SYNCHROWAVE Central Software Instruction Manual

Introduction

The SEL-5078-2 SYNCHROWAVE® Central Software provides both real-time situational awareness and historical analytics for electric power system engineering, operations, and planning.

SYNCHROWAVE Central is the overall name for a software package that includes four main components:

1. Historian—Connects to multiple synchrophasor sources (Phasor Measurement Units [PMUs] or Phasor Data Concentrators [PDC]) and stores all received data in the synchrophasor database.

2. Services—Connects the Historian and/or ACSELERATOR database to the SYNCHROWAVE Central web-based application.

3. Admin—Configuration application for the system.

4. SYNCHROWAVE Central and SYNCHROWAVE Event 2015—The primary web interface.

The SYNCHROWAVE Central Software system receives data from any IEEE C37.118-compliant PMUs directly or via one or more PDCs, such as the SEL-5073 SYNCHROWAVE PDC or the SEL-3373 Station PDC.

SYNCHROWAVE Central can be operated as a single server, or with a second server operating as backup. If two servers are used, all clients automatically switch to the backup server if any problems with the primary server are detected.
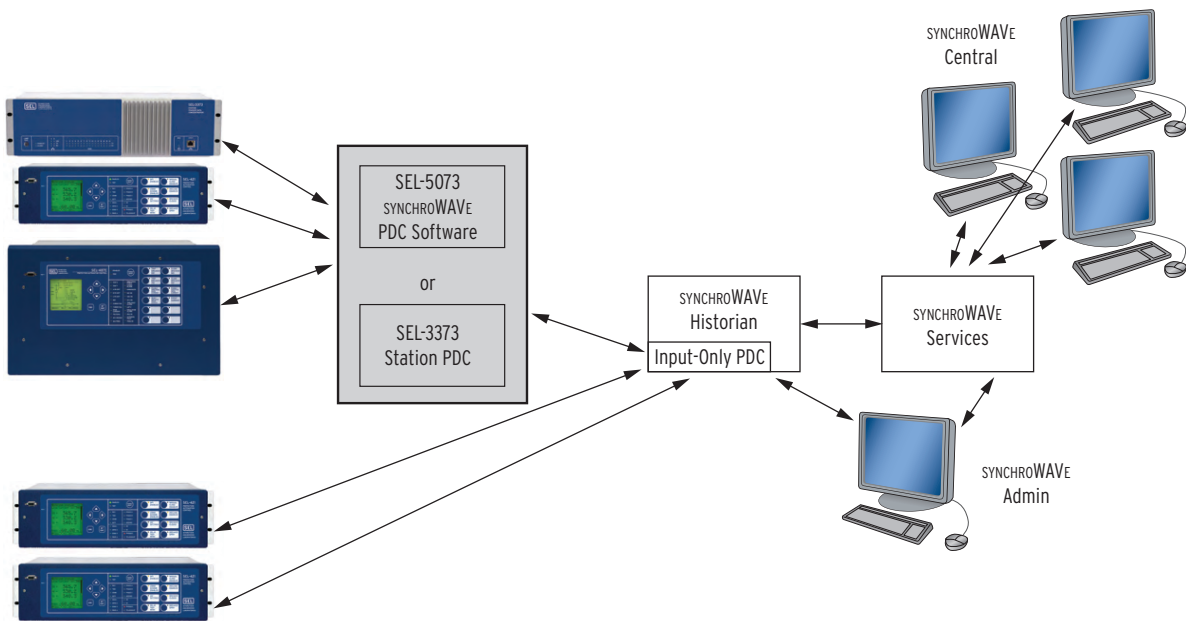
Figure 1 Synchrophasor Data Architecture for SYNCHROWAVE Central Software Package (Single Server Configuration)
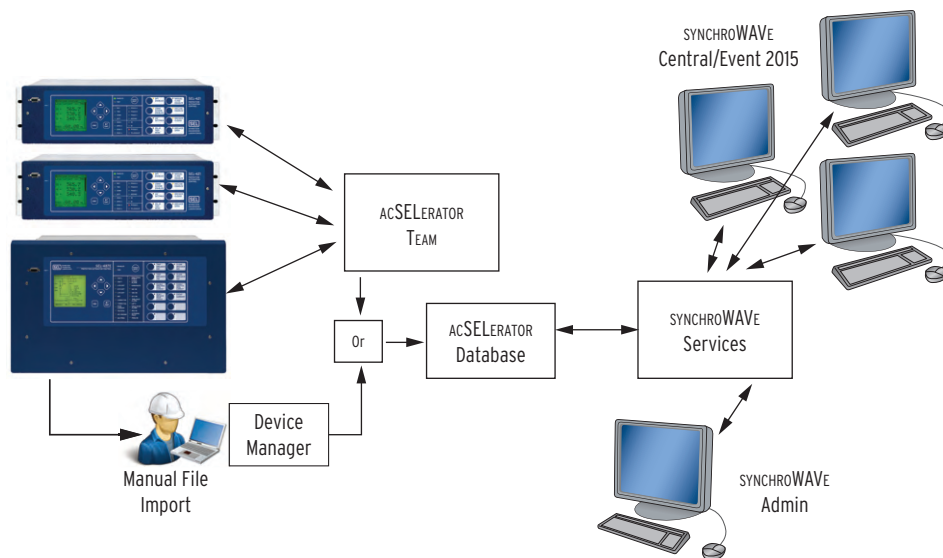
Figure 2 Event Data Architecture for SYNCHROWAVE Central Software Package

Applications

See the Real-Time System State

Improve situational awareness by viewing live, subsecond, and time-aligned information from across your power system. Unstable behavior, such as growing oscillations, is clearly visible through graphical representation of streaming time-synchronized phasor measurements. Understanding the dynamic behavior enhances decision making and improves system reliability.

Turn Data Into Information

Identify the root cause of disturbances by searching historical data waveforms, both wide area (synchrophasor) and at the relay level (event report). View system data over large periods of time or zoom to the subsecond level detail. All received data are archived and searchable. Save and share results with colleagues through the use of snapshots.

Combine with ACSELERATOR TEAM® SEL-5045 Software to view event report data within seconds of the event. Perform phasor and symmetric component analysis. Set up custom equations for advanced analysis.

Turn Information Into Action

Monitor events in real time while simultaneously observing prior signal behavior. The prior state conditions are useful information when determining appropriate control actions. Optional alarms can alert operators to abnormal conditions.

Benefit From Angle Measurements

Angle differences provide an early warning of system stress and help with generator black-start, microgrid, and island synchronization success.

Benefit From Oscillation Monitoring

Power system modes are calculated and displayed along with the original signal. The displayed values include color-coded damping and oscillation frequency.

Get Instant Feedback

Switch a line in or out of service and promptly see the system response. Unstable behavior, such as growing oscillations, is clearly visible through graphical representation of streaming time-synchronized phasor measurements.

Validate and Improve System Models

SYNCHROWAVE Central is a convenient solution for validating and improving system models. It is easy to export exactly what is on the screen to COMTRADE or CSV files. Analyze archived system disturbance responses and compare these to modeled responses.

Validate and Improve System Settings

View the historical inertial, governor, and automatic generation control (AGC) response of your system with high-resolution, time-aligned information. Determine if oscillations are initiated during system events and measure the oscillation frequency and decay characteristics. Use this information to ensure settings in governors, power system stabilizers, and other controllers are appropriate.

Reliably Integrate Renewables

Integrating an increasing amount of renewable energy into the power system can result in reduced system stability and introduction of new oscillatory modes. System dynamics from these generation sources often change quickly—too quickly to see with SCADA systems. Use high-resolution displays in SYNCHROWAVE Central to measure and understand the impact of renewables on your system.

Understand Root Cause

Locate events by viewing long-term data, searching, and zooming in on points of interest. Multiple views help you gain insight into system behavior.

Installation and Licensing

Installation

NOTE: The default location of the SEL SYNCHROWAVE Services directory is C:\Program Files\SEL\.

Run the installation executables on the computer where you want SYNCHROWAVE Historian and Services to reside. This is most likely a main server computer that is accessible by multiple individuals in your group, and is able to run continuously to archive received PMU data as they arrive.

For single-user applications, you may wish to install SYNCHROWAVE Central on the same computer or laptop that also runs the web browser for viewing data. For laptop installation, note that no data are archived when the laptop is turned off.

If you have an existing version of SYNCHROWAVE Central, the installer will automatically preserve any existing settings and the license. However, SEL recommends that you make a backup copy of your license and SYNCHROWAVE Config.xml files (located in the SEL SYNCHROWAVE Services directory) prior to upgrading the software. You may discard the backup files once installation is complete and SYNCHROWAVE Central Admin has been successfully launched.

There is one installer for SYNCHROWAVE Historian and one installer for SYNCHROWAVE Services. Having two separate installers allows future upgrades to one of these applications without impacting the other application.

SYNCHROWAVE Historian	➤ Installer file name: SEL SynchroWAVe Historian Setup.exe ➤ The installer automatically installs Microsoft .NET 4.0, as required.
SYNCHROWAVE Services	➤ Installer file name: SEL SynchroWAVe Services Setup.exe ➤ The installer automatically installs Microsoft IIS Express, if required.

> NOTE: If existing archived data from SYNCHROWAVE Central 1.1 or 1.0 are detected by the installer, it will alert you that it needs to rearrange the archived data to a new structure. This step does not change the location or contents of the existing archived data. Click **OK** to continue.

> NOTE: The following steps assume that the CD-ROM drive letter is D:. Replace D: as needed to conform to the configuration of your server computer.

After installation, please reload any SYNCHROWAVE Central web browsers that were open during the install.

Installation steps (the drive letter D: is for the server computer's CD-ROM).

Step 1. From the Windows **Start** menu, run D:\SEL synchroWAVe Historian Setup.exe

Step 2. Follow the installation instructions that appear on the computer screen while the software installs.

Step 3. From the Windows **Start** menu, run D:\SEL synchroWAVe Services Setup.exe.

Step 4. Follow the installation instructions that appear on the computer screen while the software installs.

Step 5. Launch SYNCHROWAVE Central Admin (**All Programs > SEL Applications > SEL SynchroWAVe Central > SynchroWAVe Central Admin**) to configure SYNCHROWAVE Central.

Licensing

SYNCHROWAVE Central is available in two options to meet your synchrophasor visualization needs: **Disturbance Monitoring** and **Wide Area Situational Awareness**. The set of features for each option is outlined in *Table 1*.

Disturbance Monitor: This feature set contains all the tools you need for basic viewing, archiving, and analysis of real-time and historical synchrophasor data.

Wide-Area Situational Awareness (WASA): This feature set includes additional functionality necessary for use in an operations control center where operators require real-time association of measurements with overall system health and minimal susceptibility to network or server failure.

Table 1   Features Included for Each SYNCHROWAVE Central Option
(Sheet 1 of 2)

Feature	Dist. Monitor	WASA
Real-Time\Historic Trending	X	X
Historian	X	X
Phasor Scope	X	X
Data Export	X	X

Table 1   Features Included for Each SYNCHROWAVE Central Option (Sheet 2 of 2)

Feature	Dist. Monitor	WASA
Event Timeline	X	X
Automatic Disturbance Detection	X	X
Geospatial Display		X
Power Flow		X
Modal Analysis		X
Bar Chart		X
Failover and Redundancy		X
Role-Based Access Control		X
Alarms		X

Acquire License

NOTE: If configuring a primary and backup server, a license must be acquired for each server.

When you run SYNCHROWAVE Central Admin for the first time, a Host ID will be generated based on your machine configuration and displayed in the Host ID box of the following message pop-up:
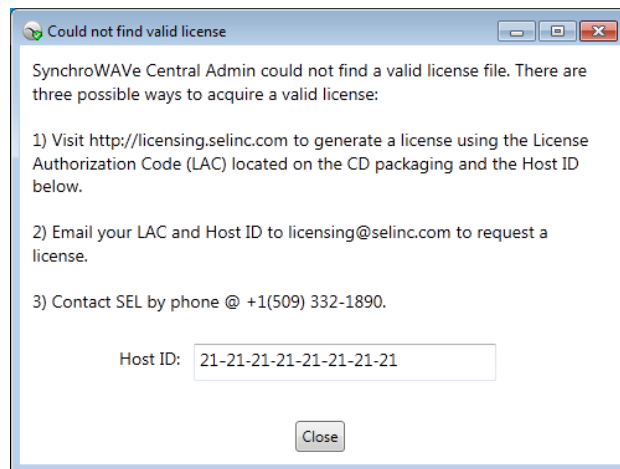

Follow the instructions to acquire a license file by using the generated Host ID. Place the file in your SEL SYNCHROWAVE Services directory and restart SYNCHROWAVE Central Admin.

Quick Start

After installation, you have the option of starting to use SYNCHROWAVE Central with minimal setup. In this case, the signal names default to the PMU station names. Follow these steps:

Step 1.   Open SYNCHROWAVE Central Admin from the Windows **Start** menu. Click the **Start** button and navigate to **All Programs > SEL Applications > SEL SynchroWAVe Central > SynchroWAVe Central Admin**.
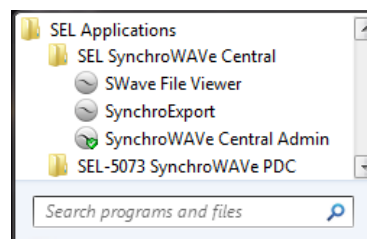
Step 2.   Select the **Historian** page from the list on the left side of the screen. Enter the IP address and port number corresponding to

your synchrophasor source (the PDC and/or PMU from which you wish to receive synchrophasor data). Click the ⊞ button to add the synchrophasor source to the **Input Connections** list. The port number should match the port in the synchrophasor source (SEL-5073, SEL-3373, or PMU) output settings. If a PDC is installed on the same computer where SYNCHROWAVE Historian/Services is installed, use 127.0.0.1 as the IP address.

Figure 3   SYNCHRO**WAVE** Historian Settings

Step 3.   Set the path to where you want to store the synchrophasor database.

Step 4.   Enter the age of data you wish to downsample and select the desired rate. To delete the data, set the rate to **Delete**.

Step 5.   Click the **Submit Changes** button. The synchrophasor source connection status is shown in real time at the bottom of this settings page. A green connected message indicates that SYNCHROWAVE Historian is receiving data from the synchrophasor source. If another message is displayed, please check the Admin settings and PDC or PMU settings for consistent values.

Step 6.   Select **Yes** to confirm you want to save the changes.

Open Central

NOTE: Your web browser may prompt you to install or update the Microsoft Silverlight plugin before proceeding.

Open SYNCHROWAVE Central by following these instructions:

Step 1.   Open a web browser and enter the following URL.

http://server_name/

If you open the web browser on the same machine where SYNCHROWAVE Services is installed, try "localhost" or "127.0.0.1" as the server_name.

Step 2.   An online quick-start guide appears. It will help you navigate and use SYNCHROWAVE Central features.

The default port for the web server is Port 80. If you already have a web server running on this computer, Port 80 may already be in use. In this case, you will need to select a new port number. You can try 8080 as an alternative port number (your URL would then be http://server_name:8080) or contact your Information Services department. The port number setting is under the **Security** tab of Admin.

Using the Web Browser

This section lists some special considerations related to the use of a web browser for displaying synchrophasor measurements.

Clicking the **X** in the upper right corner of the web browser immediately closes the browser without warning. Closing SYNCHROWAVE Central has no effect on SYNCHROWAVE Historian or Services (including the alarm detector). These programs continue to run and store received data in the archive.

Clicking this box closes SYNCHROWAVE Central without a warning or a confirmation request.

SYNCHROWAVE Admin settings are not stored as part of the local web browser data and settings are not affected by clearing browser history, cookies, or temporary files.

To more efficiently use screen space, you can hide the browser address bar and menus by pressing **<F11>**. Press **<F11>** again to restore the previous state.

Configuring SYNCHROWAVE Central

The configuration application is called SYNCHROWAVE Central Admin. It is accessible from the computer on which SYNCHROWAVE Central is installed. Admin configuration information is available to anyone with Windows administrative rights logged into this machine. You can restrict access to Admin by securing the machine on which it is installed.

Run Admin from the Windows **Start** menu. Click the **Start** button and navigate to **All Programs > SEL Applications > SEL SynchroWAVe Central > SynchroWAVe Central Admin**.

The following sections describe the settings on each Admin settings page in detail. Each Admin settings page also provides help information.

Status

This settings page shows the software version, a database report, and system logs. System logs are also available from a webpage (see *SYNCHROWAVE Central Logs on page 28*). A **Service Management** button is also available for revealing additional options, but these options are not needed for normal operations. **Service Management** is available for use during certain advanced tasks such as importing complicated data sets.

Security

SYNCHROWAVE Central is a browser-based application that accesses the synchrophasor database through the IIS Express web interface (included as part of SYNCHROWAVE Services). SYNCHROWAVE Historian populates the synchrophasor database with data from connected PDCs and PMUs. SEL recommends that you work with your Information Services department to ensure that the overall security of the system meets your company's requirements.

Host Port—Port number that the web browsers use to connect to SYNCHROWAVE Services. The default port number is 80. Use the following addresses to connect to SYNCHROWAVE Services in your web browser:

SYNCHROWAVE Central	http://server_name:port_number
SYNCHROWAVE Logs	http://server_name:port_number/logs.html

Use of the port number in the address is not necessary when the default Port 80 is used.

SSL Enabled—When the **SSL Enabled** check box is selected, SYNCHROWAVE Central is accessible through the secure socket layer (SSL) protocol. In this case, a certificate is required.

Certificate Type—When the **SSL Enabled** check box is selected, a certificate is required. If your organization already has a certificate, you can specify its location with the settings entry fields that appear when the **SSL Enabled** check box is selected. If a certificate is not available, please work with your Information Services department to obtain one.

Authentication

All authentication is checked with the Microsoft Active Directory directory service. Select authorized users by their domain name or domain group. When the **Authentication is Enabled** check box is unchecked, no authorization is required. In this case, anyone who has access to the machine on which SYNCHROWAVE Services is installed has the ability to connect with SYNCHROWAVE Central.

When the **Authentication is Enabled** check box is checked, only the users and groups specified in the **Allowed Groups/Users** list can access synchrophasor data with SYNCHROWAVE Central. Next to each user/group name is an associated role that specifies the level of access provided to that user or group. The permissions of each access level is specified in *Table 2*.

You can add users and groups to the **Allowed Groups/Users** list by manual entry or active directory search. You must have access to the active directory domain (through your company's security setup) for the active directory search to return results. Adding users and groups manually requires no such access. If a user is assigned individual permissions and is also part of a group, the permissions available when that user is logged into SYNCHROWAVE Central, include all permissions of the individual and of the group.

Table 2   Access Roles and Their Permissions

Role	Permissions
Admin	No restrictions
Engineer	All Admin permissions except Clear/Acknowledge Alarms and viewing Logs.html
Operator	All Admin permissions except Opening Events and viewing Logs.html
Viewer	Switch views, switch between Real-Time and Historical Mode, export data, print screen

Historian (Required)

SYNCHROWAVE Historian can receive any IEEE C37.118-compliant synchrophasor data stream. SYNCHROWAVE Central PDC input capability allows it to receive data from multiple synchrophasor sources directly without requiring a dedicated external PDC. These settings tell Historian how to connect to the synchrophasor source. When these settings are changed, Historian restarts its synchrophasor input connection(s). The restart causes a temporary interruption in the received synchrophasor data, which results in a short gap in the synchrophasor archive.

Settings:

➤ Input Connection

➤ IP Address

➤ Port

➤ PMU/PDC ID

➤ Waiting Period

➤ Database Path

➤ Data Retention

The input connections table provides a way to configure multiple inputs. A PDC internal to Historian time-aligns the data from all inputs.

For each input connection, set the port and PMU/PDC ID to match the synchrophasor source setting. The IP address is the network location of the synchrophasor source. If a PDC is used and is installed on the same computer where SYNCHROWAVE Historian/Services is installed, use 127.0.0.1 as the IP address.

SYNCHROWAVE Historian stores all received synchrophasor data at the location specified by the Database Path setting. The set path must be a valid location for Historian to start correctly. For best performance, choose a location physically connected to the hardware on which Historian/Services is installed and use a dedicated drive for the synchrophasor database. If Historian/Services accesses data over a network, network latencies may cause SYNCHROWAVE Central charts to update slowly.

NOTE: If you need a networked location for the synchrophasor database, use the full network name for the path setting. Using the mapped drive letter alone does not work.

For security reasons, SYNCHROWAVE Central is, by default, run as an unprivileged user and therefore restricted from accessing network drives, which require additional permissions. Network drive access can be enabled by performing the following actions.

Step 1. Open **Control Panel > Administrative Tools > Services**.

Step 2. Right-click **SEL SynchroWAVe Historian** and select **Properties**.

Step 3. Select the **Log On** tab and enter the login information for an account that has permissions to access the network drive.

Step 4. Repeat *Step 2* and *Step 3* for **SEL SynchroWAVe Services**.

Contact SEL if you need assistance.

When the Database Path is changed and submitted, SYNCHROWAVE Historian immediately begins storing data at the new location. Temporary loss of data may occur while Historian is restarting. Data at the previous location are not changed, but they are not accessible by SYNCHROWAVE Central. In this case, please contact SEL for help in migrating existing archived data to the new location. Note that you can access data at any previous location again simply by changing the Database Path back to the previous directory location.

Display of Invalid Data

By default, SYNCHROWAVE Central does not display data having an invalid status. If display of these data is desired (when the PMUs do not have a satellite clock input, for example), the "Display Invalid Data as Valid" option may be enabled. This causes SYNCHROWAVE Central to treat data with an invalid status as valid for all functionality (chart displays, modal analysis, alarms, etc.).

When enabling the "Display Invalid Data as Valid" option in Admin, real-time and future invalid data will be visible at all zoom levels. Invalid data recorded by Historian prior to enabling this setting will be visible at zoom levels smaller than one minute, but not viewable at larger zoom levels. To enable viewing of historical invalid data at all zoom levels, contact SEL.

Data Retention

NOTE: Please note that setting the retention period to a time less than the length of time that data have been archived results in automatic deletion of the older archived data. In this case, Admin prompts for confirmation before deleting any data.

SYNCHROWAVE Historian retains all data by default. To save storage space, set Historian to downsample or delete the data beyond a specified age. Data identified by any local or shared snapshot (see *Snapshots on page 21*) are retained at full resolution independent of data retention settings. *Figure 3* shows an example in which data are retained at the original sample rate for 5 days, then downsampled to 30 msgs/sec. At 10 days old, the data are downsampled to 10 msgs/sec. Data older than 20 days are deleted.

Tag Mapping (Optional for SEL PMUs)

SYNCHROWAVE Central lets you rename the data received from PMUs. This feature allows you to select names based on your own notation, instead of existing PMU names, which are sometimes device specific.

You can run Admin multiple times, as you add PMUs to your system, to continue to update the names. The mapping settings in Admin have no effect on the archived data. These settings only change the way signals are shown on the SYNCHROWAVE Central displays. A **Refresh Data** button is provided in case new PMUs are connected while Admin is open.

Figure 4 shows an example of mapping settings for the connection of multiple PMUs through a single PDC. The upper left menu shown in *Figure 4* provides a list of the original station names for all PMUs connected to SYNCHROWAVE Central. You can only change the original station names at the PMU or at the PDC.

Figure 5 shows how asset names are displayed in SYNCHROWAVE Central for the example shown in *Figure 4*.

There are two steps to renaming the original station name via Admin. First, create the new name in the upper right **Assets** menu. The new station name is called an Asset. Then, with the lower menu, map each value (called a Tag) associated with the original station name to one of the new asset names. The Tag names are taken directly from the IEEE C37.118 packet. They cannot be modified in Admin.
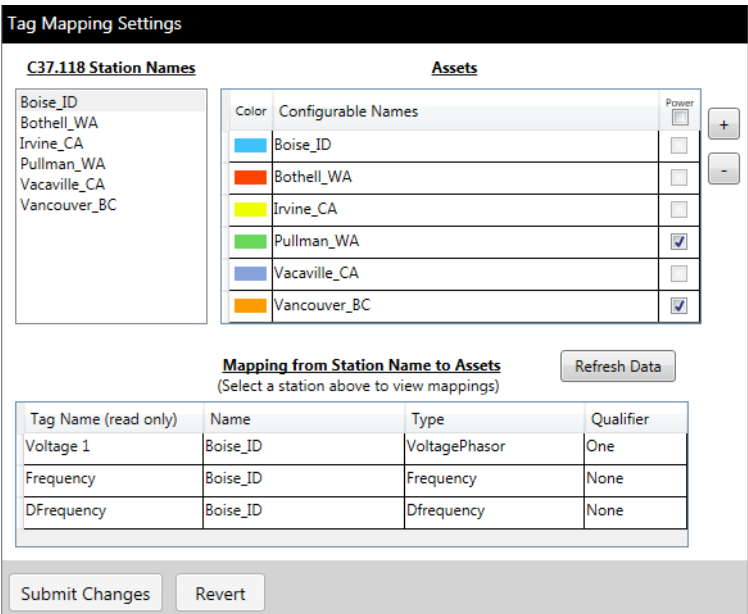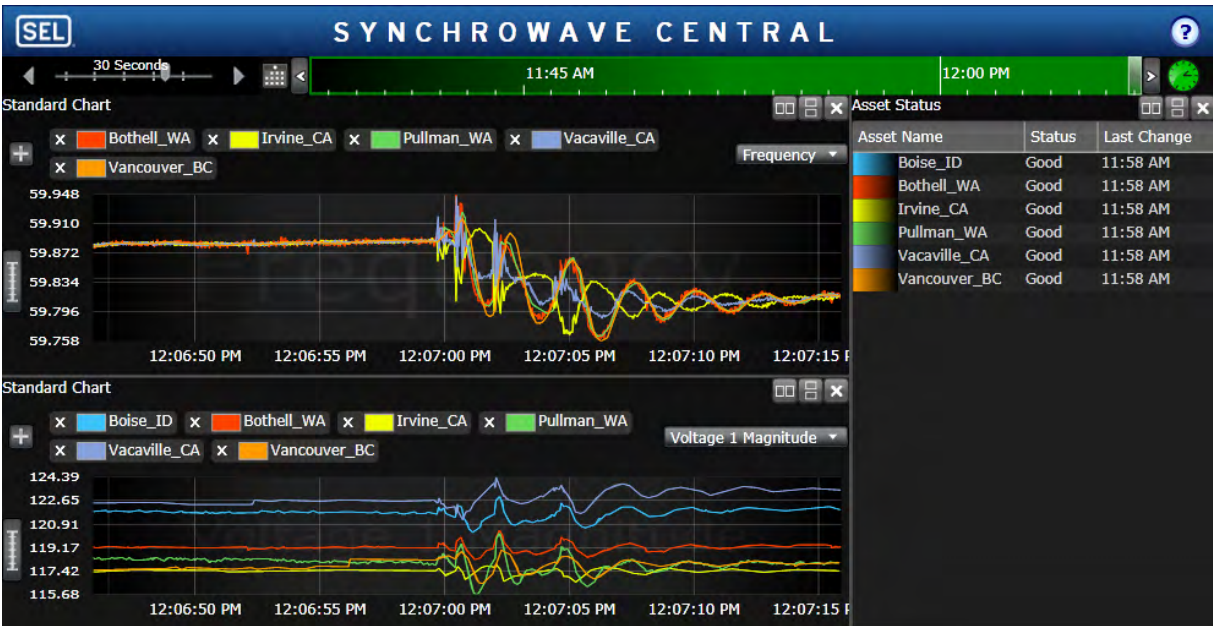
Figure 4   Tag Mapping Settings

Figure 5   SYNCHROWAVE Central Display

Assets Menu (Upper Right)

SYNCHROWAVE Admin populates a set of default names in the **Assets** menu derived from the original station names. You can change asset names by double-clicking them. You can also add assets in this menu by clicking the ⊕ menu item. The ⊖ menu item removes asset names from the list.

Each digital value received from the PMU must have its own asset name. SEL recommends creating a new asset name to identify the function of the digital value. This is also true for analog values that can be sent by PMUs, such as temperature or pressure values.

Examples of assets are transmission lines, transformers, feeders, and breakers. The following are recommendations for naming assets:

➤ The current, voltage, frequency, and other tags for a common line should all have the same asset name.

➤ Some tags are associated with multiple assets; for example, a single frequency measurement on a relay with multiple line currents.

➤ Shorter asset names are preferred because they take less space on the SYNCHROWAVE Central displays.

Mapping Menu (Lower Middle)

➤ **Tag Name**—These are read-only values taken directly from the IEEE C37.118 packet. When you select a station in the upper left menu, the set of values received from that original station name is shown under the Tag Name column.

➤ **Name**—These names are taken directly from the upper right **Assets** menu. For each tag, select one or more assets as desired. Asset names that are not mapped to any tag do not appear in the SYNCHROWAVE Central displays.

➤ **Type**—This column allows for customization of how the data for each Tag Name are displayed. The default values are taken from the IEEE C37.118 packet and are set by the PMU or PDC sending the data.

➤ **Qualifier**—(for phasor tags only) This is typically the phase (**A**, **B**, **C**, or **Neutral**) or (**Zero**, **One**, **Two**, etc.) for zero-, positive-, and negative-sequence quantities, respectively. **Sync** for synchronizing quantity is also available.

Phase-to-Phase Voltage Calculation

If positive-sequence voltage is available, a second positive-sequence voltage is calculated by scaling the positive-sequence voltage up by the square root of 3 to approximate the equivalent line-to-line level. This quantity is labeled **VLL**.

Power Calculation Settings

SYNCHROWAVE Central can automatically calculate a power signal for each asset. Select these assets by using the check box to the right of each asset, as shown in *Figure 4*. Power calculations are limited to a user-selectable subset to avoid cluttering SYNCHROWAVE Central menus with unimportant quantities. All power calculations include a scaling by three.

Assets that qualify for receiving a computed power value must be receiving both current and voltage signals (i.e., must have a tag with type voltage and a tag with type current). These tags must also have the same qualifier (i.e., both must be from the same phase or sequence).

NOTE: Explicit minimum and maximum indexing is not performed on derived quantities such as calculated power. This means that for zoom levels showing more than three minutes, the display may not show all short-duration power spikes.

Like signal naming settings, changes to power calculation settings will not affect the archived data and can be made at any time. When the settings are changed, the web browser automatically refreshes to update all open SYNCHROWAVE Central web displays to show the new quantities.

Alarm Settings (Optional)

One hundred alarms are available. To use an alarm, simply name the alarm and then select the enable check box. The alarm name appears in the SYNCHROWAVE Central displays. Next, select the asset name and quantity for the alarm from the drop-down menus. Finally, select the warning and alarm levels.

One of the alarm slots is occupied by a diagnostic alarm by default. When enabled, this alarm shows a warning if data are not displayed and an error if data are not archived.

Alarm settings apply to all SYNCHROWAVE Central displays.

Geographic Map

SYNCHROWAVE Central ships with a complete world map. Use these settings to select a subset of the geographic map for the display.

First, press the **Data Center** ⊞ button to add a data center item representing the location of your PMU or PDC. The new item is displayed on the geographic map in SYNCHROWAVE Central and provides the center points for voltage and phase angle contour interpolation. Select the asset representing the PMU data and enter the latitude and longitude specifying the desired map location of the PMU. You may also enter a nominal voltage which is used for per-unit normalization when displaying voltage contours on the graphical map.

You can also add arrows indicating the voltage phase relationship between stations. To add a voltage phase arrow, press the **Lines** ⊞ button and select the data centers representing the ends of this line. The arrow head points *from* the leading data center and *toward* the lagging data center based on the real-time voltage angle regardless of which station is specified as To and which as From.

You can also add arrows indicating power flow along a path between arbitrary points. To add a power arrow, press the **Power Path** ⊞ button. Assign a caption to identify the path and assign an asset to the power path that has one or more of the following types assigned as positive-sequence values: Real Power, Reactive Power, or Apparent Power. Assign the latitude and longitude of the start and end positions for the power path arrow. The arrow will point from the start location to the end location for positive values of power, and will reverse direction for negative values.

Below these options is the ⌄ Region Settings button, which you can click to reveal additional region-specific options where you can define one or more regions of the world map to display and associate subsets of the list of stations and power paths to display on each.

Figure 6   Geographic Map Settings

NOTE: Voltage contours in the normal range are displayed with shades of green. Therefore, it is easy to quickly understand the voltage condition.

With the regions section, define subsets of the world map. Then, in SYNCHROWAVE Central, these regions are available with a drop-down menu. For each region, select voltage magnitude and voltage angle ranges. These ranges define how the colors are displayed in the geographic map. For voltage magnitudes, voltage values that are within the minimum and maximum ranges are displayed using green shades. Voltages above the maximum value are displayed with red shades. Voltages below the minimum value are displayed with blue shades. For voltage angles, the range defines the saturation points for the color contours.

SYNCHROWAVE Central ships with default geographic maps as shapefiles. You can also load a custom shapefile if desired. Use the **Select Custom Shapefile** drop-down menu to select one of the default shapefiles or a custom shapefile, and then click **Import Shape File**. Note that the shapefile selected applies to all regions.

NOTE: Custom shapefiles should only include polygon shapes with no overlapping sides or vertices.

Modal Analysis Settings (Optional)

Power system modes are calculated in real-time and for all historical data of a single asset/quantity. Select an asset and corresponding quantity with the modal analysis settings.

Database (Optional)

The database settings allow you to rename stations or tags in the synchrophasor database. You can use this functionality to keep the synchrophasor database consistent after system configuration changes. Only archived names from the previous day or older are available for renaming.

It is important to note that SYNCHROWAVE Historian does not store values by using the mapped names. All data are archived using the station name and tag names that are received from the PMU or the PDC. Therefore, using the renaming function might require changes to the Mapping settings.

Import (Optional)

SYNCHROWAVE Central supports import of data from the SEL-3373 PDC, the SEL-5073 PDC, or a CSV file.

For PDC import, specify the IP address and port number of the PDC. The PDC import port number is the port used by PDC Assistant, not the port number from the Historian settings. Enter the PDC username and password, then click the **Load Archives** button. Select the desired import data from the preview and click the **Import** button to start the import process.

For CSV file import, first browse for the desired import files, then click the **Import** button to start the import process.

The import function will not overwrite existing data in SYNCHROWAVE Historian. If you select an import data file that overlaps with some existing data, the import will exclude any new data that overlap. If you need to overwrite existing data, first delete existing synchrophasor database files, then import the new data.

ACSELERATOR Database

To make use of the SYNCHROWAVE Event 2015 application embedded within SYNCHROWAVE Central, you must configure Admin to connect to an ACSELERATOR event report database. For information on configuring the ACSELERATOR database, see *Appendix B: Quick-Start for Configuring ACSELERATOR Database With Event Timeline.* You can manually enter event reports into the ACSELERATOR database via the Device Manager application. If purchased by your organization, ACSELERATOR TEAM Software can populate the ACSELERATOR database with event reports retrieved automatically from connected relays.

Event 2015

The default phase rotation in SYNCHROWAVE Event 2015 is ABC. A check box is included under the **Event 2015** tab in Admin to set the phase rotation to ACB when SYNCHROWAVE Event 2015 is launched from the SYNCHROWAVE Central Event Timeline. Regardless of the default, you can still modify the phase rotation setting from the **Options** menu within SYNCHROWAVE Event 2015.

Redundancy and Failover

SYNCHROWAVE Central supports automatic failover to a backup server. When failover is enabled, the health of the primary server is continuously monitored. If the primary server fails, SYNCHROWAVE Central clients connected to the primary server will display a notification of the failure with a 20-second countdown timer. Unless the **Dismiss** button is clicked prior to the countdown finishing, the client will automatically switch over to the backup server. When the status of the primary server returns to **healthy**, SYNCHROWAVE Central clients will switch back to the primary server via the same process.

NOTE: If the primary server is offline when a client attempts to connect to it, the connection process may fail. The operator will need to manually enter the backup server address in the browser to connect.

While operating with a backup server, the SYNCHROWAVE Central client main screen displays the health of both servers in the upper right corner. A server is identified as healthy if *all* four of the following criteria are met:

1. The web server is running.

2. SYNCHROWAVE Historian is writing data.

3. The data indexer is indexing data.

4. The alarms processor is operating.

See *Appendix C: Configuring SYNCHROWAVE Central for Automatic Backup Server Failover* for detailed instructions for configuring this feature.

Disturbance Detection

SYNCHROWAVE Central includes a frequency-domain anomaly detector to assist power system operators in the identification of unusual disturbances visible to PMUs. The detector works by calculating the spectral energy contained in windows of synchrophasor frequency measurements, grouping

that energy into predefined frequency bins, and statistically analyzing the variation of the energy contained in these frequency bins for anomalous behavior.

The primary metric for identifying disturbances is the disturbance level. The disturbance level is calculated by subtracting the present value for the bin oscillatory energy from its mean and dividing by the standard deviation. The disturbance factor is therefore a derived statistic, given in units of standard deviations. Mean and standard deviation are calculated individually for each frequency bin from recent synchrophasor measurements.

The detector identifies an anomalous event if the disturbance factor exceeds the **Detection Threshold** specified in the **Disturbance Detector** page of **Admin**. Both the disturbance factor and bin oscillation energy are available for plotting in the standard chart.

Select the **Disturbance Detection Enabled** check box to enable disturbance detection and reveal additional configuration options shown in *Figure 7*.

Figure 7   Disturbance Detection Settings

Set the threshold to the number of standard deviations you need to detect an anomaly. A higher threshold level will detect fewer disturbances. Set the **Detection Pickup Time (seconds)** to a non-zero value to make the detector only trigger disturbance detection if the disturbance lasts for at least that duration. You can choose to plot the disturbance level for several important stations to identify what level works best for your application.

You can also enable an alarm to trigger on disturbances. Similar to disturbance detection, the alarm has a configurable threshold (which must be greater than or equal to the disturbance detector threshold) and **Minimum Disturbance Duration (seconds)**.

Select the **Email Notifications Enabled** check box to reveal additional options for automatic email notification of disturbances. To configure automatic email notification, enter the email server IP Address and port. To add email recipients, click the ⊞ button and enter the applicable email address and a **Send Frequency** for each address.

If you set the **Send Frequency** to **Immediately**, the disturbance detector will send an email in less than one minute of the start of the disturbance. If you select **Hourly** or **Daily**, one email is sent per hour or day, respectively, with a summary of the event(s) that occurred in that period. For **Daily**, you can additionally specify the hour of the day at which the email will be sent.

Operating SYNCHROWAVE Central

SYNCHROWAVE Central provides multiple display types that can be arranged to provide a custom view to suit your application requirements. Select the type of display when you first open the panel.

Figure 8 shows a typical SYNCHROWAVE Central setup.

➤ The center portion shows real-time and historical synchrophasor data, status, snapshots, alarms, and search results.

➤ Across the top is a control for selecting the date and time range of the data.

➤ Along the bottom is where views are managed.

Each new SYNCHROWAVE Central display provides the ability to select a display type. Displays for synchrophasor data include Standard Chart, Numeric Display, Modal Analysis, Phasor Scope, and Map. Other displays include Event Timeline, Asset Status, Alarms, Snapshots, and Search. A new display is created upon initially starting SYNCHROWAVE Central or when one of the panel split icons is selected (□□ ☰ ✕). Displays can be rearranged by dragging the display title bar to the desired area of the browser window. Each type of display is explained in the following sections.
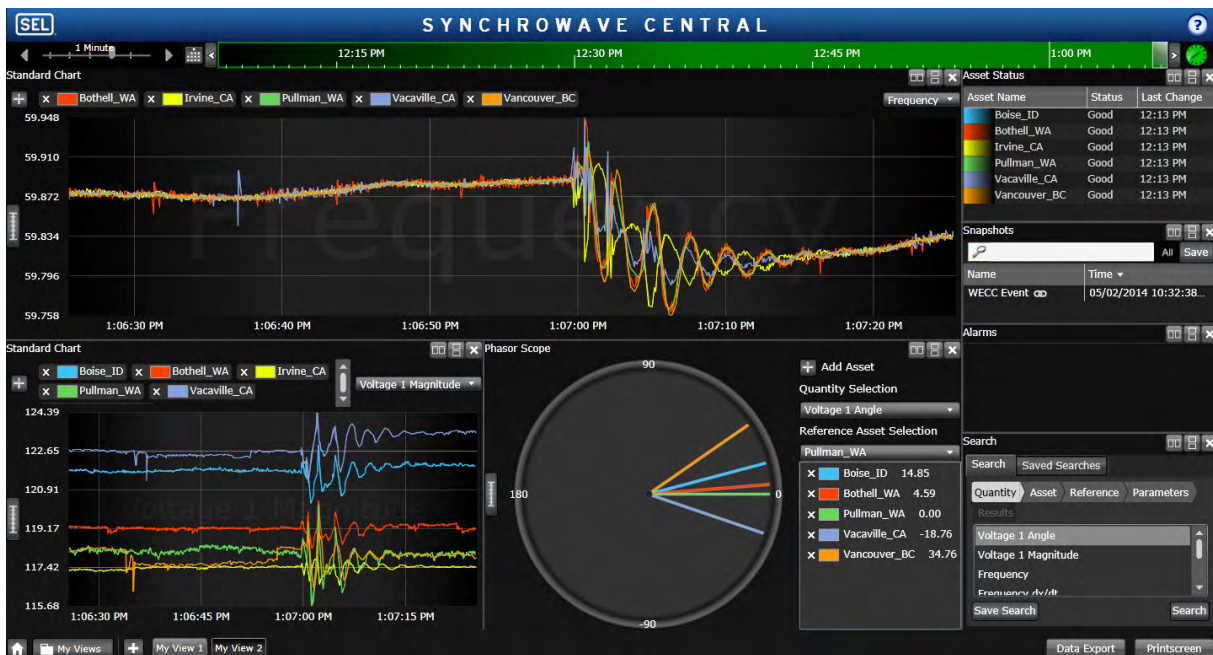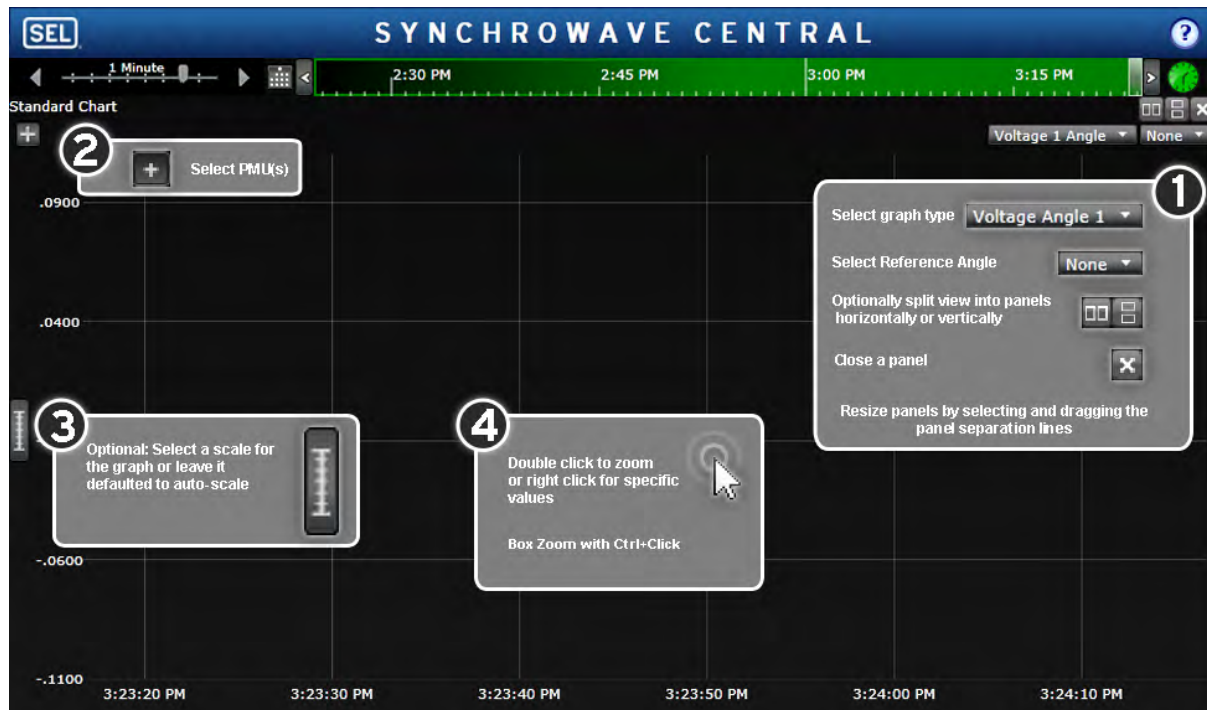

Figure 8   Typical SYNCHROWAVE Central Display

Navigating the Standard Chart

The basics of navigation for the standard chart are shown in *Figure 9*.

Figure 9   Display Navigation Steps

① Select the type of data to graph. Signals with the same type (same units) are shown on the same graph. For angles, an additional drop-down menu appears for selecting the reference angle. For voltages, if a positive-sequence voltage is mapped to an asset, an additional VLL quantity is calculated as an approximation of the line-to-line equivalent voltage corresponding to the positive-sequence voltage.

② Select a PMU with the drop-down menu in the upper left corner. The list that appears matches the list of assets that have been defined in Admin and have data available of the type selected. You can add multiple assets at once by operating SYNCHROWAVE Central using the search box and clicking **Add All**. The default asset names are the PMU names. You can use Admin to rename the PMUs to match assets in your power system.

Once assets are added, one or more assets can be emphasized on the display by clicking the asset name at the top of the display. The selected graphs will be brought to the front and emphasized, and all graphs not selected will be dimmed.

③ The displays have two standard scaling options for the vertical scale: autoscale and manual. The default scaling is autoscale.

To specify a minimum vertical range, click the vertical scale button ▐, uncheck AutoScale ✓, and type in the desired vertical range. Click **Apply**.

④ The following zoom/pan options affect the time axis of all displayed charts.

Mouse zoom controls:

Double-clicking the chart zooms in along the time axis and centers the click location on the screen.

Scrolling the mouse wheel zooms along the time axis. Holding the **<Ctrl>** key and clicking and dragging a box on a chart resizes the

contents of the box to the full chart. Holding the **<Shift>** key and clicking and dragging a box on a chart resizes the x-axis contents of the box to the full chart. The vertical axis is only zoomed on the clicked-on chart. However, the horizontal axis (i.e., the time scale) of all charts is updated to match the clicked-on chart. Restore the previous vertical axis settings by pressing the **<Z>** key or clicking the vertical arrow 🔼 button to the left of the chart.

Clicking and dragging the mouse pans the display left/right. If the Autoscale check box is selected, the vertical axis is automatically scaled. If the Autoscale check box is not selected, moving the mouse also pans in the vertical direction.

Keyboard zoom controls:

The up/down keys zoom the time axis in/out, respectively. The left/right keys pan the screen left/right, respectively.

NOTE: If keyboard arrow-based zooming is not functioning, try clicking on a display drop-down menu, such as the data type. This can help restore browser focus, which is necessary for the keyboard zoom function.

Once you have organized the displays and selected data of interest, save the view by clicking the ⊞ button in the lower left corner of SYNCHROWAVE Central. Changing between views only changes the layout of the displays and the signals shown on each display; it does not change the time of the displays. See *Views on page 26* for more information.

You can temporarily pause the display and show the numerical values of displayed quantities by right-clicking on a chart. A tooltip with the displayed values will appear on each of the standard charts. The cursor is time-aligned between the charts.

Navigating the Bar Chart

The bar chart provides a continuously updating zero-referenced bar chart capable of displaying multiple quantities of the same type (see *Figure 10*). Select additional assets, specify the range, and specify the quantity type using the same controls as the standard chart. The numerical values on the vertical axis automatically scale with the appropriate Greek prefix (e.g., k for kilo).

Figure 10   Bar Chart

Navigating the Numeric Display

The numeric display provides a display of quantities. The number of significant figures displayed is configurable; by default, four significant figures are displayed. Units, including SI prefixes (as applicable), are displayed to the right of the numeric value. If operating in real-time mode, the most recently received value is displayed. If operating in offline mode, a specific instant can be specified by right-clicking the desired location on the standard chart.

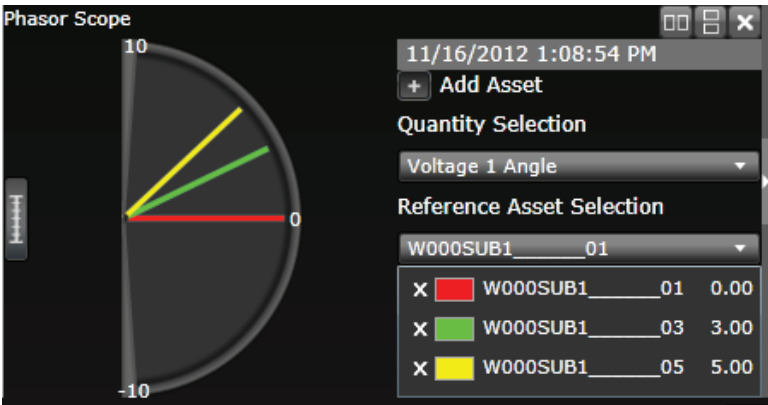## Navigating the Phasor Scope

The phasor scope is shown in *Figure 11*. Similar to the standard chart, select an asset and quantity for display. A reference angle option is also provided. Angles can be displayed as individual phases or as full three-phase quantities. The reference angle for the three-phase display is the positive-sequence angle. It is possible to display the scope in the full range (–180 to 180 degrees) mode as shown in *Figure 11(a)*, or to zoom in on the phasor scope to a smaller range on either side of the reference. Use the vertical scale button on the left side of

the display to zoom. *Figure 11(b)* shows the same data as *Figure 11(a)* but with the phasor scope zoomed to 10 degrees. You may enter any angle from 0 to 90 degrees for the phasor scope scale.
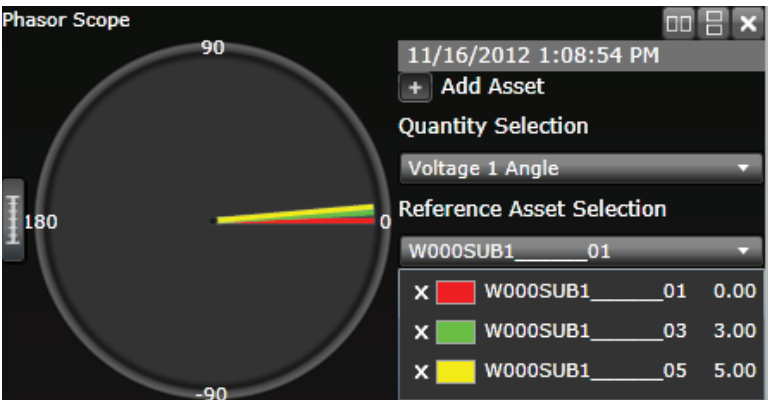
(a) Full Range

(b) Zoom

Figure 11   Phasor Scope

Navigating the Modal Analysis Display

Modal analysis operates with a 15-second window on the power system quantity of the asset selected with Admin. Supported message rates are 60, 50, 30, and 25 messages per second.

Once a new asset is selected with Admin, the modal analysis engine begins computing power system modes and storing them in the archive. A log entry is recorded when these calculations finish. These computations are applied to the entire set of archived values for the selected asset. Calculating modes on a large archive can require significant processing power.

When modal analysis (MA) is first enabled, sʏɴᴄʜʀᴏWAVᴇ Central services will require several minutes to compute the MA quantities on the archive. If you display an MA window during this calculation process, only the MA data presently computed are displayed. Changing the selected time updates historical MA data as they are calculated.

The original power system signal is displayed in a light gray color in the background. The calculated modes are represented with colored dots and are updated at a rate of once every five seconds. Across the left side of the display is the modal frequency. As many as four different mode frequencies are calculated and displayed.

The color of the mode result is as follows:

➤ Green = damping ratio >5%

➤ Yellow = damping ratio 0% to 5%

NOTE: Modal frequencies above 2.5 Hz are rejected by a prefilter and not shown.

NOTE: The modal analysis results are only valid for message rates ≥ 25 messages per second.

NOTE: While initially computing results for historical data, modal analysis will require significant computing resources.

➤ Red = damping ratio <0%

➤ Gray = not applicable (i.e., the modal signal-to-noise ratio is too low to be significant)

Navigating the Map Display

Each panel can contain a geographic map and each map can be set to show different regions of the power system. Geographic map options in SYNCHROWAVE Central include which region to display; whether to display contours representing the station voltage magnitude, voltage angle, or frequency; and whether contours and/or captions are enabled. If contours are enabled, a scale is displayed to indicate the value represented by the contour.

Phase angle arrows show differences in voltage angles between the map stations. Power Path arrows show the direction and numerical value of mapped real, reactive, and apparent power. Power magnitudes are displayed with either kilo (k) or mega (M) Greek prefixes. If real and reactive power are simultaneously displayed, the arrow direction indicates the direction of real power flow while reactive power flow direction is indicated by a (+) or (-) preceding the reactive power numerical value. Apparent power is always non-negative.

Navigating the Event Timeline Display

If SYNCHROWAVE Central is configured to communicate with an SEL ACSELERATOR database, you will be able to select the Event Timeline display. The event timeline displays a chronological display of event information as reported by the ACSELERATOR database. The vertical axis on the event timeline corresponds to different devices, i.e., two events on the same line are from the same relay. The events are represented by colored dots where the color indicates the type of event, as shown in *Table 3*.

Table 3   Event Colors

Color	Event Type
Red	Trip Event
Orange	Phase-to-Ground fault
Teal	Phase-to-Phase fault
Gray	Trigger
Yellow	All other faults
White	Multiple event group, click to show individual event information

NOTE: The mouse wheel scrolls the timeline up/down instead of adjusting time selection.

Hovering the mouse over an event displays a tooltip showing event information. Selecting an event (multiple events can be selected by holding **<Ctrl>** while clicking) and clicking the **View Selected Events** button launches the SYNCHROWAVE Event 2015 application. See the *SYNCHROWAVE Event 2015 Software Instruction Manual* for details on operating SYNCHROWAVE Event 2015.

NOTE: Browser pop-up blockers may prevent SYNCHROWAVE Event 2015 from opening. If nothing happens when you launch an event, try disabling your pop-up blocker for your SYNCHROWAVE site.

The Event Timeline has the same panning, double-click zoom, and box-zoom functionality as the standard chart. Scrolling the mouse wheel scrolls the event timeline display up and down if the chart is not tall enough to show all devices.

Snapshots

Snapshots allow you to bookmark a specific period of time for future reference. *Figure 12* shows an example of the **Snapshots** window with all snapshots (a), only shared snapshots (b), and only local snapshots (c). To use snapshots, simply select the date and time range that corresponds to signals of interest by the methods outlined in the previous section. Once an appropriate range is selected, click the **Save** button, then name the snapshot and add comments as appropriate. A note icon (▤) next to the date indicates comments associated with that snapshot. The snapshot name and comments can be edited by right-clicking the snapshot and choosing **Edit**. A snapshot is initially saved

as a local snapshot. To make this snapshot available to others, right-click on the snapshot name and select **Share**. Once shared, you will see a link icon (⬭) next to the name. You can change the display to show all snapshots, shared snapshots, or local snapshots by clicking the icon next to the **Save** button. To return to a saved snapshot, click the snapshot name. You can use the search bar at the top of the **Snapshots** window to filter the listed snapshots by name and time.

Data identified by any local or shared snapshot are retained at full resolution independent of decimation and deletion specified in the **Retention Period** settings.

(a)
All Snapshots

(b)
Shared Snapshots

(c)
Local Snapshots

Figure 12   Snapshot Window

You can edit, share, or delete a local snapshot by right-clicking on the snapshot name and choosing the appropriate action.

The snapshot list contains two columns: **Name** and **Time**. The time is defined as midway between the start and the end of the time range selected when the snapshot was saved. These times are formatted according to the current regional settings on the client machine.

The snapshot list is sortable. Clicking a column sorts the list by that column. Clicking a second time on the same column sorts the list in reverse order.

The snapshot display does not change the view. Once a snapshot is displayed, you can switch between views, which is helpful for looking at different signals associated with the same snapshot.

Snapshot names and times are stored on the server. Saving or deleting a snapshot with SYNCHRoWAVE Central does not change the snapshot data. All data are archived in SYNCHRoWAVE Historian and remain archived there independent of snapshot saving with SYNCHRoWAVE Central. The purpose of saving snapshots names and dates is simply for ease of access.
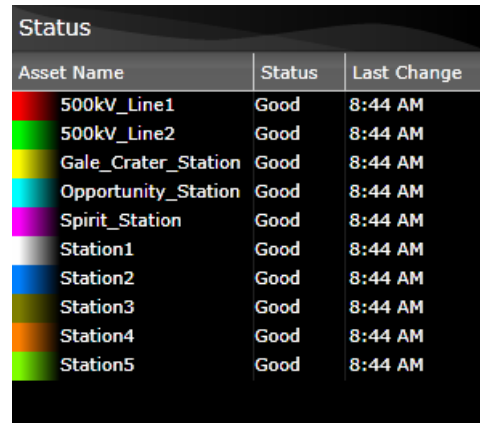
Asset Status

Figure 13 shows an example **Status** window. This window provides two important pieces of information: the status of each asset measurement and the color associated with each asset.

The date and time listed is the date/time of the most recent change of present status (Good or Error), or the date/time of the most recent web browser refresh. The status is updated approximately once per second.

Figure 13   Status Window

Status values are accompanied by a tooltip describing the status in detail. The tooltip becomes visible when your mouse hovers over the status for a given station. The four possible values for the tooltip are as follows:

NOTE: If the "Display Invalid Data as Valid" option is enabled in Admin (see Display of Invalid Data on page 9), data for measurements are shown in chart windows for both the PMU Error and Time Sync Error cases.

Tooltip	What this means for the PMU that is sending this asset measurement	Data for this measurement are shown in chart windows	Data for this measurement are stored by SYNCHROWAVE Historian in the synchrophasor database
Good Data	Data are being received properly.	Yes	Yes
PMU Error	Bit 15 (Data invalid) or Bit 14 (PMU error) in the IEEE C37.118 STAT field are set.	No	Yes
Time Sync Error	Bit 13 (PMU out of sync) in the IEEE C37.118 STAT field is set.	No	Yes
No Data	The PMU is not connected.	No	No

Status is displayed for individual assets, although it is received from individual phasor measurement units (PMUs). Therefore, it is possible that the statuses of multiple assets are received from the same PMU. In this case, if the connection to the PMU is lost, then all associated assets display Error.

The status **Last Change** time is cleared when the browser is refreshed or closed, or when navigating away from SYNCHROWAVE Central. This means that each time settings are changed with Admin, the **Last Change** times update to the present time.

Disturbance Reports

The Disturbance Reports module displays a list of detected events in the presently selected time period. When an operator clicks on a Disturbance Report, a pop-up display appears (see *Figure 14*) with summary information describing the event as well as plots of both frequency and voltage

measurements for the five most strongly affected stations. The Disturbance Factor is also plotted with a horizontal dashed line indicating the disturbance threshold.
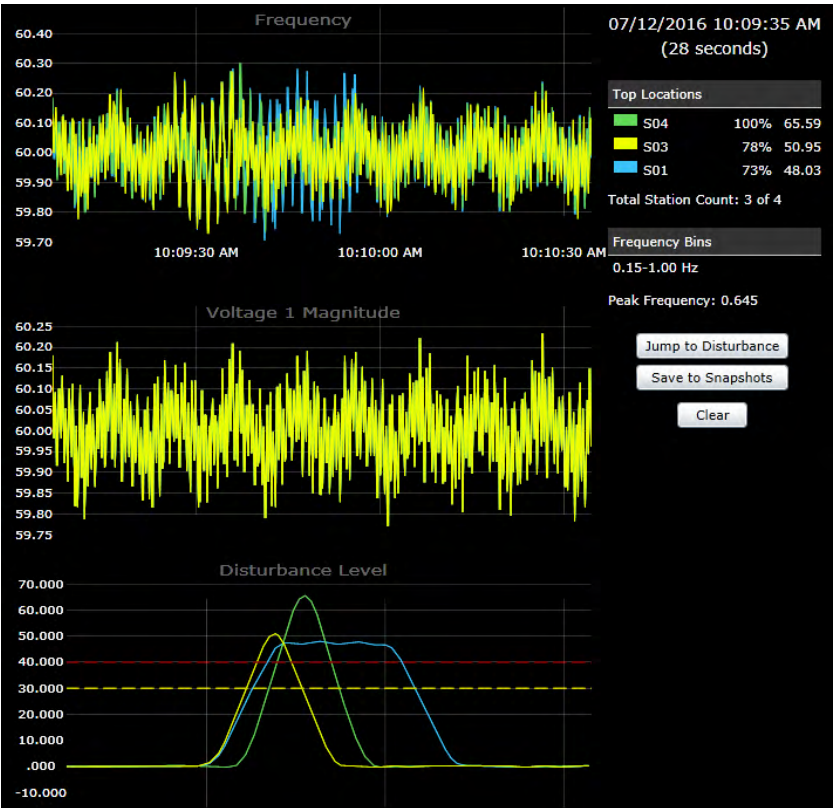

Figure 14   Disturbance Report

From this pop-up window, the operator can jump to the display period containing the disturbances or save the display period as a snapshot. The pop-up window is dismissed by clicking anywhere else on the client display.

Alarms

Each Admin-configured alarm is visible in all open SYNCHROWAVE Central displays. An alarm is hidden in its normal deasserted state. When the warning threshold is exceeded, the alarm displays flashing yellow. Similarly, when the alert threshold is exceeded, the alarm displays flashing red.

Clicking on an alarm opens a pop-up that displays information about the alarm (see *Figure 15*). From this pop-up, you can choose to acknowledge the alarm, clear the alarm, or jump to the event. Clicking away from the pop-up closes it without any actions taken.
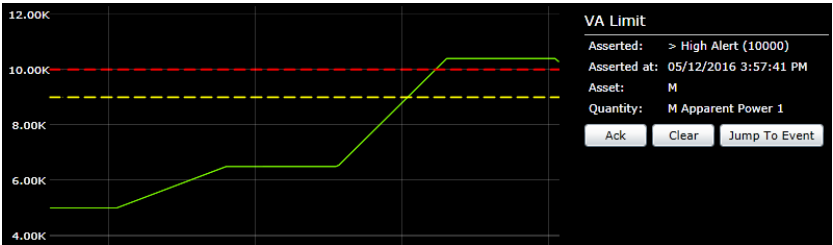

Figure 15   Alarm Pop-up

Acknowledge the alarm by clicking on the alarm and then selecting the **Ack** option. Acknowledging an alarm causes the alarm display to stop flashing and display a solid yellow or red indication. A circular indicator (present state indicator) next to the alarm shows the present state of the monitored signal with respect to the warning and alert thresholds (see *Figure 16*).
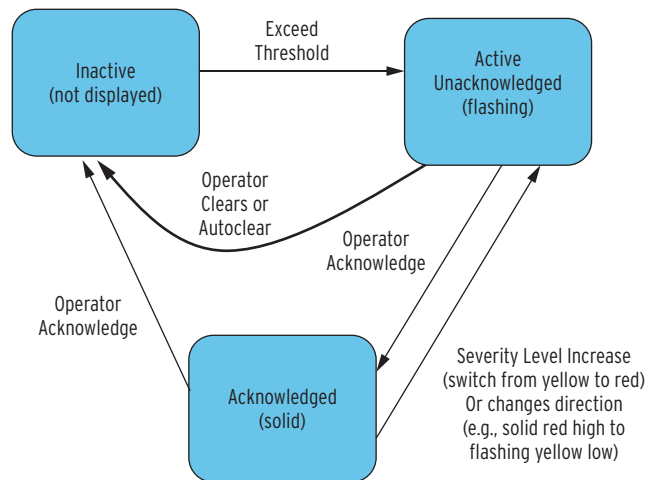
Figure 16   Alarm State Transition

Clear an alarm by clicking on the alarm and selecting the **Clear** option. An alarm can also be configured to auto-clear after a preconfigured time delay. Separate timers are provided for the warning and alert states. Clearing the alarm returns the alarm indicator to the hidden state. Any SYNCHROWAVE Central display provides the ability to acknowledge or clear the alarm.

NOTE: If authentication is enabled, only the Admin and Operator roles can acknowledge or clear alarms.

A nonfunctional alarm (e.g., resulting from bad data) is unhidden and shown dimmed with a no [⊘] symbol to the left (see *Figure 17*).

Each change of alarm state (normal, warning, error, or cleared) results in the generation of a log message. This message is available in the general Logs page (Logs.html) as well as the Alarm Logs display inside SYNCHROWAVE Central.

Present State Indicator Inactive   Present State Indicator Active

Figure 17   Alarm Present State Indicator

Search

SYNCHROWAVE Central provides a fast search of the entire set of archived synchrophasor data. Start the search by selecting the quantity of interest and its associated asset name. There are six search types provided.

➤ Signal < value—Search for all times when the selected signal is below the specified value.

➤ Signal > value—Search for all times when the selected signal is above the specified value.

➤ Signal outside range—Search for all times when the signal exceeds a minimum or a maximum value.

➤ Outside range for at least T—The same as "Signal outside range" except the criterion must be met for at least T milliseconds.

➤ Outside range and exceeds dx/dt—The same as "Signal outside range" except the signal must also exceed a minimum rate-of-change.

➤ Outside range and exceeds dx/dt for at least T—The same as "Outside range and exceeds dx/dt" except the criteria must be met for at least T milliseconds.

See *Figure 18* for the definition of the search parameters.
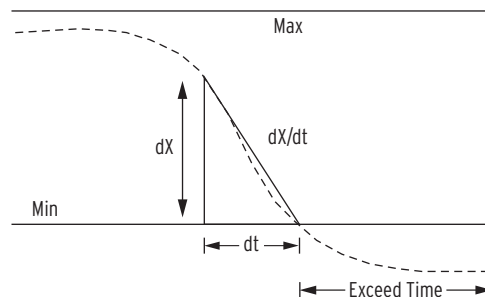
Figure 18   Definition of Search Parameters

For each of the search types there is an option to constrain the time range of the search. If this option is not selected, the full synchrophasor database is searched.

Search results are listed in chronological order. To display the result of the search, simply select the appropriate item in the list. If the time range of interest is not included in the list, use the page selection arrows at the bottom of the search results. When selected, each result is displayed with a one-minute horizontal time scale. The portion of the signal that met the search criteria is centered.

Please note that the search result does not change the signals displayed in the present SYNCHROWAVE Central view. Therefore, if the searched signal is not presently displayed, it will not become displayed upon selecting the search result. In some cases, you might want to consider creating special views for search results.

The synchrophasor database is indexed for fast search response. However, the dx/dt-based searches can take more time to complete. One approach to searching on dx/dt is to base your initial search on only signal level. For example, start with a "Signal < value" search. Then, after you have a level that returns a reasonable set of results, transition to a dx/dt-based search to further refine these results. If a dx/dt value is entered that results in an excessively long response, the search will automatically time out after one minute. If a search times out, try adjusting the search parameters slightly. Note that while the search is running, further searches are disabled.

NOTE: SYNCHROWAVE Central display data do not change when a search result is selected. If the signal of interest is not shown on the display, you can add it with the drop-down menus (see ① in Figure 9).

Views

The layout of windows in SYNCHROWAVE Central can be saved for later use, allowing for the creation of multiple views that you can quickly switch between. All views are saved on the server.

Two default view groups are defined on initial install: **My Views** and **Viewer**. Views saved to the **Viewer** view group are available to all application operators. Views saved to the **My Views** view group are only available to the operator account. Views can be moved to a different view group by right-clicking on the view name and selecting **Move**. Additional view groups can be defined by right-clicking on the view group and selecting **+ New View Group**. A new view group can be deleted later, but the **My View** and **Viewer** view groups cannot be deleted.

The **Home** button (🏠) allows you to quickly select a preferred view and view group. To assign a view as the home view, right-click on the name of the view and select **Set View As Home**.

You can switch the selected view group by clicking on the active view group button (next to the home button) and selecting a view group from the list. From this menu, you can alternatively select a specific view from that view group, resulting in the simultaneous selection of that view and view group.

Data Export

The **Data Export** button in the lower right corner of SYNCHROWAVE Central (see *Figure 8* for reference) allows you to save the screen data to a file. The file options are binary COMTRADE, ASCII COMTRADE, or CSV. When exporting data, a pop-up appears that allows you to view the data in the selected format or save the data in the selected format. The data saved are the data presently shown on the SYNCHROWAVE display. This allows easy graphical selection of the data and the time ranges to export.

Print Screen

The **Printscreen** button, also in the lower right corner, allows you to save an image file (in JPEG format) of the present display. The colors are reversed to facilitate including the information in reports.

Managing the Synchrophasor Database

NOTE: Event data are stored in the external ACSELERATOR database. See Appendix B: Quick-Start for Configuring ACSELERATOR Database With Event Timeline for details on setting up and managing the ACSELERATOR database.

All synchrophasor data received by SYNCHROWAVE Historian are stored in the synchrophasor database. This ensures that all synchrophasor data received from the PDC are saved. To change which data Historian archives, adjust the settings in the PDC. The synchrophasor database uses a file and directory oriented structure. Historian creates a directory for each PMU in which it stores the data in individual files with the extension .swave. Each SWave file contains one hour of data from the associated PMU. Further details of the database file format and help with managing the database are available from SEL upon request.

Exporting Data

NOTE: Editing CSV data in a spreadsheet can corrupt the time stamps if the editor is not configured to retain the correct formatting. This can result in a file that cannot be imported.

Two tools are available for exporting synchrophasor database information. One is the **Data Export** button on each client web display. This allows saving exactly what is being displayed into a COMTRADE ASCII file, a COMTRADE binary file, or a CSV (comma separated with .csv extension) file. The maximum length of time exportable via this method is one hour.

For exporting larger amounts of data, a command line program is available. Start this program from the Windows **Start** menu. Click the **Start** button and navigate to **All Programs > SEL Applications > SEL SynchroWAVe Central > SynchroExport**. A console window will appear with the following information:

Path to SYNCHROWAVE data files to export

SWave Path (* = wildcard) :

Then, enter the path to the synchrophasor database and the files for exporting. The synchrophasor database path will match the location specified within the **Historian** tab in SYNCHROWAVE Admin. As an example, consider the case with two PMU sources sending data. The synchrophasor database path is C:\SynchroWAVe Database. In this case, the synchrophasor database is located in the following locations.

NOTE: Large files can take a significant amount of time to export.

C:\SynchroWAVe Database\Historian\PMU1
C:\SynchroWAVe Database\Historian\PMU2

At the prompt, type the following to export all of the data for both of these PMU sources:

SWave Path (* = wildcard) : C:\SynchroWAVe Database\Historian**

The CSV files are placed in the same directory as the original data.

Importing Data

Data are imported with the SYNCHROWAVE Admin **Import** tab. A separate command line application is not needed. If modal analysis is being computed on data that come from multiple input stations (e.g., an angle that is referenced to another station), and data are imported for one of these stations, the modal analysis results will not be updated. To force the update, first disable modal analysis in Admin, wait 10 minutes, then enable it again.

Viewing Synchrophasor Database Data

All synchrophasor database data are stored in a simple SWave file. You can view the synchrophasor database contents by navigating to the synchrophasor database location and double-clicking an SWave file. The synchrophasor database location is specified within the **Historian** tab in SYNCHROWAVE Admin. There is a subdirectory named Historian\ at this location where the synchrophasor database files are located. If you double-click an SWave file that is presently updating, there will be a check box at the top of the window that allows you to view the data live during the update.

All data in the synchrophasor database are saved with the original names as received from the PMU or PDC. The mapping settings in SYNCHROWAVE Admin change how data are displayed but does not change the synchrophasor database contents.

SEL is available to help with synchrophasor database management questions.

SYNCHROWAVE Central Logs

SYNCHROWAVE Central records key system changes in a logs database that is available through a web browser or through Admin. The URL for web access is http://server_name/logs.html.

Logs are unique to each server running SYNCHROWAVE Central. Logs shown on any web browser connected to the same server will be identical to one another.

Some of the occurrences that can generate a log are:

- ➤ An enabled alarm asserted as a result of the configured signal exceeding an error threshold.
- ➤ An enabled alarm asserted as a result of the configured signal exceeding a warning threshold.
- ➤ Clearing an alarm. The user name under which the alarm was cleared is also logged.
- ➤ PMU status changed to error or good.
- ➤ Data indexing starting or completing.
- ➤ Settings changes.
- ➤ Connection to a new PDC.
- ➤ Software services starting or stopping, or a software error.
- ➤ Error in the synchrophasor database path.

Specifications

General

Operating Systems Supported

Server:	Windows 7 (32/64-bit)
	Windows 10 (32/64-bit)
	Windows Server 2008 (32/64-bit)
	Windows Server 2008 R2 (64-bit)
	Windows Server 2012 (32/64-bit)
Client:	Windows 7 (32/64-bit)
	Windows 10 (32/64-bit)
	Windows Server 2008 (32/64-bit)
	Windows Server 2008 R2 (64-bit)
	Windows Server 2012 (32/64-bit)
Browsers Supported:	Internet Explorer, version 9 (32-bit) or later

Required Browser Plugins

Microsoft Silverlight Client version 5.1

System Hardware Requirements (Server)

Recommended Minimum Configuration:	2 GHz processor 2 GB RAM
Typical Storage Requirement:	~100 GB/year/PMU (4 phasors, 2 analogs, and 16 digital bits at 60 messages per second)

Supported Protocols

IEEE C37.118

TCP

Display

Historical and real time

Web-based connection

Time scale viewing, with zoom and pan

Calendar-based, date-range selection

User-configurable display arrangement

Modal analysis

Phasor scope, with zoom

Geographic map

Event timeline

Inverse color display capture

Snapshots

Snapshot event capture and full-resolution data retention

User-Configurable Views

Switchable display views, with save/restore

Status

Provides real-time status of all inputs

Events

Retrieve event reports from ACSELERATOR database

View oscillography, phasors, and digitals

Custom calculations

Frequency plots

Alarms

100 configurable alarms

Provides four threshold levels, two for minimum and two for maximum

Search

Search capability based on signal levels and rate-of-change

Logging

Application specific logs with export capability

Synchrophasor Database

All received synchrophasor data are archived to a simple SYNCHROWAVE SWave binary file format

File Import:	CSV
	SEL-3373 Station Phasor Data Concentrator (PDC)
	SEL-5073 SYNCHROWAVE Phasor Data Concentrator (PDC)
File Export:	CSV
	Binary COMTRADE
	ASCII COMTRADE

Graphical range selection

Configuration

Application administration

User-defined signal to asset renaming

Power calculations

Security

Optional secure socket layer interface

Optional group and name authentication

Modal Analysis

Real-time calculations

Results stored in Historian

SNR and amplitude checks

Display:	Modal frequency and damping

Product Configuration

Licensing

Single, multiple, or site licensing available

Configuration Requirements

Must use an IEEE C37.118-compliant Phasor Measurement Unit or Phasor Data Concentrator as an input to the synchrophasor portion of the SEL-5078-2

Input-only PDC capability

SYNCHROWAVE Event 2015

Requires an ACSELERATOR database to store event files. Further requires ACSELERATOR TEAM for automated event files retrieval.

Appendix A: Software and Manual Versions

Determining the Software Version

The software version is available in the upper right corner of the web browser interface, and also within the **Status** tab in SYNCHROWAVE Admin.

Table 4 lists the software versions, a description of the modifications, and the instruction manual date code that corresponds to these versions. The most recent version is listed first.

Table 4   Software Revision History (Sheet 1 of 3)

Identification Numbers	Summary of Revisions	Manual Date Code
SEL-5078-2 SYNCHROWAVE Central 2.1.0	**Historian 2.1.0** ➤ No changes. **Services 2.1.0** ➤ Added sub-group capability to views. ➤ Added option to configure number of significant figures for Numeric Display. ➤ Added minimum y-axis scale option for Standard Chart. ➤ Added option to configure signal line thickness on Standard Chart. ➤ Increased web-client data export limit.	20180321
SEL-5078-2 SYNCHROWAVE Central 2.0.3	**Historian 2.0.3** ➤ Added 60-day free trial to software. **Services 2.0.3** ➤ Added 60-day free trial to software.	20170515
SEL-5078-2 SYNCHROWAVE Central 2.0.2	**Historian 2.0.2** ➤ No changes. **Services 2.0.2** ➤ Improved support for importing SYNCHROWAVE PDC archive data. ➤ Improved signal auto-mapping for third-party PMU naming conventions.	20170215
SEL-5078-2 SYNCHROWAVE Central 2.0.1	**Historian 2.0.1** ➤ No changes. **Services 2.0.1** ➤ Updated Event Timeline settings to interface with ACSELERATOR Database installed with QuickSet version 6.2.5 and later.	20160916
SEL-5078-2 SYNCHROWAVE Central 2.0.0	**Historian 2.0.0** ➤ Improved support for archiving to Network Attached Storage devices. **Services 2.0.0** ➤ Added View Groups, Authentication, Improved Alarms, Power Paths, and Bar Chart. ➤ Upgraded SYNCHROWAVE Event 2015 version 1.1.1 to version 1.2.1. ➤ Added Automatic Disturbance Detection.	20160729
SEL-5078-2 SYNCHROWAVE Central 1.8.1	**Historian 1.8.0** ➤ No changes. **Services 1.8.1** ➤ Improved processing of views templates when upgrading from version 1.7.	20150914

Table 4   Software Revision History (Sheet 2 of 3)

Identification Numbers	Summary of Revisions	Manual Date Code
SEL-5078-2 SYNCHROWAVE Central 1.8.0	**Historian 1.8.0** ➤ Updated to maintain snapshot data at full resolution independent of data retention settings. **Services 1.8.0** ➤ Implemented automatic backup server failover. ➤ Upgraded Event 2015 version 1.0 to version 1.1.1. ➤ Added numeric display.	20150619
SEL-5078-2 SYNCHROWAVE Central 1.7.4	**Historian 1.7.4** ➤ Added support for leap seconds. **Services 1.7.4** ➤ Added support for leap seconds to SWave File Viewer and SynchroExport.	20150601
SEL-5078-2 SYNCHROWAVE Central 1.7.2	**Historian 1.7.2** ➤ No changes. **Services 1.7.2** ➤ Upgraded Event Viewer to SYNCHROWAVE Event 2015. ➤ Improved robustness and reduced load time of data import tasks. ➤ Implemented web-client auto refresh.	20141208
SEL-5078-2 SYNCHROWAVE Central 1.7.1	**Historian 1.7.1** ➤ Corrected issue where previous version could drop data when archiving to network drives. **Services 1.7.1** ➤ Improved server performance on older computer hardware. ➤ Corrected issue where alarms and status could display incorrectly when time zone was set to East of Coordinated Universal Time (UTC).	20140502
SEL-5078-2 SYNCHROWAVE Central 1.7.0	**Historian 1.7.0** ➤ Added PDC input and stored data downsample capability. **Services 1.7.0** ➤ Added *Event Viewer*. ➤ Added *Shared Views* and *Snapshots*.	20140121
SEL-5078-2 SYNCHROWAVE Central 1.6.2	**Historian 1.6.0** ➤ No changes. **Services 1.6.2** ➤ Added "Show invalid data as valid" option.	20130531
SEL-5078-2 SYNCHROWAVE Central 1.6.1	**Historian 1.6.0** ➤ No changes. **Services 1.6.1** ➤ Updated Math Library.	20130401
SEL-5078-2 SYNCHROWAVE Central 1.6.0	**Historian 1.6.0 and Services 1.6.0** ➤ Geographical map. ➤ Graphical export. ➤ User interface enhancements. ➤ New Admin application. ➤ Alarm improvements. ➤ Modal analysis features.	20121212
SEL-5078-2 SYNCHROWAVE Central 1.5.1	**Historian 1.5.0** ➤ No changes. **Services 1.5.1** ➤ Enhanced multicore performance for modal analysis.	20120810

Table 4 Software Revision History (Sheet 3 of 3)

Identification Numbers	Summary of Revisions	Manual Date Code
SEL-5078-2 SYNCHROWAVE Central 1.5.0	**Historian 1.5.0** ➤ Min/max derived data calculations. **Services 1.5.0** ➤ Added phasor scope. ➤ Added modal analysis. ➤ Added search. ➤ Added logs. ➤ Added alarms. ➤ Improved security. ➤ Converted Admin to an application.	20120615
SEL-5078-2 SYNCHROWAVE Central 1.1.0	**Historian 1.0.0** ➤ No changes. **Services 1.1.0** ➤ Improved configuration menus. ➤ Corrected duplicated power calculation. ➤ Removed unnecessary log file. ➤ Added support for more PMUs.	20120214
SEL-5078-2 SYNCHROWAVE Central 1.0.0	**Historian 1.0.0** ➤ Initial version. **Services 1.0.0** ➤ Initial version.	20111111

Determining the Manual Version

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table 5 lists the product manual release dates and a description of modifications. The most recent product manual revisions are listed at the top.

Table 5 Manual Revision History (Sheet 1 of 2)

Revision Date	Summary of Revisions
20180321	➤ Updated *Navigating the Standard Chart* in *Operating SYNCHROWAVE Central*. ➤ Updated *Table 4: Software Revision History* for version 2.1.0.
20170515	➤ Updated *Table 4: Software Revision History* for version 2.0.3.
20170215	➤ Updated *Table 4: Software Revision History* for version 2.0.2.
20160916	➤ Updated *Table 4: Software Revision History* for version 2.0.1. ➤ Updated *Appendix B: Quick-Start for Configuring ACSELERATOR Database With Event Timeline*.
20160729	➤ Added *Licensing*. ➤ Updated *Figure 3: SYNCHROWAVE Historian Settings*. ➤ Updated *Authentication*. ➤ Updated *Figure 4: Tag Mapping Settings*. ➤ Updated *Figure 5: SYNCHROWAVE Central Display*. ➤ Updated *Mapping Menu*. ➤ Updated *Geographic Map*. ➤ Added *Disturbance Detection*. ➤ Updated *Figure 7: Typical SYNCHROWAVE Central Display*. ➤ Updated *Figure 8: Display Navigation Steps* and associated explanatory text. ➤ Added *Navigating the Bar Chart*. ➤ Updated *Navigating the Map Display*. ➤ Added *Disturbance Reports*.

Table 5   Manual Revision History (Sheet 2 of 2)

| Revision Date	Summary of Revisions
	➤ Updated *Alarms*. ➤ Updated *Saving Views*. ➤ Updated *Table 3: Software Revision History* for version 2.0.0.
20150914	➤ Updated *Table 2: Software Revision History* for version 1.8.1.
20150619	➤ Updated *Table 2: Software Revision History* for version 1.8.0. ➤ Moved *Appendix C: Factory Assistance* to *Appendix D*. ➤ Added *Appendix C: Configuring SYNCHROWAVE Central for Automatic Backup Server Failover*.
20150601	➤ Updated *Table 2: Software Revision History* for version 1.7.4.
20141208	➤ Removed *Operating Event Viewer* section. This information is now included in the SYNCHROWAVE Event 2015 Instruction Manual. ➤ Updated *Table 2: Software Revision History* for version 1.7.2.
20140502	➤ Updated *Table 2: Software Revision History* for version 1.7.1.
20140121	➤ Updated manual to include SYNCHROWAVE Viewer, PDC capability, and stored data downsampling. ➤ Added *Appendix B: Quick-Start for Configuring ACSELERATOR Database With SYNCHROWAVE Event Viewer*. ➤ Updated *Table 2: Software Revision History* for version 1.7.0.
20130531	➤ Updated manual to include option to display invalid data and describe gray modal analysis dots. ➤ Updated *Table 1: Software Revision History* for version 1.6.2.
20130401	➤ Updated *Table 1: Software Revision History* for version 1.6.1.
20121212	➤ Updated manual to include geographical map and associated settings, and zoom options for phasorscope. ➤ Updated tag/asset mapping options, and data import/export. ➤ Updated *Table 1: Software Revision History* for version 1.6.0.
20120810	➤ Updated *Table 1: Software Revision History* for version 1.5.1.
20120615	➤ Updated manual to include phasor scope, modal analysis, search, logs, and alarms. ➤ Updated *Security and Authentication*. ➤ Updated Historian information throughout manual. ➤ Updated *Table 1: Software Revision History* for version 1.5.0.
20120214	➤ Updated *Installation*. ➤ Updated *Licensing*. ➤ Updated *Historian Settings*. ➤ Updated *Mapping Settings*. ➤ Updated *Mapping Settings Example*. ➤ Updated *Specifications*. ➤ Updated *Table 1: Software Revision History* for version 1.1.0.
20111111	➤ Initial version.

Appendix B: Quick-Start for Configuring ᴀᴄSELᴇʀᴀᴛᴏʀ Database With Event Timeline

The following is a general overview of the steps involved in configuring an ᴀᴄSELᴇʀᴀᴛᴏʀ database and a SYNCHROWAVE server to display event reports. This is not intended to be a comprehensive guide.

Download Components to Support ᴀᴄSELᴇʀᴀᴛᴏʀ Database

If not already installed, download SEL Compass from selinc.com and install.

Open Compass. Click the **Tools** icon.
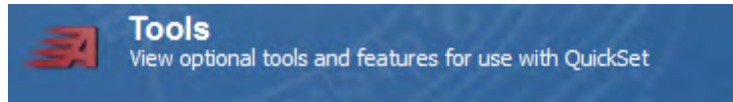
Select **SEL ᴀᴄSELᴇʀᴀᴛᴏʀ QuickSet** and the following plugins:

➤ ᴀᴄSELᴇʀᴀᴛᴏʀ Database

➤ ᴀᴄSELᴇʀᴀᴛᴏʀ Database Device Manager Support

➤ QuickSet TEAM Plugin

Set Up the Database

Once the download and install is complete, open QuickSet. Launch the Device Manager component by clicking on the cog ( ) icon.

Log on to Device Manager. If this is a fresh install, the username is "admin" and the password is blank.
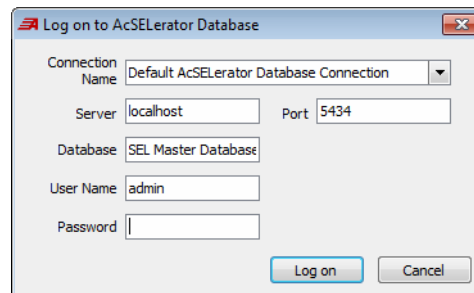
Once in Device Manager, if you have the default username/password, SEL recommends that you assign a new password. To set a new password, go to the **Tools** menu and select **Change User Password**.
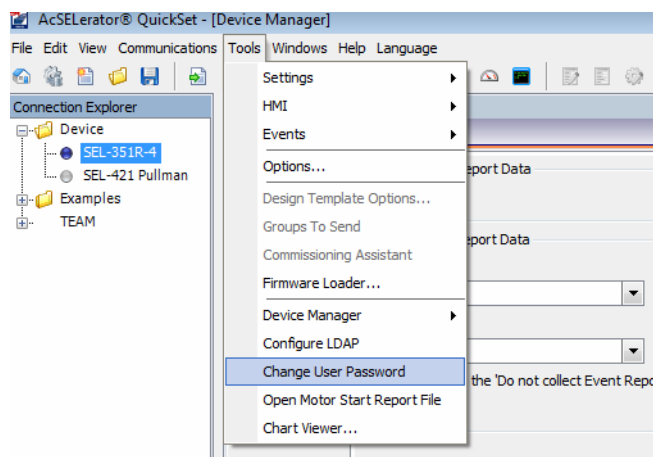
Remote Access to AcSELerator Database

If the AcSELerator database is located on a server other than the one on which SYNCHROWAVE Central is installed, remote access to the AcSELerator database will have to be granted to pull relay events into SYNCHROWAVE Central. This is accomplished by editing the pg_hba.conf file on the server running the AcSELerator database.

For Windows XP, the pg_hba.conf file is in the following folder:

Documents and Settings\All Users\Application Data\SEL\AcSELerator\ MasterDatabase\DatabaseServer\Database\data

For Vista and Windows 7, the pg_hba.conf file is in the following folder:

C:\ProgramData\SEL\AcSELerator\MasterDatabase\DatabaseServer\ Database\data

Add the IP address of the server that SYNCHROWAVE Central is installed on to the IPv4 local connections. Here is an example of an edited host entry:

IPv4 local connections:

host	all	all	127.0.0.1/32	md5 # only allow connections on local host
host	all	all	192.168.0.2/32	md5 # allow connection from synchroWAVe Central server

After saving changes to the file, restart the AcSELerator database service by performing the following steps:

Step 1.   Click the Windows **Start** button.

Step 2.   Choose **Run**.

Step 3.   Type **services.msc** and press the **<Enter>** key.
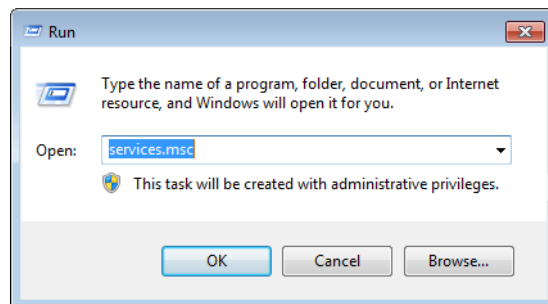
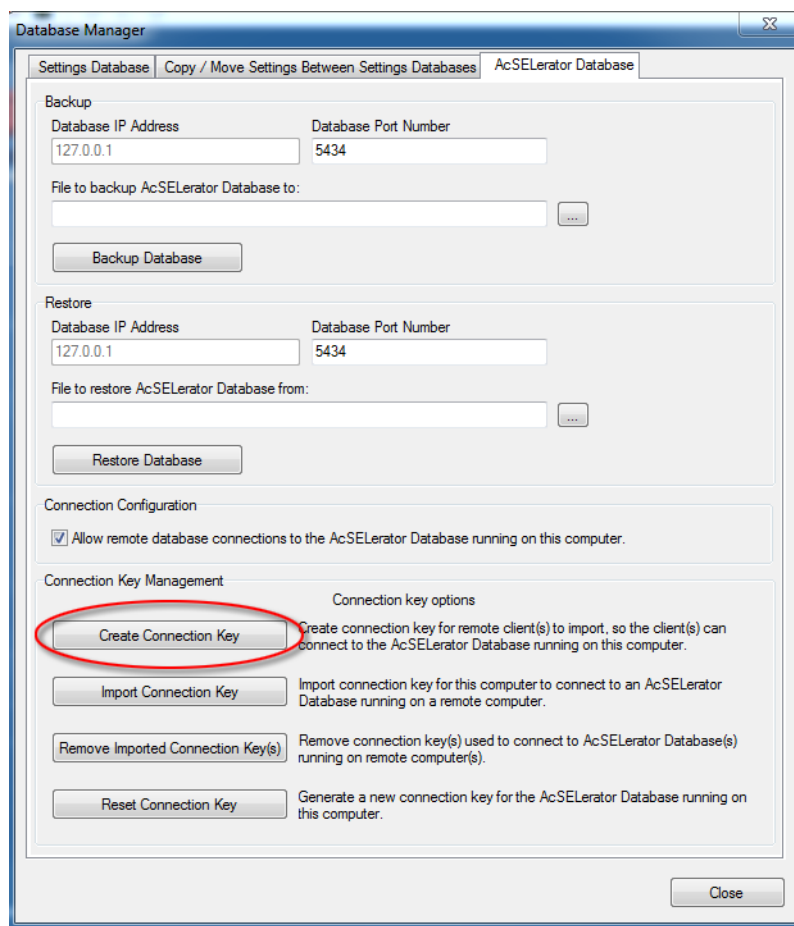In the Services menu, select **AcSELerator Database** and click **Restart**.
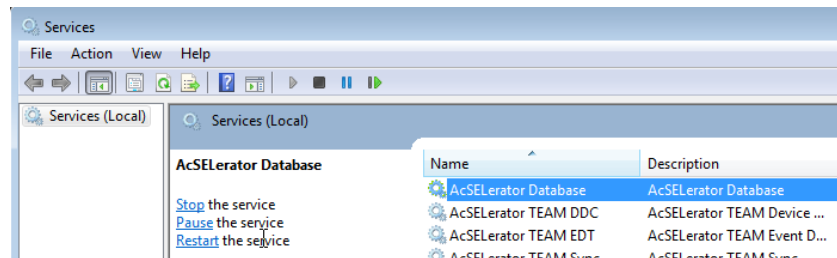
Configure
synchroWAVe Central
Admin to Access the
acSELerator Database

Retrieving Event Files From acSELerator Database Installed With QuickSet Version 6.2.5 or Later

If you are running acSELerator Database installed with QuickSet version
6.2.5 or later, you will need to create a connection key (.ckf) file in the
Database Manager.

In QuickSet, click **File > Database Manager**. Select the **AcSELerator
Database** tab and then click **Create Connection Key**. Save the file to a
convenient location.

Go to synchroWAVe Central Admin and open the **AcSELerator Database**
tab.

Select the **Use .CKF Connection Key to connect to AcSELerator Database**
check box and then click **Import .CKF connection key** to import the
connection key. You can import multiple keys, but only the key associated
with the database specified by the **Select AcSELerator Database** drop-down
menu will be used.

Retrieving Event Files From AcSELerator Database Installed With QuickSet Versions Prior to 6.2.5

Go to SYNCHROWAVE Central Admin and open the **AcSELerator Database** tab.

Ensure that the **Use .CKF Connection Key to connect to AcSELerator Database** check box is *not* selected. Enter the IP address, port, and login information for the ACSELERATOR database. The port number should be 5434 unless your ACSELERATOR database has been specifically configured otherwise.

Manually Adding Events to the ACSELERATOR Database

To manually add event reports, first add the devices that generated the reports.

Through Connection Explorer (upper left corner), create whichever organizational structure you prefer by right-clicking the menu and selecting **Add > Folder**. Inside a folder, right-click and select **Add > Device** to display a list of supported devices. Choose your device and click **OK**.

If desired, right-click on the device and rename it to conform to your organizational structure.

Once your device structure is set up, you are ready to begin adding event report files to the ACSELERATOR database. Right-click on the associated device in Device Manger and choose **View Events**.

Under the **Viewer** window, select the **Functions** tab. Click **Import** and select the event you wish to import. For COMTRADE event reports, choose the .CFG file. Now you need to associate this event with a device. Use the right side of the association window to locate your device. Highlight the device you wish to associate the event report with and click the right (>) arrow.
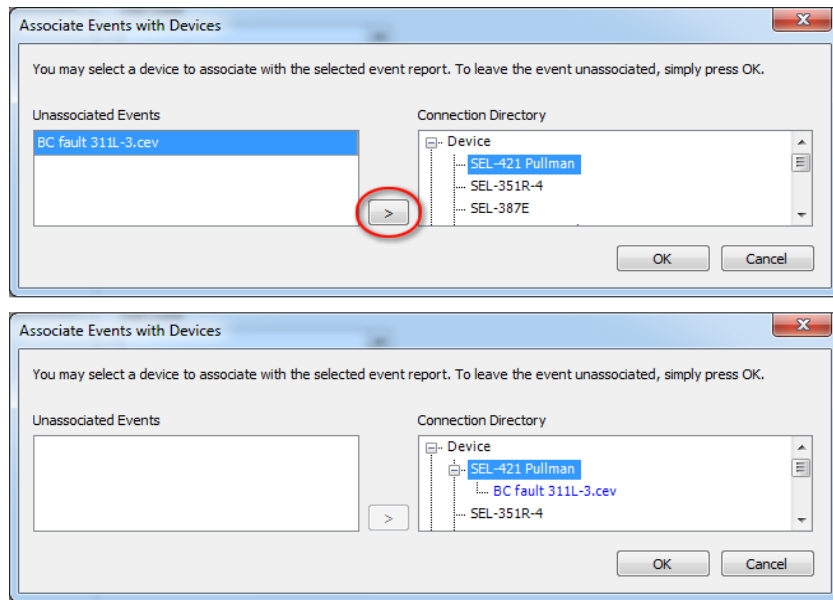
Return to the **Event Summary** tab to verify the event has been successfully
associated with your device.

View Event Reports

Load SYNCHROWAVE Central in a web browser. Open an Event Timeline in
SYNCHROWAVE Central and navigate to the time of the event. You should see
a dot representing the new event. Click the dot to select the event and click the
View Selected Events button. This will launch the SYNCHROWAVE Event
2015 application with the selected event file.

Appendix C: Configuring SYNCHROWAVE Central for Automatic Backup Server Failover

SYNCHROWAVE Central supports automatic failover to a backup server. To enable this feature, install two independently licensed copies of SYNCHROWAVE Central on separate servers. The following steps are required:

Step 1.   Set up two identical SYNCHROWAVE systems. Configure each to connect to the same incoming PMU data streams.

Step 2.   Configure each server to maintain an independent synchrophasor database.

Step 3.   Assign one server as primary and one as backup.

Step 4.   Configure the backup server so that the SYNCHROWAVE Services application runs under the same account name as the Services application on the primary server.

Step 5.   Enable authentication on both servers. Add the account described in *Step 4* to the authenticated users list.

Step 6.   Ensure that the servers are time-synchronized to within five seconds of each other.

Step 7.   If SSL security is enabled, ensure security settings on both servers match. Apply the same SSL key on both servers.

Configure **Historian** and **Redundancy and Failover** settings on both the primary and backup server, and then complete the remaining configuration process using the Admin application on the primary server only. All settings (except those within the **Historian** and **Redundancy and Failover** tabs) are periodically copied from the primary server to the backup server, and will overwrite any existing settings on the backup server.

Retention Period settings (within the **Historian** tab) for the primary and backup synchrophasor databases may be different. For example, the primary system may retain data for one year, while the backup system may only retain data for one week. While operating on the backup system, only data included in the backup server's retention period (one week in this example) will be visible.

Appendix D: Technical Support

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

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