Control.** The system shall be capable of controlling the synchronizing process by using operator initiate and abort controls or by simply selecting a breaker.
- **High-Interrupting Current Pulse Contacts.** The system shall optionally include governor and exciter pulsing contacts capable of interrupting 10 Adc with L/R = 40 ms at 125 Vdc.
- **Data Recording.** The system shall be capable of recording the correction pulse duration and controlled parameter for frequency and voltage matching functions for the last eight correction pulses. These data can be used to fine-tune the proportional pulse control slope and interval settings when commissioning the system. The system shall also record the number of correction pulses and elapsed time parameters for the synchronizing process.
- **Relay-to-Relay Logic Communications.** The system shall be capable of communicating control actions via a serial communications link to remote I/O devices. The serial communications link shall be suitable for operation via fiber-optic modems.
- **IRIG-B Time Input.** The components of the system shall include an interface port for either a standard or high-accuracy demodulated IRIG-B time-synchronization input signal.
- **Environment.** The components of the system shall be suitable for continuous operation over a temperature range of –40° to +85°C.
- **Communications.** The components of the system shall include four independent EIA-232 serial ports for external communication.
- **PC Interface.** The components of the system shall be capable of being set by Microsoft® Windows®-based graphical and ASCII terminal interfaces.

- **IEC 61850 Ethernet Communication.** The components of the system shall be capable of providing IEC 61850-compliant communication. The IEC 61850 capability shall include GOOSE messaging and defined logical node data points.
- **Distributed Network Protocol (DNP).** The components of the system shall be capable of incorporating certified DNP3 Level 2 Outstation protocol and Ethernet DNP3 LAN/WAN communication.
- **Terminal Connectors.** The components of the system shall include the ability to remove the screw-terminal block connectors from the back of the relay to disconnect I/O, dc battery monitor, and power without removing each wire connection.
- **Synchrophasors.** The components of the system shall provide high-accuracy synchrophasor data that are compliant with the IEEE C37.118 synchrophasor data standard. The IEEE C37.118 synchrophasor data shall be supported on serial and Ethernet ports of the relay. The relay shall provide the capability to produce as many as five PMU data configurations.
- **HMI Display.** The components of the system shall include custom configurable display information to display status, analog quantities with units, user-defined labels, and alarm information.
- **Reliability.** The vendor shall supply the actual measured mean time between failures (MTBF) for the components of the system upon request.
- **Service.** The components of the system shall include no-charge technical support for the life of the product.
- **Manufacturer.** The components of the system shall be manufactured in the U.S.A.
- **Conformal Coating.** The components of the system shall have optional conformal coating to protect the circuit boards from harsh environments.
- **Warranty Return.** The vendor shall support a 72-hour turnaround on all warranty repairs.
- **Warranty.** The components of the system shall include a ten-year, no-questions-asked warranty for all material and workmanship defects. In addition, the warranty shall cover accidental customer-induced damage.

Specifications

Please refer to the product data sheet for the SEL-451-5 Feeder Protection Relay for front-panel and rear-panel diagrams, relay dimensions, and additional specifications. This data sheet contains information on specific features and functions provided in the pre-engineered advanced autosynchronizer system.

General

Station Identifier:	ASCII 40 characters
Relay Identifier:	ASCII 40 characters
Nominal System Frequency:	50, 60

Device Set Up

Start Synchronizing Process Mode:	I = start/stop on ini/abort S = start/stop on CB selected
Generator Voltage Display Base:	I = Incoming voltage base R = Running voltage base
Breaker Status Sense:	52A = closed when CB closed 52B = closed when CB open
Operator Close Permissive Mode:	N = Contact not required Y = Contact required to close
Maximum Time Allowed To Synchronize:	1–120 Minutes 0 = Off
Enable RIO Module:	N = RIO module not used Y = RIO module used

Event Reporting

CT Ratio, Input W:	1–50000 turns
CT Ratio, Input X:	1–50000 turns

Sensing

Incoming PT Ratio (Input Y):	1–10000 turns
Incoming Nominal Voltage:	20–200 secondary V
Scale Incoming Voltage Display by SQRT(3):	Y, N
Running PT Ratio (Input Z):	1–10000 turns
Running Nominal Voltage:	20–200 secondary V
Scale Running Voltage Display by SQRT(3):	Y, N

Initiate Autosync

Upper Frequency Limit:	45–65 Hz
Lower Frequency Limit:	45–65 Hz
Upper Voltage Limit:	0.8–1.2 per-unit V
Lower Voltage Limit:	0.8–1.2 per-unit V

Close Acceptance

Enable IF > RF:	Y, N
Slip Frequency:	0.025–0.500 Hz
Rate-of-Change of Frequency:	0.010–1.000 Hz/s 0 = Off
Enable IV > RV:	Y, N
Voltage Difference:	0.01–0.50 per-unit V
Rate-of-Change of Voltage:	0.001–1.000 per-unit V/s 0 = Off
Enable Parallel Close Permissive:	Y, N
Parallel Close/Operator Permissive Window:	3.0°–80.0°
Dead-Bus Voltage:	0.05–0.50 per-unit V 0 = Off
Breaker Close Time:	1.00–30.00 cycles

Control

Frequency Correction Pulse Interval:	1.00–30.00 s 0 = Off
Frequency Correction Pulse Mode:	P = Proportional F = Fixed
Frequency Pulse Width:	0.01–100 seconds or seconds/Hz
Voltage Correction Pulse Interval:	1.00–30.00 s 0 = Off
Voltage Correction Pulse Mode:	P = Proportional F = Fixed
Voltage Pulse Width:	0.01–100.00 seconds or seconds/V per-unit

Close Alarms

Close Fail Time:	0.10–60.00 s
Close Fail Angle:	3.0°–80.0°
Close Lockout:	0.50–60.00 s

Technical Support

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

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