TESLA 4000

Power System Recorder
Model 4000-A

User Manual

Version 1.2 Rev 3

Preface

Information in this document is subject to change without notice.

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Using This Guide

This User Manual describes the installation and operation of the TESLA power system recorder and the accompanying TESLA Control Panel user interface software. It is intended to support the first time user and clarify the details of the equipment.

The manual uses a number of conventions to denote special information:

Example	**Describes**
Start>Settings>Control Panel	Choose the Control Panel submenu in the Settings submenu on the Start menu.
Right-click	Click the right mouse button.
Recordings	Menu items and tabs are shown in italics.
service	User input or keystrokes are shown in bold.
Text boxes similar to this one	Relate important notes and information.
..	Indicates more screens.

Table of Contents

Version Compatibility

For version compatibility, refer to the following documents on the ERLPhase website, www.erlphase.com:

- D05478 - TESLA 4000-A Firmware User Release Description

PC System Requirements and Software Installation

Hardware

The minimum hardware requirements are:

- 1 GHz processor
- 2 GB RAM
- 20 GB available hard disk space
- USB port

Operating System

The following software must be installed and functional prior to installing the applications:

- Microsoft Windows 10
- Microsoft Windows 11

Software Installation

All required software for user interface, settings and record analysis is available directly from the ERLPhase website. The following relevant software and documentation is available:

- TESLA Control Panel
- ERL 61850 Configurator Tool
- RecordGraph
- USB Driver
- AC-DC Input Module Configurator
- TESLA 4000-A User Manual

Anti-virus/Anti-spyware Software

If an anti-virus/anti-spyware software on your local system identifies any of the ERLPhase applications as a “potential threat”, it will be necessary to configure your anti-virus/anti-software to classify it as “safe” for its proper operation. Please consult the appropriate anti-virus/anti-spyware software documentation to determine the relevant procedure.

1 Overview

1.1 TESLA System Description

The TESLA 4000-A power system recorder is a multi-time domain recording system used to monitor electrical power systems. The TESLA 4000-A can record up to 36 analog channels, up to 64 external input channels and 256 virtual input channels and store up to 2500 recordings with extended storage. Up to four recorders can be operated as a cooperative group or up to eight recorders can be operated as Group Record Trigger (GRT) mode to achieve greater numbers of channels.

The TESLA can record data simultaneously in three time domains: high speed transient fault (seconds), low speed dynamic swing (minutes), and continuous disturbance recording and trend (10 second to 1 hour intervals). A wide variety of triggers are available to initiate recording.

The integrated Phasor Measurement Unit (PMU) functionality streams synchrophasor data for wide area monitoring as per IEEE C37.118 standards. It can stream up to 36 phasors, 24 analog quantities and up to 320 binary digital statuses and up to two PDCs. The integrated CDR creates continuous records without triggers which together with the fault, swing and trend records provides wide area visibility of system performance.

The TESLA system consists of a recorder, analog input isolation modules and the TESLA Control Panel user interface software. There are various analog input isolation modules available to interface to signal sources. Modules are available to connect to standard signals found in a typical electric power substation including secondary AC voltage and current and low level dc voltage and current signals. These modules can generally be installed up to 1220 meters from the recorder unit, allowing them to be located near the source of the signals being monitored.

TESLA Control Panel user interface software provides tools to configure the recorder, retrieve and manage records and display real time measured values. TESLA Control Panel also includes RecordGraph, a graphical record display and analysis software tool.

An optional central station program – RecordBase – is available to automatically collect and store records from multiple recorders. RecordBase provides fast network-based access to collected records through distributed RecordBase View desktop clients.

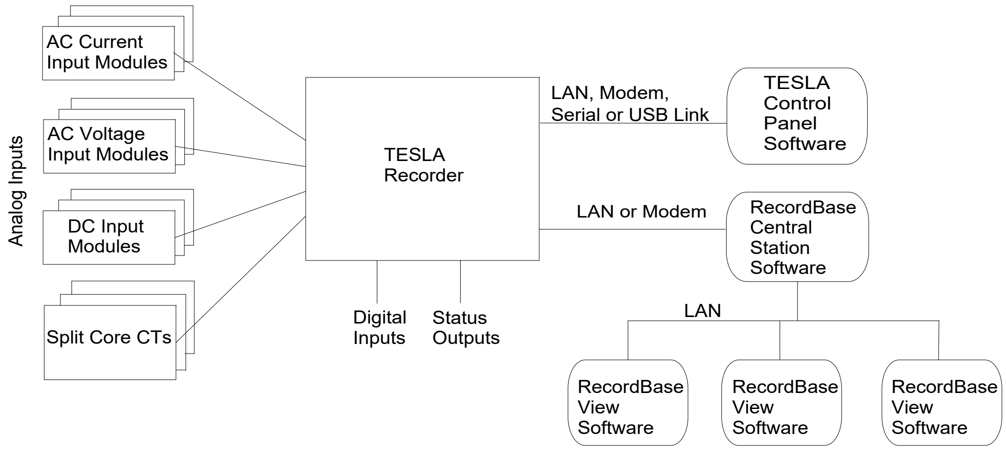


Figure 1.1: TESLA System Overview

1.2 TESLA 4000-A Features

Installation

- 19" rack-mount format
- Small 3U footprint
- Analog input isolation modules for AC and DC input signals are DIN-rail mounted to minimize rack usage and can be located up to 1220 meters from the main unit for flexible installation
- Analog input modules interface with standard signals: 1A/5A nominal AC currents, 69V (120√3) nominal AC voltage, DC current or voltage

Data Acquisition

- Up to 64 external (digital) input channels
- 256 GOOSE Virtual Input channels
- Simultaneous operation in transient fault, dynamic swing and long term trend time frames
- Sample rate for transient fault recording: 32, 64, 96, 128, 256, 384 or 512 samples per cycle
- 60 or 120 samples/second (1 or 2 samples/cycle) dynamic swing recordings
- Continuous trend logging at sample intervals from 10 seconds to one hour
- Continuous disturbance recording at rates from 6 samples/second to 60 samples/second at 60 Hz, from 5 samples/second to 50 samples/second at 50 Hz.
- Calculated channels: summations, watts, vars, power factor, positive, negative and zero sequence components, impedance, THD, fault location, frequency and harmonics

Triggers

- Rates and level triggering on all input and calculated channels with individual controls for delay, logging, record initiation and alarm contact activation
- Configurable logic channels for creating custom triggers
- User-assigned trigger priorities help identify critical events and records
- IEC 61850 recording triggering via 256 Virtual Inputs (GOOSE)

Records

- Transient fault records from 0.2 to 15.0 seconds with automatic record extension up to 30.0 seconds under multiple trigger conditions
- Dynamic swing record from 10 seconds to 15 minutes with automatic record extension up to 30 minutes under multiple trigger conditions
- Combined transient and swing records can capture a fault and the resultant system dynamic response
- Record compression to reduce record size, maximize storage capacity and minimize transmission time

Cooperative Group/GRT

- Up to 4 recorders can be operated as a cooperative group or up to 8 recorders can be operated as a GRT
- Automatic cross triggering over a LAN with time source synchronized time stamps

- Automatic record retrieval with consolidation into a single group record

Logging

- 1000 entries event log (circular)
- 90 day analog measurement trend log (circular or alarm when full)
- 90 day long-term event log (circular or alarm when full)
- Voltage sag and swell logging

Fault Location

- Automatic fault location on up to 10 lines
- Fault location data available in the event log, in recording as well as IEC 61850 and DNP3

User Interface

- Intuitive power system element model simplifies complex configurations
- Integrated record and configuration management tools
- Offline mode allows records to be viewed and configurations created without connecting to the recorder
- Record display shows record summaries with trigger event lists so that a preliminary evaluation can be made before the record is transferred
- Real-time metering display shows all input and calculated quantities in user-customizable layouts

Analysis Tools

- Recorder configuration and event information is embedded in each record
- Record graphics provide a flexible multi-page interactive display and measurement of all channels including calculated ones
- COMTRADE record export facility

Output Contacts

- Six user-configurable output contacts can be activated by triggers
- Cross-trigger contact can activate other devices
- Recorder inoperative contact

Communication Ports and Network Redundancy

- Front USB 2.0 interface, Rear serial RS-232 COM port
- Front copper and rear copper or optical Ethernet ports
- Optional PRP/RSTP network redundancy

Communication Protocols

- Standard TCP/IP used to communicate with TESLA Control Panel
- IEC 61850 Station Bus (GOOSE and MMS)
- PMU
- Syslog (RFC 5426)
- FTP
- DNP3
- Modbus

Time Coordination

- IRIG-B time code input - modulated or unmodulated. Supports IEEE 1344 and IEEE C37.118 extensions.
- PTP (IEEE 1588) synchronization (only available if hardware supports network redundancy).
- 1 ms event timetagging of events and records
- Time synchronization indicator in each record

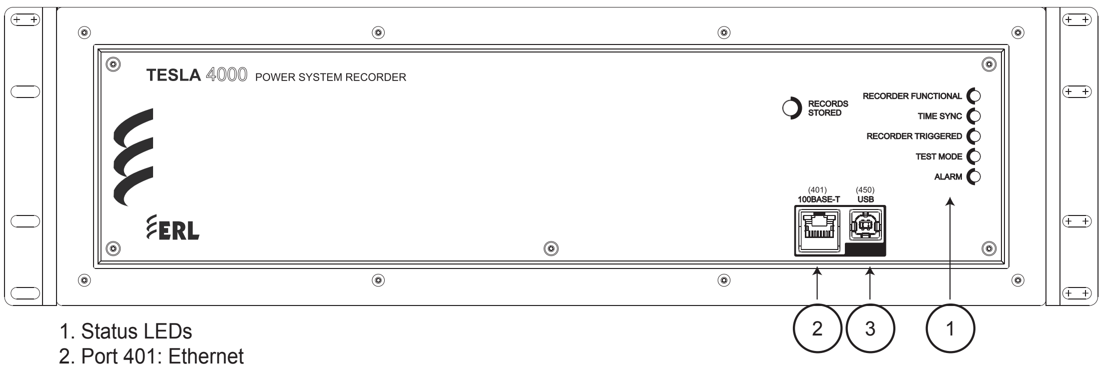
Reliability

- Self-monitoring supervisory software with self-checking circuit and failure contact ensures reliable operation
- Flash memory for record storage with separate Flash memory for program storage
- Compliance with IEC standards for temperature range, transient withstand and RF immunity

1.3 Ordering Options and Product Configuration ID

The TESLA 4000-A is available with many different configurations available at time of ordering. When each of the options are concatenated, they form the Product Configuration ID (example: TESLA 4000 A2-16-0-0-0-60-0-0-0-0-A). See the ordering template at https://www.erlphase.com/downloads/specifications/TESLA_4000_A_power_system_recorder_ordering_template.pdf for more details.

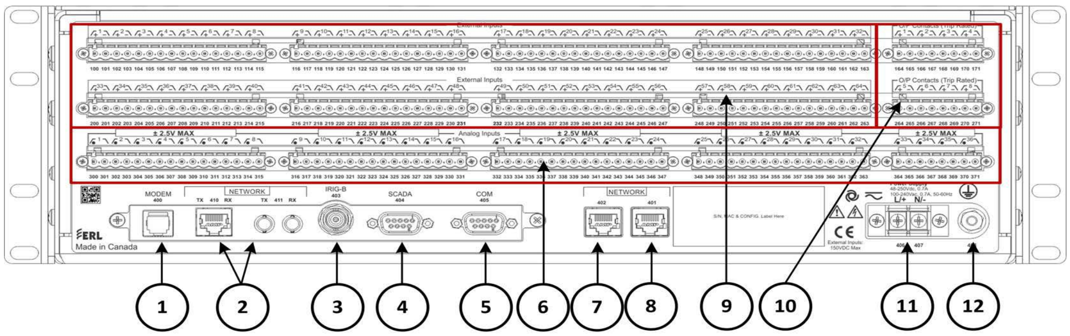
1.4 Front Panel



1. Status LEDs
2. Port 401: Ethernet
3. Port 450: USB

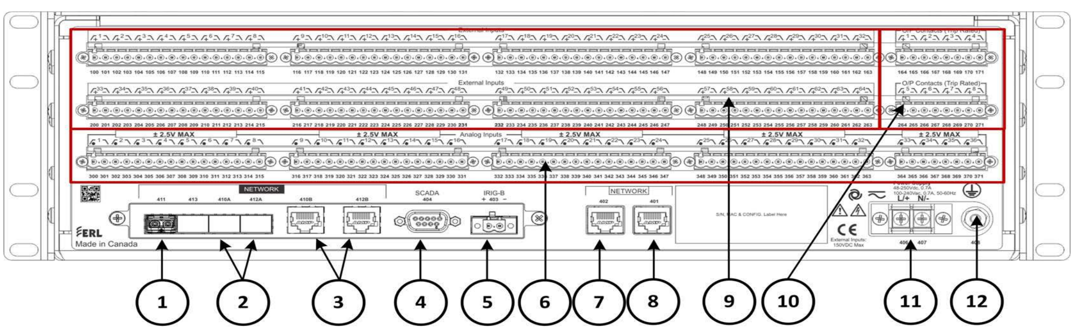
Figure 1.2: Front Panel

1.5 Rear Panel



1. Port 400: Internal Modem (option)
2. Port 410 – 411: Port 410 100 BASE-T and Port 411 100 Base-FX Ethernet Network
3. Port 403: IRIG B External Clock, modulated or unmodulated
4. Port 404: EIA 232 SCADA Communication (DNP 3 and Modbus)
5. Port 405: EIA 232 Serial Connection for PC or an external modem
6. Port 300 – 335 (18), Ports 300 – 371 (36): Analog Input Channels. Non-isolated
7. Port 402: 1000 BASE-T Ethernet Network Port
8. Port 401: 100 BASE-T Ethernet Network Port
9. Port 100 – 163 (32), Ports 100 – 163 & 200 – 263 (64): External Inputs channels
10. Ports 164-171 (4); Ports 164-171 & 264-271 (8): Output Contacts
11. Port 406 – 407 : Power Supply (48 to 250 Vdc, 100 to 240 Vac)
12. Port 408: Chassis Ground

Figure 1.3: Rear Panel, LAN Media Option 0, no redundancy



1. Port 411: 100Base-FX Optical Ethernet port
2. Port 410: 100Base-FX Optical Ethernet port, redundant, Port 410A and Port 412A - Optional
3. Port 412: 100Base-T Copper Ethernet port, redundant, Port 410B and Port 412B
4. Port 404: EIA 232 SCADA Communication (DNP 3 and Modbus)
5. Port 403: IRIG B External Clock, modulated or unmodulated
6. Port 300 – 335 (18), Ports 300 – 371 (36): Analog Input Channels. Non-isolated
7. Port 402: 1000Base-T Copper Ethernet port
8. Port 401: 100Base-T Copper Ethernet port
9. Ports 100 – 163 (32), Ports 100 – 163 & 200 – 263 (64): External Inputs channels
10. Ports 164-171 (4); Ports 164-171 & 264-271 (8): Output Contacts
11. Port 406 – 407 : Power Supply (48 to 250 Vdc, 100 to 240 Vac)
12. Port 408: Chassis Ground

Figure 1.4: Rear Panel, LAN Media Option 3, redundant

Not all possible ordering configurations are shown in the diagram above.

2 Installation and Safety Instructions

2.1 Introduction

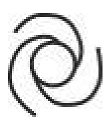
This section deals with the installation of the TESLA power system recorder when first delivered. The section covers the physical mounting, AC and DC wiring and the Communication wiring.

The following symbols are used in this manual and on the unit. They should be understood before working on the unit:

Caution: refer to equipment documentation

Caution: risk of electric shock

Protective Earth (or Ground) Terminal



Autoranging power supply

Both direct and alternating current

The equipment ratings, operating instructions and installation instructions shall be checked before commissioning or maintenance. It is the responsibility of the user to ensure that the equipment is installed, operated and used for its intended function in the manner specified in this manual. If this is not the case then any safety protection provided by the equipment may be impaired.

2.2 Physical Mounting

The recorder is designed to be mounted in a standard 19-inch equipment rack. It is 3 rack units (5.25 inches) high and 12.725 inches deep. An additional 3 inches of depth is required for rear connections and cables. A complete mechanical drawing is shown in “TESLA 4000-A Drawings” on page Appendix I-1.

To install the relay the following is needed:

- 19 inch rack
- 4 - #10 or M6 screws

WARNING!

This equipment is intended for use by trained personnel in restricted areas only. Hazardous voltages may be present at the rear of the unit and a suitable protective barrier must be provided to protect against electric shock due to accidental contact.

2.3 Case Grounding

WARNING!

The ground terminal (also known as the protective earth) on the rear of the unit and the modules must be connected as shown in Figure 2.1: Protective Earth Connection on page 2-3 before the unit is energized in order to prevent electric shock. Refer to the diagram of the rear of the unit, “Rear Panel, LAN Media Option 0, no redundancy” on page 1-7 for the location of the ground terminal. The protective earth connection shall be checked before carrying out any other actions and shall not be removed when the unit is energized.

The terminal used must be made of a material that is galvanically compatible with the zinc plated washers, nut and stud provided with the unit. Tinned terminals are acceptable. The recommended minimum protective earth conductor wire size is 3.3 mm² unless otherwise required by local or country wiring regulations. Copper wire is recommended and must be must be low-inductance and as short as possible.

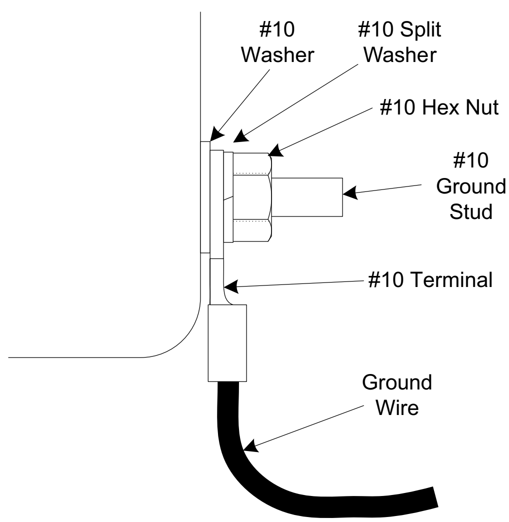


Figure 2.1: Protective Earth Connection

2.4 Power Supply

A wide range power supply is standard. The nominal operating range is 48 - 250 V_{DC}, 100 - 240 V_{AC}, 50/60 Hz (see Appendix A for more details). External overcurrent protection is required for the TESLA power supply input (5A 250V time delay, high breaking capacity fuse or 5A, 250V single pole circuit breaker in the AC LINE or DC POSITIVE power input connection).

Ensure that the chassis is grounded for proper operation and safety. The wire used for the power supply wiring should be at least 18 AWG (0.82 mm^2), 600 V.

There are no power switches on the recorder. When the power supply is connected, the recorder starts its initialization process. See “Startup Sequence” on page 2-9 for the start up process details.

#6 ring or spade terminals must be used to connect to the power supply terminals. Bare wires should never be terminated directly to the screw terminals.

The use of an external surge protection device is required to pass the surge im-munity requirements of IEC/EN 60255-22-5 Criterion A. Suitable surge ar-res-tors are to be selected and installed to limit to 1.1KV (L-N) and 1.5KV (L-PE) levels with suitable energy handling capacity. Contact ERLPhase technical support for assistance in selecting an appropriate device if needed.

One surge protector can be used to protect multiple units as long as the current limit of the surge protection device is not exceeded.

Note that this is a consumable item and not covered by ERLPhase warranty.

2.5 Signal Connections

Wiring

Pluggable terminal blocks are used for the external inputs and output contacts on the rear of the TESLA. The maximum strip length of the wire installed into these connectors should not exceed 7 mm.

Shielded wire shall be used for all connections that run outside of the panel in which the TESLA is installed. Unless otherwise specified in this manual, for inputs to the TESLA the shield must be grounded only at one end at the point where the cable enters the panel. The IRIG input is the ONLY exception which uses unbalanced co-ax cable.

In addition the individual port cabling shall comply with the following:

- External Inputs: 28 AWG (0.08 mm^2), 600 V minimum AWG and voltage rating
- Output Contacts: Minimum 16 AWG (1.31 mm^2), 600 V minimum AWG and voltage rating
- DCE ports 405: 10m Maximum cable length
- RJ-45 ethernet ports: shielded CAT5 or better cable
- 5 A current Inputs: 10 AWG (5.26 mm^2), 1000 V
- A current inputs: 14 AWG (2.08mm^2), 600 V
- Voltage inputs: 14 AWG (2.08 mm^2), 600 V

> Ensure the power supply input and the AC and DC wires are de-energized before working on the wiring. Failure to do so could result in electric shock.
>
> CT circuits shall be short-circuited before working on the current input wires.

Analog Input Channels and Input Modules

The recorder's analog inputs are generic, low level (+-2.5 V pp) non-isolated signal inputs. They take their input from external interface modules that provide scaling, isolation and surge protection.

The external input modules accept conventional substation voltage and current signals and convert them into low level voltages that are fed into the recorder's analog inputs. All modules are available for DIN rail mounting to make wiring easier and minimize rack space requirement. For added flexibility, some modules are also available in a surface mount or rack mount configuration.

Modules can be located up to 1220 meters (4000 feet) from the recorder. The wire used for the connection between the modules and the recorder can range in size from 12 to 28 AWG. 12 to 20 AWG is recommended if the modules are more than 200m from the TESLA. It is highly recommended that twisted-shielded wire be used for cables that are run outside of the panel in which the

TESLA is located. Belden 9388, or its equivalent, is an example of an acceptable cable that can be used.

Any of the recorder's analog input channels can be connected to any of the available input modules. The software configuration identifies the type of input module associated with each channel.

WARNING!

Applying signals greater than ± 2.5 V pp to the analog inputs will result in permanent damage to the unit and may result in electric shock. These inputs should only be connected to ERLPhase input modules or voltages within the specified range.

Each external module input channel can only be connected to one recorder input channel. Source and load impedance matching are used to minimize noise susceptibility; connecting to two channels will produce incorrect readings.

All input modules must be grounded via the ground stud on the module.

Re-calibration is required whenever an input module is replaced or moved to a different channel (see "Analog Input Calibration" on page 8-28)

Input Module Types

For further information on the input modules, see “Input Modules” in Appendix G.

AC Voltage Input Module

The AC Voltage Input Module provides 3 channels or 4 channels of isolation and scaling for standard secondary voltage. Inputs are AC coupled through transformers. The 401006 and 401026 models nominal signal level is 69 V_{RMS} (120/√3) with a full-scale 2x over-range capability that can be sustaining continuously. The 401028 model nominal signal level is 600 V_{RMS} with a full-scale rating of 720 V_{RMS} continuous.

AC Current Input Module

The 4 channel AC current input module provides isolation and scaling for standard current signals.The module’s channels are connected in series with the current signal source.

The Model 401025 module has a configurable dynamic range of 10x, 20x (default) or 40x nominal current and has both 1 A and 5 A inputs.

The Model 401014 and Model 110739 modules have a dynamic range of 20x nominal current with a 5 A nominal current.

The Model 401020 module has a dynamic range of 20x nominal current with a 1 A nominal current.

Split Core CT

The Split Core CT is designed to clamp around the secondary circuit wires of a primary current transformer. It is intended for situations where an outage is not possible to connect an in-line CT. The outputs from the CT are impedance matched to connect directly to the TESLA’s analog input connectors. There are 1A and 5A variants with a dynamic range that can pass 20x nominal currents continuously and another 5A variant that can pass 40x nominal currents continuously.

Model 401013 has a nominal signal level of 5 A_{RMS} (20x)

Model 401013-2 has a nominal signal level of 5 A_{RMS} (40x)

Model 401017 has a nominal signal level of 1 A_{RMS} (20x)

AC/DC Module

The AC/DC Input Modules (Models 401016 and 401027) provide DC-coupled isolation and scaling for DC or AC voltage or current channels. The Model 401016 offers 4 channels and the model 401027 offers 3 channels. AC/DC Input Module channels have a DC to 2 kHz bandwidth, but the bandwidth may be limited by the recorder’s input filters, depending on the sample rate. Externally mounted shunt resistors are required for current measurements. Output from the module is scaled to connect directly to the TESLA’s analog input terminals.

In order to configure the AC/DC Input Module (Model 401027) a PC software tool, available on the ERLPhase website, must be installed. This AC-DC Input

Module Configurator Tool is used for configuring each the channels of the module for use with Voltage or Current and AC or DC. It also provides visual guidance for wiring of the Module. A standard USB cable with a USB-B connector on the AC/DC Input Module end is required for communicating between the computer running the AC/DC Input Module Configurator Tool and the module.

External Input Channels

The recorder's external inputs are dry inputs intended for use with signals from a 48 - 250 V_{DC} station battery (3 order configurable input levels, see Appendix A for more details). The external inputs are isolated and protected against transient surges.

Alarm Contacts

The alarm contacts on the rear of the unit are dry contacts. They are isolated and protected against transient surges. The contacts are designated as follows:

1. Recorder Inoperative. Closed on failure
2. User-configurable
3. User-configurable
4. Cross-trigger
5. User-configurable
6. User-configurable
7. User-configurable
8. User-configurable

The cross-trigger contact is used to initiate recording on another recorder when this unit triggers. When activated, the cross-trigger contacts close for 0.10 seconds, regardless of the duration of the triggering condition. This ensures that the cross-trigger function does not become blocked by a continuous trigger condition.

The user-configurable alarm contacts can be defined for use as part of the recorder's trigger configuration.

IRIG-B Time Signal

The IRIG-B input provisions on the rear of the unit accepts either modulated or unmodulated IRIG-B time signals, with or without the 1344 extensions.

Communication Ports

See "Ports" on page 4-1.

2.6 Startup Sequence

Table 2.1: Startup Sequence

For ~20-30 seconds after Power Up	Front panel Test Mode LED turns on to indicate the presence of power.
~20-30 seconds after Power Up	Test Mode LED turns off
~40-50 seconds after Power Up	Records Stored and IRIG Functional LEDs turn on, if records are stored and IRIG source is present, respectively.
~70-80 seconds after Power Up	Test Mode LED turns on
~80-100 seconds after Power Up	Recorder Functional LED turns on. Test Mode LED turns off. The Startup Sequence is complete.

If the flash drive is almost full there may be some delay to this sequence.

2.7 Front Panel LEDs

Table 2.2: Front Panel LEDs

Front Panel LED	Indications
Recorder Functional	Normally active green LED that is turned on approximately 25-30 seconds after power up, indicating the unit is functional. If an internal fault is detected, the LED is turned off. The LED state corresponds directly with the Recorder Inoperative.
Tyme Sync	Green LED that is active when a valid external time synchronization signal is detected either IRIG-B, SNTP or PTP.
Recorder Triggered	Green LED that is active while the recorder is in the process of creating a record
Records Stored	Green LED that turns on when there are records stored in the recorder's memory. The LED will flash to indicate the Storage Alarm limit has been reached if so configured
Test Mode	Normally inactive red LED that turns on immediately on power up and goes of after the self-test has been completed (approximately 20-30 seconds)
Alarm	Normally inactive red LED that indicates a failure has been detected by the software. The presence of the Alarm LED means much of the system is functioning and can be accessed for diagnosis

3 TESLA Control Panel Installation

> Installation of TESLA Control Panel software may require changes to your Windows system configuration for proper operation. Please review the instructions in this chapter to ensure proper setup.

3.1 Installing TESLA Control Panel

You must be logged on to the target computer as a user with local administrator privileges to install TESLA Control Panel. Once installed, you may be logged in as a Limited User, as administrator privileges are not generally required for operation of the program.

Overview

Instructions for installing TESLA Control Panel and configuring Windows for its use are covered in the following sections.

The procedure has the following parts:

1. Install TESLA Control Panel.
2. Install the Null Modem driver.

> Once these steps are complete, go to the First Time Start-Up section for details on launching TESLA Control Panel (see “First Time Start-Up” on page 3-9).

> The user must install ERLPhase’s USB driver, available at www.erlphase.com. See section “USB Link” on page 6-2 for instructions.

Step 1: Install TESLA Control Panel Software

1. Go to www.erlphase.com and navigate to *Support > Software* where the TESLA Control Panel installation link is available.
2. Click the installation link which downloads a EXE file containing the TESLA Control Panel installer.
3. Open up the downloaded EXE file and double-click on the installer to begin the installation.
4. Follow the installation prompts. During installation a prompt appears asking whether your TESLA recorders are 50 Hz or 60 Hz units. For proper operation it is important to select the correct one. If you need to change this in the future, re-install TESLA Control Panel.
5. When the installation is complete, a TESLA Control Panel icon is placed on the desktop. Use the icon to launch TCP. If preferred, start TESLA Control Panel through the Windows start menu (*Start>Programs>ERLPhase> TESLA Control Panel)*

Step 2: Install USB Driver

Serial communication with the TESLA 4000-A may be achieved through the front panel USB serial port provided. Driver installation is required for proper serial connection and communication with the TESLA 4000-A. Install the driver before connecting the USB cable from the PC to the TESLA 4000-A.

The following procedure is used to install the ERLPhase USB Driver on a computer which will be used to communicate through the front USB port.

1. Download the ERLPhase_USB_Driver_Setup_v1.exe file from the ERLPhase Website (Support/Software).
2. Click on the "USB Driver" item to start the installation.
3. Allow the installation to continue (click on Yes) when you see the following pop-up:

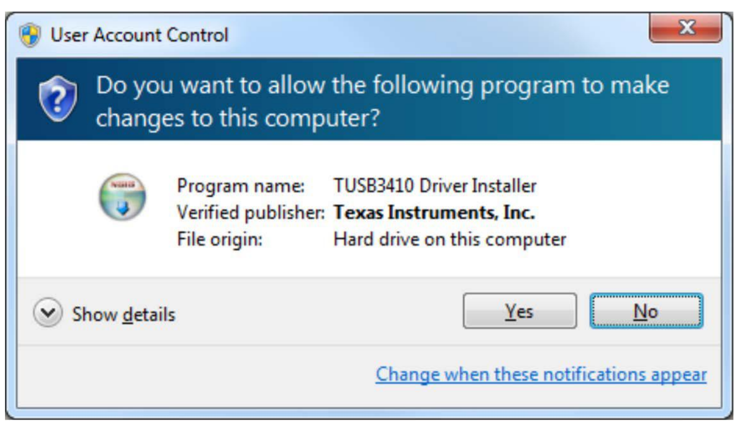


Figure 3.1: User Account Control warning screen for driver installation

4. The following install wizard will start up and install the TUSB3410 driver to the computer. At this time **do not attach** the USB cable to the front of the recorder.
5. Continue to follow the Install Wizard prompts.

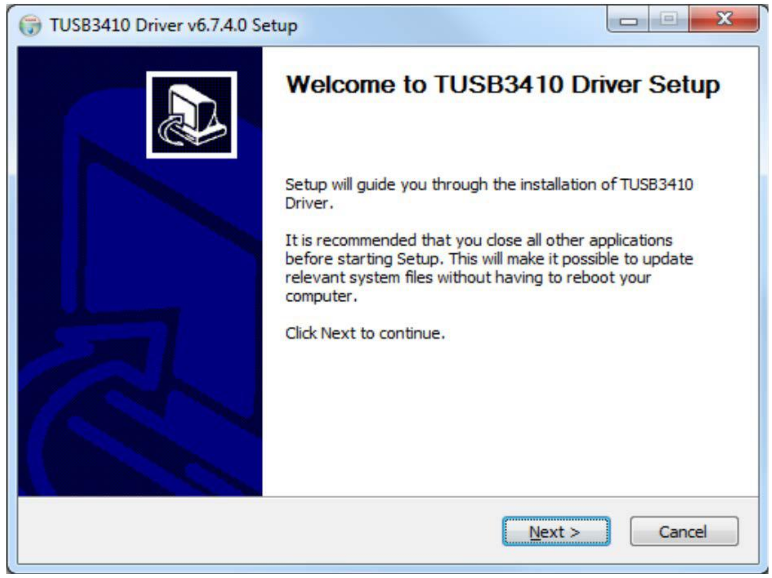


Figure 3.2: USB driver installation set-up screen

6. Users must “accept the terms of the license agreement” to successfully install the USB driver.

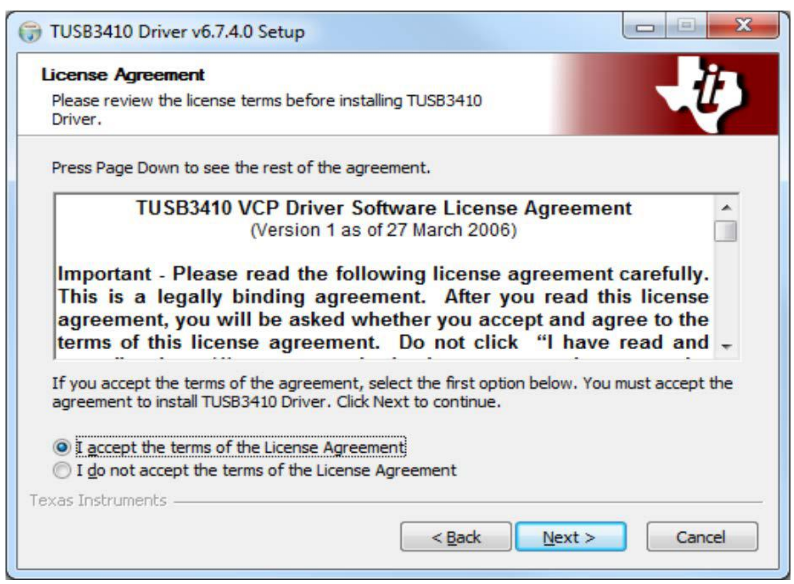


Figure 3.3: USB driver license agreement screen

7. Choose the Install Location

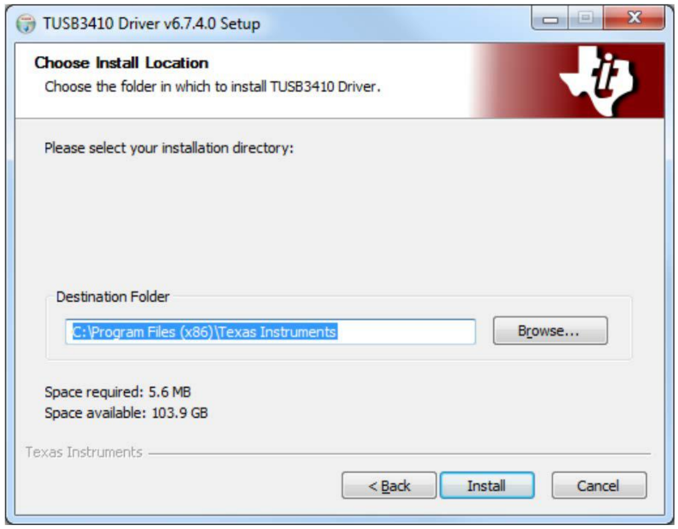


Figure 3.4: Choose install location screen

8. The “Installing” window should show progress.

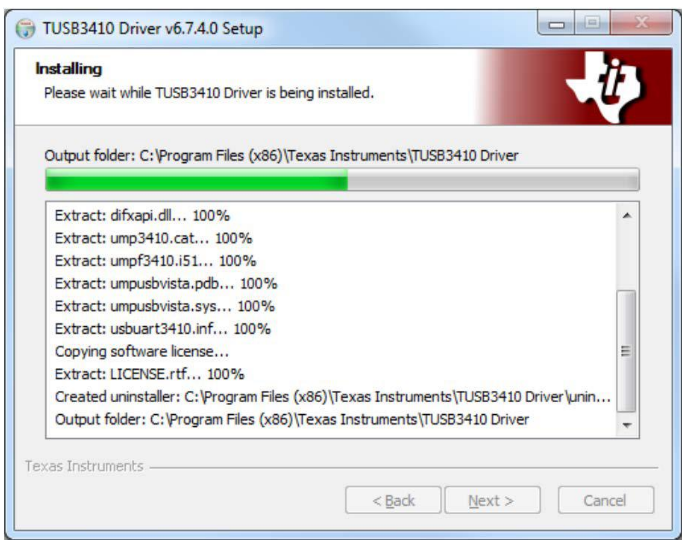


Figure 3.5: Installation progress screen

9. Click “Finish” and the USB drive is installed on the computer.

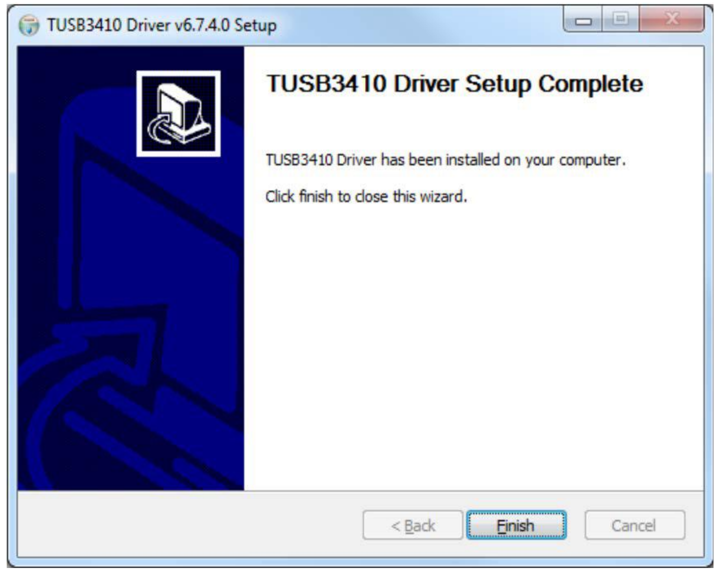


Figure 3.6: USB driver finishing screen

10. Now connect the USB cable between the TESLA 4000 and computer. This will give “Installing device driver Software” pop up at the bottom right corner of the task bar.

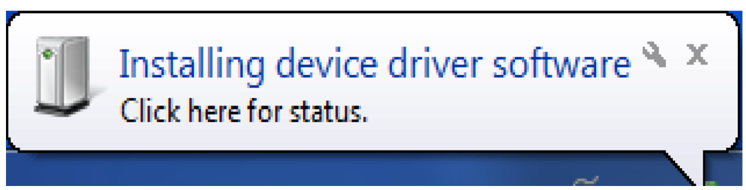


Figure 3.7: USB driver found new hardware pop up

11. Within a couple minutes “Device driver software installed successfully” pop up appears with the COM#

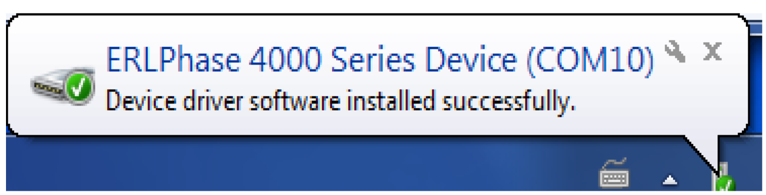


Figure 3.8: Driver found new hardware pop up

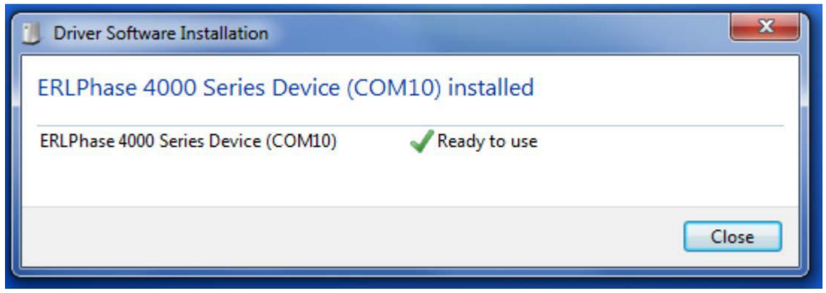


Figure 3.9: Driver installed screen

12. The following steps will verify that the USB driver has been installed. Open Windows Control Panel. Select and click on the Device Manager Icon.

13. The following screen will verify that the new USB port (COM port) is installed. Please note that the PC needs to be connected to the USB port in the front panel of the IED.

Expand the “Ports (COM & LPT)". You will see New COM port has been added:

ERLPhase 4000 Series Device (COM#)

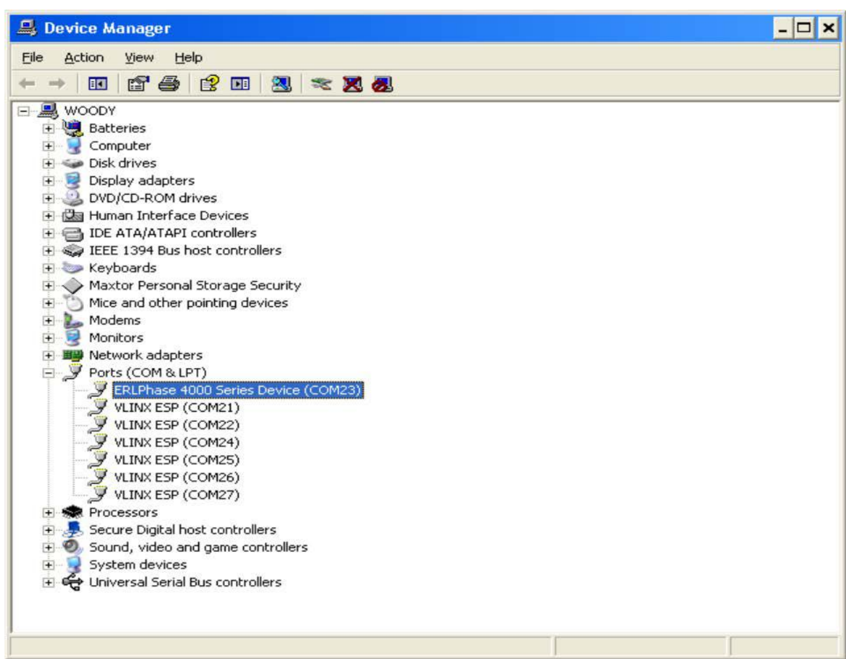


Figure 3.10: Device Manager screen

Step 3: Installing Null Modem Driver Software

A virtual software modem called a “Null Modem” must be set up for direct serial cable communication between this computer and a TESLA recorder. A Null Modem driver is provided with the TESLA installation.

This section provides step by step instructions on how to install the Null Modem driver. If you are going to communicate with a 4000 series product please ensure that you connect your computer to the front USB port of a powered up 4000 series unit prior to following these steps.

1. Start Windows Control Panel by going to *Start>Control Panel*.
2. Double-click the *Phone and Modem Options* icon.
3. Select the *Modems* tab. Select *Add* to open the Add Hardware Wizard.
4. Select *Don't detect my modem; I will select it from a list,* then select the *Next* button.

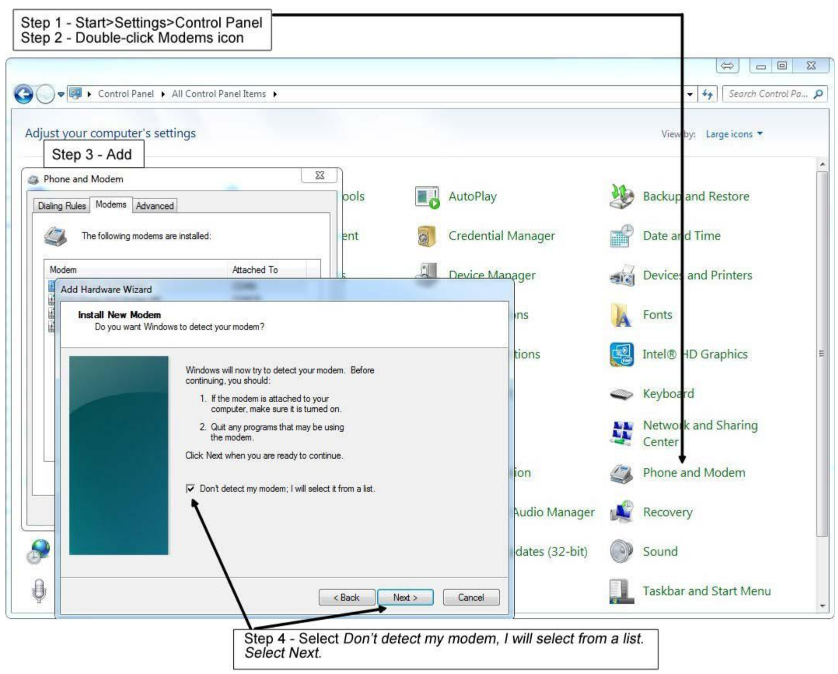


Figure 3.11: Null Modem Driver Installation

5. Select the *Have Disk* button, select *Browse*. To find the file go to *C:\Program Files (x86)\ERLPhase\TESLA Control Panel\Null_mdm.Inf.* Select *OK*. This is the default location for TESLA Control Panel. If you selected a different location to install TESLA Control Panel, you will find the Null Modem driver (Null_mdm.Inf) in that directory.

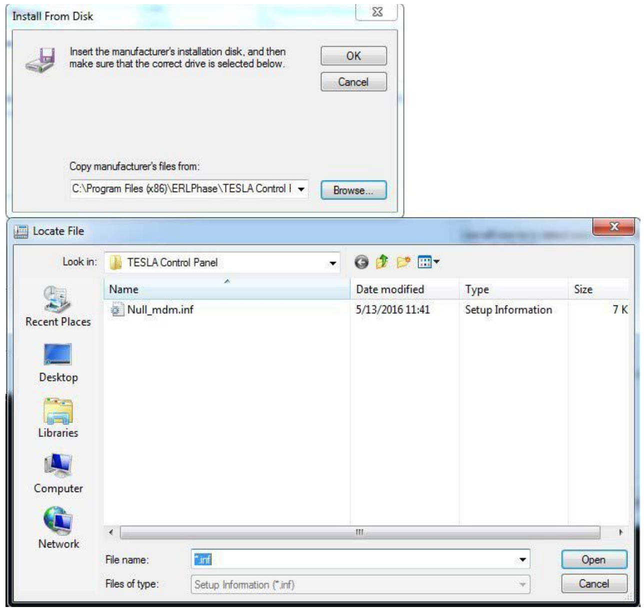


Figure 3.12: Browse for Null_mdm.Inf

6. Select the *ERLPhase Null Modem* driver and select *Next*.

7. Select the serial port you wish to use. You are setting up a serial port to be used for a direct cable connection to a TESLA. Typically COM1 or COM2 are available on a PC for this purpose. Select *Next.*

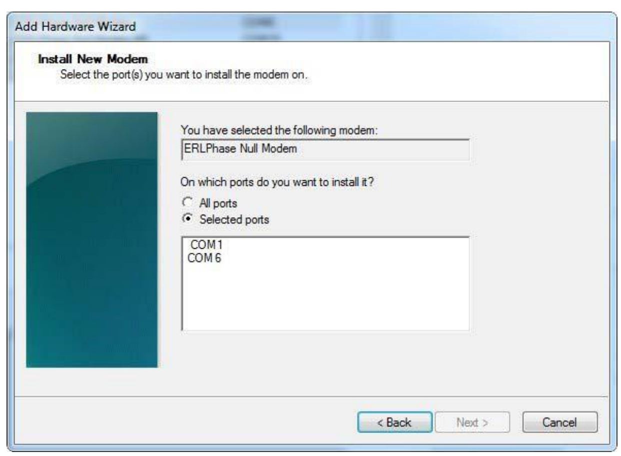


Figure 3.13: Select Serial Port

8. Select *Finish* and close the Phone and Modem Options and Control Panel dialog boxes.

3.2 First Time Start-Up

Starting TESLA Control Panel

To start TESLA Control Panel, double-click the *TESLA Control Panel* icon placed on your desktop by the installation process or select *Start>Program Files>ERLPhase>TESLA Control Panel.*

Data Location

TESLA Control Panel uses a data location on your computer to store records and settings from your recorders. By default it is *C:\Program Files (x86)\ERLPhase\TESLA Control Panel,* although you may change this later by using the *File\Data Location* command from the Main Menu.

> When you change the data location, previously configured IEDs will not be affected. Only newly created IEDs will use the new data location. To edit the data location of existing IEDs use the Main Menu *Edit* button.

> Note Microsoft Windows security may prevent non-Administrative user accounts from storing data under *C:\Program Files(x86)*; it may be necessary to change the default record and config storage locations for the IEDs.

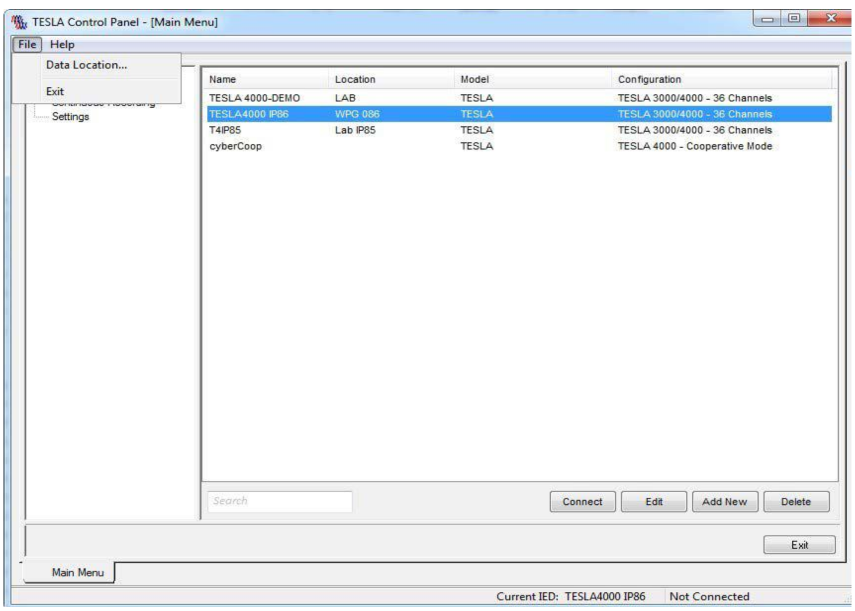


Figure 3.14: Data Location

4 Ports

This chapter describes the ports that are used to communicate with the TESLA 4000-A and the communication options available to establish a connection with the TESLA 4000-A.

4.1 Communication Ports

The TESLA recorder has multiple physical communication ports for local and remote access to its user interface and communication services.

The network ports and their available speeds and services are summarized in the table below.

Table 4.1: Summary of Network Communication Ports

Network Port	Physical Connection	Speed	Available services					
			PTP[a]	PRP/RSTP[a]	IEC61850 GOOSE Publish	IEC61850 GOOSE Subscribe	IEC61850 MMS	TESLA Control Panel, FTP, PMU
401	RJ45	100M	No	No	Yes	Yes	Yes	Yes
402	RJ45	GigE	No	No	Yes	Yes	Yes	Yes
410/412	RJ45 or LC	100M	Yes	Yes	Yes	Yes	Yes	Yes
411	LC	100M	No	No	Yes	Yes	Yes	Yes

a. Only available if ordered with redundancy selection 1, 2 or 3 (see “Ordering Options and Product Configuration ID” on page 1-6)

Detailed descriptions of all of the communication ports capabilities are described in Table 4.2: Communication Ports - Non-Redundant Configuration and Table 4.3: Communication Ports - Redundant Configuration.

Table 4.2: Communication Ports - Non-Redundant Configuration

The non-redundant configurations are LAN Media Options 0, 1 and 2. Refer to “Ordering Options and Product Configuration ID” on page 1-6 for more details.

Port	Function
Front Panel	
401	RJ-45 receptacle, 100BASE-T Ethernet interface. Default IP = 192.168.100.80 Maintenance Port.
450	USB-B receptacle, High speed USB 2.0 interface. Used for user interface access Default fixed baud rate 115,200 N81 (no parity, 8 data bits, 1 stop bit)
Rear Panel	
400	RJ11 receptacle, Internal modem interface.
401	RJ-45 receptacle, 100BASE-T Ethernet Interface. Refer to Table 4.1 for details on available port services. Same IP address as front panel Port 401.
402	RJ-45 receptacle, 1000BASE-T (GigE). Default IP = 192.168.101.80. Refer to Table 4.1 for details on available port services.
403	BNC receptacle, IRIG-B Interface. Modulated or un-modulated, 680 ohm impedance
404	RS-232 DCE female DB9. This port allows connectivity to SCADA by means of serial communications.
405	RS-232 DCE female DB9. Used for user interface and communication protocol access.
410	RJ-45 receptacle or ST type optical receptacle (ordering option). 100BASE-T or 100BASE-FX (1300nm, multi-mode) Ethernet interface. Refer to Table 4.1 for details on available port services. Default IP = 192.168.102.80
411	RJ-45 receptacle or ST type optical receptacle (ordering option). 100BASE-T or 100BASE-FX (1300nm, multi-mode) Ethernet interface. Refer to Table 4.1 for details on available port services. Default IP = 192.168.103.80

When configured with optical network ports, this is a Class I laser product and is considered safe. However, viewing fibre-optic output ports directly is not recommended.

Table 4.3: Communication Ports - Redundant Configuration

The Redundant configurations are LAN Media Options 3 and 4. Refer to "Ordering Options and Product Configuration ID" on page 1-6 for more details.

Port	Function
Front Panel	
401	RJ-45 receptacle, 100BASE-T Ethernet interface. Default IP = 192.168.100.80. Maintenance Port.
450	USB-B receptacle, High speed USB 2.0 interface. Used for user interface access Default fixed baud rate 115,200 N81 (no parity, 8 data bits, 1 stop bit)
Rear Panel	
401	RJ-45 receptacle, 100BASE-T Ethernet Interface. Refer to Table 4.1 for details on available port services. Same IP address as front panel Port 401.
402	RJ-45 receptacle, 1000BASE-T (GigE). Default IP = 192.168.101.80. Refer to Table 4.1 for details on available port services.
403	Pluggable terminal block, IRIG-B Interface. Modulated or un-modulated, 680 ohm impedance
404	RS-232 DCE female DB9. This port allows connectivity to SCADA by means of serial communications.
411	LC type optical receptacle,1300nm multi-mode, SFP (small form-factor pluggable), 100BASE-FX Ethernet Interface. Default IP = 192.168.103.80. Refer to Table 4.1 for details on available port services. SFPs should only be installed or removed when the unit is powered off.
410A	Redundant with Port 412A. LC type optical receptacle, 1300nm multi-mode, SFP (small form-factor pluggable), 100BASE-FX Ethernet Interface. Default IP = 192.168.102.80, Network Redundancy Service Default IP = 192.168.102.81. Refer to Table 4.1 for details on available port services. Port is only active when an SFP transceiver is installed. When an SFP is installed it will disable 410B. SFPs should only be installed or removed when the unit is powered off.
412A	Redundant with Port 410A.LC type optical receptacle, 1300nm multi-mode, SFP (small form-factor pluggable), 100BASE-FX Ethernet Interface. Default IP = 192.168.102.80, Network Redundancy Service Default IP = 192.168.102.81. Refer to Table 4.1 for details on available port services. Port is only active when an SFP transceiver is installed. When an SFP is installed it will disable 412B. SFPs should only be installed or removed when the unit is powered off.
410B	Redundant with Port 412B. RJ-45 receptacle, 100BASE-T Ethernet Interface. Default IP = 192.168.102.80, Network Redundancy Service Default IP = 192.168.102.81. Refer to Table 4.1 for details on available port services. Port is disabled when SFP is installed in Port 410A.
412B	Redundant with Port 410B. RJ-45 receptacle, 100BASE-T Ethernet Interface. Default IP = 192.168.102.80, Network Redundancy Service Default IP = 192.168.102.81. Refer to Table 4.1 for details on available port services. Port is disabled when SFP is installed in Port 412A.
413	**CURRENTLY NOT USED.**

4.2 Serial Ports

The serial port 405 is configured as EIA RS-232 DCE devices with female DB9 connectors. This allows them to be connected directly to a PC serial port with a standard straight-through male-to-female serial cable.

A modem adapter is available to convert a port into a DTE device, equivalent to the serial port on a PC. The adapter allows you connect an external modem to the recorder’s Port 405 using a standard modem cable.

Table 4.4: TESLA Recorder Serial Ports

Port	Location	Function
405	Rear Panel	Serial port for connection to an external modem or for direct connection to a computer (configurable). Default baud rate set at 38,400 baud. Feature not available on all IED configurations.
404	Rear Panel	Connection to SCADA (DNP3 or Modbus) interface. Default baud rate set at 19,200 baud.

Table 4.5: Signal connections to pins on Recorder Port

Signal Name	Direction PC<->IED	Pin # on the IED Port
DCD	←	1
RxD	←	2
TxD	→	3
DTR	→	4
Common		5
DSR	←	6
RTS	→	7
CTS	←	8
No connection		9

Notes:
IED is DCE, PC is DTE.
Pins 1 and 6 are tied together internal to the IED.

Table 4.6: Cable Pin Connections	
Male DB-9 Cable End for IED Port	**Female DB-9 Cable End for Computer Port**
Pin # on Cable	Pin # on Cable
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9

Table 4.7: Signal name connections to pins on Modem Adapter		
Signal Name	**Direction Modem <-> IED**	**Pin # on the Modem Adapter**
DCD	→	1
RxD	→	2
TxD	←	3
DTR	←	4
Common		5
DSR	→	6
RTS	←	7
CTS	→	8
No connection		9

Notes:
IED (with modem adapter) is DTE, modem is DCE.
Pins 1 and 6 are tied together internal to the IED.

4.3 IRIG-B Time Input

The TESLA is equipped to handle modulated or unmodulated GPS satellite time IRIG-B signals. The IRIG-B time signal is connected to the port 403 IRIG-B connection on the back of the recorder (BNC or pluggable terminal block). When the IRIG-B signal is provided to the recorder the Time Sync LED comes on and the recorder clock is referenced to this signal. No settings are required to differentiate between modulated or unmodulated signals; this is automatically detected by the recorder.

For more information on IRIG-B time input and time settings see "Time Synchronization Settings and Display" on page 8-15.

4.4 Network Redundancy

The principle of network redundancy is to create two or more data paths within a network so that a single point of failure will not disrupt network communication.

Redundant Port Configuration

The redundant TESLA 4000-A port configuration is shown in Figure 1.4: Rear Panel, LAN Media Option 3, redundant on page 1-7 and below in Figure 4.15: Redundant communication ports.

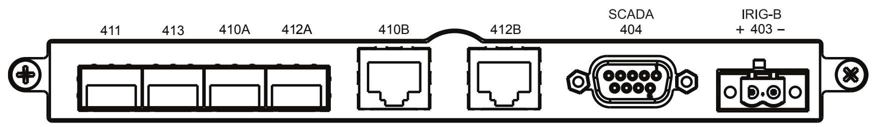


Figure 4.15: Redundant communication ports

Redundancy on the TESLA 4000-A is handled by a redundancy management processor. This processor handles the communication on ports 410, 411, 412 and 413. The hardware configuration for ports 410, 411, 412 and 413 is:

- 410A and 412A are LC type optical receptacle SFP, 100BASE-FX Ethernet interfaces
- 410B and 412B are RJ-45 receptacles, 100BASE-T Ethernet interfaces
- 411 is a non-redundant port with LC type optical receptacle SFP, 100BASE-FX Ethernet interface
- Port 413 is not used.

Redundancy Modes

The TESLA 4000-A (Must be configure at the factory, see “Ordering Options and Product Configuration ID” on page 1-6) is capable of redundancy with the following protocols on Port 410 and 412.

- RSTP (Rapid Spanning Tree Protocol; IEEE 802.1w) is for networks with multiple paths from source to target (like a mesh). RSTP uses hardware with algorithms to prevent network packets from being passed within the redundant paths and to use the quickest path from source to target. All hardware must be RSTP capable. *One data packet has many routes to get to the target.*
- PRP (Parallel Redundancy Protocol; IEC 62439-3 Clause 3). PRP is a type of redundancy where two completely separate paths are used simultaneously with the same data. The first data to arrive will be used and the second data (copy) will be discarded. Hardware at each end of the paths must be PRP capable. *There are two identical data packets, each travelling on its own independent network to the target.*

Both PRP and RSTP are available when the PRP or RSTP option is ordered. If redundancy is not required, select RSTP and only connect to port 410, leaving port 412 unconnected. Select the redundancy mode in the Active Mode pull-down on the Network Redundancy screen (see “Active Mode Selection” on page 8-11).

Redundancy Profiles

The combination of the redundancy mode and VLAN mode define the Redundancy Profiles. These profiles are selected via the “Active Mode” selection on the Network Redundancy screen (see “Active Mode Selection” on page 8-11).

For each of the Redundancy modes (HSR/RSTP/PRP), there are the following six available Redundancy Profiles:

- RSTP/PRP_410U_411U_<Revision>
- RSTP/PRP_410U_411T_<Revision>
- RSTP/PRP_410T_411U_<Revision>
- RSTP/PRP_410T_411T_<Revision>
- RSTP/PRP_410P_411X_<Revision>
- RSTP/PRP_MAINTENANCE_410_<Revision>

The first five profiles are to be used for normal operation of the TESLA 4000-A. The “Maintenance” profile is only to be used as directed by ERLPhase Customer service. The U, T, P and X notation refers to the VLAN mode (see “VLAN Modes” on page 4-9).

The *Time > PTP* screen settings and the *Communication > Network Redundancy* screen settings are both stored on the Network Redundancy Module on the Comm Board. These settings are linked to the Redundancy Profile selected via the Active Mode on the *Communication > Network Redundancy* screen. When the settings are changed and saved, they are saved to the currently selected Redundancy Profile. When the Redundancy Profile is changed, the settings on the *Time > PTP* screen settings and the *Communication > Network*

Redundancy screens will be updated with those last saved to the new Redundancy Profile.

VLAN Modes

There are multiple VLAN modes which affect the VLAN tagging of packets on Ports 410/412 and 411. The VLAN modes are described below in the table below.

Table 4.8: VLAN Modes for Redundant Network Configuration

VLAN Mode	Behaviour of Ingress Packets			Behaviour of Egress Packets	
	With defined VLAN ID	With undefined VLAN ID	Without VLAN ID	With VLAN Tag	Without VLAN Tag
U - Untagged	Accept	Deny	Accept	Strip VLAN tag	unchanged
T - Tagged	Accept	Deny	Accept	Transmit with defined VLAN ID	Tagged with native VLAN ID
P - Pass Through	Accept	Accept	Accept	Transmit with any VLAN ID	unchanged
X - Disable	Deny	Deny	Deny	No packet sent	No packet sent

The following are the pre-defined VLAN ID along with Native VLAN ID to be used for each redundancy profile. Redundancy hardware supports up to 16 user-defined VLAN ID, if a user-defined VLAN ID is required or the Native VLAN ID is needed to be changed, please contact ERLPhase Customer Service team for the assistance.

Table 4.9: Default VLAN ID for Redundancy Profiles

Redundancy Profile	Default pre-defined VLAN ID	Native VLAN ID
410U	1	99
410T	1,2,4,6,8,20,40,60	99
411U		3
411T	3,5,7,9,10,30	98

For ports 401 and 402, all network traffic is accepted whether it is tagged or untagged. GOOSE packets egress tagged if GOOSE publication is enabled.

Note that for the non-redundancy network configuration (see “Ordering Options and Product Configuration ID” on page 1-6), all network traffic is accepted whether it is tagged or untagged for ports 401, 402, 410 and 411. GOOSE packets egress tagged if GOOSE publication is enabled.

IP Addresses

There are three IP addresses associated with the redundancy configuration:

- 1 IP address for port 411
- 1 IP address for redundant ports 410/412 A and B
- 1 IP address for the redundancy management processor on the redundancy communication board. The IP address selection should be compatible with the devices on the network connected to port 410/412. This address is configurable via the Network Redundancy screen (see “Configuration” on page 8-11). The redundancy management processor is only accessible via port 410/412 if the “Advanced Configuration” box is checked on the Network Redundancy screen. Advanced configuration should only be selected under the direction of ERLPhase Customer Service.

5 Services

The purpose of this section is to give an overview of the services available on the TESLA 4000-A. This section uses the term “services” to refer to application level communication protocols providing access to TESLA functions and data. The services are categorized into two groups:

- SCADA, Automation and Monitoring
- Interactive User Services

The services and the ports they are available on are shown in Table 5.1: Services and ports.

Table 5.1: Services and ports

Service	Physical Port	IP Port/Ethernet		Service can be disabled	Notes
		Default	Configurable		
SCADA, Automation and Time Services					
DNP3	401,402, 410, 411	20000	Yes	Yes	DNP3 and MODBUS are mutually exclusive
	404				
MODBUS	404			Yes	
IEC61850	401,402, 410, 411			Yes	410, 411, 401 and 402 are mutually exclusive
MMS		102	No		
GOOSE		Ethernet	Yes		
PMU	401,402, 410, 411	4712	Yes	Yes	
	400,405				
SNTP	401,402, 410, 411	123/ UDP	No	Yes	TESLA connects to this port
Syslog	401,402, 410, 411	514	Yes	Yes	
Interactive User Services					
TCP	401,402, 410, 411	7631	Yes	No	
	450				
	400,405			Yes	
RBCS	401,402, 410, 411	1081	Yes	Yes	TESLA connects to this port
	400,405				

Table 5.1: (Continued)Services and ports

FTP	401,402, 410, 411	20,21	Yes	Yes	
	400,405				
Terminal UI	450			No	

5.1 Data Communication Services

DNP3

The DNP3 protocol is available on the TESLA 4000-A for use with SCADA client software. DNP3 is available for Ethernet or Serial communication. The DNP3 communication settings and point mapping are configured in TESLA Control Panel. For more information see “SCADA Point Mapping Configuration” on page 9-16 and “DNP3 Device Profile” in Appendix F.

MODBUS

The MODBUS protocol is available on the TESLA 4000-A for use with SCADA client software. MODBUS RTU and ASCII are both available. The MODBUS communication settings are configured in TESLA Control Panel. For more information see “SCADA Point Mapping Configuration” on page 9-16 and “Modbus Functions” in Appendix E.

IEC 61850

The TESLA 4000-A is an IEC 61850 enabled device. For details on the IEC 61850 implementation on the TESLA 4000-A, refer to “IEC 61850 Edition 2.0 Implementation” on page 19-4. Also, refer to Appendix J for the relevant conformance statements and data mapping specification.

The IEC 61850 port configuration is available in TESLA Control Panel on the *Communication > IEC 61850* screens.

PMU

The Phasor Measurement Unit (PMU) module is a standard feature on the TESLA 4000-A. The phasor information is available via the Ethernet ports at rates up to 60 frames each second. For more information on PMU, see Chapter 17 PMU Functionality and Appendix D PMU Standards.

The PMU port selection, and other communication configuration settings, is available in TESLA Control Panel on the *Communication > PMU* screen.

Syslog

The Syslog protocol is available on TESLA 4000-A for use with RFC5424/RFC5426 compliant server. Messages available to server are restricted to Cyber Security activity only. For information on Syslog protocol settings see “Syslog Communication Settings” on page 8-34.

The Syslog port selection, and other communication configuration settings, is available in TESLA Control Panel on the *Communication > Syslog* screen.

PTP (IEEE 1588)

The Precision Time Protocol (IEEE 1588) is a network based time source which provides high accuracy over an Ethernet Network connection. The TESLA 4000-A uses the IEEE C37.238 Power Profile making it suitable for use in Power System applications. In Sampled Value applications high time accuracy is critical, making PTP the best synchronization source for Sampled Value usage.

For more details on PTP see “PTP” on page 8-18.

SNTP

An SNTP time source has a lower order of precedence from a valid IRIG-B source. SNTP operation (primary and secondary) requires network access and the selection and configuration of suitable SNTP network sources. The SNTP time may be configured for re-synchronization cycles ranging from 15 minutes to 36 hours, adjusting the IED system time to an accuracy within +/- 1 second. Use of an SNTP time source for PMU and CDR applications is not recommended, however is considered suitable for data recording and trending purposes.

5.2 Interactive User Services

TESLA Control Panel (TCP)

TESLA Control Panel (TCP) is the main user interface for the TESLA 4000-A recorder. TCP is a Windows software used for configuration, metering, log management and maintenance. TCP communicates with IEDs over Ethernet LAN or Serial communications. For more information on working with TCP, see "Working with TESLA Control Panel" on page 6-12. Other sections throughout the manual describe how to use various functions within TCP.

RecordBase Central Station (RBCS)

RecordBase Central Station (RBCS) is a stand-alone record collection and data management software for records from ERL products, including the TESLA 4000-A. RBCS communicates with the IED over Ethernet LAN or Modem communication and uses FTP to collect records. For more information on working with RBCS, see the RBCS manual included with the software.

FTP

The TESLA 4000-A supports File Transfer Protocol (FTP) for transferring records directly from the IED and for loading IEC 61850 configuration files to the IED. The FTP protocol is protected by the TESLA Cyber Security system and can only be accessed using valid login credentials. The access to folders and files within the IED are limited depending on which roles are assigned to the user, as shown in Table 5.2: FTP Access and Roles.

Table 5.2: FTP Access and Roles

Privilege	Roles	Notes
View Record List, Read Records	OPERATOR, ENGINEER, RCDREADER, UPDATE, RBCS	Used by third party record readers
View communication (IEC 61850 only) configuration	ENGINEER, INSTALLER, SECADM	Used by ERL61850 Configurator Tool
Change communication (IEC 61850 only) configuration		

Terminal UI

The Terminal User Interface (UI) is used for restoring the security configuration to factory default and for retrieving the network configuration. It is accessed using a terminal emulation software such as HyperTerminal and is only available on the front USB Port 450. For more information on using the Terminal UI, see "Default Security Configuration Settings" on page 8-41 and "Network Configuration Recovery Utility" on page 8-7.

6 Communicating with the Recorder

The user interface and communication services are accessed by:

- Front or rear copper or optical Ethernet network link (user interface, SCADA and IEC 61850)
- Front USB 2.0 interface (user interface)
- Direct serial link (user interface and SCADA)
- External or internal modem link (user interface only)
- Modem LAN Gateway

This chapter describes first the communication links with the TESLA 4000-A and then describes working with the main user interface, TESLA Control Panel.

6.1 Communication Links

The TESLA offers communication interfaces on both the front and rear panel of the IED. The recorder front panel provides one USB Standard-B receptacle and one Ethernet connection port. The rear panel provides up to five Ethernet ports and up to one serial port, depending on ordering configuration, available for unit communications.

Ethernet LAN Link

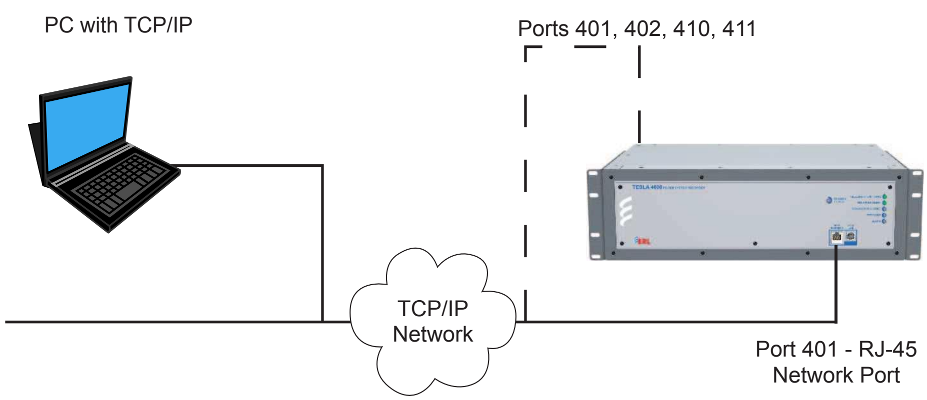


Figure 6.1: Ethernet LAN Link

An Ethernet LAN link via the Ethernet ports is used to access the user interface and communication protocols (IEC 61850, PMU, Syslog). The rear Ethernet ports 401 (100BASE-T) and 402 (1000BASE-T) are copper interface with an RJ-45 connector. The rear ports 410, 411 and 412 are either copper interface with RJ-45 connector or optical interface with ST type optical receptacle connector (see “Ordering Options and Product Configuration ID” on page 1-6).

The front Port 401 is 100BASE-T copper interface with an RJ-45 connector.

Each port’s IP address and network mask and the default gateway may be edited on the Ethernet tab on the Communication screen in TESLA Control Panel. See “Ethernet Configuration” on page 8-6.

VLAN IDs

For the non-redundant network hardware configuration (see “Ordering Options and Product Configuration ID” on page 1-6), all network traffic is accepted whether it is tagged or untagged for all network ports (401, 402, 410 and 411). GOOSE packets egress tagged if GOOSE publication is enabled.

For the redundant network configuration (see “Ordering Options and Product Configuration ID” on page 1-6), Ports 411 and 410/412 have various VLAN modes based on the Redundancy Profile. See for details “VLAN Modes” on page 4-9). For Ports 401 and 402, all network traffic is accepted whether it is tagged or untagged. GOOSE packets egress tagged if GOOSE publication is enabled.

USB Link

Your PC must be appropriately configured for USB communication (see “TESLA Control Panel Installation” on page 3-1).

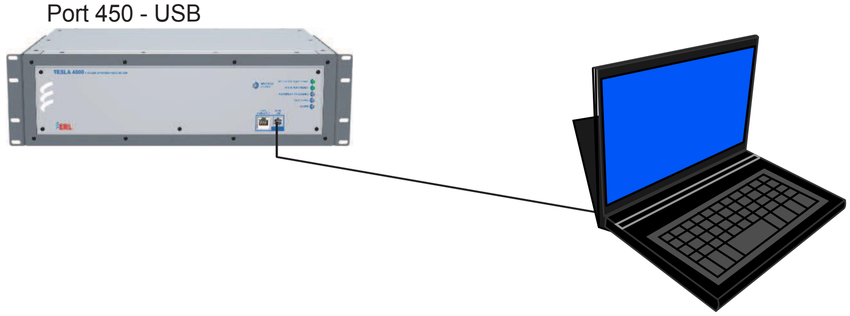


Figure 6.2: USB Link

To create an USB link between the recorder and the computer, first the USB driver for the ERLPhase 4000 Series Device needs to be installed, as follows:

Unzip the file (can be obtained from ERLPhase website):

ERLPhase_USB_driver.zip

In this case we assume you unzipped to the Desktop.

In Windows 7 or Windows 10

Connect a USB port of the PC to Port 450 (USB front) of the TESLA 4000-A. The TESLA 4000-A was already powered on.

In the window

“Welcome to the Found New Hardware Wizard”

“Can Windows connect to Windows Update to search for software?”

Check the option “No, not this time”

In the window

“This wizard helps you install software for:”

ERLPhase 4000 Series Device

“What do you want the wizard to do?”

Check the option “Install from a list or specific location (Advanced)”

In the window

“Please choose your search and installation options”

“Search for the best driver in these locations”

“Uncheck the option “Search removable media (floppy, CD-ROM.)”
Check the option “Include this location in the search”
Browse for the following folder:
C:\WINDOWS\tiinst\TUSB3410

In the window

“Hardware Installation”

“The software you are installing for this hardware”

“ERLPhase 4000 Series Device”

“Windows can’t verify the publisher”

Hit *Continue Anyway*

In the window

“Completing the Found New Hardware Wizard”

“The wizard has finished installing the software for”

“ERLPhase 4000 Series Device”

Hit *Finish*

To verify the installation was successful, and to which comm port is the ERLPhase 4000 Series Device configured, do the following:

In Windows 7 ‘small icons’ view, go to

Start>Control Panel>Device Manager>Ports

Look for the port number associated to this device.“ERLPhase 4000 Series Device”

Look for a COM#, where “#” can be 1, 2, 3, etc. Leave the default settings for this port.

It is recommended to restart the PC after the USB driver installation.

The default baud rate for the recorder USB Port 450 is 115200, however to double check it login to the recorder display and go to:

Main Menu> System> Recorder Comm Setup

To establish a USB link between the recorder and your computer, connect your computer’s USB port and Port 450 on the recorder’s front panel. Use a standard USB peripheral cable.

1. Ensure the recorder port and your PC's port have the same baud rate and communication parameters.
   - The recorder's USB port appears as a serial port to the PC and is fixed at 8 data bits, no parity and 1 stop bit and has a default baud rates of 115,200 bauds.
   - The baud rate and communication parameters of your computer's USB port is set automatically by TESLA Control Panel *(Edit IED>Communication>Direct Serial Link*)
2. Choose the target recorder from the *Select IED* list in TESLA Control Panel's Main Menu.
   - If there is not already an entry for this recorder, create one using the *Add New* button.
   - The method of communication with the recorder is specified as part of its IED definition. Use the *Edit* button to view or change this information. Ensure the *Direct Serial Link* option is selected.
   - For details on IED definitions see "Working with TESLA Control Panel" on page 6-12.
3. Initiate the connection by selecting the *Connect* button.
   - A dialog box will appear to show connection progress.
   - The connection state and the current IED you are connected to is shown on the Windows status bar at the bottom of the screen.

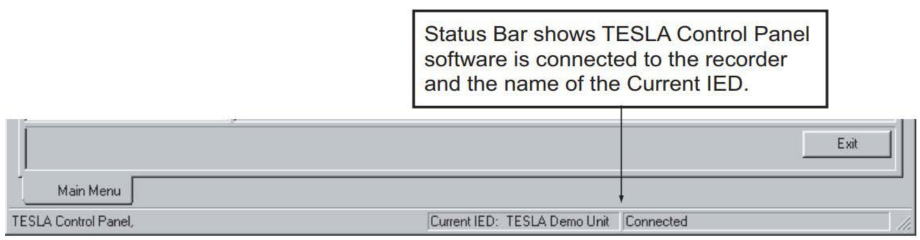


Figure 6.3: Status Bar

If the connection fails, check the following:

- The communication parameters are the same on both ends (see Step 1 above).
- The correct serial port has been selected on your computer.

Direct Serial Link

Your PC must be appropriately configured for serial communication (see “TESLA Control Panel Installation” on page 3-1) and Port 405 must be available on the IED to enable a direct serial link.

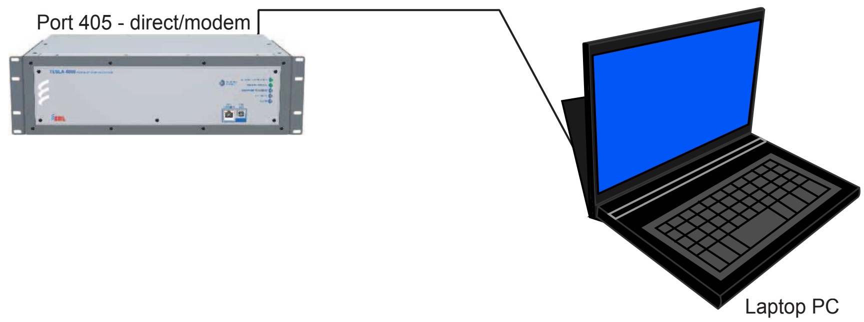


Figure 6.4: Direct Serial Link

To create a serial link between the recorder and your computer, connect your computer’s serial port (or USB port with USB to Serial converter) and Port 405 on the recorder’s rear panel.

The serial port is configured as EIR RS-232 Data Communications Equipment (DCE) devices with female DB9 connectors. This allows it to be connected directly to a PC serial port with standard straight-through male-to-female serial cable.

1. Ensure the recorder port and your PC’s port have the same baud rate and communication parameters.
   - Port 405 is fixed at 8 data bits, no parity and 1 stop bit and has a default baud rate of 38,400 baud (configurable).
   - The baud rate and communication parameters of your computer's USB port is set automatically by TESLA Control Panel *(Edit IED>Communication>Direct Serial Link*)
2. Choose the target recorder from the *Select IED* list in TESLA Control Panel’s Main Menu.
   - If there is not already an entry for this recorder, create one using the *Add New* button.
   - The method of communication with the recorder is specified as part of its IED definition. Use the *Edit* button to view or change this information. Ensure the *Direct Serial Link* option is selected.
   - For details on IED definitions see “Working with TESLA Control Panel” on page 6-12.
3. Initiate the connection by selecting the *Connect* button.
   - A dialog box will appear to show connection progress.
   - The connection state and the current IED you are connected to is shown on the Windows status bar at the bottom of the screen.

Most new computers do not have serial ports. A USB serial converter adapter can provide a surrogate serial port for a direct connection to the TESLA recorder.

TESLA Control Panel Setup

1. Ensure that the computer running TESLA Control Panel has access to the Ethernet network or USB port to which the recorder has been connected.
2. Start TESLA Control Panel.
3. Choose the target recorder from the *Select IED* list in TESLA Control Panel's Main Menu.
    - If there is not already an entry for this recorder, create one using the *Add New* button

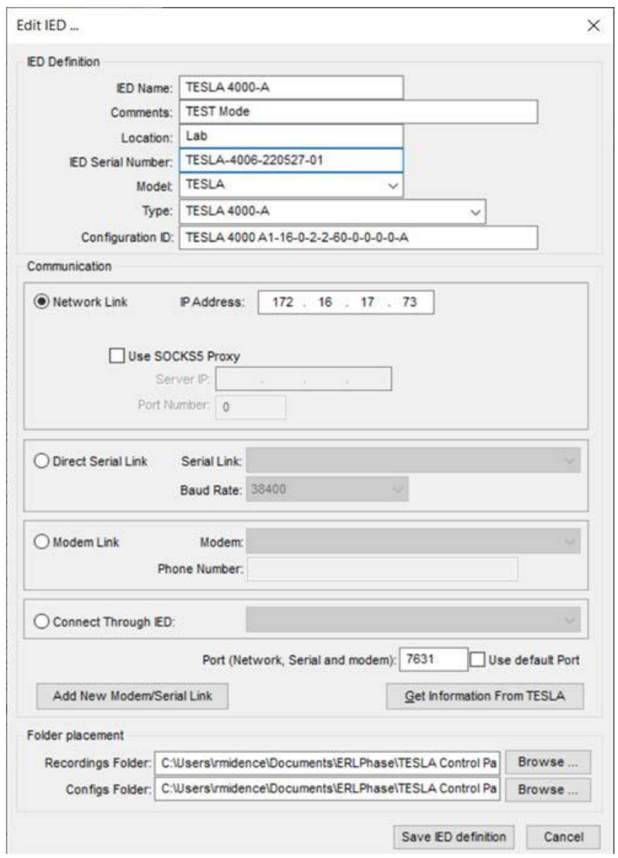


Figure 6.5: Add New/Edit IED

- The method of communication with the recorder is specified as part of its IED definition. The *Network Link* option is shown in the figure above. The recorder's IP address is entered. Alternatively, the Direct Serial Link may be selected and used.

4. Initiate the connection by selecting the *Connect* button.
    - A dialog box will appear to show connection progress.
    - The connection state and the current IED you are connected to is shown on the Windows status bar

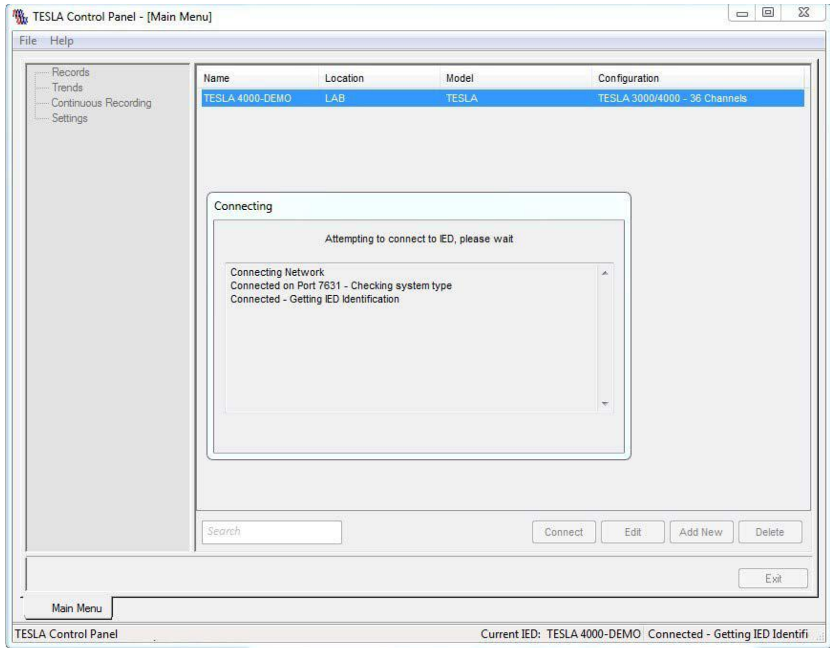


Figure 6.6: Connect Button Dialog Box

External Modem Link

Your PC must be appropriately configured for modem communication and Port 405 must be available on the IED to enable an external modem link.

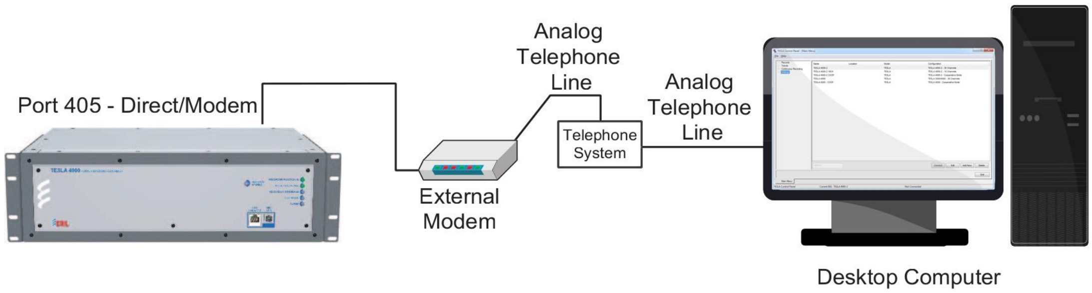


Figure 6.7: Modem Link - External

Using an external modem, you can also access the recorder's user interface through a telephone link between the recorder and your computer.

Recorder Setup

1. Connect a PC-compatible external serial modem to Port 405 on the rear of the recorder.
   - The cable between the recorder and the modem requires a crossover and a gender change as both devices are configured as RS-232 DCE ports.
   - You can use the ERLPhase Modem Port Adapter to make the recorder's Port 405 appear as a DTE (like a PC serial port). A standard modem cable can then be used to connect to the recorder.
   - For port pin-out and cabling information see "IRIG-B Time Input" on page 4-6.
   - If the unit has an internal modem, an external modem will not work.
2. Connect the modem to an analog telephone line or switch and turn it on.
   - A standard telephone cable with an RJ-11 connector is used.
3. Configure the recorder's Port 405 to work with the modem.
   - Port 405 settings are accessed through the recorder's standard user interface.
     a. Establish a network or a USB connection between your computer and Port 401 or 450 on the recorder, run TESLA Control Panel software and initiate a connection to the unit.
     b. When connected, select *Utilities* in the Main Menu list, and go to the *Communication* tab to access the Port 405's settings.

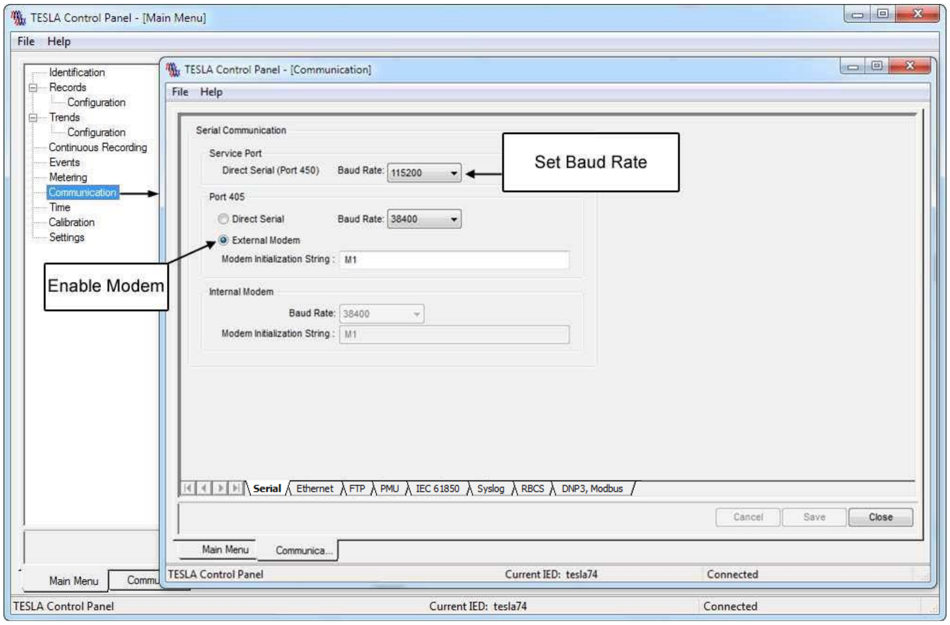


Figure 6.8: Communications Setup Utility

c. Set the Baud Rate. This will be the rate at which the recorder will communicate with the external modem. It does not control the rate at which the modems communicate with each other. Unlike a direct serial link, there is no need for this baud rate to match that of the remote computer. A rate faster than the modem's top speed is recommended to take full advantage of the modem's compression capabilities.

d. Select External Modem.

e. The Modem Initialization String lets you set any special command codes required by your modem. The factory default for this field is "M1" for external modems. These default values are all that are required for most modems.

f. Save your changes, close the Utilities tab and disconnect.

TESLA Control Panel Setup

1. Configure your computer to work with its modem. Refer to your computer and modem documentation.
2. Choose the target recorder from the Select IED list in TESLA Control Panel's Main Menu.
   - If there is not already an entry for this recorder, create one using the *Add New* button.
   - The method of communication with the recorder is part of each IED's definition. Use the *Edit* button to view or change this information. Ensure the Modem Link option is selected and the telephone number of the recorder's modem is entered.

- For details on IED definitions see “Working with TESLA Control Panel” on page 6-12.

3. Initiate the connection by selecting the *Connect* button
   - A dialogue box will appear to show connection progress.
   - The connection state and the current IED you are connected to is shown on the Windows status bar.

Internal Modem Link

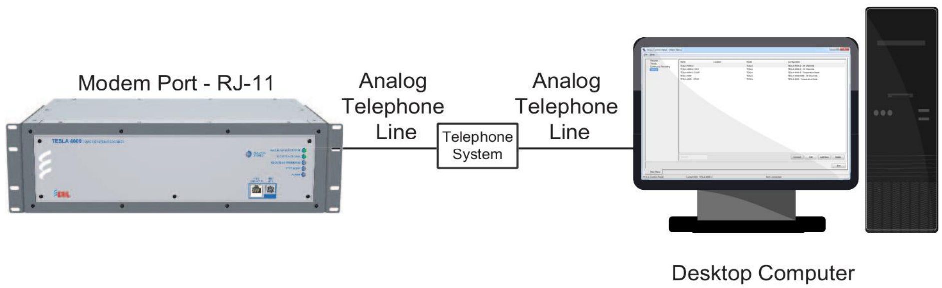


Figure 6.9: Modem Link - Internal

You can access the recorder’s user interface through a telephone link between the recorder and your computer using an optional internal modem (Port 400 if installed).

Connect the recorder's Port 400 to an analog telephone line or switch using a standard RJ-11 connector.

Internal modem configuration is done the same way as for external modem. Modem initialization string is M1 for internal modem.

If an internal modem was installed at the factory, it will already be appropriately configured. An internal modem option is not available when the advanced communications option is selected.

The TESLA 4000-A only supports internal or external modem one at a time. If you enable internal modem, you can’t use external and vice versa.

> The use of external and internal modem on the TESLA 4000-A are mutually exclusive. Connecting internal AND external at the same time is not supported. The user can only select one or the other at a time but not both. When Internal modem is in use, port 405 can still be used as an additional serial port for other purposes.

Modem LAN Gateway

Recorders on a LAN can be remotely accessed through a modem on a designated master recorder. The master acts as a gateway to the LAN, providing a route for IP communication between TESLA Control Panel or RecordBase and other TESLA 4000 recorders to the network. Although commonly used as a part of a cooperative group configuration, a gateway modem can also be used simply as a means to communicate with networked recorders.

1. Connect the recorders to the LAN and set their IP addresses. Ensure that all recorders that are to be accessed via the Modem LAN Gateway use the same TCP/IP Port number as the master record. If different Port numbers are used, communication will fail.
2. Configure one of the recorders (now designated the master recorder) with an internal or external modem (see “Internal Modem Link” on page 6-10).
3. Enable TCP packets forwarding on the master recorder (for details see 8.3 Ethernet Configuration on page 8-6).
4. Set up TESLA Control Panel to communicate with the master recorder via the PC’s modem and create and configure an appropriate *IED Definition* for it.
5. Create an (or modify existing) *IED Definition* for each recorder to be accessed through the gateway (not including the master recorder). Under *Communication*, select *Connect Through IED* and pick the master IED created in the previous setup.
6. To initiate communication with any of the recorders, choose the target recorder from the Select IED list in TESLA Control Panel’s Main Menu and use the *Connect* button.
7. You will be prompted to login to both IEDs. The first login prompt is for the “Master IED” and the second login prompt is for the “Target” IED. Ensure that the proper security credentials are entered for each IED.

> When configured with optical network ports, this is a Class I laser product and is considered safe. However, viewing fiber-optic output ports directly is not recommended.

The Modem LAN Gateway featured described in this section allows convenient access to any TCP/IP enabled device on the remote network connected to the remote TESLA. When TESLA Control Panel or RecordBase Central Station have an active and open connection to the TESLA while running on the modem enabled PC, the user on this PC will have full access to the remote network. Any security implications related to this should be considered and mitigated.

6.2 Working with TESLA Control Panel

In order to access each screen in TESLA Control Panel the user account must have proper security roles assigned. For more information, see “User Account Management” on page 8-36 and “Authentication and Authorization System” on page 18-5.

Recorder Workspace

TESLA Control Panel supports multiple recorders. Each recorder has its own workspace within TESLA Control Panel that stores its communications parameters, records and configuration files.

A separate workspace should be created for each recorder on your system to store its configuration files and records.

When first installed, TESLA Control Panel includes a workspace for a recorder called TESLA 4000 Demo Unit. It contains sample records and configuration files and is configured for network connection with an evaluation unit.

Selecting a Recorder Workspace

To work with a particular recorder, select it from the *Select IED* box on the *Main Menu* tab. If you are already connected to an IED you will not be able to select a different IED until you disconnect.

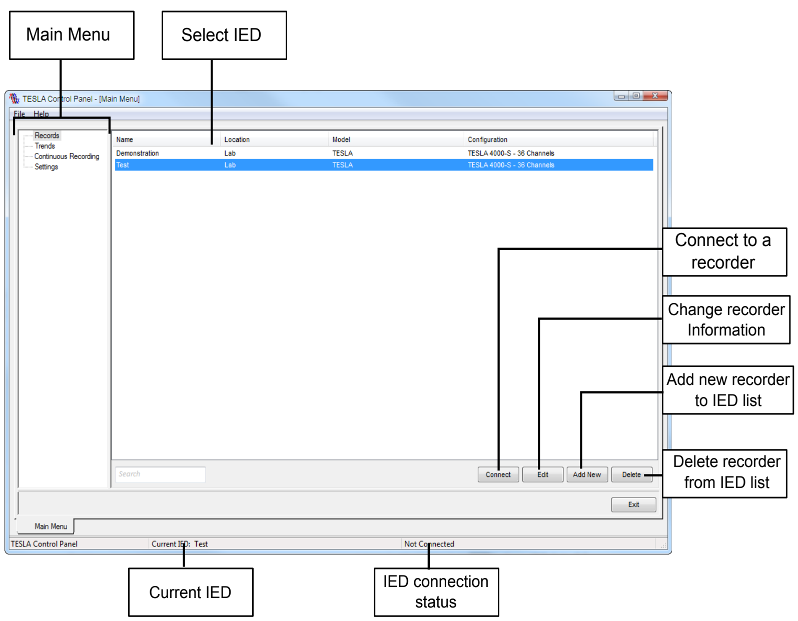


Figure 6.10: Selecting a Recorder Workspace

Current IED

Selecting a recorder sets TESLA Control Panel’s focus to that recorder’s workspace, known as the Current IED. The records and configuration files belong to the selected recorder.

If you initiate a connection using TESLA Control Panel, it connects to the current IED using the communication parameters specified for this IED.

> The name of the Current IED is always displayed in the Status Bar at the bottom of the TESLA Control Panel window (for details see Figure 6.10: Selecting a Recorder Workspace on page 6-12).

TESLA Control Panel assumes that the recorder it is communicating with is the one identified as the Current IED. Forcing a connection with a different recorder (i.e. moving the serial cable without telling TESLA Control Panel to disconnect), can cause the records and configuration files of that recorder to be mixed with those of the Current IED.

Adding/Editing a Recorder Workspace Definition

Recorder workspaces are added, modified or deleted from the TESLA Control Panel Main Menu using controls in the *Select IED* dialog box (for details see Figure 6.10: Selecting a Recorder Workspace on page 6-12) The *Edit* button displays the selected recorder's definition screen. The *Add New* button is used to create a new recorder definition. The *IED* definition is shown in Figure 6.11: Recorder Workspace Definition and the settings are described in the following table.

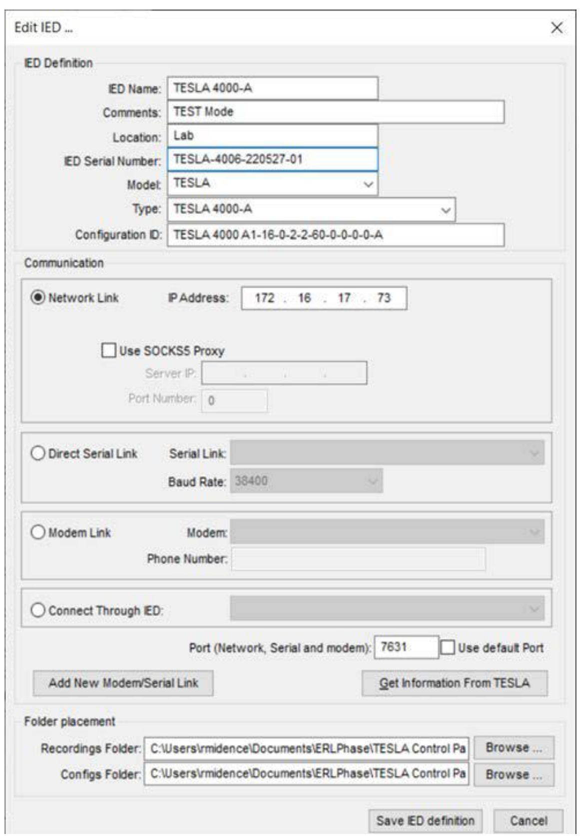


Figure 6.11: Recorder Workspace Definition

Table 6.1: IED Workspace Settings	
IED Definition	
IED Name	The IED Name is the name you assign to this recorder’s workspace. It appears in the IED selection and the Current IED display at the bottom of the TESLA Control Panel window. We recommend that you use the same name for this workspace as the Unit Name given to the recorder (“Unit Identification” on page 8-2).
Comments	User-defined, for your reference only.
Location	User-defined, for your reference only.
IED Serial Number	Enter the IED Serial Number to match the serial number of the actual recorder.
Get Information from IED	Connects to the recorder and retrieves its configured name, location and serial number. The corresponding fields in the IED Definitions are overwritten.
Model	TESLA, TESLA LITE, TESLA 4003, IO Expansion
Type	TESLA 2000 / 3000 / 4000 18 or 36 channel, TESLA 4000-A, TESLA-SV, TESLA 3000 /4000 Cooperative Mode, TESLA 4000-SV/A Cooperative Mode
Configuration ID	The configuration string identifies the ordering options of the specific IED (number of channels, communication ports etc.). During offline mode this field must be filed manually.
Configuration	
IP Address	IP addresses of the recorder. The recorder’s default factory IP addresses are 192.168.100.80 and 192.168.101.80. It is changed from the *Communication > Ethernet* screen in TESLA Control Panel,
Communication	
Direct Serial Link	Connect to this recorder through a serial cable.
Network Link	Connect to this recorder via a TCP/IP network.
Connect Through IED	Connect to this recorder through another recorder that is providing a modem-Lan gateway. An IED Definition for the selected recorder must already exist.
Port	Set the port number for the corresponding connection communication protocol. If “Set to Default” is checked, then the default ERLPhase IANA port 7631 is used (for some legacy products TCP auto-detects the default port as port 2000).
Folder Placement	The Default Folder directory applied to new IED definitions can be modified with the *File>Data Locations* command from the Main Menu.
Recordings Folder	The directory where the IED’s retrieved records are stored.
Configs Folder	The directory where the IED’s configuration files are saved.

You can share configuration files and records with other TESLA Control Panel users by using common folders

Online and Offline Operation

TESLA Control Panel can be used with or without a connection to the selected recorder. Both offline and online modes work within the selected Current IED workspace.

Offline (Not Connected)

In Offline mode, you can manage and display a recorder's local (previously uploaded) records and create and edit configuration files without being connected to the unit.

Online (Connected)

In Online mode you are connected to the recorder and have access to both local and remote data and functions:

- Records (both local and on the recorder)
- Event log
- Metering (real-time readings of input and calculated channels)
- Channel and trigger configurations (the one presently active in the recorder and any saved ones you may have created)
- Setup utilities and record configuration screens
- Record graphics display
- Trend logs
- Maintenance functions

Connection Status

The Status Bar at the bottom right side of the TESLA Control Panel window shows if you are presently online or offline.

Navigating TESLA Control Panel

TESLA Control Panel uses a split screen format. The left pane is used for navigation or selection. The right pane is the working area for each of the program's main sections. To bring up the Control Tabs, shown below, you must select the appropriate item on the Navigation Tree by double-clicking.

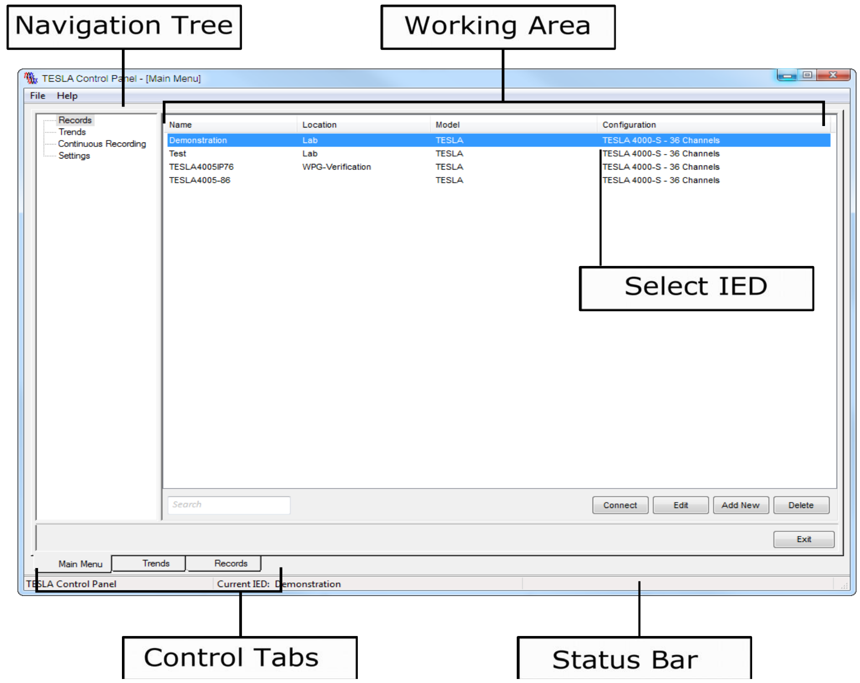


Figure 6.12: TESLA Control Panel Display Sections Navigation Tree

The left pane provides a means of moving between TESLA Control Panel functions or selecting items within a function (e.g. channels from a record). TESLA Control Panel functions—Records, Trend, Events, Metering, Utilities and Configuration are activated by a double-click.

You can optimize the screen space between the tree and the working area to create a larger working area. Some screens have a *Hide Tree* button to maximize the working area.

Working Area

The Working Area on the right pane of the display represents the main working area of each section of the TESLA Control Panel.

Control Tabs

The Control Tabs are a row of selection tabs near the bottom of the screen. Each time you start a function, a corresponding tab is created. Select the control tabs to navigate from one screen to another or the *Main Menu* item. Use the *Close* button to close the screen.

Status Bar

The Status Bar at the bottom of the TESLA Control Panel displays the name of the selected recorder workspace and the status of the connections.

7 Metering Display

The recorder has a full set of real-time metering displays that provide present readings from the analog and digital input channels, and the calculated channels.

The Metering display is accessed through the *Metering* item in the *Main Menu* tab’s function list.

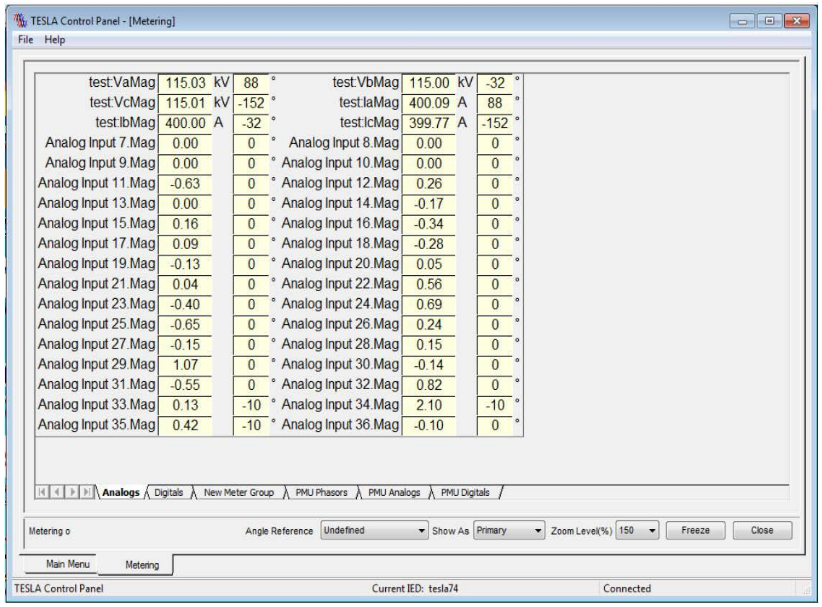


Figure 7.1: Metering Display

Standard Metering Screens

The Metering display provides tabs at the bottom to select among multiple display screens. The first two tabs, *Analogs* and *Digitals* are the default tabs and present the readings from the analog inputs and external inputs.

User-Defined Metering Screens

You can define an additional ten user-defined metering screens. Setup of these additional screens is part of the recorder’s configuration (see “Meter Groups” on page 9-60).

Angle Reference

Angle information displayed on the metering screen may be referenced to any angle reference setting in the configuration file. This feature modifies the display of information on the metering screen and has no impact on recording or communications.

Primary/ Secondary

Metered values can be shown as either system primary or secondary quantities.

Display Zoom

The magnification of metering screens can be adjusted using the *Zoom Level* (%) control. This allows the display to be enlarged for easy viewing while commissioning or testing.

Freeze

The *Freeze* button provides a way to temporarily stop the update of the display. It can be used to ensure a synchronized set of readings for documentation purposes. The metering display can be exported to another program using Windows built-in Alt PrintScreen key and standard paste functions.

> Phase angle readings displayed in meter groups are based on the configured Phase Angle Reference Channel (see “Phase Angle Reference Channel” on page 9-22).

Metering Quality

If the associated metering data does not have “Good” quality (i.e. data quality is “Questionable” or “Invalid”) then the cell for this channel will be displayed with a Red background. For more information on data quality, see “Data Quality” on page 20-1.

8 Recorder Setup

The TESLA recorder has global setup parameters that establish its identity and define its operation. Setup parameters define:

- Unit identification
- Communication port parameters
- Ethernet configuration
- Network Redundancy configuration
- FTP Communication configuration
- IEC 61850 Port Configuration
- Recording configuration
- Trend Recording configuration
- Time Synchronization Settings and Display
- Syslog configuration
- Security accounts

Multiple screens in TESLA Control Panel contain the setup parameters. TESLA Control Panel must be communicating with the IED, and the user account must have appropriate security roles assigned to access the desired screens.

For details on security roles and privileges see "Authentication and Authorization System" on page 18-5.

For details on connecting to the recorder using TESLA Control Panel software see "Network Redundancy" on page 4-7.

8.1 Unit Identification

The Unit Identification screen identifies a particular recorder and its records. Navigate to *Identification* from the Main Menu.

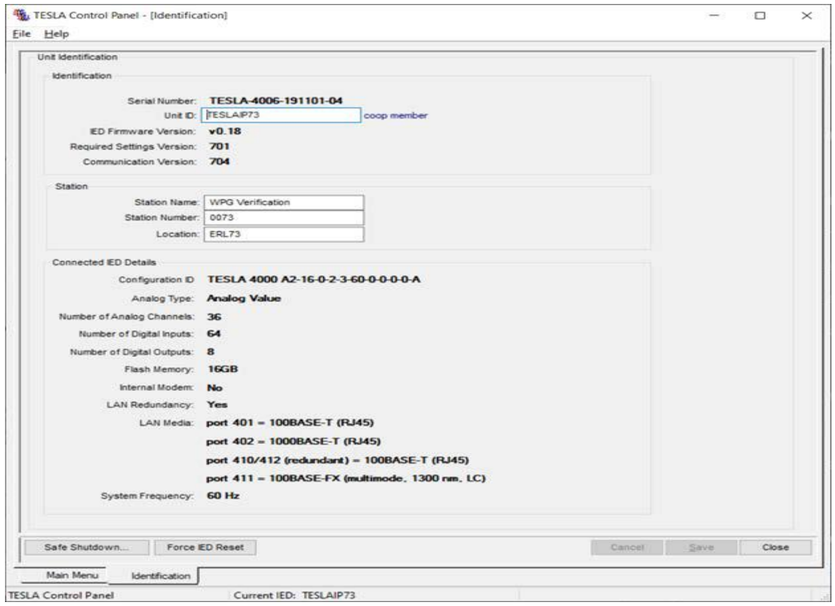


Figure 8.2: Recorder Setup - Unit Identification.

Settings

The following table describes the Unit Identification Settings:

Table 8.1: Unit Identification Settings	
Identification	
Serial Number	Read-only field, displays the serial number of the TESLA unit currently connected.
Unit ID	User-entered field that identifies the unit. It is part of the name given to records produced by the unit to identify their origin. By convention, this name should be the same as the “IED Name” assigned to the recorder and recorder’s workspace. The name must not contain the following: “,” “/” “\” “:” or any other character not valid for a Windows file name.
IED Firmware Version	Read-only field that displays the firmware version of the currently connected TESLA unit.
Required Settings Version	Describes the version of the settings file required by the connected recorder. TESLA Control Panel is capable of creating older versions of settings files for use with recorders whose firmware has not been updated (see “Managing Settings File” on page 9-1).
Communication Version	Read-only field that displays the version of the communications protocol used by the currently connected TESLA unit.
System Frequency	Read-only field that displays the assumed power system frequency of the recorder. This is a factory setting.
Station	

Table 8.1: Unit Identification Settings	
Station Name	User-defined, for your reference only.
Station Number	User-defined, for your reference only.
Location	User-defined, for your reference only.
Safe Shutdown Mode	This command suspends TESLA Application for 15 minutes to allow user safely power off the unit. While TESLA Application is suspended, the front Test and Alarm LEDs are flashing alternatively. If IED is not powered off within 15 minutes, TESLA Application resumes. for details see Safe Shutdown Mode on page 12-6.
Force IED Restart	This command initiates an IED hardware reboot immediately after pressing the TESLA Control Panel button.

8.2 Serial Communication Settings

The Serial Communication settings control the modes and baud rates of the recorder's communication ports. The serial communication port settings are access through the Communication screen on the Serial Tab.

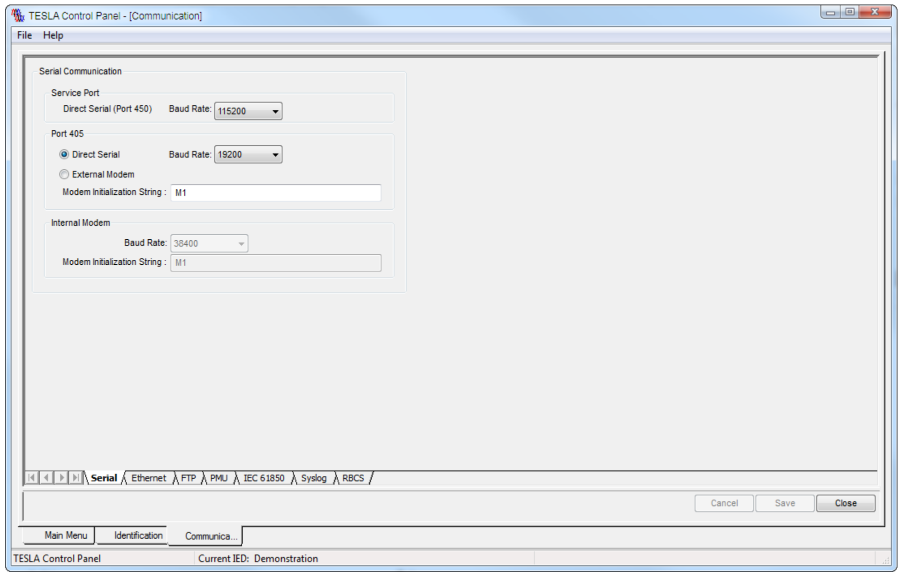


Figure 8.3: Serial Communication Setup

Settings

The following table describes the Serial Communication Port Settings:

Table 8.2: Serial Communication Settings	
Service Port	
The Service Port is Port 450 on the front of the recorder. It can be used for connection with TESLA Control Panel or a terminal program (to access the Terminal UI).	
Baud Rate	Sets the baud rate of the port. The default baud rate is 115,200 N81 baud. Note: The baud rate must match that of the port of the computer connected to this port. For best results, use the maximum baud rate that your communication link and equipment can sustain.

Table 8.2: Serial Communication Settings	
Direct/Modem Port	
The Direct/Modem Port refers to either the recorder's rear panel Port 405 or its Internal Modem port (not supported), depending on the Port Select setting. Direct/Modem Port functionality is not available on all TESLA 4000-A IED configurations.	
Port Select	Direct Serial: Port 405 is enabled for a direct serial connection with TESLA Control Panel or a terminal program (to access the Terminal UI). Only supported on non-redundant network configuration (see "Ordering Options and Product Configuration ID" on page 1-6) (Currently Not Supported) External Modem: Port 405 can be used to connect to an external modem through a serial link. (Currently Not supported) Internal Modem: Enables a modem connection through the recorder's rear panel RJ-11 Internal Modem Port. Requires that the recorder has the internal modem option installed.
Baud Rate	Sets the baud rate of port 405. The default baud rate is 38,400 baud. For a direct serial connection on Port 405, the baud rate must match that of the port of the computer connected to this port. For best results, use the maximum baud rate that your communication link and equipment can sustain.
Modem Initialization String	When using an internal or external modem, a modem initialization string can be entered containing modem control codes. The factory default for this field is "M1". Refer to the modem manual for details.

For details regarding the data and functions available on the TESLA recorder's SCADA port see "Modbus Functions" in Appendix E and "DNP3 Device Profile" in Appendix F.

8.3 Ethernet Configuration

The IED Ethernet Configuration is accessed from the Communication screen on the Ethernet tab.

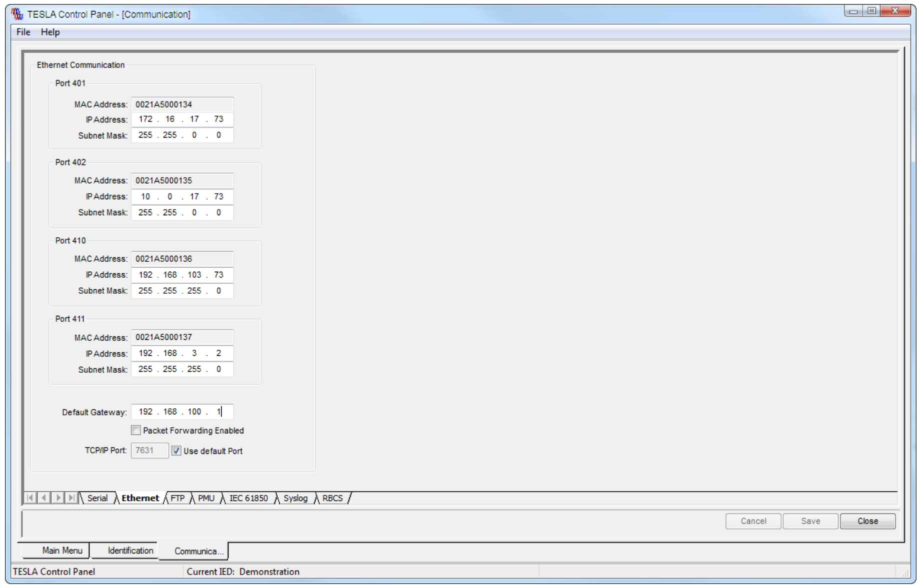


Figure 8.4: Communication - Ethernet Configuration

Settings

The following table describes the Ethernet Settings:

Table 8.3: Ethernet Settings

Ethernet Communication	
Port 401	Displays MAC address of Port 401. Set the IP Address and Subnet mask. Default IP Address = 192.168.100.80
Port 402	Displays MAC address of Port 402. Set the IP Address and Subnet mask. Default IP Address = 192.168.101.80
Port 410	Displays MAC address of Port 410. Set the IP Address and Subnet mask. Default IP Address = 192.168.102.80
Port 411	Displays MAC address of Port 411. Set the IP Address and Subnet mask. Default IP Address = 192.168.103.80
Default Gateway	Set the Default Gateway.
Packet Forwarding enabling	This setting must be enabled for cooperative mode functionality with a modem and for modem LAN gateway communication.
TCP/IP Port Selection	Set the TCP/IP Port. Range is 1025 to 65535. Default is ERLPhase Registered IANA Port 7631.

After a setting has been changed, the IED must be manually rebooted in order for the changes to take place.

Network Configuration Recovery Utility

The TESLA 4000-A contains a contingency feature for recovering the network configuration. This utility allows for viewing of the Port 401 IP Address, Network Mask and Port via a USB serial connection and a terminal emulator program such as HyperTerminal. This utility is to be used if the user is unable to establish a serial or network connection to the TESLA 4000-A via TESLA Control Panel.

Connecting to the Network Configuration Recovery Utility

To connect to the Network Configuration Recovery Utility use a terminal emulator program. HyperTerminal is used for here for demonstration purposes. To connect to the Network Configuration Recovery Utility:

1. Connect USB cable from PC to front USB Port 450 on the TESLA 4000-A.

> This procedure assumes that the ERLPhase driver has already been installed to create a USB serial connection to the TESLA. See “Network Redundancy” on page 4-7 for more details.

2. Open HyperTerminal.
3. Create a new connection. Click OK.

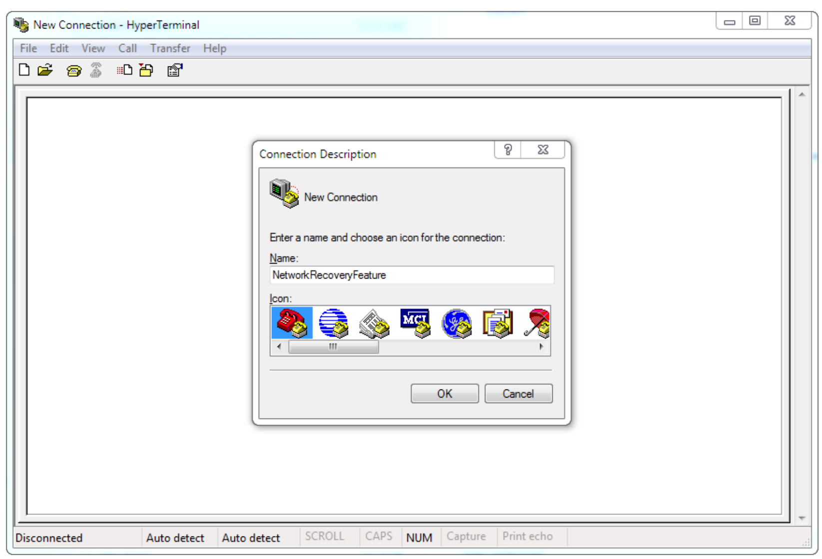


Figure 8.5: New connection

4. Select COM Port connected to the TESLA. Click OK.

To see which COM Port the TESLA is connected to on your PC, check *Control Panel > Device Manager > Ports*.

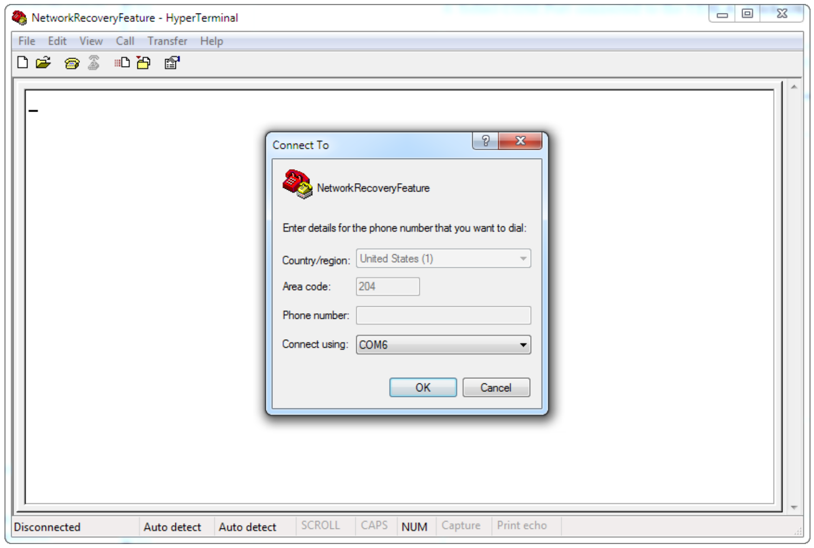


Figure 8.6: Select COM Port

5. Choose Baud Rate of 115,200. Click OK.

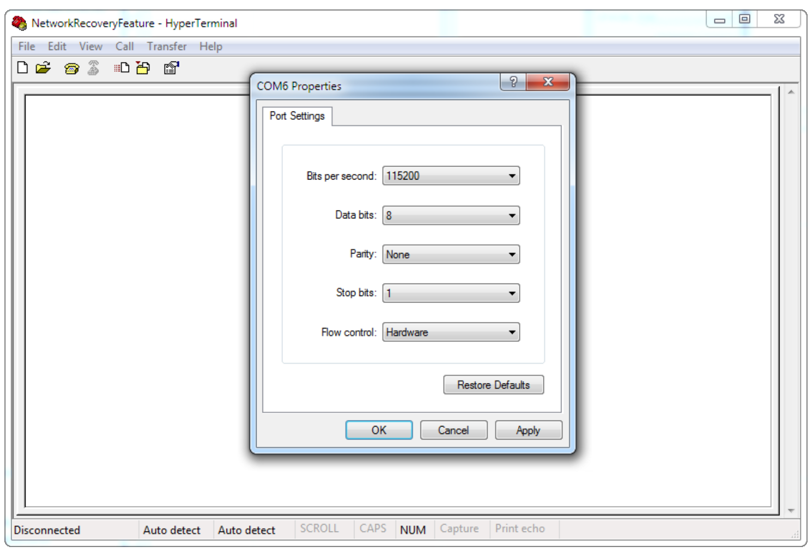


Figure 8.7: Set Baud Rate

6. Enter a '?' character. This launches the network recovery utility. If another character is entered before the '?', the network recovery utility will not launch. User must disconnect, reconnect, and then try again.

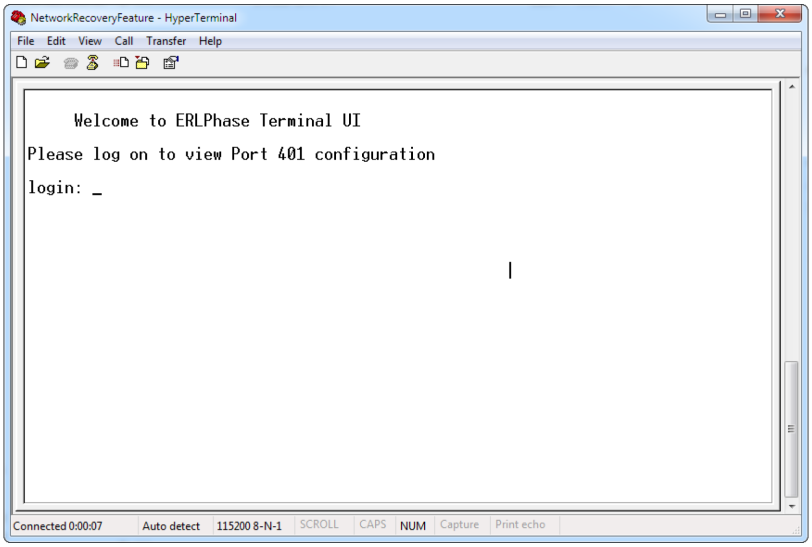


Figure 8.8: Launch Network Recovery Utility

7. The Network Recovery Utility is protected by the Role-Based Access Control security system. Enter valid login credentials and press *Enter* to login to the Utility. The user account must have adequate Roles assigned to read the communication configuration. The default "service" account is shown here as an example. For more information on Role assignments, see "TESLA Role List" on page 18-7. For more information on Default Accounts, see "Default User Accounts" on page 8-42.

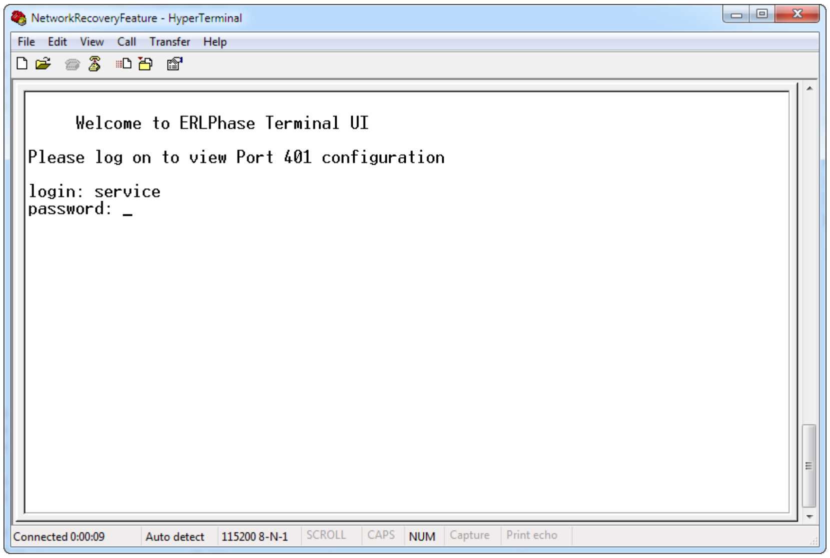


Figure 8.9: Enter valid login credentials

8. The Port 401 Network Configuration is displayed once valid login credentials have been entered.

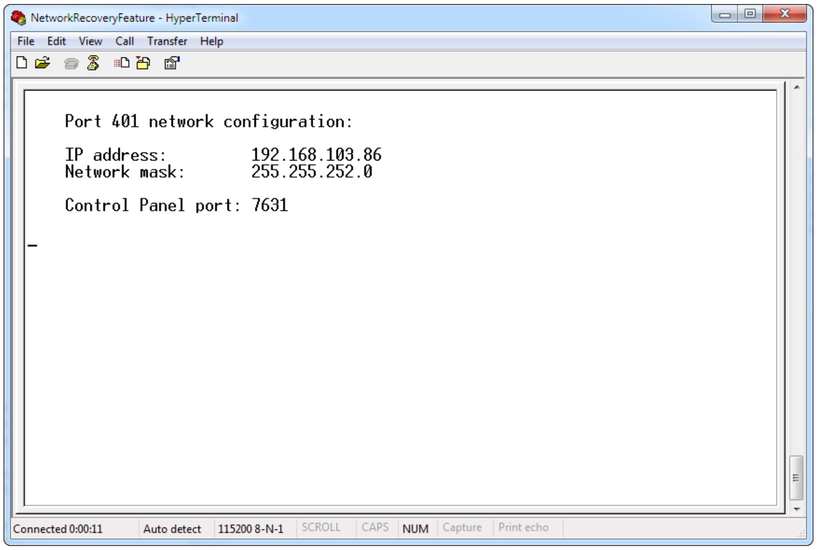


Figure 8.10: View the network configuration

8.4 Network Redundancy Configuration

The Network Redundancy Configuration screen is used to perform the configuration of the Network Redundancy profiles, Redundancy network configuration and provides identification information of the redundancy module.

The *Communication > Network Redundancy* screen settings and the *Time > PTP* screen settings are both stored on the redundancy communication board. These settings are linked to the Active Mode selected in the *Communication > Network Redundancy* screen. When the settings are changed and saved, they are saved to the currently selected Active Mode. When the Active Mode is changed, the settings on the *Time > PTP* screen settings and the *Communication > Network Redundancy* screens will be updated with those last saved to the new Active Mode profile.

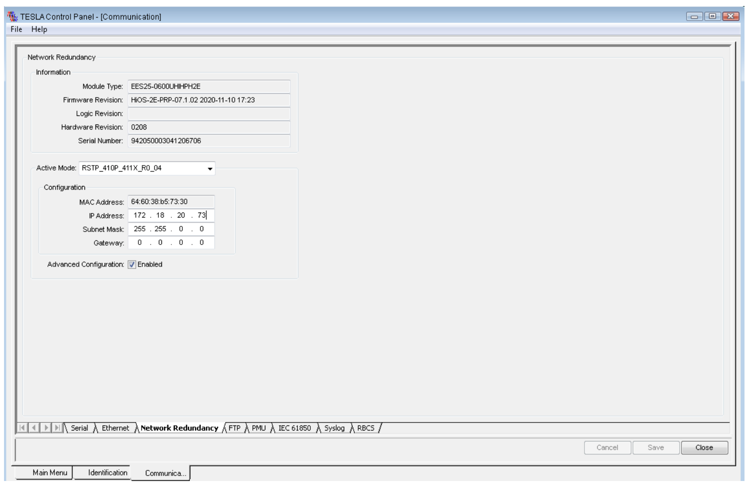


Figure 8.11: Network Redundancy Configuration

Information

The Information section of the Network Redundancy screen provides identification information of the built-in redundancy module, including the module type, firmware revision, logic revision, hardware revision and serial number. This information is read-only.

Configuration

The Configuration section of the Network Redundancy screen allows for configuration of the network settings of the built-in redundancy module. Under normal circumstances, these network settings are not required to be changed. If using the Advanced Configuration, as directed by ERLPhase Customer Service, then the redundancy network configuration may need to be changed.

Active Mode Selection

The Active Mode drop-down box is where the redundancy profile is selected. Refer to “Redundancy Profiles” on page 4-8 for more details.

Advanced Configuration

The Advanced Configuration is only to be used as directed by ERLPhase Customer Service. It allows for advanced configuration of the redundancy hardware.

8.5 FTP Communication Configuration

The FTP Communication configuration is accessed from the Communication screen on the FTP tab. FTP Communication is used for transferring files to and from the IED via peripheral software tools. ERL 61850 IED Configurator uses the FTP protocol to transfer configurations to and from the TESLA.

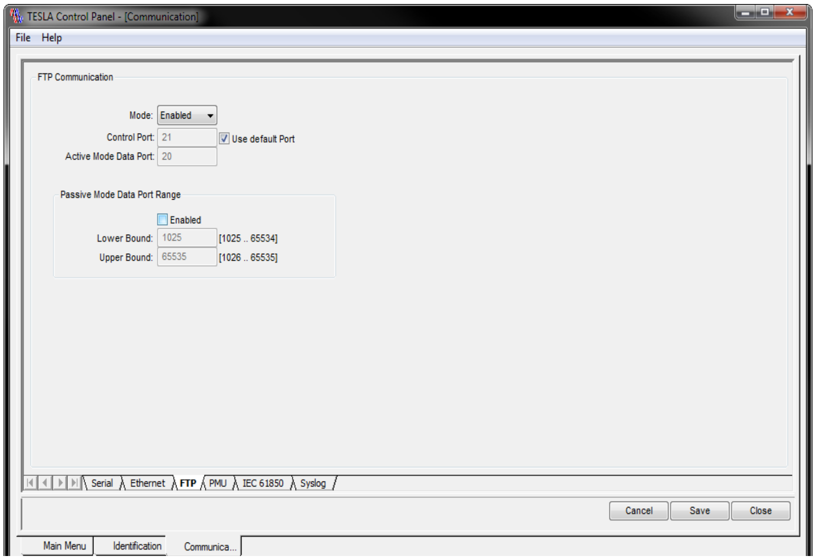


Figure 8.12: FTP Communication Screen

> FTP Communication must be enabled and the port settings must match the ERL 61850 IED Configurator software to ensure that the software can communicate with the TESLA.

Settings

The following table describes the FTP Communication Settings:

Table 8.4: FTP Communication Settings

FTP Communication	
Mode	Enabled/Disabled
Control Port	FTP Control Port setting. Default value is 21.
Use Default Port	Check-box used to revert setting to default value.
Active Mode Data Port	Port setting is read-only. Value is automatically set to the Control Port value minus one. i.e. If Control Port is set to 21, Active Mode Data Port is set to 20.
Passive Mode Data Port Range	
Enabled Check-box	Enable or disable the Passive Mode Data Port Range
Lower Bound	User configurable lower bound
Upper Bound	User configurable upper bound

8.6 IEC 61850 Port Configuration

The *Communication > IEC 61850* screen allows the user to enable or disable each of the four Ethernet ports for IEC 61850 GOOSE and MMS communication. When the port is enabled, the GOOSE and MMS communication is available, according to the IEC 61850 configuration loaded to the unit via the CID file (using the ERL 61850 Configurator Tool).

Note that MMS communication can be disabled only if all the 61850 ports are disabled, otherwise it will be enabled on all ports.

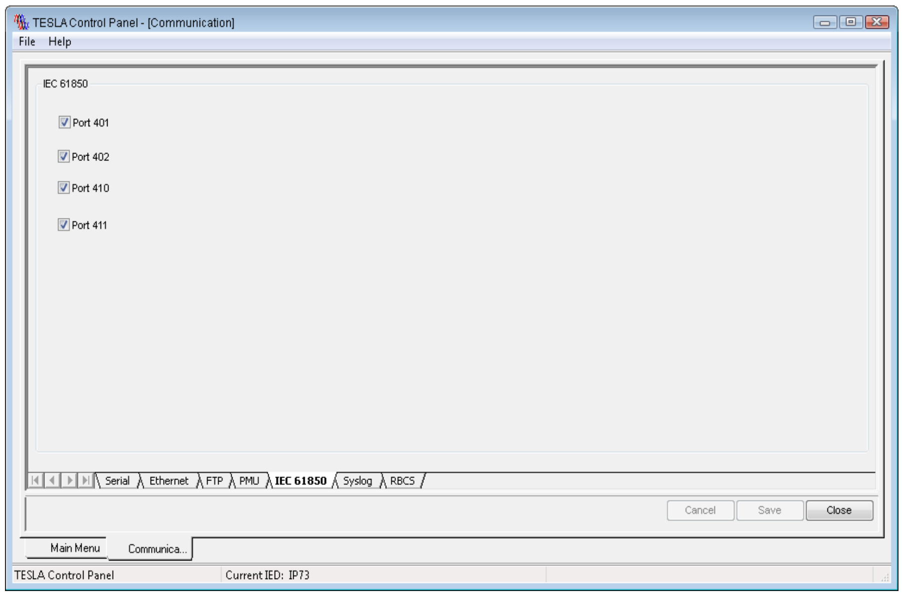


Figure 8.13: IEC 61850 Port Configuration Screen

Settings

The following table describes the IEC 61850 Port Settings:

Table 8.5: IEC 61850 Port Settings

Port	Setting	Services Affected by setting
Port 401	Enabled/Disabled	GOOSE subscription and publication MMS
Port 402	Enabled/Disabled	GOOSE subscription and publication MMS
Port 410	Enabled/Disabled	GOOSE subscription and publication MMS
Port 411	Enabled/Disabled	GOOSE subscription and publication MMS

8.7 Trend Recording Configuration

The Trend Recording Configuration is available on the Trend Recording Configuration screen in TESLA Control Panel.

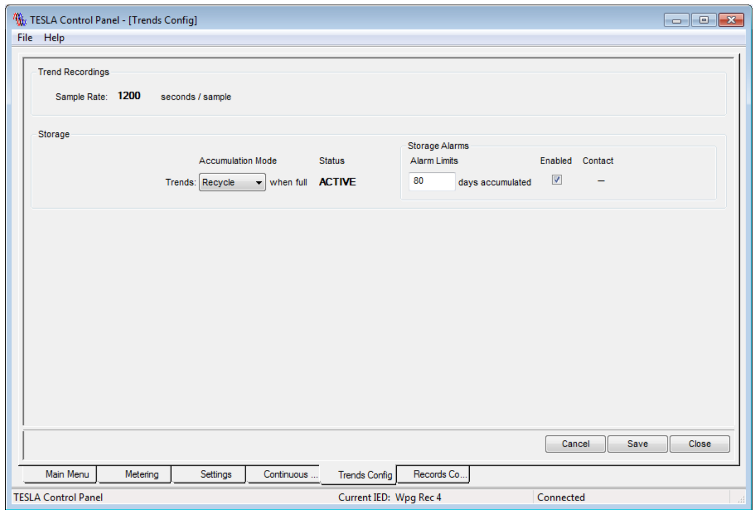


Figure 8.14: Trend Recording Configuration Screen

Settings

The following table describes the recording control settings:

Table 8.6: Trend Recording Configuration	
Trends Recordings	
Sample Rate	Read-only display of the trending interval in seconds. The trend logging rate is configured in the recorder's setting file (see "Trend Logging" on page 9-61).
Storage	
Trend Accumulation Mode	Selects whether to overwrite the oldest trend data when the 90 day storage limit has been reached or to stop trend. The Storage Alarm can be used in conjunction with the Stop setting to provide notification in advance of the full condition.
Trend Storage Alarm Limits	When enabled, you can enter a limit giving the number of days of accumulated trend information that causes an alarm condition. Enter a number of days between 10 and 90. The storage alarm condition is indicated by flashing the front panel "Record Storage" LED and activating a selected alarm contact. Note: the alarm contact assigned to this is displayed as a read-only value. It's set as part of the recorder's configuration (see "TESLA Alarms" on page 9-10).

8.8 Time Synchronization Settings and Display

TESLA Control Panel provides configuration options for the IED time settings and for the display of timestamps on the various TESLA Control Panel screens. The IED time is determined by the Time Source configuration and the settings on the Time screen. The display of timestamps on the various screens in TESLA Control Panel is determined by a combination the *Options > Time Display Settings*, the IED time and the local PC time settings.

The display and setting of the IED time and the TESLA Control Panel timestamps are described in detail in the following section.

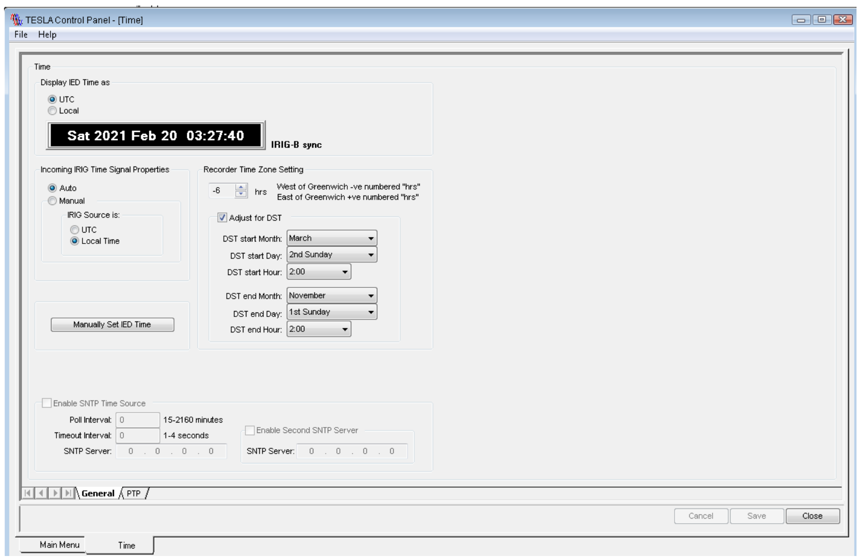


Figure 8.15: Recorder Setup Utilities - Time

The TESLA 4000-A uses time as the basis of data recording and requires the presence of a source time signal on the IED. The recorder supports the following time sources:

- IRIG-B (modulated or unmodulated)
- PTP (IEEE 1588)
- System Sync
- RTC (Real-Time clock) internal free-running oscillator
- SNTP

IRIG-B

Using IRIG-B as a time source is a high accuracy option suitable for use in PMU and CDR applications. The IRIG-B signal is acquired via the IRIG-B on the rear of the recorder.

IRIG-B Signal Interpretation

The IRIG-B source format may or may not contain the following fields; Year (Y), Offset (O) and DST (D). The TESLA provides Auto and Manual mode for interpreting the IRIG-B source information to account for the many different IRIG-B formats.

In Auto mode (recommended setting), the TESLA attempts to automatically interpret the information available in the IRIG-B source. If the IRIG-B source does not contain all relevant fields (Y, O, D), then the user settings are automatically used to supplement the missing fields (see Table 8.7). Since Auto mode may use the user settings (see Figure 8.16 for available user settings), it is important to set the DST, Offset and Year correctly, even when using Auto mode. This ensures that even if the IRIG-B source doesn’t include all fields, they will be replaced with the correct information.

> TESLA is expected to correctly interpret any IRIG format in Auto mode. Please contact ERLPhase customer support if Auto mode setting results in incorrect time.

> Regardless of the mode setting, the TESLA automatically switches to Auto mode when C37.118-2011 compliant IRIG-B source is detected.

In Manual mode, the TESLA relies on the user settings to interpret the IRIG-B source and calculate displayed time. The available user settings are; Year (Y1), Time (T1), Time Zone Offset Setting (O1) and DST (D1) as shown in the figure below. Refer to Table 8.7 for more details on how Manual mode is used.

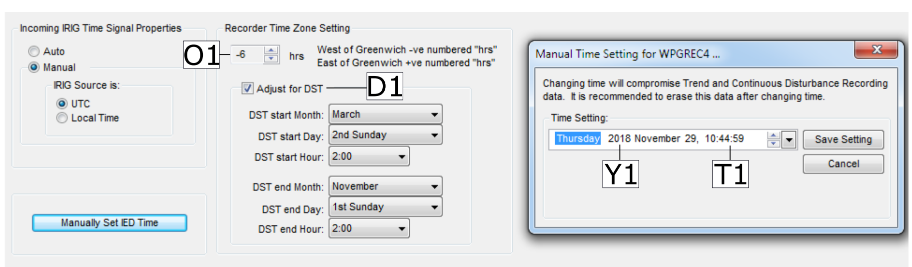


Figure 8.16: User Settings for IRIG-B Interpretation

The following table describes how the TESLA determines the displayed time depending on the Mode setting, the information available in the IRIG-B source and the user settings:

Table 8.7: IRIG-B Signal Interpretation

Mode	Time Field	IRIG-B Source	User Setting	Fields used to determine displayed time
Auto	Year	Y	Y1	Y - if available. Y1 - if Y is not available.
	Time	T	T1	T - if O and D are available. T adjusted by O1 and/or D1 - if O and/or D are not available. T1 is always ignored if an IRIG-B source is present.
	Offset	O	O1	O - if available. O1 - if O is not available.
	DST	D	D1	D - if available. D1 - if D is not available.
Manual	Year	Y	Y1	Y - if available. Y1 - if Y is not available.
	Time	T	T1	T adjusted by O1 and D1. T1 is always ignored if an IRIG-B source is present.
	Offset	O	O1	O - if source is C37.118-2011 compliant[a]. O1 - if source is not C37.118-2011 compliant.
	DST	D	D1	D - if source is IEEE1344 extension[b]. D1 - if source is not IEEE1344 extension.

a. If the IRIG-B source is C37.118-2011 compliant, the mode will automatically revert to Auto after saving the time configuration.

b. IEEE1344 extension includes the following IRIG-B formats:
- IEEE1344
- C37.118-2005
- C37.118-2011

PTP

The TESLA 4000-A supports synchronization via the Precision Time Protocol (PTP) if redundant network configuration is selected at time of ordering (see “Ordering Options and Product Configuration ID” on page 1-6).

The Precision Time Protocol (IEEE 1588) is a network based time source which provides high accuracy over an Ethernet Network connection.

The TESLA 4000-A uses the IEEE C37.238 Power Profile making it suitable for its use in Power System applications.

The *Time* > *PTP* screen settings and the *Communication* > *Network Redundancy* screen settings are both stored on the redundancy communication board. These settings are linked to the Active Mode selected in the *Communication* > *Network Redundancy* screen. When the settings are changed and saved, they are saved to the currently selected Active Mode. When the Active Mode is changed, the settings on the *Time* > *PTP* screen settings and the *Communication* > *Network Redundancy* screens will be updated with those last saved to the new Active Mode profile.

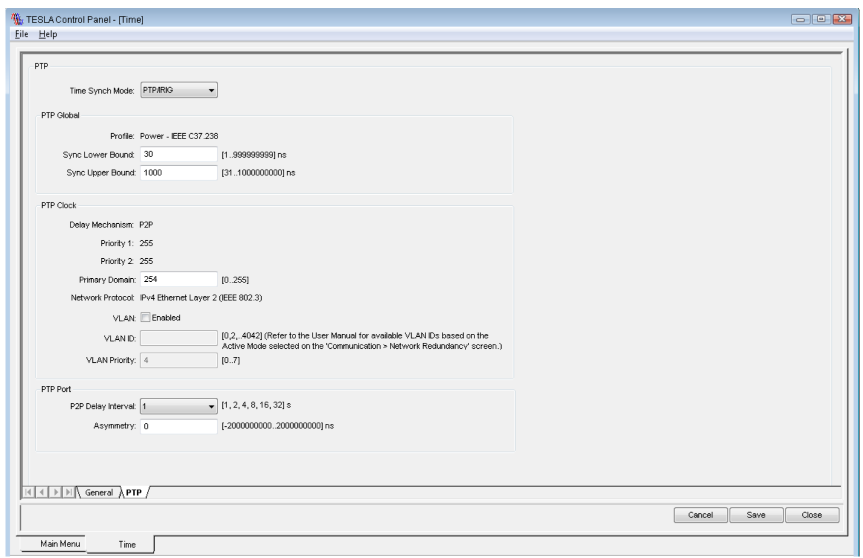


Figure 8.17: Time > PTP Configuration Screen

PTP Configuration

The PTP Configuration is performed on the PTP tab of the Time screen. Ensure that the PTP Settings match that of the Master clock. The settings are described in the table below:

Table 8.8: Time > PTP Settings

Setting	Range/Options	Description
Time Synch Mode	PTP Only or IRIG Only	PTP Only mode uses PTP exclusively and will ignore IRIG signal. IRIG Only mode uses IRIG exclusively and will ignore PTP signal. All settings below are greyed-off when IRIG Only mode is selected.
PTP Global		
Profile	Power - IEEE C37.238 (read-only)	
Sync Lower Bound	1 to 999999999 ns (Default = 30 ns)	The lower threshold value in nanoseconds for the path difference between the local clock and the reference time source (Grandmaster). If the path difference falls below this value once, then the local clock is classified as synchronized.
Sync Upper Bound	Sync Lower Bound to 1000000000 ns (Default = 1000 ns)	The upper bound in nanoseconds for the path difference between the local clock and the reference time source (Grandmaster). If the path difference exceeds this value once, then the local clock is classified as unsynchronized.
PTP Clock Global		
Delay Mechanism	P2P (read only)	Peer-to-peer
Priority 1	255 (read only)	
Priority 2	255 (read only)	
Primary Domain	0 to 255 (Default = 254)	The domain in which PTP traffic occurs, all other domains are ignored
Network Protocol	IPv4 Ethernet Layer 2 (IEEE 802.3) (read-only)	Transport layer used for PTP communication
VLAN	Enabled/Disabled (Default = Disabled)	If enabled, VLAN ID and Priority are enabled and configurable.

Table 8.8: Time > PTP Settings		
VLAN ID	0, 2 to 4042 (Default = 0)	Refer to “VLAN Modes” on page 4-9 for available VLAN IDs based on Active Mode selection
VLAN Priority	0 to 7 (Default =4)	
PTP Clock Port		
P2P Delay Interval	1, 2, 4, 8, 16, 32 s (Default = 1s)	Specifies the interval in seconds at which the port measures the Peer-to-Peer delay
Asymmetry	-2000000000 to 2000000000 ns (Default = 0 ns)	Corrects the measured delay value corrupted by asymmetrical transmission path

System Sync

The TESLA 4000-A supports synchronization via the ERLPhase System Sync time source from the IO Expansion IED. The IO Expansion IED may act as a stand-alone clock using an IRIG type signal. This signal is acquired via the IRIG-B port on the rear of the recorder. For more information regarding the System Sync source, refer to the IO Expansion user manual.

RTC

An internal free-running oscillator, referred to here as a Real-Time Clock (RTC), is always present on the IED and, in the absence of any external time source, will become the default mode of time synchronization. The IED comes equipped with an internal free-running oscillator used to generate a 1 PPS time signal in the absence of any alternate available time source. Use of this oscillator as the primary IED time source requires manual time configuration, with the general accuracy subject to user input parameters, and is recommended primarily for stand-alone, unsynchronized applications. The internal oscillator carries a lifetime accuracy (including temperature effects and aging) of +/-50 ppm.

Order of Precedence

The TESLA 4000-A implements the following order of precedence to determine which time source will be used at any given time:

1. PTP
2. IRIG-B or System Sync
3. RTC
4. SNTP

General Time Settings

The following table describes the time settings on the *Time* > *General* screen:

Table 8.9: Time > General Settings

Display IED Time as	
UTC	Sets the time display to Universal Coordinated Time (UTC). Note that UTC time is not affected by the Record Time Zone setting or Daylight Savings Time.
Local	Sets the time display on the Time screen to Local Time. Local time includes time zone offset and one hour DST adjustment, if DST is applicable. Local time is converted from UTC using the Recorder Time Zone and DST setting.
Current Time Display	When connected to a recorder, the recorder's current time is shown and continually updated. The specified time settings (e.g. Local Time) are applied to the displayed time.
DST Indicator	A text field which is displayed when DST is applicable and in effect in the currently displayed time.
Synchronization Indicator	A text field which is displays the recorder's current time synchronization status. The possible synchronization status indicators are: • IRIG-B Sync • IRIG-B Unlocked • PTP Sync • System Sync • SNTP Sync • No Sync
Incoming IRIG-B Signal Properties	
This group of settings defines how the recorder interprets the incoming IRIG-B signal.	
Auto	Recommended Setting. Instructs the recorder to decode the IRIG-B signal automatically by interpreting the IRIG-B fields. See Table 8.7 for details on how Auto mode is used.
Manual	Instructs the recorder to use user settings for interpreting the IRIG-B signal. See Table 8.7 for details on how Manual mode is used.
IRIG Source is:	When Manual mode is selected, the setting instructs the recorder to interpret IRIG-B time of day as UTC or Local. Setting must match the IRIG-B source configuration.

Table 8.9: Time > General Settings	
Recorder Time Zone Setting	
Offset	Provides the offset from local time to UTC in hours. For example, Central Time has a -6 hour offset from UTC.
Adjust for DST	Instructs recorder to perform Daylight Savings Time calculations, if the IRIG-B DST flag is not used.
DST Start Time	Instructs recorder when (Month, Day, Hour) Daylight Savings Time begins.
DST End Time	Instructs recorder when (Month, Day, Hour) Daylight Savings Time ends.
Manually Set IED Time	
Allows the recorder's clock to be manually set. Year and Time of Year may be set manually. If a synchronization source (IRIG-B) is present, some or all of the manually set time settings may be overridden by the time source. For more details on how the manually set time settings work with an IRIG-B source, see Table 8.7.	
SNTP Time Source	
Enable SNTP Time Source	Activates the IED to attempt SNTP time synchronization based on the user configuration parameters (primary and secondary) for IED synchronization in the absence of an IRIG-B time source.
SNTP Poll Interval	User configurable parameter for defining SNTP server synchronization time cycle (primary and secondary).
SNTP Timeout Interval	User configurable time duration to wait for a server response following an attempted SNTP network synchronization before considering the target server lost.
SNTP Server	IP address for network based primary and secondary SNTP servers to be used as IED time sources (if enabled) in the absence of a valid IRIG-B signal.

Changing time manually and/or IRIG-B re-synchronization causes discontinuity in the trend and continuous disturbance recording data.

IED Time Display

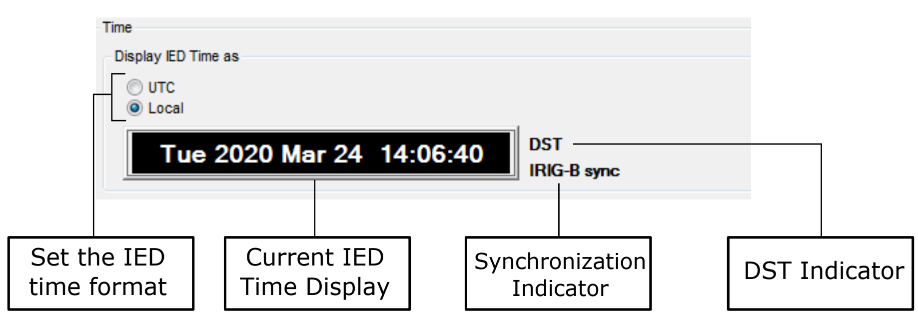


Figure 8.18: Time Screen IED Time display

The Time screen provides the current IED time display. The time and date value displayed is the result of the time source selection and time calculations, regardless of where the time value, time zone offset and DST information comes from (external source or internal clock).

The time format is determined by the UTC/Local selection. Local time includes time zone offset and one hour DST adjustment, if DST is applicable.

If DST is applicable and in effect then a “DST” indication is shown on right side of the displayed Time.

The current time source is also shown on the right side of the displayed time.

Time Display Settings

TESLA Control Panel provides configuration of the timestamp display format. The *Option > Time Display Setting* dialog box controls the time display format on the Events, Records, CDR and Trend screens. The Time Display Setting appears in the Options menu only when viewing these four screens.

The Time Display Settings and how they affect the various TESLA Control Panel screens, are shown below.

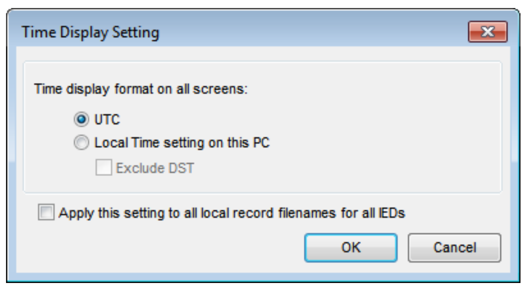


Figure 8.19: Time Display Settings

Table 8.10: Time Display Settings

Time display format on all screens:	
UTC	Displays the timestamps according to the Coordinated Universal Time (Offset = +0:00).
Local Time setting on this PC	Displays the timestamps according to the time settings on the local PC. Uses the Time Zone and DST settings of the PC to determine the timestamp displayed in the record.
Exclude DST	Displays the timestamps according to the time settings on the local PC. Uses the Time Zone, but excludes the DST setting of the PC to determine the timestamp displayed in the record.

Table 8.10: Time Display Settings	
Apply this setting to all local record filenames for all IEDs	When this setting is applied, all local record names for all IEDs in the IED list (on the Main Menu screen) will be converted to the selected format. Note: A progress bar is displayed during the renaming process with an option to cancel the process. If the process is cancelled, the records which have already been renamed will not be reverted to their original name. Note: This setting does not modify records which use the IEEE C37-232-2011 Long Filename format as these always use UTC format as defined by the standard.

A Time Display Setting change made in TESLA Control Panel will automatically be set in RecordGraph, RecordBase and RecordBase View (if these software applications are installed).

It is not recommended to repeatedly switch between time display settings as it may cause confusion when determining the sequence of events and recordings. ERLPhase recommends “setting-and-forgetting” the Time Display Setting.

Event Timestamps

The Event Log timestamps on the Events screen are displayed according to the Time Display Setting and are updated dynamically when the setting is changed. A UTC Offset field on the Event Log displays the UTC Offset recorded by the IED (not the local PC). The timestamp column title changes according to the Time Display Setting. The possible timestamp column titles are “UTC Time”, “Local Time” or “Local Time (exclude DST)”.

Audit Trail Timestamps

The Audit Trail timestamps are always displayed according to the IED local time. The Time Display Setting does not apply to the Audit Trail. Refer to the TESLA 4000-A Security Notification Guide for further details on the Audit Trail time format.

Record Timestamps

The Records screen timestamps are affected by the *Options > Time Display Setting,* as described below:

Table 8.11: Record Screen Time Display	
Record List (LHS)	
On IED (Remote)	The Remote Record names are displayed according to the Time Display Setting and are updated dynamically when a Time Display Setting change is made.

Table 8.11: Record Screen Time Display	
Local	Local files are renamed when the Time Display Setting is toggled and the 'apply this setting to all local record filenames' is selected. A progress dialog will be displayed with a Cancel button while this is happening. If the renaming process is cancelled, all local records already renamed will remain in that state (i.e. the cancelled action will not be rolled back). Note: The local records which use the IEEE C37-232-2011 Long Filename format are not affected by the Time Display Settings and are always displayed in UTC as required by the standard.
Record Summary	
The Record Summary title will display as "Record Summary (UTC)" if the Time Display Setting is set to UTC and will display as "Record Summary" otherwise.	
Trigger Time	The Trigger Time is displayed according the Time Display Setting and is updated dynamically when a Time Display Setting change is made.
UTC Offset	Displays the IED UTC Offset determined by the IED time source and the DST and time zone settings on the Time screen. Not affected by the Time Display Setting.
Events	
Event Timestamp	The Event timestamp is displayed according the Time Display Setting and is updated dynamically when a Time Display Setting change is made.

Record Export Timestamps

COMTRADE records exported from TESLA Control Panel/Record Graph contain data displayed according to the UTC time. The Time Display Setting is not applicable to the COMTRADE export as well as view the COMTRADE records.

CSV records exported from TESLA Control Panel contain data displayed according to the current Time Display setting. An indication of the time display format in the file's header.

CDR Timestamps

The Continuous Disturbance Recording screen timestamps are affected by the *Options > Time Display Setting,* as described below:

Table 8.12: CDR Screen Time Display
The CDR Record Summary title will display as "Record Summary (UTC)" if the Time Display Setting is set to UTC and will display as "Record Summary" otherwise.
Record List (LHS)

Table 8.12: CDR Screen Time Display	
Local	Local files are renamed when the display format is toggled if the ‘apply this setting to all local record filenames’ is selected; a progress dialog will be displayed with a Cancel button while this is happening. If the renaming process is cancelled, all local records already renamed will remain in that state (i.e. the cancelled action will not be rolled back). Note: The records which use the IEEE C37-232-2011 Long Filename format are not affected by the Time Display Settings and are always displayed in UTC as required by the standard.
Data Summary	
Retention Period	The 'Retention Period' will adjust according to the Time Display Setting. The Retention Period title will display as “Retention Period (UTC)” if the Time Display Setting is set to UTC and will display as “Retention Period” otherwise.
Start Date	The 'Start Date' will adjust according to the Time Display Setting. The Start Date title will display as “Start Date (UTC)” if the Time Display Setting is set to UTC and will display as “Start Date” otherwise.

CDR data during a DST crossover period (when DST is moving from ON to OFF or OFF to ON) may not be retrieved correctly if the Time Display Setting is set to Local.

It is recommended to use Local (Exclude DST) or UTC Time Display option when retrieving CDR data for a period which includes a DST crossover.

Trend Timestamps

The Trends screen contains timestamps are affected by the *Options > Time Display Setting,* as described below:

Table 8.13: Trend Screen Time Display	
Range of Dates for Trends and Events	
From	The “From” range is adjusted according to the Time Display Setting.
To	The “To” range is adjusted according to the Time Display Setting.
Events	
Time column	Event time stamp is dynamically changed according to Time Display Setting. Column title will change from “UTC Time” to “Local Time” to “Local Time (exclude DST)”.
UTC Offset	Displays the UTC Offset recorded by the IED and is not affected by the Time Display Setting.

Settings Timestamps

The Time Display Setting does not apply to the Settings screen. The Name column timestamps are based on the local time of the PC which retrieved the settings file. The Settings Date column timestamps are based on the local time of the PC which created or modified the settings file.

System Diagnostics Log Timestamps

The System Diagnostics Log on the *Maintenance* > *System Diagnostics* screen is always displayed in UTC time. The Time Display Setting does not apply to the System Diagnostics Log.

8.9 Analog Input Calibration

The Calibration Utility provides a means of calibrating the recorder's analog input channels. It is accessed through the TESLA Control Panel's Calibration screen.

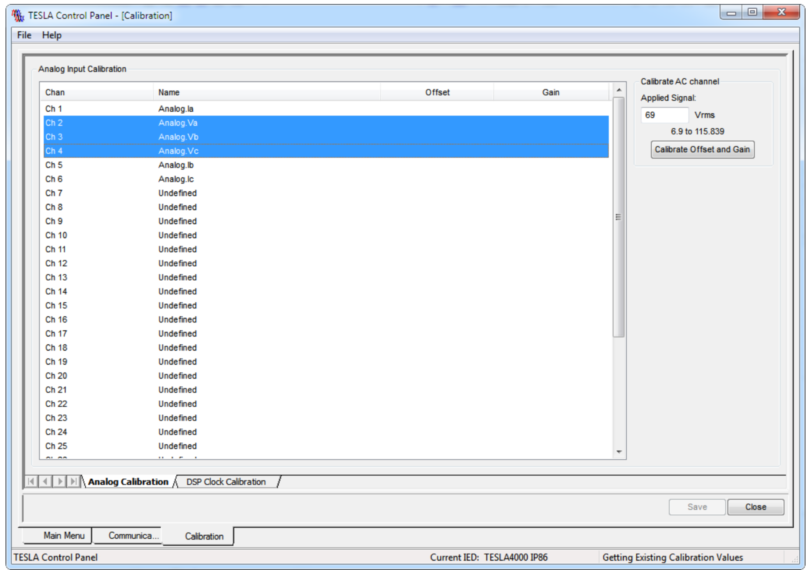


Figure 8.20: Analog Input Calibration

When To Calibrate

If the type of isolation module is changed, for example from a voltage to a current the readings will be significantly wrong until calibration has been performed.

Only the channels associated with the altered module need be re-calibrated.

Also, when a new TESLA recorder is installed it should be calibrated.

> The recorder's analog input channels should be re-calibrated whenever an analog isolation module is changed or when wiring between the module and the TESLA has been modified.

AC Channel Calibration Process

To calibrate a channel (*Main Menu>Calibration)*:

1. Select the channel or channels from the list. More than one channel of voltage or current can be chosen using the *Control/Shift + left-click*.

> It is possible to calibrate multiple channels simultaneously by using the mouse to select a set of channels from the list. Multiple channels can be selected using standard Windows selection methods.
>
> All channels in the selected set must have the same type of input module.

2. Enter the voltage or current magnitude that is applied to the isolation module associated with the channel Applied Signal field. The signal magnitude level should be measured with a precision calibrated instrument.
3. Press the *Calibrate Offset* and *Gain* button. If a channel has not yet been configured, only *Calibrate Offset* will be displayed.
4. Under the *Offset* and *Gain* columns the line of the channel being calibrated *OK* or *No* will be displayed (see "Analog Input Calibration" on page 8-28).
5. Repeat for all other channels being used.
6. Use the *Save* button to load the new calibration to the recorder.

DC Channel Calibration Process

The DC calibration procedure is a two-step procedure. When one or more compatible DC channels are selected, two calibration areas appear on the screen. You may calibrate the points in either order as is convenient. DC calibration is not complete until both points have been calibrated, and the associated offset and gain values accepted.

Out of Range

An error message is displayed if the applied signal as seen by the recorder differs from the value entered in the Applied Signal field by more than 20%. This helps to prevent erroneous calibration.

> If you change the type of isolation module associated with a channel, you must specify the new module type in the input channel's configuration before calibrating.

8.10 Notify RecordBase Central Station (RBCS)

The TESLA recorder can call an ERLPhase RecordBase Central Station via modem or LAN to notify it of selected events.

Notification is used for two purposes:

1. To initiate cross-triggering of dynamic swing records on other recorders.
2. To initiate record transfer to RecordBase when a new record is created.

The Notify RBCS tab on the Communication screen contains settings to control the dial-out process and the initiation of record transfers.

Automatic Record Transfer

You can control which records are automatically transferred to the RecordBase Central Station by specifying the required record priority. The setting ranges from 0 (all records) to 3 (highest priority only) and provides an option to disable automatic record transfers completely.

Record priority is determined by the highest priority trigger included in the record. Trigger priority is set as part of each channel's configuration.

Cross-Trigger Notification

A notification call to RecordBase to trigger swing recordings on other recorders can be initiated by any of the recorder's triggers. Cross-trigger notification is selected as part of each channel's configuration.

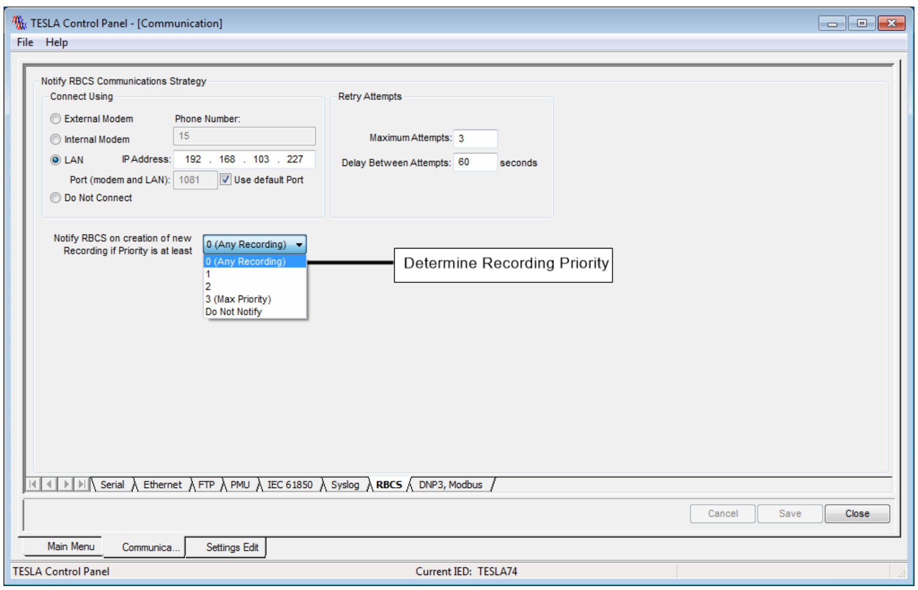


Figure 8.21: Notify Communication Strategy

Settings

The following table describes the Notify RBCS settings:

Table 8.14: Notify RBCS Settings

Connect Using	The TESLA recorder can be set to notify a RecordBase Central Station via modem or LAN, or to not notify at all. These 3 options are mutually exclusive. Note that the availability of these controls is dependent on the hardware options and configuration of the recorder.
Modem	If *Modem* is selected, enter the telephone number of the RecordBase call-in modem. All standard modem dialing characters are supported (e.g. a comma is used to specify a pause in the dialing sequence).
LAN	If *LAN* is selected, enter the IP address of the computer running RecordBase Central Station.
Do Not Connect	If *Do Not Connect* is selected, the TESLA recorder will not notify RecordBase Central Station of new records or cross triggers. This is a global setting and can be used to temporarily disable notification.
Retry Attempts	These rules are applied when the TESLA recorder fails to establish communication with RecordBase Central Station (i.e. if the phone line is busy, or if the network is down).
Maximum Attempts	When the TESLA recorder fails to establish contact with RecordBase central station, this is the maximum number of attempts it will make before giving up.
Delay Between Attempts	Specifies the delay, in seconds, that the TESLA will wait before making another notification attempt.
Notify on creation of new Recording if Priority is at least	Controls which records, if any, are automatically transferred to the RecordBase Central Station. When a record is created with a priority equal to or greater than the specified value, the recorder sends a New Record Created notification message to RecordBase. The setting can range from 0 (all records) to 3 (highest priority only). Selecting Do Not Notify disables automatic record transfers completely. Record priority is determined by the highest priority trigger included in the record. Trigger priority is set as part of each channel’s configuration.

8.11 SCADA Communication

Configuration of the SCADA communication parameters is performed on the DNP3, Modbus screen in the Communication menu. This screen contains all of the communication parameters required to establish SCADA communication. The configurable DNP mapping is not performed on this screen. For more information on DNP mapping, see “SCADA Point Mapping Configuration” on page 9-16.

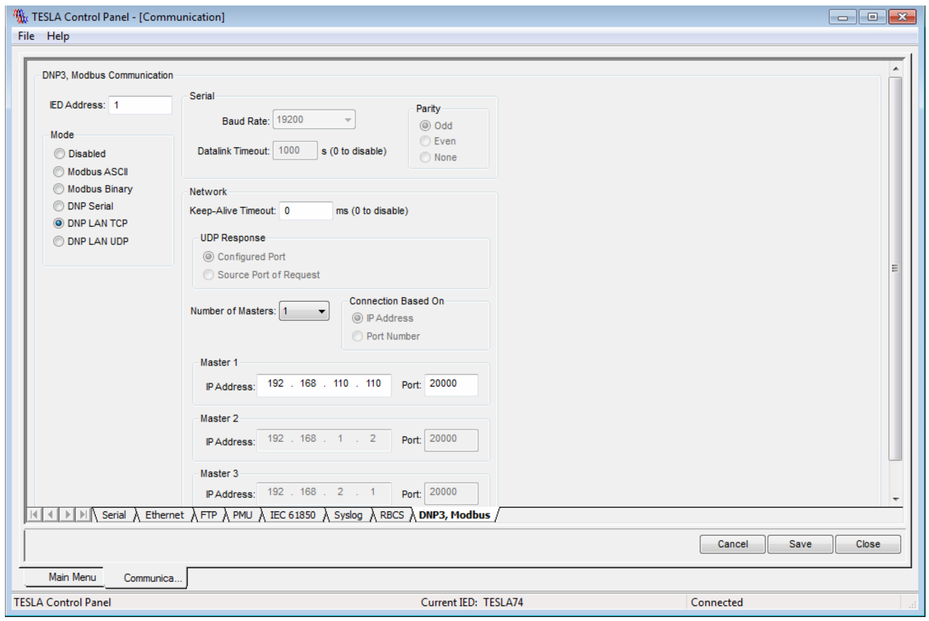


Figure 8.22: SCADA Protocol Settings

The recorder supports a DNP3 (Level 2) SCADA connection. DNP3 is available via a direct serial link or an Ethernet LAN connection using either TCP or UDP.

The record supports a Modbus ASCII or Modbus Binary (RTU) SCADA connection. Modbus is available via a direct serial link only.

Serial DNP and Modbus communications and can be utilized exclusively via serial Comm Port 404. Comm Port 404 is an RS232 DCE DB9F port located on the back of the recorder. An external RS-232 to RS-485 converter can be used to connect the recorder to an RS-485 network.

Network DNP communications can be utilized via physical LAN provisions. DNP communications can be used with multiple masters when it is utilized with TCP.

Settings

The following table describes the SCADA protocol settings:

Table 8.15: SCADA Protocol Settings

Mode	Select one of the available SCADA modes.
Baud Rate	Port 404 serial baud rate. Default is 19,200.
Parity	Port 404 serial parity. Note: When parity is set to None and a Modbus protocol is selected, the number of stop bits automatically is set to 2, as per the Modbus standard.
Stop Bits	(Automatic setting). Always set to 1 stop bit except as noted in Parity setting above.
Data Bits	(Automatic setting) The number of data bits is controlled by the selected protocol mode. Modbus ASCII:7 data bits Modbus RTU:8 data bits DNP 3:8 data bits
IED Address	Identifies the unit to the SCADA master.
Keep-Alive Timeout	(DNP) Specifies the time in which the recorder expects a response from the SCADA master to primary frame messages. If a response is not received in this time, the recorder will re-transmit the message. The timeout is usually set to 0 milliseconds per DNP3 Technical Bulletin 9804-002. This document is available from the DNP3 User's Group (www.dnp.org)
UDP Response (DNP LAN UDP only)	May be set to either Configured Port or Source Port of Request.
Number of Masters (DNP LAN TCP only)	Defines how many master SCADA devices will be polling the TESLA. May be set to 1, 2 or 3.
Connection Based On (DNP LAN TCP only)	Determines if the master SCADA device will establish a connection based on IP Address or Port Number.
Master IP Address (DNP LAN TCP or DNP LAN UDP)	Defines the IP addresses of the master SCADA devices that will be polling the TESLA. This prevents unauthorized master devices from communicating with the TESLA. Note: These settings do not control IP address of the TESLA's Ethernet card. That is done from the TESLA Control Panel *Communication > Ethernet* screen. Make sure the Master IP Addresses are different from the TESLA IP Address.
Port	DNP (TCP or UDP) Defines the TCP or UDP port on which the DNP service may be accessed. Usually set to 20000. Note: Ensure that the DNP Port selection does not conflict with any other listening ports for the other communication services (ie. do not set the same port for TCP/IP Port and DNP Master’s ports)

8.12 Syslog Communication Settings

The Syslog communication settings are accessed via the Syslog Screen in the Communication menu. For more information on the Security Notification System and the Syslog protocol implementation, see “Security Notification System” on page 18-10.

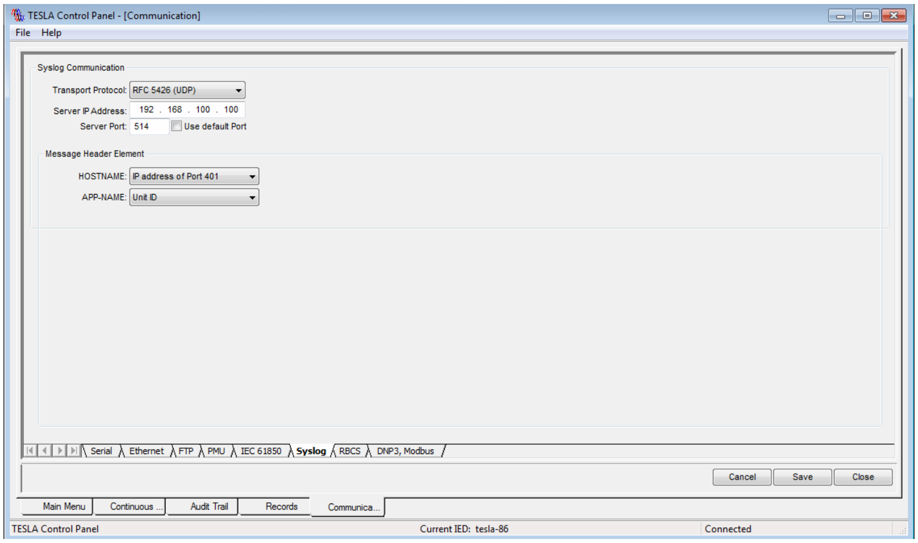


Figure 8.23: Syslog Communication Settings

Settings

The following table describes the Syslog Communication settings:

Table 8.16: Syslog Communication Settings	
Transport Protocol	Set to Disabled or RFC 5426 (UDP). If set to disabled, the communication to the Syslog server is disabled. If set to RFC 5426 (UDP) the UDP protocol is used for communication with Syslog server.
Server IP Address	This parameter defines the Syslog server IP Address.
Server Port	This parameter defines Syslog server IP port for receiving Syslog messages. It can be set to default (514) or to any port number from 1 to 65535.
Message Header Element	
HOSTNAME	This setting is used for the Syslog message HOSTNAME field. May be set to “IP address of Port 401”, “IP address of Port 402”, “IP address of Port 410” or “IP address of Port 411”.
APP-NAME	This setting is used for the Syslog message device identifier APP-NAME field. May be set to one of the following values: • Not Used • Serial Number • Unit ID • Product Model

8.13 Security Setup

The TESLA 4000-A features a comprehensive cyber-security system. This section describes how a security administrator can setup user accounts within this system. For more detailed information on the cyber-security features employed in the TESLA 4000-A see Section 18 Cyber Security.

Security Screen

The security configuration for the TESLA 4000-A is performed on the Security screen. To access the Security screen, the user must login with an account that has "SECADM" privileges. On the initial security setup, use the default "secadmin" account. Once logged in to the IED using the "secadmin" account, click on *Security* from the *Main Menu*. For more information on default user accounts, see "Default Security Configuration Settings" on page 8-41.

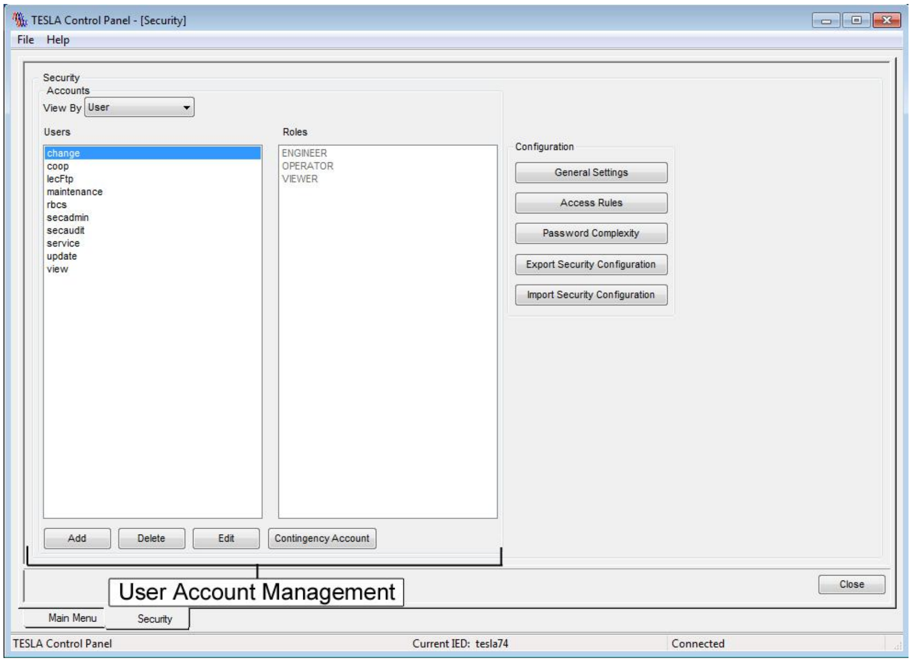


Figure 8.24: Security Screen

The left side of the Security screen provides options to configure and manage individual user accounts. The right side of the Security screen provides options for general security configuration and management.

User Account Management

The security screen provides means to add, delete and edit user accounts.

View By

There are two views available on the security screen: *View By Role* and *View By User*. Toggle between these views using the *View By* drop-down box.

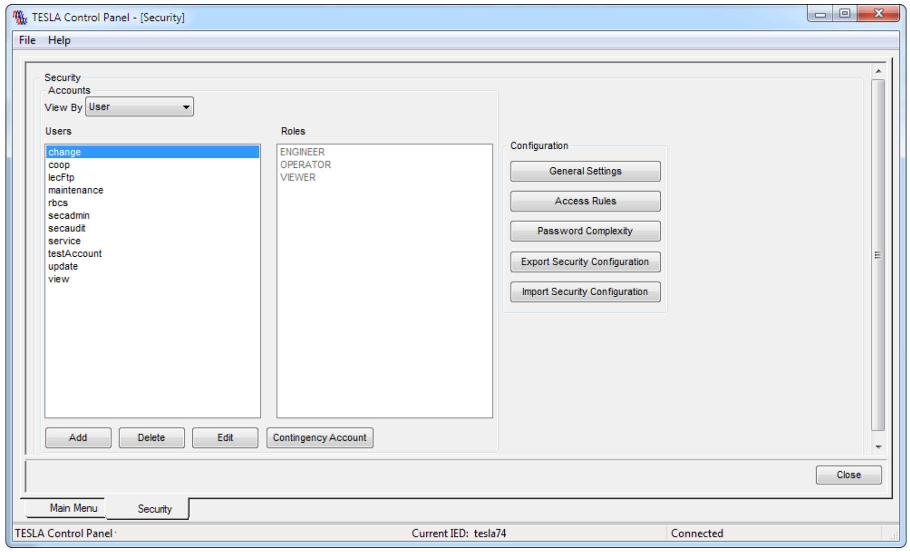


Figure 8.25: View By User

View By User displays all user accounts in the left window. Selecting a user displays the assigned roles for that user in the right window.

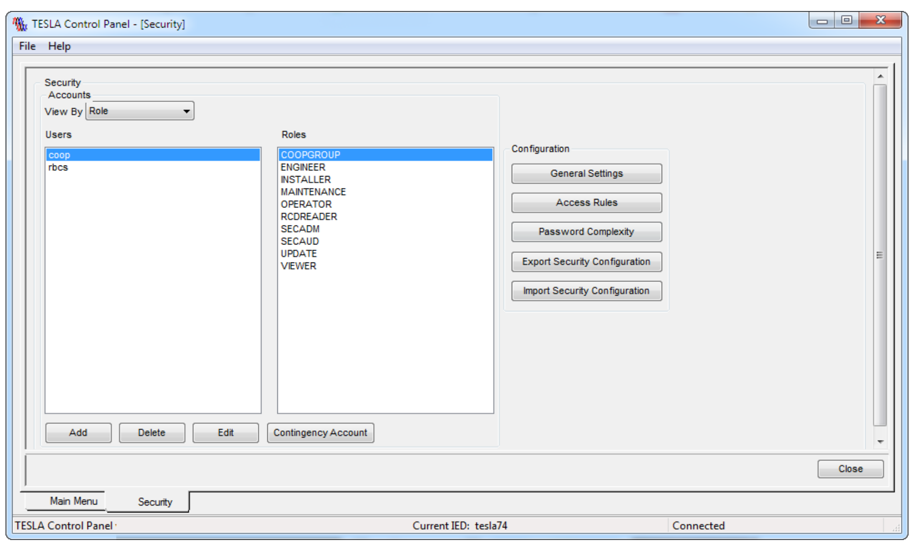


Figure 8.26: View by Role

View By Role displays all roles in the right window. Selecting a role displays the user accounts which are assigned that role in the left window.

Adding a New User

Clicking on *Add* launches a pop-up window for creating a new user account. This window provides means to define account activation rules and role assignments.

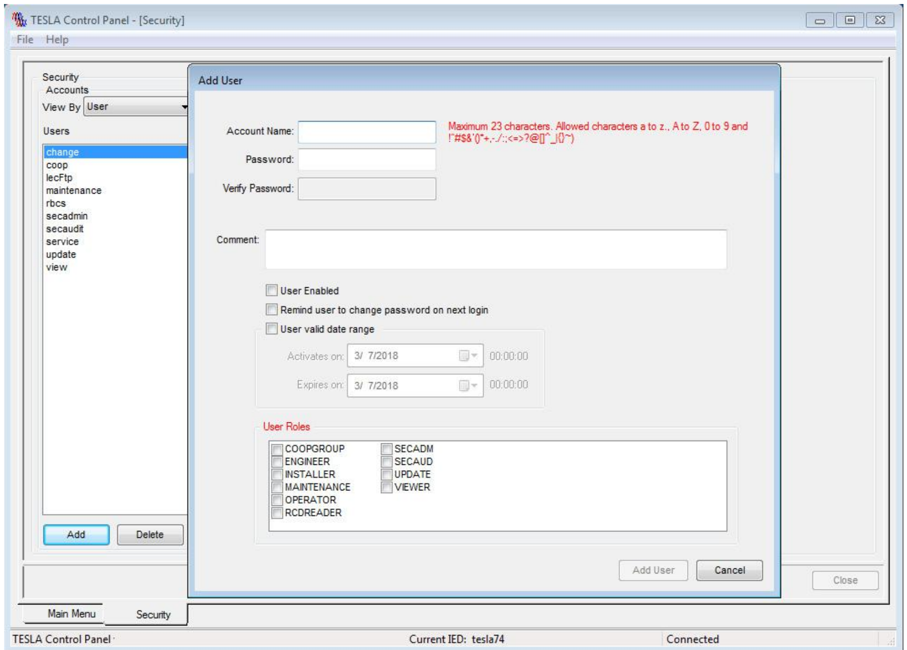


Figure 8.27: Add User

For more information on the individual user account settings, see “User Accounts” on page 18-5.

> ERLPhase recommends that during the initial setup Security Administrator change the default passwords for all accounts.

Deleting a User

To delete a user account, select a user account from the left side window and then press the *Delete* button.

Editing a User

To edit an existing user account, select the user from the left side window and press the *Edit* button. Upon pressing the *Edit* button, an *Edit User* window opens (similar to the *Add User* window) and all account settings can be modified.

Contingency Account

A Contingency Account for restoring security configuration to factory default is provided. The Contingency Account uses a “Challenge-Response” method for restoring Security Configuration to Factory Defaults. To view the Challenge, or to generate a new Challenge, click on the *Contingency Account* button. For more information on the Contingency Account and how to restore to factory default, see “Security Configuration Restoration to Factory Defaults” on page 8-43.

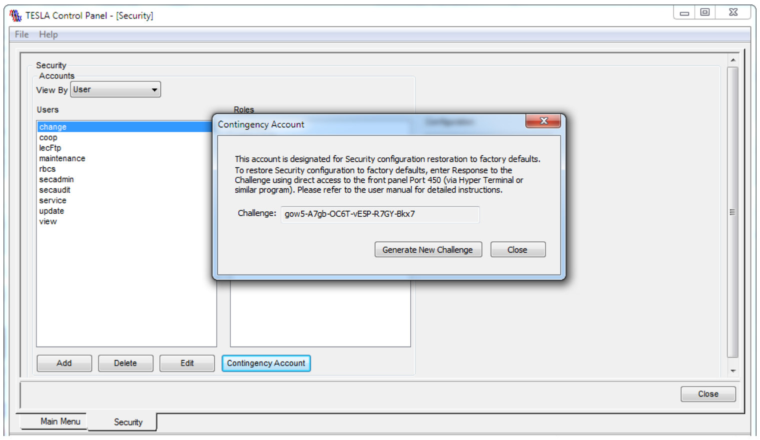


Figure 8.28: Contingency Account

General Settings

The *General Settings* window provides means to enable or disable Remote Firmware Update.

If Remote Firmware Update is enabled, users assigned the “Update” role have the ability to perform a firmware update over Ethernet LAN. If Remote Firmware Update is disabled, users assigned the “Update” role will only have the ability to perform a firmware update with front panel USB (Port 450) connection.

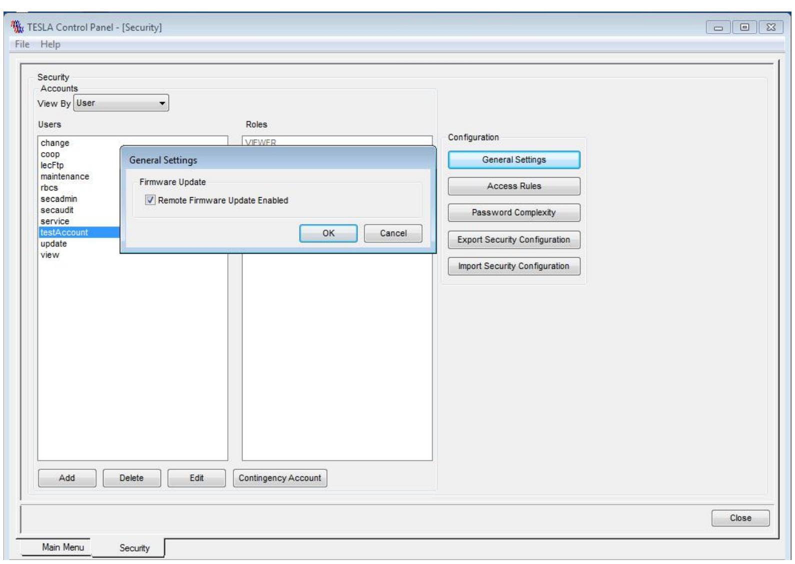


Figure 8.29: General Settings

Access Policies

The *Access Policies* window provides configuration of user login and session duration rules. For more information, see “Access Rules” on page 18-3.

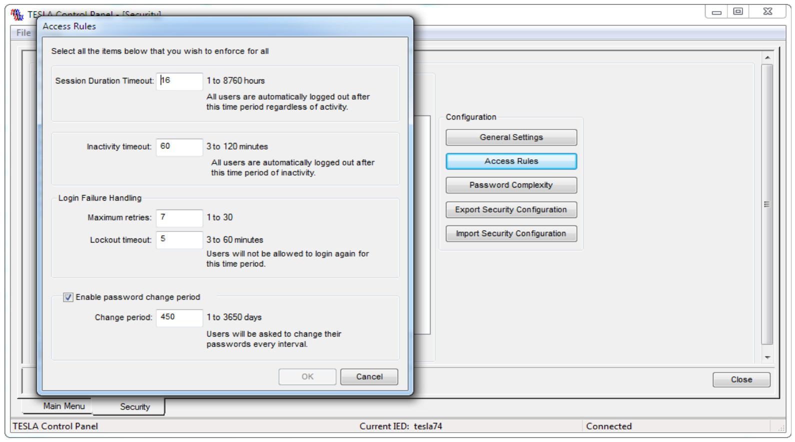


Figure 8.30: Access Policies

Password Complexity

The *Password Complexity Rules* window provides configuration of user account password complexity rules. For more information on the Password Complexity rules, see “Password Complexity Rules” on page 18-3.

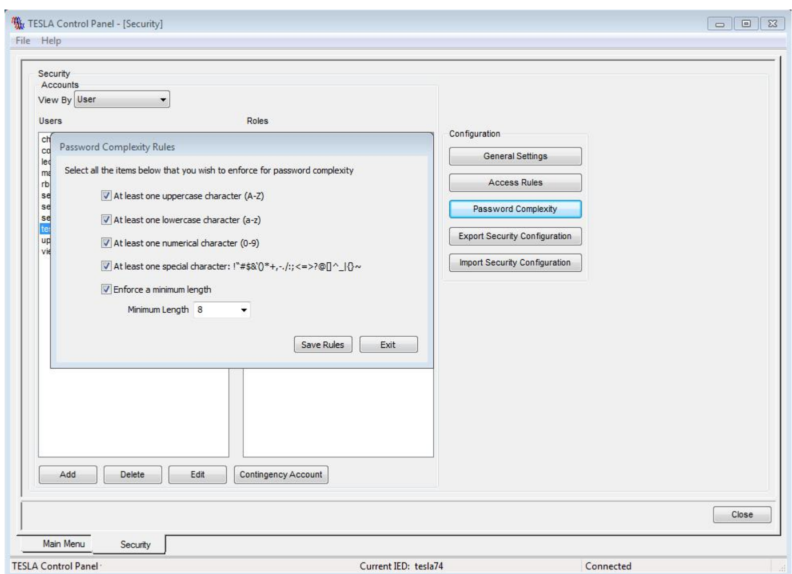


Figure 8.31: Password Complexity rules

Export and Import Security Configuration

The Export Security Configuration option allows the security administrator to save an entire security configuration to a file location. The Import Security Configuration option allows this security configuration to be imported back to the IED to restore a previously saved configuration. The exported security configuration is encrypted to ensure that critical security information is not accessible. All security configurations outlined in the previous sections are included in the exported security configuration file.

To export the security configuration, select the *Export Security Configuration* button, select a file location for saving, and select *Save*. To import a security configuration, select the *Import Security Configuration* button, select a previously saved configuration, and select *Open*.

The Imported Security Configuration takes effect immediately and does not require IED reboot.

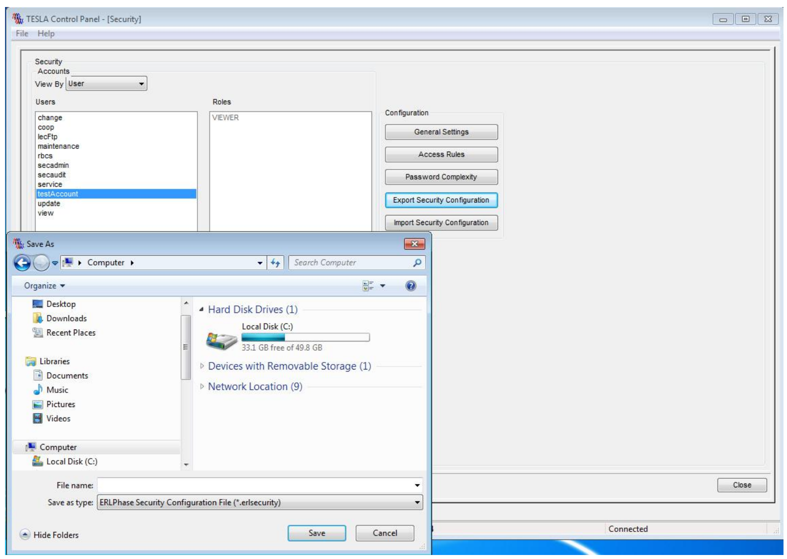


Figure 8.32: Export Security Configuration

Default Security Configuration Settings

The TESLA 4000-A is shipped from the factory configured with Default Security Configuration settings. The Default Security Configuration settings are shown in Table 8.17: Default Security Configuration settings and Table 8.18: Default User Accounts.

Table 8.17: Default Security Configuration settings

Group	Name	Value	Notes
General Settings	Remote Firmware Update Enabled	OFF	
Access Rules	Session Duration Timeout	16	Hours
	Session Inactivity Timeout	60	Minutes
	Failed login handling:		
	Maximum Retries	7	
	Lockout Timeout	5	Minutes
	Password Change Period:		
	Enable	OFF	
	Change Period	450	Days
Password Complexity Rules	At least one upper case character	OFF	
	At least one lower case character	OFF	
	At least one numerical character	OFF	
	At least one special character	OFF	
	Enforce a minimum length	OFF	
	Minimum length	OFF	
User Accounts	Refer to Table 8.18: Default User Accounts		“User Enabled” is set to ON; “Change password on the next login” is set to OFF; “User valid date range” is set to OFF.

Table 8.18: Default User Accounts

User Name	Password	Assigned Roles
view	view	VIEWER, OPERATOR
change	change	VIEWER, OPERATOR, ENGINEER
service	service	VIEWER, OPERATOR, ENGINEER, UPDATE, MAINTENANCE
update	Update@2015	UPDATE
maintenance	Maintenance@2015	MAINTENANCE
coop	Coop@2015	COOPGROUP
rbcs	Rbcs@2015	RBCS
rcdreader	Rcdreader@2015	RCDREADER
secadmin	Secadmin@2015	SECADM
secaudit	Secaudit@2015	SECAUD
IecFtp	ERLPhase2010	INSTALLER

Security Configuration Restoration to Factory Defaults

The Security Configuration restoration to Factory Defaults is available only to Terminal User Interface (UI) service. The Terminal UI is accessed using any Terminal emulation software, such as Microsoft HyperTerminal, and is only available on the front USB serial port 450. The Terminal UI Service implements a Challenge-Response protocol described in “Contingency Account” on page 18-6.

The Terminal UI service performs the following functions:

1. Read Challenge
2. Update Challenge
3. Restore Security Configuration to Factory Defaults

Starting the Terminal User Interface service

Prepare a USB link as described in “USB Link” on page 6-2.

Start a terminal emulation software such as HyperTerminal. Configure the terminal emulation program for a serial connection (115200; 8-bit data, no parity, 1 stop bit, hardware flow control) using “ERLPhase 4000 Series Device”. Ensure that the terminal emulation program is logically disconnected.

Press the ‘#’ symbol to start the Terminal UI service. If another key is accidentally pressed before the ‘#’, the utility will not launch. User must disconnect, reconnect, and then try again. The service shows a greeting and offers menu option selection as shown in Figure 8.33: Security Terminal User Interface service.

```
         Welcome to ERLPhase Security UI
This UI restores IED's security configuration to factory defaults.
Restoration process is protected by the Challenge-Response method.
Please contact ERLPhase customer support to generate Response
for the Challenge shown below.

     email: support@erlphase.com
     pnone: 204-477-0591

Current Challenge is: 'n88m-G31g-mcoN-1wZ5-fQGR-ekGc'

Please select one of the following options:

1. Enter Response to restore security configuration.
2. Enter '+' to update Challenge.
3. Press 'Enter' to exit.

#
```

Figure 8.33: Security Terminal User Interface service

> Single quotes at the beginning and end of the Challenge are text delimiters and are not part of the Challenge.

The Terminal UI executes the selected option and then exits. The Access Policies are applied to the Terminal UI sessions. The IED closes the Terminal UI session when the “Session Duration Timeout” or “Session Inactivity Timeout” expire.

Restoring Security Configuration to Factory Default

To restore the Security Configuration to Factory Default, enter the Response at the prompt and press *Enter*. The IED executes the operation as shown in Figure 8.34: Security Configuration restoration to Factory Default example**.**

```
        Welcome to ERLPhase Security UI
This UI restores IED's security configuration to factory defaults.
Restoration process is protected by the Challenge-Response method.
Please contact ERLPhase customer support to generate Response
for the Challenge shown below.

     email: support@erlphase.com
     phone: 204-477-0591

Current Challenge is: 'n88m-G31g-mcoN-1wZ5-fQGR-ekGc'

Please select one of the following options:

1. Enter Response to restore security configuration.
2. Enter '+' to update Challenge.
3. Press 'Enter' to exit.

#3EPf-RjbO-+okB-9hpU-Kmpo-ROnY

Processing Response. Please wait...

Operation successful.
Exiting
```

Figure 8.34: Security Configuration restoration to Factory Default example

User entered Response is shown in red text.

Updating the Challenge

To update the Challenge, enter '+' character and press enter. The IED executes operation and prints a new Challenge as shown in Figure 8.35: Challenge update example.

```
        Welcome to ERLPhase Security UI
This UI restores IED's security configuration to factory defaults.
Restoration process is protected by the Challenge-Response method.
Please contact ERLPhase customer support to generate Response
for the Challenge shown below.

     email: support@erlphase.com
     phone: 204-477-0591

Current Challenge is: 'T48d-elj/-JH/V-M2ns-Zbu3-aDt6'

Please select one of the following options:

1. Enter Response to restore security configuration.
2. Enter '+' to update Challenge.
3. Press 'Enter' to exit.

#+
New Challenge is: 'p6QI-3cVQ-a01X-hwm0-taSM-L22r'

Exiting
```

Figure 8.35: Challenge update example

9 Recorder Settings

This chapter describes the Settings File which defines the individual channels and record triggers.

The Settings file identifies and adjusts the recorder's input channels, derived (calculated) channels, record triggers, recording configuration, metering displays and trend logs. The settings file is created and managed by TESLA Control Panel and loaded into the recorder's non-volatile memory through the communications link.

9.1 Managing Settings File

TESLA Control Panel's *Settings* screen creates and manages Settings files and handles transfer to and from the recorder.The *Settings* screen can be opened directly from the *Main Menu*.

The settings shown on the *Settings* screen are specific to the selected Current IED. To work with settings from another recorder, you must first select that unit as the Current IED (from the Main Menu).

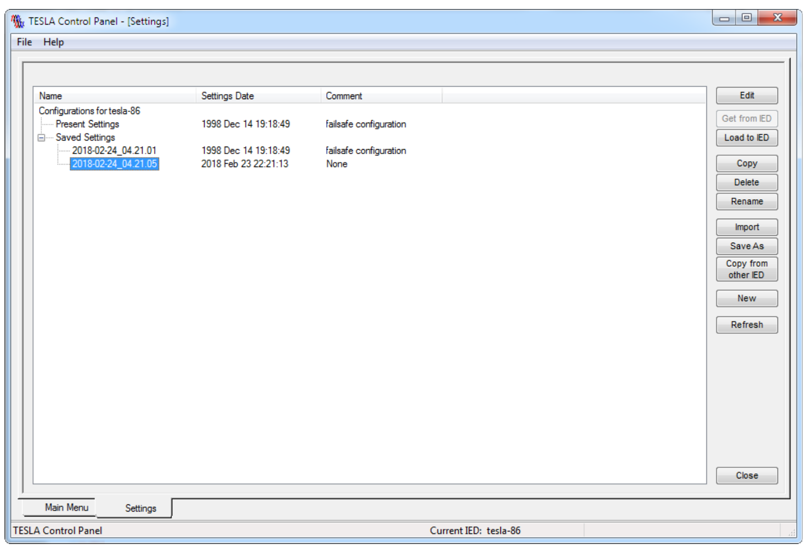


Figure 9.1: Settings Manager

If a communication link to the Current IED is available, you can work directly with the recorder's Settings by either double-clicking on the *Present Settings* item in the list or by selecting *Present Settings* and clicking the *Edit* button.

Editing a Recorder's Present Settings

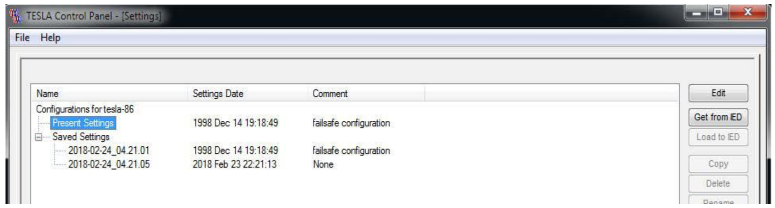


Figure 9.2: Recorder Settings access

When you close the Settings Editor, you are given an option of loading the configuration back into the recorder. This gives you a quick way to make changes on the fly.

You can also save recorder Settings into a file in TESLA Control Panel using the *Get from IED* button. The Settings appear on the Saved Settings list, when transfer is completed.

Saved Settings Files

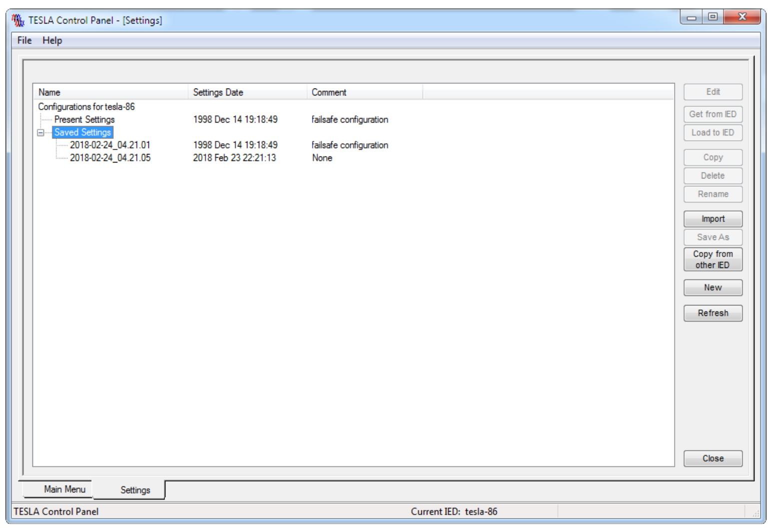


Figure 9.3: Saved Configurations

Saved settings are shown under the Saved Settings heading in the list. TESLA Control Panel can store many Settings files, limited only by hard disk and Windows operating system constraints.

Settings files can be created, displayed and modified, copied, renamed, deleted or loaded into the recorder. Select the desired Settings file from the list, then select the appropriate action button on the right of the screen. Double-clicking is equivalent to clicking the *Edit* button.

> It is recommended that you maintain a copy of each recorder's current Settings as a Saved Setting for a backup. It can be loaded into a replacement recorder if the unit ever needs to be serviced.

> **Note:** A Settings file must be compatible with the recorder's Firmware in order to be loaded. Compatibility is defined by the *Settings Version,* a number which identifies the version of settings file a given version of firmware requires.
>
> TESLA Control Panel will either prevent incompatible settings files from being loaded or will offer to make the setting compatible before it loads it.

Loading a Saved Setting

To load a Settings file to the IED, you must be logged into the recorder. Initiate the load by selecting the desired Settings file and clicking the *Load to IED* button. The recorder will immediately load and run the new Settings. Complex Settings can take a few minutes to transfer and load, depending in part on communications rate.

> **Note:** The recorder will automatically go through a reset when loaded with a Settings that changes its sample rate. This will add approximately two minutes to the load time.

Creating a New Setting

Use the *New* button to create a new Settings file. New Settings files are compatible with the latest Setting Version by default. The Settings Version can be changed when creating Settings files for older recorders.

The fixed information in the Device Configuration screen is derived from the IED Definition ("Adding/Editing a Recorder Workspace Definition" on page 6-13).

Using Another Recorder's Settings as a Starting Point

You can use the *Copy from Other IED* button to create a Settings for the current recorder based on an existing one from another recorder. The Settings can be selected from the Saved Settings list of the other IEDs.

9.2 Settings Editor

The Settings Editor provides the means to create, display and modify Settings for the recorder. To start the editor from the Settings Manager screen, either double-click on a Settings name or select a Settings name and click on the *Edit* button.

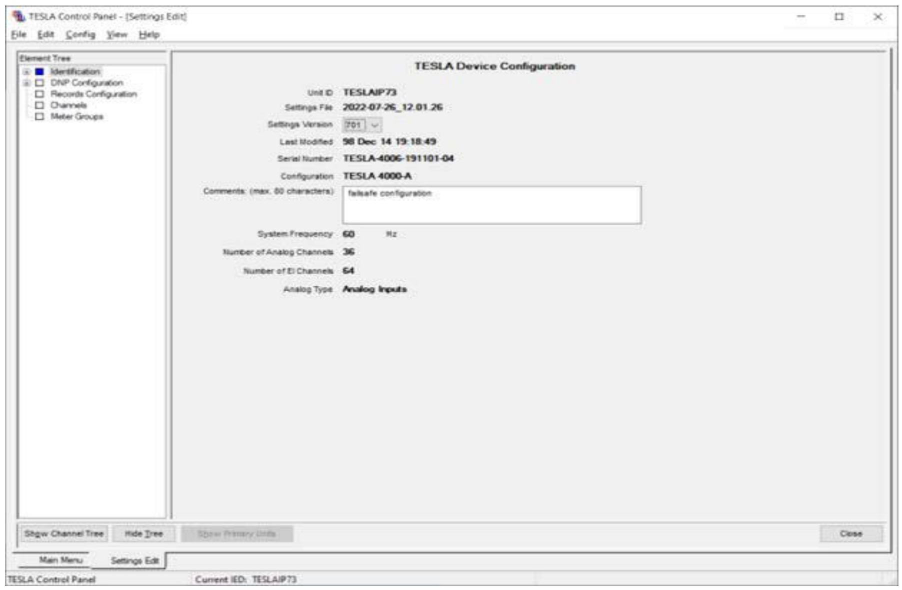


Figure 9.4: TESLA Settings Editor

Navigation Tree

The left-side pane of the Settings Editor window provides a navigation tree to access the various sections of the Settings. Selecting an item in the tree changes the large right pane view to the appropriate section. Double-clicking on a tree branch in the left pane that has a small "+" to its left or selecting on the "+" expands or collapses the tree.

Right-Click Menu

A right-click in the editor provides you with options appropriate to your present context. For example, you can create a new element by selecting the appropriate channel group, right-clicking and selecting *Add Element*. Alternatively, the same function is in the *Config* menu.

Closing

The Close button is available to you when you are finished viewing or making changes to the Settings. If you made changes, the text on the Close button changes to Save/Close as a reminder that TESLA Control Panel gives you an opportunity to save your changes to a file (or send them to the IED) before closing the Settings Editor. To close without saving changes, use the *Save/ Close* button and then select *Exit Without Saving* and *Discard* on the subsequent screens.

9.3 Identification

Device Configuration

The Device Configuration screen is displayed when you select the Identification item in the Navigation Tree (“TESLA Settings Editor” on page 9-4). It provides information about the selected IED and the particular configuration file being edited. Most of the information is drawn from the IED Definition and identifies the target recorder (“Adding/Editing a Recorder Workspace Definition” on page 6-13).

The Device Configuration screen has three configuration values that are detailed below.

Settings Version

Recorders with older firmware may require older versions of settings files. Compatibility between a settings file and firmware versions is defined by the *Settings Version.*

The Settings Version required by a TESLA recorder is shown on the Unit Identification screen of the Utilities menu (“Unit Identification” on page 8-2). You must be connected to the recorder to view this information. Settings Version requirements are also listed in the compatibility table in the Firmware Release. The TESLA 4000-A Settings Versions begin at 701.

The version of a Settings file is controlled through the *Settings Version* field in the main identification screen (see: “TESLA Settings Editor” on page 9-4). Changing the Settings automatically converts the Settings file to the selected Settings Version. If the conversion results in the loss of Settings from the file (i.e. the target version does not support functions which were enabled in the original), a list of the affected Settings is displayed and you have the choice of canceling the conversion or continuing. If the conversion results in the addition of new functionality, the settings for the new functions will be in a default or disabled state. If you choose to close the Settings file without saving, the conversion is also abandoned.

A new Settings file is set to the latest Setting Version by default. To create a new Settings file for a recorder with older firmware, change the Setting Version appropriately after creating the new Settings.

> TESLA Control Panel should be updated as needed whenever you update the firmware on your recorders. This will ensure it can generate Settings files with the latest Settings Version.
>
> Since TESLA Control Panel can work with old versions of Settings files and can communicate with recorders with older firmware, the newest version of TESLA Control Panel can always be safely installed.

Sample Rate

The *Sample Rate* setting controls the rate at which the TESLA 4000-A reads its analog and digital input channels. The setting determines the number of samples per second stored in high speed fault records and used to display calculated high speed channels. The sample rate does not affect the data rate of derived (calculated) data that generate data for low speed swing recordings, low speed calculated channels, the metering display update rate or the trending rate.

The *Sample Rate* also determines the frequency response of the front-end anti-aliasing filters and therefore the bandwith of the analog channels. See the following tables:

Table 9.1: Sample Rates (60 Hz System Frequency)

Samples / Second	Samples /Cycle	Analog Channels	External Channels	Highest Harmonic*	Approx. Record Size** (kbytes)
8 Channel Recorder					
1,920	32	8	32	8	35
3,840	64	8	32	16	44
5,760	96	8	32	25	51
7,680	128	8	32	33	59
15,360	256	8	32	66	80
23,040	384	8	32	100	109
30,720	512	8	32	100	140
12 Channel Recorder					
1,920	32	12	32	8	46
3,840	64	12	32	16	59
5,760	96	12	32	25	69
7,680	128	12	32	33	81
15,360	256	12	32	66	112
23,040	384	12	32	100	157
30,720	512	12	32	100	202
18 Channel Recorder					
1,920	32	18	32	8	81
3,840	64	18	32	16	136
5,760	96	18	32	25	191
7,680	128	18	32	33	246
15,360	256	18	32	66	465
23,040	384	18	32	100	684
30,720	512	18	32	100	836

Table 9.1: Sample Rates (60 Hz System Frequency)

36 Channel Recorder					
1,920	32	36	64	8	158
3,840	64	36	64	16	267
5,760	96	36	64	25	377
7,680	128	36	64	33	487
15,360	256	36	64	66	925
23,040	384	36	64	100	1,364
30,720	512	36	64	100	1,667

Table 9.2: Sample Rates (50 Hz System Frequency)

Samples / Second	Samples / Cycle	Analog Channels	External Channels	Highest Harmonic*	Approx. Record Size** (kbytes)
8 Channel Recorder					
1,600	32	8	32	8	33
3,200	64	8	32	16	40
4,800	96	8	32	25	45
6,400	128	8	32	33	53
12,800	256	8	32	66	69
19,200	384	8	32	100	92
25,600	512	8	32	100	123
12 Channel Recorder					
1,600	32	12	32	8	42
3,200	64	12	32	16	53
4,800	96	12	32	25	61
6,400	128	12	32	33	71
12,800	256	12	32	66	97
19,200	384	12	32	100	134
25,600	512	12	32	100	177
18 Channel Recorder					
1,600	32	18	32	8	72
3,200	64	18	32	16	118
4,800	96	18	32	25	163
6,400	128	18	32	33	209

Table 9.2: Sample Rates (50 Hz System Frequency)

12,800	256	18	32	66	392
19,200	384	18	32	100	575
25,600	512	18	32	100	701
36 Channel Recorder					
1,600	32	36	64	8	139
3,200	64	36	64	16	231
4,800	96	36	64	25	322
6,400	128	36	64	33	413
12,800	256	36	64	66	779
19,200	384	36	64	100	1,145
25,600	512	36	64	100	1,398

*Limited by the anti-aliasing filters
**For a 1 second fault record assuming typical compression. Record size varies depending of number of channels configured. The Settings file is also included in the record and will therefore affect the size of the record.

Comments

In the Comments section you can enter a description of the Settings for reference purposes. This description is also displayed in the *Settings* screen to identify saved Settings.

Chatter Limits

The *Limits* screen, accessed by expanding the *Identification* branch in the Navigation tree, lets you define how the recorder behaves when dealing with numerous, repetitive triggers.

The chatter limit settings can be enabled or disabled for both External Inputs and Analog Inputs by selecting the Detection Enabled checkbox. User can configure the following chatter detection criteria:

Table 9.3: Chatter Limits

Detection Threshold	Number of chatters detected within the Detection window. The Detection Threshold is monitored individually per External Input (EI) and per Analog trigger condition. If the number of triggers within the Detection Window exceeds the threshold for a given EI or Analog trigger, then block further triggers on that EI or trigger until number of triggers are less than the Threshold setting within the Recovery Time. No records or events are created for a given EI or Analog trigger when blocking is active. All other EIs and triggers remain active and operate normally. Range = 2 to 31, default = 4

Table 9.3: Chatter Limits	
Detection Window	Duration where it counts for the number of chatters detected within its setting range. Range = 1 to 10 seconds, steps of 1/8 cycle, default =1s
Recovery Time	Duration to reset the chatter alarm for the given input when number of chatters is less than the Threshold setting. Range = 1x to 31x of Detection Window, default =1x
Alarm Pickup Delay	Delays to issue the chatter alarm to avoid unwanted chatter alarm. Range = 0 to 31x of Recovery Time, steps of 1x, default = 0s

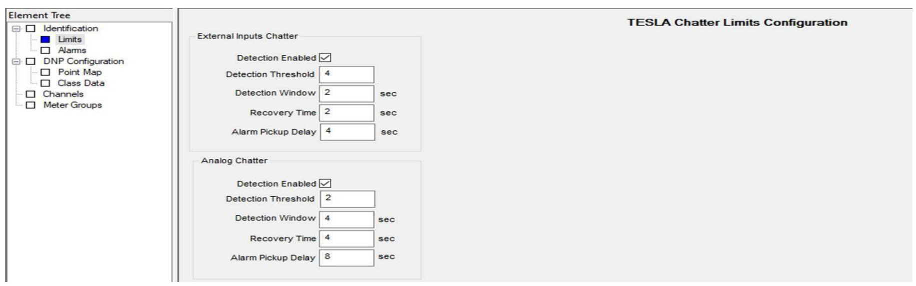


Figure 9.5: Chatter limits configuration

The following example in Figure 9.6 demonstrates the chatter detection logic details. For example, if the threshold setting is equal to 3, the chatter SOE and its associated recording will be validated within the detection window, if the number of chatters exceeded the threshold setting, the next chatter after the threshold will be marked with invalid data quality and the rest of the chatters will be ignored in SOE as well as in recording. When the number of chatter is still more than the threshold setting within the recovery window, the chatter alarm will be activated at the end of the recovery window if the alarm pick is set to equal to the recovery window. The recovery window will continue to extend to monitor the chatter condition, if the number of chatter is less than the threshold setting within the last recovery window, at the end of the recovery window, the chatter alarm condition will be deactivated.

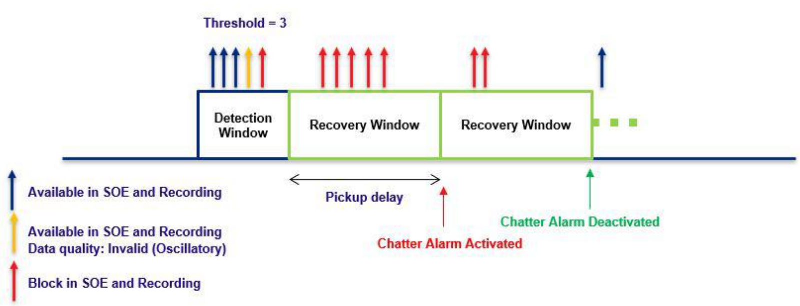


Figure 9.6: Chatter detection operation logic example

TESLA Alarms

The *TESLA Alarms* screen, accessed by expanding the *Identification* branch in the Settings Editor Navigation tree, lets you select the output contact to be closed when the following alarm conditions are meet:

High speed and low speed records storage alarm: It activates when selected alarm conditions is detected. See Table 9.4 for storage alarm trigger setting conditions details.

Trend records storage alarm: It activates when trend limit setting is exceeded. See Table 8.6 for trend storage alarm limit settings details.

Time sync loss alarm: It activates when external time source is not detected.

IEC 61850 GOOSE communication alarm: It activates when any one of the subscribed GOOSE is not detected.

Chatter alarm: It activates when chatter alarm condition is meet. See “Chatter Limits” for details.

9.4 Recording Configuration

The Recording Configuration controls the durations of the High Speed Recording and Low Speed Recording.

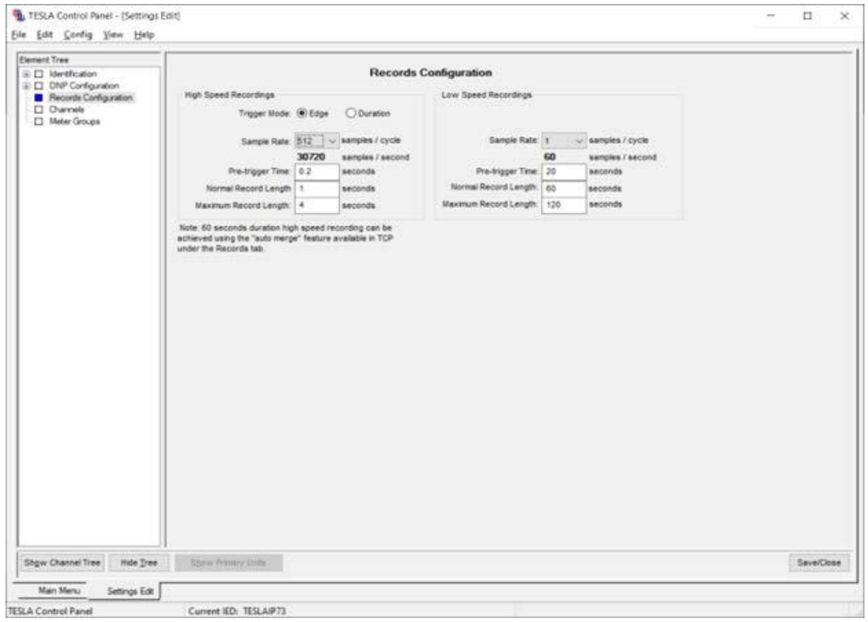


Figure 9.7: Records Configuration Screen

For High Speed and Low Speed Recording the TESLA recorder can create up to three records simultaneously. The TESLA employs sophisticated trigger combination algorithms used to combine data from multiple events into a single record and also to reduce the amount of redundant data in the records. In addition, the TESLA will combine data captured using multiple time-frames into a single record.

There are two modes of capturing data; Edge Recording and Duration Recording. Both modes are available for High Speed Recording, only Edge Recording is available for Low Speed Recording.

Edge Mode

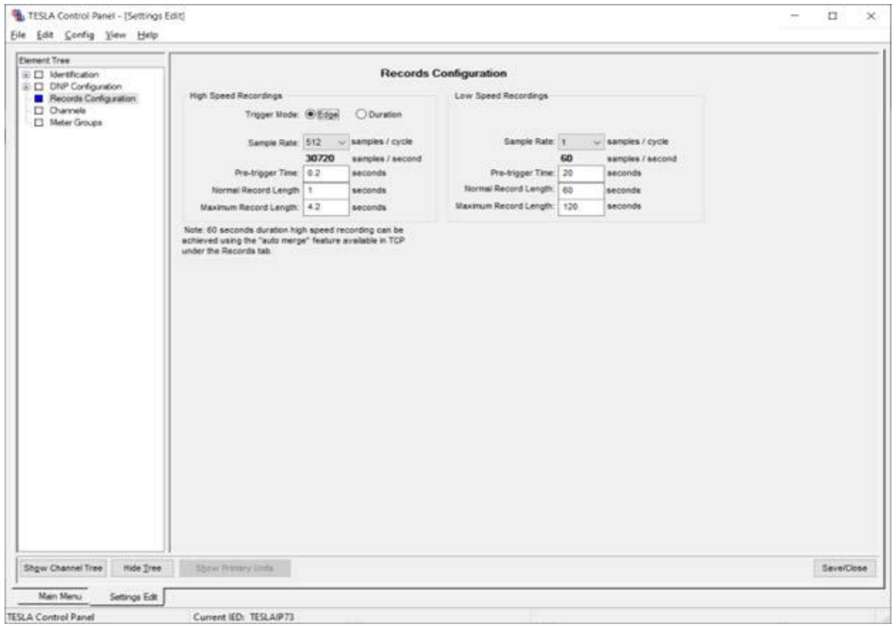


Figure 9.8: Records Configuration - Edge Recording

In Edge Recording, the rising edge of the trigger is used to create a record that has a set amount of pre-trigger data and a set amount of post-trigger. This is known as a normal length record. If another trigger is processed while the record is being created, the record may be extended to the full normal length of data associated with the new trigger. Multiple extensions can occur up to the Maximum Record Length limit. Records with combined High Speed and Low Speed data can only be extended during the High Speed data capture portion of the record.

Edge Recording mode tends to create smaller records that contain useful fault data around the start of the trigger, but may not capture data for the entire duration of the trigger.

> To enable record auto-extension for multiple triggers, the Maximum record Length must be larger than the Normal Record Length.
>
> A small amount of pre-trigger time is recommended to ensure the triggering event is included in the records.

Duration Mode

Figure 9.9: Records Configuration - Duration Recording

In Duration Recording, the duration of the trigger determines the record length. The record stores the configured amount of pre-trigger data, continues to record while the trigger is active and then records a configured amount of post-trigger data. If a trigger remains active, the TESLA stops recording once the Maximum Record Length limit is reached. If a subsequent trigger occurs while a record is being created, it will be combined with the first trigger using a logical OR operation as long as it is not near to the maximum record length limit. If the trigger is processed near the end of the record, a new overlapping record will be created instead of combining the triggers. Records with combined High Speed and Low Speed data can only be combined during the High Speed data capture portion of the record.

Duration Recording mode captures all the data during the fault trigger, but tends to create larger records that may contain unimportant data.

Settings

The following table describes the recording control settings.

Table 9.4: Recording Control Settings

High Speed Recording	
Trigger Mode	Select Edge or Duration mode. See above for descriptions.
Sample Rate	Read-only display of the configured high speed sample rate. The sample rate is set in the configuration file downloaded to the recorder. (See “Sample Rate” on page 9-6).
Pre-trigger Time (Edge Mode)	The length of data that is recorded prior to the trigger time. At least 0.1 seconds of pre-trigger time is recommended to ensure the triggering event is included in the records.
Normal Record Length (Edge Mode)	Normal Record Length is the total length of the record, including pre-trigger data, without any record extension.
Post-Trigger Time (Duration Mode)	Post Trigger Time is the length of data that is captured after the falling edge of trigger event.
Maximum Record Length	Edge Mode: The maximum length of the record including pre-trigger, post-trigger and extensions. To enable record auto-extension for multiple triggers, the Maximum record Length must be larger than the Normal Record. Duration Mode: The maximum length of the record including pre-trigger, trigger and post-trigger. Longer records than the “Maximum Record Length” are possible using the Auto-Merge feature. See “Auto Merge Fault Records” on page 11-2.
Low Speed Recording	
Sample Rate	Samples at 50 or 60 samples/second (1 or 2 samples/cycle) producing record lengths of a few minutes to capture slower system dynamic swings. The sample rate for low speed recording is based on the recorder’s system frequency which is a factory setting.
Pre-trigger Time	The length of data prior to the trigger time included in the recording.
Normal Record Length	The total duration of each recording under single trigger conditions. Includes the pre-trigger time.
Max. Extended Record Length	The maximum length of the record including pre-trigger, post-trigger and extensions. To enable record auto-extension for multiple triggers, the Maximum Record Length must be larger than the Normal Record.
Storage (Requires connection to the IED Main Menu->Records->Configuration)	
High/Low Speed Accumulation Mode	Select Recycle Mode to overwrite the oldest record with the latest record or Select Stop Mode to stop the recording when High/Low speed record storage is full.

Table 9.4: Recording Control Settings	
High/Low Speed Storage Alarm Limits	When accumulation Mode is set as Stop, High/Low Speed record storage alarm can be enabled and activated when Usage percentage setting is meet or exceeded. Usage setting can be configured between 60 to 99 percent. When accumulation Mode is set as Recycle, High/Low Speed record storage alarm can be enabled and activated when both retention period in days setting and usage percent setting are meet or exceeded. Retention period setting is configurable between 1 to 100 days, the real time retention period is estimated and displayed in Records screen above record percentage progress bar when connecting to the IED. The retention period is calculated using the current IED time minus the oldest records time and displayed in days and hours. The storage alarm condition is indicated by flashing the front panel “Record Storage” LED and activating a selected alarm contact. Note: the alarm contact assigned to this is displayed as a read-only value. It’s set as part of the recorder’s configuration (see “TESLA Alarms” on page 9-10).

9.5 SCADA Point Mapping Configuration

The following section describes how to configure the SCADA point mapping. For details on SCADA Communication setup, see “SCADA Communication” on page 8-32.

Modbus Protocol

The data points available for Modbus SCADA interface are fixed and are not selectable by the user. Complete details regarding the Modbus protocol emulation and data point lists can be found in “Modbus Functions” on page Appendix E-1.

DNP Protocol

The data points available for DNP SCADA interface are selectable by the user through the DNP Configuration section of the recorder settings; point selection is done through the Point Map configuration; class assignments for selected points are done through the Class Data configuration. Complete details regarding the DNP3 protocol implementation and data point lists can be found in DNP3 Device Profile on “DNP3 Device Profile” on page Appendix F-1.

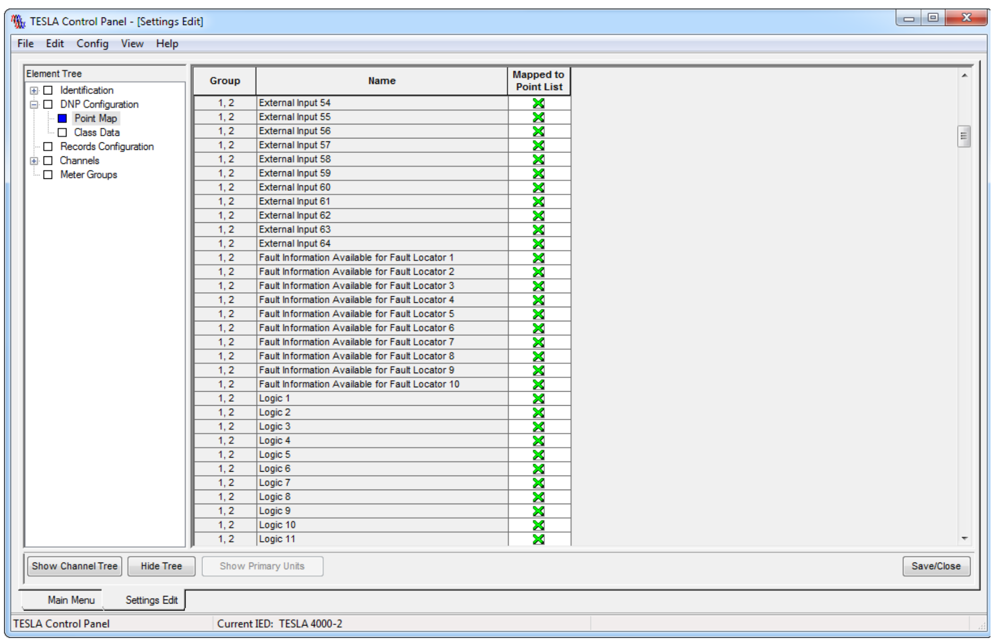


Figure 9.10: DNP Point Map

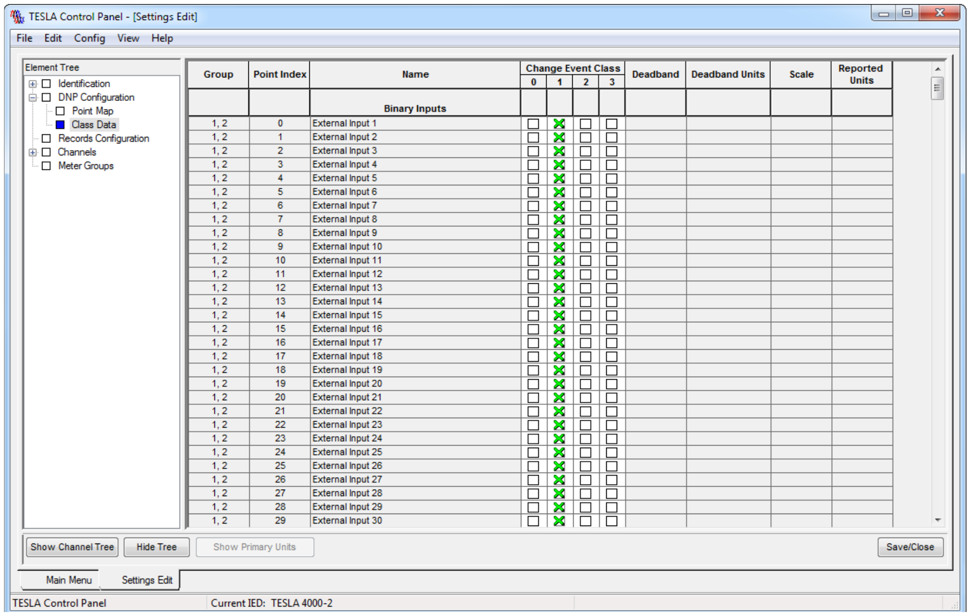


Figure 9.11: DNP class data

9.6 Channels and Triggers

The Channels and Triggers branch of the Navigation tree is where you define the recorder's input channels, calculated channels and triggers. It is significant tool with a variety of views and displays to help manage complex recorder's settings.

Channel Grouping and Naming

With the large number of input and calculated channels available, it is worthwhile to apply consistent channel organization and naming conventions in the settings. This section describes how the record handles channel names.

An effective way to organize the many channels available on the recorder is to group them by the power system element they are monitoring. With the Settings Editor, you can identify each monitored element and use its name to group and identify the analog, digital and calculated channels associated with it.

For example, if you have a transmission line named #1, you can define an element and name it "Line #1." The channels associated with that element might then be:

Line #1:Va	Line #1:Ia
Line #1:Vb	Line #1:Ib
Line #1:Vc	Line #1:Ic

External (digital) inputs can also be reasonably associated with the Line #1:

Line #1:EI:BRKR1_a

Line #1EI:21N_Trip

Calculated channels fit the model as well:

Line #1:W/V (watts and vars)

Line #1:Iseq (current channel sequence components)

Channel Types and Naming

Channel names consist of three parts: the Element Name, the Channel Type and an optional Descripton field. These fields are combined to produce the full channel name in the format:

Element:Type:Description

e.g. Line #1.EI.BRKR1_a

This is the name that will appear beside a channel when it is displayed in a graph or a log. For example the recorder's Event Log might contain this entry for a change in state of a external input:

Line	UTC Time	UTC Offset	Station Name	Unit ID	Event
1	2019-10-10 19:34:40.00	-05:00	Lab	TESLA 4000-A Demo	Line #1.EI BRKR1_a open

Details on the channel name components are given in the following table

Table 9.5: Channel Name

Element Name (10 chars)	Free-form text describing the power system element associated with this channel (e.g. Line #1). Channels that are logically related can be grouped through the use of the same element name.	
Channel Type	Standardized channel type descriptors are automatically generated when you select the channel type.	
	Examples	
	Va	Phase A voltage
	Ic	Phase C current
	In	Neutral current
	Vac	Generic AC voltage
	EI	External inputs
	Vseq	Sequence component set (pos, neg, zero)
	VaSum	Summation of Phase A voltages
	W/V	Watts/vars set
	PF	Power factor
	Z1	Impedance
	Logic	Logic function
	FLoc	Fault locator
	Freq	Frequency
Description (optional) (12 chars)	Often the combination of the Element Name and the Channel Type is sufficient to fully identify a channel (e.g. Line #1:Va). In other cases, the Description is required to clarify the channel name. (e.g. You might name an external input channel as “Line #1:EI:BRKR1_a).	

Element and Channel Tree Views

The Config Editor can display recorder channels in two distinct views - Element View and Channel View. The title at the top of the tree pane indicates the present viewing mode. The button at the bottom of the tree pane lets you switch to the other viewing mode.

Element Tree

The Element Tree View organizes channels by the element names you create. In the following figure, Element “Line #1” has been expanded to show some of the channels associated with it, such as Va.

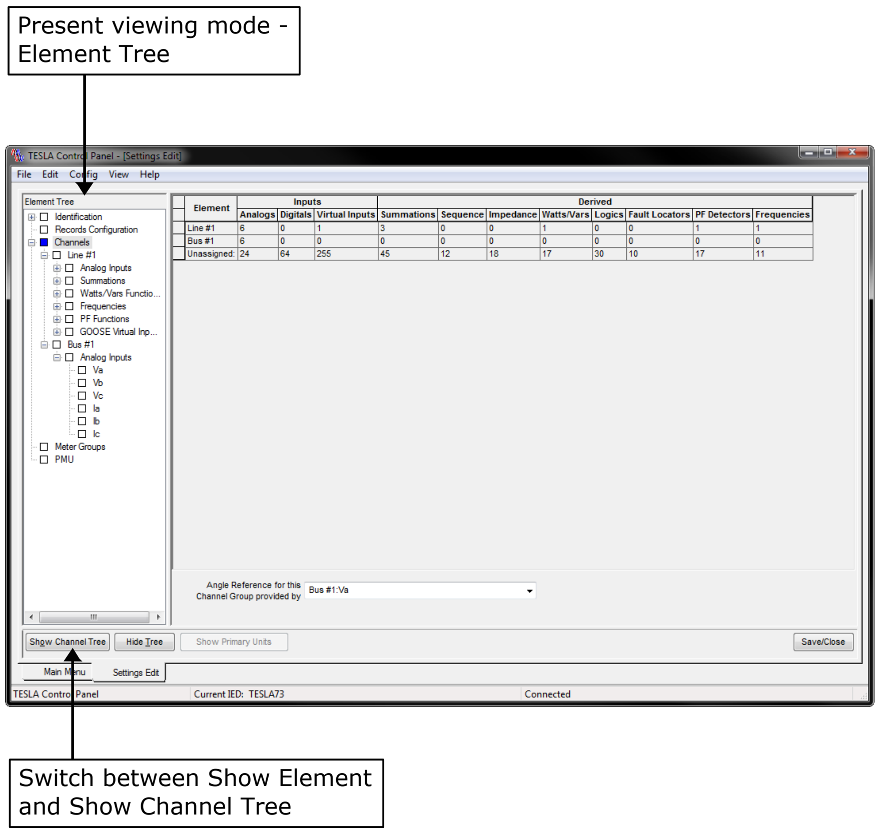


Figure 9.12: Element Tree View

Channel View

The Channel Tree View displays the same configuration organized by channel type. You can use this view to gain an overview of channel usage. Although you can chose to work in either view, the Element View is recommended for most operations as it provides an automatic way of grouping related channels.

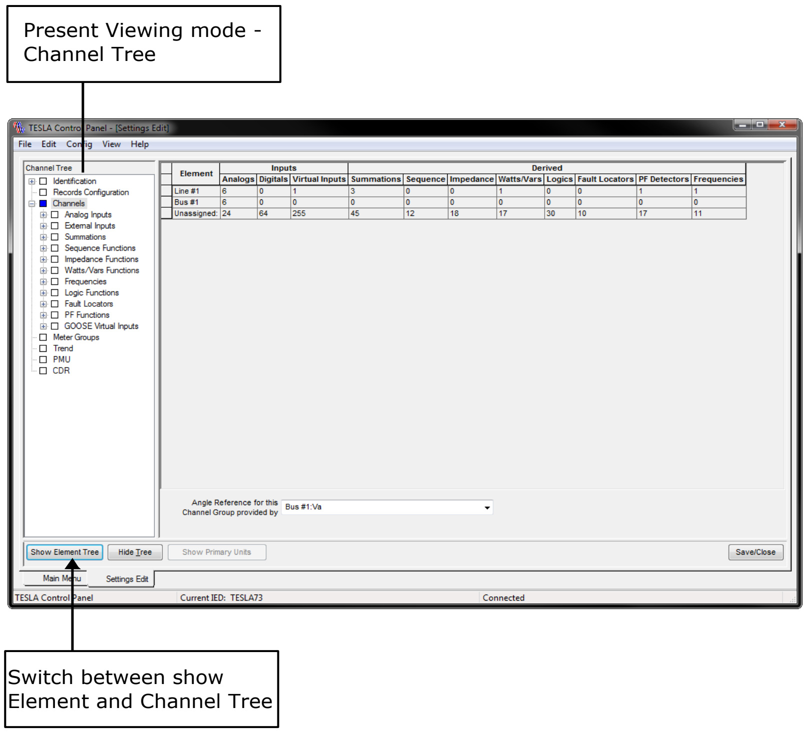


Figure 9.13: Channel Tree View

Element Overview

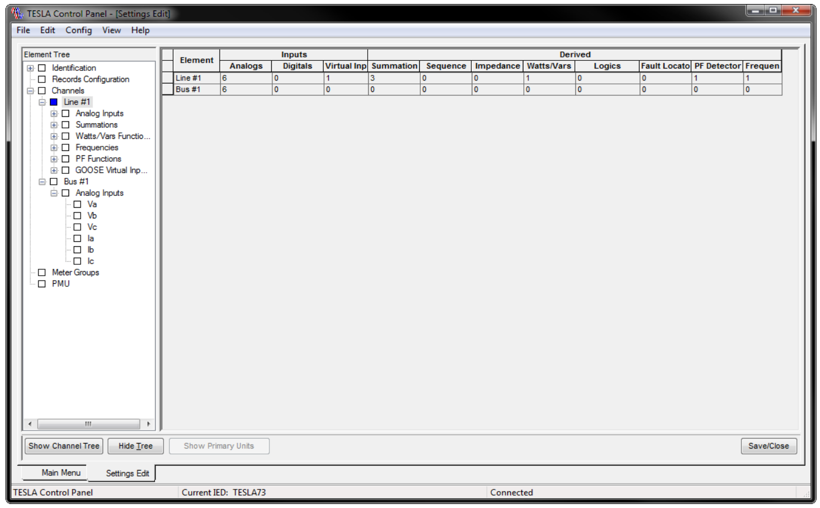


Figure 9.14: Element Overview Screen

An overview of the configured elements is available by selecting an element or the channel group heading in the Navigation tree. The last row of the display shows the channels and functions that are unassigned and available.

Phase Angle Reference Channel

The Element Overview screen, displayed by selecting Channels in the Navigation tree, is where you select the analog input channel to be used as the reference channel for angle measurements. All channels use the same reference to provide relative angle calculations. Typically, a phase A voltage channel is used as the reference. When PMU is enabled, PMU (GPS, 1PPS) must be selected as the angle reference.

Channel Overview

An overview of the configured channels is available by selecting the associated channel type heading from the Navigation tree. For example, selecting *Analog Inputs* displays a table of all defined analog channels.

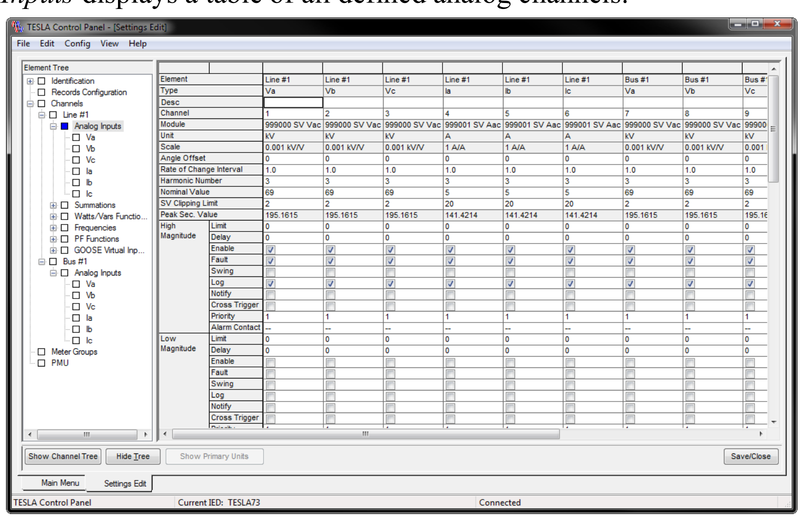


Figure 9.15: Channel Overview Screen

Channel settings can be edited in the Channel Overview display, providing an alternate way to enter channel settings that helps maintain consistency between channels.

The column width can be adjusted on the overview tables to optimize the layout for the particular configuration.

Individual Channel Screens

Detailed channel configuration is displayed on an individual channel basis. The settings for each channel can be displayed in individual screens by selecting the specific channel in the Navigation. Each channel type has its own configuration screen with parameters appropriate for its type.

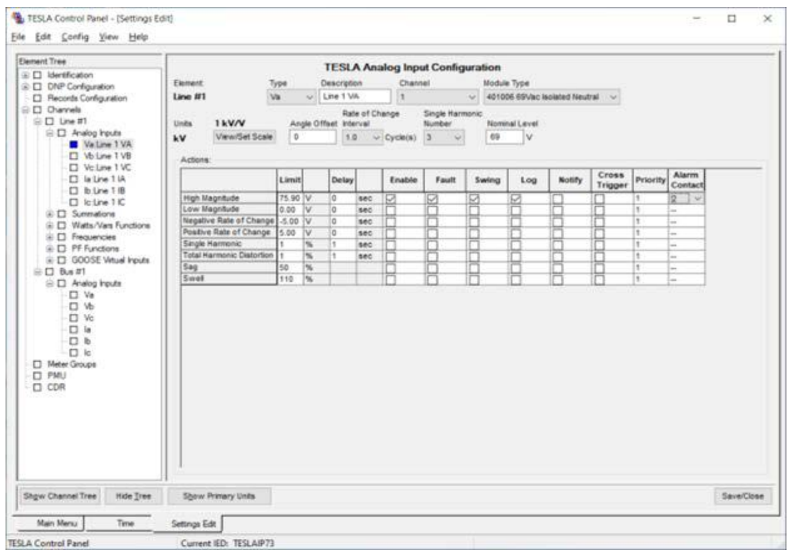


Figure 9.16: Individual Channel Configuration Screen

Adding an Element

To create a new element you must be in the Element Tree view (“Element and Channel Tree Views” on page 9-20):

1. Right-click and select *Add Element or Insert Element* from the shortcut menu. *Add Element* creates the new element at the end of the present Element list. *Insert Element* creates the new element above your current selection.
2. Type the element name and *Enter*. The typed text replaces the *New Element* text.

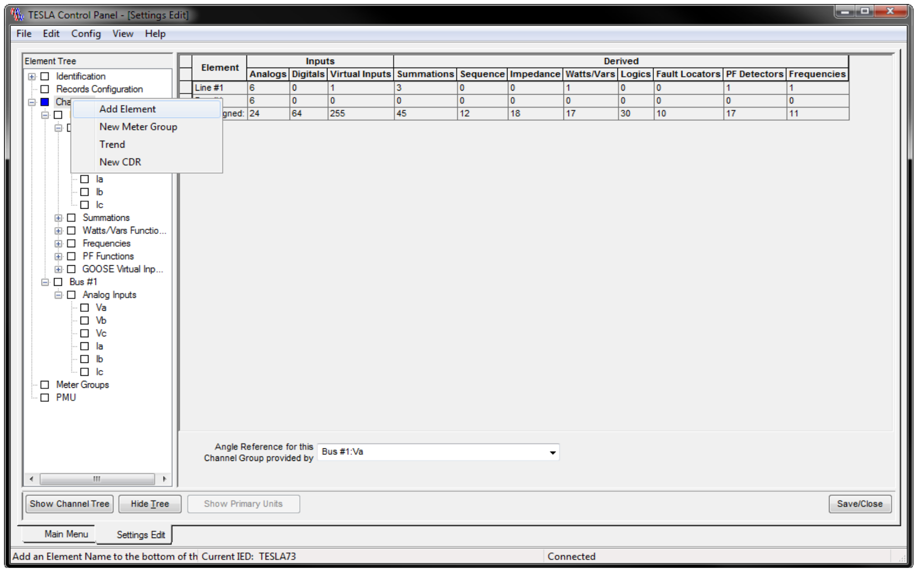


Figure 9.17: Add an Element

Deleting an Element

To remove an element from the tree, select it and press the <Del> key or right-click and select *Delete Element* from the shortcut menu.

Adding a Channel

Channels can be created in either the Element Tree view or the Channel Tree View (“Element and Channel Tree Views” on page 9-20).

To create a new channel in the Element Tree view

1. Select the desired element in the tree.
2. Right-click and select the desired channel type. If appropriate, choose the type that matches the input you are monitoring (e.g. Va). For an ac signal that has no specific phase designation you can select *New AC Voltage* or *New AC Current.* If you chose *New Ia, Ib, Ic* or *New Va, Vb, Vc*, three entries are created and the configuration screen for the first is displayed. The new channel(s) will be inserted automatically in the list.

To create a new channel in the Channel Tree view

1. Select the desired element in the tree.
2. Expand the branches in the tree to show the channels for each group.
3. Select the channel number and an input screen appears on the right side.
4. Type in the information required to configure the channel.
5. When you close the screen, you are asked to save the configuration to the recorder. Select *Save to Recorder.*

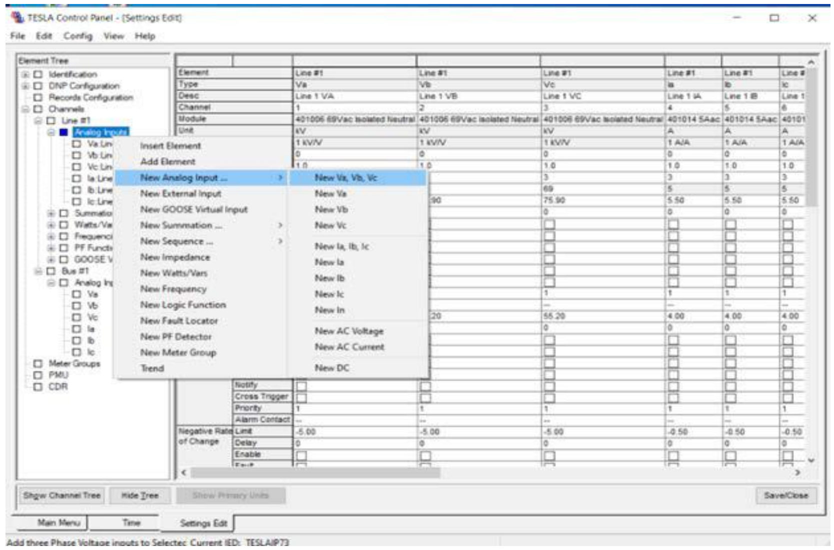


Figure 9.18: Adding Analog Input Channels from the Element Tree

Deleting a Channel

To remove an channel from the tree, select it and press the <Del> key or right-click and select the appropriate *Delete* entry from the shortcut menu.

Copying and Pasting Channel Configurations

A copy and paste function is provided for copying and pasting channel configuration data between channels of the channel same type. This feature aids in the efficiency of creating configurations with multiple similar channels. All of the channel configuration data, except for the channel name, will be copied.

To copy channel configuration data from one channel, simply right-click on the channel in the left-hand menu and select “Copy *Channel Type*” (where *Channel Type* is Analog Input, Summation, Sequence etc.). Then select the destination channel for pasting the data, right-click the channel in the left-hand menu and select Paste. *Ctrl-C* and *Ctrl-P* may also be used for copying and pasting channel configurations respectively.

Copying and pasting may only be performed on channels of the same type. For example, an Analog Voltage channel may be copied and pasted to another Analog Voltage channel, but it cannot be pasted to a Summation channel.

9.7 Analog Input Channels

Description

Basic recording channels for the recorder's analog input signals.

Input

The recorder's physical analog input channels.

Calculation

The rms amplitude of the fundamental is calculated using a DFT function. The resultant phasors are used for rate and level triggers, metering, low speed recording, trending and sag/swell detection. The single harmonic and THD detectors are calculated directly from the input samples.

Triggers

- High & low magnitude
- Negative and positive rate of change
- Single harmonic magnitude
- THD magnitude
- Sag and swell

To prevent multiple triggers on threshold conditions, an hysteresis of 2% of setting is applied to magnitude triggers.

Recording

High Speed**:** records the samples generated from the A / D converters at the selected sample rate.

Low Speed**:** records the calculated phasors at a rate of one or two samples per cycle.

Number of Channels

Up to 36[1] Analog Input Channels can be defined, one for each physical input.

Types

Specific: Va, Vb, Vc, Ia, Ib, Ic, In (use where appropriate)

Generic: Vac, Iac, dc

Note: the DC type indicates that a DC Input Isolation Module is used on this channel. This module can in fact be used with either AC or DC signals.

Notes

The Analog Input Channel also produces THD and Single Harmonic readings that are available to the metering display, SCADA and the long term trending function.

TESLA 4000 Power System Recorder input modules are optional and a variety of input modules for voltage and current inputs are available, therefore, you must calibrate the input modules. Refer to "Analog Input Calibration" on page 8-28 for details on how to calibrate the modules.

1.For details see "Model Options" on page 1-5.

Settings

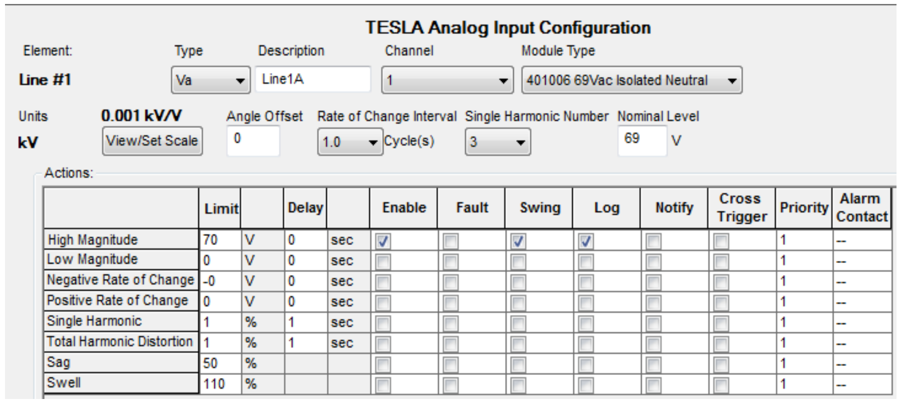


Figure 9.19: Analog Input Channel Configuration Screen

Table 9.6: Analog Input Channel Settings	
Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Type	Identifies the type of signal being applied to this input channel. The Type forms a part of the channel name (Element:Type:Description). Selecting the appropriate Type can simplify channel naming by eliminating the need for the optional Description field (e.g. Line #1:Va uniquely defines the channel). Initially set when the channel was created, the Type can be changed to refer to a different phase as needed.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Use if Element Name and channel Type do not sufficiently identify the channel. (“Channel Grouping and Naming” on page 9-18).
Channel	Identifies the physical input used by this channel. This number is identified on the rear of the TESLA chassis. The list shows only inputs not assigned to other channels. To get an overview of channel assignments, switch to the Channel Tree view and look at the Analog Channel list.
Module Type	Indicates the type of external input isolation module used with this channel. The list is limited to those modules appropriate for the selected channel type. The module defines input scaling information to the system.
View/Set Scale	Sets the primary to secondary scale factor. See details below.

Table 9.6: Analog Input Channel Settings	
Angle Offset	Specifies a phase angle offset to be applied to the channel. The offset is included in: • Meter readings • Trigger calculations • Low speed recordings (phasors) • Trend channels • Output to calculated channels (watts, vars, Impedance, Summations, Sequence components, etc.) that use this channel as their input. High speed recordings of this channel will *not* have the phase angle applied as they are basic representations of the individual sampled points. When the Angle Offset is used on a channel that has been designated as the reference channel, it affects the angle measurement of all other channels. (See: “Phase Angle Reference Channel” on page 9-22).
Trigger Settings	
Rate of Change Interval	Specifies the period of time over which both positive and negative rate of change is measured. TESLA takes two samples per cycle, so setting is selectable in 0.5 cycle increments. For example, for a 1.5 ROC setting, TESLA compares previous 1.5 cycle window to the current 1.5 cycle window and checks if ROC condition is met. Setting range is 0.5 to 8.0 cycles.
Single Harmonic Number	Selects the harmonic of fundamental frequency that will be used by the Single Harmonic trigger. 2 to the highest harmonic allowed, which is defined in Table 9.1, “Sample Rates (60 Hz System Frequency),” on page 6 and Table 9.2, “Sample Rates (50 Hz System Frequency),” on page 7.
Nominal Level	Provides a nominal level for the sag and swell detectors. Configurable on voltage channels only (fixed for current channels). See sag and swell detector details below. The Nominal Level setting is also used as a threshold for frequency calculation. A minimum of 0.1 * Nominal Level must be present in order frequency to be calculated for the channel.
Limit	Specifies the trigger levels for the magnitude, single harmonic, THD, sag and swell triggers. Specifies the magnitude portion of the rate for rate of change triggers.
Delay	Specifies how long the trigger condition must be present before a trigger is declared. Magnitude and Rate of Change triggers: 0 to 1,200 seconds in half-cycle increments. Single harmonic and THD triggers: 0 to 10,000 seconds in half-cycle increments.
Trigger Actions	
Enable	Enables or disables the associated trigger. A trigger can be disabled without altering the rest of its settings.
Fault	Initiates a fault (high speed) recording when triggered.
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered.

Table 9.6: Analog Input Channel Settings

Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer (“Notify RecordBase Central Station (RBCS)” on page 8-30)
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority). (“Notify RecordBase Central Station (RBCS)” on page 8-30).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms or Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

Scaling Input Channels

AC Scaling

When you select the *View/Set Scale* button on the Analog Input form for an AC channel, Control Panel displays the Scaling dialog box for details see Figure 9.20: AC Scaling on Appendix 9. The scaling factor represents the turns ratio of the primary transducer (CT or PT). The nominal secondary value is used as the default calibration level for the channel.

If you are using an AC module to measure the AC quantity, Control Panel sets the Full Scale quantity appropriately for modules with fixed full scale rating (see Appendix F). For AC current input modules with a user selectable full scale rating, enter the Full Scale value associated with the shunt resistor R_{SH} installed on the module in Control Panel as seen in Figure 9.20: AC Scaling on page 9-29.

For the 401027 AC/DC Input module enter the Full Scale value from the AC-DC Configurator Tool. For the 401016 AC/DC input module enter the Full Scale value associated with the values of the scaling resistors R_{SH}, R_{IN} and R_{FB} as listed in “Input Modules” on page Appendix G-1.

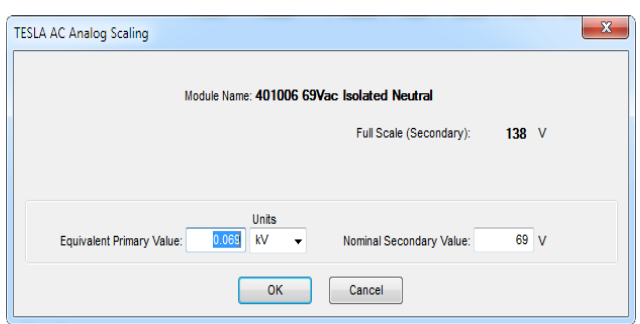


Figure 9.20: AC Scaling

DC Scaling

When you select the *View/Set Scale* button on the Analog Input form for a DC channel, Control Panel displays the DC scaling dialog box. You must set the Full Scale value, which can be determined using the same model specific procedure indicated above for AC scaling. For DC channels, TESLA uses two-point scaling, whereby the conversion process performs a linear transformation between two points. The secondary values are the default calibration points for the channel.

The terms Primary and Secondary are used in the case where a measurement transducer is applied and the output of the transducer is routed to the input of the DC module. In this case, Secondary refers to the output of the transducer; Primary refers to the scale and units of the signal measured by the transducer.

There are two types of AC/DC modules, model 401016 and model 401027. Refer to for details see Table G.1: Mounting Options on Appendix G for further details regarding the configuration of the modules.

Determine the full scale value using the same process as indicated in the AC Scaling section above. Enter this as the Full Scale (Secondary) value. If you are measuring a DC voltage or current directly, enter the same values as Primary and Secondary for each of Points 1 and 2. The specific values for Point 1 and 2, provided they are reasonably separated, are not significant, except that they are used as default values for the calibration activity. For instance, if you are directly measuring a 48 Vdc input, you may wish to enter 0 V for Point 1 and 48 V for Point 2.

If you are monitoring an AC signal through a DC module, you must define the signal as an AC signal (see above).

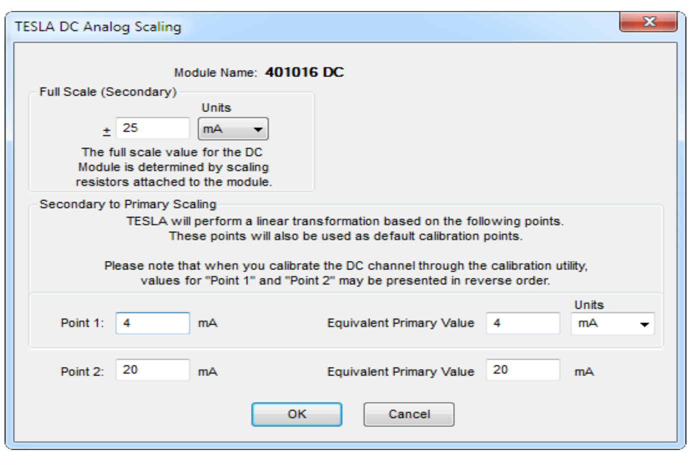


Figure 9.21: DC Scaling

Sag and Swell Detectors

Sag and Swell detectors are available on voltage channels. There are three related fields in the Configuration screen controlling Sag and Swell detectors. The definition of a Sag or Swell depends on a Nominal Level of voltage. The Sag and Swell thresholds are expressed as a percentage of the Nominal Level. The Sag upper limit is configurable between 50% and 90% of Nominal. The

Sag lower limit is fixed at 10% of Nominal. The Swell lower limit is configurable between 110% and 150% of Nominal. The Swell level upper limit is fixed at 180% of Nominal. Sag or Swell is triggered when the input voltage is between the lower and upper limits.

The duration of a Sag or Swell is fixed at any value between 0.5 cycle and 1 minute.

9.8 External Input Channels

Description

Recording channels for the recorder's external (digital) input signals.

Input

The recorder's physical external input channels.

Calculation

The binary state of each external input is read at the selected high speed sample rate. A filter is applied to the samples to prevent triggering on spurious state changes, requiring that a state change be present continuously for a minimum of approximately 700 microseconds to be considered valid for triggering purposes.

Triggers

- Active state
- Inactive state

Recording

Records the state of all external input channels at the selected high speed sample rate. The input filter is not applied to the recorded data; all state changes are included in the records.

Number of Channels

Up to 64 External Input Channels can be defined, one for each physical input.

Types

EI

Settings

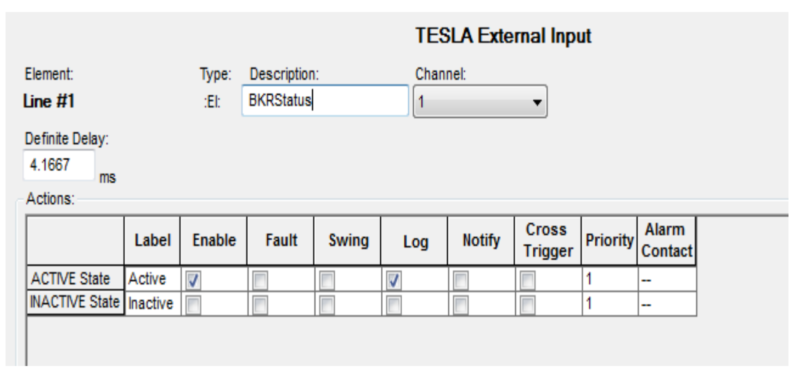


Figure 9.22: External Input Channel Configuration Screen

Table 9.7: External Input Channel Settings

Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Should always be used with External Input channels to uniquely name the channel. (“Channel Grouping and Naming” on page 9-18).
Channel	Identifies the physical External Input used by this channel. This number is identified on the rear of the TESLA chassis. The list only shows inputs which have not been assigned to other channels. To get an overview of channel assignments, switch to the Channel Tree view and look at the External Channel list.
Trigger Settings	
Definite Delay	Specifies how long the trigger condition must be present before a trigger is declared. Settable from 0 to 5,000 ms in eighth cycle increments. The delay setting is in addition to the pickup delay imposed by the input “glitch” filtering, which is approximately 700 microseconds.
Label	Text to designate the active and inactive states. Default is “Active” and “Inactive”. Maximum 8 characters.
Trigger Actions	
Enable	This setting is always selected when EI channel is added.
Fault	Initiates a fault (high speed) recording when triggered.
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered. This setting is always selected when EI channel is added.
Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer. **NOTE:** Notify is currently unsupported for TESLA 4000-A.
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms, Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.9 GOOSE Virtual Input Channels

Description

Recording channels for the recorder's GOOSE Virtual Input signals. The GOOSE Virtual Inputs are configured in the DVI Logical Device. Refer to "Logical Device: DVI" on page Appendix J-58 and to the ERL 61850 IED Configurator Manual for details on mapping.

Input

The recorder's digital subscription input channels via IEC 61850 GOOSE messages, with origin time stamping provided by the publishing IED.

Event Time Stamps

In the associated events for GOOSE Virtual Input channels, there are two events created, one is labeled "L" and one is labeled "G". The event labeled "G" contains the time stamp of the incoming GOOSE message which is set by the publishing IED (i.e. the origin time stamp). The event labeled "L" contains the time stamp of the instant that the TESLA 4000-A received and processed the incoming GOOSE. It is normal to see a small discrepancy between the "G" and "L" timestamps due to the real-world transmission time of the GOOSE message (may vary depending on network conditions) and time synchronization differences between IEDs.

Calculation

When a GOOSE message is received by the TESLA 4000-A it is processed and states are updated according to the data received in the GOOSE.

Triggers

- Active state (for Boolean data type)
- Inactive state (for Boolean data type)
- Change state (for types other than Boolean)

Recording

Records the state of all virtual input channels using the origin time stamp information included within the GOOSE message provided by the publishing IED.

Number of Channels

Up to 256 GOOSE Virtual Input Channels can be defined. There is no limit to how many channels may be used for each type (see Types below), as long as the total number of Virtual Input channels does not exceed 256.

Types

Boolean, Dbpos, Health, INT32, INT32U

> Currently, RecordGraph only supports graphing of Boolean digital channels. For all other types, the channels will not be available to add into digital graphs. However all data types are available for CSV export.

Settings

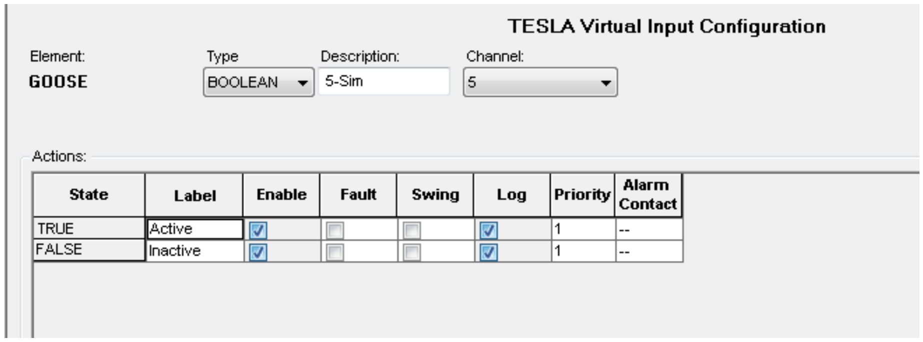


Figure 9.23: GOOSE Virtual Input Channel Configuration Screen

Table 9.8: GOOSE Virtual Input Channel Settings	
Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Type	The type of data mapped into this GOOSE Virtual Input. Options are Boolean, Dbpos, Health, INT32, INT32U. Setting must match the type of data mapped in the CID file loaded to the IED. For Boolean type, “Active” and “Inactive” state triggers are available. For all other types, a “Change” state trigger is available.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Should always be used with GOOSE Virtual Input channels to uniquely name the channel.
Channel	Identifies the Virtual Input assigned to this channel. The list will only show inputs which have not already been assigned to other channels. To get an overview of channel assignments, switch to the Channel Tree view and look at the GOOSE Virtual Inputs list.
Trigger Settings	
Label	Text to designate the active and inactive states. Default is “Active” and “Inactive” for Boolean. Maximum 6 characters (excluding defaults). Label is only available for Boolean type.
Trigger Actions	
Enable	Enables or disables the associated trigger. For the GOOSE channels, True and False state are always forced to Enabled.
Fault	Initiates a fault (high speed) recording when triggered.
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will not attempt to create a combined record. Separate fault and swing records will be created.
Log	Logs a message in the Event Log when triggered.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms ,Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.10 Summation Channel

Description

Summation Channels combine up to three analog inputs to create a summed channel. Each input can be scaled and rotated before it is summed. Previously combined summation channels can be used as an input to a new summation channel.

> Note: Summation Channels are handled as phasor sums for triggering, metering, low speed recording and trending. Both the *Scale Factor* and *Angle Offset* settings are applied for these uses.

Input

Analog Input Channels or other Summation Channels can be used as inputs to a Summation Channel. The summation can have two or three inputs. If a Summation Channel is used as an input, it must have a lower *Summation Index.*

Calculation

Each input is converted to a phasor using a DFT function and is scaled and rotated using the *Scale Factor* and *Angle Offset* settings.The resulting phasors are added to form the summation.

The high speed recording of a Summation Channel is created by adding the individual data points from the input channels. The *Scale Factor* is applied to each channel before the addition.

Triggers

- High & low magnitude
- Negative and positive rate of change

To prevent multiple triggers on threshold conditions, an hysteresis of 2% of setting is applied to magnitude triggers.

Recording

High Speed**:** generates a channel that is the sum of the individual data samples with the *Scale Factor* applied.

Low Speed**:** generates a channel that is phasor sum of the input channels at a rate of one phasor per cycle.

Number of Channels

48 Summation Channels are available.

Types

Va, Vb, Vc, Vn, Ia, Ib, Ic, In (use where appropriate)

Notes

The primary to secondary scale factor used by the Summation Channel is the same as that of its first input channel.

Settings

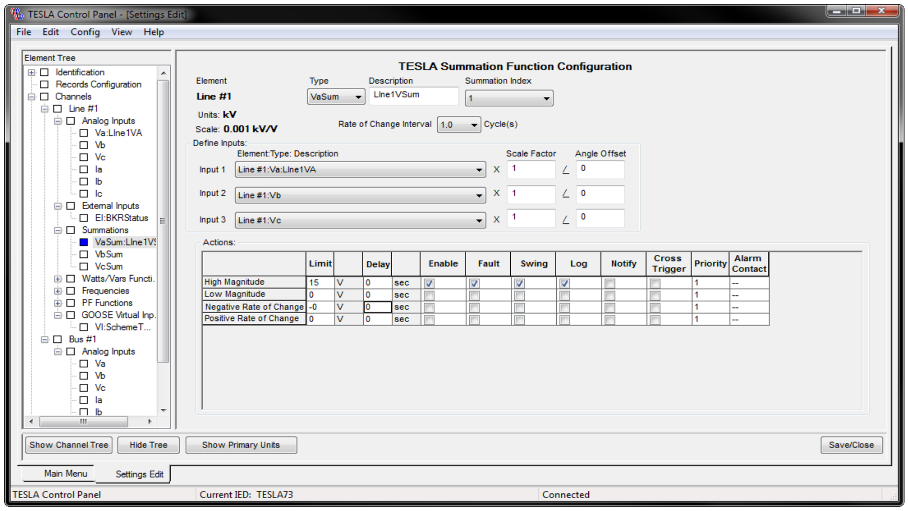


Figure 9.24: Summation Channel Configuration Screen

Table 9.9: Summation Channel Settings	
Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Type	Identifies the type of signal being applied to this input channel. The Type forms a part of the channel name (Element:Type:Description). Selecting the appropriate Type can simplify channel naming by eliminating the need for the optional Description field (e.g. Line #1:IaSum uniquely defines the channel). Initially set when the channel was created, the Type can be changed to refer to a different phase as needed.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Use if Element Name and channel Type do not sufficiently identify the channel. (“Channel Grouping and Naming” on page 9-18).
Summation Index	Identifies the summation channel. Unlike the analog and external input channels, this is not associated with a hardware input, but simply identifies which of the internal virtual summation channels will be used. You can select any available channel; the only restriction is that nested summations require the input summation to have a lower Summation Index. If the only option is “undefined”, you have already used all available channels.
Input 1, Input 2, Input 3	Identifies the channels to be used in the summation. The available list includes all previously defined analog channels and any summation channel with a lower summation index number. The list grows automatically as you define new channels.
Scale Factor	Specifies a multiplier for each of the inputs. The scale factor is applied in the secondary domain.

Table 9.9: Summation Channel Settings	
Angle Offset	Specifies a phase angle shift to be applied to each of the inputs. Note that when an offset is specified, a high speed summation recording - which uses sample by sample addition rather than phasor addition - is not generated. All other functions, including low speed recording, are available and will reflect the offset.
Trigger Settings	
Rate of Change Interval	Specifies the period of time over which both positive and negative rate of change is measured. TESLA takes two samples per cycle, so setting is selectable in 0.5 cycle increments. For example, for a 1.5 ROC setting, TESLA compares previous 1.5 cycle window to the current 1.5 cycle window and checks if ROC condition is met. Setting range is 0.5 to 8.0 cycles.
Limit	Specifies the trigger levels for the magnitude triggers and the magnitude portion of the rate for the rate of change triggers. The period portion of the rate is specified by the *Rate of Change Interval*.
Delay	Specifies how long the trigger condition must be present before a trigger is declared. 0 to 1,200 seconds in half-cycle increments.
Trigger Actions	
Enable	Enables or disables the associated trigger. A trigger can be disabled without altering the rest of its settings.
Fault	Initiates a fault (high speed) recording when triggered.
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered.
Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer. **NOTE:** Notify is currently unsupported for TESLA 4000-A.
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms, Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.11 Sequence Component Channels

Description

Sequence Component Channels calculates positive, negative, and zero sequence components in one step. The positive sequence component may also be used as an input to a watts/vars or impedance function.

Input

Analog Input Channels or Summation Channels can be used as inputs to a Sequence Component Channel.

Calculation

The sequence component algorithm is applied to produce positive, negative and zero sequence components.

Triggers

- Positive sequence high and low magnitude
- Positive sequence negative and positive rate of change
- Negative sequence high magnitude
- Zero sequence high magnitude

To prevent multiple triggers on threshold conditions, an hysteresis of 2% of setting is applied to magnitude triggers.

Recording

High Speed**:** Positive, negative and zero sequence values at a rate of eight values per cycle (regardless of the system sample rate).

Low Speed**:** Positive, negative and zero sequence values at a rate of one value per cycle.

Number of Channels

24 Sequence Component Channels are available.

Types

Vseq, Iseq

Notes

The primary to secondary scale factor used by the Sequence Component Channel is the same as that of the selected Phase A channel.

Settings

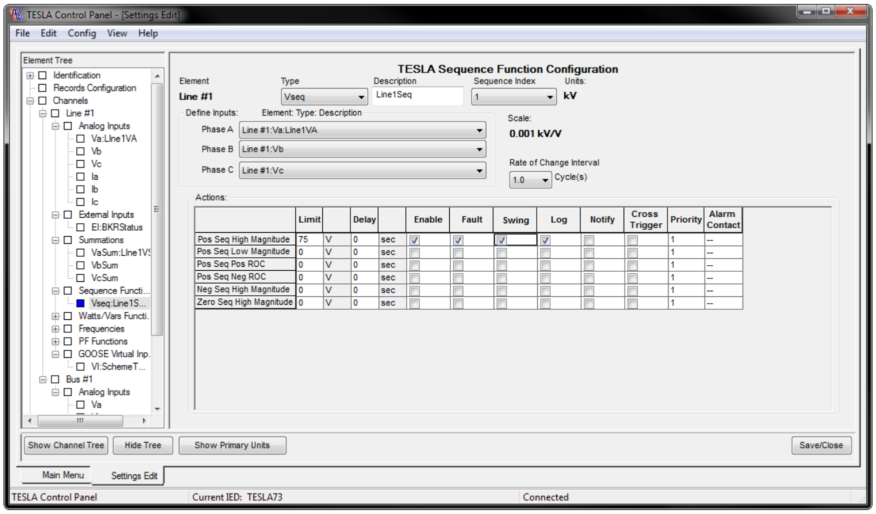


Figure 9.25: Sequence Channel Configuration Screen

Table 9.10: Sequence Component Channel Settings	
Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Type	Identifies the type of signal being applied to this input channel. The Type forms a part of the channel name (Element:Type:Description). Selecting the appropriate Type can simplify channel naming by eliminating the need for the optional Description field (e.g. Line #1:VSeq uniquely defines the channel). Initially set when the channel was created, the Type can be changed to refer to a different phase as needed.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Use if Element Name and channel Type do not sufficiently identify the channel. (“Channel Grouping and Naming” on page 9-18).
Sequence Index	Identifies the Sequence Component channel. Unlike the analog and external input channels, this is not associated with a hardware input, but simply identifies which of the internal virtual summation channels will be used. You can select any available channel without restriction. If the only option is “undefined”, you have already used all available channels.
Phase A, Phase B, Phase C	Identifies the channels used to create the sequence set. The list is limited to channels of the correct type (voltage or current) and includes analog input or summation channels which have already been defined. The list grows automatically as you define new channels.
Trigger Settings	

Table 9.10: Sequence Component Channel Settings	
Rate of Change Interval	Specifies the period of time over which both positive and negative rate of change is measured. TESLA takes two samples per cycle, so setting is selectable in 0.5 cycle increments. For example, for a 1.5 ROC setting, TESLA compares previous 1.5 cycle window to current 1.5 cycle window and checks if ROC condition is met. Setting range is 0.5 to 8.0 cycles.
Limit	Specifies the trigger levels for the magnitude triggers and the magnitude portion of the rate for the rate of change triggers. The period portion of the rate is specified by the *Rate of Change Interval*.
Delay	Specifies how long the trigger condition must be present before a trigger is declared. 0 to 1,200 seconds in half-cycle increments.
Trigger Actions	
Enable	Enables or disables the associated trigger. A trigger can be disabled without altering the rest of its settings.
Fault	Initiates a fault (high speed) recording when triggered.
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered.
Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer.
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms, Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.12 Impedance Channels

Description

Impedance Channels calculate impedance from voltage and current inputs. The channel can produce either single phase or three phase values. Triggering is based on the rate of impedance within a defined impedance circle centered around the origin.

Input

Analog Input Channels, Summation Channels or Sequence Component channel can be used as inputs to an Impedance Channel. Using Sequence Component as an input results in a three-phase impedance.

Calculation

The impedance calculation continuously recalculates the apparent impedance from the selected voltage and current signals, then subtracts an earlier calculated value (determined by the “Rate of Change Interval” setting). The impedance trigger operates if the difference is between the “Minimum Change” and “Maximum Change” settings, and the calculated impedance is within “Circle Radius” of the origin.

Triggers

Rate of impedance within a defined impedance circle.

Recording

Low Speed: Impedance magnitude at a rate of one value per cycle.

Number of Channels

18 Impedance Channels are available.

Types

Z1 (impedance)

Notes

The impedance magnitude and angle readings are also available to the metering display, IEC 61850 and the long term trending function.

Settings

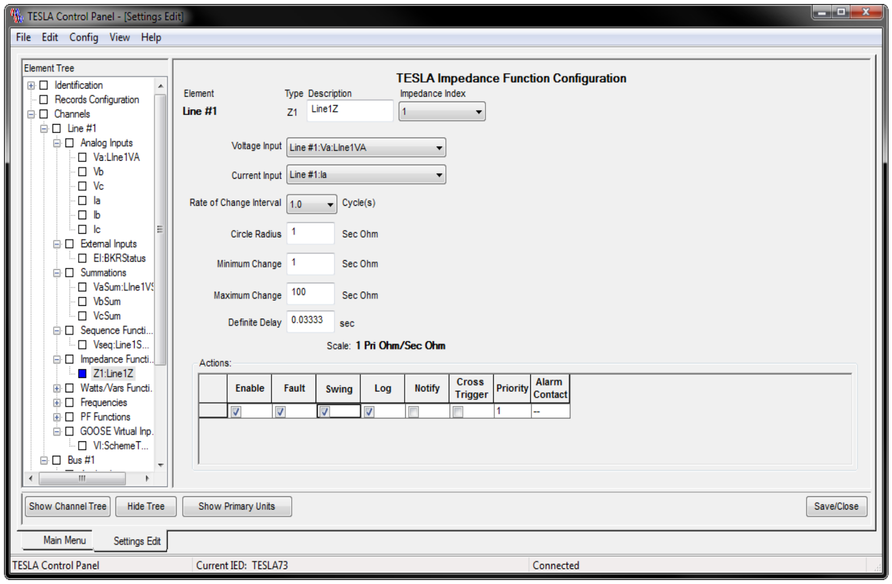


Figure 9.26: Impedance Channel Configuration Screen

Table 9.11: Impedance Channel Settings	
Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Use if Element Name and channel Type do not sufficiently identify the channel. (“Channel Grouping and Naming” on page 9-18).
Impedance Index	Identifies the Impedance channel. Unlike the analog and external input channels, this is not associated with a hardware input, but simply identifies which of the internal virtual impedance channels will be used. You can select any available channel without restriction. If the only option is “undefined”, you have already used all available channels.
Voltage Input, Current Input	Identifies the channels to be used to create the impedance. If you select analog or summation channels as inputs, the impedance channel calculates single-phase impedance; if you select sequence channels, it calculates three-phase impedance.The list is limited to channels of the correct type (voltage or current) and includes analog input or summation channels which have already been defined. The list grows automatically as you define new channels.

Table 9.11: Impedance Channel Settings

Trigger Settings	
Rate of Change Interval	Specifies the period of time over which both positive and negative rate of change is measured. TESLA takes two samples per cycle, so setting is selectable in 0.5 cycle increments. For example, for a 1.5 ROC setting, TESLA compares previous 1.5 cycle window to the current 1.5 cycle window and checks if ROC condition is met. Setting range is 0.5 to 8.0 cycles.
Circle Radius	Specifies the radius of the impedance circle in secondary ohms.
Minimum Change	Specifies the minimum impedance change to be detected.
Maximum Change	Specifies the maximum impedance change to be detected.
Definite Delay	Requires the element to be energized before an active state is determined. Settable from 0 to 1,200 seconds in half-cycle increments.
Trigger Actions	
Enable	Enables or disables the associated trigger. A trigger can be disabled without altering the rest of its settings.
Fault	Initiates a fault (high speed) recording when triggered.
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered.
Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer.
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms ,Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.13 Watts and Vars Channels

Description

The Watts/Vars Channels calculate apparent power (volt-amps), real power (watts) and reactive power (vars) from voltage input and current inputs. The channel can produce either single phase or three phase values.

Input

Analog Input Channels, Summation Channels or Sequence Component channel can be used as inputs to a Watts/Vars Channel. Using a Sequence Component as an input results in three-phase Watts and Vars.

Calculation

Voltage and current are multiplied to calculate apparent power, real power and reactive power.

Triggers

- Watts: high and low level (2)
- Watts: positive and negative rate of change (2)
- Vars: high and low level
- Vars: positive and negative rate of change
- Dual triggers for Watts allows fault and swing recordings to be triggered by different settings (e.g. Rate of Change Interval), if desired.

To prevent multiple triggers on threshold conditions, an hysteresis of 2% of setting is applied to magnitude triggers.

Recording

High Speed**:** Watt and Var values at a rate of eight values per cycle (regardless of the system sample rate).

Low Speed**:** Watt and Var values at a rate of one value per cycle.

Number of Channels

18 Watts/Vars Channels are available.

Types

W/V

Notes

The primary to secondary scale factor used by the Watts/Vars Channel is based on those of its voltage and current input channels.

Watts, Vars, and Volt-Amp magnitudes are also available to the metering display, IEC 61850 and the long term trending function.

Settings

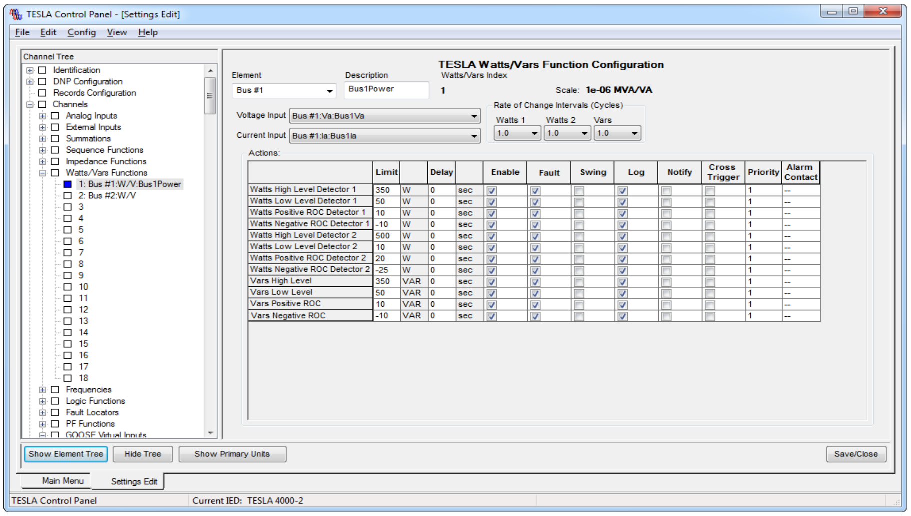


Figure 9.27: Watts/Vars Channel Configuration Screen

Table 9.12: Watts/Vars Channel Settings	
Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Use if Element Name and channel Type do not sufficiently identify the channel. (“Channel Grouping and Naming” on page 9-18).
Watts/Vars Index	Identifies the watts/vars channel. Unlike the analog and external input channels, this is not associated with a hardware input, but simply identifies which of the internal virtual watts/vars channels will be used. You can select any available channel without restriction. If the only option is “undefined”, you have already used all available channels.
Voltage Input	Identifies the voltage channels to be used to create the watts and vars. These can be either analog input channels, summations or positive sequences. If you select analog or summation channels as inputs, single phase watts and vars will be calculated; if you select sequence channels, three-phase watts and vars will be calculated.
Current Input	Identifies the current channels to be used to create the watts and vars. These can be either analog input channels, summations or positive sequences. If you select analog or summation channels as inputs, single phase watts and vars will be calculated; if you select sequence channels, three-phase watts and vars will be calculated.
Trigger Settings	
Watts 1, Watts 2, Watts 3	Period of time over which both positive and negative rate of change for each Watts Detector is measured. 0.5 to 8.0 cycles.
Vars	Period of time over which both positive and negative rate of change for Var Detector is measured. 0.5 to 8.0 cycles.

Table 9.12: Watts/Vars Channel Settings	
Limit	Specifies the trigger levels for the magnitude triggers and the magnitude portion of the rate for the rate of change triggers. The period portion of the rate is specified by the *Rate of Change Interval*.
Delay	Specifies how long the trigger condition must be present before a trigger is declared. 0 to 1,200 seconds in half-cycle increments.
Trigger Actions	
Enable	Enables or disables the associated trigger. A trigger can be disabled without altering the rest of its settings.
Fault	Initiates a fault (high speed) recording when triggered.
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered.
Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer.
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms ,Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.14 Frequency Channels

Description

The Frequency Channels measure the frequency on their assigned input channel.

Input

Any Analog Input Channel. A voltage channel is recommended for best results.

Calculation

Frequency is measured over a multi-second time window to improve resolution and accuracy. The frequency measurement operates in a band that is approximately +/-15% of the nominal frequency. Noise observed in the frequency measurement can be reduced using the Frequency Filter.

Frequency measurement requires that the selected input channel has a signal present with a minimum magnitude of 0.1 * Nominal Level. For example, if a Va channel has a Nominal Level configured as 69V and is set as the input for a frequency channel, then a minimum of 6.9V must be present on the Va channel in order for frequency to be measured.

Triggers

- High & low magnitude
- Negative and positive rate of change

To prevent multiple triggers on threshold conditions, the frequency magnitude triggers have a fixed 0.02 Hz hysteresis.

Recording

Low Speed: Frequency measurements at a rate of one value per cycle.

Number of Channels

12 Frequency Channels are available.

Types

Freq

Settings

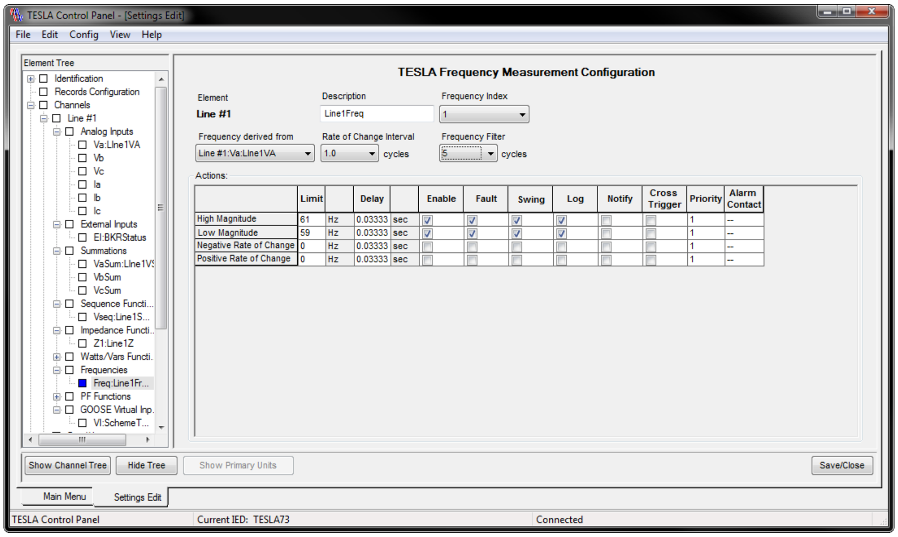


Figure 9.28: Frequency Channel Configuration Screen

Table 9.13: Frequency Channel Settings	
Frequency derived from	Identifies the analog input channel on which to measure frequency. A voltage channel is recommended for best results.
Frequency filter	Specifies the time constant of the low-pass filter which is applied for frequency measurements. 0 to 60 cycles in 5-cycle increments (for 60 Hz system frequency). 0 to 50 cycles in 5-cycle increments (for 50 Hz system frequency). Use of 0 cycles will disable the low-pass filter.
Trigger Settings	
Rate of Change Interval	Specifies the period of time over which both positive and negative rate of change is measured. TESLA takes two samples per cycle, so setting is selectable in 0.5 cycle increments. For example, for a 1.5 ROC setting, TESLA compares previous 1.5 cycle window to the current 1.5 cycle window and checks if ROC condition is met. Setting range is 0.5 to 8.0 cycles.
Limit	Specifies the trigger levels for the magnitude triggers and the magnitude portion of the rate for the rate of change triggers. The period portion of the rate is specified by the *Rate of Change Interval*. The high magnitude limit is 7/6 x nominal frequency, low magnitude limit is 5/6 x nominal frequency.
Delay	Specifies how long the trigger condition must be present before a trigger is declared. 0.0333 (2 cycles) to 1,200 seconds in half-cycle increments.
Trigger Actions	
Enable	Enables or disables the associated trigger. A trigger can be disabled without altering the rest of its settings.
Fault	Initiates a fault (high speed) recording when triggered.

Table 9.13: Frequency Channel Settings	
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered.
Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer.
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms ,Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.15 Logic Functions

Description

Logic Functions are boolean logic statements that can be applied to External Input Channels, GOOSE Virtual Input Channels (Boolean type only) and trigger detectors from other channels. You can choose up to 5 inputs, each of which may be inverted, and specify a chain of logic operations to be performed on each.

Input

Up to 5 inputs. Each can be an External Input Channel, GOOSE Virtual Input Channel or the output of a trigger detector from any channel, including other Logic Functions with lower Indexes.

Calculation

Boolean logic is applied to each input in succession.

Triggers

- Active state
- Inactive state

Recording

High Speed**:** Logic functions recorded at a rate of eight values per cycle (regardless of the system sample rate).

Low Speed**:** Logic functions recorded at a rate of one value per cycle.

Number of Channels

30 Logic Functions are available.

Types

Logic

Notes

The output of the Logic functions is available to the metering display, IEC 61850 and the long term trending function.

Settings

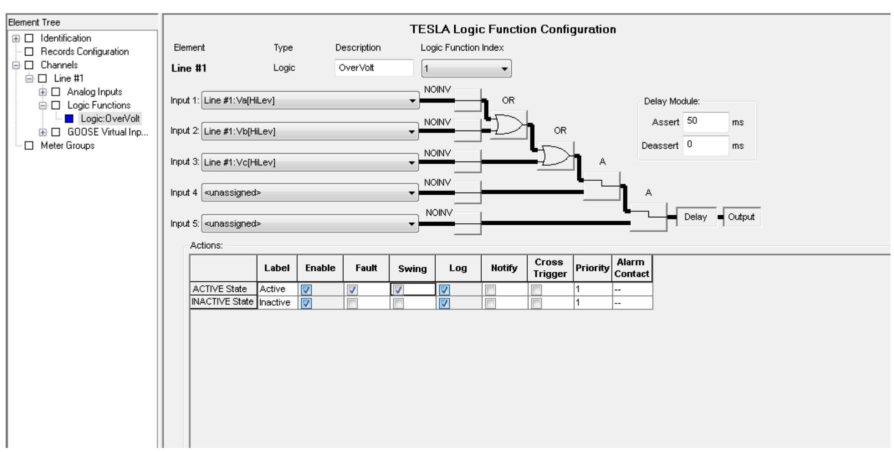


Figure 9.29: Logic Function Configuration

Table 9.14: Logic Function Settings

Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Use if Element Name and channel Type do not sufficiently identify the channel. (“Channel Grouping and Naming” on page 9-18).
Logic Function Index	Identifies the logic function. You can select any available function; the only restriction is that nested logic functions require the input logic to have a lower Logic Function Index. If the only option is “undefined”, you have already used all available channels.
Inputs 1–5	Selects the source of the input state for each stage of the boolean calculation. External Input Channels, GOOSE Virtual Input Channels, trigger detectors from other channels and previously-defined Logic Functions are available.
Inversion Blocks	Allows the input state to be inverted. Click to activate and move mouse to select option before releasing.
Logic Gates	NOT, AND, NAND, OR, NOR, Exclusive OR, and Exclusive NOR. Click to activate, scroll window to display, click icon to select
Delay Module	Assert: delays the output for the specified time. Deassert: locks in the output state for the specified time. 0 to 20 seconds in half-cycle increments.
Trigger Action	
Enable	This setting is always selected when Logic channel is added.
Fault	Initiates a fault (high speed) recording when triggered.
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered.This setting is always selected when Logic channel is added.
Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer.
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms ,Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.16 Fault Locator Functions

Description

Fault Locator Functions produce distance-to-fault informations based on the impedance measured on the specified voltage and current channels. The information is logged and available through IEC 61850.

Input

Initiating Event: any External Input Channel, GOOSE Virtual Input Channel or trigger detector from any other channel or function.

Voltage Channels: must be Analog Input Channels monitoring voltage.

Current Channels: can be Analog Input Channels or Summation Channels monitoring current.

The correct phases must be selected to achieve the desired results.

Calculation

When a user-configurable event occurs, the fault locator assesses the distance to fault using the user-supplied line parameters. If one or more of the impedances is consistent with a fault on the line, fault identification (e.g. B-G) and location information is generated in the form of an event message.

A fault location event will be calculated if the following conditions are met (as shown in “Fault Locator calculation” on page 9-55):

1. The initiating event goes high AND
2. The fault impedance is within the fault location pick-up zone. This zone is 0% to 120% forward reach of the circle and calculated distance is less than the line length.

The lowest impedance within the pick-up zone between Zan, Zbn, Zcn, Zab, Zbc and Zca is used to calculate the fault location.

> The fault location is automatically determined as the average of the fault location at 1.5 and 2 cycles after the initiation.

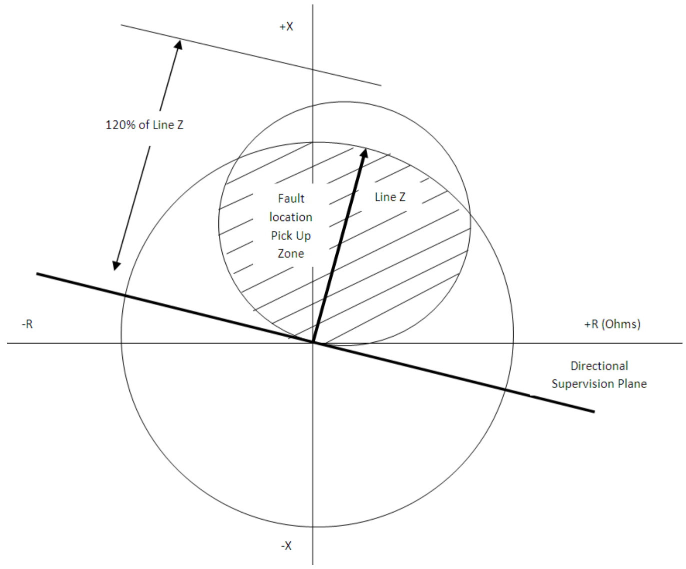


Figure 9.30: Fault Locator calculation

Triggers

N/A

Recording

Fault Locator Functions are not recorded.

Number of Channels

10 Fault Locator Functions are available.

Types

FLoc

Notes

When a Fault Locator Function is triggered, it writes a message into the Event Log identifying the time, the Element, the faulted type (e.g. A-B, B-G...) and the distance to fault.

The output of the Fault Locator Function is available through IEC 61850. It cannot be metered or trended.

Settings

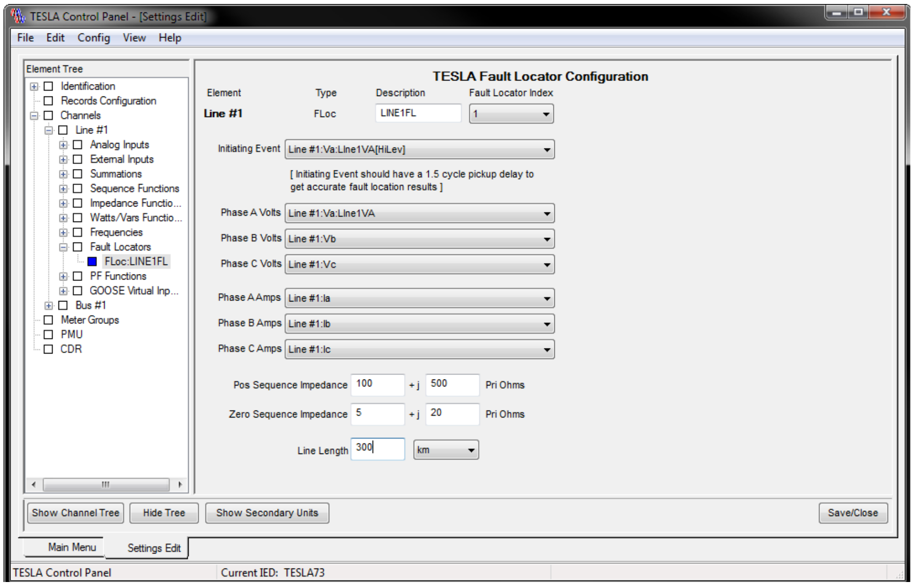


Figure 9.31: Fault Locator Function Configuration

Table 9.15: Fault Locator Function Settings	
Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Use if Element Name and channel Type do not sufficiently identify the channel. (Ref: “Channel Grouping and Naming” on page 9-18).
Fault Locator Index	Identifies the Fault Location function. You can select any available function. If the only option is “undefined”, you have already used all available channels.
Initiating Event	Any External Input Channel, GOOSE Virtual Input Channel or trigger detector from any other channel or function. Note that the initiating Event typically requires a 1.5 cycle delay to obtain accurate fault location information.
Voltage and Current Inputs	Select the voltage and current inputs used for Fault Location calculation.
Line Impedance	The Positive and Zero sequence impedance of the line. You may enter in either Primary or Secondary Ohms by toggling the “Show Primary/Secondary Units” button.
Line Length	Length of the line in either kilometres or miles.

9.17 Power Factor Functions

Description

Power Factor Functions monitor the real and reactive power values calculated by a Watts/Vars Channel and trigger depending on total power level. Inductive power factor is defined as a situation where the calculated reactive power is positive. Capacitive power factor is defined as a situation where the reactive power is negative.

Input

A previously-defined Watts/Vars Channel.

Calculation

The Power Factor Detector monitors the watts, vars, and volt-amps values computed by its input channel and operates when the power factor is less than a user-specified threshold. Separate detectors allow separate thresholds for lagging (inductive) and leading (capacitive) power factors. To reduce the incidence of nuisance operations, you may specify a minimum volt-amps setting.

Triggers

Inductive power factor – Low magnitude

Capacitive power factor – Low magnitude

To prevent multiple triggers on threshold conditions, the power factor triggers have a fixed hysteresis of 0.05.

Recording

Power Factor Functions are recorded in the low-speed recordings.

Number of Channels

18 Power Factor Functions are available.

Types

PF

Notes

Power factor readings are available to the metering display, IEC 61850 and the long term trending function.

Settings

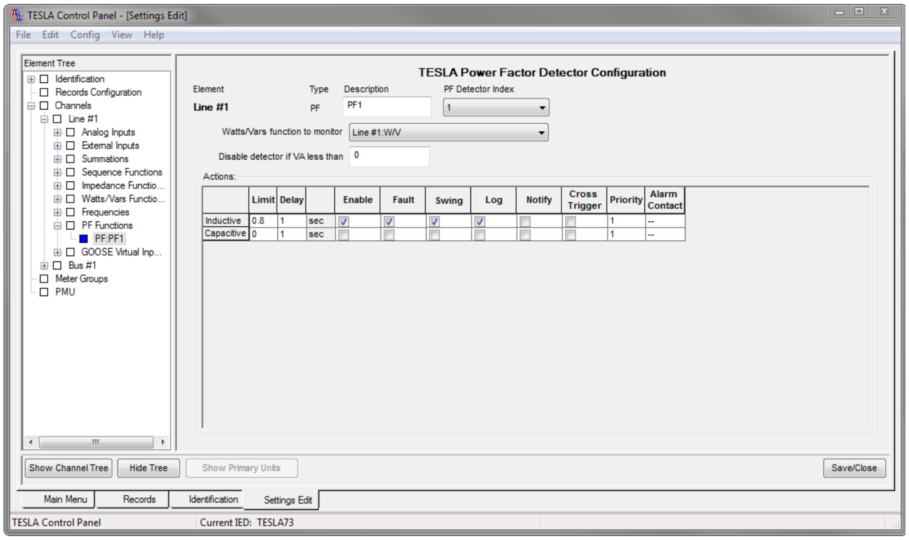


Figure 9.32: Power Factor Function Configuration

Table 9.16: Power Factor Function Settings	
Element	Identifies the group to which this channel belongs. The Element forms the first part of the channel name. The Element is selected when the channel is created and is fixed once assigned when you are working in the Element Tree view.
Description	Optional field (12 characters). Provides an additional description of the channel that forms part of the channel name. Use if Element Name and channel Type do not sufficiently identify the channel. (“Channel Grouping and Naming” on page 9-18).
PF Detector Index	Identifies the Power Factor function. You can select any available function. If the only option is “undefined”, you have already used all available channels.
Watts/Vars function to monitor	Specifies which Watts/Vars channel to use as input. Must be previously defined.
Trigger Settings	
Disable detector if VA less than	Allows the trigger to be supervised by a minimum VA level. Can be set in primary or secondary units.
Limit	Power factor trigger level. 0 to 1 in 0.001 increments.
Delay	Requires the element to be energized before an active state is determined. Settable from 1 to 10,000 seconds in 1 second increments.
Trigger Action	
Enable	Enables or disables the associated trigger. A trigger can be disabled without altering the rest of its settings.
Fault	Initiates a fault (high speed) recording when triggered.

Table 9.16: Power Factor Function Settings	
Swing	Initiates a swing (low speed) recording when triggered. If both Fault and Swing are enabled, the recorder will attempt to create a combined record.
Log	Logs a message in the Event Log when triggered.
Notify	Contacts the RecordBase Central Station when triggered. Can be used to initiate wide area swing recordings and/or automated record transfer.
Cross Trigger	Activates the cross-trigger contact (#4) to trigger another device.
Priority	Specifies the priority to be assigned to records created by this trigger. The priority is used to determine Central Station notification. 1 - 3 (3 is the highest priority).
Alarm Contact	Specifies a rear panel contact to be closed when triggered. Contacts are closed momentarily for one second. Contact assignment is not exclusive, allowing multiple triggers to activate the same contact. Available contacts: 2 or 3 on a 8/12/18 channel model and 2, 3, 5, 6, 7 or 8 on a 36 channel model. Contacts 1 and 4 are reserved for Recorder Functional and Cross-Trigger respectively. Contacts assigned for storage alarms or Time Sync loss alarm or IEC 61850 communication failure alarm (“TESLA Alarms” on page 9-10) will not be available for use here.

9.18 Meter Groups

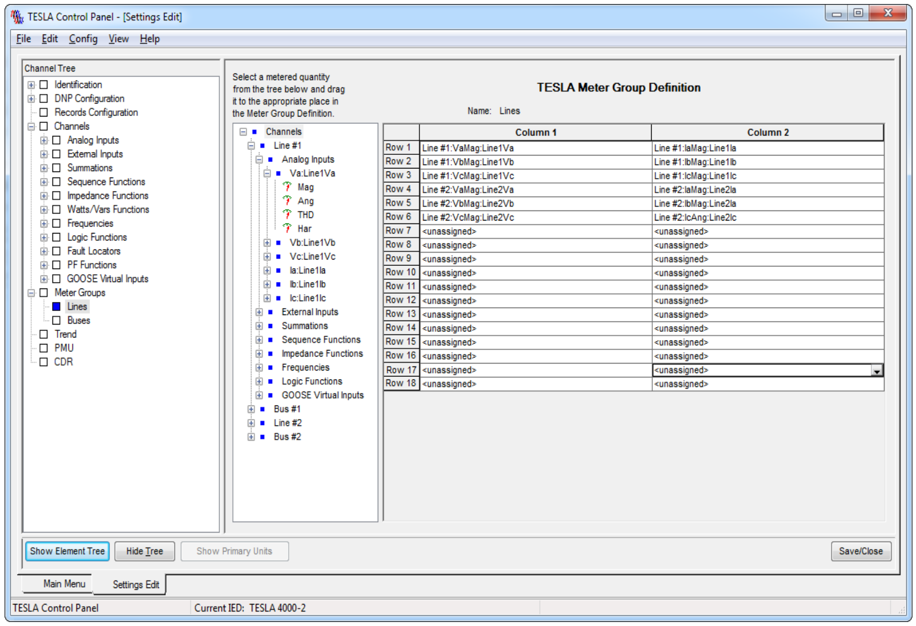


Figure 9.33: Meter Group Configuration Screen

A Meter Group is a collection of measured and calculated values that are presented as a group by the TESLA Control Panel's Metering function. Metering Groups are referred to by a user-specified name, and the name of the Metering Group appears on the tab in the Metering display.

There are two default metering groups and ten user-defined groups for a total of twelve metering groups.

The Metering display has fixed displays for analog and external input channels. You may add additional displays containing any set of channels, organized as you wish.

1. To create a meter group, right-click on the *Meter Groups* entry in the Configuration menu.
2. Select *Add Meter Group*. A New Meter Group line appears, and the New Meter Group text is selected.
3. Type the Meter Group name, then *Enter*. The text you type replaces the New Meter Group text.
4. In the meter group screen, you can place any defined channel in any cell. The resultant meter group display will show the desired channels in the specified place on the screen.

Phase angle readings displayed in meter groups are based on the configured Phase Angle Reference Channel "Phase Angle Reference Channel" on page 9-22.

9.19 Trend Logging

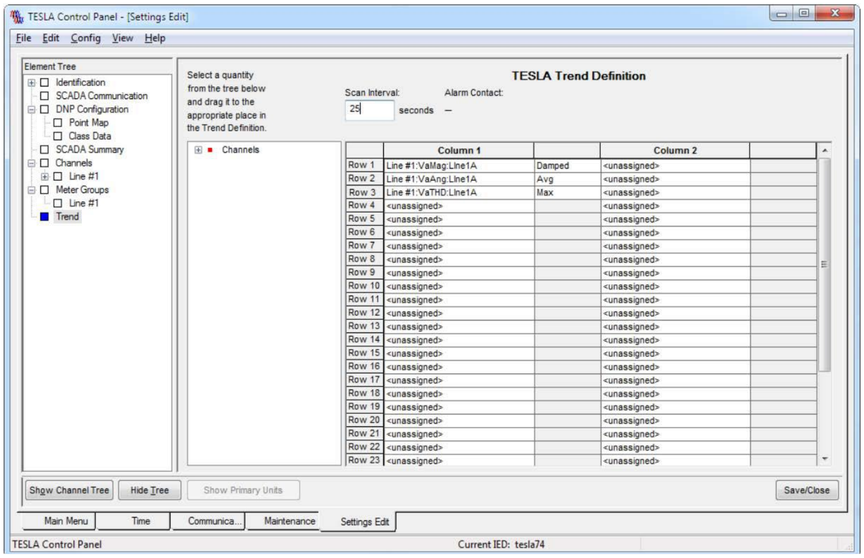


Figure 9.34: Trend Log Configuration

The TESLA recorder can log periodic measurements over an extended period of time. Up to 60 values can be logged at intervals ranging from 10 seconds to one hour.

All recorder channels and calculated values are available for trending. Event messages can also be stored in the trend log, allowing them to be saved from the normal circular overwrite of the Event Log.

The trend log accumulates data for up to 90 days. When it is full, it can either be set to automatically overwrite the oldest data or to stop logging. A “near full” alarm function is available. The accumulation settings are defined in the Trend Configuration menu (see “Network Redundancy Configuration” on page 8-11).

To configure trend logging select either *New Trend* from the Config menu or *New Trend* from the right-click context menu in either the Channel Tree or Element Tree.

The *Scan Interval* (see Scan Interval on page 9-63) determines the frequency of data logging. It can be set from 10 seconds to 3,600 seconds (one hour).

Choose channels to be trended by clicking on one of the (larger) spaces in the trend grid. Clicking on the arrow that appears, lists all the available channels in the list box that appears adjacent to the space you originally clicked. Alternatively, use the selection tree that appears to the immediate left of the trend grid. Use the tree’s expansion buttons to locate the desired channel, then drag and drop your selection on the grid.

You can control how the data is accumulated between logged values for each trended value. The *Accumulation Modes* are as follows:

Table 9.17: Trend Accumulation Modes:	
Damped (default)	Logs a value representative of the measurements during the interval.
Undamped	Logs the latest value measured during the interval.
Avg	Logs the average measured value over the interval.
Min	Logs the minimum measured value over the interval.
Max	Logs the maximum measured value over the interval.

For more details on trend accumulation modes, see “Trend Accumulation Mode Calculations” on page 9-62.

You can record the same channel with more than one accumulation mode, but you can not record the same channel with the same accumulation mode more than once.

When you have defined a trending process, a long-term event log is started automatically.

If you wish to have the long-term event log without trending any data, define a trend without any channels in it. A daily limit of 1000 events can be stored in the trend log.

Trend Accumulation Mode Calculations

There are five trend accumulation modes available for trend value calculation; Damped, Undamped, Avg, Min and Max. The following is a detailed description of how these five accumulation modes are used to calculate trend data.

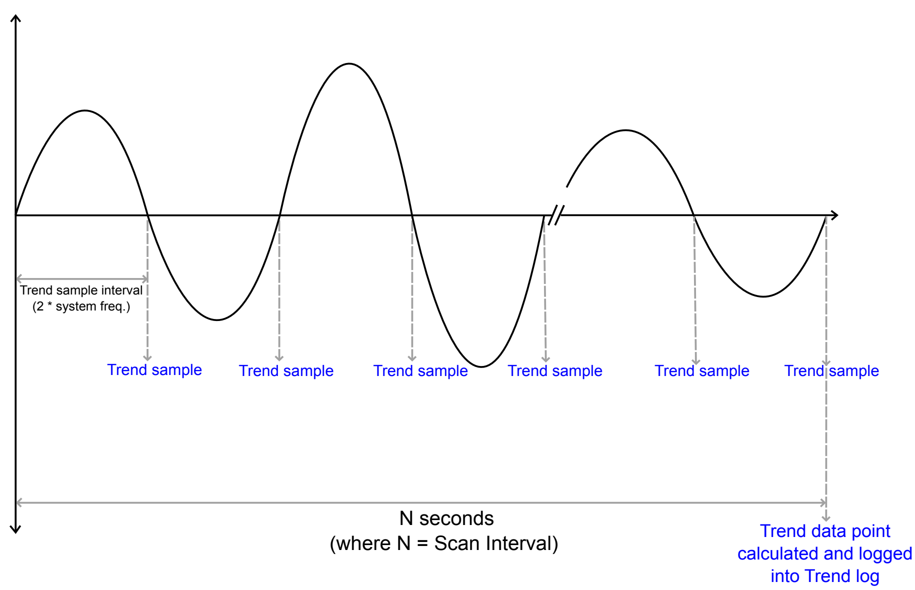


Figure 9.35: Trend calculation

In Figure 9.35, there are two important concepts related the trend calculation process:

- **Trend Sampling:**
  The trend sample is a measurement taken over the trend sample interval. The trend sampling occurs at the frequency of 2 * System Frequency (trend sample interval is 8.33ms for 60Hz or 10ms for 50Hz).
- **Scan Interval:**
  The scan interval determines how frequently one trend sample is logged into the trend log. For Damped and Undamped modes, the latest trend sample in the Scan Interval is directly logged into the trend log. For Avg, Min and Max modes an additional calculation is performed over the entire Scan Interval before a trend sample is logged into the trend log.

Damped

Damped mode uses the following formula for calculating trend samples. This calculation is performed by the TESLA after every trend sample interval.

$$NewDampedValue = PreviousDampedValue + \frac{2 \times (NewSample - PreviousDampedValue)}{SamplingRate}$$

Where,

SamplingRate = 120 for 60Hz or 100 for 50Hz

At the end of the Scan Interval, the latest damped value is logged into the trend log.

Undamped

In Undamped mode, at the end of the Scan Interval, the latest trend sample is directly logged into the trend log.

Avg

In Avg mode, at the end of the Scan Interval, the average value of all trend samples over the entire Scan Interval is calculated and logged into the trend log.

Min

In Min mode, at the end of the Scan Interval, the trend sample with the minimum value within the Scan Interval is logged into the trend log.

Max

In Max mode, at the end of the Scan Interval, the trend sample with the maximum value within the Scan Interval is logged into the trend log.

9.20 Printing

Printing a Configuration

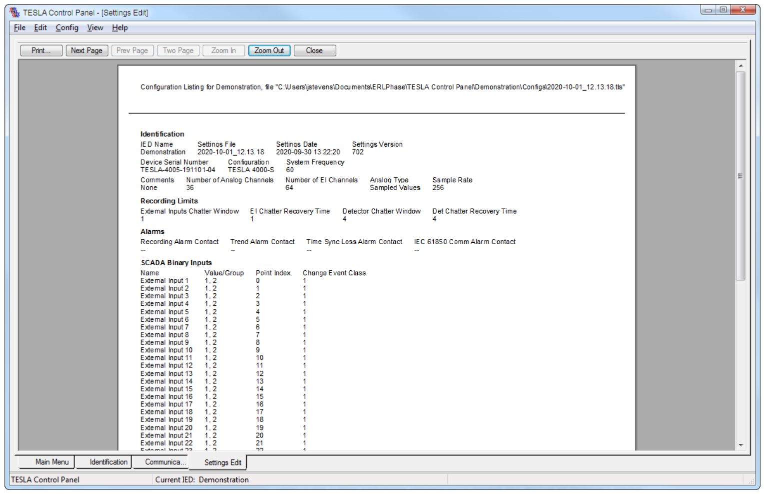


Figure 9.36: Print a Configuration

Generate a Configuration print at any time by selecting *Print Settings* from the *File* menu. The printed output follows the same general layout as the Element Tree. Where applicable, the settings are given in secondary units. The exception is the Fault Location parameters which are given in primary units.

You can preview the printed output by selecting *Print Preview* from the *File* menu.

Print Config function is also available under the *Config* menu.

Printing a DNP Point List

The DNP point list shows all of the functions defined in the TESLA recorder, (see see Appendix F) Selecting the *Print DNP* settings item from the *File* menu generates a listing that is configurable - listing the full function names in Element-Function-Description format along with the equivalent DNP points.

You can preview the printed output by selecting *Print DNP Preview* from the *File* menu.

Print DNP function is also available under the *Config* menu.

10 Setting Files Comparison Tool

Setting Files Comparison tool is used to compare two configuration setting files of TESLA and this tool is integrated with TESLA Control Panel (TCP) software itself.

This tool compares TESLA 4000 setting version 406 and up for Model 4000, and all setting versions of Model 4000-SV and Model 4000-A.

10.1 Launching the Tool

"Compare Settings" command button is available in Settings tab.

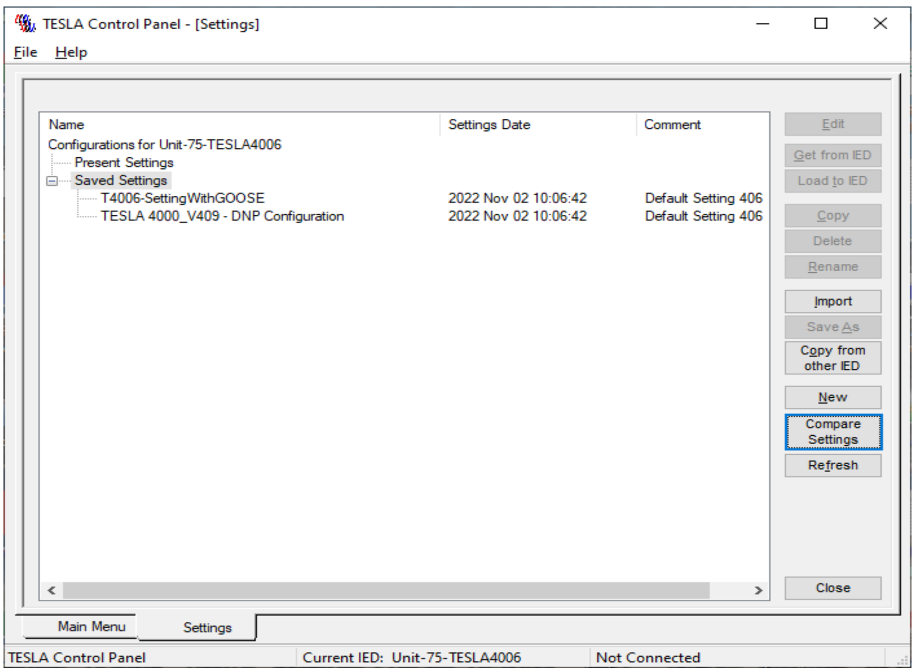


Figure 10.1: Button "Compare Settings" on TESLA Control Panel

By clicking this button will launch the "Tesla Settings File Comparison" tool in separate window.

Select *Import File 1* button to choose the first file to be compared, select *Import File 2* button to choose the second file and select *Compare* button to display the comparison.

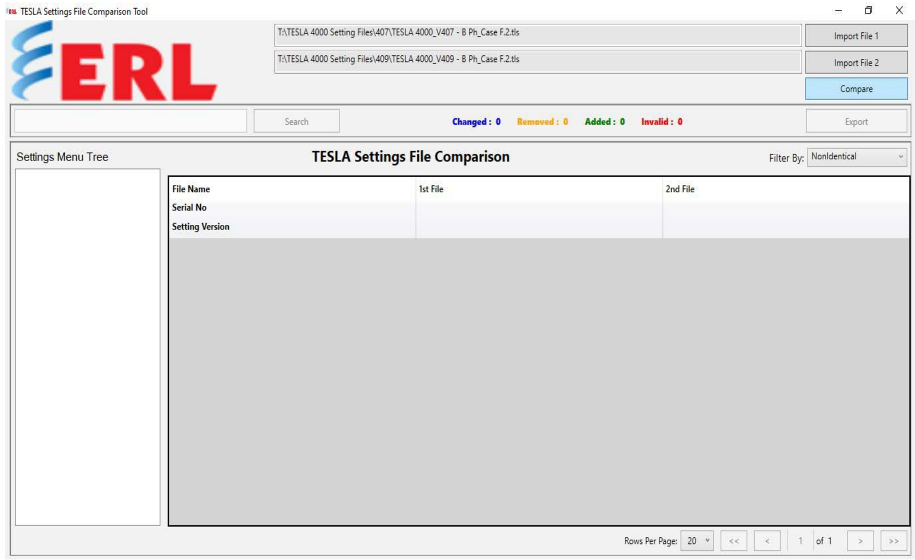


Figure 10.2: TESLA Settings Comparison Tool main screen

10.2 Understanding the TESLA Setting File Comparison Tool

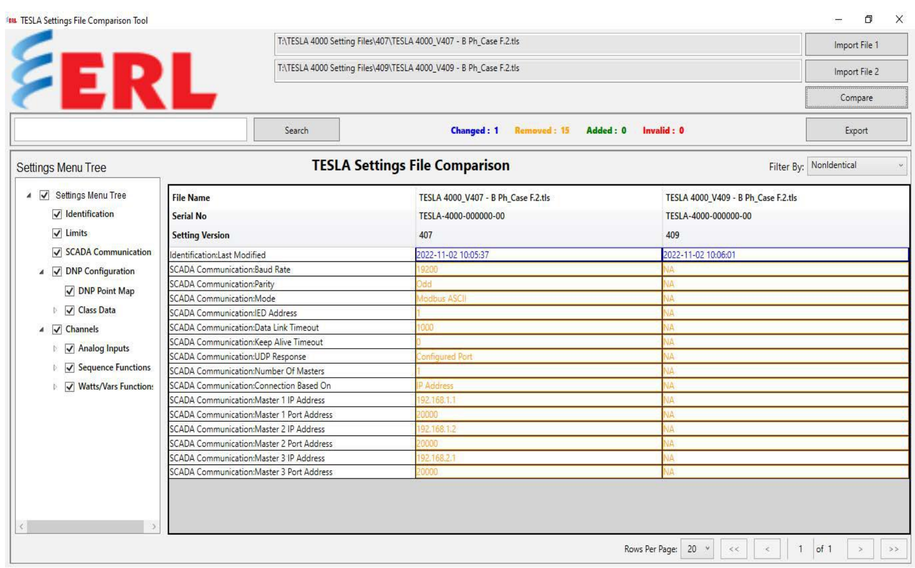


Figure 10.3: TESLA Settings Comparison information display

Settings Menu Tree - This box will display a tree of available channels according to the files selected for comparison. As default all check boxes are selected and “Filter By: Nonidentical” option is setup.

TESLA Settings File Comparison - TESLA Settings File Comparison table displays the setting parameters based on the settings selected under Settings Menu Tree and the filter by option.

This tool uses the setting file 1 as reference file and compare the setting file 2 to find the Nonidentical and Identical setting details.

Nonidentical setting has further categorized as “Changed”, “Removed”, “Added” and “Invalid” to give more distinguished information from the tool.

Filter By: - This is a filter that works along with the items selected on “Settings Menu Tree”. This will display the combination of the selected settings on “Settings Menu Tree” with one of the following options: All, Changed, Removed, Added, Invalid, Identical or Non-Identical.

- **Changed:**

Any setting value is changed in file 2 with reference to file 1 is listed under Changed category and the setting values are shown in Blue color.

- **Removed:**

Any setting parameter is removed in file 2 with reference to file 1 is listed under Removed category and the setting values are shown in Orange color.

- **Added:**

Any setting parameter is added in file 2 with reference to file 1 is listed under Added category and the setting values are shown in Green color.

- **Invalid:**

Any setting value is illegal in file 2 with reference to file 1 is listed under Invalid category and the setting values are shown in Red color.

- **Identical:**

Setting values are same in both the files are listed under Identical category and the setting values are shown in Black color.

Rows Per Page - This is to select the number of rows per page to display in the TESLA Settings File Comparison table.

Pagination - This is to navigate throughout the pages if more than one page is available. The page number is a editable field where user can type the page to be displayed in the TESLA Settings File Comparison table.

Search - This is to search the specific information available in any of the three columns of TESLA Settings File Comparison table. Search command will find the information and displays the setting parameters based on the selection in Settings Menu Tree and the filter by option.

Export - This feature is to provide the report based on the selections in Settings Menu Tree and Filter By option. This tool can export the report files in CSV, Excel, HTML, PDF and XML formats.

Important Note: This tool may compare configuration setting files from previous TESLA Models, however, the result may not be accurate.

11 Record and Log Management

11.1 Records

The Record management services are available from the *Records* tab, accessible from the *Main Menu*.

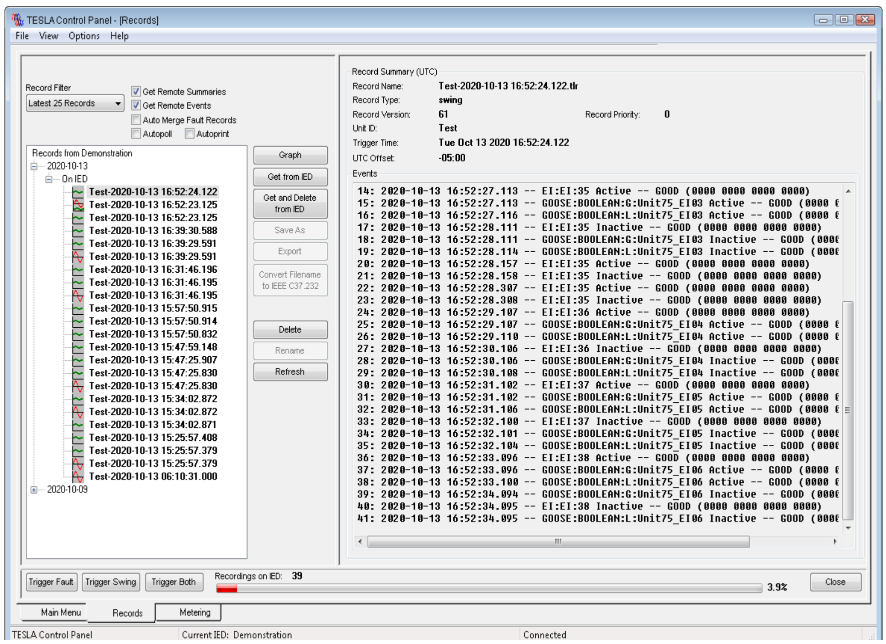


Figure 11.1: Record Listing

Record Lists

The left side of the *Records* tab shows lists of records for the current IED organized by date. Expanding a date entry shows *On IED* and *Local* headings. Records presently on the recorder are shown under the *On IED* heading. Records that have been previously transferred to TESLA Control Panel are shown under the *Local* heading. Records on the IED that have not been transferred to TESLA Control Panel are shown in bold-face. If working offline, only local records are shown.

Record Filter

The list of records displayed is controlled by the *Record Filter* control. The filter applies to both *On IED* and *Local* record lists. The time taken to access the directory can be controlled by selecting an appropriate number of records in the *Record Filter*.

Note that if additional recordings are created through the Trigger Fault, Trigger Swing or Trigger Both buttons, these new records do not displace the earliest fetch/displayed file records in the tree.

> Record timestamps are received from the recorder are in UTC. The record timestamp also displays a “UTC Offset” depending on the time-zone and DST setting on the time screen.

Record Summary

The right side of the *Records* tab shows summary information on the selected record. The summary includes the list of events which occurred during the time-span of the record from the recorder's event log.

Get Remote Summaries/Get Remote Events

When both *Get Remote Summaries* and *Get Remote Events* options are checked, TESLA Control Panel accesses and displays the corresponding recording information in the *Record Summary* and *Events* sections of the right-hand pane. You may eliminate the delay involved in accessing this information by disabling the corresponding check-boxes.

Auto Merge Fault Records

Enabling this feature allows for longer high speed records during conditions with many consecutive triggers. Depending on triggering conditions and configured record lengths, high speed records with durations greater than one minute are possible.

When *Auto Merge Fault Records* is enabled, TESLA Control Panel will merge records with overlapping time durations into a single record. Two or more consecutive records occurring on the same IED will be merged together, as long as the durations of the records overlap. The record merging is handled locally by the TESLA Control Panel software, the records stored on the IED are not affected by this setting. The merging process occurs during the retrieval process when multiple overlapping records are retrieved using the "Get *From IED"* or "*Graph*" buttons.

Autopoll/ Autoprint

When *Autopoll* is checked, TESLA Control Panel will poll the connected TESLA recorder for new record files every 60 seconds and automatically transfer them to the local computer. Only one new record will be transferred at each poll, starting with the newest record. The state of the *Autopoll* enable is persistent to the local computer and retained between TESLA Control Panel sessions and menu navigation. During periods of user inactivity, a count of *Autopoll* records transferred is indicated within the record tab when this feature is active.

Checking *Autoprint* will cause each transferred (via *Autopoll*) record file to be automatically printed on the default Windows printer using RecordGraph's default template. The state of the *Autoprint* enable is persistent to the local computer and retained between TESLA Control Panel sessions and menu navigation and only available when the *Autopoll* feature is enabled.

Graph

Records can be viewed with RecordGraph, ERLPhase's interactive graphing software. To launch RecordGraph, select one or more local records and select the *Graph* button. RecordGraph is also launched when double-clicking on a record.

Get from IED

Selecting a recorder file under *On IED* and then selecting the *Get from IED* button causes a record file on the IED to be transferred from the recorder to your local computer. More than one file can be transferred at the time using Windows file selection function (*Control*/*Shift* + *left*-click). This action will not delete the record on the IED.

Get from IED and Delete

The *Get From IED* and *Delete* button erases the records on the recorder after they have been transferred to TESLA Control Panel and verified.

Save As

Selecting a local record and selecting the *Save As* button copies a record to a specified file. The .tlr file suffix should be retained.

Export

Selecting a local record and selecting the *Export* button launches the Export Utility. Records can be exported in common formats such as COMTRADE for use in other software or playback, for details see 14 Record Export Utility on page 14-1.

Convert Filename to IEEE C37.232

The *Convert Filename to IEEE C37.232* button toggles the filename format between the IEEE C37.232 standard format and the ERLPhase proprietary format. User must enable this option via the *Tools* > *Options* menu. For more information, see “IEEE C37.232 TSD File Naming” on page 14-9.

Delete

The *Delete* button can be used to delete records on the IED or locally. Multiple files can be deleted simultaneously using Windows file selection functions (*Ctrl/Shift* + *left-click*).

Rename

Select *Rename* to allow a local record file to be renamed. Records on the recorder cannot be renamed.

Refresh

Selecting *Refresh* updates the *Recordings* screen. It checks the local directory and the remote IED (if connected) for new and stored files, updates TESLA Control Panel’s records database and refreshes the screen.

Trigger Fault/ Swing/Both

The recorder can be manually triggered to generate different types of records. *Trigger Fault* creates a high speed transient recording. *Trigger Swing* creates a low speed swing recording. *Trigger Both* creates a combined record.

Note the Swing records may take up to 15 minutes to generate depending on the recorder’s settings.

Recordings on IED

Shows the number of records stored on the recorder and percentage of recording space used.

File>Select Remote

This function is available through the *On IED* menu. If you are online with your TESLA, this function selects all of the recording files displayed in the record list that have not yet been transferred to your local Recordings directory. You may then perform whatever command is appropriate for the selection set, such as a *Get from IED* or a *Get and Delete from IED* Command.

11.2 Trend Log

The trend manager services are available from the *Trend* item, accessible from the *Main Menu*.

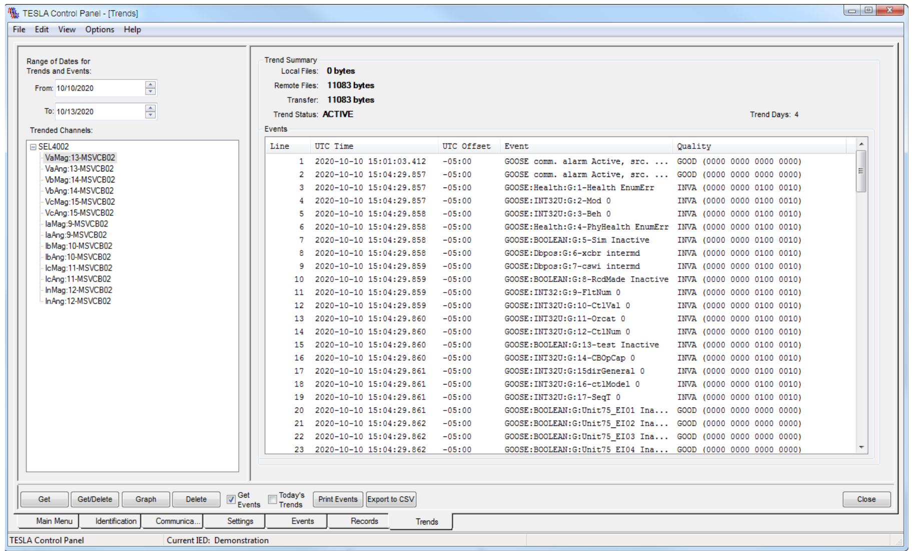


Figure 11.2: Trend Listing

Range of Dates

Set the time range using the two date control boxes, *From* and *To*. The initial setting is for the previous three days. When you change these settings, the remainder of the display updates to show data pertinent to your chosen period. If you are connected to a TESLA, both local and remote data are combined in the tree; otherwise, the display shows only data resident on your local computer.

Trended Channel

The tree on the left side of the screen shows the channel names of the trended data available for the period you have selected. You may select any number of channels from the tree for further operations.

Select more than one channel by using the Ctrl and Shift keys in conjunction with mouse clicks and arrow keys.

Trend Summary

The *Trend Summary* section of the screen shows statistical information about the selected files. *Local Files* indicates the amount of space used by the selected trend files on your local computer. *Remote Files* indicates the amount of space used by the selected trend files on the IED. *Transfer* refers to files that are on the IED, but not on your local computer, and represents the total amount of bytes in stored trend files that would be transferred before further processing takes place.

Events

The *Events* section of the display shows all the events recorded during the period of interest set with the range of dates. The Event log includes the associated Data Quality (see “Data Quality” on page 20-1).

Get, Get/Delete

When you click *Get* all of the trends not previously transferred are transferred to your computer. If you select *Get/Delete*, all files successfully transferred from the IED will also be deleted from the IED.

Graph

The trend data selected in the Trended Channels list is viewed with Record-Graph, ERLPhase's interactive graphing software, for details see 13 Graphing Records on page 13-1. Any selected trend data not already in your computer is transferred prior to graphing.

Delete

The trend data selected in the Trend Channel list is removed from your computer. If you are currently connected, you have the option of removing the data on the IED files as well.

Get Events

Each time you change the Range of Dates, the list of events on the right side of the screen is updated. If you are not interested in this action, remove the check mark from the checkbox.

Today's Trends

If the Range of Dates includes data that is currently being recorded, some of the data may not be in a form suitable for transfer to TESLA Control Panel. If this checkbox is selected, TESLA Control Panel will send a request to the IED to convert the most recent data so that it can be transferred. The time that this takes may be significant, and if you do not have a need for this data, the feature may be disabled by removing the check mark from the check box.

Print Events

The list of events in the *Events* portion of your screen is printed.

11.3 Event Log

The event log services are available from the *Events* tab, accessible from the *Main Menu*.

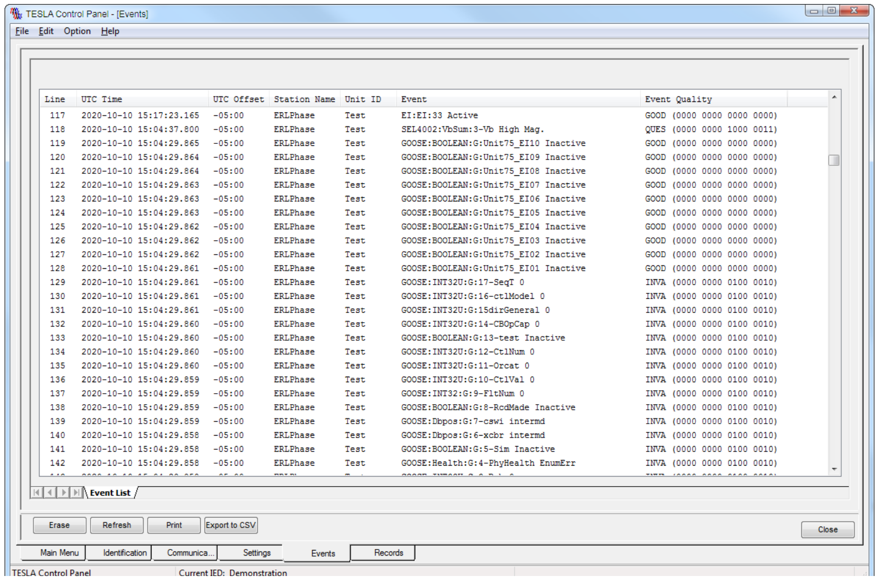


Figure 11.3: Event Log Display

The recorder maintains a log of time-stamped events. Event messages can be produced by any of the recorder's detectors if configured to do so.

Event messages can also be viewed in the Record Summary and Trend Summary displays

Circular Storage

The Event Log stores up to 1000 events with automatic overwrite of the oldest event. For greater event storage, or to prevent automatic overwrite, the recorder's trending function can also be used to store event messages.

Event Messages

The text of an event message is derived from the configuration of the detector that generates it.

The general format for event message is:

Line# Date/Time UTC Offset Station ID Unit ID Event Description Event Quality

Table 11.18: Event Log Message Details

Line #	Index number for identifying events. Newest event is #1
Date/Time	Date and time of the event. Displayed according to time display setting (see “Time Display Settings” on page 8-23)
UTC Offset	The IED’s UTC Offset (see “Time Display Settings” on page 8-23)
Station ID	The Station ID, determined by the setting on the Identification screen (see “Unit Identification” on page 8-2)
Unit ID	The Unit ID, determined by the setting on the Identification screen (see “Unit Identification” on page 8-2)
Event Description	Description of the event which generated the event message
Event Quality	The data quality associated with the event. See “Data Quality” on page 20-1 for more details on the Data Quality implementation.

Examples of Event Messages can be seen above in Figure 11.3: Event Log Display.

Printing Event Log

The events in the Event Log are available for copying and printing while connected to the IED. To print the event log either press the *Print* button at the bottom of the screen, select *File > Print Events,* or press *Ctrl-P*.

Controls

The event display is a static snapshot of the contents of the event log. You can use the buttons at the bottom to access the Erase, Refresh, Print functions, and Export to CSV function. Users can copy selected events by selecting *Edit > Copy*, or by pressing *Ctrl-C*. Print commands are available under the File menu.

Table 11.19: Event Screen Functions

Refresh	Updates Event List by getting a new list from remote IED and updates the Event List screen.
Erase	Removes all events from remote IED.
Print	Prints all the events (up to 500 events) to a local printer.
Export to CSV	Exports the event list to CSV format to a user-selected file location.

11.4 Audit Trail

The Audit Trail is accessed by selecting *Audit Trail* from the *Main Menu.* Audit Trail is only accessible to users with the “SECAUD” role assigned. The purpose of the Audit Trail is to display a log of sequential timestamped security notifications. For more information on the Security Notifications, see section 18.4 Security Notification System on page 18-10.

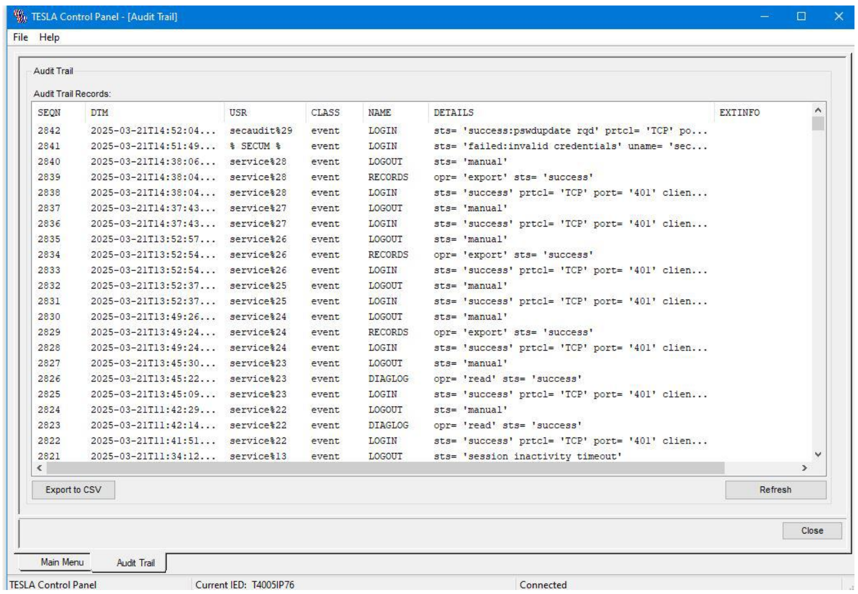


Figure 11.4: Audit Trail

Export to CSV

The *Export to CSV* option allows for saving of the current Audit Trail to csv format.

Refresh

The *Refresh* button updates the Audit Trail to display any new security alarms or events.

12 Continuous Disturbance Recording

Continuous Disturbance Recording (CDR) implemented in the TESLA 4000-A recorder allows the gathering of power system disturbance data to review and analyze transmission and generation protection systems. The TESLA 4000-A recording system incorporated CDR for NERC standards requirements, including user-selectable recording channels and user-selectable recording sample rate.

NERC Standards:

1. Standard PRC-002-5 – Disturbance Monitoring and Reporting Requirements
2. Standard PRC-028-1 – Disturbance Monitoring and Reporting Requirements for Inverter-Based Resources

The CDR feature incorporated in the TESLA 4000-A Recording System meets and exceeds the requirements of NERC Standards as represented in the following table. As per the latest NERC standard PRC-028-1, TESLA 4000-A with 64 GB or 1 TB flash memory option can store CDR data for more than 20 days with 60 samples per second rate with all the analog channels configured.

Table 12.1: NERC Standards

Continuous Recording Requirements	PRC-002	PRC-028	TESLA 4000-A
Input sampling rate (samples per second)	At least 960	At least 960	1920 - 30960
Output recording rate (records per second per channel)	At least 30	At least 60	6 - 60
Data retention period (days)	10	20	At least 6 days with maximum reporting rate and maximum 36 number of channels configured for the standard storage. With extended storage, it can be extended up to 36 days.

The continuous disturbance recording data retention period depends on the number of selected channels, flash memory size ordered and on the selected sample rate. Estimated continuous disturbance recording data retention periods (in days) for various combinations of channel numbers, flash memory and the sampling rates are shown in Table 12.2.

Table 12.2: Estimated CDR retention period in days at 60Hz

	Number of channels	Sample Rate (RMS records per second per channel)						
		6	**10**	**12**	**15**	**20**	**30**	**60**
16GB	8	183	110	91	73	55	36	18
	12	143	85	71	57	42	28	14
	18	107	64	53	42	32	21	10
	36	61	36	30	24	18	12	6
64GB	8	673	404	336	269	202	134	67
	12	523	314	261	209	157	104	52
	18	392	235	196	157	117	78	39
	36	224	134	112	89	67	44	22
1TB	8	1082	649	541	432	324	216	108
	12	841	505	420	336	252	168	84
	18	631	378	315	252	189	126	63
	36	360	216	180	144	108	72	36

The general configuration screen is reached by selecting *Settings* from the *Main Menu*; the main Continuous Recording screen is reached by selecting *Continuous Recording*. See Figure 12.1: Main Menu showing the Continuous Recording menu option.

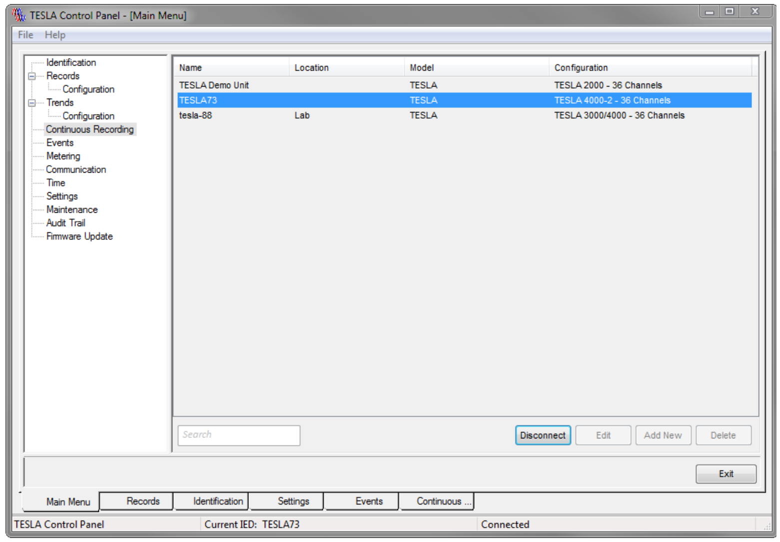


Figure 12.1: Main Menu showing the Continuous Recording menu option

Configuration

Selecting *Settings* from the main menu of the TESLA Control Panel shows a configuration view. If the Continuous Disturbance Recording is not configured, right-click and select New CDR to display the continuous disturbance recording channel configuration view.

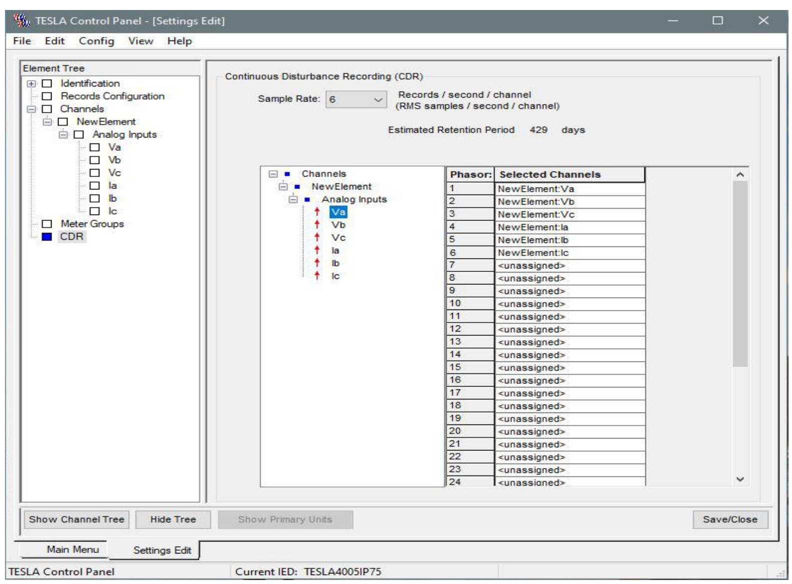


Figure 12.2: Configuring Continuous Disturbance Recording

Select channels from the tree view by dragging the channel name and dropping it on the selected channels grid view on the right hand side or by selecting a channel from the list in the grid view - a maximum of 36 channels can be selected.

Select the continuous disturbance recording rate from the *Sample Rate* list box. Depending on the system frequency, the list box is filled with available sample rates. Selecting channels based on the current Sample Rate, displays available data retention period in the read-only *Estimated retention period (days)* display box.

CDR Sampling Rates

The following table shows the available sampling rates at the corresponding system frequency.

Table 12.3: CDR Sampling Rates

System Frequency	Continuous disturbance recording sample rates (rms records/second/channel)						
60 Hz	6	10	12	15	20	30	60
50 Hz	5	-	10	-	-	25	50

Number of Continuous Disturbance Recording Channels

The number of continuous disturbance recording channels is user-configurable and limited only by the number of analog inputs available at any given time according to the CDR sampling rate as shown above. Only analog input data and frequency channels are stored; use RecordGraph software for derived channels, such as Watts, Vars, etc.

Data Storage and Retention Period

Standard capacity TESLA 4000-A units come equipped with a 16-gigabyte flash drive for data storage suitably partitioned for continuous disturbance recording to function. Optional 64GB and 1TB flash memories are available.

Continuous disturbance recording data retention period depends on the number of selected channels, the selected sample rate and the flash memory option selected while ordering. Estimated continuous disturbance recording data retention periods (in days) for various combinations of channel number and sampling rate are displayed in TESLA Control Panel's Configuration screen, for details see "Configuring Continuous Disturbance Recording" on page 12-3.

After all storage space designated for the continuous recording data is consumed, the oldest data is automatically deleted and released storage space is reused to store newly accumulated data. There is no indication about recycling of the continuous disturbance recording data storage space provided.

Continuous Disturbance Recording Status

The status of continuous disturbance recording and the time interval for each unit that has continuous recording data accumulated is displayed in TESLA Control Panel's *Continuous Recording* screen. The following Status types are possible:

- Not Connected: not connected to TESLA
- Active: CDR active, normal operation
- Disabled: CDR is not configured Alarm: CDR storage corruption

In the case of the Alarm status of continuous recording, an appropriate message is logged to the Event Log.

Continuous Recording Screen

Selecting the Continuous Recording branch in the left-hand side tree brings up the Continuous Recording Screen below:

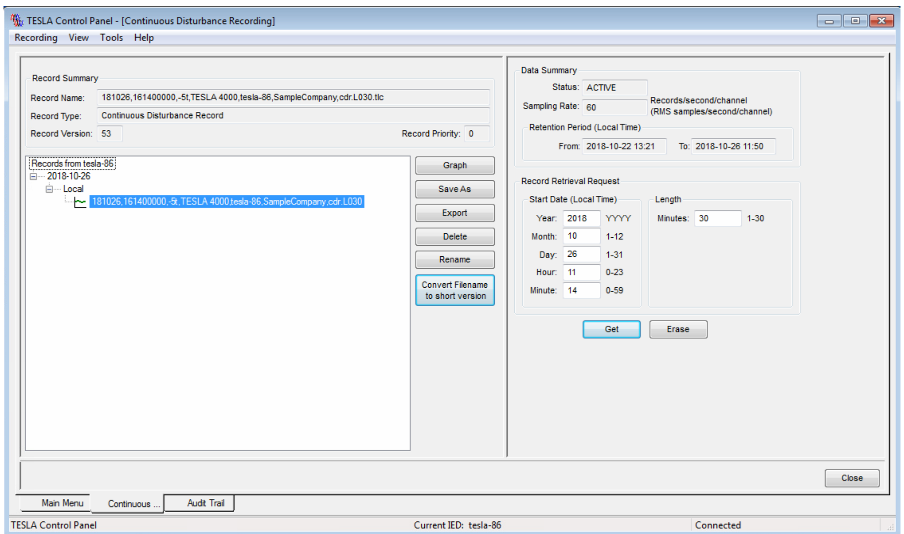


Figure 12.3: Continuous Disturbance Recording Screen

Table 12.4: CDR Screen controls	
Get	Entering appropriate parameters in the Record Retrieval Request section and selecting the **Get** button retrieves and saves a CDR record to the local disk.
Erase	Selecting the **Erase** button erases all CDR data on the TESLA recorder. A confirmation dialog is displayed before this action is carried out.
Record Retrieval Request	Enter year, month, day, hour and minute information in the start date Section, and a Length for the requested record. These fields are pre-filled with a time that is computed from the To time minus the initial Length value.
Graph	Launch RecordGraph with the selected record or records.
Save as	Brings up a dialog to save the selected record with a new name and/or location.
Export	Brings up the Export utility to export the selected record in a different format.

Table 12.4: CDR Screen controls	
Delete	Deletes the selected records from the local file system.
Rename	Allows the user to rename the record keeping the original file extension.
Convert Filename	Allows the user to toggle between the ERLPhase proprietary and IEEE C37.232 file naming structures. Note: The IEEE C37.232 Long Filenames setting must be enabled from the Options menu in order for this feature to feature to be available. See “IEEE C37.232 TSD File Naming” on page 14-9 for more details.

Safe Shutdown Mode

Since data is being continuously written to the storage device, it is important to follow a safe shutdown procedure. This will ensure data integrity.

Safe Shutdown Mode is available on the TESLA Control Panel Identification screen.

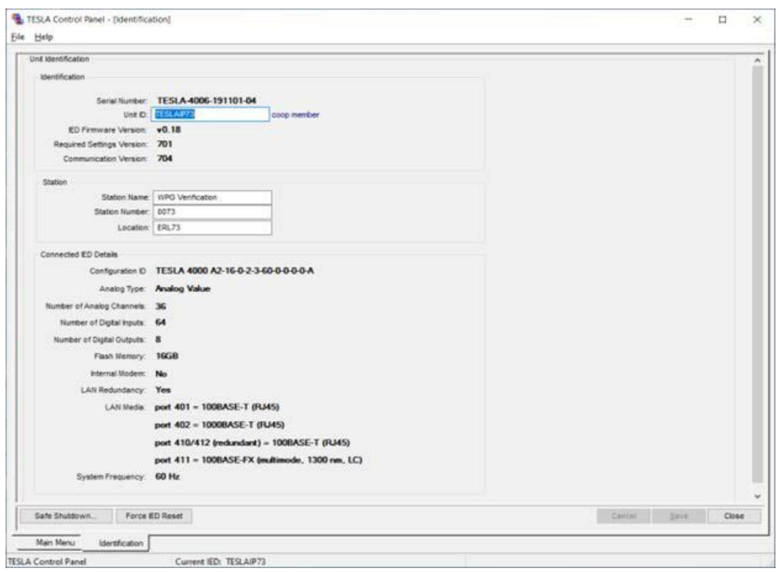


Figure 12.4: Unit Identification - Safe Shutdown

The command Safe Shutdown Mode is available only at the service access level for TESLA Control Panel or via Port 450 login for maintenance utilities. When the command Safe Shutdown Mode is used, all TESLA 4000-A application tasks are stopped ensuring all accumulated data are written out to the flash drive, all open files are closed and the file system status is updated. The front panel Test Mode and Alarm LEDs start blinking indicating that it is safe to turn off the unit. The unit stays in the safe shutdown mode for 15 minutes and then is rebooted automatically. The Event Log will maintain a record of all received Safe Shutdown commands.

Handling Configuration Changes

All accumulated continuous disturbance recording data is discarded every time new settings with modified continuous recording configuration are loaded on TESLA 4000-A. Continuous recording configuration includes sample rate, analog input configuration, continuous recording channel selection and order.

If changes to existing settings are made and user attempts to load them into the TESLA, the following dialog will appear:

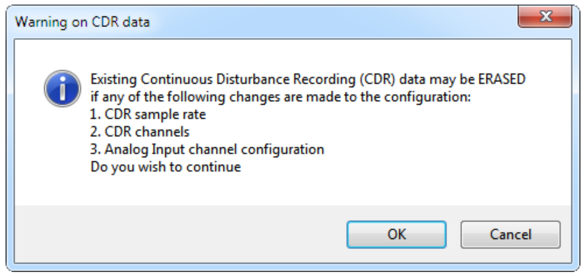


Figure 12.5: Warning on CDR Data

Time Synchronization

In order to accurately calculate the CDR date and time and to ensure data continuity, a valid IRIG-B or PTP sync is required. The use of any other synchronization method (RTC) may cause data continuity issues and for this reason only IRIG-B and PTP sync is supported for use with CDR.

13 Graphing Records

13.1 Getting Started

RecordGraph is a tool used to display and analyze records from ERLPhase relays and recorders. Use it to graphically view the data recorded during fault, swing and trend modes. RecordGraph is integrated with TESLA Control Panel. For more information on RecordGraph and working with records, see the RecordGraph user manual included with the RecordGraph software.

Launch RecordGraph from TESLA Control Panel

Method 1: Records

1. Open TESLA Control Panel.
2. If remote records are to be accessed, login to the recorder using a user-account that has access to remote records. If only locally stored records are to be retrieved, skip this step.
3. Open the *Records* screen from the *Main Menu*.
4. Select a local record from the tree list. If a remote record is to be graphed, select a record from the *On IED* list and press the *Get* button, or double-click on the record. Double-clicking on a remote record will also automatically launch RecordGraph.
5. Click the *Graph* button.

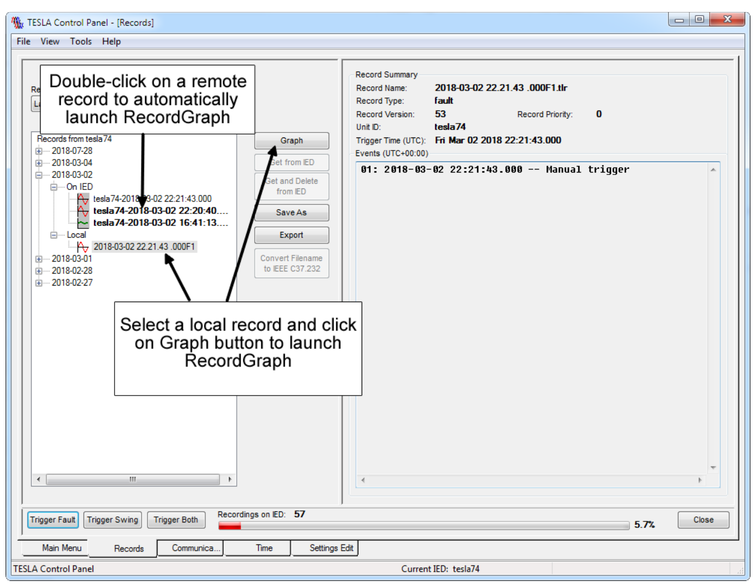


Figure 13.1: Launching RecordGraph from TESLA Control Panel

When the Graph button is clicked from the TESLA Control Panel, RecordGraph is launched with the selected record.

Method 2: Auto Print

If the Auto Print option is checked (enabled) in the Records list view, then RecordGraph will be automatically launched and prints the channels directly on to the Default printer. The layout and channel information is predefined in the <Default> or User-defined template.

Method 3: Trends

1. Double-click *Trends* from the Main Menu.
2. Select the record from the list. To select multiple records, press *Ctrl* key and click on the desired records.
3. Select the *Graph* button at bottom of screen.

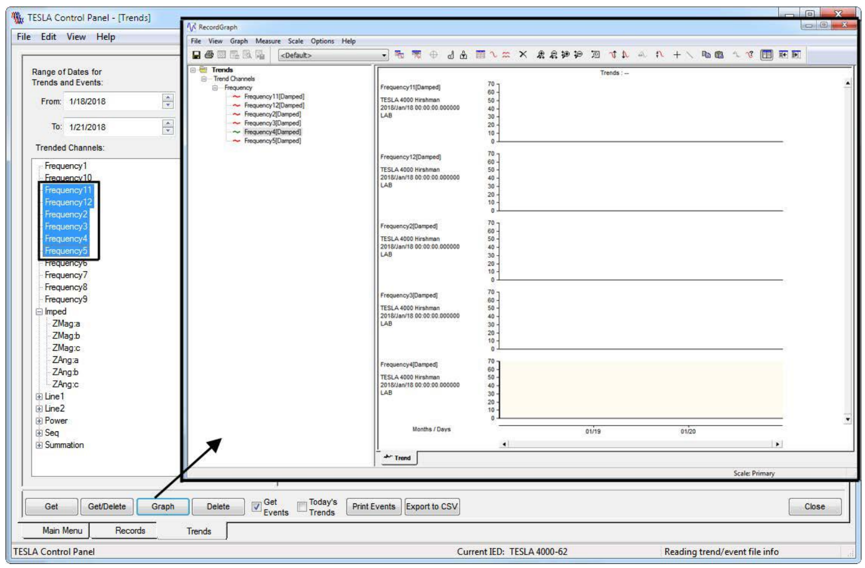


Figure 13.2: Display Trend Records

14 Record Export Utility

The record export utility lets you convert records into different formats for use with other software tools.

COMTRADE

Common Format for Transient Data Exchange (COMTRADE) is an industry standard record format used to share data between tools and to replay faults through a test set. The export utility supports both ASCII and binary COMTRADE formats and creates output that complies with the latest (2013) or older version (1999/1991) of the standard.

PTI

Power Technologies Incorporated (PTI) produces widely used power system modeling tools. TESLA records can be exported in a PTI-compliant format for import into PTI tools. The export utility supports ASCII format and creates output that complies with PTI version 1 or version 2 formats.

CSV

TESLA records can be exported in basic comma separated values (also known as comma-delimited) ASCII format suitable for importing into standard tools such as Microsoft Excel.

Launch the Export Utility

To launch the export utility:

1. Double-click *Records* from the *Main Menu*.
2. Select a local record from the record list.
3. Select the *Export* button to launch the Export window.
4. Select the desired export output format and select *OK*.

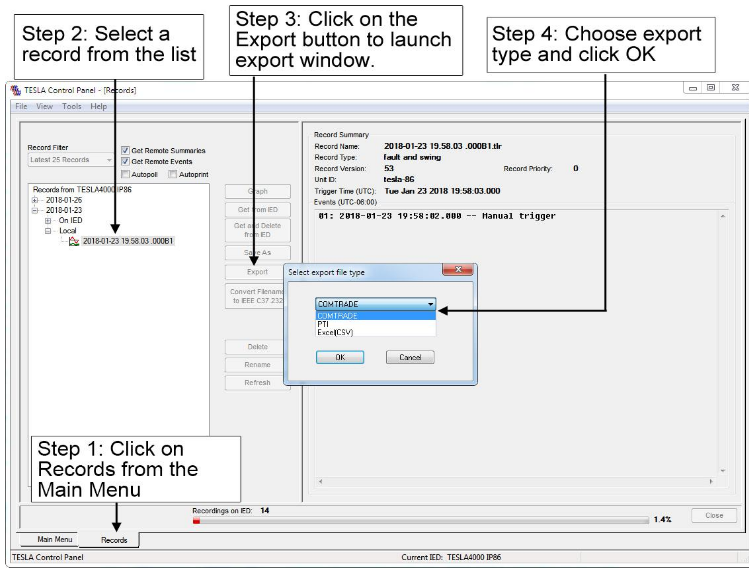


Figure 14.1: Select Export File Type

14.1 COMTRADE Format

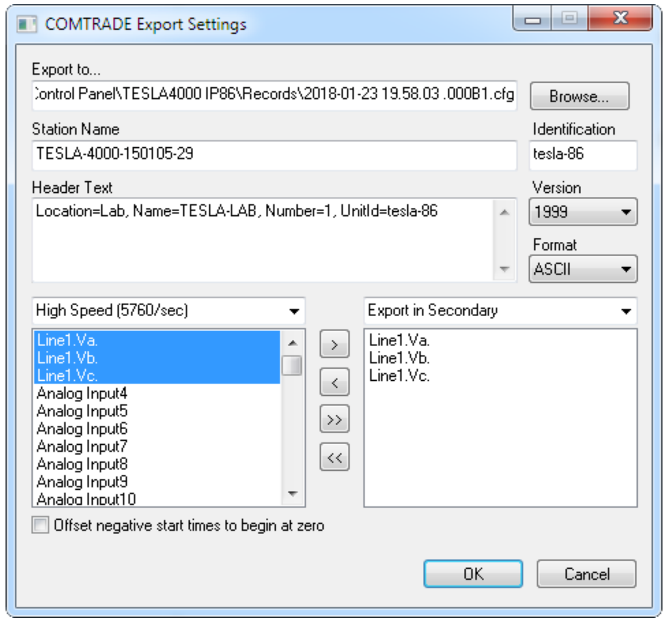


Figure 14.2: COMTRADE Settings

The COMTRADE format (IEEE C37.111) defines a common format for storing digital data records of transient and dynamic swing events. It consists of up to four output files with the same base name and different file extensions: configuration files (.cfg), header files (.hdr), data files (.dat) and optional information files (.inf). The COMTRADE Export Utility produces the configuration, header and data files.

With reference to Figure 14.2: COMTRADE Settings,

Table 14.1: COMTRADE Export Settings

Name	Function
Export to...	The base filename and directory of the output files are set using the Export to. option. By default the base filename is the same as the record you are exporting. You can edit this or use the Browse button to set a new directory and/or base filename.
Station Name and Identification	The Station Name and Identification fields are set by default using information from this recorder. They are written as the first line in the.cfg output file.
Header Text	The Header Text field contains the text written into the COMTRADE header (.hdr) file. By default, the field contains the Location, Name, Number and the Unit ID of the unit that produced the record. This text can be modified, deleted or extended as desired.

Table 14.1: COMTRADE Export Settings

Version	The Version field lets you select the revision of COMTRADE standard to produce. COMTRADE has been an evolving standard and a number of changes have been made over the years. 2013, 1991 and 1999 COMTRADE versions are supported.
Format	The Format field specifies that the data in the COMTRADE file (ASCII or BINARY format). ASCII data has the advantage of being usable by simple text editor and spreadsheet programs, but results in a significantly larger record relative to binary format. BINARY format is therefore recommended if the software package you will be using the data in supports binary format COMTRADE.
Selecting Channels (Exported Channels)	You must select the channels from the record that you want to include in the output file. For convenience, the digital data recorded is classified into: • High Speed: Analog and external digital input channels sampled at the high speed transient data rate. • Low Speed: Analog input channels sampled at the low speed swing data rate. Select the desired channel from the list with a left-click. Multiple channels can be selected using standard Windows selection actions (click + Ctrl or Shift keys).
>	Place selected channels in the Exported Channels list box.
>>	Place all channels into the Exported Channels list box.
<	Delete a channel from the Exported Channel list box.
<<	Delete all channels from the Exported Channel list box.
Offset negative start times to begin at zero	When checked, this option shifts the negative time to start from zero.

See “Record Export Timestamps” on page 8-25 for details on the COMTRADE export timestamp format.

14.2 PTI Format

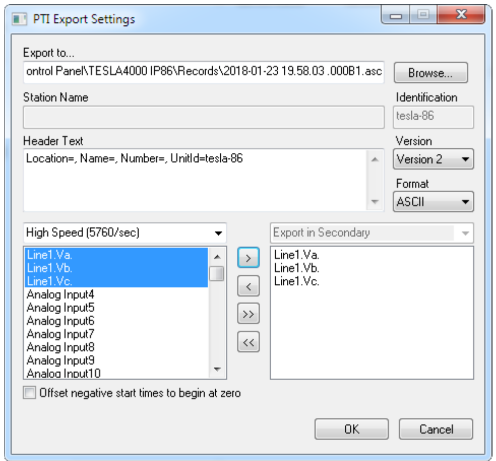


Figure 14.3: PTI Settings

The PTI file format is used to import records into the Power Technologies Incorporated system modeling software.

Output File PTI export produces a single output file with an .asc extension.

Table 14.2: PTI Settings

Name	Title
Export to...	The base filename and directory of the output files are set using the Export to. option. By default the base filename is the same as the record you are exporting. You can edit this or use the Browse button to set a new directory and/or base filename.
Station Name and Identification	The Station Name field is set by default using the unit's Station Name setting. It is written as the third line in the output file. If desired, you can edit this text. The Identification field is not written to the PTI output file.
Header Text	The Header Text field contains the text that is written as a single line in the fourth line in the output file. By default, the field contains the Location, Name, Number and Unit ID of the recorder that produced the record. This text can be modified, deleted or extended as desired.
Version	The Version field lets you select between PTI version 1 and version 2. Please refer to PTI documentation for details on the differences of these versions. Format Only ASCII format output files are available.
Format	ASCII is the only format option for PTI.

Table 14.2: PTI Settings	
Channel Selection	Use Channel Selection to select channels to export. You must select the channels from the record that you want to include in the output file. For convenience, the digital data recorded is classified into: • High Speed: Analog and external digital input channels sampled at the high speed transient data rate. • High Speed (480/sec): Analog and internal logic channels produced 8 times per cycle. • Low Speed (60/sec): Analog input channels sampled at the low speed swing data rate. • Low Speed (120/sec): Analog calculated channels sampled at the low speed data rate. Select the desired channel from the list with a left-click. Multiple channels can be selected using standard Windows selection actions (click + Ctrl or Shift keys).
>	Place selected channels in the Exported Channels list box.
>>	Place all channels into the Exported Channels list box.
<	Delete a channel from the Exported Channel list box.
<<	Delete all channels from the Exported Channel list box.
Offset negative start times to begin at zero	When checked, this option shifts the negative time to start from zero.

14.3 CSV Format

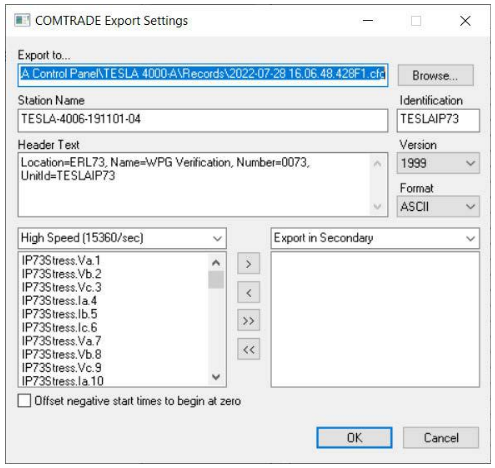


Figure 14.4: Excel (CSV) Settings

The CSV (Comma Separated Value) format is used to import records into a spreadsheet software, such as Microsoft Excel. This format is also known as comma delimited ASCII and can generally be used by most programs that import data arrays.

CSV export produces a single output file with a .csv extension, which is recognized by Microsoft Excel.

Table 14.3: CSV Export Settings

Name	Function
Export to...	The base filename and directory of the output files are set using the Export to... option. By default the base filename is the same as the record you are exporting. You can edit this or use the Browse button to set a new directory and/or base filename.
Station Name and Unit ID	The Station Name and Identification fields are not written to the CSV format output file.
Header Text	There is no header text written to the CSV format output file.
Version	There are no version options for the CSV output.
Format	ASCII is the only format options for the CSV output.

Table 14.3: CSV Export Settings

Channel Selection	You must select the channels from the record that you want to include in the output file. For convenience, the digital data recorded is classified into: • High Speed: Analog and external digital input channels sampled at the high speed transient data rate. • High Speed (480/sec): Analog and internal logic channels produced 8 times per cycle. • Low Speed (60/sec): Analog input channels sampled at the low speed swing data rate. • Low Speed (120/sec): Analog calculated channels sampled at the low speed data rate. Select the desired channel from the list with a left-click. Multiple channels can be selected using standard Windows selection actions (click + Ctrl or Shift keys).
>	Place selected channels in the Exported Channels list box.
>>	Place all channels into the Exported Channels list box.
<	Delete a channel from the Exported Channel list box.
<<	Delete all channels from the Exported Channel list box.
Offset negative start times to begin at zero	When checked, this option shifts the negative time to start from zero.
Include Data Quality	When checked, this option includes the data quality as a column for each channel

See “Record Export Timestamps” on page 8-25 for details on the CSV export timestamp format.

14.4 IEEE C37.232 TSD File Naming

TESLA Control Panel supports the use of the C37.232-2011 IEEE Standard for Common Format for Naming Time Sequence Data Files (COMNAME). Feature set-up is accessed by selecting *Tools > Options* in the Records and CDR menus, allowing the user to activate the C37.232 conversion capability at a workstation level. A company Name entry is required and used as a portion of the filename construction.

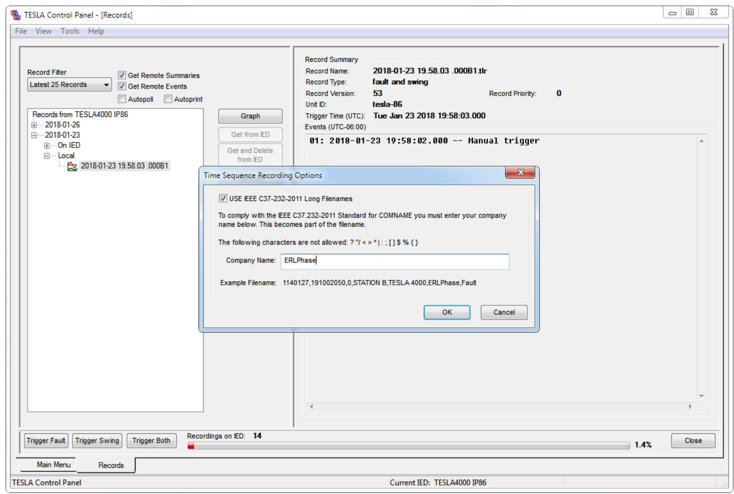


Figure 14.5: Time Sequence Data (TSD) Record Settings

Feature activation allows local TSD Record and CDR names to be toggled between ERLPhase proprietary and C37.232 file naming structures. This does not affect records currently stored on the IED.

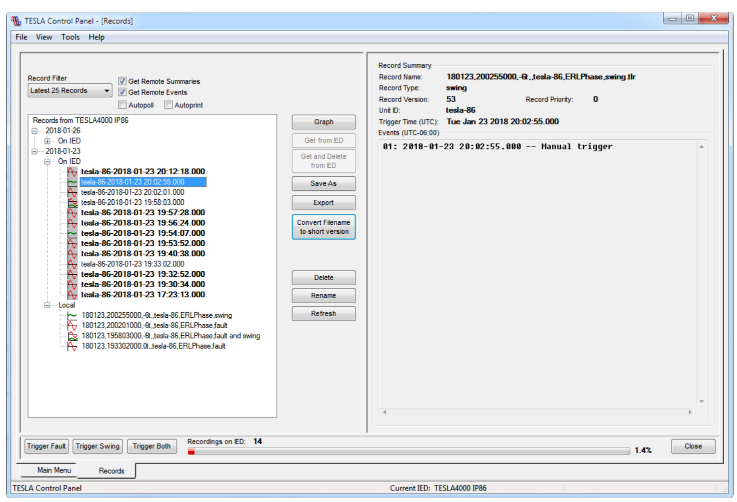


Figure 14.6: IEEE C37.232 Filename Conversion Feature - Records Screen

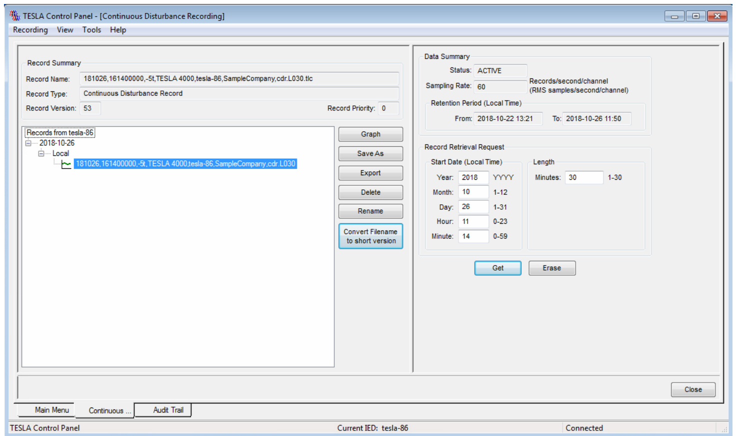


Figure 14.7: IEEE C37.232 Filename Conversion Feature - CDR Screen

15 Cooperative Recorder Group and Group Record Trigger (GRT)

15.1 Overview

A cooperative recorder group combines the easy-to-use interface of a single TESLA 4000-A recorder with the recording capabilities of up to four recorders. A cooperative recorder group consists of two to four TESLA 4000-A recorders working together to form a larger virtual recorder. This virtual recorder has one assigned “master” unit acting as the primary recorder for the group. An Ethernet LAN connects the group of recorders and TESLA Control Panel provides the user interface. Each recorder continues to function as a stand-alone unit independent of its involvement in a cooperative group.

A cooperative recorder group provides the following functions:

- Automatic triggering of synchronous recordings on all group members whenever any member is triggered.
- Transfer and combination of the synchronized records from all group members to TESLA Control Panel into a single record.

Starting with firmware version 1.2, the TESLA4000-A introduces a Group Trigger and Record Combine system, in addition to the conventional cooperative mode. This feature serves as an alternative to the cooperative mode, particularly when configuring a Group Record Trigger (GRT) across different types of recorders. The GRT mode allows users to group up to eight IEDs within the same network. Unlike the cooperative mode setup, establishing communication between different recorders requires creating Group Record Trigger (GRT) mappings using the ERL 61850 IED Configurator.

15.2 Details

Local Network

A cooperative recorder group is comprised of two to four TESLA 4000-A recorders, typically located in one location (ie. the same substation control house). The recorders communicate with each other through an Ethernet LAN which allows cross-triggering between recorders along with the normal record transfer and user interface functions. The cooperative recorder group can have its own network or can be connected to a larger network.

Remote Access

Remotely access a cooperative recorder group over a wide area network via the Ethernet ports. Serial/Modem connection is not supported for the TESLA 4000-A Cooperative Mode.

Master Recorder

One member of the cooperative recorder group is designated as the Master Recorder. The Master Recorder is the primary interface between the cooperative recorder group and TESLA Control Panel. In addition to its normal recording role, the Master Recorder:

- Maintains the list of group recordings.
- Provides IP address information about the other group members.
- Acts as the communication gateway for remote access when a modem link is used.

Cooperative Group IED

Within TESLA Control Panel a virtual Cooperative Group IED is created to work with the cooperative recording group. When connected to the Cooperative Group IED, TESLA Control Panel functions are applied to the group of recorders rather than an individual one. Records from the cooperative recorder group are transferred, combined and viewed in this way.

Triggering and Recording

In a cooperative recorder group a trigger detected by any recorder results in time-synchronized recordings on all group members. These records are retrieved and combined into a single record by TESLA Control Panel.

Cross-triggering between group members takes place over the LAN. The trigger message includes the timestamp of the initiating trigger to allow each recorder to capture data from the same time period. Sample clock coordination among the group recorders, derived from the source clock signal, ensures that the data points from all the recorders are synchronous.

The trigger message also specifies the type of recording to be created. If the initiating trigger was configured to produce a transient recording, a swing recording, or both, the receiving units will create the same type of record or records. If multiple recorders detect a trigger during the same disturbance, each will send a trigger message to the others. A trigger buffer is used by each recorder to sequence overlapping triggers and produce a single record whose trigger time is that of the first detected event.

Time Synchronization

All cooperative group recorders must be synchronized from a common external IRIG-B or PTP time source. Operating without any synchronization source is not recommended in cooperative mode.

Record Collection and Consolidation

Records are retrieved from cooperative group members and combined into a single group record by TESLA Control Panel. When you initiate a record transfer from the group's Master recorder, TESLA Control Panel automatically transfers the corresponding records from the other group members and combines them into a single record. Within TESLA Control Panel, the resultant record is stored under group's Cooperative Group IED record list.

In some circumstances a record from a group member may be omitted from the combined record. This could be caused by a settings mismatch, network communication problem or loss of time signal synchronization. If the record was captured by the recorder it can still be retrieved and viewed as a single record from the individual recorder using standard (i.e. non-cooperative mode) methods.

For further details on cooperative group records, see “Records” on page 15-13.

RecordBase Central Station

RecordBase Central Station v5.2 and above can work with a TESLA 4000-A cooperative recording group. RecordBase can:

- Collect records from group members and combine them into a single record.
- Issue swing record cross-trigger commands to the group.
- Communicate with individual group members via WAN.

15.3 Assembly

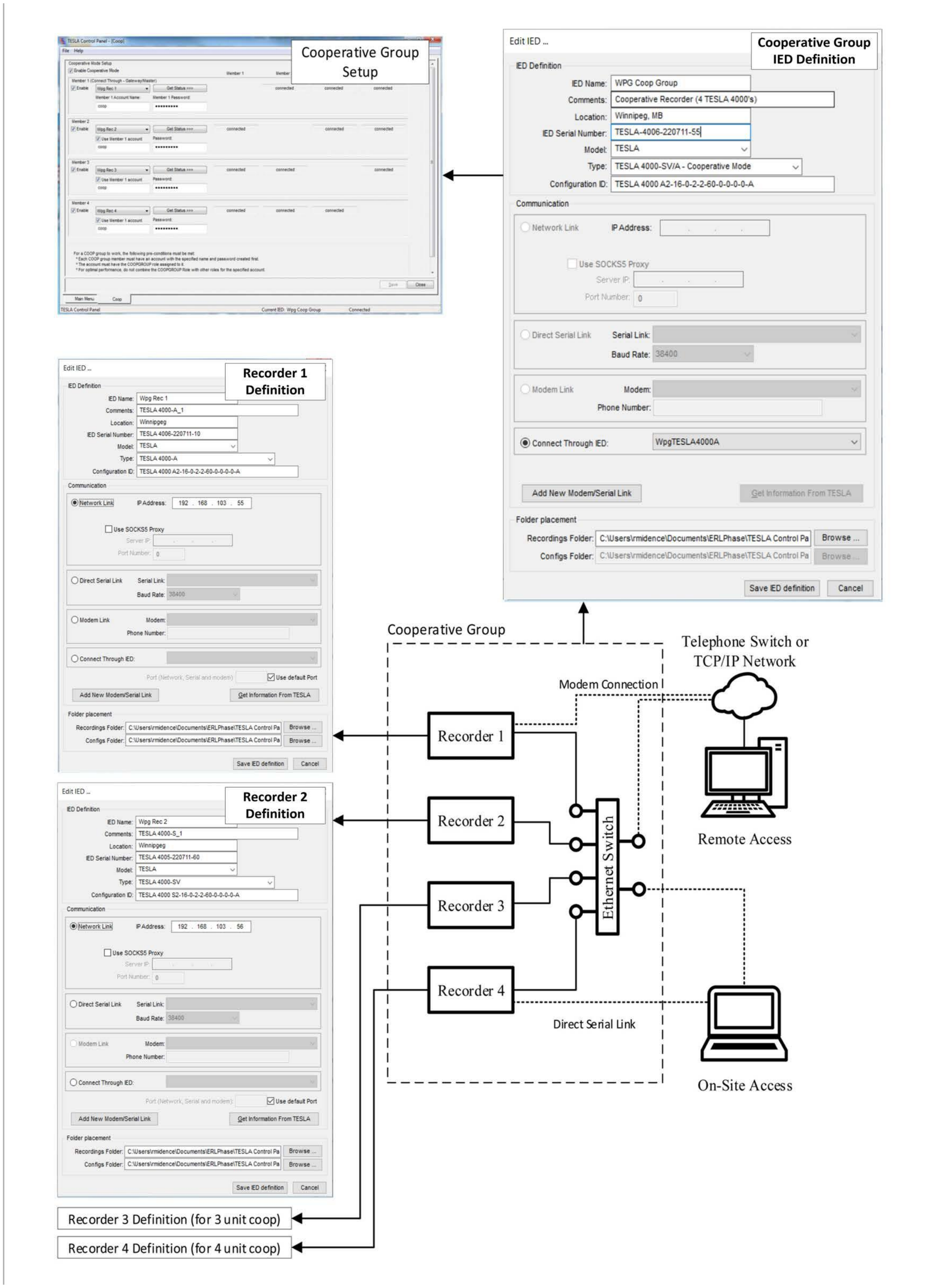


Figure 15.1: Cooperative Recording Group with Remote Access

4000-A units, 4000-SV units, and a mix of 4000-A and 4000-SV units, can be in the same coop group, as shown in Figure 14.1, as long as the following conditions are met on all the units:

1. High speed sampling rate must be the same
2. Low speed sampling rate must be the same
3. Pre-trigger time for high-speed channels must be the same
4. Pre-trigger time for low-speed channels must be the same
5. Trigger time must be the same
6. IED must be verified to be used as a pass through or COOP member

#3, #4 and #6 are handled when setting up a coop configuration

#1 & #2 are handled by inter-TESLA communication

#5 is handled at record combining time when records are retrieved from the Coop Group IED.

Moreover, the following should be noted:

1. Only IEDs that have been verified will show up in the Connect Through dropdown in the edit IED dialogue box
2. Only IEDs that have been verified, have identical system frequency and, identical Inter TESLA communication versions will be in the coop dropdown box in the coop setup screen

When downloading a coop record warning dialogs will appear if the following do not match in the records:

1. Record version is the same
2. Sample rate is the same
3. System frequency is the same
4. Pre-trigger time is the same
5. IRIG-B sync is off

There are three main steps to setting up a cooperative recording group:

- Step 1: Set up the network in the substation.
- Step 2: Configure the individual recorders.
- Step 3: Configure the Cooperative Recording Group.

> A cooperative group must only include recorders from the same generation when combining TESLA 4000, 4003 and 3000 models. The TESLA 4000-A and TESLA 4000-SV are the exception and they can be combined into the same coop group as shown in Figure 15.1.

Step 1: Set up the Network

1. Create IED definitions for each recorder.

   This step is shown in Figure 15.1. See “Adding/Editing a Recorder Workspace Definition” on page 6-13 for how to create IED definitions.

2. Connect the LAN ports on each recorder to the Ethernet switch.

   Use an industrial-quality 100BASE-T Ethernet Switch for best performance. The rear Ethernet ports are either 100BASE-T copper interface or a 100BASE-FX optical interface. Connect the recorders using either a CAT5 cable with an RJ-45 connector or 100BASE-FX 1300 nm multimode optical fiber with an ST style connector. For a group of only two recorders, a cross-over Ethernet network cable can be used instead of an Ethernet switch.

   When connected to a larger network, consideration should be given to network load. The recorders can tolerate considerable delay in the delivery of inter-recorder trigger messages. The network load resulting from the transfer of large records may impact other devices on the network.

3. Configure Ethernet Communication settings.

   The Ethernet Communication settings are configured on the *Communication > Ethernet* screen in TESLA Control Panel (see “Ethernet Configuration” on page 8-6).

   - Assign unique IP addresses to each recorder.
   - Ensure IP addresses for all recorders belong to the same local network.
   - Ensure TCP/IP Port setting is the same for all recorders.

4. Configure the Master Recorder's modem and connect to the telephone switch.

   This step is only required if remote access to the recorders will take place through modem rather than a wide area network. The set-up of both internal and external modems is described in "Communicating with the Recorder" on page 6-1.

> To make use of a modem link connection to multiple recorders, the TESLA Control Panel user must be logged into Windows with local administrator privileges. This is required to permit temporary access to the computer's network routing table.

Step 2: Set Up the Individual Recorders

1. Create/edit an IED Definition for the Master Recorder.

   The Master Recorder is the recorder designated as the primary interface between the recorder group and TESLA Control Panel. The Master is the recorder that is used to "Connect Through" to access the other members in the cooperative group. Communication between members is done on a peer-to-peer basis.

   The following table provides a setting guide for the Master Recorder's IED definition:

Table 15.4: IED Definitions for the Master Recorder

IED Name	• Should identify both the recorder and its cooperative group. • Should have the same name as the recorder's *Unit ID*. (The *Unit ID* is configured in the recorder through the *Identification* menu in TESLA Control Panel. See "Unit Identification" on page 8-2).
Comment	Should indicate that the IED is the Master Recorder for the group.
Location	Should be the name and/or location of the Substation.
IED Serial Number	Can be left blank if the unit's serial number is not known. The serial number can also be automatically obtained from the recorder later using the *Get Information from IED* button (see below).
Model	Select TESLA.
Type	Select TESLA 4000-A
Configuration	Insert the product configuration ID
Communication	Select *Network Link* and enter IP address
Get Information from IED	(optional): If a communications link is available to the recorder, this button can be used to retrieve the recorder's name, location and serial number information. Any information in the corresponding fields of the IED Definition will be overwritten and saved if you exit with *OK*. These values are configured on the recorder as part of its Unit Identification.

2. Create/edit IED definitions for the remaining group members.

The group can have up to four recorders. The following table provides a setting guide for the IED definitions of group members.:

Table 15.5: IED Definitions for the Other Group Recorders

IED Name	• Should identify both the recorder and its cooperative group. • Should have the same name as the recorder's *Unit ID*. (The *Unit ID* is configured on the recorder through the *Identification* menu in TESLA Control Panel. See "Unit Identification" on page 8-2).
Comment	Should indicate that the IED is a group member.
Location	Should be the name and/or location of the Substation.
IED Serial Number	Can be left blank if the unit's serial number is not known. The serial number can also be automatically obtained from the recorder later using the *Get Information from IED* button (see below).
Model	Select *TESLA*
Communication	Use *Network Link* and enter the IP address of the IED.
Get Information from IED	(Optional): If a communications link is available to the recorder, this button can be used to retrieve the recorder's name, location and serial number information. Any information in the corresponding fields of the IED Definition will be overwritten and saved if you exit with *OK*. These values are configured on the recorder as part of its Unit Identification.

3. Configure the individual recorders.

Each recorder must be configured as a stand-alone unit with its channels and triggers defined. Chapter 8: Recorder Setup and Chapter 9: Recorder Settings cover this in detail.

Important:
Certain settings must be the same on all recorders for cooperative mode to function correctly. See "Required Settings" on page 15-14 for the list.

4. Configure the security accounts for the individual recorders.

   In cooperative mode there are two connection types that occur:

   - TCP-Member connection
   - Inter-Member connection

   These connection types require different security roles and require careful consideration by the security administrator to ensure that cooperative communication will work as expected. See “Security Setup” on page 8-35 and “Authentication and Authorization System” on page 18-5 for further details on security configuration.

   The TCP-Member connection is established via TESLA Control Panel for the purposes of configuration and record management. When the user logs into the Cooperative Group IED they are prompted to provide login credentials. TESLA Control Panel uses these login credentials to login to each of the group’s recorders through the Master recorder. To access and configure the cooperative configuration on the *Coop* screen, adequate security roles must be assigned to the login account. See Table 15.6 for more details.

   The Inter-Member connection is established between members of the cooperative group for cross-triggering records. The Inter-Member communication requires each member to login to all other members in the group using a valid login account. This login account is configured on the *Coop* screen in TESLA Control Panel. See Table 15.6 for more details.

Table 15.6: Cooperative Group Security Setup Summary

Connection Type	Where to Enter Credentials	Requirements	Recommended Default Accounts
TCP-Member	When connecting to the Cooperative Group IED via TESLA Control Panel. TCP connects through the Master IED to all of the other group members.	• Same user account must exist on all IEDs in the group, with the same password • User account must contain ENGINEER or UPDATE role to configure cooperative mode	change service update
Inter-Member	On the *Coop* screen in TESLA Control Panel. Enter credentials for each member in the group.	• User accounts must contain COOPGROUP role. • A different login account may be used for each member, but it is recommended to use the same account for each member to simplify setup procedure • Login Failure Handling Maximum Retries should be set to value greater than 3 to avoid a lockout condition if invalid credentials are accidentally entered	coop

Step 3: Configure the Cooperative Recording Group

1. Create a Cooperative Group IED Definition in TESLA Control Panel.

   The Cooperative Group IED is a virtual TESLA recorder which combines up to four recorders into one. The Cooperative Group IED is used to configure the group of recorders and for retrieving and managing the combined records. The following table provides a setting guide for the Cooperative Group IED definition:

Table 15.7: IED Definitions for the Cooperative Group IED

IED Name	Should identify this as the Cooperative Group IED
Comment	Should indicate that this IED represents the whole group
Location	Should be the name and/or location of the Substation
IED Serial Number	blank
Model	Must be TESLA 4000-A Cooperative Mode
IP Address	Blank
Communication	Must be *Connect Through IED* with the Master Recorder selected

2. Select the cooperative recording group members.

   A Cooperative Mode Setup screen (called *Coop*) is available when connected to the Cooperative Group IED. This screen allows the user to specify which recorders are part of the cooperative group. It also provides connection status information about the group of recorders. To access the *Coop* screen and configure the group:

   a. Connect to the Cooperative Group IED by selecting the it from the IED list on the Main Menu tab and pressing *Connect*. Login to the Cooperative Group IED by using valid login credentials (see Table 15.6 for details).

   b. Select the *Coop* screen by double-clicking on *Coop* in the *Main Menu* tree. See the *Coop* screen in Figure 15.2.

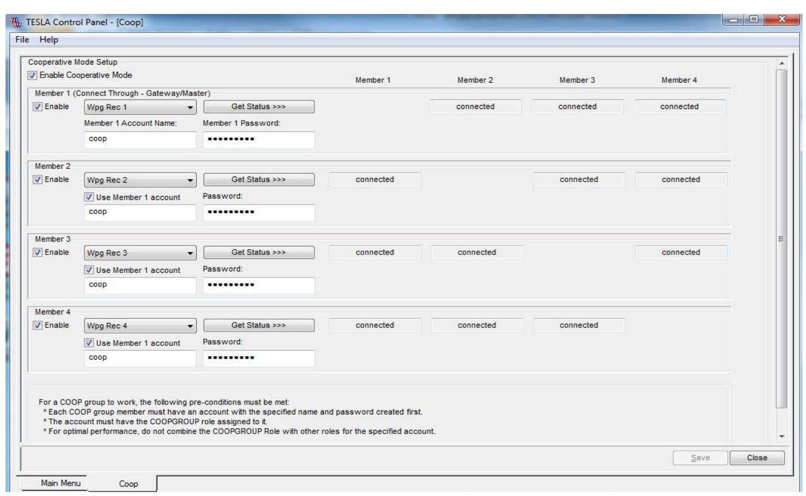


Figure 15.2: Cooperative Mode Setup Screen

Select the recorders that are to be part of the cooperative group using the pick-lists. Enable each member by using the “Enable” check-box. The master recorder is automatically assigned as Member 1. Once two or more recorders are enabled, then the global “Enable Cooperative Mode” option can be enabled. If an expected recorder does not appear in the Member pick list, check the recorder’s IED Definition for errors.

> The Member Number (Member 1, Member 2 etc.) determines the numbering used in the combined records. The channels in the combined recorder are labelled with a number before the channel name. This identifies which IED the channel is from.

c. Enter valid login credentials for each IED (see Table 15.6 for details). Figure 15.2 shows an example with each member using the default account. If all members are to use the same login credentials select the “Use Member 1 Account” check-box.

3. Enable cooperative recording group operation.

a. Save the configuration.

TESLA Control Panel will connect to each member recorder to provide member IP addresses and enable cross-triggering. The connection status of each member is displayed after approximately 75 seconds. Figure 14.2 shows all members are connected to each other. If a proper connection is not established, then useful status messages are displayed in the connection matrix. For a full list of status messages, and how to troubleshoot connection issues, see “Maintenance Functions and Diagnostic Tools” on page 16-4.

> The *Get Status* button beside the member recorder names in Figure 15.2 initiates a status check of the communications between the member recorders. It can be used at any time.

b. Click *Close.*

The cooperative recording group configuration is now complete and cross-triggering, record collection and combining of member records are enabled.

c. Verify that all members are successfully added to the group.

The *Identification* screen in TESLA Control Panel displays a cooperative group status message for each IED in the group. Login to each individual IED in the group and ensure the *Identification* screen displays “coop member”. If at any point a communication or setup error occurs, the *Identification* screen will display “coop comm error” in red flashing text. A pop-up message will also be displayed in TESLA Control Panel upon connecting to an IED with a “coop comm. error”. Login to the Cooperative Group IED and begin the troubleshooting process as described in “Maintenance Functions and Diagnostic Tools” on page 16-4.

15.4 Assembly without External Ethernet Switch

A TESLA Cooperative Recorder Group may also be assembled without the use of an external Ethernet switch. Instead, the recorders may be connected in such a way that utilizes the internal Ethernet switches provided inside the TESLA.

In order to assemble a Cooperative Recorder Group without an External Ethernet switch, follow the same steps outlined in “Assembly” on page 15-4, except at Step 1: Set up the Network, do the following.

Connect each TESLA in a “daisy-chain” method, as shown in Figure 15.3. This requires connecting the rear port 401 of Recorder 1 to the front port 401 of Recorder 2. Connect the rear port of Recorder 2 to the front port 401 of Recorder 3. Connect the rear port 401 of Recorder 3 to the rear port 401 of Recorder 4.

This will create a closed LAN within the Cooperative Group. This Cooperative Group may then be accessed via a PC connection to the front port 401 or USB port of Recorder 1.

After connecting the recorders in this manner, follow all of the same steps outlined in “Assembly” on page 15-4 to complete the Cooperative Recorder Group assembly.

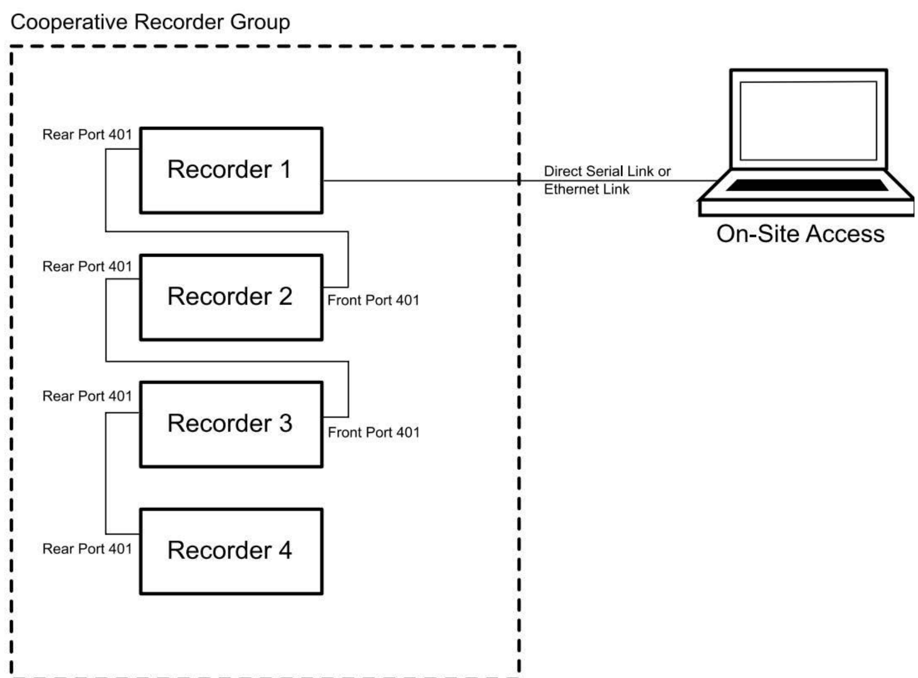


Figure 15.3: Cooperative Recorder Group Assembly without External Ethernet Switch

15.5 Records

Cooperative recording group records are managed in TESLA Control Panel in the same way as records from individual recorders (see Chapter 10: Setting Files Comparison Tool).

To access a group's records, connect to the Cooperative Group IED using valid credentials. Once connected, double-click Records in the menu tree to open the Records screen. Local records which have already been retrieved can be accessed by navigating to the Records screen without logging in.

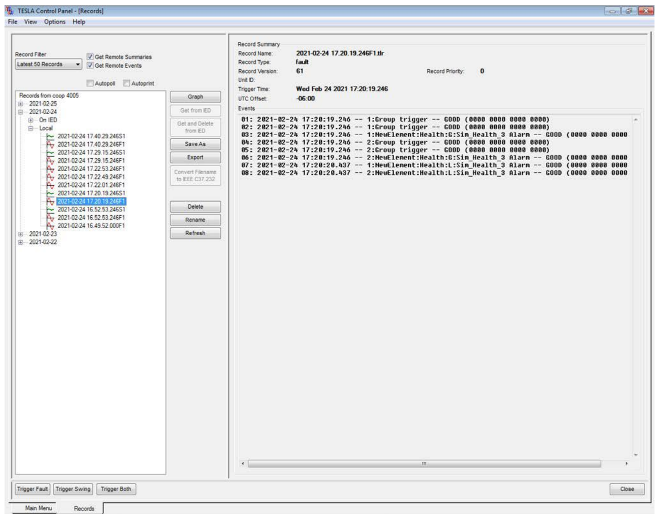


Figure 15.4: Records display

Records shown as “On IED” are on the Master Recorder. When initiating record retrieval (“Get from IED”), TESLA Control Panel retrieves records with the same timestamp from all group members and combines them into a single record. The record also combines event data from all recorders in the group, chronologically sorted. Records listed under the Local branch have already been retrieved and combined.

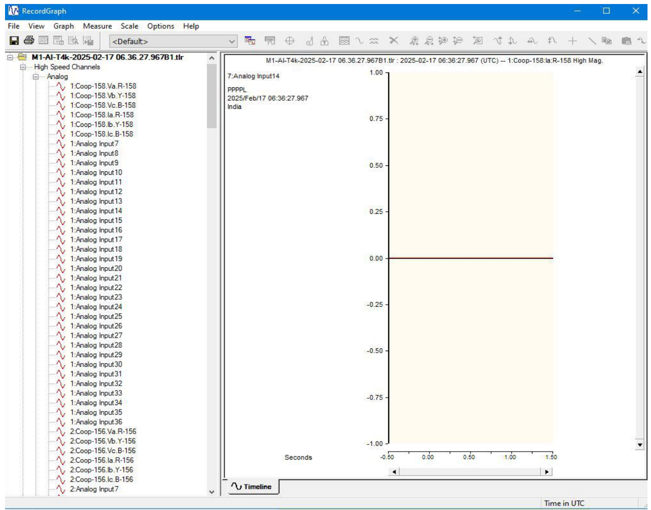


Figure 15.5: Coop combined record shows in RecordGraph

Each recorder’s channel names and event entries in the combined record are labeled with “1:”, “2:”, “3:”, and “4:” to avoid ambiguity. These prefixes correspond to the member number defined in the *Coop* screen.

Calculated channels are automatically generated when the records are retrieved to TESLA Control Panel. This differs from individual recorder records where calculated channels are generated when the record is first displayed by RecordGraph.

The displayed record summary information is derived from the Master Recorder. The preview of events cannot be shown until the combined record has been generated. The event list is only displayed for locally stored records.

Delete remote records by selecting records from the “On IED” list. Record deletion for a Cooperative Group IED deletes the associated record from each group member.

15.6 Required Settings

Cooperative mode operation requires some key settings to be consistent on all recorders in the group. Table 15.8 identifies those settings and guidelines for selecting appropriate values.

Table 15.8: Cooperative Mode Settings

Setting	Effect on Cooperative Operation	Guideline

Table 15.8: Cooperative Mode Settings

Firmware Version	May cause compatibility issues between group members.	All group members must be operating with same firmware version with the exception of the TESLA 4000-A and TESLA-SV. Members can be either 8 channel or 12 channel or 18 channel or 36 channel configurations. Mixing of 8 channel, 12 channel, 18 channel and 36 channel configurations in the coop group is also allowed.
Incoming IRIG Time Signal Properties	May cause a UTC time mismatch between recorders that results in trigger messages being rejected.	Setting should be the same on all group members. All IEDs must be synchronized to the same IRIG time source.
Recorder Time Zone Setting	May cause a UTC time mismatch between recorders that results in trigger messages being rejected.	Setting should be the same on all group members.
TCP/IP Port Number	Allows TESLA Control Panel to establish communication.	Setting must be the same on all group members.
System Frequency	Allows proper cooperative group setup and record combining.	System frequency must be the same on all group members
Recording Control Settings *(Settings/Records Configuration)*		
Trigger Mode	In *Duration* mode, triggers from other recorders result in a record of *Maximum Record Length* as their duration is not evident to the receiving recorder.	Setting should be *Edge* on all group members.
Pre-Trigger Mode	Records with a pretrigger time different from that of the Master Recorder's record will be left out of the combined group record.	Setting must be the same on all group members.
Normal Record Length	Records of different duration can be combined into a group record. The group record can be displayed.	Settings should be the same if COMTRADE export of the combined record is desired.
Maximum Record Length	Controls the capability of each recorder to automatically extend a recording to include subsequent triggers.	A minimum of 3.0 seconds of auto-extension *(Maximum Record Length > Normal Record Length)* is automatically added to avoid multiple overlapping records in the case of near-coincident triggers.
TESLA Device Configuration *(Settings/Records Configuration)*		
Setting	**Effect on Cooperative Operation**	**Guideline**
Sample Rate	Records with a sample rate different from that of the Master Recorder's record will be left out of the combined record group.	Setting must be the same on all group members.

15.7 Disassembly

It is important that cooperative mode is disabled correctly before removing group members for maintenance. The TESLA is designed to handle cooperative mode configuration issues, however unexpected behaviors may be observed on group member IEDs if the proper disabling procedure is not followed. This procedure should be followed when performing firmware updates on cooperative group members.

To properly disable the cooperative mode, perform the following steps:

1. Connect to the Cooperative Group IED.

   In TESLA Control Panel on the Main screen, select the Cooperative Group IED from the IED list, and press *Connect.* Login to the Cooperative Group IED using valid login credentials.

2. Navigate to the *Coop* screen to begin disabling the Cooperative mode.

   To disable the cooperative mode on one or all of the group members, un-check the “Enable” check-box for each group member that is to be removed. If the entire Cooperative Group is to be dismantled, un-check the “Enable” check-box for each member and the global “Enable Cooperative Mode” check-box.

3. Save the changes.

   Wait for approximately 75 seconds while the changes are saved. After the saving process is complete, the members which have been removed should display “not connected”.

4. Verify that members have been removed from the Cooperative Group.

   Login to each of the individual members and check the *Identification* screen. There should be no Cooperative status message displayed on the screen. If “coop member” or “coop comm. error” is displayed on the screen, then the member has not been removed from the group correctly. Ensure steps 1-3 have been followed correctly. Consult “Maintenance Functions and Diagnostic Tools” on page 16-4 if further troubleshooting is required.

15.8 Group Record Trigger Mode

In addition to the conventional cooperative mode, starting from firmware 1.2, TESLA4000-A allows to setup a group trigger and records combine system between TESLA4000 IEDs. This feature serves as an alternative to the cooperative mode, especially when the user wants to configure a Group Record Trigger (GRT) Mode across different types of recorders. The GRT mode enables users to add up to eight IEDs into the same group within the same network. Unlike the cooperative mode setup procedure, establishing communication between different types of recorders requires creating Group Record Trigger (GRT) mappings between GRT members using the ERL 61850 IED Configurator as well. When an IED is configured in the cooperative mode setup, its GRT trigger functionality will be automatically disabled if the trigger is initiated within the coop member. Below is an overview of the setup requirements and procedure for configuring the Record Trigger Group.

Setup Requirements:

- **Firmware:**
  - TESLA4000 firmware ≥ v2.4
  - TESLA4000-A firmware ≥ v1.2
- **Communication:** All members must be in the same Ethernet network.
- **Time Synchronization:** All members should be time-synchronized.
- **System Frequency:** All members should operate on the same system frequency.
- **Sample Rate:** All members must use the same sample rate.
- **Record Length:** All members must have the same record length configuration.

Configuration Procedure:

Step 1: Create GRT Mapping Using IED Configurator

1. For the GRT initiator (publisher), create a dataset with the GRT output attributes (stVal, q, t) from the Records.GRTGGIO1.ISCSO1 data object (Figure 15.5).

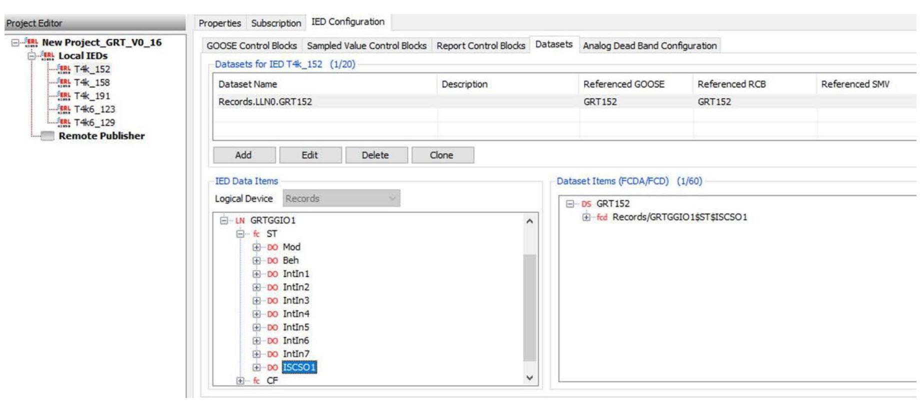


Figure 15.6: Create Dataset to include GRT output

2. Create a GOOSE Control Block to include this dataset, publishing a GOOSE message for the Group Record Trigger (Figure 15.6).

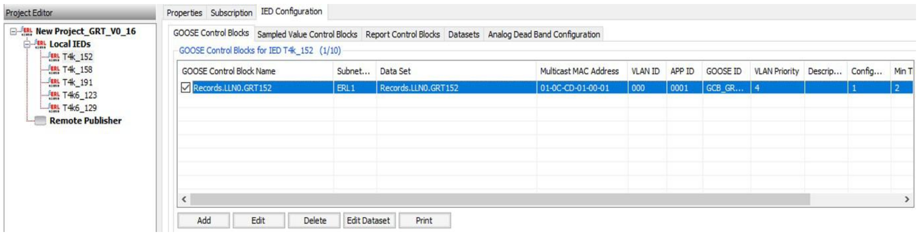


Figure 15.7: Create GOOSE Control Block for Group Record Trigger

3. Repeat these steps for all members associated with the GRT mapping.
4. Go to **Subscription -> GOOSE Mapping**, select the **Group Record Trigger** tab, and map each member's GRT output to its GRT inputs (Figure 15.7).

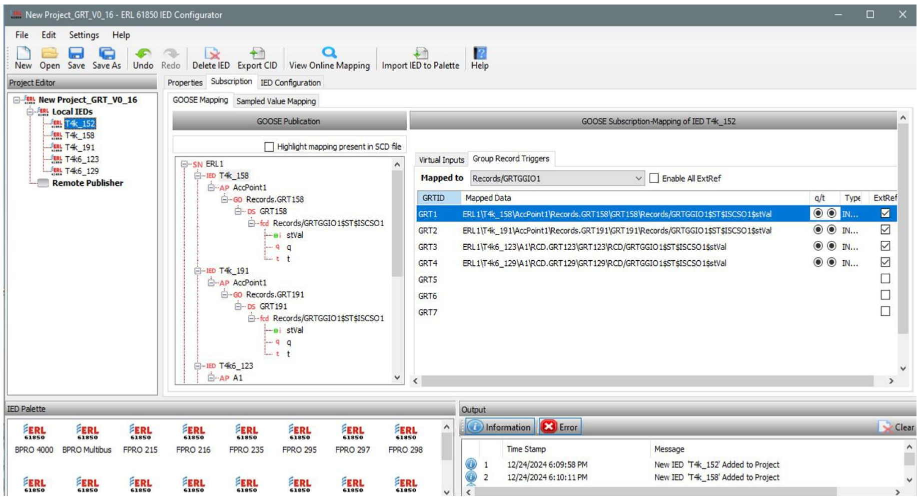


Figure 15.8: GRT Mapping

5. Send the CID file to each member and reboot the unit after successfully uploading the file.

Testing the Group Record Trigger

1. Manually trigger a record from any member. This action should initiate a group record trigger with a unique ID reflecting its IED identity and record type. Example:
   - 01: 2025-01-06 17:39:06.000 -- Initiating Group Record Trg. ID 0x01187a19
   - 02: 2025-01-06 17:39:06.000 -- Manual trigger
2. Verify that other members received this trigger with the same trigger time and GRT ID. Example:

- 01: 2025-01-06 17:39:06.000 -- Received Group Record Trg. ID 0x01187a19 -- GOOD (0000 0000 0000 0000)

Step 2: Configure Group Record Trigger Mode in TESLA Control Panel

1. Add a new group IED entry by selecting **TESLA4000/SV/A Group Record Trigger Mode** under the Type pick-list (Figure 15.8).

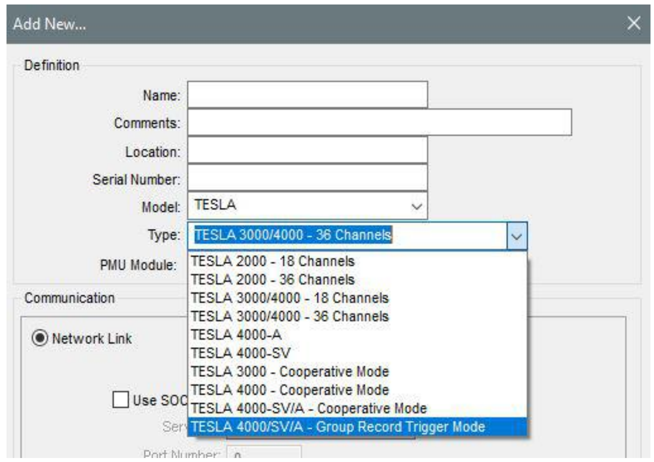


Figure 15.9: Add New Group Record Trigger Mode in TESLA Control Panel

2. After adding the group IED, two menu items, **Records** and **Setup**, will appear in the left-hand tree view (Figure 15.9).

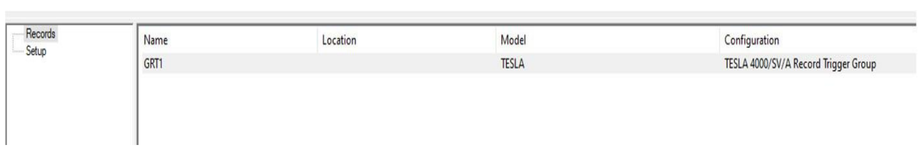


Figure 15.10: Group Record Trigger Mode IED entry shown in main menu

3. Select **Setup** to configure members. Example:

- Select the correct IED members and credentials.
- Click the
- **Check** button to verify member connectivity and communication requirements.
- Save the configuration once all members indicate an “OK” status.

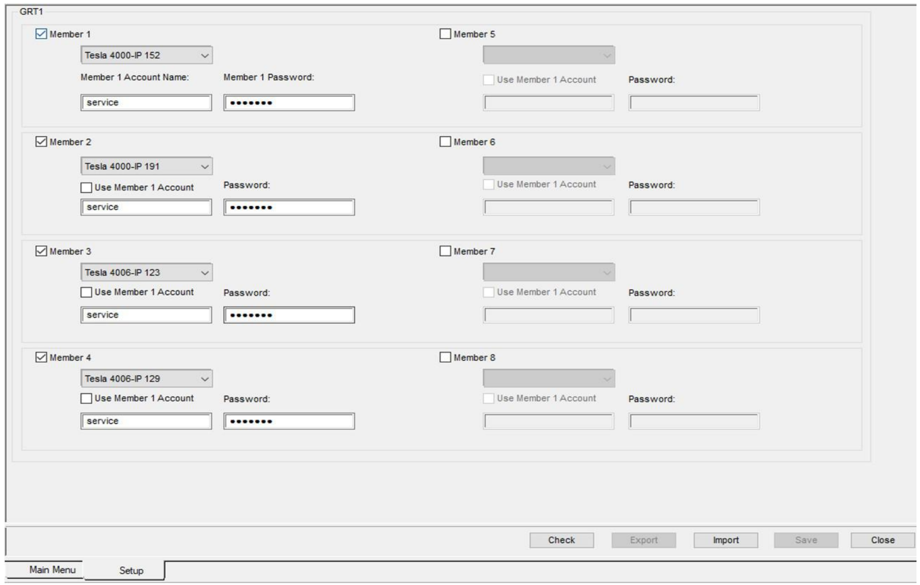


Figure 15.11: GRT member configuration

4. Export the configuration as a .xml file by selecting the **Export** button. The file can be imported later into the TESLA Control Panel or RecordBase Collector to replicate the configuration.

Step 3: Test the Group Record Combination

1. Select the previously configured GRT entry in the main menu and click **Connect** to establish a connection to the first member IED.
2. Select **Records** in the left-hand tree view to open the Records screen.
3. Manually trigger a fault record by clicking the **Trigger Fault** button at the bottom.
4. Select the newly triggered record from the record list and click the **Graph** button. The TESLA Control Panel will:
   - Collect records from each member based on the configuration.
   - Process the record combination.
5. Verify that the opened record includes member indices matching the Record Trigger Group configuration (Figure 15.11).

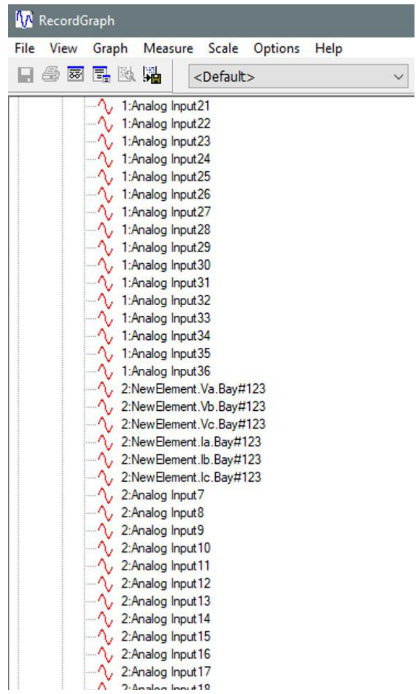


Figure 15.12: Combined record member indices

16 Recorder Health Monitoring and Maintenance

The TESLA 4000-A has a built-in health monitoring system. This system is comprised of two sets of features:

1. Self-checking for continuous IED health monitoring.
2. Maintenance tools for diagnosing and recovering from issues detected by the self-check features.

16.1 Health monitoring and self-recovery features

Health Monitoring

The TESLA 4000-A has the following features for continuous IED health monitoring:

- Supervisory software to monitor IED operations
- Watchdog to monitor operations of the supervisory software

The supervisory software continuously monitors the TESLA 4000-A's operations. It detects and provides indication for the following conditions:

- Storage failure
- Incomplete firmware update [1]
- Compromised system security
- Abnormal TESLA 4000-A software behaviour patterns
- Incompatible PMU installation (for models with PMU support)
- Post-failure recovery

The hardware watchdog continuously monitors the behavior pattern of the supervisory software.

Self-Recovery Procedure

The TESLA 4000-A, when not in its normal operating state, can be in one of the following states:

- Software restart
- Hardware restart
- Persistent error state
- Post-failure recovery (after software restart, hardware restart or persistent error state)

If an issue is detected, the supervisory software handles the recovery process and the recorder's transitions between states. The basic flow of the TESLA

1. Refer to the firmware update instructions to recover IED reporting incomplete firmware update.

4000-A's state transitions is shown in Figure 16.1: Error Handling. For a more detailed flowchart and description of the TESLA 4000-A's self-check and recovery process, see Appendix K TESLA Self-Check and Recovery.

If a failure is detected, the Supervisory software attempts to resolve the problem with a software restart. The software restart occurs quickly with no external indication given.

If the failure persists after multiple software restarts, the unit will initiate a hardware restart. The hardware restart takes approximately 1.5 minutes to complete. If the problem is not cleared after four consecutive restarts, the unit enters the Persistent Error State. In this state, the recorder activates its failure indicators and stops initiating resets to avoid interfering with any diagnostic investigation.

If the Supervisory software determines that the problem has been cleared, it automatically returns the unit to its normal operating state, clearing the failure indicators.

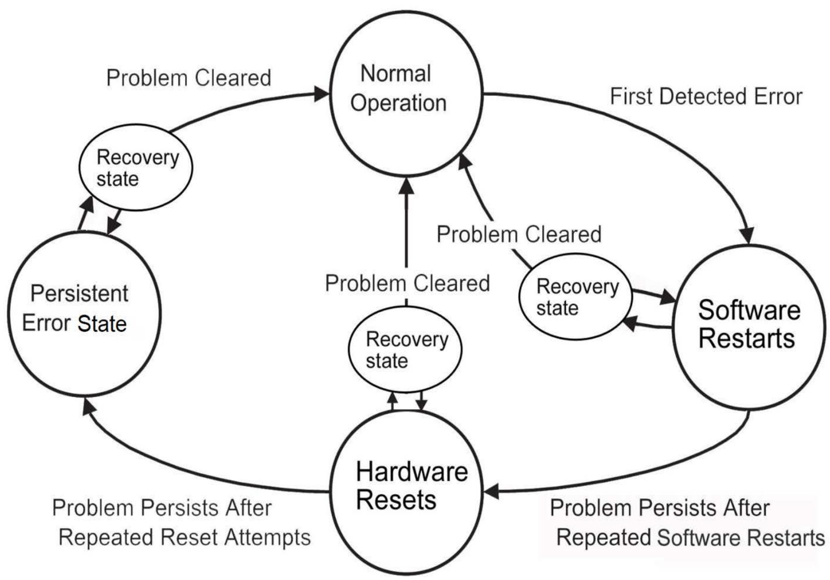


Figure 16.1: Error Handling

Recorder's State Indication

The recorder states are listed in the section Self-Recovery Procedure list above.

The TESLA 4000-A recorder has the following features to indicate its state and to deliver IED status warnings:

- Recorder Inoperative output contact
- Front Panel Recorder Functional LED
- Front Panel Alarm LED
- Front Panel Test Mode LED
- TESLA Control Panel warnings displayed upon reconnection to recorder

Table 16.1: Recorder States and State Indicators

Recorder State	Recorder Inoperative Output Contact	Front Panel LED			TESLA Control Panel Warnings	Actions and Maintenance
		Recorder Functional	Alarm	Test Mode		
Normal Operation	Open	On	Off	Off	None	None
Software Restarts	Open	On	Off	Off	Self-check state	None
Hardware Restarts	Closed	Off	Off	Changes between On and Off	Self-check state	Wait 3-5 minutes to let IED recover or enter the Persistent Error State
Persistent Error State	Closed	Off	Permanently On or Off depending on the type of failure	Permanently On or Off depending on the type of failure	List of the IED health conditions detected by the supervisory software	Refer to Maintenance section for diagnostics tools and recovery options
Recovery	Retains Persistent Error/Software/Hardware restart state during the recovery	Retains Persistent Error/Software/Hardware restart state during the recovery	Retains alarm/Restart state	Off	Self-check state	Wait 3-15 minutes to let IED recover or re-enter the Persistent Error State

16.2 Maintenance Functions and Diagnostic Tools

Access to Maintenance Functions and Diagnostic Tools

TESLA Control Panel provides access to the recorder's diagnostic tools and maintenance functions. Refer to the section "Ports" on page 4-1 for the information on how to connect the TESLA Control Panel software to a recorder. It may take TESLA Control Panel longer to establish connection to a recorder in the Persistent Error (inoperative) state.

To log in to the IED, use the default maintenance account provided with the TESLA firmware or use any customized user account with the "MAINTENANCE" role.

On successful login, TESLA Control Panel software will display IED Status Warning if the supervisory software has detected any issues.

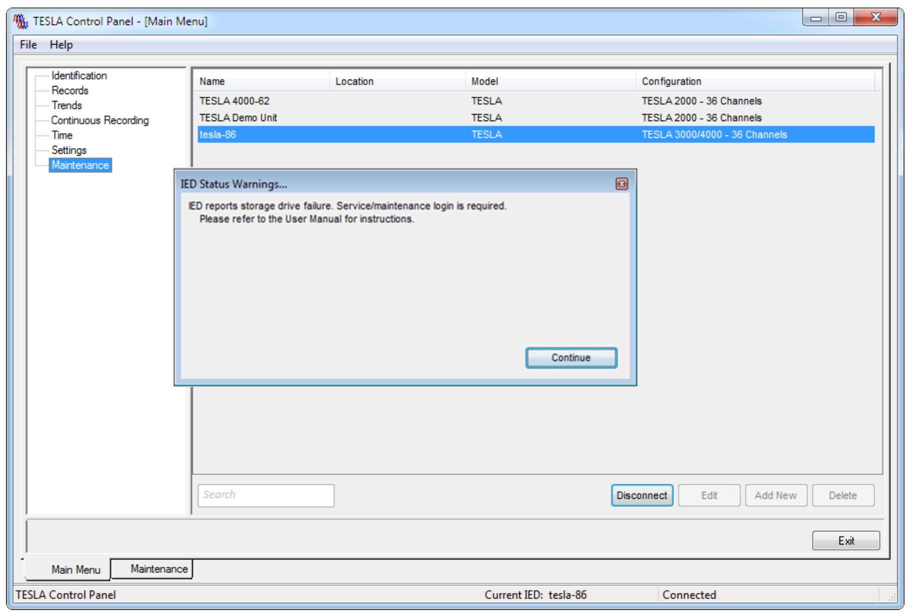


Figure 16.2: Example of IED Status Warning

If the IED Status Warning message pops up, review the warnings and press the *Continue* button to proceed to the Maintenance Menu.

Access the Maintenance menu by selecting *Maintenance* from the *Main Menu.* Access to the recorder's diagnostic tools and maintenance functions is restricted and is granted only to the users assigned the "MAINTENANCE" Role. Please contact your system administrator and request maintenance access if the Maintenance entry does not appear on the Main Menu after successful login. See "Authentication and Authorization System" on page 18-5 for information on user accounts and Roles. An example of TESLA Control Panel Main Menu with Maintenance access is shown in Figure 16.3: Main Menu with Maintenance access.

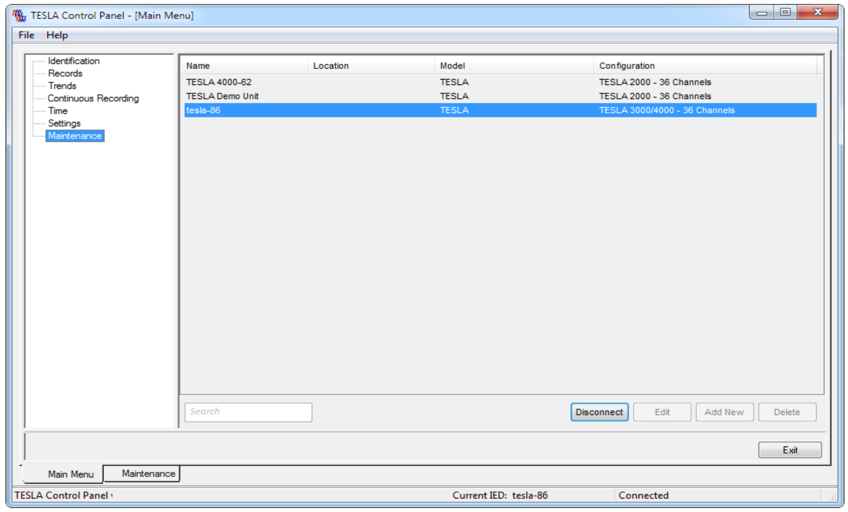


Figure 16.3: Main Menu with Maintenance access

Maintenance Functions Overview

An overview of the Maintenance Menu function groups and their intended use is provided in Table 16.2: TESLA Maintenance Functions Overview.

Table 16.2: TESLA Maintenance Functions Overview

Tab	Functions	Use	
		Normal Operational State	**Alarm (inoperative) state**
System Diagnostics tab	Access to the system diagnostics	View system diagnostics to check for: •Time sync issues; •Communication configuration issues •Soft restart reports	Retrieve system diagnostics file to submit to the ERLPhase customer support along with a support request.
Restore Defaults tab	Restoration of default unit setup and channel configuration	Clean up recorder's customized configuration	Recover IED that entered the Persistent Error state after loading new settings, calibration or set-up modification.
Storage Memory tab	Storage memory maintenance tools	Check IED storage memory status.	Check IED storage memory status. Recover IED that reports Storage Memory issue.
IED Network Utilities tab	Network diagnostic tools	Troubleshoot network communication issues.	Troubleshoot network communication issues. Assess network traffic going through recorder.

Table 16.2: TESLA Maintenance Functions Overview

PPP IP Addresses tab	Network over serial diag- nostics and configuration tools	Troubleshoot PPP related TESLA Control Panel and RBCS communication issues over serial connec- tion. PPP IP addresses con- figuration.	No usage
PTP Status	Check status of PTP Global, Clock and Port	Check PTP related status	Troubleshoot PTP syn- chronization issues

System Diagnostics

The System Diagnostics tab displays the IED's internal system diagnostics data and provides controls to retrieve system diagnostics file to a PC.

To view recorder's system diagnostics report, scroll the “System Diagnostics” view.

The purpose of the system diagnostics file is to send to ERLPhase Customer Support for issue investigation purposes. To retrieve system diagnostics file to PC, press the *Get Diagnostics* button. A “Save As” dialog with a recommended diagnostics file name will be displayed when the diagnostics are collected and ready to be saved on PC. The recommended system diagnostics file name includes configurable unit identifier (or unit serial number if unit identifier is not available), and date and time of the diagnostics file creation. The recommended diagnostics file name is unique for each new diagnostics file created by IED and does not need to be modified. The “Save As” dialog provides interface to modify the diagnostics file name if desired, though it is preferable to keep the date and time sections of the diagnostics file name as created by IED.

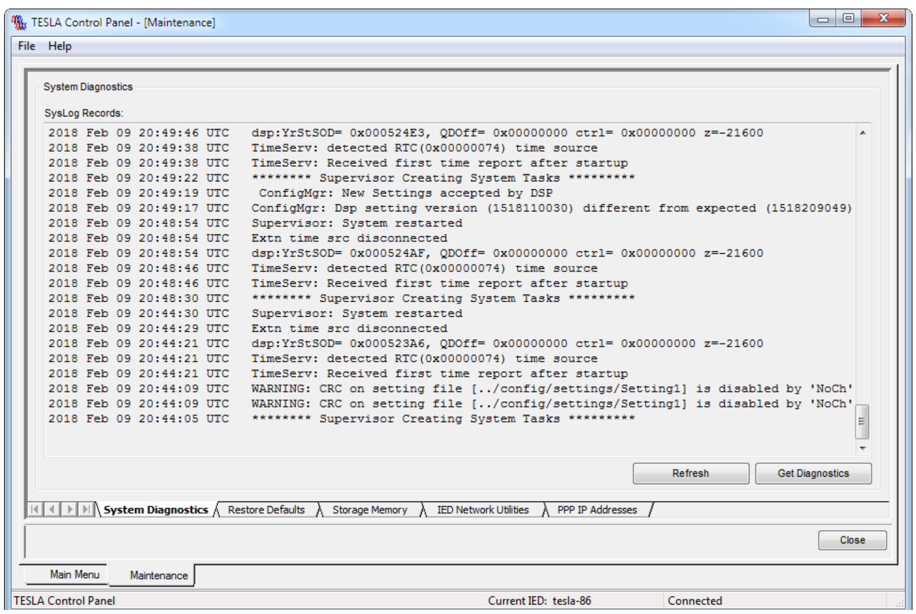


Figure 16.4: System Diagnostics tab.

Restore Defaults

The Restore Defaults tab provides controls to restore recorder's default set-up and/or channel configuration.

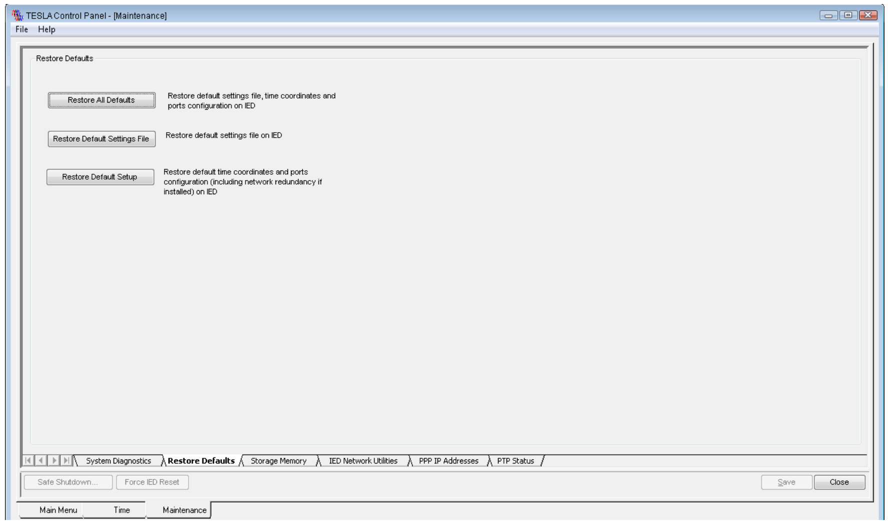


Figure 16.5: Restore Defaults tab

The recorder's Restore Defaults maintenance commands are described in Table 16.3:

Table 16.3: Restore Defaults Maintenance Commands

Command	Description
Restore Default Setting File	This command replaces recorder’s current setting file with the default setting file. All recorder channel configuration will be lost after command execution.
Restore Default Setup	This command restores recorder’s default configuration of Unit Identification, time coordinates, serial and modem ports, High and Low Speed recording, Trend recording, DSP clock calibration and PMU communication.
Restore All Defaults	This command restores Default Setting File, and recorder’s Default Setup, as described above, plus recorder’s default calibration.

Storage Memory

The Storage Memory tab provides controls to select and execute a storage memory maintenance command and displays IED's report after the execution of selected command.

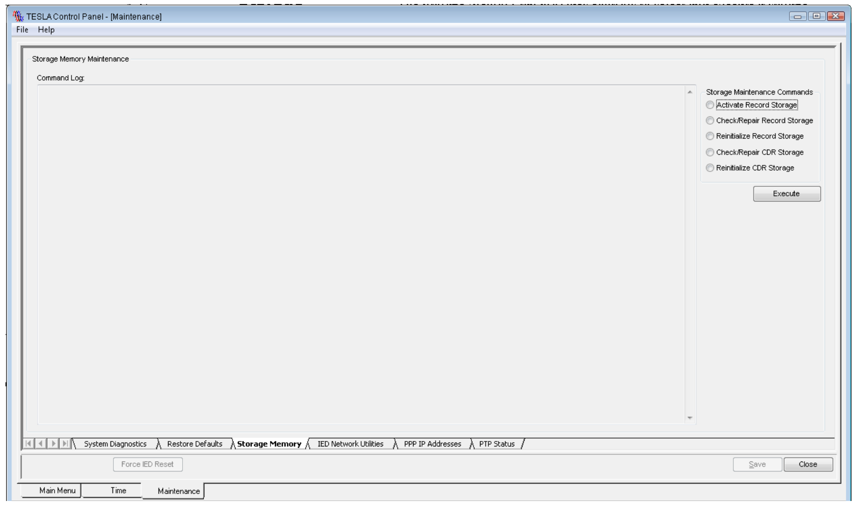


Figure 16.6: Storage Memory tab

The recorder's Storage Memory maintenance commands are described in Table 16.4:

Table 16.4: Storage Memory Maintenance Commands

Command	Description
Check/Repair Record Storage	This command checks the file system of the Record Storage and corrects fixable file system issues. Some transient, swing or trend records may be lost after command execution as a result of the file system repair.
Reinitialize Record Storage	This command reinitializes the file system of the Record Storage. All transient, swing and trend records will be lost after command execution.
Check/Repair CDR Storage	This command checks the file system of the CDR data Storage and corrects fixable file system issues. Some CDR data may be lost after command execution as a result of the file system repair.
Reinitialize CDR Storage	This command reinitializes the file system of the CDR data Storage. All CDR data will be lost after command execution.
Activate Record storage	This command verifies new record storage replacement device and ensures its compatibility with the current recorder's firmware.

> **Warning:**
>
> Improper power-off of TESLA recorder may damage its Storage Memory. Please put recorder in the Safe Shutdown state before turning off or disconnecting its power supply. Refer to “Safe Shutdown Mode” on page 12-6 for information on the recorder’s safe shutdown procedure.

IED Network Utilities

The IED Network Utilities tab displays the recorder’s network status and provides controls to issue ping requests to other network devices.

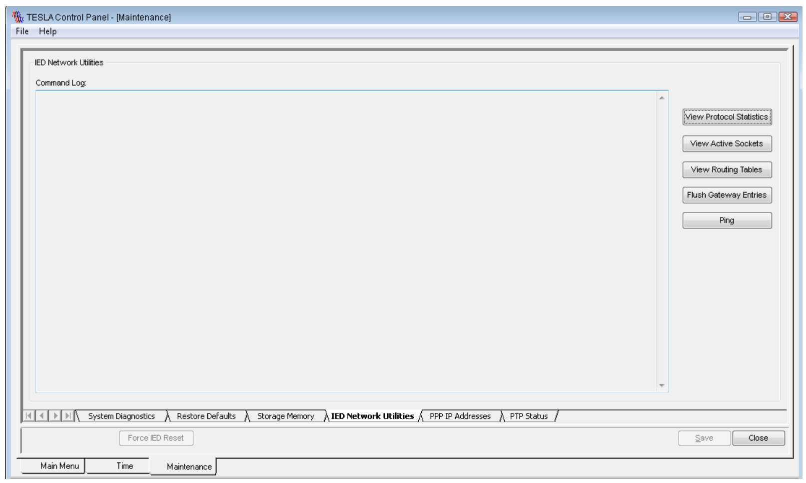


Figure 16.7: IED Network Utilities tab

The recorder’s Network Utilities maintenance commands are described in Table 16.5:

Table 16.5: IED Network Commands

Command	Description
View Protocol Statistics	This command retrieves network protocol statistics from IED and displays them in the Command Log view.
View Active Sockets	This command retrieves active socket information from IED and displays it in the Command Log view.
View Routing Table	This command retrieves network routing table from IED and displays it in the Command Log view.
Flush Gateway Entries	This command flushes recorder’s routing table including the default gateway if used. Unit reboot will be required to reinstate default gateway functionality.
Ping	This command provides user interface to enter an IP address and initiates 3 ping requests to the provided IP address. Ping execution report is displayed in the Command Log view.

Serial/Modem Access Issues troubleshooting

The PPP protocol is used to establish TCP/IP communication over serial connection. Normally the default PPP IP addresses do not have to be modified. Modification of the PPP IP addresses may be required only when the recorder's default PPP IP addresses conflict with the actual LAN IP addresses in use.

The PPP IP Addresses tab allows for viewing and modification of the recorder's PPP configuration.

The following conditions must be met for configuring the PPP addresses:

- The local-remote IP addresses for each port must be on the same network.
- Each pair of local-remote IP addresses must be on a different network.
- All PPP IP addresses must be on a different network than the recorder's LAN/WAN.

TESLA Control Panel enforces these three conditions and will not allow the user to save an invalid configuration.

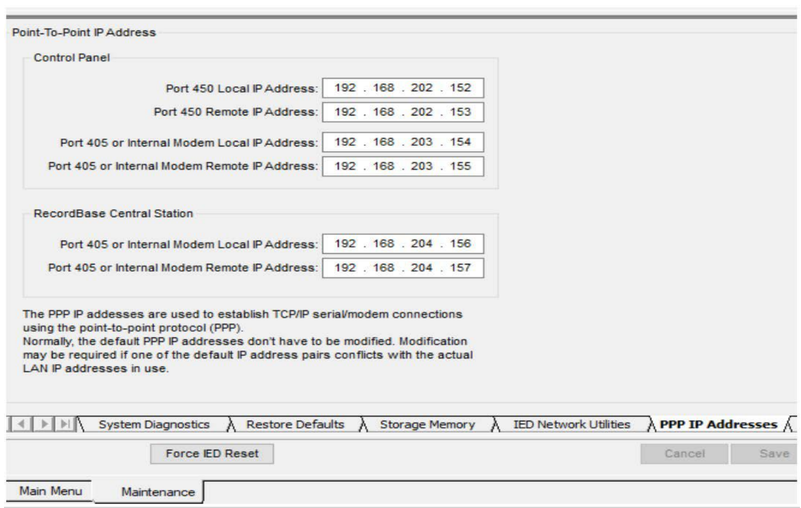


Figure 16.8: PPP IP Addresses tab

PTP Status

The PTP Status tab of the Maintenance screen provides status information for the PTP sync at a Global, Clock and Port level. This tab is provided when the unit is ordered with a redundant configuration, and PTP time sync mode is enabled.

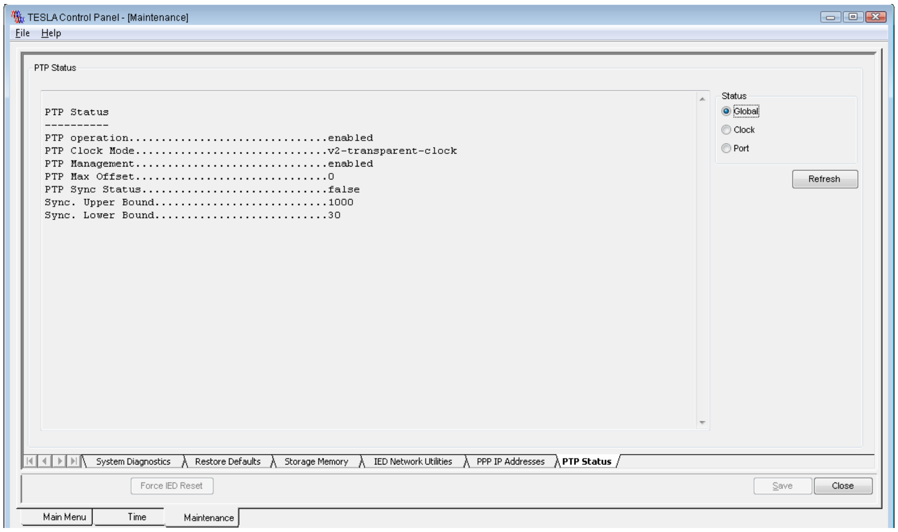


Figure 16.9: PTP Status Tab

Table 16.6: PTP Status

Status Level	Description
Global	Provides global PTP status information such as if PTP is enabled, clock mode, sync status and sync upper and lower bounds.
Clock	Provides PTP transparent clock status and sync information such as the local and master clock identities, network protocol, delay mechanism, domain, VLAD ID and priority, offset from master and end-to-end delay
Port	Provides PTP port status information such as the delay interval, delay and asymmetry, for each interface

16.3 Troubleshooting

The *Coop* screen of the Cooperative Recorder Group provides tools to view and check current status of the Inter-Member communication. The tools provided are a “Check Status” button and corresponding Member status indicators. The following table provides a summary of possible Member’s statuses and guidelines to address Cooperative Recorder Group communication or configuration issues.

Table 16.7: Cooperative Configuration Troubleshooting

Text in the Member Y Column of the Member X row	Cooperative Recorder Group condition description	Actions
connected	Normal operation	None
not connected	Member Y is not connected to Member X – network connection or configuration issue	• Verify Member X IP address is entered correctly. • Using maintenance Ping command, ping Member X IP address from the Member Y IED, and then ping Member Y IP address from the Member X IED. Ensure the ping works in both directions. • Review and save cooperative group configuration again.
TCP not connected	TESLA Control Panel is unable to connect to Member X. Network connection or security account configuration issue.	• Ping Member X IP address from the PC. If the ping fails, ensure there is network connection from the PC to the Member X. • For modem connections, go to *Communication* > *Ethernet* and verify that packet forwarding is enabled on the Gateway /Master IED. • Ensure that the login credentials used to login to the Master recorder via TESLA Control Panel exist on all group members. • Review and save cooperative group configuration again.
login failed	Incorrect or invalid Member X login credentials entered in Coop view.	• Verify Member X IED has the account with specified user name and password and that account is enabled and active. • Check IED Member X Audit Trail for login errors. • Verify correct Member X account credentials are used on the Coop screen, re-enter password if necessary, and save cooperative group again.
not compatible	Members X and Y have incompatible firmware	• Run firmware update(s) to bring all cooperative group members to the same firmware level.

Table 16.7: Cooperative Configuration Troubleshooting

Text in the Member Y Column of the Member X row	Cooperative Recorder Group condition description	Actions
connected to	Member X is connected to Member Y, but Member Y is not connected to Member X. This may be an indication of: • a transitional state while group members are processing new configuration; • a permanent state indicating cooperative group configuration issue • network connection or configuration issue	• Using maintenance Ping command, ping Member X IP address from the Member Y IED. Ensure the ping works. • Wait a few minutes and press Member X's Get Status button. • If the status remains unchanged, check the status of Member X in the Member Y row for additional information. If there is an indication of failed login or firmware incompatibility, correct the issue. Otherwise, review and save cooperative group configuration one more time.
connected from	Member Y is connected to Member X, but Member X is not connected to Member Y. This may be an indication of: • a transitional state while group members are processing new configuration • a permanent state indicating cooperative group configuration issue • network connection or configuration issue	• Using maintenance Ping command, ping Member Y IP address from the Member X IED. Ensure the ping works. • Wait a few minutes and press Member X's Get Status button. • If the status remains unchanged, check the status of Member X in the Member Y row for additional information. If there is an indication of failed login or firmware incompatibility, correct the issue. Otherwise, review and save cooperative group configuration one more time.
waiting	Transitional state indicating TESLA Control Panel activity	None
fetching config	Transitional state indicating TESLA Control Panel activity	None
checking	Transitional state indicating TESLA Control Panel activity	None
saved, verify	Transitional state indicating TESLA Control Panel activity	None
unknown	IED is not a member of this cooperative group or has not been checked yet	None

17 PMU Functionality

This chapter describes the operation of the TESLA 4000-A PMU functionality.

17.1 Overview

Phasor Measurement Unit (PMU) Description

Synchrophasors, phasor measurements with angles referenced to a global time standard, have been used in limited scope by electric power utilities for well over a decade for measuring and predicting dynamic stability of the power grid.

To transmit the PMU data reliably, you must enable PTP Time Synchronization, refer to Section PTP on page 8-18, and/or be connected to an IRIG-B signal from a Global Positioning System (GPS) clock or receiver to the TESLA 4000-A. The GPS signal must comply with the specification as mentioned in the IEEE C37.118 standard. An SNTP time synchronization source is not recommended for PMU applications.

The PMU module is a standard feature on the TESLA 4000-A. The PMU functionality complies/supports standards for Synchrophasors for Power Systems as described below:

- Complies with IEEE C37.118 – 2005
- Complies with IEEE C37.118.1a – 2014 and IEEE/IEC 60255-118-1-2018 for P class application
- Supports IEEE C37.118.1a – 2014 and IEEE/IEC 60255-118-1-2018 for M-class application

The TESLA 4000-A can transmit up to 36 user-selectable phasors as:

- individual phase quantities
- three-phase positive, negative or zero sequence phasors
- summated phasors

The phasor information is available via the Ethernet port at rates up to 60 frames each second.

The TESLA 4000-A can also transmit 24 Analog quantities consisting of any combination of Watts, VARS, VA, DC Value, frequency and THD and up to 320 digital quantities which includes 32/64 External Inputs status and 256 Boolean Virtual Inputs status. The PMU functionality does not affect the existing TESLA features; it is designed to work simultaneously with the existing features such as triggering, recording, and trending.

17.2 TESLA 4000-A PMU Features

Phasor Estimation

The PMU functional module estimates the phasor using the DFT algorithm, assuming the IED is receiving an IRIG-B signal from a reliable GPS receiver as per the C37.118 standard. The phasor magnitude and phase angle, once estimated, is compensated for the frequency variation over a wide range, covering the requirements specified in the C37.118 standards.

Phasor Reporting

Phasor data is transmitted in polar form (magnitude and phase angle) and is configurable to provide information in either Integer or Floating-Point format. Phasor data is transmitted using Ethernet (TCP/IP or UDP) communication. The phase angle is referenced to the absolute time of the GPS (IRIG-B signal) as per the C37.118 standard. The time stamp is based on the UTC time.

Number of Synchrophasors

Up to 36 user-selectable phasors, a combination of any of 36 discrete phasors (any analog channel input) and/or any of 12 sequence phasor channels and/or 48 summation channels.

Phasors selection is user-configurable via TESLA Control Panel software.

Number of Frequency Channels

One frequency channel (Frequency-1) per recorder. Inputs to the “Frequency-1” is user configurable using TESLA Control Panel software. Rate of change of frequency information (ROCOF) reported will be based on the frequency channel as configured by the user. Frequency channel data may be configured to provide information in either Integer or Floating-Point format.

Analog Data

There are 24 PMU Analog channels per TESLA 4000-A 8/12/18/36 analog channel recorder that can be streamed to a remote PDC (Phasor Data Concentrator). The quantities available are MW, MVAR, MVA, frequency, THD and DC. Analog data channels may be configured to provide information in either Integer or Floating Point format.

When the reporting format is integer, analog measurements are calculated as follows:

Analog measurement = analog value * PDC_SCALE * scale per bit

where, scale per bit= 10^-5

Unit corresponding to each 'Code' provided in configuration data frame are given in Table 17.1: Unit Codes for Analog Data on page 17-3

Table 17.1: Unit Codes for Analog Data

Code	Unit
65	V
66	kV
67	MV
68	A
69	mA
70	kA
71	W
72	kW
73	MW
74	VAR
75	kVar
76	MVar
77	VA
78	kVA
79	MVA
80	mV
81	Hz
82	ohms
83	degrees
84	PU
85	%
86	°C
87	°F
88	kWh
89	MWh

Digital Status Data

There are up to 320 PMU digital channels per TESLA 4000-A recorder that can be streamed to a remote PDC (Phasor Data Concentrator).

PMU Reporting Rate

Table 17.2: PMU Reporting Rate										
System Frequency	60 Hz						50 Hz			
Reporting rate - frames per second	10	12	15	20	30	60	5	10	25	50

PMU Reporting Times

For a reporting rate of N frames per second, the reporting times are evenly spaced through each second with frame number 0 (numbered 0 through N-1) coincident with UTC second rollover (usually the 1 second PPS provided by GPS). These reporting times (time-tags) are to be used for determining the instantaneous values of the synchrophasor. This is illustrated below in Figure 1, where the reporting times are a 0, T_0, $2T_0$, $3T_0$, $4T_0$, etc (as per IEEE C37.118 standard).

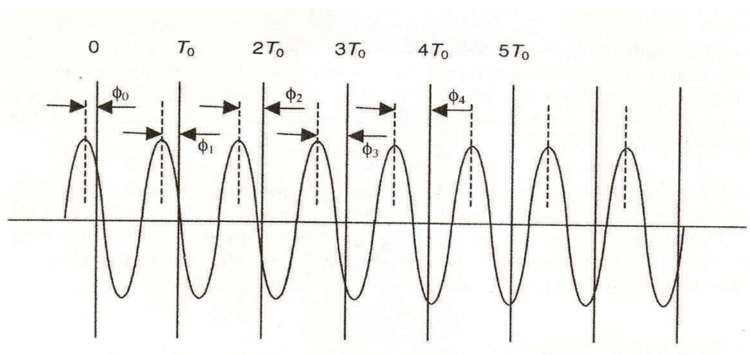


Figure 17.1: A sinusoid with a period of T observed at instants that are multiples of the T_O apart. T_O is not an integer multiple of T.

PMU Standards Options

In PMU definition, from the PMU standards option, the standard by which the data should be streamed can be selected. The following three options are available in the drop down selection:

1. C37.118 - 2005
2. C37.118.1 - 2011 (P - Class)
3. C37.118.1 - 2011 (M- Class)

PMU Response Time

The response time is the interval of time between the instant the step change is applied and the time-tag of the first phasor measurement for which the TVE (total vector error) enters and stays in the specified accuracy zone corresponding to the compliance level (as per the standard selected).

PMU Accuracy

Total Vector Error: (TVE) according to the standard selected.

Signal Frequency Variation

According to the standard selected.

Signal Magnitude

According to the standard selected.

Phase Angle

According to the standard selected.

Total Harmonic Distortion

According to the standard selected.

GPS Clock Signal Requirements

A reliable GPS clock signal (IRIG-B) as per the IEEE C37.118 specification.

The PMU module uses a GPS signal (IRIG-B) connected on the rear of the IED as global reference for reporting the phasors.

Control Panel

This is available for installation from www.erlphase.com.

Calibration

The TESLA 4000-A Power System Recorder has a variety of optional input modules for voltage and/or current available, therefore, you must calibrate the input modules. The PMU calibration requires both the magnitude and phase angle calibration at nominal signal level. This is very important in order to meet the TVE as per the standard selected.

Phasor magnitude and angle calibration are required whenever the input module and/or system frequency is changed.

It is also recommended to perform the calibration whenever the sample rate and/or PMU standard settings are changed to ensure the best accuracy.

Test Set Requirements

An accurate calibration test set to achieve high accuracy is required. Any calibration test set which generates GPS controlled signal with the accuracy as specified in the standard IEEE C37.118 is a good candidate. ERLPhase recommends the Doble F6150 Test Set with the associated GPS equipment.

Magnitude Calibration

Magnitude calibration is required whenever a input module is changed. Calibration is also recommended whenever the PMU Standard selection has changed.

Angle Calibration

Phase angle calibration is achieved by comparing the known applied phase angle from the test set and the phase angle reported in the TESLA PMU module metering screen. For example, if the test set is applying a sinusoidal signal at nominal voltage of 69 Vrms at 0 degree phase angle at nominal system frequency, its cosine referenced signal will be 69 Vrms at -90 degrees. The PMU should report 69 Vrms at -90 degrees. If the PMU reports -89.5 degrees, there is a difference of -0.5 degrees with respect to the applied signal (assuming that the test set phase angle is accurate within tolerable limits as per IEEE C37.118). This phase angle offset can be introduced in the analog channel configuration as shown, “Setting up angle calibration offset through analog channel configuration” on page 17-6.

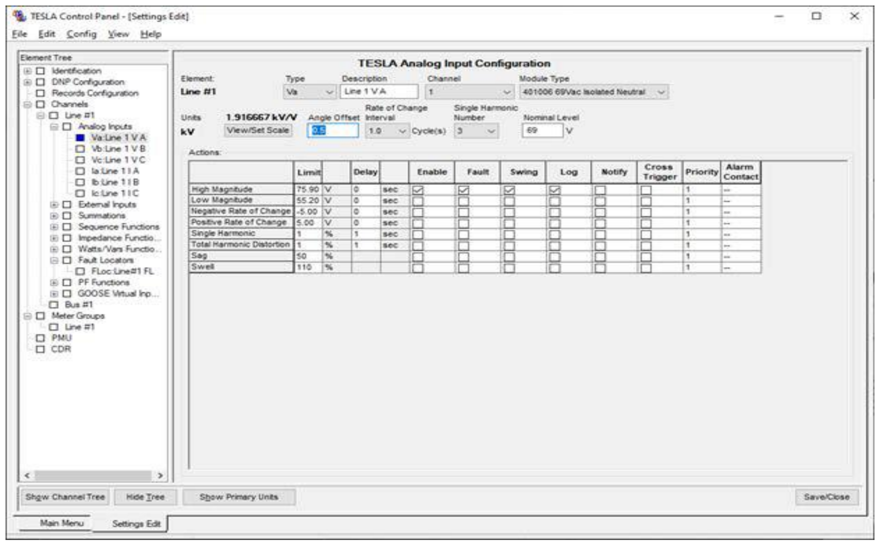


Figure 17.2: Setting up angle calibration offset through analog channel configuration

Once this phase angle offset is incorporated in the configuration, reload the configuration back to the TESLA recorder. Apply the known signal at any phase angle, and PMU should report the phase angle with the accuracy to meet the TVE as per the C37.118 standard selected. Phase angle calibration is required for all analog channels used in the PMU phasor configuration.

17.3 Communication with the PMU

PMU communication setup is done through TESLA Control Panel software. For the PMU, you must set the rate at which the data needs to be transferred, and the communication mode such as TCP/IP, UDP. You must also setup the Phasor Data Concentrator (PDC or DC as mentioned here and in TESLA Control Panel) information to transfer the data.

17.4 Setting up PMU Communication Mode

Phasor data is transmitted using Ethernet (TCP/IP or UDP) communication. Connect to a TESLA unit and click on the *Communication* > *PMU* tab to modify the PMU Communication setup.

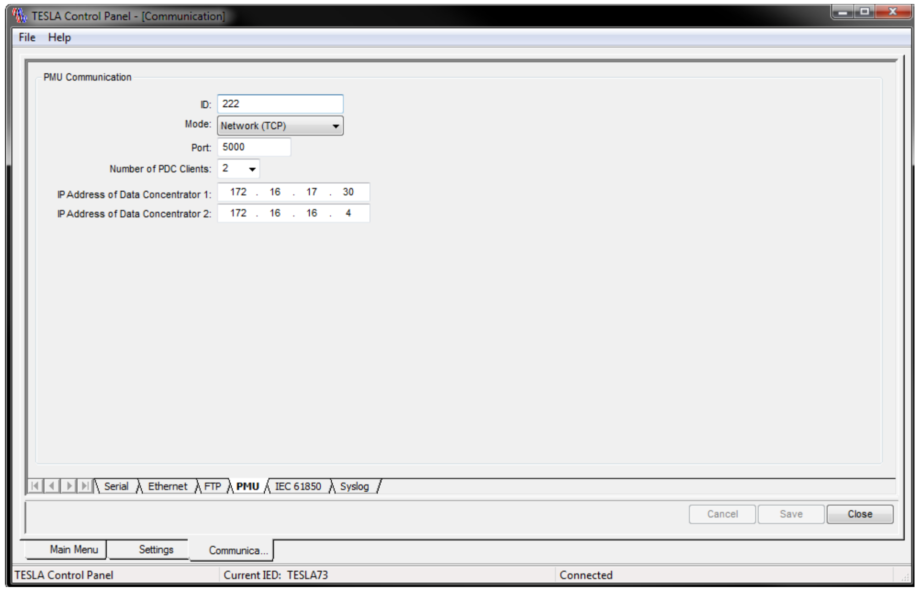


Figure 17.3: PMU communication setup screen

Settings

PMU group is available to set the PMU identification and communication.

ID control of the PMU group allows setting PMU identification number (16-bit integer).

Mode control of the PMU group allows selecting communication mode for the real-time transfer of the PMU data. The following commutation options are available for the selection via the Mode control:

- Do Not Transmit: With this choice, no PMU data is reported to the DC (Data Concentrator). Useful for maintenance purposes.
- Network (TCP): This choice transmits the PMU data using network communication link (as set by the user in the IED settings) and using TCP protocol. The port number of the DC is required to set this communication choice.
- Network (UDP): This choice transmits the PMU data using network communication link (as set by the user in the IED settings) and using UDP protocol. IP address and the port number of the PDC are required to set this communication choice.

The initial values of the above controls are based on the data received from the unit on connect.

The PDC options are:

- IP Address of Data Concentrator 1, IP Address of Data Concentrator 2: This option is enabled only if the Mode is either Network (TCP) or Network (UDP) otherwise it is disabled. The table below describes the cases where IP Address of Data Concentrator is enabled or disabled.
- Port: This option allows user to configure the listening port number of the recorder to which a PDC client will connect via the network link.
- Number of PDC Clients: This option allows user to set the number of PDC clients that can connect to the recorder simultaneously. The TESLA 4000-A supports up to two PDC clients.

Table 17.3: Data Concentrator IP Address State

Mode	Network (UDP)	Network (TCP)	
Number of PDC Clients	1 (fixed)	1	2
IP Address of Data Concentrator 1	Enabled	Enabled	Enabled
IP Address of Data Concentrator 2	Disabled	Disabled	Enabled

17.5 PMU Configuration

Configuring PMU Phasors with Existing Settings

Select an existing configuration file by double-clicking on the file and the following screen appears.

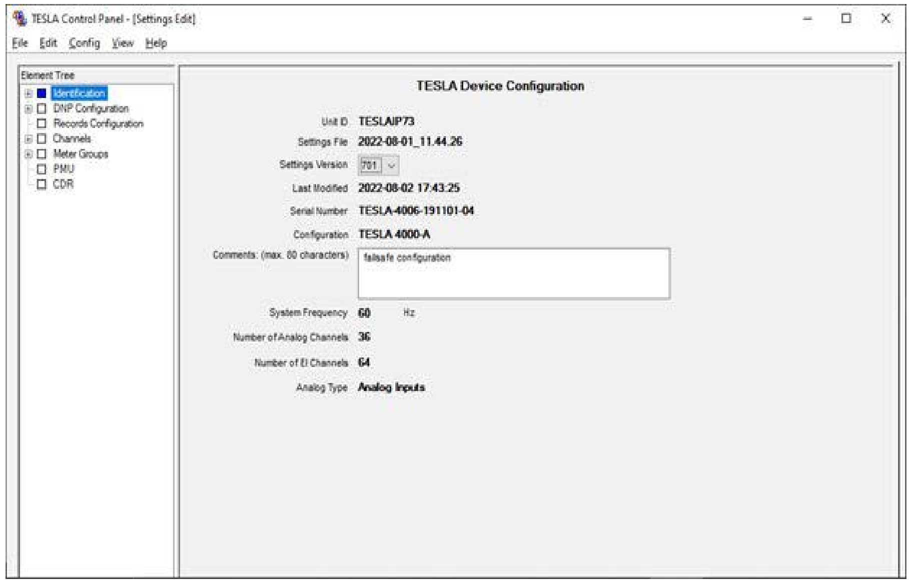


Figure 17.4: Setting version conversion view

Right-click on the Channel Group1 to display the choice to add a PMU as shown below.

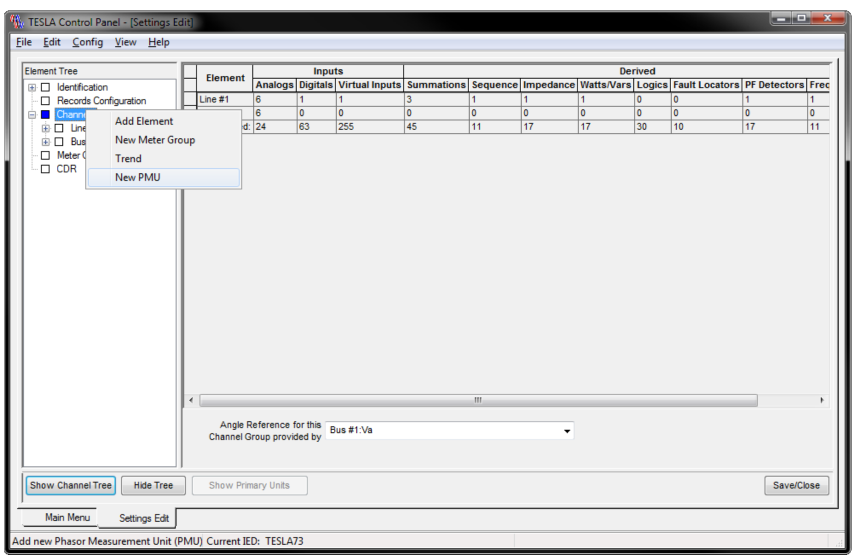


Figure 17.5: Invoking PMU configuration through right-click menu

Select the PMU choice and the following screen appears allowing you to select the Phasors.

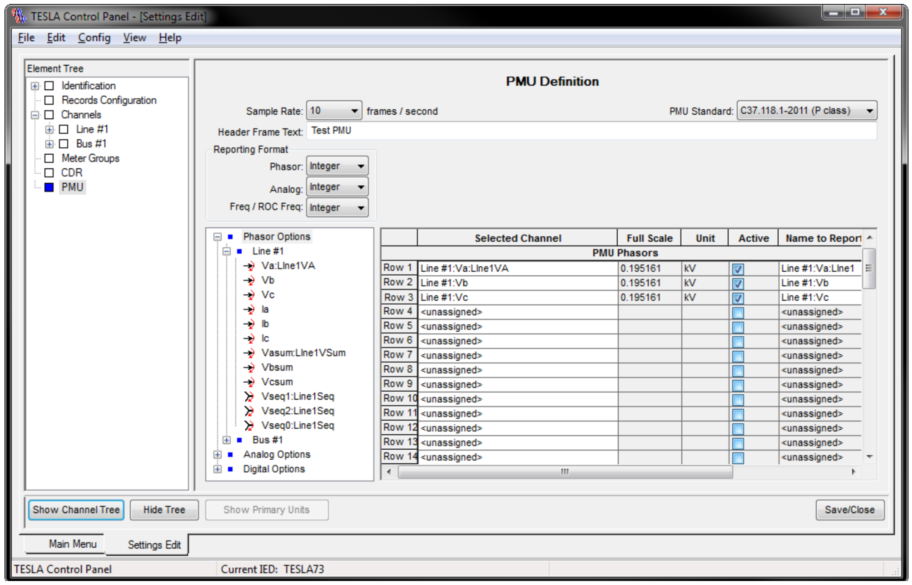


Figure 17.6: PMU configuration screen

In the PMU Definition Screen, Analog Inputs (voltage & currents), Summations and Sequence Functions channels are available for PMU Phasors reporting. You can select up to 36 phasors by dragging and dropping the channels on the Selected Channels list or by selecting the phasors from the Combo Box as shown below. In addition up to 24 analog quantities (Watt, Vars, VA, frequency and THD), 32/64 External Inputs and 256 Boolean VI inputs can be selected in the PMU definition screen for streaming to the PDC. Analog, PMU and Frequency data formats may be user configured to provide information in Integer or Floating-Point form.

The following features can be observed with the PMU Definition configuration screen:

A PMU item appears on the left-hand side tree view.

On the right-hand side the PMU Definition Configuration screen displays the following configuration items:

- Sample Rate - sample rate for the PMU to report. The default setting is set to 10 frames per second. Different samples rates can be chosen: 10, 12, 15, 20, 30 or 60 frames per second for the 60 Hz power system. For the 50 Hz power system the sample rates are 5, 10, 25 or 50 frames per second. Selection is by drop down selection.
- Header Frame Text - You can enter comments up to 80 characters using this option by default the value is blank.

The lower part of the PMU Definition screen is made up of two sections. To the left is the selection tree. To the right are the placement columns where the quantities are dragged to from the left selection tree or selection can be done by the drop-down columns in each of the right-hand columns.

The right-hand PMU Definition screen is made up of three sections, Selected Channels: PMU Phasors, PMU Analogs, PMU Digitals

Selection Channel Column

PMU Phasor section allows up to 36 PMU Phasors to be selected from the Phasor Options left hand tree by selecting from the tree, drag and drop into one of the up to 36 rows under PMU Phasor column. The user can also use the row drop down selection tool. A PMU Phasor can be; an analog voltage or current phasor, a summated voltage or current phasor or a voltage/current sequence component (Pos., Neg., or a Zero sequence) phasor.

PMU Analog allows 24 PMU Analogs to be selected from the Analog Options left hand tree by selecting from the tree, drag and drop into one of the 24 rows under PMU Analog column. User can also use the row drop down selection tool. A PMU Analog can be MWatts, MVars, MVA, DC, frequency and/or THD values.

PMU Digital allows up to 320 PMU digital channels per TESLA recorder. When a digital channel is configured it will be automatically placed in the PMU Digital section of the screen.

As soon as the phasor, analog value or digital channel is selected, corresponding channel name will be displayed in the Name to Report column with the default name as depicted under Selected Channels. If the name as appearing in the Selected Channels is greater than 16 characters, it will be truncated to 16 characters before it is displayed

If no phasors are selected (no discrete phasor channels and no positive sequence phasor channels) then the real time PMU data will not be transmitted, even though the other parameters are available. You must select at least one phasor channel in order for the PMU to report the phasor information in real time.

Full Scale Column (PMU Phasor and Analog sections)

For PMU Phasors, this column's values are automatically calculated and inserted. These values are derived by the full scale of the input device (voltage or current modules) times the PT or CT ratio. The voltage module's full scale is 138 volts. The current module's full scale is 20 x In -1 amp module = 20 amps, 5 amps module = 100 amps. These are multiplied by the PT / CT ratios to get the full scale value in this column

For the PMU Analog section, this column's value have a default value which is calculated by multiplying the full scale values of the voltage and current from the PMU Phasors' section.

Unit Column (PMU Phasors and Analog sections)

This column will automatically place the primary unit scale of the voltage and current phasors in the PMU Phasors Section

In the PMU Analog section column will automatically place the primary unit scale of the Watts (MW), Vars (MVAR), VoltAmps (MVA), Frequency (Hz) and THD (%).

Active Column (Digitals)

This column shows check boxes, where you can enable or disable the PMU streaming of these PMU digital quantities to the Data Concentrator. A check will enable this PMU channel.

Name to Report (PMU Phasors, Analog and Digitals)

This column allows the user to re-name the streaming PMU channel that will be reported to the remote Data Concentrator.

Note that the saved PMU configuration is automatically used in the PMU metering display, when this file is loaded on the TESLA 4000-A.

Use Save/Close option to save the PMU information in the setting file for later retrieval and/or loading into TESLA 4000-A.

Configuring PMU from a New Setting File

Before setting up PMU configuration, you must set up the desired analog and/or summation and/or sequence channels as explained in the Configuring the Recorder section of the TESLA User Manual. Once the channels are defined, the procedure as explained in “PMU Configuration” can be followed to define PMU phasors.

17.6 PMU Metering

PMU metering does not require any special configuration settings. Once the PMU phasors are defined as explained in the previous section, the PMU metering automatically displays the metering screen through a separate PMU tab. Phasor magnitude and respective phase angles are displayed in primary or secondary units. All the user interface and update features available for the normal metering are also available for the PMU metering. In addition to the phasor channels configured in the PMU configuration, a frequency channel will also be displayed, if one is already configured. A typical PMU metering screen is as shown below.

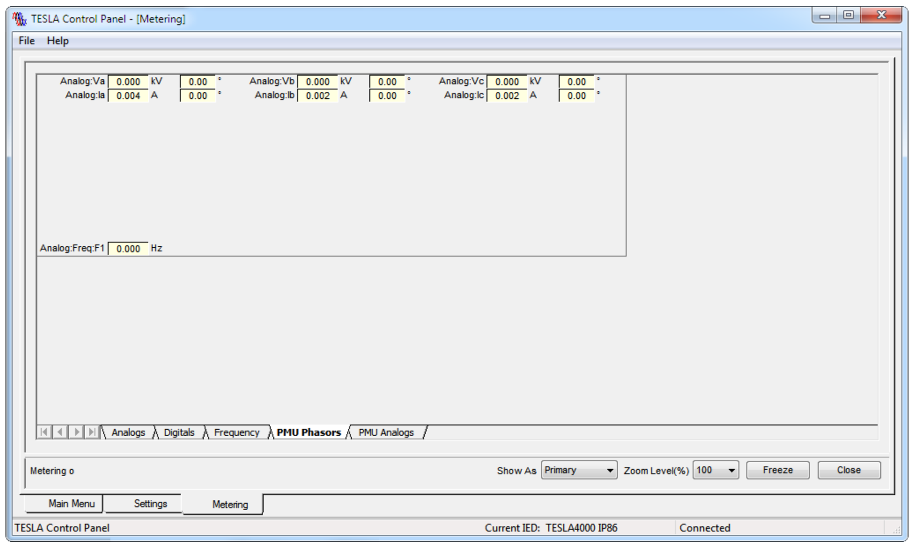


Figure 17.7: Typical PMU metering screen

17.7 PMU Stream Quality on Time Synchronization Loss

The TESLA meets all of the IEEE C37.118.2 requirements, including time-quality reporting, when connected to an IRIG-timing source that is complaint with the standard. However, in the event of the loss of the required high accuracy timing signal, the following summarizes the expected response/behavior of the recorder during this type of condition.

Internal Clock Drift

The biggest factor in the internal clock drift is whether or not the TESLA has been connected to a C37.118 compliant timing source during the current power cycle.

When the TESLA 4000-A is synchronized to a highly accurate external time reference, it counts the number of internal oscillator clock cycles between consecutive starts of each second (consecutive PPS - Pulse Per Second), and stores this count value as PPS_COUNT. PPS_COUNT remains stable because the time source is stable and the oscillator frequency is stable. It is within +/- one count value of the actual PPS when synchronized to an external reference. The TESLA 4000-A internal oscillator is 133MHz therefore one count value is 7.5ns.

If external time synchronization is lost, the TESLA 4000-A continues to operate using the PPS_COUNT captured prior to losing sync. Each future PPS is assumed to occur PPS_COUNT clock cycles after the previous PPS, and this is used to maintain internal time in the absence of an external time reference. Since the PPS_COUNT value was within +/- one count of the true PPS prior to sync loss, and the TESLA 4000-A internal oscillator is 133MHz where one count is 7.5ns, the time drift could be as high as 7.5ns per second (I.E. per PPS), or 648us per day (7.5ns/s x 86,400 s/day).

If the TESLA 4000-A is powered up without ever connecting to a valid external time reference, PPS_COUNT accuracy is based on the accuracy of the internal clock oscillator which is 50ppm. 50ppm results in a time drift of 50/ 1,000,000 x 86,400 s/day = 4.32 s/day. This is unacceptable for PMU applications.

It is worth noting that the front panel “Time Sync” LED is not a Time Sync Loss indication, but is actually an indication that a good Time Signal is available and the recorder has synchronized to it. The loss of time sync source is reported via the various supported communication protocols and in the case of PMU streaming, it is handled as explained above, and specified in C37.118.2, Section 6 “Synchrophasor Message Format”, specifically in sub-sections 6.1 - 6.2.

18 Cyber Security

The TESLA Cyber Security System is designed to address cyber security requirements specified by NERC-CIP ([1], [2]) and IEEE ([3]) standards.

The IEEE Std 1686-2013 Table of Compliance is shown in Appendix L IEEE 1686-2013 Table of Compliance on page L-1.

For remote access protection the TESLA 4000-A relies on the Electronic Security Perimeter concept ([1]).

> For references indicated in square parentheses [#], see 18.5 Cyber Security Reference Documents on page 18-12.

18.1 Ports and Services

Table 5.1 on page 5-1 shows a list of Services supported by the TESLA 4000-A. This table also shows which services can be enabled or disabled. There are two groups of services:

- Data communication services
- Interactive User services

System access control for the data communication group of services relies on specific protection mechanisms defined by corresponding service protocol.

System access control for the Interactive User group of services is described in “System Access Control” on page 18-2.

18.2 System Access Control

The TESLA 4000-A enforces interactive user (User) authentication. The User must provide valid Credentials to get access to IED. Credentials include the User Name and Password.

The User provides Credentials during the login procedure. Each login starts a User Access Session (User Session). The User Session ends, when the User logs out or is forced to logout.

All User Sessions share a common set of properties that define session lifetime. These properties are called Access Polices (see "Access Rules" on page 18-3).

IED continuously monitors User activity. Each logged in User is assigned a unique id (User ID) and their activity is being tracked separately (for details see "Security Notification System" on page 18-10). The User ID consist of two parts

- User Name
- Session ID

The Session ID is a unique programmatically generated number used to differentiate User Sessions, in case several Users with the same credentials are logged into the system simultaneously. The Session ID is reset to 1 on system start-up.

The User credentials are also used for authorization purposes (for details see 18.3 Authentication and Authorization System on page 18-5). If the User authentication (login) is successful, then the User is assigned a set of privileges (Rights). This set of Rights is used to authorize the User activity. Any attempt to perform non-authorized actions will fail.

User Rights are configurable. Rights assigned to a User at login time are valid until the end of the User Session. If User Rights change, they will affect only new sessions.

An Account is associated with each User. User Credentials and Rights information is stored on the Account (for details see User Accounts on page 18-5).

IED limits the total number of simultaneously logged-in interactive Users to 7.

Credentials

User Credentials include User Name and Password. The User Name and Password are ASCII strings.

The maximum length of User Name and Password is 23 characters. Character set includes:

- Upper case and lower case characters
- Numerical characters
- Special characters

Appendix M Credential Character List on page M-1 contains a complete list of characters allowed for User Name and Password.

Password Complexity Rules

The IED enforces Password Complexity Rules for all User constructed passwords. Password Complexity Rules are configurable and include the following Password properties:

- Contain at least one upper-case character;
- Contain at least one lower-case character;
- Contain at least one numerical character;
- Contain at least one special character;
- Enforce minimum Password length (8 to 20 characters).

See “Password Complexity” on page 8-39 for details on configuring the Password Complexity Rules.

Access Rules

The Access Rules are listed in Table 17.1 below.

Table 18.1: Access Rules

Policy	**Units**	**Min**	**Max**
Session Duration Timeout	Hours	1	8760
Session Inactivity Timeout	Minutes	1	120
Failed Login Handling:			
Maximum Retries		1	30
Lockout Timeout	Minutes	3	60
Password Change Period:			
Enable		OFF	ON
Change Period	days	1	3650

Session Duration Timeout

The “Session Duration Timeout” defines the maximum duration of the User Session. The IED forcefully logs the User out and closes the session after the timeout expires.

Session Inactivity Timeout

The “Session Inactivity Timeout” defines the maximum time the User can remain inactive during a session. Inactivity is defined as the absence of user communication with the IED. The IED forcefully logs the User out and closes the session if user is inactive for a period exceeding the timeout setting.

> The minimum inactivity timeout should not be set to less than 3 minutes on an IED that is used as the gateway for connect-through sessions (including for Cooperative Mode Master Recorder)

Failed Login Handling

"Failed login handling" defines the IED behavior in the case of failed login attempts. The IED allows for a number of failed login attempts for the same User. The IED locks the User out after the number of consecutive failed login attempts reaches a configurable maximum. This maximum value is defined by the "Maximum retries" setting. The User is locked out for the period of time defined by the "Lockout timeout" setting. Any login attempts (with or without correct Credentials) are invalidated (failed) until lockout timeout expires. User is allowed to login after lockout timeout expires.

The IED keeps track of failed logins by associating a failed logins counter with each User. The User is locked out when counter reaches the "Maximum retries" value. The counter is cleared and the User is allowed to login after the lockout timeout expires.

The failed logins counter is cleared, when outside of the lockout period, under these conditions:

- On a successful login
- If there are no login attempts within a period of time defined by "Lockout timeout" setting (prevents accumulation of failed login attempts over long period of time).

> Failed logins counters are not persistent across system start-ups. All counters are cleared on start-up.

Password Change Period

The "Password change period" setting is used to support the NERC CIP requirement to periodically update User passwords. If the "Password change period" setting is enabled, the IED compares the current date against the date Password was last updated on User login. If the difference exceeds "Change period" setting value, then the User gets a Password change notification. The IED doesn't enforce Password change, but rather informs the User that update is required. The User is still granted access and allowed using all services assigned to them.

> TESLA Control Panel prompts the User to enter a new password, if password change period has expired. The User can discard the prompt and continue using services.

Refer to "Access Policies" on page 8-39 for details on how to configure Access Policies.

18.3 Authentication and Authorization System

TESLA uses an accounts system for User authentication and authorization. The Account system is used for all types of interactive User services. The Account system is stored locally on IED.

There are two types of accounts:

- Multi-purpose User Accounts
- Contingency Account for Security Configuration recovery to factory defaults.

Authentication Defeat Mechanism

There are no means to defeat or circumvent the IED Authentication System. A Role Based Access Control (RBAC) model is used for User authorization.

User Accounts

Number of User Accounts

The TESLA 4000-A supports up to 32 User Accounts.

Account Properties

The properties associated with the User Accounts are shown in Table 18.2 Account Properties:

Table 18.2: Account Properties

Property	Value	Notes
User Name	Text string	User name used at login time
Password	Text string	Password used at login time
Account enabled	ON/OFF	Used to enable/disable account
Password change on the next login	ON/OFF	Advises user to change password on login
Active date	Date	Date when user account becomes active
Expiration date	Date	Date when user account expires
Roles		A list of Roles (privileges) assigned to the user
Comments	Text	General purpose notes describing the user account

The “User Name” and “Password” are used for authentication purposes.

The IED stores a password signature instead of a clear text password. The clear text password is converted into a signature when an account is created or updated. The User entered password is converted into a signature at login time and the result is compared against the signature stored on the account.

The “account enabled” property allows to manually disable the account. If the account is disabled, it is not used for User authentication purposes.

The “password change on the next login” property advises the User to change the password. This property allows the security administrator to manually initiate individual password updates. If enabled, this property remains enabled until the User updates their password. The property is set automatically when time period defined by “Password change period” setting expires (see “Password Complexity Rules” on page 18-3). The password change is not enforced.

If the “Active period validation” property is enabled, it instructs the IED to validate the date at the time of login. The “Active date” and “Expiration date” settings are used for validation. User authentication fails if the login date is outside of the period defined by “Active date” (lower bound) and “Expiration date” (upper bound).

> The “Active period validation” is disabled for users with the SECADM role. This guarantees continuous control over system accessibility.

The “Roles” property is used for authorization purposes. It contains a list of Roles assigned to the User. Refer to “Authentication and Authorization System” on page 18-5 for more details.

The “Comments” property is a general purpose text describing the account. The maximum text length is 79 characters. This property is not used by the IED and is for displaying purposes only.

Refer to “User Account Management” on page 8-36 for how to create and manage User Accounts.

Contingency Account

The Contingency Account is used for authorization of Security Configuration restoration to Factory Defaults operation.

Challenge-Response protocol

The IED uses a Challenge-Response protocol to Restore Security Configuration to Factory Defaults.

The IED programmatically generates a Challenge Authorization String (Challenge) based on a randomly generated number. The Challenge is a 24-character ASCII string. The character “-” is used as a separator for readability purpose and is not part of the Challenge. The Challenge is presented to a user in a format as follows

XXXX-XXXX-XXXX-XXXX-XXXX-XXXX

The User provides the IED with a Response Authorization String (Response). The IED validates this Response and restores Security Configuration to factory defaults, if the Response is valid. The Response format is also a 24-character ASCII string, similar to the Challenge.

Challenges and Responses are unique to the IED they are generated by/for. The Responses generated for one IED are invalid for all others.

Challenge lifetime

A Challenge never expires. It is updated programmatically after the Security Configuration restoration operation. Alternatively, the User can trigger a Challenge update manually at any time. Challenge update is available in the Security Configuration “Contingency Account” dialog or Terminal UI dialog (see “Default Security Configuration Settings” on page 8-41 for more details).

> Please contact ERLPhase customer support to generate a Response. A request for Response should include the Challenge.

Responses are specific to Challenges. A new Response is required every time the Challenge is updated.

Authorization System

The TESLA authorization system complies with RBAC model specified in [4]. Table 18.3 TESLA Role List lists supported User Roles.

Table 18.3: TESLA Role List

Role Name	Comment
Pre-defined User Roles defined in IEC 62351-8	
VIEWER	Can view parameters and browse menus
OPERATOR	Can read parameters and perform control operations
ENGINEER	Can read and change parameters, change configuration (other than security) and settings, full access to files
INSTALLER	Can view parameters, change configuration (other than security) and settings
SECADM	Can read and change security configuration
SECAUD	Can read and download audit trail log
TESLA 4000-A default User Roles	
MAINTENANCE	Can perform TESLA 4000-A maintenance functions
UPDATE	Can perform TESLA 4000-A firmware update
RCDREADER	Can access TESLA 4000-A record storage
COOPGROUP	Role is designated for the inter-TESLA COOP mode communication.
RBCS	Role is designated for RecordBase Central Station access to the TESLA 4000-A record storage and RBCS related communication configuration.

> RBACMNT Role defined in the IEC 62351-8 standard is not supported.

Roles assigned to a User define user privileges. See Table 18.4 Privilege to Roles Assignment.

Table 18.4: Privilege to Roles Assignment

Privilege	Roles										
	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RCDREADER	COOPGROUP	MAINTENANCE	UPDATE	RBCS
View unit identification information	X	X	X	X	X	X	X	X	X	X	X
Change unit identification information			X	X	X						
View IED’s cooperative mode status	X	X	X					X		X	X
View record list	X	X	X				X			X	X
Read records		X	X				X			X	X
Delete records			X								X
Manually trigger recording		X						X			X
Read recording configuration		X	X				X			X	X
Change recording configuration			X								
View trend channel list	X	X	X							X	
Read trend data		X	X							X	
Delete trend data			X								
Read trend configuration		X	X							X	
Change trend configuration			X								
View Continuous Disturbance Recording summary	X	X	X								X
Read Continuous Disturbance Recording data		X	X								X
Erase Continuous Disturbance Recording data			X								
View events	X	X	X								X
Erase events			X								
View metering data	X	X	X	X							
Read cooperative group configuration		X	X					X		X	X
Change cooperative group configuration			X							X	
Trigger cooperative group recording		X						X			X
View IED setting file description	X	X	X	X						X	
Read IED settings file		X	X	X						X	
Load settings file to IED			X							X	
Read communication configuration		X	X	X	X						X[1]
Change communication configuration			X	X	X						
View IED time	X	X	X	X	X	X			X	X	
Read time configuration		X	X	X	X				X	X	
Change time and time configuration			X	X	X				X		
Calibrate			X	X							
Update firmware										X	
Read/download system diagnostics									X	X	
Restore default configuration									X	X	

Table 18.4: Privilege to Roles Assignment

Privilege	Roles										
	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RCDREADER	COOPGROUP	MAINTENANCE	UPDATE	RBCS
Activate safe shutdown mode		X							X		
Force restart									X		
Access network utilities									X		
Activate new storage device									X		
Repair storage device									X	X	
Manage security configuration					X						
Read/download Audit Trail						X					

1. RBCS role has a privilege to read FTP communication configuration.

> TESLA RBAC model maps IED privileges to mandatory pre-defined Rights defined in [4]. Mapping is not shown in Table 18.4 Privilege to Roles Assignment.

Separation of Duties

Users may be assigned any combination of Roles except for the “SECADM” Role. “SECADM” cannot be combined with any other Role.

18.4 Security Notification System

The TESLA implements a Security Notification System to monitor cyber security related User activity. A Security Notification is an alert generated if User actions compromise or may compromise IED Cyber Security.

Security Notifications are categorized by class and type. There are two Security Notification classes, Security Events and Security Alarms:

- A Security Event is an alert related to an authorized activity.
- A Security Alarm is an alert related to an unauthorized activity or an activity critical to the operation of the IED

The Security Notification types are shown in Table 18.5 Security Notification Types.

Table 18.5: Security Notification Types

Name	Description
AUTH	Security Notifications related to Authentication and Authorization activity.
ACCS	Security Notifications related to access to IED Data and Control.
SECU	Security Notifications related to access to IED Security Data and Control.
SYST	Security Notifications related to IED System state change

The Security Notification contains information necessary to identify a nature of the alert, whose actions triggered it and when it happened. The Security Notification structure is shown in Table 18.6 Security Notification Structure.

Table 18.6: Security Notification Structure

Field	Description
Sequence Number	Automatically incremented sequence number
Time and Date	Time and date stamp
User ID	User ID includes User Name and Session ID
Notification ID	A number that uniquely identifies name, class, and type of Security Notification
Details	Security Notification specific details

Refer to [5] for Security Notification System detailed description.

Audit Trail

The TESLA records Security Notifications into a local security log called the Audit Trail. The Audit Trail size is limited to 2048 records (one Security Notification per record).

Records are handled in First-In-First-Out (FIFO) manner where the newest record overwrites the oldest one, if Audit Trail is full.

Audit Trail cannot be reset or erased and individual records cannot be deleted.

The validity of each record is protected by a signature.

Access to Audit Trail is available via TESLA Control Panel (see “Audit Trail” on page 11-8).

Syslog

The TESLA provides Cyber Security Notification messages to an external (relative to the TESLA) Syslog server. The Syslog server interface complies with RFC5424 (“The Syslog protocol”) and RFC5426 (“Transmission of Syslog messages over UDP”) standards.

The Syslog server settings are available on the *Syslog* tab in the *Communication* menu in TESLA Control Panel (see “Syslog Communication Settings” on page 8-34).

18.5 Cyber Security Reference Documents

[1] CIP-005-5 Cyber Security – Electronic Security Perimeter

[2] CIP-007-6 Cyber Security – System Security Management

[3] IEEE Std 1686-2013 IEEE Standard for Intelligent Electronic Devices Cyber Security Capabilities

[4] IEC/TS 62351-8 Power systems management and associated exchange – Data and communications security – Part 8: Role-based access control

[5] Security Notification System User Guide v1.01

19 IEC 61850 Implementation Overview

19.1 Introduction

The IEC 61850 standard defines a suite of protocols that permit substation equipment from different manufacturers to communicate with each other. ERL is dedicated to developing IEC 61850-based devices that can be used as part of an open and versatile communications network for power system automation.

The IEC 61850 defines an Ethernet-based protocol used in power systems for data communication. Power systems implement a number of devices for protection, measurement, detection, alarms, and monitoring. System implementation is often slowed down by the fact that the devices produced by different manufacturers are incompatible, since they do not support the same communication protocols. The problems associated with this incompatibility are quite serious, and result in increased costs for protocol integration and system maintenance.

The IEC 61850 is a broad ranging standard which encompasses the entire scope of power system automation, from the highest level of substation design to the lowest level of the communication protocol implementation on IEDs. The IEC 61850 Standard also defines a standard Engineering Process which is an iterative process which allows for the implementation and management of power system automation.

Some key concepts which are discussed further in the following sections are:

- Substation Configuration Language (see Section 19.2)
- The Engineering Process (see Section 19.3)
- Edition 2.0 Implementation (see Section 19.4)
- Sampled Value Subscription (see Section Figure 19.11:)

Parts of the Standard

The IEC 61850 Standard is comprised of many parts. The parts of the standard which are most relevant to the implementation in this device are:

- IEC 61850-6:2010 Edition 2.0: Configuration description language for communication in electrical substations related to IEDs
- IEC 61850-7-2:2010 Edition 2.0: Basic information and communication structure – Abstract communication service interface (ACSI)
- IEC 61850-7-3:2010 Edition 2.0: Basic communication structure – Common data classes
- IEC 61850 -7-4:2010 Edition 2.0: Basic communication structure – Compatible logical node classes and data object classes
- IEC 61850-8-1:2010 Edition 2.0: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
- Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2:2010 (also known as IEC 61850 9-2LE)

19.2 The Substation Configuration Language (SCL)

The Substation Configuration Language (SCL) is an XML based language which provides the basis for interoperable data exchange between IEDs from different vendors and between configuration tools. The SCL file structure is comprised of five main parts:

- Header - defines file information history
- Communication - defines access points and network configurations
- Substation - defines the substation equipment and provides coordinates for locating equipment on a Single Line Diagram
- IED - provides the definition of the IED(s) including the Services, Logical Devices, Logical Nodes, DataSets, Report Control Blocks, GOOSE Control Blocks and Sampled Value Control Blocks
- DataType Templates - contains the templates which define common data used within the data model

There are multiple types of SCL files which are used for different applications within the Engineering Process. Each type of SCL file is constructed using the sections defined above, but not all SCL file types contain all five sections (for example, the CID file type does not include a Substation section).

The SCL File types are:

- SSD - System Specification Description.
  Data exchange from a system specification tool to the system configuration tool.
- SED - System Exchange Description.
  Data exchange between system configuration tools of different projects.
- SCD - System Configuration Description.
  Data exchange from the system configuration tool to IED configuration tools.
- ICD - IED Configuration Description.
  Data exchange from the IED configuration tool to the system configuration tool. Defines the IEDs capabilities and Data Model.
- IID - Instantiated IED Description.
  Data exchange from the IED configuration tool to the system configuration tool which contains add-on and/or modified values.
- CID - Configured IED Description.
  Data exchange from the IED configuration tool to the IED.

ERL 61850 IED Configurator supports all of the SCL File types which are directly related to IED configuration (SCD, ICD, IID and CID).

19.3 The Engineering Process

The IEC 61850 standard defines an Engineering Process which is used to manage and implement substation automation. The basic Engineering Process is shown in the diagrams below. For further details, refer to IEC 61850-6 Edition 2.0.

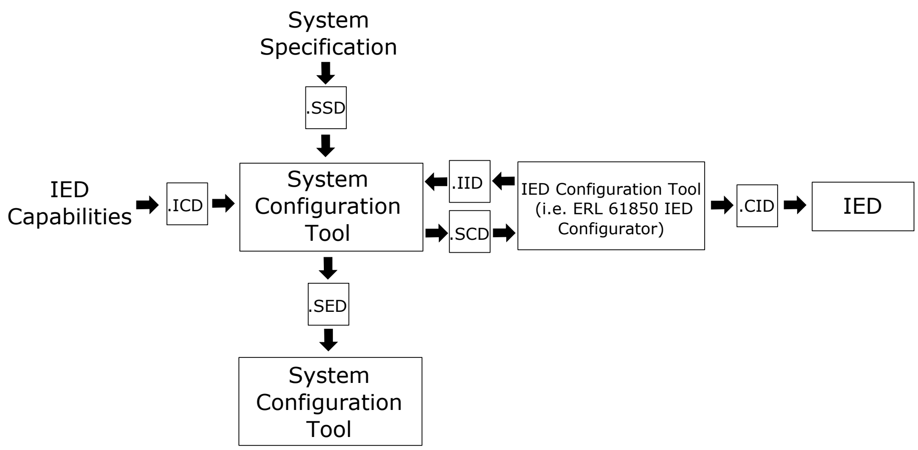


Figure 19.8: The Engineering Process

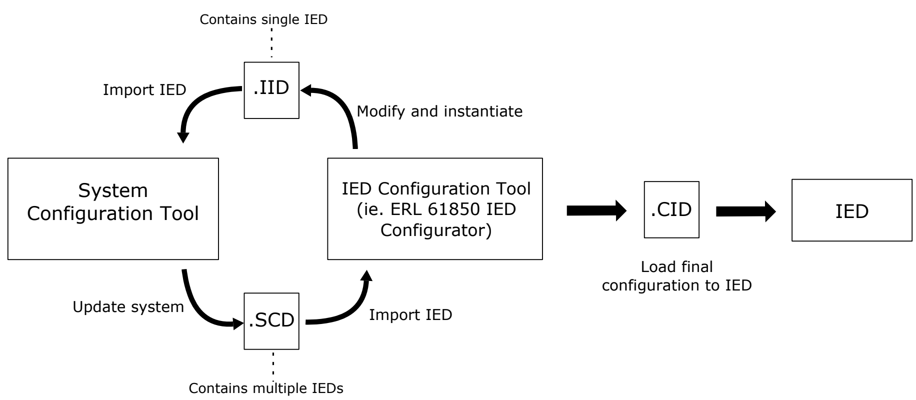


Figure 19.9: Iterations between IED Configuration Tool and System Configuration tool

ERL 61850 IED Configurator supports import and export of CID, ICD, IID and SCD, thus making it compatible with the Engineering Process. Refer to the ERL 61850 IED Configurator user manual for more details.

Note: Importing SCD files which contain mapping to ERL Devices which use IEC 61850 Edition 1.0 is not fully supported and is not recommended. ERL devices which support IEC 61850 Edition 2.0 fully support the SCD import feature and thus are compatible with System Configuration Tools as part of the Engineering Process.

19.4 IEC 61850 Edition 2.0 Implementation

The TESLA 4000-A uses the second edition of the 61850 Standard. Edition 2.0 of the standard provides many new functionalities. The major changes which have been implemented in the TESLA 4000-A from Edition 2.0 of the standard are described below.

Subscription Supervision via LGOS

LGOS has been added in Edition 2.0 to provide the ability to supervise GOOSE subscription statuses. The LGOS LN is used to monitor GOOSE subscriptions.

In order to enable the use of the LGOS subscription supervision, the “GOOSE Subscription Supervision” check-box must be enabled in IEC 61850 IED Configurator (see IEC 61850 IED Configurator User Manual for more details).

One LGOS LN is created for each GOOSE Control Block which the IED subscribes to.

The data objects of the LGOS LN are described in the table below:

Table 19.7: LGOS LN (based on IEC 61850 7-4:2010 5.3.6 (Edition 2.0))

Attribute	Description
NdsCom	Subscription needs commissioning
St	Status of the subscription (True = active, False = not active). If LGOS.St = False, this means that this GOOSE has not been received for 2x Time Allowed to Live.
SimSt	Status showing if simulated messages are received and accepted
LastStNum	Last state number received
ConfRevNum	Expected configuration revision number
GoCBRef	Reference to the subscribed GOOSE control block

Use of Subscription Supervision in the TESLA Event Log

The LGOS logical node are used to indicate GOOSE Communication Alarms in the Event Log. When the LGOS.St attributes transition states, an event is logged into the TESLA event log with the indexed logical node name. This indexed logical node may be used to troubleshoot communication issues.

Note that these messages are only logged into the Event Log if the “GOOSE Subscription Supervision” check-box is enabled in IEC 61850 IED Configurator.

Line	Local Time	UTC Offset	Station Name	Unit ID	Event
9	2019-11-15 13:32:39.000	-06:00		TESLA4005IP73	GOOSE comm. alarm Inactive, src. LGOS6
10	2019-11-15 13:32:39.000	-06:00		TESLA4005IP73	GOOSE comm. alarm Inactive, src. LGOS2
11	2019-11-15 13:32:38.000	-06:00		TESLA4005IP73	GOOSE comm. alarm Active, src. LGOS2
12	2019-11-15 13:32:37.000	-06:00		TESLA4005IP73	GOOSE comm. alarm Active, src. LGOS6
13	2019-11-15 13:31:50.000	-06:00		TESLA4005IP73	SMV comm. alarm Inactive, src. LSVS5

Figure 19.10: LGOS shown in the Event Log

Subscription to *ldname*

There are two Logical Device naming methods (LDName), used for object references, described in IEC 61850-6:2010 Edition 2.0. These methods are:

- Product-related naming
- Function-related naming

In product-related naming, the LDName is comprised of the IED name and the LDevice inst attribute. ERL IEDs only use product-related naming for Logical Device naming. For example, for a TESLA 4000-A with the IED name “MyTESLA”, the LDName for the Recorder LD would be:

LDName = IED name/LDevice inst = **MyTESLA/RCD**

In function-related naming, the LDName is derived from the LDevice *ldName* attribute. For IEDs to support the use of *ldName*, they must support the free setting of the Logical Device names. ERL IEDs do not support free setting of the Logical Device names, and so do not use the *ldName* attribute. However, Edition 2.0 ERL IEDs do support subscribing to data from other vendor's IEDs which use the function-related naming via the *ldName* attribute.

Data from an IED which uses the *ldName* attribute may be mapped to the ERL Edition 2.0 IED for subscription.

Subscription to Fixed-Length GOOSE

In IEC 61850 Edition 2.0, fixed-length encoded GOOSE messages were introduced. This is an optimized version of GOOSE encoding which uses a fixed length offset for each field of the GOOSE packet. If a GOOSE Control Block has the fixedOffs attribute set to True, this indicates that the GOOSE message uses fixed-length encoding.

ERL IEDs do not support publishing the fixed-length encoded GOOSE messages (fixedOffs attribute is always set to False). However, ERL IEDs can subscribe to GOOSE messages from other vendors which use fixed-length encoded GOOSE messages.

The fixed-length GOOSE subscription is backwards compatible, meaning that even ERL devices which use Edition 1.0 of the standard can subscribe to fixed-length GOOSE messages.

GOOSE Publishing

TESLA 4000-A can publish GOOSE on different SubNetworks (network ports). A GOOSE message can be published on one Subnetwork only. GOOSE message Subnetwork is selected in ERL 61850 Configurator, when configuring GOOSE message.

Simulation Mode

TESLA 4000-A supports simulation mode for GOOSE and SMV subscriptions. Simulation Mode is set (on/off) for the entire IED. Simulation mode is controlled via LD0.LPHD1.Sim data object.

LD Mode control hierarchy

LDs are organized in a hierarchy, where LD0 is a parent to all other LDs. Behavior of LNs of all LDs can be controlled by setting appropriately LD0/LLN0.Mod DataObject (Global Mode Control).
In addition to Global Mode Control, SVI (SMV subscription) and DVI (Virtual Inputs subscription) LDs each have a separate Mode Control.
SVI/LLN0.Mod is used to control Mode of all LNs in the SVI LD.
DVI/LLN0.Mod is used to control Mode of all LNs in the DVI LD.

All Mode Controls are implemented as “direct with normal security” controls. A new Mode takes effect immediately upon control command completion.

GOOSE subscription

TESLA invalidates incoming GOOSE data, when DVI LD is in “on” Mode and incoming data quality test bit is set to true. IED allows for incoming messages to contain a mix of valid and invalid data. The invalid data is discarded. The valid is processed.
GOOSE data is always processed in “test”/”test/blocked” Mode regardless of the state of data quality test bit.

Once the incoming GOOSE message is successfully subscribed, the corresponding GOOSE Virtual Input associated events will be shown in the Event log with two designated letter 'L' and 'G' which refers to 'Local' and 'GOOSE' correspondingly. These two events refer to the same subscribed GOOSE operation however indicate with different time stamps. 'G' refers to the remote GOOSE message's time stamp, which came from either the remote publisher GOOSE data item's 't' attributes, or from the GOOSE header time stamp if 't' attribute is not defined in the dataset. 'L' refers to the local subscriber's incoming GOOSE message's local arrived and processed time stamp. In theory, if publisher and subscriber are precisely time synchronized, 'G' time stamp is always earlier than 'L' time stamp to accommodate the signal propagation delay as well as process time. Typically, time difference between 'L' and 'G' for the same operation event is around 2-4ms. If the time difference between the two events are noticeable large or 'L' time stamp is earlier than 'G' time stamp, then publisher and subscriber may face time synchronization issue, this issue may affect proper record trigger in some case.

IED Name Length

Edition 2.0 of the IEC 61850 standard allows for longer IED names. The maximum *IED name* length allowed according to the standard is 64 characters. However, this is limited by the total maximum allowed length for LDName references which is also limited 64 characters. The LDName is defined as *IED name/LDevice inst*. The total *IED name* + *LDevice inst* character count may not exceed 64 characters. This is handled automatically in ERL 61850 IED Configurator. The software ensures that *IED name* length does cause the maximum length for the LDName to be exceeded. For example, if the longest *LDevice* *inst* name is 10 characters long, then *IED name* length is limited to 54 characters, so that *IED name* + *LDevice inst* does not exceed 64 characters.

Common Data Classes

In Edition 2.0 of the IEC 61850 Standard some new Common Data Classes (CDC) were added and others were updated. The only CDC change in Edition 2.0 which affects the TESLA 4000-A implementation is the LLN0.Beh data object uses CDC Type ENS.

Edition 1.0 Compatibility

In general, Edition 1.0 and Edition 2.0 devices are compatible with each other for GOOSE and SMV mapping. However, there are some backward compatibility issues which the user should be aware of before attempting mapping between Edition 1.0 and Edition 2.0 devices.

Mapping Edition 1.0 Data to an Edition 2.0 IED

There are no compatibility issues when mapping data from an Edition 1.0 ERL IED to an Edition 2.0 ERL IED. The Edition 2.0 of the IEC 61850 Standard is designed to handle this forward-compatibility case.

Mapping Edition 2.0 Data to an Edition 1.0 IED

Edition 2.0 of the IEC 61850 introduced some backward-compatibility limitations when mapping to an Edition 1.0 IED. The user should be aware of these limitations before configuring mapping Edition 2.0 data to an Edition 1.0 IED.

In order to map data from an Edition 2.0 IED to an Edition 1 IED, the following restrictions must be followed:

- The IED Name on the Edition 2.0 IED (publisher) must be limited such that *IED Name + Longest LD Inst* does not exceed 32 characters. This restriction is not enforced by ERL IEC 61850 Configurator, it is the responsibility of the user to ensure name length on the Edition 2.0 IED is not too long.
- The Edition 2.0 publisher cannot use function-related naming (i.e. *ldName* attribute). Edition 1.0 does not support the *ldName* attribute. If the Edition 2.0 publisher uses the *ldName* attribute, then its data may not be mapped to an Edition 1.0 ERL IED. ERL 61850 IED Configurator prevents this mapping when attempted by the user. The TESLA 4000-A does not support publishing the *ldName* attribute, so this condition only applies when mapping with third party vendors who support the *ldName* attribute.
- In Edition 2.0 of the standard, new CDCs were introduced which may cause backward-compatibility issues. These new CDCs do not apply to the implementation in the TESLA 4000-A and therefore this should not cause any issues when mapping between ERL Edition 1.0 and 2.0 devices. However, the user should be aware when mapping from other vendor's IEDs that there may be issues if using data from CDCs which are newly introduced in Edition 2.0.

19.5 LD0 Logical Device

LD0 is the Root Logical Device of the TESLA 4000-A data model. The Root Logical Device contains the Physical Device information and it acts as the parent Logical Device of all other Logical Devices.

The LD0 contains the Unit Identification information in the LPHD and LLN0 Logical Nodes (LPHD.PhyNam and LLN0.NamPlt). The table below shows how the Physical Device information stored in the LPHD LN relates to the Unit Identification information displayed in TCP (see “Unit Identification” on page 8-2).

Table 19.8: LD0 and TESLA Control Panel Unit Identification

LD0 Unit Identification	TESLA Control Panel Unit Identification
LPHD.PhyNam.Vendor	*ERLPhase*
LPHD.PhyNam.swRev	IED Firmware Version
LPHD.PhyNam.serNum	Serial Number
LPHD.PhyNam.model	*TESLA 4000-A*
LPHD.PhyNam.location	Location
LPHD.PhyNam.ePSName	Station Name
LPHD.PhyNam.mRID	Unit ID
LLN0.NamPlt.Vendor	*ERLPhase*
LLN0.NamPlt.swRev	IED Firmware Version
LLN0.NamPlt.ConfigRev	Configuration ID

The LD0 LD will serve an increasingly role in future development of the TESLA 4000-A.

19.6 SYS Logical Device

The SYS Logical Device is the System Logical Device of the TESLA 4000-A data model. The SYS LD contains the following information:

- Output Contact status information (OCGGIO LNs)
- Time Synchronization status information (TMSRCLTMS LN)
- Subscription Supervision information (LGOS)
- Physical communication channel supervision (P401LCCH1 to P412LCCH5)

There is one Output Contact LN per Output Contact on the TESLA.

The Time Synchronization LN contains information regarding the active time source on the TESLA.

For more information regarding the Subscription Supervision LNs, refer to “Subscription Supervision via LGOS” on page 19-4.

Each Ethernet Port communication status is supervised by the LN LCCH, its prefix refers to the physical port number. For instance, P401LCCH1 refers to the communication status on the front and rear Port 401, when the data packet is not received within a predefined time interval, its corresponding data attribute ChLiv status will change from true to false. For the IED that supports network redundancy, redundant port 412's status will be shown under P410LCCH3.RedChLiv when the Active Mode is set to PRP profile. When the Active Mode is set to RSTP profile, Port 412's status will be shown under P412LCCH5.ChLiv. The response time of the status change will vary depends on the port as well as received data packet condition. For details, refer to Appendix J.

The data contained within the Logical Nodes in the SYS LD may be added to Datasets for use in Report Control Blocks or GOOSE Control Blocks or may monitored directly via a 61850 client. Refer to the ERL 61850 IED Configurator User Manual for more information regarding configuration of the 61850 services. Refer to For details, refer to Appendix J for more details regarding the SYS LD and it’s associated LNs.

19.7 RCD Logical Device

The RCD Logical Device is the Records Logical Device of the TESLA 4000-A data model. The RCD LD contains all of the information regarding trigger statuses for each of the possible channels in the TESLA setting file:

- Analog channel triggers (ANALOGRADR LNs)
- Sequence channel triggers (SEQRADR LNs)
- Summation channel triggers (SUMRADR LNs)
- Frequency channel triggers (FREQRADR LNs)
- Impedance channel triggers (IMPRADR LNs)
- External input channel triggers (EIRBDR LNs)
- Logic channel triggers (LOGICRBDR LNs)
- Power function channel triggers (PFRADR LNs)
- Watt/Var channel triggers (WVARRADR LNs)
- Fault Recorder status (DFRRDRE LN)

For each possible channel in the TESLA setting file there is one associated LN. Note that this LN always exists in the data model but will only be applicable if there is an associated channel configured in the setting file.

The Fault Recorder status LN (DFRRDRE) contains information about the recording status of the IED including number of records stored, percent of memory used and whether recording is currently in progress.

The data contained within the Logical Nodes in the RCD LD may be added to Datasets for use in Report Control Blocks or GOOSE Control Blocks or may be monitored directly via a 61850 client. Refer to the ERL 61850 IED Configurator User Manual for more information regarding configuration of the 61850 services. Refer to For details, refer to Appendix J for more details regarding the RCD LD and it’s associated LNs.

19.8 MEAS Logical Device

The MEAS Logical Device is the Measurements Logical Device of the TESLA 4000-A data model. The MEAS LD contains all of the information regarding measurement data for each of the possible channels in the TESLA setting file:

- Analog measurement data (ANLMAGMMXN, ANLANGGIO LNs)
- Sequence measurement data (SEQMSQI LNs)
- Summation measurement data (SUMMAGMMXN, SUMANGGIO LNs)
- Frequency measurement data (FREQMMXN LNs)
- Impedance measurement data (IMPMMXN LNs)
- Power factor measurement data (PFMMXN LNs)
- Watt/Var measurement data (WVARMMXN LNs)

For each analog (direct measurement or calculated) channel in the TESLA setting file there is one associated LN. Note that this LN always exists in the data model but will only be applicable if there is an associated channel configured in the setting file. For phasor data (direct analog channels and summation channels) there are two LNs per channel, one for magnitude values and one for angle values.

The data contained within the Logical Nodes in the MEAS LD may be added to Datasets for use in Report Control Blocks or may be monitored directly via a 61850 Client to obtain metered values. Refer to the ERL 61850 IED Configurator User Manual for more information regarding configuration of the 61850 services. Refer to For details, refer to Appendix J for more details regarding the MEAS LD and it's associated LNs.

19.9 FLTL Logical Device

The FLTL Logical Device is the Fault Locator Logical Device of the TESLA 4000-A data model. The FLTL LD contains all of the information regarding the Fault Locator functions in the TESLA setting file. There is one Fault Locator logical node (FLTLOCRFLO LN) per available Fault Locator function.

The Fault Distance and Fault Impedance data is available for each Fault Locator. Note that this LN always exists in the data model but will only be applicable if there is an associated channel configured in the setting file.

The data contained within the Logical Nodes in the FLTL LD may be added to Datasets for use in Report Control Blocks or may be monitored directly via a 61850 Client. Refer to the ERL 61850 IED Configurator User Manual for more information regarding configuration of the 61850 services. Refer to For details, refer to Appendix J for more details regarding the FLTL LD and it's associated LNs.

19.10 DVI Logical Device

The DVI Logical Device is the GOOSE Digital Value Input Logical Device of the TESLA 4000-A data model. The DVI LD is used for subscription to GOOSE data. There is one GOOSE virtual input receptor logical node (VIGGIO LN) per available GOOSE virtual input channel on the TESLA (256). Each LN in the DVI LD acts as an a receiver of a specific data attribute/object contained in a dataset within a GOOSE message. Each of these VIGGIO LNs corresponds to a GOOSE Virtual Input Channel in the TESLA Setting File.

Refer to the ERL 61850 IED Configurator User Manual for more information regarding configuration of the 61850 services and to For details, refer to Appendix J for more details regarding the DVI LD and it's associated LNs.

GOOSE Mapping

In ERL 61850 IED Configurator, data from GOOSE publishers (other IEDs) are mapped to the VIGGIO LNs. There are 256 inputs provided with the TESLA 4000-A. These GOOSE inputs are labeled VI001 - VI256 in the ERL 61850 IED Configurator. See ERL 61850 IED Configurator User Manual for more details on how to perform mapping.

The GOOSE subscription inputs VI001-VI256 correlate to the GOOSE Virtual Input channels 1 to 256 in the Setting File. For example, if GOOSE data is mapped from another IED to input VI004, then in the TESLA's settings, GOOSE Virtual Input channel 4 is configured as the associated channel for this mapping.

The TESLA 4000-A can subscribe to GOOSE data of the following data types:

- Boolean
- Dpos
- Health
- Int32
- Int32u

The data type mapped must match with the Type setting on the GOOSE Virtual Input channel configuration in the TESLA setting file (see “GOOSE Mapping and Channel Assignment” on page 19-14).

> Currently, RecordGraph only supports graphing of Boolean digital channels. For all other types, the channels will not be available to add into digital graphs. However all data types are available for CSV export.

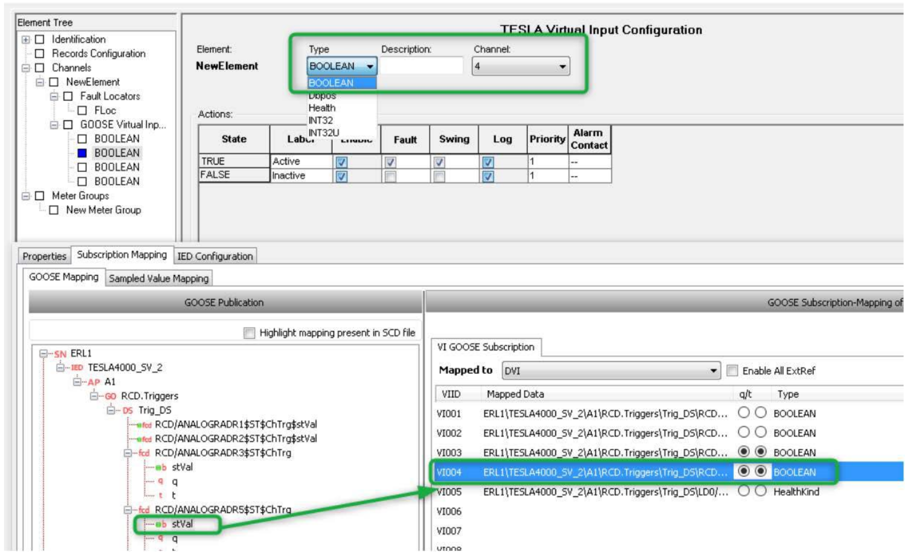


Figure 19.11: GOOSE Mapping and Channel Assignment

20 Data Quality

The TESLA 4000-A receives data from various sources, for example IEC 61850 GOOSE, and it produces and records useful data for user analysis such as records, events and metering. As the TESLA 4000-A is only as reliable as the data it receives and produces, the concept of "data quality" is very important. Data quality allows the user to know if the incoming or outgoing data is trustworthy and aids in troubleshooting of issues. Data quality is a concept introduced in the IEC 61850 standard (refer to IEC61850 standards 61850-7-3 Section 6.2 and 61850-8-1 Section 8.2).

The factors which affect the quality of data produced by the TESLA 4000-A are:

- The quality of the incoming Analog input samples
- The quality of the incoming IEC 61850 GOOSE data
- User operations (i.e. putting the unit into test mode)

The data quality information is displayed to the user clearly in the events, recording (high speed, low speed, trend, CDR), CSV export and metering.

20.1 Data Quality Sources

The factors which affect the quality of data produced by the TESLA 4000-A are:

- The quality of the incoming Analog input samples
- The quality of the incoming IEC 61850 GOOSE data
- User operations (i.e. putting the unit into test mode)

IEC 61850 GOOSE

The TESLA 4000-A uses IEC 61850 GOOSE subscription to acquire status messages from other IEDs. The incoming GOOSE messages contain 16-bits of quality information (if the GOOSE publisher is configured to publish the quality). The data quality of the incoming GOOSE message will be reflected in all associated metering channels and all associated events and recording.

If the subscribed GOOSE message does not include data quality information, the validity of data is handled as "Good".

External Inputs

The External Inputs data quality validity is normally set to "Good", however in cases where grounding issues are present and the External Input is repeatedly changing states (i.e. chattering), the detailed quality bit "oscillatory" will be set to true and the validity will be set to "Invalid".

20.2 Data Quality Display

Data quality is comprised of a 16-bit string which indicates various conditions. The 16 bits are outlined in the table below:

Table 20.9: Data Quality Bits

Bits	Identifier	Value Description
0-1	Validity	00 (GOOD), 01 or 10 (INVALID), 11 (QUESTIONABLE)
2	Overflow	Possible associated validity: Invalid
3	OutofRange	Possible associated validity: Invalid, Questionable
4	BadReference	Possible associated validity: Invalid, Questionable
5	Oscillatory	Possible associated validity: Invalid, Questionable
6	Failure	Possible associated validity: Invalid
7	OldData	Possible associated validity: Questionable
8	Inconsistent	Possible associated validity: Questionable
9	Inaccurate	Possible associated validity: Questionable
10	Substitued	
11	Test	
12	OperatorBlocked	
13	Unused	
14	Unused	
15	Unused	

For example if the following data quality may be observed:

(QUES) 0000 0000 1000 0011

This data quality would refer to data with Questionable validity due to OldData (bits 0,1,7 are high).

This 16 bit string is displayed in the event log, record event summary, trend event summary and CSV exports. It is also available in the CDR records via CSV export.

Appendix A Specifications

TESLA 4000-A Power System Recorder		
Item	**Quantity/Specs**	**Notes**
General		
Overvoltage Category	Overvoltage Category III	
Pollution Degree	Pollution Degree 2	
Insulation Class	Class I	
Ingress Protection	IP30 standard	
Nominal Frequency	50 or 60 Hz	
Power Supply	48 - 250 Vdc, 100 - 240 Vac	Voltage tolerance: AC = +/- 10%, DC =+20%/-10% Maximum current: 0.7 A Maximum Power Consumption: 34 W
Memory	Settings and records are stored in non-volatile memory	Records are stored in a circular buffer
Sample Rate	32, 64, 96, 128, 256, 384 or 512 samples/cycle (s/c)	Frequency response of 8th (32s/c) to the 100th (512 s/c) harmonic of fundamental frequency
Measurement Accuracy	Amplitude Measurement Accuracy: Better than 0.1% of full scale Phase Measurement Accuracy: ±0.1 degrees at system frequency Frequency Measurement Accuracy: ±0.001 Hz at system frequency	
A/D Resolution	16 bits, 65536 counts full scale	
Noise	Signal to Noise ratio: 70dB at full scale Common mode rejection: 70dB at full scale Crosstalk: -07dB	
Temperature	-10°C to 55°C Operating -40°C to 85°C Storage	
Operating Humidity	Up to 95% without condensation	
Channels and Triggers		
Analog Inputs	High and low threshold, positive and negative rate of change, harmonic level, THD level, sags, swells.	All triggers have independent controls for delay, logging, transient or swing record initiation, alarm contact activation and cross triggering.
Summations	High/low threshold, +/- rate of change	1 or 2 or 3 input channels
Positive Sequence	High/low threshold, +/- rate of change	
Negative Sequence	High level	

TESLA 4000-A Power System Recorder

Item	Quantity/Specs	Notes
Zero Sequence	High level	
Watts/Vars	High/low threshold, +/- rate of change	
Frequency	High/low threshold, +/- rate of change	
Impedance	Positive sequence circle with absolute rate of change	
External Inputs (digital)	Rising edge, falling edge or both	
GOOSE Virtual Inputs (digital)	Active, Inactive or both	256 Virtual Inputs available Boolean, Health, Int32, Int32u, Dpos data types supported
Logic	Rising edge, falling edge or both	
Fault Locator	Triggered by internal or external events	
Sags and Swells	Sag and swell detection can be enabled on any voltage analog input channel	
Recording and Logging		
Transient Fault	Record Length 0.2 to 15 seconds, 30 second extended	32, 64, 96, 128, 256, 384 or 512 samples/cycle (s/c) User-configurable prefault length 0 to 8 seconds.
Dynamic Swing	Record length 10 seconds to 15 minutes, 30 minute extended	1 or 2 samples/cycle User-configurable prefault length 0 to 60 seconds.
Trending	User-selectable sampling interval from 10 to 3600 seconds Up to 60 channels can be trended simultaneously The recorder can store 90 days of data from each trend channel	5 accumulation modes – Damped, Undamped, Avg, Min, Max. Each mode is treated as a separate channel. Evaluated phasor magnitude and angle quantities will be recorded as separate channels.
Event Logging	1000 events in the regular log	Up to 1000 events can be stored as a daily trend record
Record Capacity	Standard Capacity with 16GB flash up to 1000 5-second fault records with all 36 channels sampled at 96 samples/cycle or a combination of fault and swing records.	Optional extended storage supports 64 GB and 1 TB which allows more number of HS/LS records and longer CDR retention.
Continuous Disturbance Recording (CDR)		
Continuous Disturbance Recording (CDR)	6 to 60 samples/second at 60Hz or 5 to 50 samples/second at 50 Hz for up to 36 selectable Analog Input channels in the CDR configuration, all the calculated channels including summation channel, sequence channel, watt/var channel, etc. will be derived from the channel settings if available.	Retention period calculation is estimated in CDR configuration, the number of retention days depends on the sample rate and number of channel selection. Please refer to Table 12.2 for calculation example.

TESLA 4000-A Power System Recorder

Item	Quantity/Specs	Notes
Phasor Measurement Unit (PMU)		
Phasor Measurement Unit (PMU)	Up to 36 user-selectable phasors	Single-phase quantities or 3-phase positive, negative or zero sequence phasors/ summated phasors
	1 frequency channel	ROCOF reported based on user-configured frequency channel
	24 analog values	MWatts, MVars MVA, DC value and frequency.
	Up to 64 External Inputs and 256 GOOSE Boolean Virtual Input Status data	Status data reported as 16 bit digital words
Inputs and Outputs		
Remote Analog Inputs	4 input current module, 3 or 4 input voltage module, 3 or 4 input DC isolation module or split-core CTs. See module data sheets for more information.	Modules mount on DINrail (35mm EN50022), up to 1200 meters (4000 feet) away from recorder chassis using twisted/ shielded communication wiring.
Analog Input Channels Ratings	For module specific ratings refer to Table G.2:AC Voltage Input Modules, Table G.4: AC Current Input Modules, and Table G.8: AC/DC Input Model 401016 Module Ratings, Table G.9: AC/DC Input Module (Model 401027) Ratings in Appendix G.	8 or 12 or 18 or 36 per unit* (see table for details), 144 maximum using 4 units in "Cooperative Mode".
External Inputs (digital)	32/64 per unit Burden: 0.03W @ 48Vdc 0.07W @ 125Vdc 0.14W @ 250Vdc 0.17W @ 300Vdc Isolation: Optically Isolated Turn-on voltage: 48 Vdc range = 38 to 40 Vdc 125 Vdc range = 80 to 90 Vdc 250 Vdc range = 165 to 180 Vdc	Optional 48, 110/125 or 220/250 Vdc nominal, externally wetted. Specified voltages are over full ambient temperature range.

TESLA 4000-A Power System Recorder

Item	Quantity/Specs	Notes
Alarm Contacts	8 contacts per unit 300 Vdc max Externally wetted If labelled “trip rated” on rear Make: 30 A per IEEE C37.90 Carry: 8 A for 5 minutes, 6 A for 60 minutes, 4 A continuous Break: 0.9 A at 125 Vdc resistive 0.35 A at 250 Vdc resistive	Contact #1: “Recorder Functional”. Normally closed contact. Opens ~45 seconds after recorder power is applied during the IED boot-up sequence. Closed on failure. Contacts #2 to #8 - Normally Open contacts that close when triggered. Contact #4: Cross trigger contact – Pick-up <10 ms, latch 100 ms User-definable trigger alarm contacts Pick-up <1.0 s, latch 1.0 s when enabled in channel trigger setting; when enabled in Alarms setting, the duration of the latch follows the status of the alarm initiator, the selected Alarm contact will become exclusive when used to any of this settings. All contacts can be active simultaneously.
Virtual Inputs	256 GOOSE Virtual Inputs	
Interface & Communication		
Front Panel Indicators	6 LEDs	Recorder Functional, IRIG-B Functional, Recorder Triggered, Records Stored, Test Mode, Alarm
Front User Interfaces	USB port and 100BASE-T Ethernet port	
Rear Ethernet User Interfaces	LAN Ports: Copper, Optical (ST) style connector or Optical (LC) Style Connector	Copper: RJ-45, 100BASE-T (Port 401, option for Port 410/411/412), 1000BASE-T (Port 402) Optical (ST): 100BASE-FX, Multimode, 1300nm, ST (option for Port 410/411/412) Optical (LC): 100BASE-FX, Multimode, 1310nm, LC (option for Port 410/411/412)
Serial User Interface	Two serial RS-232 ports to 115 kbd	10m Maximum cable length
Internal Modem *Currently Not Used*	38.4 Kbps, V.32 bis	Optional
Configurable Alarms	6 contacts /unit	Normally open
Cross-trigger	1 contact/unit	Normally open
Self Checking/Recorder Inoperative	1 contact (#1)	Normally closed

TESLA 4000-A Power System Recorder

Item	Quantity/Specs	Notes
IRIG Time Sync	1 BNC or pluggable terminal block connector/unit. IEEE Std C37.118-2011 (IRIG Standard 200-04 B004/B005/B124/B125) IEEE Std C37.118-2005 (IRIG Standard 200-04 B004/B005/B124/B125) [1]IEEE Std 1344-1995 (IRIG Standard 200-04 B004/ B005/B124/B125) [1]IRIG Standard 200-04 B000/B001/B002/B003/ B006/B007/B120/B121/B122/B123/B126/B127 [1]May require use of Manual mode to manually set time configuration. See “IRIG-B Signal Interpretation” on page 8-16.	Modulated or unmodulated Input impedance = 680 ohms Leap Second is supported according to IRIG-B time code extensions which is defined in IEEE.C37.118
Physical		
Weight	24lbs	10.89 kg
Dimensions	3U high (5.25"), 19" wide, 12.725" deep	3U high (13.34 cm), 48.26 cm wide, 32.32 cm deep
Mounting	Horizontal rack mount	

TESLA 4000-A Power System Recorder		
Item	**Quantity/Specs**	**Notes**
Time Synchronization		
External Time Source	Synchronized using SNTP, IRIG-B input (modulated or unmodulated) or PTP (IEEE 1588)	Upon the loss of an external time source, the recorder maintains time with a maximum 0.236 seconds drift per year at a constant temperature of 25°C. The recorder can detect loss or re-establishment of external time source and automatically switch between internal and external time.

Type Tests

Test	Description		Test Level
	Type Test	Test Points	
Electromagnetic Compatibility			
CISPR 11 & 32 FCC 15 - ICES 003 IEC 60255-26	Power Line Conducted Emissions	Power ports	Class A
	Radiated Emissions	Enclosure	Class A
IEC 60255-26 IEC 61000-4-2 IEEE C37.90.3	Electro-Static Discharge	Enclosure contact	± 8kV
		Enclosure air	± 15kV
IEC 60255-26 IEC 61000-4-3	Radiated Field Immunity	Enclosure	10V/m: 80 MHz – 1 GHz and 1.4 GHz – 2.7 GHz
IEC 60255-26 IEC 61000-4-4	Electrical Fast Transients (Bursts)	Power ports	±4kV
		Communication ports	±2kV
		I/O ports	±4kV
IEC 60255-26 IEC 61000-4-5	Surge Immunity	DC power ports	±2kV L-L, ±4kV L–G
		Communication ports	±4kV L–G
		I/O ports	±2kV L-L, ±4kV L–G
IEC 60255-26 IEC 61000-4-6	Conducted RF Immunity	Power ports	10 Vrms: 150 kHz – 80 MHz
		Communication ports	10 Vrms: 150 kHz – 80 MHz
		I/O ports	10 Vrms: 150 kHz – 80 MHz
IEC 60255-26 IEC 61000-4-8	Power Frequency Magnetic Field	Enclosure	100 A/m Continuous (60s) 1000 A/m Pulse (3s)
IEC 60255-26 IEC 61000-4-11	AC Voltage Dips and Interrupts	AC power port	100% reduction for 100ms
IEC 60255-26 IEC 61000-4-16	Power Frequency	External Input ports	150Vrms Differential 300Vrms Common
IEC 60255-26 IEC 61000-4-17	AC Ripple on DC Power Port	DC power port	15% of Rated DC Value 100/120 Hz
IEC 60255-26 IEC 61000-4-18	Damped Oscillatory Wave Immunity Test	Power ports	±1kV Differential ±2.5kV Common
		Communication ports	±1kV Common
		I/O ports	±1kV Differential ±2.5kV Common
IEC 60255-26 IEC 61000-4-29	DC Voltage Dips and Interrupts	DC power port	100% for 100ms

Type Tests

Test	Description		Test Level
	Type Test	Test Points	
IEC 60255-26 Clause 7.2.13	Gradual Shutdown/ Start-up	DC power port	Shut-down ramp: 60s Power off: 5min Start-up ramp: 60s
Safety			
IEC 60255-27 Clause 10.6.4.2	HV Impulse	I/O ports and boards	±5kV
		Power ports	±5kV
IEC 60255-27 Clause 10.6.4.3	Dielectric / HiPot	Communication ports	0.5kV
		Power ports	2.2kV (AC)
		I/O ports	2.2kV (AC)
IEC 60255-27 Clause 10.6.4.4	Insulation Resistance	Communication ports	500V (DC)
		Power ports	500V (DC)
		I/O ports	500V (DC)
Environmental Tests			
IEC 60068-2-1	Cold (operating and storage)	Enclosure	-40°C, 16Hrs
IEC 60068-2-2	Hot (operating and storage)	Enclosure	+55°C, 16Hrs
IEC 60068-2-14	Change of Temperature	Enclosure	5 cycles of 1.5hrs at -10°C and 1.5hrs at 60°C
IEC 60068-2-30	Cyclic Temperature with Humidity	Enclosure	6 cycles of: +55°C and 93% rh, 12Hrs +25°C and 95% rh, 12Hrs
IEC 60068-2-78	Damp Heat Steady State	Enclosure	10 days at 40°C, 93% rh
Mechanical			
IEC 60068-2-6 IEC 60255-21-1	Sinusoidal Vibration	Enclosure	Class 1: 1g, 10 Hz to 150 Hz, 20 sweep cycles per axis
IEC 60255-21-3	Earthquake	Enclosure	Class 1: 0.5g X & 1.0g Y, 5 Hz to 35Hz, one sweep cycle per axis
IEC 60068-2-27 IEC 60255-21-2	Shock	Enclosure	Class 1: 15g, 3 pulses per direction per axis
IEC 60068-2-27 IEC 60255-21-2	Bump	Enclosure	Class 1: 10g, 1000 pulses per direction per axis

Appendix B TESLA Hardware Description

Main Processor Board

The Main Processor Board consists of a DSP, a power PC processor, serial ports, Ethernet ports, an IRIG-B processor, a watchdog and a power supply that supplies the other boards. All other boards are connected to the MPB as I/O. The MPB has a socket for an optional internal modem.

External Input Boards #1 and #2

The TESLA has 32 external inputs and 4 contact outputs provided by each External Input Board. Inputs are optically isolated and accept up to 300 Vdc.

Two external input boards combine for a total of 64 external inputs and 8 outputs. Rear panel connection to the board is provided by removable screw terminal strips. Terminal strips are keyed to ensure that the correct terminal strip is installed into the correct bank.

Comm Board

The standard (non-redundant) Comm Board provides the TESLA with two RS-232 ports, IRIG-B time synchronization input, four network ports and a modem port. The RS-232 port is female DB-9 connectors, IRIG-B is a male BNC, the modem jack is an RJ-11 and the network ports are either RJ-45 or ST optical connectors depending on the unit configuration.

The Comm Board, if the hardware supports Network Redundancy, provides the TESLA with one RS-232 port, 8 network ports and an IRIG-B pluggable terminal block. The network ports are a combination of RJ-45 and LC optical connectors. Refer to “Ordering Options and Product Configuration ID” on page 1-6 and “Communication Ports - Redundant Configuration” on page 4-3 for more details. The Comm Board contains the Network Redundancy Module and runs the Network Redundancy Module Firmware.

Power Supply

The Power Supply conditions and converts the input power for use by the internal electronics. The wide input voltage provides the TESLA with the ability to operate from 48 to 250 Vdc +20%/-10% or 100-240 Vac +/-10%.

Storage

Data storage capacity options for the TESLA recorder is a 16GB, 64G, 1TB (order configurable) solid state Flash. If the recorder needs to comply NERC PRC-028-1 requirement then the user shall select 64 GB or 1 TB flash memory option to store more than 20 days of CDR data on to the unit.

Front Panel Board

The Front Panel Board provides visual indication of the status of the TESLA recorder and USB and network ports.

Appendix C Glossary

AC Analog Input	An ac current or voltage that is obtained from a current transformer or a voltage transformer connected to an element on the power system.
AC Analog Summation	Configuration of TESLA allows two AC analog quantities to be summed. For example, currents from two parallel lines can be summed to produce a set of combined currents.
AC Input Module	This device takes in the voltage or current quantities (4 currents or 3 voltages, dependent on model), modifies these input quantities into low level signals that are suitable for input into the TESLA recorder back panel. The conversion ratio is stated on the module. Outputs from these modules can be connected to any of the Analog Input terminals on TESLA
COMTRADE	Common Format for Transient Data Exchange. IEEE standard C37.111-2013/1999/1991, IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, which describes a common format for exchange of recorded power systems data between different manufacturers' recorders.
DC Input Module	An external input module that can be scaled to accept a wide range of voltage or current signals. The model provides galvanic isolation and accepts DC signals or AC signals up to 2 kHz.
DCE	Data Communications Equipment, an RS-232 term for modems and similar equipment. DCEs generally have a female DB connector.
DFT	Discrete Fourier Transform. A mathematical function used in signal processing to transform an input signal in a frequency domain representation.
DST	Daylight Savings Time. A seasonal adjustment of time applied in many jurisdictions to compensate for varying day lengths. Most often, an hour is added to the system time to begin on the second Sunday in March and end the first Sunday in November.
DTE	Data Terminal Equipment, an RS-232 term for a terminal or computer. DTEs generally have a male DB connector.
EIA RS-232C	Electronics Industries Association recommended standard 232, revision C, Interface between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange. Defines the most popular electrical connection for serial binary data interchange, available on almost all computer systems.
Element	A component in the power system that conveys bulk power within the power system. TESLA Control Panel provides for a naming convention that groups real and calculated channels with a given element name. Has three voltages and three currents associated with it. For example, a transmission line, or a transformer.
External Input	A contact status brought into TESLA from the outside world. This contact must be externally wetted with a voltage from 30 to 150 Vdc. Correct polarity must be observed.
GOOSE	Generic Object Oriented Substation Events. A protocol contained within the IEC 61850 standard for communication in substation automation applications.
IEC 61850	A standard developed through the International Electrotechnical Commission related to the architecture of electric power systems, specifically the design of electrical substation automation.
IED	Intelligent Electronic Device, referring to a power system substation device which communications on a substation network, such as Modbus.

IEEE 1344	IEEE 1344 is an enhancement to the basic IRIG-B time code that embeds information such as the year, the UTC/local offset (under certain conditions only) and daylight savings time into the time stream. IEEE standard 1344-95, IEEE Standard for Synchrophasors for Power Systems, outlines the implementation and use of accurate time standards for power systems relaying and recording. Annex F describes an IRIG-B extension (using previously unused control bits in the signal) which provides extensive information beyond that of standard IRIG-B.
IEEE 1588	IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.
IEEE C37.232	An IEEE standard related to the procedure for the naming of Time Sequence Data (TSD) files produced by digital fault recorders in power systems applications.
IEEE C37.238	IEEE Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications
IRIG-B	Inter-Range Instrumentation Group time code format type B, see Range Commanders Council Telecommunications and Timing Group, IRIG standard 200-95, IRIG Serial Time Code Formats. Describes an implementation for distribution of precise timing information, especially to power systems relays and recorders. IRIG-B is typically provided by a satellite clock (e.g. GPS or GOES).
Modbus	Modbus is a network using a master/slave protocol often used in power system substations. Its function was developed and is defined by Modicon, Inc., North Andover, MA, USA. Refer to Modbus Protocol Reference Guide, Modicon document PI-MBUS-300.
PRP	Parallel Redundancy Protocol. A data communications network which allows the system to overcome any single network failure without impacting data transmission through the use of parallel and similar network topologies connected to each node.
PTI	Power Technologies Incorporated
PTP	Precision Time Protocol. A network protocol used for high-accuracy synchronization of devices and equipment to a common, network based time source
RSTP	Rapid Spanning Tree Protocol. A network protocol design to eliminate the negative effect of network loops and introduce redundancy in link connections.
SFP	The small form-factor pluggable (SFP) is a compact, pluggable optical transceiver used for networking applications.
SNTP	Simple Network Time Protocol. A simplified version of Network Time Protocol (NTP) use for synchronizing devices and equipment to a common, network based time source in the form of an SNTP server. SNTP time synchronization is not recommended in application where time accuracy is required.
Trigger	A situation that can initiate a recording.
UTC	Universally Coordinated Time. Approximately equivalent to Greenwich Mean Time (GMT). A universal time maintained by time standards bodies worldwide. All local times are expressed as an offset from UTC.

Appendix D PMU Standards

The PMU functionality in TESLA 4000-A complies with the IEEE C37.118-2005 standards for Synchrophasor for Power Systems and the IEEE C37.118.1a – 2014 standards for Synchrophasor measurements for Power Systems. PMU certification tests were carried out by approved IEEE PMU test lab to determine how close the TESLA 4000-A is with the standard requirements according to IEC/IEEE 60255-118-1:2018 (both P - Class and M – Class). The following tables shows the compliance of the TESLA 4000-A with the standards.

D.1 IEEE C37.118 – 2005 Standards

Table D.1: PMU Standards and test results – Level 1

Influence Quantity	Reference Conditions	Range of influence quantity change with respect to reference and maximum allowable TVE in percent (%) for each compliance level		
		Level 1		
		Range	TVE (%)	
			Std. Requirements	Results 50/60Hz
Signal Frequency	$F_{nominal}$	±5Hz	**1.0**	**0.257/0.317**
Signal Magnitude	100% rated	10.0% to 120% rated	**1.0**	**0.653-0.069/ 0.725-0.083**
Phase angle	0 radians	±π radians	**1.0**	**0.09/0.17**
Harmonic Distortion	<0.2% of (THD)	10.0%, any harmonic up to 50^{th}	**1.0**	**0.08/0.015**
Out-of-band interfering signal, at frequency f_i where $\mid f_i - f_o \mid > F_s/2$, F_s = Phasor reporting rate $F_o = F_{nominal}$	<0.2%of input signal magnitude	10.0% of input signal magnitude	**1.0**	**0.625/0.544**

D.2 IEC/IEEE 60255-11-1: 2018 (Superseded IEEE C37.118.1-2011 and IEEE C37.118.1a-2014)

The subsequent tables present the PMU performance of TESLA 4000-A with the PMU reporting rates of 50 fps at a system frequency of 50Hz, and 60 fps at a system frequency of 60Hz.

Table D.2 Steady-state synchrophasor measurement standard requirements and test results

Influence quantity	Reference condition	Minimum range of influence quantity over which PMU shall be within given TVE limit					
		Performance – P class			Performance – M class		
		Range	Max. TVE %		Range	Max. TVE %	
			Std. Requirements	Results 50/60Hz		Std. Requirements	Results 50/60Hz
Signal Frequency	Frequency = f_0 ($f_{nominal}$)	±2.0 Hz	**1**	**V (0.19) A (0.53)/ V (0.17) A (0.18)**	±2.0 Hz for F_s< 10 ±F_s/5 for $10 \leq F_s < 25$ ± 5.0 Hz for $F_s \geq 25$	**1**	**V (0.40) A (0.77)/ V (0.36) A (0.39)**
Voltage signal magnitude	100% rated	80 % – 120 % rated	**1**	**0.03/0.06**	10 % – 120 % rated	**1**	**0.63/0.57**
Current signal magnitude	100% rated	10 % – 200 % rated	**1**	**0.90/0.73**	10 % – 200 % rated	**1**	**0.88/0.76**
Harmonic distortion (single harmonic)	< 0.2% (THD)	1 %. each harmonic up to 50th	**1**	**V(0.03) A(0.48)/ V(0.07) A(0.23)**	10% each harmonic up to 50th	**1**	**V(0.06) A(0.51)/ V(0.07) A(0.15)**
Out of band interference	< 0.2% of input signal magnitude		**None**	**None**	10% of input signal magnitude for F_s ≥ 10. No requirement for F_s < 10.	**1.3**	**V(0.29) A(0.60)/ V(0.26) A(0.32)**

Table D.3: Steady-state frequency and ROCOF measurement requirements and test results									
Influence quantity	**Reference condition**	**Error requirements for compliance**							
		P class				**M class**			
Signal frequency	Frequency = $f0$ ($f$nominal) Phase angle constant	Range: $f0$ ± 2.0 Hz				Range: $f0$ ± 2.0 Hz for Fs ≤ 10 ± Fs/5 for 10 ≤ Fs < 25 ± 5.0 Hz for Fs ≥ 25			
		Max. |FE|		**Max. |RFE|**		**Max. |FE|**		**Max. |RFE|**	
		Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz
		0.005 Hz	**0.0022/ 0.0016**	**0.4 Hz/s**	**0.085/ 0.101**	**0.005 Hz**	**0.0042/ 0.0040**	**0.1 Hz/s**	**0.038/ 0.039**
Harmonic distortion (single harmonic)	< 0.2 % THD	Range:1 %. each harmonic up to 50th				Range:10 %. each harmonic up to 50th			
	Fs > 20	**0.005 Hz**	**0.0004/ 0.0006**	**0.4 Hz/s**	**0.042/ 0.068**	**0.025 Hz**	**0.0010/ 0.0029**	**Not required**	**-**
	Fs ≤ 20	**0.005 Hz**	**-**	**0.4 Hz/s**	**-**	**0.005 Hz**	**-**	**Not required**	**-**
Out-of-band interference	< 0.2 % of input signal magnitude	Range: No requirements				Range: Interfering signal 10 % of signal magnitude			
		Not required	**-**	**Not required**	**-**	**0.01 Hz**	**0.0094/ 0.0094**	**Not required**	**-**

Table D.4: Synchrophasor measurement bandwidth requirements and test results using modulated test signals							
Modulation level	Reference condition	Minimum range of influence quantity over which PMU shall be within given TVE limit					
		P class			M class		
		Range	Max. TVE		Range	Max. TVE	
			Std. requirements	Results 50/60Hz		Std. requirements	Results 50/60Hz
*k*x = 0.1. *k*a = 0	100 % rated signal magnitude. *f*nominal	Modulation frequency 0.1 to lesser of *F*s/10 or 2 Hz	**3 %**	**V(0.08) A(0.51)/ V(0.11) A(0.29)**	Modulation frequency 0.1 to lesser of *F*s/ 5 or 5 Hz	**3 %**	**V(0.16) A(0.58)/ V(0.16) A(0.15)**
*k*x = 0. *k*a = 0.1	100 % rated signal magnitude. *f*nominal		**3 %**	**V(0.07) A(0.48)/ V(0.08) A(0.24)**		**3 %**	**V(0.08) A(0.49)/ V(0.08) A(0.12)**

Table D.5: Frequency and ROCOF performance requirements and test results under modulation tests										
Frequency and ROCOF performance limits	Error requirements for compliance									
	P class					M class				
Reporting rate *F*s Hz	*F*r Hz	Max. |FE|		Max. |RFE|		*F*r Hz	Max. |FE|		Max. |RFE|	
		Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz		Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz
50	2	**0.06**	**0.0136**	**2.3**	**0.336**	5	**0.30**	**0.0813**	**14**	**5.014**
60	2	**0.06**	**0.0113**	**2.3**	**0.307**	5	**0.30**	**0.0681**	**14**	**4.098**
Formulas	min (*F*s/ 10.2)	0.03 × *F*r		0.18 × π × *F*r2		min (*F*s/ 5.5)	0.06 × *F*r		0.18 × π × *F*r2	

Table D.6: Synchrophasor performance requirements and test results under frequency ramp tests							
Test signal	**Reference condition**	**Influence quantity test limits over which PMU shall be within given TVE limit**					
		Ramp rate (Rf) (positive and negative ramp)	**Performance class**	**Exclusion interval**	**Ramp range**	**Max. TVE**	
						Std. requirements	**Results 50/60Hz**
Linear frequency ramp	100 % rated signal magnitude, and fnominal at a non-excluded point during the test	±1.0 Hz/s	P class	Larger of 2/Fs or 2/f0	±2 Hz	**1 %**	**V(0.2) A(0.56)/ V(0.19) A(0.33)**
			M class	Larger of 7/Fs or 7/f0	Lesser of ±(Fs / 5) Hz or ±5 Hzb	**1 %**	**V(0.38) A(0.72)/ V(0.34) A(0.35)**

Table D.7: Frequency and ROCOF performance requirements and test results under frequency ramp tests										
Signal specification	**Reference condition**	**Exclusion interval**	**Error requirements for compliance**							
Ramp tests – Linear frequency ramp	100 % rated signal magnitude and 0 radian base angle	Same as specified in Table 6	**P class**				**M class**			
			Max. |FE|		**Max. |RFE|**		**Max. |FE|**		**Max. |RFE|**	
			Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz
			0.01 Hz	**0.007/ 0.0057**	**0.4 Hz/s**	**0.060/ 0.072**	**0.01 Hz**	**0.0093/ 0.0081**	**0.2 Hz/s**	**0.036/ 0.039**

Table D.8: Phasor performance requirements and test results for input step change

Step change spec.	Ref. condition	Maximum response time. delay time. and overshoot											
		P class						M class					
		Response time s		|Delay time|		Max. Overshoot/ undershoot		Response time s		|Delay time|		Max. overshoot/ undershoot	
		Std. requirements	Results 50/ 60Hz	Std. requirements	Results 50/ 60Hz	Std. requirements	Results 50/ 60Hz	Std. requirements	Results 50/ 60Hz	Std. requirements	Results 50/ 60Hz	Std. requirements	Results 50/ 60Hz
Magnitude = ±10%. kx = ±0.1. ka = 0	All test conditions nominal at start or end of step	**2/*f*0**	**V(0.024) A(0.024) / V(0.020) A(0.019)**	**1/(4 × Fs)**	**V(0.0017) A(0.0017) / V(0.0014) A(0.0014)**	**5 % of step magnitude**	**V(0.48) A(0.45)/ V(0.45) A(0.49)**	**Larger of 7/Fs or 7/f0**	**V(0.031) A(0.057) / V(0.029) A(0.029)**	**1/(4 × Fs)**	**V(0.0018) A(0.0018) / V(0.0015) A(0.0016**	**10 % of step magnitude**	**V(6.36) A(6.34)/ V(6.38) A(6.49)**
Angle ±10°. kx = 0. ka = ±π/18	All test conditions nominal at start or end of step	**2/*f*0**	**V(0.029) A(0.030) / V(0.024) A(0.024)**	**1/(4 × Fs)**	**V(0.0012) A(0.0012) / V(0.0010) A(0.0010)**	**5 % of step magnitude**	**V(0.73) A(0.74)/ V(0.76) A(0.85)**	**Larger of 7/Fs or 7/*f*0**	**V(0.074) A(0.077) / V(0.070) A(0.070)**	**1/(4 × Fs)**	**V(0.0010) A(0.0010) / V(0.0008) A(0.0008)**	**10 % of step magnitude**	**V(6.58) A(6.48)/ V(6.50) A(6.51)**

Table D.9: Frequency and ROCOF performance requirements and test results for input step change

Signal specification	Reference condition	Maximum susceptibility response time							
		P class				M class			
		Frequency response time		ROCOF response time		Frequency response time		ROCOF response time	
		Std. requirements	Results 50/60Hz	Std. requirements	Results 50/ 60Hz	Std. requirements	Results 50/60Hz	Std. requirements	Results 50/60Hz
Magnitude test as in Table D.8	Same as in Table D.8	**4.5/*f*0**	**0.045/ 0.038**	**6/*f*0**	**0.055/ 0.047**	**Greater of 14/Fs or 14/*f*0**	**0.120/ 0.111**	**Greater of 14/ Fs or 14/*f*0**	**0.193/ 0.183**
Phase test as in Table D.8	Same as in Table D.8	**4.5/*f*0**	**0.086/ 0.039**	**6/*f*0**	**0.017/ 0.048**	**Greater of 14/Fs or 14/f0**	**0.178/ 0.167**	**Greater of 14/ Fs or 14/*f*0**	**0.195/ 0.187**

Table D.10: PMU reporting latency and test requirements		
Performance class	**Maximum PMU reporting latency (s)**	
	Std. requirements	Results 50/60Hz
P class	**Greater of 2/F_S or 2/f_0**	34 ms (for 50 Hz, 50fps) 19 ms (for 60 Hz, 60 fps)
M class	**Greater of 7/F_S or 7/f_0**	103 ms (for 50 Hz, 50fps) 114 ms (for 60 Hz, 60 fps)
Note: Latency is limited by the need to include at least one cycle of the power system waveform for synchrophasor calculation.		

Appendix E Modbus Functions

The TESLA recorder operates as a slave device on the Modbus network, with an address of 1 to 247 (decimal), 0x01 to 0xF7. The Point List can be printed through TESLA Control Panel to display the point names as they are configured. Please refer to “Printing a DNP Point List” on page 9-64.

For further information on Modbus, please refer to your Modbus master device manual, or obtain Modicon’s *Modbus Protocol Reference Guide*, document PI-MBUS-300.

Read Coil Status (Function Code 01, 0X References)			
Channel	**Address**	**Value**	
Hold Readings	00001	0: Readings not held	1:Readings held
Reserved	00257	Reserved	
Contact 2	00513	0: Contact open (inactive)	1: Contact closed (active)
Contact 3	00514	0: Contact open (inactive)	1: Contact closed (active)
Contact 4	00515	0: Contact open (inactive)	1: Contact closed (active)
Contact 5	00516	0: Contact open (inactive)	1: Contact closed (active)
Contact 6	00517	0: Contact open (inactive)	1: Contact closed (active)
Contact 7	00518	0: Contact open (inactive)	1: Contact closed (active)
Contact 8	00519	0: Contact open (inactive)	1: Contact closed (active)
Logic Detector 1	00769	0: Off (inactive)	1: On (active)
Logic Detector 2	00770	0: Off (inactive)	1: On (active)
Logic Detector 3	00771	0: Off (inactive)	1: On (active)
Logic Detector 4	00772	0: Off (inactive)	1: On (active)
Logic Detector 5	00773	0: Off (inactive)	1: On (active)
Logic Detector 6	00774	0: Off (inactive)	1: On (active)
Logic Detector 7	00775	0: Off (inactive)	1: On (active)
Logic Detector 8	00776	0: Off (inactive)	1: On (active)
Logic Detector 9	00777	0: Off (inactive)	1: On (active)
Logic Detector 10	00778	0: Off (inactive)	1: On (active)
Logic Detector 11	00779	0: Off (inactive)	1: On (active)
Logic Detector 12	00780	0: Off (inactive)	1: On (active)
Logic Detector 13	00781	0: Off (inactive)	1: On (active)
Logic Detector 14	00782	0: Off (inactive)	1: On (active)
Logic Detector 15	00783	0: Off (inactive)	1: On (active)
Logic Detector 16	00784	0: Off (inactive)	1: On (active)
Logic Detector 17	00785	0: Off (inactive)	1: On (active)
Logic Detector 18	00786	0: Off (inactive)	1: On (active)
Logic Detector 19	00787	0: Off (inactive)	1: On (active)

Logic Detector 20	00788	0: Off (inactive)	1: On (active)
Logic Detector 21	00789	0: Off (inactive)	1: On (active)
Logic Detector 22	00790	0: Off (inactive)	1: On (active)
Logic Detector 23	00791	0: Off (inactive)	1: On (active)
Logic Detector 24	00792	0: Off (inactive)	1: On (active)
Logic Detector 25	00793	0: Off (inactive)	1: On (active)
Logic Detector 26	00794	0: Off (inactive)	1: On (active)
Logic Detector 27	00795	0: Off (inactive)	1: On (active)
Logic Detector 28	00796	0: Off (inactive)	1: On (active)
Logic Detector 29	00797	0: Off (inactive)	1: On (active)
Logic Detector 30	00798	0: Off (inactive)	1: On (active)
High/low speed recording active	01025	0: Off (inactive)	1: On (active)
High/low speed recording space nearly full alarm	01026	0: Off (inactive)	1: On (active)
Trend Recording Active	01281	0: Off (inactive)	1: On (active)
Trend Recording Accumulation Alarm	01282	0: Off (inactive)	1: On (active)

Read Input Status (Function Code 02, 1X References)			
Channel	**Address**	**Value**	
External I/P 1	10001	0: Off (inactive)	1: On (active)
External I/P 2	10002	0: Off (inactive)	1: On (active)
External I/P 3	10003	0: Off (inactive)	1: On (active)
External I/P 4	10004	0: Off (inactive)	1: On (active)
External I/P 5	10005	0: Off (inactive)	1: On (active)
External I/P 6	10006	0: Off (inactive)	1: On (active)
External I/P 7	10007	0: Off (inactive)	1: On (active)
External I/P 8	10008	0: Off (inactive)	1: On (active)
External I/P 9	10009	0: Off (inactive)	1: On (active)
External I/P 10	10010	0: Off (inactive)	1: On (active)
External I/P 11	10011	0: Off (inactive)	1: On (active)
External I/P 12	10012	0: Off (inactive)	1: On (active)
External I/P 13	10013	0: Off (inactive)	1: On (active)
External I/P 14	10014	0: Off (inactive)	1: On (active)
External I/P 15	10015	0: Off (inactive)	1: On (active)
External I/P 16	10016	0: Off (inactive)	1: On (active)
External I/P 17	10017	0: Off (inactive)	1: On (active)
External I/P 18	10018	0: Off (inactive)	1: On (active)
External I/P 19	10019	0: Off (inactive)	1: On (active)

External I/P 20	10020	0: Off (inactive)	1: On (active)
External I/P 21	10021	0: Off (inactive)	1: On (active)
External I/P 22	10022	0: Off (inactive)	1: On (active)
External I/P 23	10023	0: Off (inactive)	1: On (active)
External I/P 24	10024	0: Off (inactive)	1: On (active)
External I/P 25	10025	0: Off (inactive)	1: On (active)
External I/P 26	10026	0: Off (inactive)	1: On (active)
External I/P 27	10027	0: Off (inactive)	1: On (active)
External I/P 28	10028	0: Off (inactive)	1: On (active)
External I/P 29	10029	0: Off (inactive)	1: On (active)
External I/P 30	10030	0: Off (inactive)	1: On (active)
External I/P 31	10031	0: Off (inactive)	1: On (active)
External I/P 32	10032	0: Off (inactive)	1: On (active)
External I/P33	10033	0: Off (inactive)	1: On (active)
External I/P 34	10034	0: Off (inactive)	1: On (active)
External I/P 35	10035	0: Off (inactive)	1: On (active)
External I/P 36	10036	0: Off (inactive)	1: On (active)
External I/P 37	10037	0: Off (inactive)	1: On (active)
External I/P 38	10038	0: Off (inactive)	1: On (active)
External I/P 39	10039	0: Off (inactive)	1: On (active)
External I/P 40	10040	0: Off (inactive)	1: On (active)
External I/P 41	10041	0: Off (inactive)	1: On (active)
External I/P 42	10042	0: Off (inactive)	1: On (active)
External I/P 43	10043	0: Off (inactive)	1: On (active)
External I/P 44	10044	0: Off (inactive)	1: On (active)
External I/P 45	10045	0: Off (inactive)	1: On (active)
External I/P 46	10046	0: Off (inactive)	1: On (active)
External I/P 47	10047	0: Off (inactive)	1: On (active)
External I/P 48	10048	0: Off (inactive)	1: On (active)
External I/P 49	10049	0: Off (inactive)	1: On (active)
External I/P 50	10050	0: Off (inactive)	1: On (active)
External I/P 51	10051	0: Off (inactive)	1: On (active)
External I/P 52	10052	0: Off (inactive)	1: On (active)
External I/P 53	10053	0: Off (inactive)	1: On (active)
External I/P 54	10054	0: Off (inactive)	1: On (active)
External I/P 55	10055	0: Off (inactive)	1: On (active)
External I/P 56	10056	0: Off (inactive)	1: On (active)
External I/P 57	10057	0: Off (inactive)	1: On (active)
External I/P 58	10058	0: Off (inactive)	1: On (active)
External I/P 59	10059	0: Off (inactive)	1: On (active)

External I/P 60	10060	0: Off (inactive)	1: On (active)
External I/P 61	10061	0: Off (inactive)	1: On (active)
External I/P 62	10062	0: Off (inactive)	1: On (active)
External I/P 63	10063	0: Off (inactive)	1: On (active)
External I/P 64	10064	0: Off (inactive)	1: On (active)
External I/P1 Change latch	10257	0: Off (no change)	1: On (change)
External I/P 2 Change latch	10258	0: Off (no change)	1: On (change)
External I/P 3 Change latch	10259	0: Off (no change)	1: On (change)
External I/P 4 Change latch	10260	0: Off (no change)	1: On (change)
External I/P 5 Change latch	10261	0: Off (no change)	1: On (change)
External I/P 6 Change latch	10262	0: Off (no change)	1: On (change)
External I/P 7 Change latch	10263	0: Off (no change)	1: On (change)
External I/P 8 Change latch	10264	0: Off (no change)	1: On (change)
External I/P 9 Change latch	10265	0: Off (no change)	1: On (change)
External I/P 10 Change latch	10266	0: Off (no change)	1: On (change)
External I/P 11Change latch	10267	0: Off (no change)	1: On (change)
External I/P 12 Change latch	10268	0: Off (no change)	1: On (change)
External I/P 13 Change latch	10269	0: Off (no change)	1: On (change)
External I/P 14 Change latch	10270	0: Off (no change)	1: On (change)
External I/P 15 Change latch	10271	0: Off (no change)	1: On (change)
External I/P 16 Change latch	10272	0: Off (no change)	1: On (change)
External I/P 17 Change latch	10273	0: Off (no change)	1: On (change)
External I/P 18 Change latch	10274	0: Off (no change)	1: On (change)
External I/P 19 Change latch	10275	0: Off (no change)	1: On (change)
External I/P 20 Change latch	10276	0: Off (no change)	1: On (change)
External I/P 21 Change latch	10277	0: Off (no change)	1: On (change)
External I/P 22 Change latch	10278	0: Off (no change)	1: On (change)
External I/P 23 Change latch	10279	0: Off (no change)	1: On (change)
External I/P 24 Change latch	10280	0: Off (no change)	1: On (change)
External I/P 25 Change latch	10281	0: Off (no change)	1: On (change)
External I/P 26 Change latch	10282	0: Off (no change)	1: On (change)
External I/P 27 Change latch	10283	0: Off (no change)	1: On (change)
External I/P 28 Change latch	10284	0: Off (no change)	1: On (change)
External I/P 29 Change latch	10285	0: Off (no change)	1: On (change)
External I/P 30 Change latch	10286	0: Off (no change)	1: On (change)
External I/P 31 Change latch	10287	0: Off (no change)	1: On (change)
External I/P 32 Change latch	10288	0: Off (no change)	1: On (change)
External I/P 33 Change latch	10289	0: Off (no change)	1: On (change)
External I/P 34 Change latch	10290	0: Off (no change)	1: On (change)
External I/P 35 Change latch	10291	0: Off (no change)	1: On (change)

External I/P 36 Change latch	10292	0: Off (no change)	1: On (change)
External I/P 37 Change latch	10293	0: Off (no change)	1: On (change)
External I/P 38 Change latch	10294	0: Off (no change)	1: On (change)
External I/P 39 Change latch	10295	0: Off (no change)	1: On (change)
External I/P 40 Change latch	10296	0: Off (no change)	1: On (change)
External I/P 41 Change latch	10297	0: Off (no change)	1: On (change)
External I/P 42 Change latch	10298	0: Off (no change)	1: On (change)
External I/P 43 Change latch	10299	0: Off (no change)	1: On (change)
External I/P 44 Change latch	10300	0: Off (no change)	1: On (change)
External I/P 45 Change latch	10301	0: Off (no change)	1: On (change)
External I/P 46 Change latch	10302	0: Off (no change)	1: On (change)
External I/P 47 Change latch	10303	0: Off (no change)	1: On (change)
External I/P 48 Change latch	10304	0: Off (no change)	1: On (change)
External I/P 49 Change latch	10305	0: Off (no change)	1: On (change)
External I/P 50 Change latch	10306	0: Off (no change)	1: On (change)
External I/P 51 Change latch	10307	0: Off (no change)	1: On (change)
External I/P 52 Change latch	10308	0: Off (no change)	1: On (change)
External I/P 53 Change latch	10309	0: Off (no change)	1: On (change)
External I/P 54 Change latch	10310	0: Off (no change)	1: On (change)
External I/P 55 Change latch	10311	0: Off (no change)	1: On (change)
External I/P 56 Change latch	10312	0: Off (no change)	1: On (change)
External I/P 57 Change latch	10313	0: Off (no change)	1: On (change)
External I/P 58 Change latch	10314	0: Off (no change)	1: On (change)
External I/P 59 Change latch	10315	0: Off (no change)	1: On (change)
External I/P 60 Change latch	10316	0: Off (no change)	1: On (change)
External I/P 61 Change latch	10317	0: Off (no change)	1: On (change)
External I/P 62 Change latch	10318	0: Off (no change)	1: On (change)
External I/P 63 Change latch	10319	0: Off (no change)	1: On (change)
External I/P 64 Change latch	10320	0: Off (no change)	1: On (change)

Read Holding Register (Function Code 03, 4X References			
Channel	**Address**	**Value**	**Scaled up by**
TESLA Clock Time (UTC). Read all in same query to ensure consistent time reading data			
Milliseconds Now * Millisecond information not supported.	40001	0	1
Seconds Now	40002	0-59	1
Minutes Now	40003	0-59	1
Hours Now	40004	0-23	1

Day of Year Now	40005	1-365 (up to 366 if leap year)	1
Years since 1900	40006	90-137	1
Sync'd to IRIG-B	40007	0: No, 1: Yes	1
Time of Acquisition (UTC). Read all in same query to ensure consistent time reading data			
Milliseconds Acquisition * Millisecond information not supported.	40008	0	1
Seconds Acquisition	40009	0-59	1
Minutes Acquisition	40010	0-59	1
Hours Acquisition	40011	0-23	1
Day of Year Acquisition	40012	1-365 (up to 366 if leap year)	1
Years since 1900	40013	90-137	1
Acquisition Time Sync'd to IRIG-B	40014	0: No 1: Yes	1
Offset of UTC to IED Local Time	40015	2's complement half hours, North America is negative	1

Analog Magnitude and Angle Metering Channels			
Channel	**Address**	**Value**	**Scaled up by**
AI1 Magnitude	40257	0 to 3276.7 units	10
AI1 Angle	40258	-180° to 180°	10
AI2 Magnitude	40259	0 to 3276.7 units	10
AI2 Angle	40260	-180° to 180°	10
AI3 Magnitude	40261	0 to 3276.7 units	10
AI3 Angle	40262	-180° to 180°	10
AI4 Magnitude	40263	0 to 3276.7 units	10
AI4 Angle	40264	-180° to 180°	10
AI5 Magnitude	40265	0 to 3276.7 units	10
AI5 Angle	40266	-180° to 180°	10
AI6 Magnitude	40267	0 to 3276.7 units	10
AI6 Angle	40268	-180° to 180°	10
AI7 Magnitude	40269	0 to 3276.7 units	10
AI7 Angle	40270	-180° to 180°	10
AI8 Magnitude	40271	0 to 3276.7 units	10
AI8 Angle	40272	-180° to 180°	10
AI9 Magnitude	40273	0 to 3276.7 units	10
AI9 Angle	40274	-180° to 180°	10
AI10 Magnitude	40275	0 to 3276.7 units	10
AI10 Angle	40276	-180° to 180°	10
AI11 Magnitude	40277	0 to 3276.7 units	10
AI11 Angle	40278	-180° to 180°	10

AI12 Magnitude	40279	0 to 3276.7 units	10
AI12 Angle	40280	-180° to 180°	10
AI13 Magnitude	40281	0 to 3276.7 units	10
AI13 Angle	40282	-180° to 180°	10
AI14 Magnitude	40283	0 to 3276.7 units	10
AI14 Angle	40284	-180° to 180°	10
AI15 Magnitude	40285	0 to 3276.7 units	10
AI15 Angle	40286	-180° to 180°	10
AI16 Magnitude	40287	0 to 3276.7 units	10
AI16 Angle	40288	-180° to 180°	10
AI17 Magnitude	40289	0 to 3276.7 units	10
AI17 Angle	40290	-180° to 180°	10
AI18 Magnitude	40291	0 to 3276.7 units	10
AI18 Angle	40292	-180° to 180°	10
AI19 Magnitude	40293	0 to 3276.7 units	10
AI19 Angle	40294	-180° to 180°	10
AI20 Magnitude	40295	0 to 3276.7 units	10
AI20 Angle	40296	-180° to 180°	10
AI21 Magnitude	40297	0 to 3276.7 units	10
AI21 Angle	40298	-180° to 180°	10
AI22 Magnitude	40299	0 to 3276.7 units	10
AI22 Angle	40300	-180° to 180°	10
AI23 Magnitude	40301	0 to 3276.7 units	10
AI23Angle	40302	-180° to 180°	10
AI24 Magnitude	40303	0 to 3276.7 units	10
AI24 Angle	40304	-180° to 180°	10
AI25 Magnitude	40305	0 to 3276.7 units	10
AI25 Angle	40306	-180° to 180°	10
AI26 Magnitude	40307	0 to 3276.7 units	10
AI26 Angle	40308	-180° to 180°	10
AI27 Magnitude	40309	0 to 3276.7 units	10
AI27 Angle	40310	-180° to 180°	10
AI28 Magnitude	40311	0 to 3276.7 units	10
AI28 Angle	40312	-180° to 180°	10
AI29 Magnitude	40313	0 to 3276.7 units	10
AI29 Angle	40314	-180° to 180°	10
AI30 Magnitude	40315	0 to 3276.7 units	10
AI30 Angle	40316	-180° to 180°	10
AI31 Magnitude	40317	0 to 3276.7 units	10
AI31 Angle	40318	-180° to 180°	10

AI32 Magnitude	40319	0 to 3276.7 units	10
AI32 Angle	40320	-180° to 180°	10
AI33 Magnitude	40321	0 to 3276.7 units	10
AI33 Angle	40322	-180° to 180°	10
AI34 Magnitude	40323	0 to 3276.7 units	10
AI34 Angle	40324	-180° to 180°	10
AI35 Magnitude	40325	0 to 3276.7 units	10
AI35 Angle	40326	-180° to 180°	10
AI36 Magnitude	40327	0 to 3276.7 units	10
AI36 Angle	40328	-180° to 180°	10
Total Harmonic Distortion, Single Harmonic Level, DC Metering Channels			
* not supported yet			
AI1 THD	40513	0 to 327.67%	100
AI1 SHL	40514	0 to 327.67%	100
AI1 DC*	40515	-3276.8 to 3276.7 units	10
AI2 THD	40516	0 to 327.67%	100
AI2 SHL	40517	0 to 327.67%	100
AI2 DC*	40518	-3276.8 to 3276.7 units	10
AI3 THD	40519	0 to 327.67%	100
AI3 SHL	40520	0 to 327.67%	100
AI3 DC*	40521	-3276.8 to 3276.7 units	10
AI4 THD	40522	0 to 327.67%	100
AI4 SHL	40523	0 to 327.67%	100
AI4 DC*	40524	-3276.8 to 3276.7 units	10
AI5 THD	40525	0 to 327.67%	100
AI5 SHL	40526	0 to 327.67%	100
AI5 DC*	40527	-3276.8 to 3276.7 units	10
AI6 THD	40528	0 to 327.67%	100
AI6 SHL	40529	0 to 327.67%	100
AI6 DC*	40530	-3276.8 to 3276.7 units	10
AI7 THD	40531	0 to 327.67%	100
AI7 SHL	40532	0 to 327.67%	100
AI7 DC*	40533	-3276.8 to 3276.7 units	10
AI8 THD	40534	0 to 327.67%	100
AI8 SHL	40535	0 to 327.67%	100
AI8 DC*	40536	-3276.8 to 3276.7 units	10
AI9 THD	40537	0 to 327.67%	100
AI9 SHL	40538	0 to 327.67%	100
AI9 DC*	40539	-3276.8 to 3276.7 units	10
AI10 THD	40540	0 to 327.67%	100

AI10 SHL	40541	0 to 327.67%	100
AI10 DC*	40542	-3276.8 to 3276.7 units	10
AI11 THD	40543	0 to 327.67%	100
AI11 SHL	40544	0 to 327.67%	100
AI11 DC*	40545	-3276.8 to 3276.7 units	10
AI12 THD	40546	0 to 327.67%	100
AI12 SHL	40547	0 to 327.67%	100
AI12 DC*	40548	-3276.8 to 3276.7 units	10
AI13 THD	40549	0 to 327.67%	100
AI13 SHL	40550	0 to 327.67%	100
AI13 DC*	40551	-3276.8 to 3276.7 units	10
AI14 THD	40552	0 to 327.67%	100
AI14 SHL	40553	0 to 327.67%	100
AI14 DC*	40554	-3276.8 to 3276.7 units	10
AI15 THD	40555	0 to 327.67%	100
AI15 SHL	40556	0 to 327.67%	100
AI15 DC*	40557	-3276.8 to 3276.7 units	10
AI16 THD	40558	0 to 327.67%	100
AI16 SHL	40559	0 to 327.67%	100
AI16 DC*	40560	-3276.8 to 3276.7 units	10
AI17 THD	40561	0 to 327.67%	100
AI17 SHL	40562	0 to 327.67%	100
AI17 DC*	40563	-3276.8 to 3276.7 units	10
AI18 THD	40564	0 to 327.67%	100
AI18 SHL	40565	0 to 327.67%	100
AI18 DC*	40566	-3276.8 to 3276.7 units	10
AI19 THD	40567	0 to 327.67%	100
AI19 SHL	40568	0 to 327.67%	100
AI19 DC*	40569	-3276.8 to 3276.7 units	10
AI20 THD	40570	0 to 327.67%	100
AI20 SHL	40571	0 to 327.67%	100
AI20 DC*	40572	-3276.8 to 3276.7 units	10
AI21 THD	40573	0 to 327.67%	100
AI21 SHL	40574	0 to 327.67%	100
AI21 DC*	40575	-3276.8 to 3276.7 units	10
AI22 THD	40576	0 to 327.67%	100
AI22 SHL	40577	0 to 327.67%	100
AI22 DC*	40578	-3276.8 to 3276.7 units	10
AI23 THD	40579	0 to 327.67%	100
AI23 SHL	40580	0 to 327.67%	100

AI23 DC*	40581	-3276.8 to 3276.7 units	10
AI24 THD	40582	0 to 327.67%	100
AI24 SHL	40583	0 to 327.67%	100
AI24 DC*	40584	-3276.8 to 3276.7 units	10
AI25 THD	40585	0 to 327.67%	100
AI25 SHL	40586	0 to 327.67%	100
AI25 DC*	40587	-3276.8 to 3276.7 units	10
AI26 THD	40588	0 to 327.67%	100
AI26 SHL	40589	0 to 327.67%	100
AI26 DC*	40590	-3276.8 to 3276.7 units	10
AI27 THD	40591	0 to 327.67%	100
AI27 SHL	40592	0 to 327.67%	100
AI27 DC*	40593	-3276.8 to 3276.7 units	10
AI28 THD	40594	0 to 327.67%	100
AI28 SHL	40595	0 to 327.67%	100
AI28 DC*	40596	-3276.8 to 3276.7 units	10
AI29 THD	40597	0 to 327.67%	100
AI29 SHL	40598	0 to 327.67%	100
AI29 DC*	40599	-3276.8 to 3276.7 units	10
AI30 THD	40600	0 to 327.67%	100
AI30 SHL	40601	0 to 327.67%	100
AI30 DC*	40602	-3276.8 to 3276.7 units	10
AI31 THD	40603	0 to 327.67%	100
AI31 SHL	40604	0 to 327.67%	100
AI31 DC*	40605	-3276.8 to 3276.7 units	10
AI32 THD	40606	0 to 327.67%	100
AI32 SHL	40607	0 to 327.67%	100
AI32 DC*	40608	-3276.8 to 3276.7 units	10
AI33 THD	40609	0 to 327.67%	100
AI33 SHL	40610	0 to 327.67%	100
AI33 DC*	40611	-3276.8 to 3276.7 units	10
AI34 THD	40612	0 to 327.67%	100
AI34 SHL	40613	0 to 327.67%	100
AI34 DC*	40614	-3276.8 to 3276.7 units	10
AI35 THD	40615	0 to 327.67%	100
AI35 SHL	40616	0 to 327.67%	100
AI35 DC*	40617	-3276.8 to 3276.7 units	10
AI36 THD	40618	0 to 327.67%	100
AI36 SHL	40619	0 to 327.67%	100
AI36 DC*	40620	-3276.8 to 3276.7 units	10

Summation Metering Channels			
SUM1 Magnitude	40769	0 to 3276.7 units	10
SUM1 Angle	40770	-180° to 180°	10
SUM2 Magnitude	40771	0 to 3276.7 units	10
SUM2 Angle	40772	-180° to 180°	10
SUM3 Magnitude	40773	0 to 3276.7 units	10
SUM3 Angle	40774	-180° to 180°	10
SUM4 Magnitude	40775	0 to 3276.7 units	10
SUM4 Angle	40776	-180° to 180°	10
SUM5 Magnitude	40777	0 to 3276.7 units	10
SUM5 Angle	40778	-180° to 180°	10
SUM6 Magnitude	40779	0 to 3276.7 units	10
SUM6 Angle	40780	-180° to 180°	10
SUM7 Magnitude	40781	0 to 3276.7 units	10
SUM7 Angle	40782	-180° to 180°	10
SUM8 Magnitude	40783	0 to 3276.7 units	10
SUM8 Angle	40784	-180° to 180°	10
SUM9 Magnitude	40785	0 to 3276.7 units	10
SUM9 Angle	40786	-180° to 180°	10
SUM10 Magnitude	40787	0 to 3276.7 units	10
SUM10 Angle	40788	-180° to 180°	10
SUM11 Magnitude	40789	0 to 3276.7 units	10
SUM11 Angle	40790	-180° to 180°	10
SUM12 Magnitude	40791	0 to 3276.7 units	10
SUM12 Angle	40792	-180° to 180°	10
SUM13 Magnitude	40793	0 to 3276.7 units	10
SUM13 Angle	40794	-180° to 180°	10
SUM14 Magnitude	40795	0 to 3276.7 units	10
SUM14 Angle	40796	-180° to 180°	10
SUM15 Magnitude	40797	0 to 3276.7 units	10
SUM15 Angle	40798	-180° to 180°	10
SUM16 Magnitude	40799	0 to 3276.7 units	10
SUM16 Angle	40800	-180° to 180°	10
SUM17 Magnitude	40801	0 to 3276.7 units	10
SUM17 Angle	40802	-180° to 180°	10
SUM18 Magnitude	40803	0 to 3276.7 units	10
SUM18 Angle	40804	-180° to 180°	10
SUM19 Magnitude	40805	0 to 3276.7 units	10
SUM19 Angle	40806	-180° to 180°	10
SUM20 Magnitude	40807	0 to 3276.7 units	10

SUM20 Angle	40808	-180° to 180°	10
SUM21 Magnitude	40809	0 to 3276.7 units	10
SUM21 Angle	40810	-180° to 180°	10
SUM22 Magnitude	40811	0 to 3276.7 units	10
SUM22 Angle	40812	-180° to 180°	10
SUM23 Magnitude	40813	0 to 3276.7 units	10
SUM23 Angle	40814	-180° to 180°	10
SUM24 Magnitude	40815	0 to 3276.7 units	10
SUM24 Angle	40816	-180° to 180°	10
SUM25 Magnitude	40817	0 to 3276.7 units	10
SUM25 Angle	40818	-180° to 180°	10
SUM26 Magnitude	40819	0 to 3276.7 units	10
SUM26 Angle	40820	-180° to 180°	10
SUM27 Magnitude	40821	0 to 3276.7 units	10
SUM27 Angle	40822	-180° to 180°	10
SUM28 Magnitude	40823	0 to 3276.7 units	10
SUM28 Angle	40824	-180° to 180°	10
SUM29 Magnitude	40825	0 to 3276.7 units	10
SUM29 Angle	40826	-180° to 180°	10
SUM30 Magnitude	40827	0 to 3276.7 units	10
SUM30 Angle	40828	-180° to 180°	10
SUM 31 Magnitude	40829	0 to 3276.7 units	10
SUM 31 Angle	40830	-180° to 180°	10
SUM 32 Magnitude	40831	0 to 3276.7 units	10
SUM 32 Angle	40832	-180° to 180°	10
SUM 33 Magnitude	40833	0 to 3276.7 units	10
SUM 33 Angle	40834	-180° to 180°	10
SUM 34 Magnitude	40835	0 to 3276.7 units	10
SUM 34 Angle	40836	-180° to 180°	10
SUM 35 Magnitude	40837	0 to 3276.7 units	10
SUM 35 Angle	40838	-180° to 180°	10
SUM 36 Magnitude	40839	0 to 3276.7 units	10
SUM 36 Angle	40840	-180° to 180°	10
SUM 37 Magnitude	40841	0 to 3276.7 units	10
SUM 37 Angle	40842	-180° to 180°	10
SUM 38 Magnitude	40843	0 to 3276.7 units	10
SUM 38 Angle	40844	-180° to 180°	10
SUM 39 Magnitude	40845	0 to 3276.7 units	10
SUM 39 Angle	40846	-180° to 180°	10
SUM 40 Magnitude	40847	0 to 3276.7 units	10

SUM 40 Angle	40848	-180° to 180°	10
SUM 41 Magnitude	40849	0 to 3276.7 units	10
SUM 41 Angle	40850	-180° to 180°	10
SUM 42 Magnitude	40851	0 to 3276.7 units	10
SUM 42 Angle	40852	-180° to 180°	10
SUM 43 Magnitude	40853	0 to 3276.7 units	10
SUM 43 Angle	40854	-180° to 180°	10
SUM 44 Magnitude	40855	0 to 3276.7 units	10
SUM 44 Angle	40856	-180° to 180°	10
SUM 45 Magnitude	40857	0 to 3276.7 units	10
SUM 45 Angle	40858	-180° to 180°	10
SUM 46 Magnitude	40859	0 to 3276.7 units	10
SUM 46 Angle	40860	-180° to 180°	10
SUM 47 Magnitude	40861	0 to 3276.7 units	10
SUM 47 Angle	40862	-180° to 180°	10
SUM 48 Magnitude	40863	0 to 3276.7 units	10
SUM 48 Angle	40864	-180° to 180°	10
Sequence Metering Channels			
SEQ1 Positive	41025	0 to 3276.7 units	10
SEQ1 Negative	41026	0 to 3276.7 units	10
SEQ1 Zero	41027	0 to 3276.7 units	10
SEQ2 Positive	41028	0 to 3276.7 units	10
SEQ2 Negative	41029	0 to 3276.7 units	10
SEQ2 Zero	41030	0 to 3276.7 units	10
SEQ3 Positive	41031	0 to 3276.7 units	10
SEQ3 Negative	41032	0 to 3276.7 units	10
SEQ3 Zero	41033	0 to 3276.7 units	10
SEQ4 Positive	41034	0 to 3276.7 units	10
SEQ4 Negative	41035	0 to 3276.7 units	10
SEQ4 Zero	41036	0 to 3276.7 units	10
SEQ5 Positive	41037	0 to 3276.7 units	10
SEQ5 Negative	41038	0 to 3276.7 units	10
SEQ5 Zero	41039	0 to 3276.7 units	10
SEQ6 Positive	41040	0 to 3276.7 units	10
SEQ6 Negative	41041	0 to 3276.7 units	10
SEQ6 Zero	41042	0 to 3276.7 units	10
SEQ7 Positive	41043	0 to 3276.7 units	10
SEQ7 Negative	41044	0 to 3276.7 units	10
SEQ7 Zero	41045	0 to 3276.7 units	10
SEQ8 Positive	41046	0 to 3276.7 units	10

SEQ8 Negative	41047	0 to 3276.7 units	10
SEQ8 Zero	41048	0 to 3276.7 units	10
SEQ9 Positive	41049	0 to 3276.7 units	10
SEQ9 Negative	41050	0 to 3276.7 units	10
SEQ9 Zero	41051	0 to 3276.7 units	10
SEQ10 Positive	41052	0 to 3276.7 units	10
SEQ10 Negative	41053	0 to 3276.7 units	10
SEQ10 Zero	41054	0 to 3276.7 units	10
SEQ11 Positive	41055	0 to 3276.7 units	10
SEQ11 Negative	41056	0 to 3276.7 units	10
SEQ11 Zero	41057	0 to 3276.7 units	10
SEQ12 Positive	41058	0 to 3276.7 units	10
SEQ12 Negative	41059	0 to 3276.7 units	10
SEQ12 Zero	41060	0 to 3276.7 units	10
SEQ13 Positive	41061	0 to 3276.7 units	10
SEQ13 Negative	41062	0 to 3276.7 units	10
SEQ13 Zero	41063	0 to 3276.7 units	10
SEQ14 Positive	41064	0 to 3276.7 units	10
SEQ14 Negative	41065	0 to 3276.7 units	10
SEQ14 Zero	41066	0 to 3276.7 units	10
SEQ15 Positive	41067	0 to 3276.7 units	10
SEQ15 Negative	41068	0 to 3276.7 units	10
SEQ15 Zero	41069	0 to 3276.7 units	10
SEQ16 Positive	41070	0 to 3276.7 units	10
SEQ16 Negative	41071	0 to 3276.7 units	10
SEQ16 Zero	41072	0 to 3276.7 units	10
SEQ17 Positive	41073	0 to 3276.7 units	10
SEQ17 Negative	41074	0 to 3276.7 units	10
SEQ17 Zero	41075	0 to 3276.7 units	10
SEQ18 Positive	41076	0 to 3276.7 units	10
SEQ18Negative	41077	0 to 3276.7 units	10
SEQ18 Zero	41078	0 to 3276.7 units	10
SEQ19 Positive	41079	0 to 3276.7 units	10
SEQ19 Negative	41080	0 to 3276.7 units	10
SEQ19 Zero	41081	0 to 3276.7 units	10
SEQ20 Positive	41082	0 to 3276.7 units	10
SEQ20 Negative	41083	0 to 3276.7 units	10
SEQ20 Zero	41084	0 to 3276.7 units	10
SEQ21 Positive	41085	0 to 3276.7 units	10
SEQ21 Negative	41086	0 to 3276.7 units	10

SEQ21 Zero	41087	0 to 3276.7 units	10
SEQ22 Positive	41088	0 to 3276.7 units	10
SEQ22 Negative	41089	0 to 3276.7 units	10
SEQ22 Zero	41090	0 to 3276.7 units	10
SEQ23 Positive	41091	0 to 3276.7 units	10
SEQ23 Negative	41092	0 to 3276.7 units	10
SEQ23 Zero	41093	0 to 3276.7 units	10
SEQ24 Positive	41094	0 to 3276.7 units	10
SEQ24 Negative	41095	0 to 3276.7 units	10
SEQ24 Zero	41096	0 to 3276.7 units	10
Watts/Vars Metering Channels			
WV1 P	41281	-3276.8 to 3276.7 W	10
WV1 Q	41282	-3276.8 to 3276.7 Var	10
WV1 S	41283	0 to 3276.7 VA	10
WV2 P	41284	-3276.8 to 3276.7 W	10
WV2 Q	41285	-3276.8 to 3276.7 Var	10
WV2 S	41286	0 to 3276.7 VA	10
WV3 P	41287	-3276.8 to 3276.7 W	10
WV3 Q	41288	-3276.8 to 3276.7 Var	10
WV3 S	41289	0 to 3276.7 VA	10
WV4 P	41290	-3276.8 to 3276.7 W	10
WV4 Q	41291	-3276.8 to 3276.7 Var	10
WV4 S	41292	0 to 3276.7 VA	10
WV5 P	41293	-3276.8 to 3276.7 W	10
WV5 Q	41294	-3276.8 to 3276.7 Var	10
WV5 S	41295	0 to 3276.7 VA	10
WV6 P	41296	-3276.8 to 3276.7 W	10
WV6 Q	41297	-3276.8 to 3276.7 Var	10
WV6 S	41298	0 to 3276.7 VA	10
WV7 P	41299	-3276.8 to 3276.7 W	10
WV7 Q	41300	-3276.8 to 3276.7 Var	10
WV7 S	41301	0 to 3276.7 VA	10
WV8 P	41302	-3276.8 to 3276.7 W	10
WV8 Q	41303	-3276.8 to 3276.7 Var	10
WV8 S	41304	0 to 3276.7 VA	10
WV9 P	41305	-3276.8 to 3276.7 W	10
WV9 Q	41306	-3276.8 to 3276.7 Var	10
WV9 S	41307	0 to 3276.7 VA	10
WV10 P	41308	-3276.8 to 3276.7 W	10
WV10 Q	41309	-3276.8 to 3276.7 Var	10

WV10S	41310	0 to 3276.7 VA	10
WV11 P	41311	-3276.8 to 3276.7 W	10
WV11 Q	41312	-3276.8 to 3276.7 Var	10
WV11S	41313	0 to 3276.7 VA	10
WV12 P	41314	-3276.8 to 3276.7 W	10
WV12 Q	41315	-3276.8 to 3276.7 Var	10
WV12S	41316	0 to 3276.7 VA	10
WV13 P	41317	-3276.8 to 3276.7 W	10
WV13 Q	41318	-3276.8 to 3276.7 Var	10
WV13S	41319	0 to 3276.7 VA	10
WV14 P	41320	-3276.8 to 3276.7 W	10
WV14 Q	41321	-3276.8 to 3276.7 Var	10
WV14S	41322	0 to 3276.7 VA	10
WV15 P	41323	-3276.8 to 3276.7 W	10
WV15 Q	41324	-3276.8 to 3276.7 Var	10
WV15S	41325	0 to 3276.7 VA	10
WV16 P	41326	-3276.8 to 3276.7 W	10
WV16 Q	41327	-3276.8 to 3276.7 Var	10
WV16S	41328	0 to 3276.7 VA	10
WV17 P	41329	-3276.8 to 3276.7 W	10
WV17 Q	41330	-3276.8 to 3276.7 Var	10
WV17S	41331	0 to 3276.7 VA	10
WV18 P	41332	-3276.8 to 3276.7 W	10
WV18 Q	41333	-3276.8 to 3276.7 Var	10
WV18S	41334	0 to 3276.7 VA	10
Frequency Metering Channels			
Channel Group 1 Frequency	41537	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 2 Frequency	41538	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 3 Frequency	41539	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 4 Frequency	41540	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 5 Frequency	41541	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 6 Frequency	41542	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 7 Frequency	41543	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 8 Frequency	41544	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 9 Frequency	41545	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 10 Frequency	41546	5/6 f_nominal to 7/6 nominal frequency	100

Channel Group 11 Frequency	41547	5/6 f_nominal to 7/6 nominal frequency	100
Channel Group 12 Frequency	41548	5/6 f_nominal to 7/6 nominal frequency	100
Impedance Metering Channels			
Impedance 1Magnitude	41793	0 to 3276.7 ohm	10
Impedance 1 Angle	41794	-180° to 180°	10
Impedance2 Magnitude	41795	0 to 3276.7 ohm	10
Impedance 2 Angle	41796	-180° to 180°	10
Impedance 3 Magnitude	41797	0 to 3276.7 ohm	10
Impedance 3 Angle	41798	-180° to 180°	10
Impedance 4 Magnitude	41799	0 to 3276.7 ohm	10
Impedance 4 Angle	41800	-180° to 180°	10
Impedance 5 Magnitude	41801	0 to 3276.7 ohm	10
Impedance 5 Angle	41802	-180° to 180°	10
Impedance 6 Magnitude	41803	0 to 3276.7 ohm	10
Impedance 6 Angle	41804	-180° to 180°	10
Impedance 7 Magnitude	41805	0 to 3276.7 ohm	10
Impedance 7 Angle	41806	-180° to 180°	10
Impedance 8 Magnitude	41807	0 to 3276.7 ohm	10
Impedance 8 Angle	41808	-180° to 180°	10
Impedance 9 Magnitude	41809	0 to 3276.7 ohm	10
Impedance 9 Angle	41810	-180° to 180°	10
Impedance 10 Magnitude	41811	0 to 3276.7 ohm	10
Impedance 10 Angle	41812	-180° to 180°	10
Impedance 11 Magnitude	41813	0 to 3276.7 ohm	10
Impedance 11 Angle	41814	-180° to 180°	10
Impedance 12 Magnitude	41815	0 to 3276.7 ohm	10
Impedance 12 Angle	41816	-180° to 180°	10
Impedance 13 Magnitude	41817	0 to 3276.7 ohm	10
Impedance 13 Angle	41818	-180° to 180°	10
Impedance 14 Magnitude	41819	0 to 3276.7 ohm	10
Impedance 14 Angle	41820	-180° to 180°	10
Impedance 15 Magnitude	41821	0 to 3276.7 ohm	10
Impedance 15 Angle	41822	-180° to 180°	10
Impedance 16 Magnitude	41823	0 to 3276.7 ohm	10
Impedance 16 Angle	41824	-180° to 180°	10
Impedance 17 Magnitude	41825	0 to 3276.7 ohm	10
Impedance 17 Angle	41826	-180° to 180°	10
Impedance 18 Magnitude	41827	0 to 3276.7 ohm	10
Impedance 18 Angle	41828	-180° to 180°	10

Event Information (See Accessing TESLA Event Information below)	42052 – 42144		
Length (in 16 bit registers) of the current event message	42052		
Event Identification	42053		
Event Message	42054–42137		
Fault Locator ID	42138		
Fault Type	42139		
Fault Distance	42140		10
Fault Time	42141 – 42144		
Power Factor Function 1 Level	42305	0.0 to 1.0	100
Power Factor Function 2 Level	42306	0.0 to 1.0	100
Power Factor Function 3 Level	42307	0.0 to 1.0	100
Power Factor Function 4 Level	42308	0.0 to 1.0	100
Power Factor Function 5 Level	42309	0.0 to 1.0	100
Power Factor Function 6 Level	42310	0.0 to 1.0	100
Power Factor Function 7 Level	42311	0.0 to 1.0	100
Power Factor Function 8 Level	42312	0.0 to 1.0	100
Power Factor Function 9 Level	42313	0.0 to 1.0	100
Power Factor Function 10 Level	42314	0.0 to 1.0	100
Power Factor Function 11 Level	42315	0.0 to 1.0	100
Power Factor Function 12 Level	42316	0.0 to 1.0	100
Power Factor Function 13 Level	42317	0.0 to 1.0	100
Power Factor Function 14 Level	42318	0.0 to 1.0	100
Power Factor Function 15 Level	42319	0.0 to 1.0	100
Power Factor Function 16 Level	42320	0.0 to 1.0	100
Power Factor Function 17 Level	42321	0.0 to 1.0	100
Power Factor Function 18 Level	42322	0.0 to 1.0	100
High/low speed recording space used	42561	0.0 to 100.0	10
Trend Recording Days Accumulated	42817	0 to 90	1

Read Input Register (Function Code 04)
No input registers supported. Response from IED indicates “ILLEGAL FUNCTION.”

Force Single Coil (Function Code 05)			
Only the “hold readings” coil can be forced. When active, this coil locks all coil, input and holding register readings simultaneously at their present values. When inactive, coil, input and holding register values will read their most recently available state.			
Channel	**Type**	**Address**	**Value**
Hold Readings	Read/Write	01	0000: Readings update normally (inactive) FF00: Hold readings (active)

Preset Single Register (Function Code 06)			
Channel	**Address**	**Value**	**Scaled Up By**
Event Information (See **Accessing TESLA Event Information, below)**	42099 – 42051		
Refresh event list	42049	No data required	N/A
Acknowledge the current event and get the next event	42050	No data required	N/A
Get the next event (without acknowledge)	42051	No data required	N/A

Diagnostic Subfunctions (Function Code 08)	
Return Query Data (Subfunction 00)	This provides an echo of the submitted message.
Restart Comm. Option (Subfunction 01)	This restarts the Modbus communications process.
Force Listen Only Mode (Subfunction 04)	No response is returned. IED enters “Listen Only” mode. This mode can only be exited by the “Restart Comm. Option” command.

Report Slave ID (Function Code 17/0x11)			
A fixed response is returned by the IED, including system model, version and issue numbers.			
Channel	**Type**	**Bytes**	**Value**
Model Number	Read Only	0 and 1	0xFA6 = 4006 decimal
Version Number	Read Only	2 and 3	Version number
Issue Number	Read Only	4 and 5	Issue number

- The TESLA 4000 IED model number is 4000-A, reported as 4006.
- Version and issue will each be positive integers, say X and Y.
- The TESLA 4000 is defined as “TESLA 4000, Model 4000-A, Version X Issue Y”

Accessing TESLA Event Information	
All TESLA detector event messages displayed in the Event Log are available via Modbus. This includes fault location information. The following controls are available.	
Refresh Event List	(Function Code 6, address 42049): Fetches the latest events from the TESLA's event log and makes them available for Modbus access. The most recent event becomes the current event available for reading.
Acknowledge Current Event and Get Next Event	(Function Code 6, address 42050): Clears the current event from the read registers and places the next event into them. An acknowledged event is no longer available for reading.

Get Next Event	(Function Code 6, address 42051): Places the next event in the read registers without acknowledging the current event. The current event will reappear in the list when Refresh Event List is used.
Size of Current Event Message	(Function Code 3, address 42052): Indicates the number of 16 bit registers used to contain the current event. Event data is stored with two characters per register. A reading of zero indicates that there are no unacknowledged events available in the current set. (NB. The Refresh Event List function can be used to check for new events that have occurred since the last Refresh Event List.)
Fault Location Event Preset When Set to 0x464C	(Function Code 3, address 42053): Identifies fault location events. These events are identified by “FL” (0x464C) in this register. Non-fault location events contain “ ” in this location.
Read Event Message	(Function Code 3, addresses 42054 - 42137): Contains the current event message. Two ASCII characters are packed into each 16 bit register. All unused registers in the set are set to 0.
Fault Location – Fault Locator ID	(Function Code 3, address 42138): If the current event is a fault location event, this register contains the ID of the fault locator. The numbers from 1 to 10 are used for 8/12/18/36-channel recorders.
Fault Information – Type	(Function Code 3, address 42139): If the current event is a fault location event, this register contains the type of the fault. The following type bitmap: 0x0001 - Phase A 0x0002 - Phase B 0x0004 - Phase C 0x0008 - Ground Any number of the flags may be set for a given fault. If recorder could not determine the fault type, then the register will not have any flags set and will read 0x0000.
Fault Information – Fault Distance	(Function Code 3, address 42140): If the current event is a fault location event, this register contains the distance to the fault. It is scaled up by a factor of 10. The units are the same as the units set in the relay configuration.
Fault Information –Time of Fault	(Function Code 3, addresses 42141 and 42144): If the current event is a fault location event, these registers contain the time of the fault in seconds since 1970. Each of these 16-bit registers contains an 8-bit portion of a 32-bit time value. Register 42141 contains the upper 16 bits, register 42144 contains the lower 16 bits.

Register	**Value**	**Meaning**	
	High Byte	Low Byte	
42052	0x00	0x1B	Event text size = 27 (0x1B hex)
42053	0x46	0x4C	‘F,L’ - Fault locator event
42054	0x32	0x30	‘2’, ‘0’
42055	0x30	0x30	‘0’, ‘0’
42056	0x53	0x65	‘S’, ‘e’
42057	0x70	0x32	‘p’, ‘2’
42058	0x31	0x20	‘1’, ‘ ’
42059	0x32	0x30	‘2’, ‘0’
42060	0x3A	0x31	‘:’, ‘1’
42061	0x36	0x3A	‘6’, ‘:’

Register	Value	Meaning	
42062	0x31	0x36	‘1’, ‘6’
42063	0x2E	0x39	‘.’, ‘9’
42064	0x36	0x36	‘6’, ‘6’
42065	0x20	0x3A	‘ ’, ‘:’
42066	0x20	0x4C	‘ ’, ‘L’
42067	0x69	0x6E	‘i’, ‘n’
42068	0x65	0x20	‘e’, ‘ ‘
42069	0x31	0x36	‘1’, ‘6’
42070	0x3A	0x46	‘:’, ‘F’
42071	0x4C	0x6F	‘L’, ‘o’
42072	0x63	0x20	‘c’, ‘ ‘
42073	0x42	0x47	‘B’, ‘G’
42074	0x20	0x33	‘ ’, ‘3’
42075	0x39	0x2E	‘9’, ‘.’
42076	0x37	0x20	‘7’, ‘ ‘
42077	0x6D	0x69	‘m’, ‘i’
42078	0x6C	0x65	‘l’, ‘e’
42079	0x73	0x00	‘s’

Appendix F DNP3 Device Profile

Device Properties

This document shows the device capabilities and the current value of each parameter for the default unit configuration as defined in the default configuration file.

1.1 Device Identification	Capabilities	Current Value	If configurable, list methods
1.1.1 Device Function:	○ Master ● Outstation	○ Master ● Outstation	
1.1.2 Vendor Name:		ERLPhase Power Technologies Ltd.	
1.1.3 Device Name:		TESLA 4000-A	
1.1.4 Device manufacturer's hardware version string:		NA	
1.1.5 Device manufacturer's software version string:		NA	
1.1.6 Device Profile Document Version Number:		V01.0, May 31, 2022	
1.1.7 DNP Levels Supported for:	Masters Only RequestsResponses ☐☐None ☐☐Level 1 ☐☐Level 2 ☐☐Level 3 Outstations Only Requests and Responses ☐None ☐Level 1 ☒Level 2 ☐Level 3		
1.1.8 Supported Function Blocks:	☐ Self-Address Reservation ☐ Object 0 - attribute objects ☐ Data Sets ☐ File Transfer ☐ Virtual Terminal ☐ Mapping to IEC 61850 Object Models defined in a DNP3 XML file		

1.1 Device Identification	Capabilities	Current Value	If configurable, list methods
1.1.9 Notable Additions:	• Start-stop (qualifier codes 0x00 and 0x01), limited quantity (qualifier codes 0x07 and 0x08) and indices (qualifier codes 0x17 and 0x28) for Binary Inputs, Binary Outputs and Analog Inputs (object groups 1, 10 and 30) • 32-bit and 16-bit Analog Inputs with and without flag (variations 1, 2, 3 and 4) • Analog Input events with time (variations 3 and 4) • Fault Location information as analog readings • Event Log messages as Object groups 110 and 111		
1.1.10 Methods to set Configurable Parameters:	☐ XML - Loaded via DNP3 File Transfer ☐ XML - Loaded via other transport mechanism ☐ Terminal - ASCII Terminal Command Line ☒ Software - Vendor software named TESLA Control Panel ☐ Proprietary file loaded via DNP3 file transfer ☐ Proprietary file loaded via other transport mechanism ☐ Direct - Keypad on device front panel ☐ Factory - Specified when device is ordered ☐ Protocol - Set via DNP3 (e.g. assign class) ☐ Other - explain _________________		
1.1.11 DNP3 XML files available On-Line:	RdWrFilenameDescription of Contents ☐ dnpDP.xml Complete Device Profile ☐ dnpDPcap.xml Device Profile Capabilities ☐ dnpDPcfg.xml Device Profile config. values ☐ ☐ _____*.xml ___________________ *The Complete Device Profile Document contains the capabilities, Current Value, and configurable methods columns. *The Device Profile Capabilities contains only the capabilities and configurable methods columns. *The Device Profile Config. Values contains only the Current Value column.	Not supported	
1.1.12 External DNP3 XML files available Off-line:	Rd WrFilenameDescription of Contents ☐ ☐ dnpDP.xml Complete Device Profile ☐ ☐ dnpDPcap.xml Device Profile Capabilities ☐ ☐ dnpDPcfg.xml Device Profile config. values ☐ ☐ _______*.xml ___________________ *The Complete Device Profile Document contains the capabilities, Current Value, and configurable methods columns. *The Device Profile Capabilities contains only the capabilities and configurable methods columns. *The Device Profile Config. Values contains only the Current Value column.	Not supported	
1.1.13 Connections Supported:	☒ Serial (complete section 1.2) ☒ IP Networking (complete section 1.3) ☐ Other, explain ______________________		

1.2 Serial Connections	Capabilities	Current Value	If configurable, list methods
1.2.1 Port Name	SCADA (Port 404)		
1.2.2 Serial Connection Parameters:	☐ Asynchronous - 8 Data Bits, 1 Start Bit, 1 Stop Bit, No Parity ☒ Other, explain - Asynchronous with selectable parity	Not configured for DNP	TESLA Control Panel
1.2.3 Baud Rate:	☐ Fixed at _______ ☐ Configurable, range _______ to _______ ☒ Configurable, selectable from 1200, 2400, 9600, 19200, 38400, 57600 and 115200. ☐ Configurable, other, describe_______________	Not configured for DNP	TESLA Control Panel
1.2.4 Hardware Flow Control (Handshaking): Describe hardware signaling requirements of the interface. Where a transmitter or receiver is inhibited until a given control signal is asserted, it is considered to require that signal prior to sending or receiving characters. Where a signal is asserted prior to transmitting, that signal will be maintained active until after the end of transmission. Where a signal is asserted to enable reception, any data sent to the device when the signal is not active could be discarded.	☐ None **RS-232 / V.24 / V.28 Options:** Before Tx, Asserts:☐ RTS ☐ DTR Before Rx, Asserts:☐ RTS ☐ DTR Always Asserts: ☒ RTS ☒ DTR Before Tx, Requires: AssertedDeasserted ☐☐ CTS ☐☐ DCD ☐☐ DSR ☐☐ RI ☐☐ Rx Inactive Before Rx, Requires: AssertedDeasserted ☐☐ CTS ☐☐ DCD ☐☐ DSR ☐☐ RI Always Ignores: ☒ CTS ☒ DCD ☒ DSR ☒ RI ☐ Other, explain ____________ **RS-422 / V.11 Options:** ☐ Requires Indication before Rx ☐ Asserts Control before Tx ☐ Other, explain ____________ **RS-485 Options:** ☐ Requires Rx inactive before Tx ☐ Other, explain ____________		
1.2.5 Interval to Request Link Status:	☒ Not Supported ☐ Fixed at_________ seconds ☐ Configurable, range _____ to ______ seconds ☐ Configurable, selectable from __,__,__ seconds ☐ Configurable, other, describe______________		
1.2.6 Supports DNP3 Collision Avoidance:	☒ No ☐ Yes, explain ______________________		

1.2 Serial Connections	Capabilities	Current Value	If configurable, list methods
1.2.7 Receiver Inter-character Timeout:	☒ Not checked ☐ No gap permitted ☐ Fixed at _____ bit times ☐ Fixed at _____ ms ☐ Configurable, range ____ to ____ bit times ☐ Configurable, range ____ to ____ ms ☐ Configurable, Selectable from __,__,__bit times ☐ Configurable, Selectable from ___, ___, ___ ms ☐ Configurable, other, describe______________ ☐ Variable, explain ____		
1.2.8 Inter-character gaps in transmission:	☒ None (always transmits with no inter-character gap) ☐ Maximum _____ bit times ☐ Maximum _____ ms		

1.3 IP Networking	Capabilities	Current Value	If configurable, list methods
1.3.1 Port Name	Port 411 or Port 412		
1.3.2 Type of End Point:	☐ TCP Initiating (Master Only) ☒ TCP Listening (Outstation Only) ☐ TCP Dual (required for Masters) ☒ UDP Datagram (required)	Not configured for DNP	TESLA Control Panel
1.3.3 IP Address of this Device:		192.168.100.10 1	TESLA Mainte-nance utilities
1.3.4 Subnet Mask:		Not set	TESLA Mainte-nance utilities
1.3.5 Gateway IP Address:		Not set	TESLA Mainte-nance utilities
1.3.6 Accepts TCP Connections or UDP Datagrams from:	☒ Allows all (show as *.*.*.* in 1.3.7) ☒ Limits based on an IP address ☒ Limits based on list of IP addresses ☐ Limits based on a wildcard IP address ☐ Limits based on list of wildcard IP addresses ☐ Other validation, explain_________________	Limits based on an IP address	TESLA Control Panel
1.3.7 IP Address(es) from which TCP Connections or UDP Datagrams are accepted:		192.168.1.1	TESLA Control Panel
1.3.8 TCP Listen Port Number:	☐ Not Applicable (Master w/o dual end point) ☐ Fixed at 20,000 ☒ Configurable, range 1025 to 65535 ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	20,000	TESLA Control Panel
1.3.9 TCP Listen Port Number of remote device:	☒ Not Applicable (Outstation w/o dual end point) ☐ Fixed at 20,000 ☐ Configurable, range _______ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	NA	
1.3.10 TCP Keep-alive timer:	☐ Fixed at ___________ms ☒ Configurable, range 5 to 3,600 s ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe______________	Disabled	TESLA Control Panel
1.3.11 Local UDP port:	☐ Fixed at 20,000 ☒ Configurable, range 1025 to 65535 ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________ ☐ Let system choose (Master only)	20,000	TESLA Control Panel
1.3.12 Destination UDP port for DNP3 Requests (Master Only):		NA	
1.3.13 Destination UDP port for initial unsolicited null responses (UDP only Outstations):	☒ None ☐ Fixed at 20,000 ☐ Configurable, range _______ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	NA	

1.3 IP Networking	**Capabilities**	**Current Value**	**If configurable, list methods**
1.3.14 Destination UDP port for responses:	☐ None ☐ Fixed at 20,000 ☒ Configurable, range 1025 to 65535 ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________ ☐ Use source port number	20,000	TESLA Control Panel
1.3.15 Multiple master connections (Outstations Only):	☒ Supports multiple masters (Outstations only) If supported, the following methods may be used: ☒ Method 1 (based on IP address) - required ☒ Method 2 (based on IP port number) - recommended ☒ Method 3 (browsing for static data) - optional	Method 1 (based on IP address)	TESLA Control Panel
1.3.16 Time synchronization support:	☐ DNP3 LAN procedure (function code 24) ☐ DNP3 Write Time (not recommended over LAN) ☐ Other, explain _________________________ ☒ Not Supported		

1.4 Link Layer	Capabilities	Current Value	If configurable, list methods
1.4.1 Data Link Address:	☐ Fixed at______ ☒ Configurable, range 1 to 65519 ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	1	TESLA Control Panel
1.4.2 DNP3 Source Address Validation:	☒ Never ☐ Always, one address allowed (shown in 1.4.3) ☐ Always, any one of multiple addresses allowed ☐ (each selectable as shown in 1.4.3) ☐ Sometimes, explain________________		
1.4.3 DNP3 Source Address(es) expected when Validation is Enabled:	☐ Configurable to any 16 bit DNP Data Link Address value ☐ Configurable, range _______ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	NA	
1.4.4 Self Address Support using address 0xFFFC:	☐ Yes (only allowed if configurable) ☒ No	NA	
1.4.5 Sends Confirmed User Data Frames:	☐ Always ☐ Sometimes, explain _____________________ ☐ Never ☒ Configurable, either always or never		TESLA Control Panel (to disable, set Data Link Time-out to 0)
1.4.6 Data Link Layer Confirmation Timeout:	☐ None ☐ Fixed at _ ms ☒ Configurable, range __0____to 2,000 ms ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe________________ ☐ Variable, explain _______________________	2,000	
1.4.7 Maximum Data Link Retries:	☐ Never Retries ☒ Fixed at 3 ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	3	
1.4.8 Maximum number of octets Transmitted in a Data Link Frame:	☒ Fixed at 292 ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	292	
1.4.9 Maximum number of octets that can be Received in a Data Link Frame:	☒ Fixed at 292 ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	292	

1.5 Application Layer		Capabilities	Current Value	If configurable, list methods
1.5.1	Maximum number of octets Transmitted in an Application Layer Fragment other than File Transfer:	☒ Fixed at 2048 ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	2048	
1.5.2	Maximum number of octets Transmitted in an Application Layer Fragment containing File Transfer:	☐ Fixed at ___________ ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	NA	
1.5.3	Maximum number of octets that can be Received in an Application Layer Fragment:	☒ Fixed at 2048 ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________	2048	
1.5.4	Timeout waiting for Complete Application Layer Fragment:	☐ None ☒ Fixed at 2,000 ms ☐ Configurable, range _______ to _______ms ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe______________ ☐ Variable, explain ______________________	2,000 ms	
1.5.5	Maximum number of objects allowed in a single control request for CROB (group 12):	☒ Fixed at 16 ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________ ☐ Variable, explain ______________________	16	
1.5.6	Maximum number of objects allowed in a single control request for Analog Outputs (group 41):	☐ Fixed at _ ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________ ☐ Variable, explain ______________________	Analog Outputs not supported	
1.5.7	Maximum number of objects allowed in a single control request for Data Sets (groups 85,86,87):	☐ Fixed at __ ☐ Configurable, range ________ to _______ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe______________ ☐ Variable, explain ______________________	Data Sets not supported	
1.5.8	Supports mixing object groups (AOBs, CROBs and Data Sets) in the same control request:	☐ Not applicable - controls are not supported ☐ Yes ☒ No	Analog Outputs not supported	

1.6 Fill Out The Following Items For Outstations Only	Capabilities	Current Value	If configurable, list methods
1.6.1 Timeout waiting for Application Confirm of solicited response message:	☐ None ☒ Fixed at 5,000 ms ☐ Configurable, range _______ to _______ms ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe______________ ☐ Variable, explain _______________________	5,000 ms	
1.6.2 How often is time synchronization required from the master?	☒ Never needs time ☐ Within ______ seconds after IIN1.4 is set ☐ Periodically every _______ seconds		
1.6.3 Device Trouble Bit IIN1.6:	☐ Never used ☒ Reason for setting: Unable to access requested data or execute CROB, assuming a valid request has been received		
1.6.4 File Handle Timeout:	☒ Not applicable, files not supported ☐ Fixed at______ ms ☐ Configurable, range _______ to _______ms ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe______________ ☐ Variable, explain _______________________		
1.6.5 Event Buffer Overflow Behaviour:	☐ Discard the oldest event ☒ Discard the newest event ☐ Other, explain _________________________		
1.6.6 Event Buffer Organization:	• Single buffer for the Object Groups 2 and 32, size 200. • Separate buffer for the Object Group 111, size 100. • Separate buffer for the Fault Locator events, size 100.		
1.6.7 Sends Multi-Fragment Responses:	☒ Yes ☐ No		
1.6.8 DNP Command Settings preserved through a device reset:	☐ Assign Class ☐ Analog Deadbands ☐ Data Set Prototypes ☐ Data Set Descriptors	Not supported	

1.7 Outstation Unsolicited Response Support	Capabilities	Current Value	If configurable, list methods
1.7.1 Supports Unsolicited Reporting:	☒ Not Supported ☐ Configurable, selectable from On and Off	NA	

1.8 Outstation Performance		Capabilities	Current Value	If configurable, list methods
1.8.1	Maximum Time Base Drift (milliseconds per minute):		NA, not synchronized by DNP	
1.8.2	When does outstation set IIN1.4?	☒ Never ☐ Asserted at startup until first Time Synchronization request received ☐ Periodically, range ____to____ seconds ☐ Periodically, selectable from ____,____,___ seconds ☐ Range ____to____ seconds after last time sync ☐ Selectable from___,___,___seconds after last time sync ☐ When time error may have drifted by range ____to____ ms ☐ When time error may have drifted by selectable from ____,____,___	NA	
1.8.3	Maximum Internal Time Reference Error when set via DNP (ms):		NA	
1.8.4	Maximum Delay Measurement error (ms):		NA	
1.8.5	Maximum Response time (ms):		100 ms (for the case all supported points mapped to the DNP point lists)	TESLA Control Panel
1.8.6	Maximum time from start-up to IIN 1.4 assertion (ms):		NA	
1.8.7	Maximum Event Time-tag error for local Binary and Double-bit I/O (ms):		• 0.1736 ms for 60Hz systems • 0.2083 ms for 50 Hz systems	
1.8.8	Maximum Event Time-tag error for local I/O other than Binary and Double-bit data types (ms):		• 0.1736 ms for 60Hz systems • 0.2083 ms for 50 Hz systems	

Capabilities and Current Settings for Device Database

The following tables identify the capabilities and current settings for each DNP3 data type. Each data type also provides a table defining the data points available in the device or a description of how this information can be obtained if the database is configurable.

2.1 Single-Bit Binary Inputs Static (Steady-State) Group Number: 1 Event Group Number: 2	**Capabilities**	**Current Value**	**If configurable, list methods**
2.1.1 Static Variation reported when variation 0 requested:	☒ Variation 1 - Single-bit Packed format ☐ Variation 2 - Single-bit with flag ☐ Based on point Index (add column to table below)		
2.1.2 Event Variation reported when variation 0 requested:	☐ Variation 1 - without time ☒ Variation 2 - with absolute time ☐ Variation 3 - with relative time ☐ Based on point Index (add column to table below)		
2.1.3 Event reporting mode:	☐ Only most recent ☒ All events		
2.1.4 Binary Inputs included in Class 0 response:	☒ Always ☐ Never ☐ Only if point is assigned to Class 1, 2, or 3 ☐ Based on point Index (add column to table below)		TESLA Control Panel
2.1.5 Definition of Binary Input Point List:	☐ Fixed, list shown in table below ☒ Configurable ☐ Other, explain______________________	Complete list is shown in the table below; points excluded from the default configuration are marked with '*'	TESLA Control Panel

NOTES	1. Binary Inputs are scanned with 1 ms resolution. 2. Binary Input data points are user selectable; the data points available in the device for any given Binary Input point selection can be obtained through the TESLA Control Panel software (see SCADA Setting Summary).

Point Index	**Name**	**Default Class Assigned to Events (1, 2, 3 or none)**	**Name for State when value is 0**	**Name for State when value is 1**	**Description**
0	External Input 1	1	Inactive	Active	
1	External Input 2	1	Inactive	Active	
2	External Input 3	1	Inactive	Active	
3	External Input 4	1	Inactive	Active	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Name for State when value is 0	Name for State when value is 1	Description
4	External Input 5	1	Inactive	Active	
5	External Input 6	1	Inactive	Active	
6	External Input 7	1	Inactive	Active	
7	External Input 8	1	Inactive	Active	
8	External Input 9	1	Inactive	Active	
9	External Input 10	1	Inactive	Active	
10	External Input 11	1	Inactive	Active	
11	External Input 12	1	Inactive	Active	
12	External Input 13	1	Inactive	Active	
13	External Input 14	1	Inactive	Active	
14	External Input 15	1	Inactive	Active	
15	External Input 16	1	Inactive	Active	
16	External Input17	1	Inactive	Active	
17	External Input 18	1	Inactive	Active	
18	External Input19	1	Inactive	Active	
19	External Input 20	1	Inactive	Active	
20	External Input 21	1	Inactive	Active	
21	External Input 22	1	Inactive	Active	
22	External Input 23	1	Inactive	Active	
23	External Input 24	1	Inactive	Active	
24	External Input 25	1	Inactive	Active	
25	External Input 26	1	Inactive	Active	
26	External Input 27	1	Inactive	Active	
27	External Input 28	1	Inactive	Active	
28	External Input 29	1	Inactive	Active	
29	External Input 30	1	Inactive	Active	
30	External Input 31	1	Inactive	Active	
31	External Input 32	1	Inactive	Active	
32	External Input 32	1	Inactive	Active	
33	External Input 34	1	Inactive	Active	
34	External Input 35	1	Inactive	Active	
35	External Input 36	1	Inactive	Active	
36	External Input 37	1	Inactive	Active	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Name for State when value is 0	Name for State when value is 1	Description
37	External Input 38	1	Inactive	Active	
38	External Input 39	1	Inactive	Active	
39	External Input 40	1	Inactive	Active	
40	External Input 41	1	Inactive	Active	
41	External Input 42	1	Inactive	Active	
42	External Input 43	1	Inactive	Active	
43	External Input 44	1	Inactive	Active	
44	External Input 45	1	Inactive	Active	
45	External Input 46	1	Inactive	Active	
46	External Input 47	1	Inactive	Active	
47	External Input 48	1	Inactive	Active	
48	External Input 49	1	Inactive	Active	
49	External Input 50	1	Inactive	Active	
50	External Input 51	1	Inactive	Active	
51	External Input 52	1	Inactive	Active	
52	External Input 53	1	Inactive	Active	
53	External Input 54	1	Inactive	Active	
54	External Input 55	1	Inactive	Active	
55	External Input 56	1	Inactive	Active	
56	External Input 57	1	Inactive	Active	
57	External Input 58	1	Inactive	Active	
58	External Input 59	1	Inactive	Active	
59	External Input 60	1	Inactive	Active	
60	External Input 61	1	Inactive	Active	
61	External Input 62	1	Inactive	Active	
62	External Input 63	1	Inactive	Active	
63	External Input 64	1	Inactive	Active	
64	Fault Information Available for Fault Locator 1	1	Inactive	Active	
65	Fault Information Available for Fault Locator 2	1	Inactive	Active	
66	Fault Information Available for Fault Locator 3	1	Inactive	Active	
67	Fault Information Available for Fault Locator 4	1	Inactive	Active	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Name for State when value is 0	Name for State when value is 1	Description
68	Fault Information Available for Fault Locator 5	1	Inactive	Active	
69	Fault Information Available for Fault Locator 6	1	Inactive	Active	
70	Fault Information Available for Fault Locator 7	1	Inactive	Active	
71	Fault Information Available for Fault Locator 8	1	Inactive	Active	
72	Fault Information Available for Fault Locator 9	1	Inactive	Active	
73	Fault Information Available for Fault Locator 10	1	Inactive	Active	
74	Logic 1	1	Inactive	Active	
75	Logic 2	1	Inactive	Active	
76	Logic 3	1	Inactive	Active	
77	Logic 4	1	Inactive	Active	
78	Logic 5	1	Inactive	Active	
79	Logic 6	1	Inactive	Active	
80	Logic 7	1	Inactive	Active	
81	Logic 8	1	Inactive	Active	
82	Logic 9	1	Inactive	Active	
83	Logic 10	1	Inactive	Active	
84	Logic 11	1	Inactive	Active	
85	Logic 12	1	Inactive	Active	
86	Logic 13	1	Inactive	Active	
87	Logic 14	1	Inactive	Active	
88	Logic 15	1	Inactive	Active	
89	Logic 16	1	Inactive	Active	
90	Logic 17	1	Inactive	Active	
91	Logic 18	1	Inactive	Active	
92	Logic 19	1	Inactive	Active	
93	Logic 20	1	Inactive	Active	
94	Logic 21	1	Inactive	Active	
95	Logic 22	1	Inactive	Active	
96	Logic 23	1	Inactive	Active	
97	Logic 24	1	Inactive	Active	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Name for State when value is 0	Name for State when value is 1	Description
98	Logic 25	1	Inactive	Active	
99	Logic 26	1	Inactive	Active	
100	Logic 27	1	Inactive	Active	
101	Logic 28	1	Inactive	Active	
102	Logic 29	1	Inactive	Active	
103	Logic 30	1	Inactive	Active	
104	High/low speed recording active[a]	none	Inactive	Active	
105	High/low speed recording space nearly full alarm	1	Inactive	Active	
106	Trend Recording Active	none	Inactive	Active	
107	Trend Recording Accumu-lation Alarm	1	Inactive	Active	
108*	Output Contact 2	1	Inactive	Active	
109*	Output Contact 3	1	Inactive	Active	
110*	Output Contact 4	1	Inactive	Active	
111*	Output Contact 5	1	Inactive	Active	
112*	Output Contact 6	1	Inactive	Active	
113*	Output Contact 7	1	Inactive	Active	
114*	Output Contact 8	1	Inactive	Active	

a. This point is normally set to High. If the recorder is set to stop recording when full, then when the recorder reaches 100% storage capacity, this point goes Low.

2.2 Binary Output Status And Control Relay Output Block Binary Output Status Group Number: 10 Binary Output Event Group Number: 11 CROB Group Number: 12 Binary Output Command Event Object Num: 13	**Capabilities**	**Current Value**	**If configurable, list methods**
2.2.1 Minimum pulse time allowed with Trip, Close, and Pulse On commands:	☒ Fixed at 0,000 ms (hardware may limit this further) ☐ Based on point Index (add column to table below)		
2.2.2 Maximum pulse time allowed with Trip, Close, and Pulse On commands:	☒ Fixed at 0,000 ms (hardware may limit this further) ☐ Based on point Index (add column to table below)		
2.2.3 Binary Output Status included in Class 0 response:	☒ Always ☐ Never ☐ Only if point is assigned to Class 1, 2, or 3 ☐ Based on point Index (add column to table below)		
2.2.4 Reports Output Command Event Objects:	☒ Never ☐ Only upon a successful Control ☐ Upon all control attempts	Not supported	
2.2.5 Event Variation reported when variation 0 requested:	☐ Variation 1 - without time ☐ Variation 2 - with absolute time ☐ Based on point Index (add column to table below)	Not supported	TESLA Control Panel (See Note 2 below)
2.2.6 Command Event Variation reported when variation 0 requested:	☐ Variation 1 - without time ☐ Variation 2 - with absolute time ☐ Based on point Index (add column to table below)	Not supported	TESLA Control Panel (See Note 2 below)
2.2.7 Event reporting mode:	☐ Only most recent ☐ All events	Not supported	TESLA Control Panel (See Note 2 below)
2.2.8 Command Event reporting mode:	☐ Only most recent ☐ All events	Not supported	
2.2.9 Maximum Time between Select and Operate:	☐ Not Applicable ☒ Fixed at 10 seconds ☐ Configurable, range ______ to ______ seconds ☐ Configurable, selectable from___,___,___seconds ☐ Configurable, other, describe______________ ☐ Variable, explain ______________________ ☐ Based on point Index (add column to table below)	10 s	
2.2.10 Definition of Binary Output Status/Control relay output block (CROB) Point List:	☐ Fixed, list shown in table below ☒ Configurable ☐ Other, explain____________________	Complete list is shown in the table below; points excluded from the default configuration are marked with '*'	TESLA Control Panel

NOTES	
	1. Binary Outputs are scanned with 500 ms resolution. 2. Events are not supported for Binary Outputs (group 10), but most of Binary Output points can be mapped to Binary Inputs (group 2) with full Event and Class Data support. See TESLA Control Panel /DNP Configuration/Point Map screen for complete point lists and configuration options. 3. Binary Output data points are user selectable; the data points available in the device for any given Binary Output point selection can be obtained through the TESLA Control Panel software (see SCADA Setting Summary).

Point Index	Name	Supported Control Operations											Name for State when value is 0	Name for State when value is 1	Default Class Assigned to Events (1, 2, 3 or none)		Description
		Select/Operate	Direct Operate	Direct Operate - No Ack	Pulse On / NUL	Pulse Off	Latch On / NUL	Latch Off / NUL	Trip	Close	Count > 1	Cancel Currently Running Operation			Change	Command	
0	Output contact 2	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
1	Output contact 3	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
2	Output contact 4	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
3	Output contact 5	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
4	Output contact 6	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
5	Output contact 7	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
6	Output contact 8	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
7	Retrieve Next Fault Information Event for Fault Locator 1	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1
8	Retrieve Next Fault Information Event for Fault Locator 2	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1
9	Retrieve Next Fault Information Event for Fault Locator 3	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1
10	Retrieve Next Fault Information Event for Fault Locator 4	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1
11	Retrieve Next Fault Information Event for Fault Locator 5	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1
12	Retrieve Next Fault Information Event for Fault Locator 6	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1

		Supported Control Operations													Default Class Assigned to Events (1, 2, 3 or none)		
Point Index	Name	Select/Operate	Direct Operate	Direct Operate - No Ack	Pulse On / NUL	Pulse Off	Latch On / NUL	Latch Off / NUL	Trip	Close	Count > 1	Cancel Currently Running Operation	Name for State when value is 0	Name for State when value is 1	Change	Command	Description
13	Retrieve Next Fault Information Event for Fault Locator 7	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1
14	Retrieve Next Fault Information Event for Fault Locator 8	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1
15	Retrieve Next Fault Information Event for Fault Locator 9	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1
16	Retrieve Next Fault Information Event for Fault Locator 10	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1

2.3 Analog Input Points Static (Steady-State) Group Number: 30 Event Group Number: 32	**Capabilities**	**Current Value**	**If configurable, list methods**
2.3.1 Static Variation reported when variation 0 requested:	☐ Variation 1 - 32-bit with flag ☐ Variation 2 - 16-bit with flag ☐ Variation 3 - 32-bit without flag ☒ Variation 4 - 16-bit without flag ☐ Variation 5 - single-precision floating point with flag ☐ Variation 6 - double-precision floating point with flag ☐ Based on point Index (add column to table below)		
2.3.2 Event Variation reported when variation 0 requested:	☐ Variation 1 - 32-bit without time ☒ Variation 2 - 16-bit without time ☐ Variation 3 - 32-bit with time ☐ Variation 4 - 16-bit with time ☐ Variation 5 - single-precision floating point w/o time ☐ Variation 6 - double-precision floating point w/o time ☐ Variation 7 - single-precision floating point with time ☐ Variation 8 - double-precision floating point with time ☐ Based on point Index (add column to table below)		
2.3.3 Event reporting mode:	☐ Only most recent ☒ All events		
2.3.4 Analog Inputs Included in Class 0 response:	☒ Always ☐ Never ☐ Only if point is assigned to Class 1, 2, or 3 ☐ Based on point Index (add column to table below)		
2.3.5 How Deadbands are set:	☐ A. Global Fixed ☐ B. Configurable through DNP ☒ C. Configurable via other means ☐ D. Other, explain ________________________ ☐ Based on point Index - column specifies which of the options applies, B, C, or D		TESLA Control Panel
2.3.6 Analog Deadband Algorithm: simple - just compares the difference from the previous reported value	☒ Simple ☐ Integrating ☐ Other, explain __________________________		
2.3.7 Definition of Analog Input Point List:	☐ Fixed, list shown in table below ☒ Configurable ☐ Other, explain_____________________	Default list is shown in table below	TESLA Control Panel

NOTES	1. Analog Inputs are scanned with 500 ms resolution. 2. Nominal values in calculations for the following table are based on 69V secondary voltage * PT ratio for voltage channels, and either 1 A or 5A secondary current * CT ratio for current channels dependent upon the format of CT installed in the TESLA. 3. Analog Input data points are user selectable; the data points available in the device for any given Analog Input point selection can be obtained through the TESLA Control Panel software (see SCADA Setting Summary). 4. When a fault location event is available for any of the 10 fault locator functions, associated Binary Input “Fault Information Available for Fault Locator x” (default point indices 64-73) is asserted while there are still fault location events in the buffer (size 200). When a Pulse or Latch is received for the Binary Output “Retrieve Next Fault Information Event for Fault Locator x” (default point indices 7-16, previous state is not important), fault event information is put into the Analog Inputs (default point indices 388-437). If there is no fault location event available when the Binary Output is pulsed, the fault type is set to zero. Not all fault location events are reported trough DNP. In a burst of fault locations from a fault, only the first processed event is available through DNP, all other events within the following 100 ms interval are ignored. Outside 100 ms from the processed fault location event, the system accepts another fault location event and performs the same filtering. The following bitmap id used for the fault information Type points: 0x0001 - Phase A 0x0002 - Phase B 0x0004 - Phase C 0x0008 - Ground

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
0	Analog Input 1 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
1	Analog Input 1 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
2	Analog Input 1 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
3	Analog Input 1 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
4	Analog Input 1 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
5	Analog Input 2 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
6	Analog Input 2 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
7	Analog Input 2 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
8	Analog Input 2 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
9	Analog Input 2 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.01/0.01	
10	Analog Input 3 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
11	Analog Input 3 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
12	Analog Input 3 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
13	Analog Input 3 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
14	Analog Input 3 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
15	Analog Input 4 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
16	Analog Input 4 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
17	Analog Input 4 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
18	Analog Input 4 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
19	Analog Input 4 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
20	Analog Input 5 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
21	Analog Input 5 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
22	Analog Input 5 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
23	Analog Input 5 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
24	Analog Input 5 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
25	Analog Input 6 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
26	Analog Input 6 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
27	Analog Input 6 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
28	Analog Input 6 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
29	Analog Input 6 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
30	Analog Input 7 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
31	Analog Input 7 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
32	Analog Input 7 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
33	Analog Input 7 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
34	Analog Input 7 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
35	Analog Input 8 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
36	Analog Input 8 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
37	Analog Input 8 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
38	Analog Input 8 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
39	Analog Input 8 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
40	Analog Input 9 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
41	Analog Input 9 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
42	Analog Input 9 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
43	Analog Input 9 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
44	Analog Input 9 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
45	Analog Input 10 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
46	Analog Input 10 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
47	Analog Input 10 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
48	Analog Input 10 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
49	Analog Input 10 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
50	Analog Input 11 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
51	Analog Input 11 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
52	Analog Input 11 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
53	Analog Input 11 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
54	Analog Input 11 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
55	Analog Input 12 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
56	Analog Input 12 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
57	Analog Input 12 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
58	Analog Input 12 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
59	Analog Input 12 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
60	Analog Input 13 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
61	Analog Input 13 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
62	Analog Input 13 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
63	Analog Input 13 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
64	Analog Input 13 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
65	Analog Input 14 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
66	Analog Input 14 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
67	Analog Input 14 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
68	Analog Input 14 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
69	Analog Input 14 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
70	Analog Input 15 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
71	Analog Input 15 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
72	Analog Input 15 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
73	Analog Input 15 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
74	Analog Input 15 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
75	Analog Input 16 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
76	Analog Input 16 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
77	Analog Input 16 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
78	Analog Input 16 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
79	Analog Input 16 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
80	Analog Input 17 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
81	Analog Input 17 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
82	Analog Input 17 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
83	Analog Input 17 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
84	Analog Input 17 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
85	Analog Input 18 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
86	Analog Input 18 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
87	Analog Input 18 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
88	Analog Input 18 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
89	Analog Input 18 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
90	Analog Input 19 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
91	Analog Input 19 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
92	Analog Input 19 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
93	Analog Input 19 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
94	Analog Input 19 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
95	Analog Input 20 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
96	Analog Input 20 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
97	Analog Input 20 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
98	Analog Input 20 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
99	Analog Input 20 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
100	Analog Input 21 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
101	Analog Input 21 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
102	Analog Input 21 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
103	Analog Input 21 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
104	Analog Input 21 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
105	Analog Input 22 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
106	Analog Input 22 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
107	Analog Input 22 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
108	Analog Input 22 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
109	Analog Input 22 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
110	Analog Input 23 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
111	Analog Input 23 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
112	Analog Input 23 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
113	Analog Input 23 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
114	Analog Input 23 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
115	Analog Input 24 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
116	Analog Input 24 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
117	Analog Input 24 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
118	Analog Input 24 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
119	Analog Input 24 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
120	Analog Input 25 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
121	Analog Input 25 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
122	Analog Input 25 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
123	Analog Input 25 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
124	Analog Input 25 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
125	Analog Input 26 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
126	Analog Input 26 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
127	Analog Input 26 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
128	Analog Input 26 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
129	Analog Input 26 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
130	Analog Input 27 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
131	Analog Input 27 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
132	Analog Input 27 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
133	Analog Input 27 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
134	Analog Input 27 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
135	Analog Input 28 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
136	Analog Input 28 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
137	Analog Input 28 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
138	Analog Input 28 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
139	Analog Input 28 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
140	Analog Input 29 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
141	Analog Input 29 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
142	Analog Input 29 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
143	Analog Input 29 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
144	Analog Input29 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
145	Analog Input 30 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
146	Analog Input 30 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
147	Analog Input 30 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
148	Analog Input 30 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
149	Analog Input 30 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
150	Analog Input 31 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
151	Analog Input 31 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
152	Analog Input 31 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
153	Analog Input 31 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
154	Analog Input 31 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
155	Analog Input 32 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
156	Analog Input 32 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
157	Analog Input 32 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
158	Analog Input 32 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
159	Analog Input 32 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
160	Analog Input 33 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
161	Analog Input 33 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
162	Analog Input 33 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
163	Analog Input 33 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
164	Analog Input 33 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
165	Analog Input 34 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
166	Analog Input 34 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
167	Analog Input 34 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
168	Analog Input 34 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
169	Analog Input 34 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
170	Analog Input 35 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
171	Analog Input 35 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
172	Analog Input 35 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
173	Analog Input 35 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
174	Analog Input 35 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
175	Analog Input 36 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
176	Analog Input 36 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
177	Analog Input 36 THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
178	Analog Input 36 SHL	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01/0.01	
179	Analog Input 36 DC	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
180	Summation 1 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
181	Summation 1 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
182	Summation 2 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
183	Summation 2 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
184	Summation 3 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
185	Summation 3 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
186	Summation 4 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
187	Summation 4 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
188	Summation 5 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
189	Summation 5 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
190	Summation 6 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
191	Summation 6 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
192	Summation 7 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
193	Summation 7 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
194	Summation 8 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
195	Summation 8 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
196	Summation 9 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
197	Summation 9 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
198	Summation10 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
199	Summation 10 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
200	Summation 11 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
201	Summation 11 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
202	Summation 12 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
203	Summation 12 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
204	Summation 13 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
205	Summation 13 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
206	Summation 14 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
207	Summation 14 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
208	Summation 15 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
209	Summation 15 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
210	Summation 16 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
211	Summation 16 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
212	Summation 17 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
213	Summation 17 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
214	Summation 18 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
215	Summation 18 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
216	Summation 19 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
217	Summation 19 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
218	Summation 20 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
219	Summation 20 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
220	Summation 21 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
221	Summation 21 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
222	Summation 22 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
223	Summation 22 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
224	Summation 23 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
225	Summation 23 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
226	Summation 24 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
227	Summation 24 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
228	Summation 25 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
229	Summation 25 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
230	Summation 26 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
231	Summation 26 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
232	Summation 27 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
233	Summation 27 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
234	Summation 28 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
235	Summation 28 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
236	Summation 29 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
237	Summation 29 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
238	Summation 30 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
239	Summation 30 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
240	Summation 31 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
241	Summation 31 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
242	Summation 32 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
243	Summation 32 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
244	Summation 33 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
245	Summation 33 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
246	Summation 34 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
247	Summation 34 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
248	Summation 35 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
249	Summation 35 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
250	Summation 36 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
251	Summation 36 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
252	Summation 37 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
253	Summation 37 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
254	Summation 38 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
255	Summation 38 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
256	Summation 39 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
257	Summation 39 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
258	Summation 40 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
259	Summation 40 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
260	Summation 41 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
261	Summation 41 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
262	Summation 42 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
263	Summation 42 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
264	Summation 43 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
265	Summation 43 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
266	Summation 44 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
267	Summation 44 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
268	Summation 45 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
269	Summation 45 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
270	Summation 46 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
271	Summation 46 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
272	Summation 47 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
273	Summation 47 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
274	Summation 48 Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
275	Summation 48 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
276	Sequence Function 1 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
277	Sequence Function 1 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
278	Sequence Function 1 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
279	Sequence Function 2 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
280	Sequence Function 2 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
281	Sequence Function 2 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
282	Sequence Function 3 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
283	Sequence Function 3 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
284	Sequence Function 3 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
285	Sequence Function 4 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
286	Sequence Function 4 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
287	Sequence Function 4 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
288	Sequence Function 5 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
289	Sequence Function 5 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
290	Sequence Function 5 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
291	Sequence Function 6 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
292	Sequence Function 6 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
293	Sequence Function 6 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
294	Sequence Function 7 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
295	Sequence Function 7 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
296	Sequence Function 7 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
297	Sequence Function 8 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
298	Sequence Function 8 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
299	Sequence Function 8 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
300	Sequence Function 9 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
301	Sequence Function 9 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
302	Sequence Function 9 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
303	Sequence Function 10 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
304	Sequence Function 10 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
305	Sequence Function 10 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
306	Sequence Function 11 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
307	Sequence Function 11 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
308	Sequence Function 11 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
309	Sequence Function 12 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
310	Sequence Function 12 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
311	Sequence Function 12 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
312	Sequence Function 13 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
313	Sequence Function 13 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
314	Sequence Function 13 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
315	Sequence Function 14 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
316	Sequence Function 14 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
317	Sequence Function 14 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
318	Sequence Function 15 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
319	Sequence Function 15 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
320	Sequence Function 15 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
321	Sequence Function 16 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
322	Sequence Function 16 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
323	Sequence Function 16 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
324	Sequence Function 17 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
325	Sequence Function 17 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
326	Sequence Function 17 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
327	Sequence Function 18 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
328	Sequence Function 18 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
329	Sequence Function 18 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
330	Sequence Function 19 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
331	Sequence Function 19 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
332	Sequence Function 19 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
333	Sequence Function 20 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
334	Sequence Function 20 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
335	Sequence Function 20 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
336	Sequence Function 21 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
337	Sequence Function 21 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
338	Sequence Function 21 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
339	Sequence Function 22 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
340	Sequence Function 22 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
341	Sequence Function 22 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
342	Sequence Function 23 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
343	Sequence Function 23 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
344	Sequence Function 23 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
345	Sequence Function 24 Positive	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
346	Sequence Function 24 Negative	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
347	Sequence Function 24 Zero	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Configurable	0.1 / 0.00001	
348	Watts/Vars Function 1 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
349	Watts/Vars Function 1 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
350	Watts/Vars Function 1 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
351	Watts/Vars Function 2 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	

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352	Watts/Vars Function 2 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
353	Watts/Vars Function 2 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
354	Watts/Vars Function 3 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
355	Watts/Vars Function 3 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
356	Watts/Vars Function 3 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
357	Watts/Vars Function 4 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
358	Watts/Vars Function 4 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
359	Watts/Vars Function 4 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
360	Watts/Vars Function 5 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
361	Watts/Vars Function 5 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
362	Watts/Vars Function 5 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
363	Watts/Vars Function 6 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
364	Watts/Vars Function 6 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
365	Watts/Vars Function 6 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
366	Watts/Vars Function 7 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
367	Watts/Vars Function 7 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
368	Watts/Vars Function 7 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
369	Watts/Vars Function 8 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
370	Watts/Vars Function 8 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
371	Watts/Vars Function 8 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
372	Watts/Vars Function 9 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
373	Watts/Vars Function 9 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
374	Watts/Vars Function 9 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
375	Watts/Vars Function 10 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
376	Watts/Vars Function 10 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
377	Watts/Vars Function 10 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
378	Watts/Vars Function 11 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
379	Watts/Vars Function 11 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
380	Watts/Vars Function 11 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
381	Watts/Vars Function 12 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
382	Watts/Vars Function 12 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	

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383	Watts/Vars Function 12 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
384	Watts/Vars Function 13 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
385	Watts/Vars Function 13 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
386	Watts/Vars Function 13 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
387	Watts/Vars Function 14 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
388	Watts/Vars Function 14 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
389	Watts/Vars Function 14 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
390	Watts/Vars Function 15 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
391	Watts/Vars Function 15 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
392	Watts/Vars Function 15 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
393	Watts/Vars Function 16 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
394	Watts/Vars Function 16 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
395	Watts/Vars Function 16 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
396	Watts/Vars Function 17 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
397	Watts/Vars Function 17 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
398	Watts/Vars Function 17 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
399	Watts/Vars Function 18 P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
400	Watts/Vars Function 18 Q	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MVAR	0.1 / 0.00001	
401	Watts/Vars Function 18 S	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
402	Frequency 1	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
403	Frequency 2	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
404	Frequency 3	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
405	Frequency 4	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
406	Frequency 5	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
407	Frequency 6	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
408	Frequency 7	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
409	Frequency 8	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
410	Frequency 9	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
411	Frequency 10	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
412	Frequency 11	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
413	Frequency 12	2	0	Configurable	0.01 / (0.001 - 1.0)	0.0	Hz	0.01 / 0.001	
414	Impedance Function 1 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
415	Impedance Function 1 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
416	Impedance Function 2 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
417	Impedance Function 2 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
418	Impedance Function 3 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
419	Impedance Function 3 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
420	Impedance Function 4 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
421	Impedance Function 4 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
422	Impedance Function 5 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
423	Impedance Function 5 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
424	Impedance Function 6 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
425	Impedance Function 6 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
426	Impedance Function 7 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
427	Impedance Function 7 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
428	Impedance Function 8 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
429	Impedance Function 8 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
430	Impedance Function 9 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
431	Impedance Function 9 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
432	Impedance Function 10 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
433	Impedance Function 10 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
434	Impedance Function 11 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
435	Impedance Function 11 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
436	Impedance Function 12 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
437	Impedance Function 12 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
438	Impedance Function 13 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
439	Impedance Function 13 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
440	Impedance Function 14 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
441	Impedance Function 14 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
442	Impedance Function 15 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
443	Impedance Function 15 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
444	Impedance Function 16 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
445	Impedance Function 16 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
446	Impedance Function 17 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	
447	Impedance Function 17 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
448	Impedance Function 18 Mag	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	Ohm	0.1 / 0.00001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
449	Impedance Function 18 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	degrees	0.1 / 0.01	
450	Power Factor Function 1 Level	none	0	1.0	0.01	0.0		0.01	
451	Power Factor Function 2 Level	none	0	1.0	0.01	0.0		0.01	
452	Power Factor Function 3 Level	none	0	1.0	0.01	0.0		0.01	
453	Power Factor Function 4 Level	none	0	1.0	0.01	0.0		0.01	
454	Power Factor Function 5 Level	none	0	1.0	0.01	0.0		0.01	
455	Power Factor Function 6 Level	none	0	1.0	0.01	0.0		0.01	
456	Power Factor Function 7 Level	none	0	1.0	0.01	0.0		0.01	
457	Power Factor Function 8 Level	none	0	1.0	0.01	0.0		0.01	
458	Power Factor Function 9 Level	none	0	1.0	0.01	0.0		0.01	
459	Power Factor Function 10 Level	none	0	1.0	0.01	0.0		0.01	
460	Power Factor Function 11 Level	none	0	1.0	0.01	0.0		0.01	
461	Power Factor Function 12 Level	none	0	1.0	0.01	0.0		0.01	
462	Power Factor Function 13 Level	none	0	1.0	0.01	0.0		0.01	
463	Power Factor Function 14 Level	none	0	1.0	0.01	0.0		0.01	
464	Power Factor Function 15 Level	none	0	1.0	0.01	0.0		0.01	
465	Power Factor Function 16 Level	none	0	1.0	0.01	0.0		0.01	
466	Power Factor Function 17 Level	none	0	1.0	0.01	0.0		0.01	
467	Power Factor Function 18 Level	none	0	1.0	0.01	0.0		0.01	
468	High/low speed recording space used	none	0	100	1.0	0.0	%	1.0	
469	Trend Recording days Accumulated	none	0	90	1.0	0.0	day	1.0	
Fault Locator 1									
470	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Information
471	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
472	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
473	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
474	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
Fault Locator 2									
475	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Information

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a] Minimum	Transmitted Value[a] Maximum[d]	Scaling[b] Multiplier (default/ (range))	Scaling[b] Offset	Units	Resolution (default/ maximal)[c]	Description
476	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
477	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
478	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
479	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
Fault Locator3									
480	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Infor-mation
481	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
482	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
483	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
484	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
Fault Locator 4									
485	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Infor-mation
486	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
487	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
488	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
489	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
Fault Locator 5									
490	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Infor-mation
491	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
492	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
493	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
494	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
Fault Locator 6									
495	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Infor-mation
496	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
497	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
498	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution (default/ maximal)[c]	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
499	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
Fault Locator 7									
500	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Information
501	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
502	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
503	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
504	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
Fault Locator 8									
505	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Information
506	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
507	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
508	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
509	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
Fault Locator 9									
510	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Information
511	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
512	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
513	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
514	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	
F1ult Locator 10									
515	Fault Information - DNP Time - High 16 bits	none	0	65,535	1.0	0.0	NA	1.0	See note #4 above on how to access Fault Information
516	Fault Information - DNP Time - Middle 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
517	Fault Information - DNP Time - Low 16 bits	none	0	65,535	1.0	0.0	NA	1.0	
518	Fault Information - Distance	none	0	Configurable	0.1	0.0	Configurable	0.1	
519	Fault Information - Type	none	0	15	1.0	0.0	NA	1.0	

a. The minimum and maximum transmitted values are the lowest and highest values that the outstation will report in DNP analog input objects. These values are integers if the outstation transmits only integers. If the outstation is capable of transmitting both integers and floating-point, then integer and floating-point values are required for the minimums and maximums.

For example, a pressure sensor is able to measure 0 to 500 kPa. The outstation provides a linear conversion of the sensor's output signal to integers in the range of 0 to 25000 or floating-point values of 0 to 500.000. The sensor and outstation are used in an application where the maximum possible pressure is 380 kPa. For this input, the minimum transmitted value would be stated as 0 / 0.0 and the maximum transmitted value would be stated as 19000 / 380.000.

b. The scaling information for each point specifies how data transmitted in integer variations (16 bit and 32 bit) is converted to engineering units when received by the Master (i.e. scaled according to the equation: scaled value = multiplier * raw + offset). Scaling is not applied to Floating point variations since they are already transmitted in engineering units.

c. Resolution is the smallest change that may be detected in the value due to quantization errors and is given in the units shown in the previous column. This parameter does not represent the accuracy of the measurement.

d. Maximal values are calculated as (2 * Configured Nominal / Multiplier) for voltage channels and as (20 * Configured Nominal / Multiplier) for current channels (see Note 2 above for the nominal definitions).

2.4 Octet String Points Static (Steady-State) Group Number: 110 Event Group Number: 111	**Capabilities**	**Current Value**	**If configurable, list methods**
2.4.1 Event reporting mode *:	☐ Only most recent ☒ All events		
2.4.2 Octet Strings Included in Class 0 response:	☐ Always ☒ Never ☐ Only if point is assigned to Class 1, 2, or 3 ☐ Based on point Index (add column to table below)		
2.4.3 Definition of Octet String Point List:	☐ Fixed, list shown in table below ☐ Configurable (current list may be shown in table below) ☒ Other, explain <u>Used for Event Log access as described below</u>		

* Object 110 and 111 are Octet String Object used to provide access to the Event Log text of the relay. Object 110 always contains the most recent event in the relay. Object 111 is the corresponding change event object.

As stated in the DNP specifications, the variation of the response object represents the length of the string. The string represents the ASCII values of the event text. The first two characters in the string can be used to quickly identify fault location events. Fault locator events begin with the characters "FL" (0x46, 0x4C hex). The following example shows a fault distance event returned through either of the octet string objects:

Event Message:

FL2000Sep21 20:16:16.966: Line 16:FLoc BG 39.7 miles

DNP Octet string object components:					
0x46	0x4C	0x32	0x30	0x30	0x30
0x53	0x65	0x70	0x32	0x31	0x20
0x33	0x30	0x3A	0x31	0x36	0x3A
0x31	0x36	0x2E	0x39	0x36	0x36
0x20	0x3A	0x20	0x4C	0x69	0x6E
0x65	0x20	0x31	0x36	0x3A	0x46
0x4C	0x6F	0x63	0x20	0x42	0x47
0x20	0x33	0x39	0x2E	0x37	0x20
0x6D	0x69	0x6C	0x65	0x73	

Implementation Table

The following implementation table identifies which object groups and variations, function codes and qualifiers the device supports in both requests and responses. The Request columns identify all requests that are parsed by an Outstation. The Response columns identify all responses that may be sent by an Outstation.

NOTES	The implementation table lists all functionality required by the device (Outstation) as defined within the DNP3 IED Conformance Test Procedures. Any functionality beyond the highest subset level supported is indicated by highlighted rows. Any Object Groups not provided by an outstation are indicated by strike-through (note these Object Groups will still be parsed).

DNP Object Group & Variation			Request Outstation parses		Response Outstation can issue	
Group Num	Var Num	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes (dec)	Qualifier Codes (hex)
1	0	Binary Input - Any Variation	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
1	1	Binary Input - Packed format	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
1	2	Binary Input - With flags	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
2	0	Binary Input Event - Any Variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response)	17, 28 (index)
2	1	Binary Input Event - Without time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
2	2	Binary Input Event - With absolute time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
2	3	Binary Input Event - With relative time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
10	0	Binary Output - Any Variation	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
10	2	Binary Output - Output Status with flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
12	1	Binary Command - Control relay output block (CROB)	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, no ack)	17, 28 (index)	129 (response)	Echo of request
20	0	~~Counter - Any Variation~~	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack)	06 (no range, or all)	129 (response)	

DNP Object Group & Variation			**Request** **Outstation parses**		**Response** **Outstation can issue**	
Group Num	**Var Num**	**Description**	**Function Codes (dec)**	**Qualifier Codes (hex)**	**Function Codes (dec)**	**Qualifier Codes (hex)**
20	1	~~Counter - 32-bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
20	2	~~Counter - 16-bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
20	5	~~Counter - 32-bit without flag~~			129 (response)	~~00, 01 (start-stop)~~
20	6	~~Counter - 16-bit without flag~~			129 (response)	~~00, 01 (start-stop)~~
21	0	~~Frozen Counter - Any Variation~~	1 (read)	06 (no range, or all)		
21	1	~~Frozen Counter - 32-bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
21	2	~~Frozen Counter - 16-bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
21	9	~~Frozen Counter - 32-bit without flag~~			129 (response)	~~00, 01 (start-stop)~~
21	10	~~Frozen Counter - 16-bit without flag~~			129 (response)	~~00, 01 (start-stop)~~
22	0	~~Counter Event - Any Variation~~	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
22	1	~~Counter Event - 32-bit with flag~~			129 (response) ~~130 (unsol. resp)~~	~~17, 28 (index)~~
22	2	~~Counter Event - 16-bit with flag~~			129 (response) ~~130 (unsol. resp)~~	~~17, 28 (index)~~
30	0	Analog Input - Any Variation	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
30	1	Analog Input - 32-bit with flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
30	2	Analog Input - 16-bit with flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
30	3	Analog Input - 32-bit without flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
30	4	Analog Input - 16-bit without flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	
32	0	Analog Input Event - Any Variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response)	17, 28 (index)
32	1	Analog Input Event - 32-bit without time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
32	2	Analog Input Event - 16-bit without time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
32	3	Analog Input Event - 32-bit with time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response)	17, 28 (index)
32	4	Analog Input Event - 16-bit with time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response)	17, 28 (index)
40	0	~~Analog Output Status - Any Variation~~	1 (read)	06 (no range, or all)	129 (response)	
40	2	~~Analog Output Status - 16-bit with flag~~			129 (response)	~~00, 01 (start-stop)~~

DNP Object Group & Variation			Request Outstation parses		Response Outstation can issue	
Group Num	**Var Num**	**Description**	**Function Codes (dec)**	**Qualifier Codes (hex)**	**Function Codes (dec)**	**Qualifier Codes (hex)**
41	2	~~Analog Output - 16-bit~~	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, no ack)	17, 28 (index)	129 (response)	~~Echo of request~~
50	1	~~Time and Date - Absolute time~~	2 (write)	07 (limited qty = 1)	129 (response)	
51	1	~~Time and Date CTO - Absolute time, synchronized~~			~~129 (response)~~ ~~130 (unsol. resp)~~	~~07 (limited qty)~~ ~~(qty = 1)~~
51	2	Time and Date CTO - Absolute time, unsynchronized			129 (response) ~~130 (unsol. resp)~~	07 (limited qty) (qty = 1)
52	1	Time Delay - Coarse			129 (response)	07 (limited qty) (qty = 1)
52	2	~~Time delay - Fine~~			~~129 (response)~~	~~07 (limited qty)~~ ~~(qty = 1)~~
60	1	Class Objects - Class 0 data	1 (read)	06 (no range, or all)	129 (response)	00, 01 (start-stop)
60	2	Class Objects - Class 1 data	1 (read)	06 (no range, or all)	129 (response)	17, 28 (index)
60	3	Class Objects - Class 2 data	1 (read)	06 (no range, or all)	129 (response)	17, 28 (index)
60	4	Class Objects - Class 3 data	1 (read)	06 (no range, or all)	129 (response)	17, 28 (index)
80	1	Internal Indications - Packet format	2 (write)	00 (start-stop) (index = 7)	129 (response)	
110	0	Octet string	1 (read)	06 (no range, or all)	129 (response)	07 (limited qty)
111	0	Octet string event	1 (read)	06 (no range, or all)	129 (response)	07 (limited qty)
No Object (function code only)			13 (cold restart)		129 (response)	
No Object (function code only)			14 (warm restart)		129 (response)	
No Object (function code only)			23 (delay meas.)		129 (response)	

Appendix G Input Modules

G.1 Installation and Safety Instructions

Introduction

This section deals with the installation of the TESLA Input Modules when first delivered. The section covers the physical mounting and wiring.

The following symbols are used in this manual and on the unit. They should be understood before working on the unit:


Caution: refer to equipment documentation


Caution: risk of electric shock


Protective Earth (or Ground) Terminal


Autoranging power supply


Both direct and alternating current

The equipment ratings, operating instructions and installation instructions shall be checked before commissioning or maintenance. It is the responsibility of the user to ensure that the equipment is installed, operated and used for its intended function in the manner specified in this manual. If this is not the case then any safety protection provided by the equipment may be impaired.

Physical Mounting

The following mounting methods are available for the input modules:

Table G.1: Mounting Options

Mounting type	Supported Module Models
Rack Mount	401025, 401026, 401027, 401028
Surface Mount	401025, 401026, 401027, 401028
DIN Mount	401006, 401014, 401021, 401025, 401026, 401027, 401028
DIN/Surface Mount	401025, 401026
Split-Core CT Mount (Hanging, Side Mount or Rear Mount)	Split-Core CTs

The rack mount plate, allows up to 3 modules to be installed in 2U of a 19" rack. Refer to Figure G.1: 2U Module Rack Mount Plate on page Appendix G-3 for the drawing of the rack mount plate. The rack mount style modules are ordered separately from the rack mount plate and the modules must be installed into the plate by the customer. Figure G.2: Installing Modules into Rack Mount Plate on page Appendix G-3 shows how to install the modules into the plate. Use 4 #10 or M6 screws to mount the rack mount plate into the 19 inch rack.

The Surface Mount allows for the input modules to be directly mounted to surfaces and panels via four mounting screw holes. Use 4 #10 or M6 screws to mount the surface mount module.

The DIN Mount allows for mounting on a standard DIN rail installation.

The DIN/Surface Mount provides flexibility for either a standard DIN rail installation or a surface mount installation.

The Split-core CTs are mounted either by simply hanging off the primary wiring or they may be securely mounted using a side mount, rear mount or DIN rail bracket.

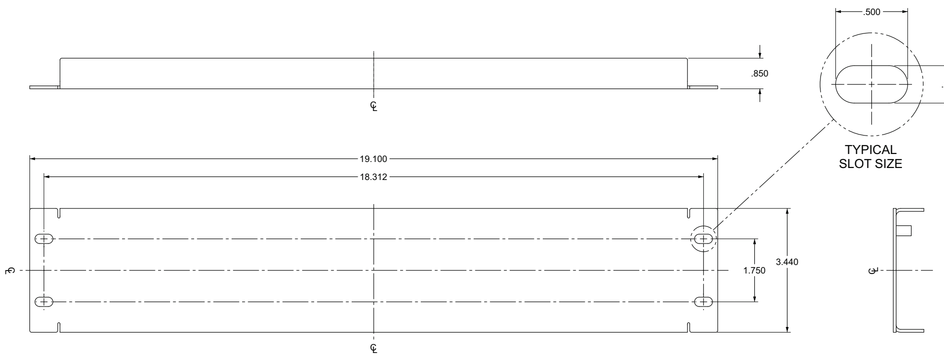


Figure G.1: 2U Module Rack Mount Plate

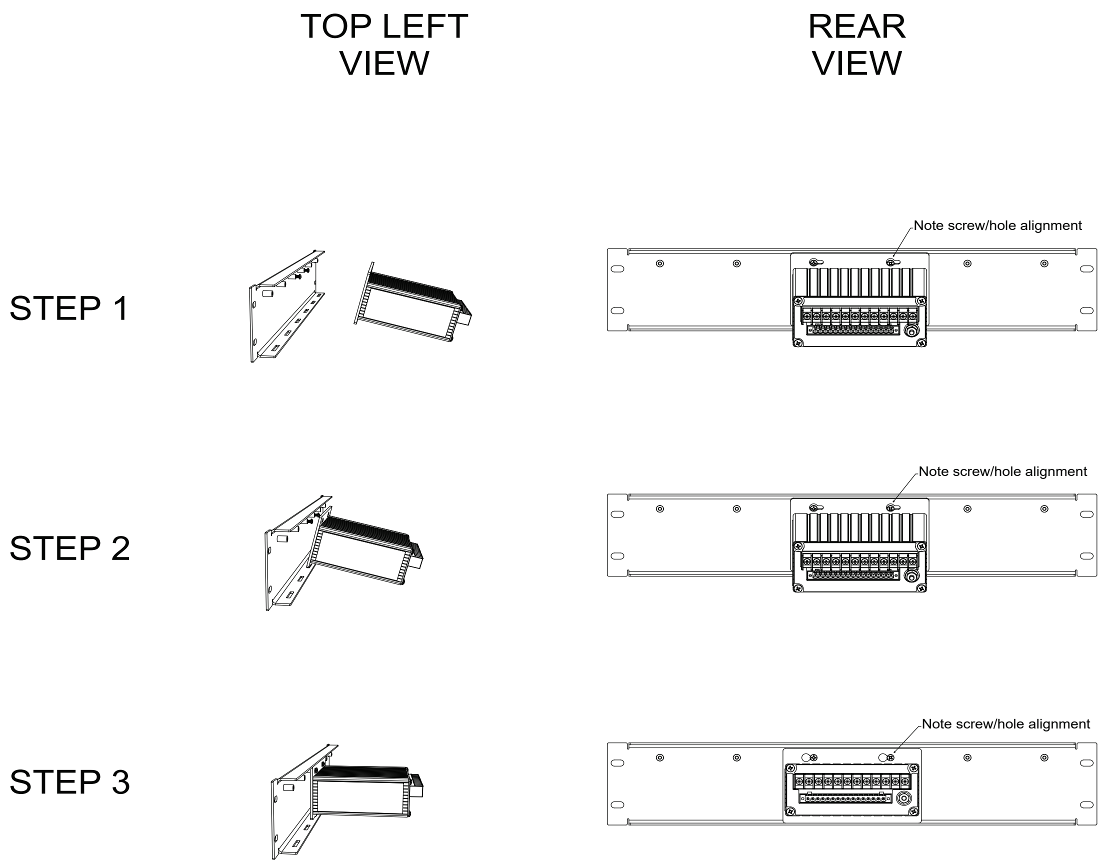


Figure G.2: Installing Modules into Rack Mount Plate

WARNING!

This equipment is intended for use by trained personnel in restricted areas only. Hazardous voltages may be present at the rear of the unit and a suitable protective barrier must be provided to protect against electric shock due to accidental contact.

Case Grounding

WARNING!

The ground terminal (also known as the protective earth) on the connector end of the unit and the modules must be connected as shown in Figure G.3 : Protective Earth Connection on page Appendix G-4 before the unit is energized in order to prevent electric shock. The protective earth connection shall be checked before carrying out any other actions and shall not be removed when the unit is energized.

The terminal used must be made of a material that is galvanically compatible with the zinc plated washers, nut and stud provided with the unit. Tinned terminals are acceptable. The recommended minimum protective earth conductor wire size is 3.3 mm² unless otherwise required by local or country wiring regulations. Copper wire is recommended and must be must be low-inductance and as short as possible.

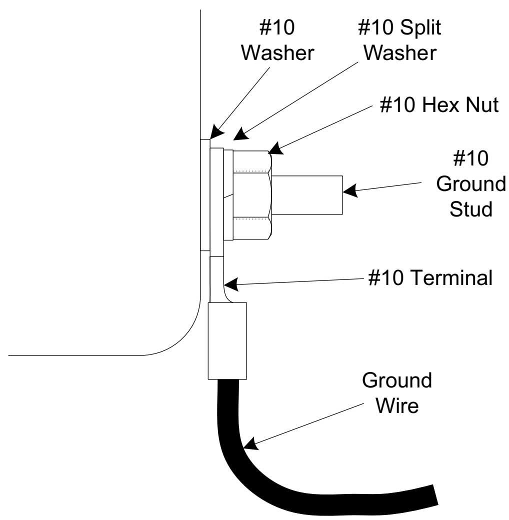


Figure G.3: Protective Earth Connection

Power Supply

All of the TESLA Input modules, except for the AC/DC Input Modules, do not have a power supply and simply require input and output and safety ground connections.

Refer to “AC/DC Input Module 401016 Model Ratings” on page Appendix G-27 for details regarding the Model 401016 power supply. Refer to “Power Supply” on page Appendix G-34 for details regarding the Model 401027 Power Supply.

There are no power switches on the AC/DC Input Modules. When the power supply is connected, the input module is ready for use.

Signal Connections

Analog Input Channels and Input Modules

The recorder's analog inputs are generic, low level (±-2.5 V pp) non-isolated signal inputs. They take their input from external interface modules that provide scaling, isolation and surge protection.

The external input modules accept conventional substation voltage and current signals and convert them into low level voltages that are fed into the recorder's analog inputs. All modules are available for DIN rail mounting to make wiring easier and minimize rack space requirement. For added flexibility, some modules are also available in a surface mount or rack mount configuration.

Most modules can be located up to 1220 meters (4000 feet) from the recorder. The wire used for the connection between the modules and the recorder can range in size from 12 to 28 AWG. 12 to 20 AWG is recommended if the modules are more than 200m from the TESLA. It is highly recommended that shielded twisted-pair wire be used for cables that are run outside of the panel in which the TESLA is located. Belden 9388, or its equivalent, is an example of an acceptable cable that can be used.

Any of the recorder's analog input channels can be connected to any of the available input modules. The software configuration identifies the type of input module associated with each channel.

WARNING!

Applying signals greater than ± 2.5 V pp or a common mode voltage outside of the range of ± 3V with respect to the chassis ground to the analog inputs will result in permanent damage to the unit and may result in electric shock. These inputs should only be connected to ERLPhase input modules.

Each external module input channel can only be connected to one recorder input channel. Source and load impedance matching are used to minimize noise susceptibility; connecting to two channels will produce incorrect readings.

All input modules must be grounded via the ground stud on the module.

Re-calibration is required whenever an input module is replaced or moved to a different channel (see “Analog Input Calibration” on page 8-28)

G.2 AC Voltage Input Module

The AC Voltage Input Module provides 3 channels or 4 channels of isolation and scaling for standard secondary voltage. Inputs are AC coupled through transformers. The 401006 and 401026 models have nominal signal level is 69 V rms (120√3) with a full-scale 2x over-range capability that can be sustaining continuously. The 401028 model has a nominal signal level of 600 V_{RMS} with a full-scale rating of 720 V_{RMS} continuous.

Output from the module is scaled to connect directly to the TESLA's analog input terminals. Due to impedance matching requirements, module channels cannot be connected to more than one TESLA input channel.

Table G.2: AC Voltage Input Modules

Module Type in TESLA Control Panel	Channels	Mounting Style	Case Material	Figure
401006 69V_{AC} Isolated Neutral	3	DIN	Plastic	Figure G.4:
401026 69V_{AC} Isolated Neutral	4	DIN/Surface	Metal	Figure G.5:
401026 69V_{AC} Isolated Neutral	4	Rack	Metal	Figure G.6:
401026 69V_{AC} Isolated Neutral	4	Surface	Metal	Figure G.7:
401026 69V_{AC} Isolated Neutral	4	DIN	Metal	Figure G.8:
401028 600V_{AC} Isolated Neutral	3	DIN	Metal	Figure G.9:
401028 600V_{AC} Isolated Neutral	3	Rack	Metal	Figure G.10:
401028 600V_{AC} Isolated Neutral	3	Surface	Metal	Figure G.11:

Table G.3: AC Voltage Input Module Ratings	
Description	**Ratings**
Model 401006 69V_{AC} Isolated Neutral	Nominal Vn: 69 V_{RMS} (120 V_{RMS} L-L) Full scale and continuous: 2x Vn = 138 V_{RMS} (240V_{RMS} L-L) Thermal withstand: 4x Vn = 276 V_{RMS} (480 V_{RMS} L-L) for 3 seconds 3x Vn = 207 V_{RMS} (360 V_{RMS} L-L) for 10 seconds Burden: 0.05 VA @ 69 V_{RMS}
Model 401026 69V_{AC} Isolated Neutral	Nominal Vn: 69 V_{RMS} (120 Vrms L-L) Full scale and continuous: 2x Vn = 138 V_{RMS} (240V_{RMS} L-L) Thermal withstand: 4x Vn = 276 V_{RMS} (480 V_{RMS} L-L) for 3 seconds 3x Vn = 207 V_{RMS} (360 V_{RMS} L-L) for 10 seconds Burden: 0.03VA @ 69 V_{RMS}
Model 401028 600V_{AC} Isolated Neutral	Nominal Vn: 600 V_{RMS} Full scale (Vfs): 720 V_{RMS} Thermal withstand: 720 V_{RMS} continuous, 1000 V_{RMS} for 10 seconds Output: 3 isolated channels 1.768 V_{AC} across a 1kohm resistive load with a 720V_{AC} input

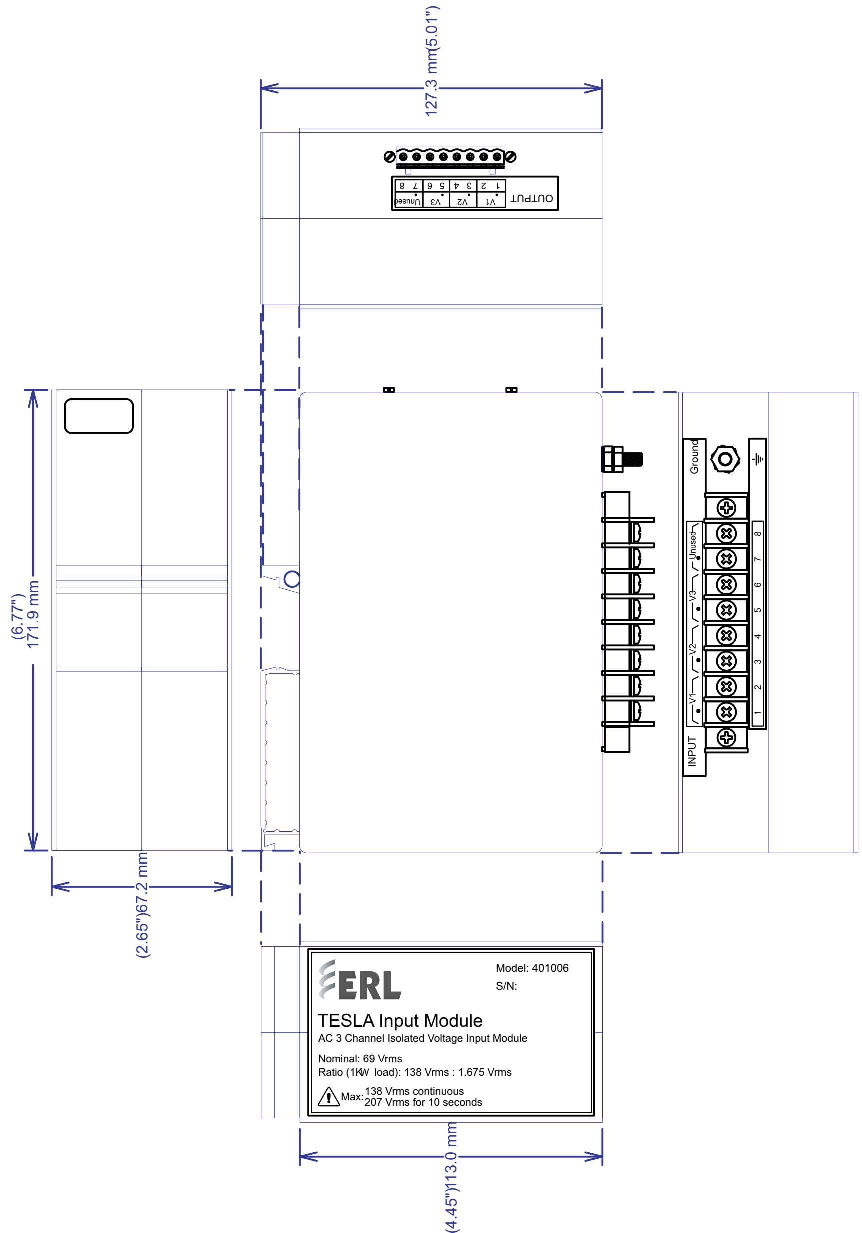


Figure G.4: 3 Channel AC Voltage Input Module (Model 401006)

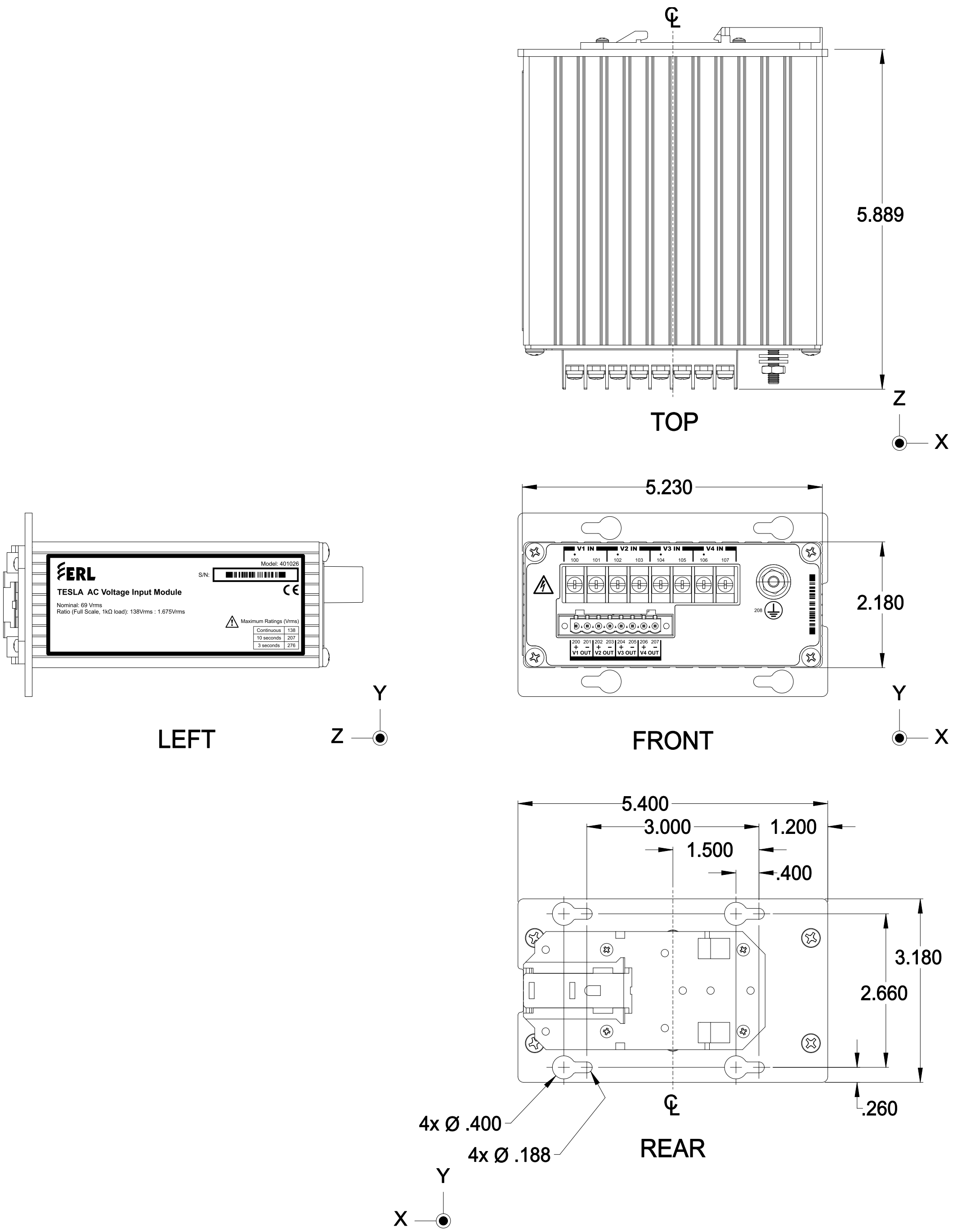


Figure G.5: 4 Channel AC Voltage Input Module Model 401026 – DIN/Surface Mount

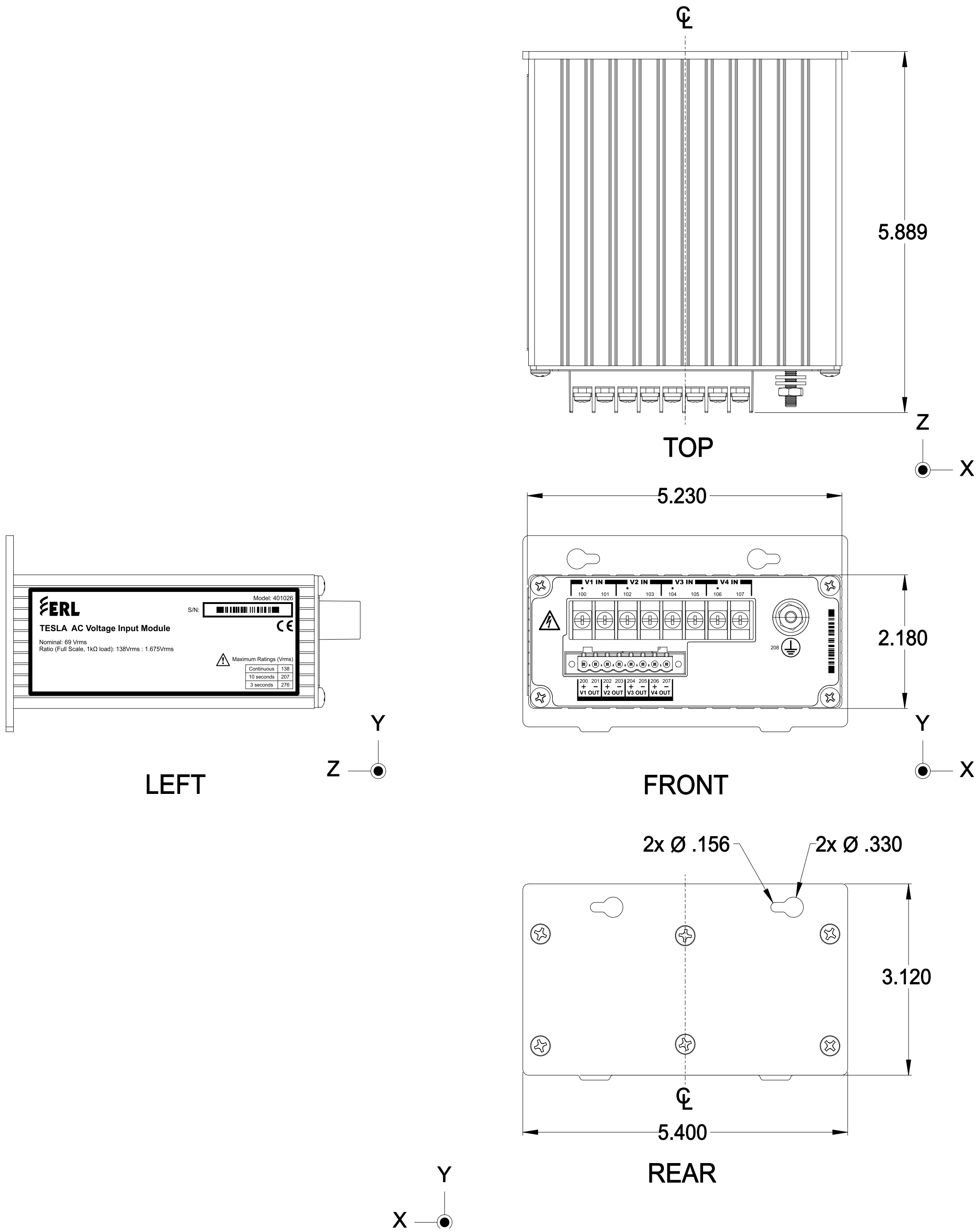


Figure G.6: 4 Channel AC Voltage Input Module Model 401026 – Rack Mount

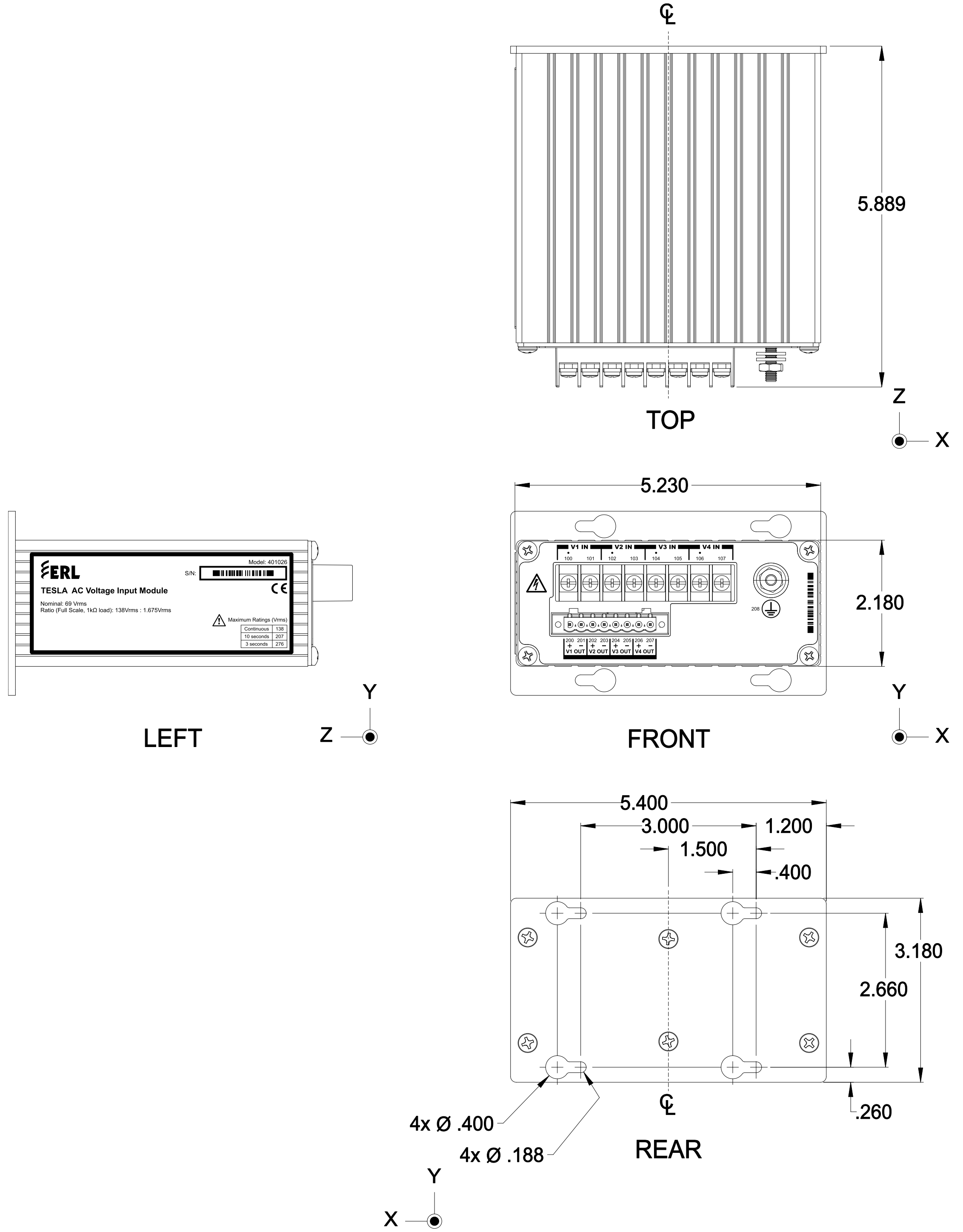


Figure G.7: 4 Channel AC Voltage Input Module Model 401026 – Surface Mount

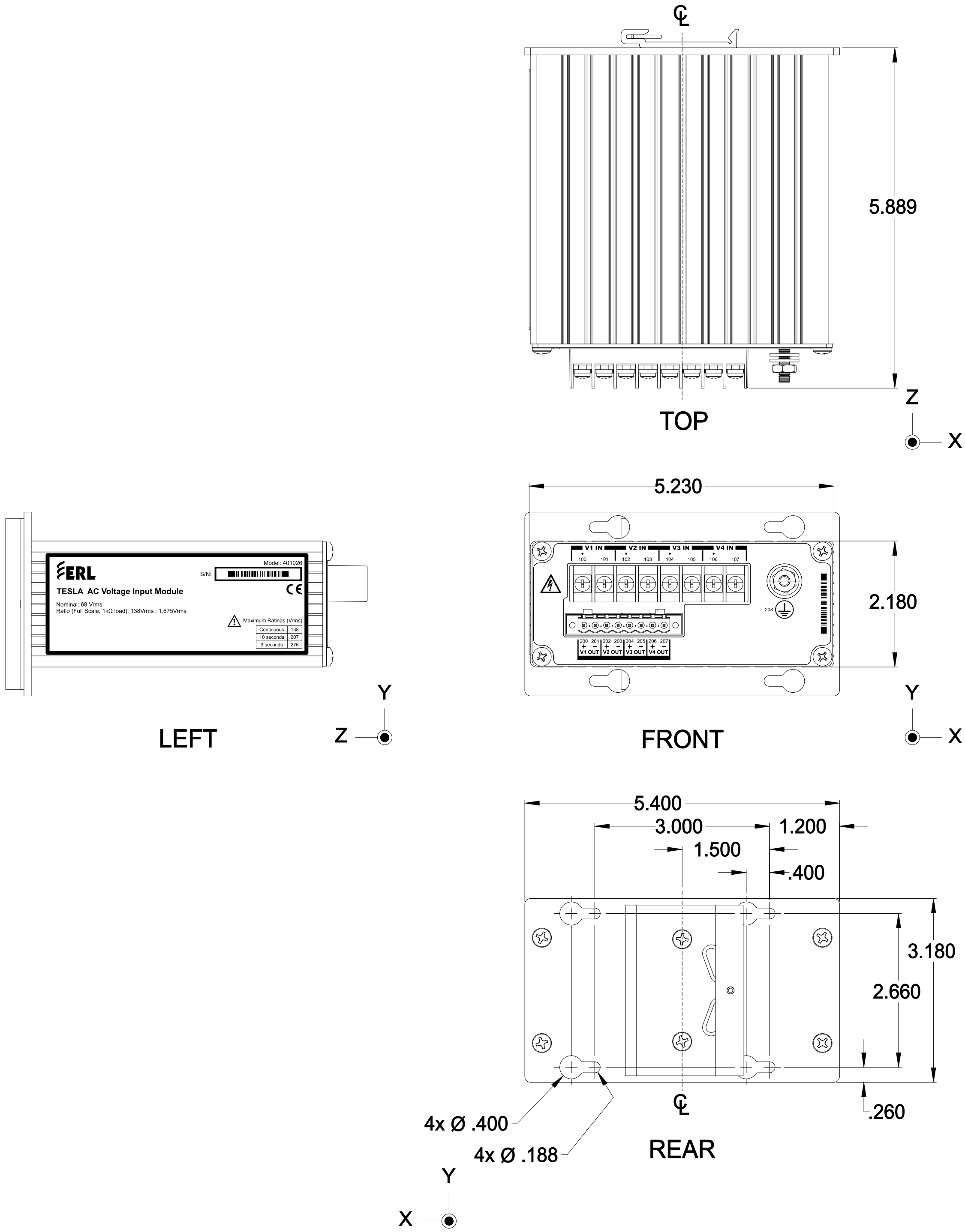


Figure G.8: 4 Channel AC Voltage Input Module Model 401026 – DIN Mount

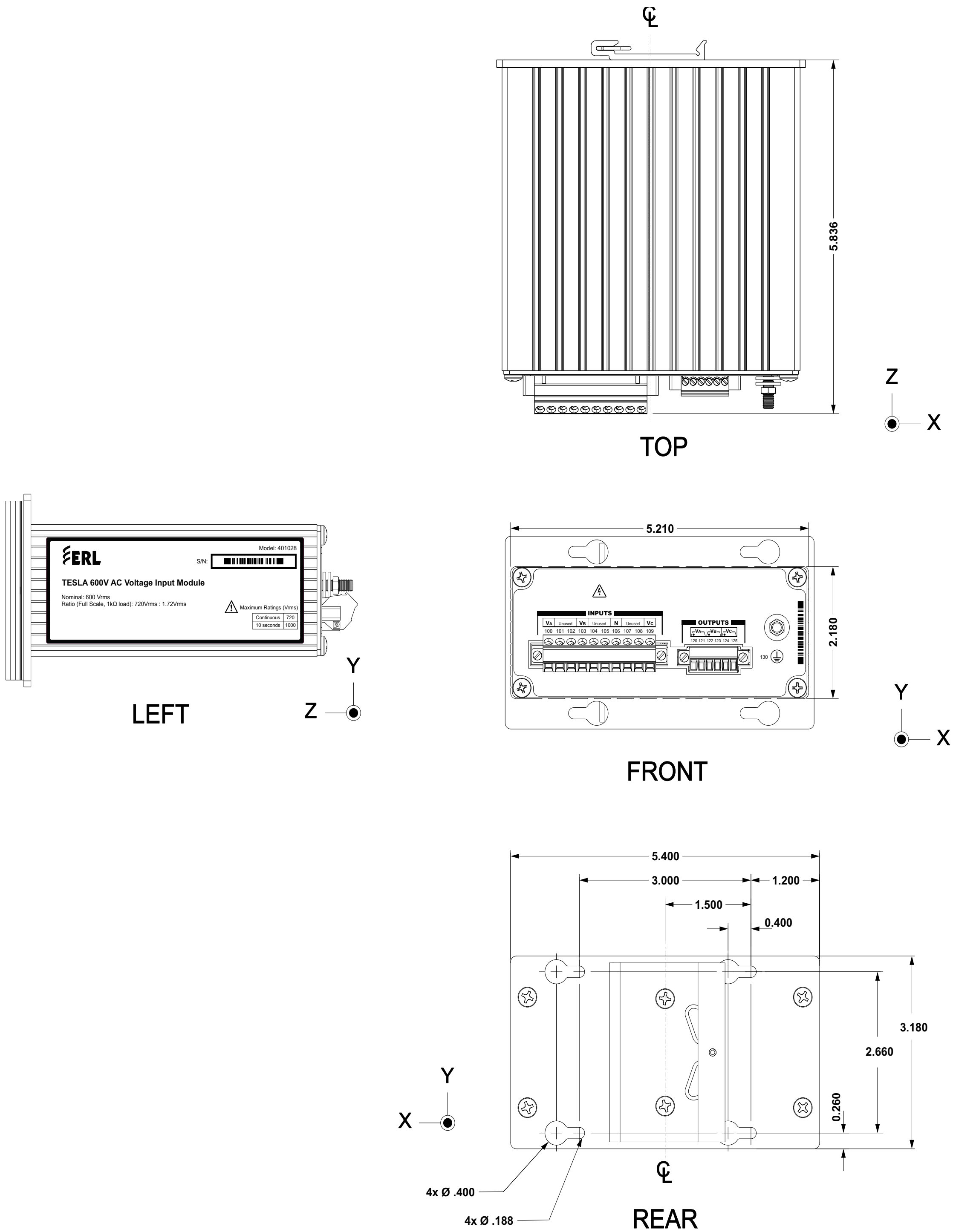


Figure G.9: 600V AC Voltage Input Module Model 401028 - DIN Mount

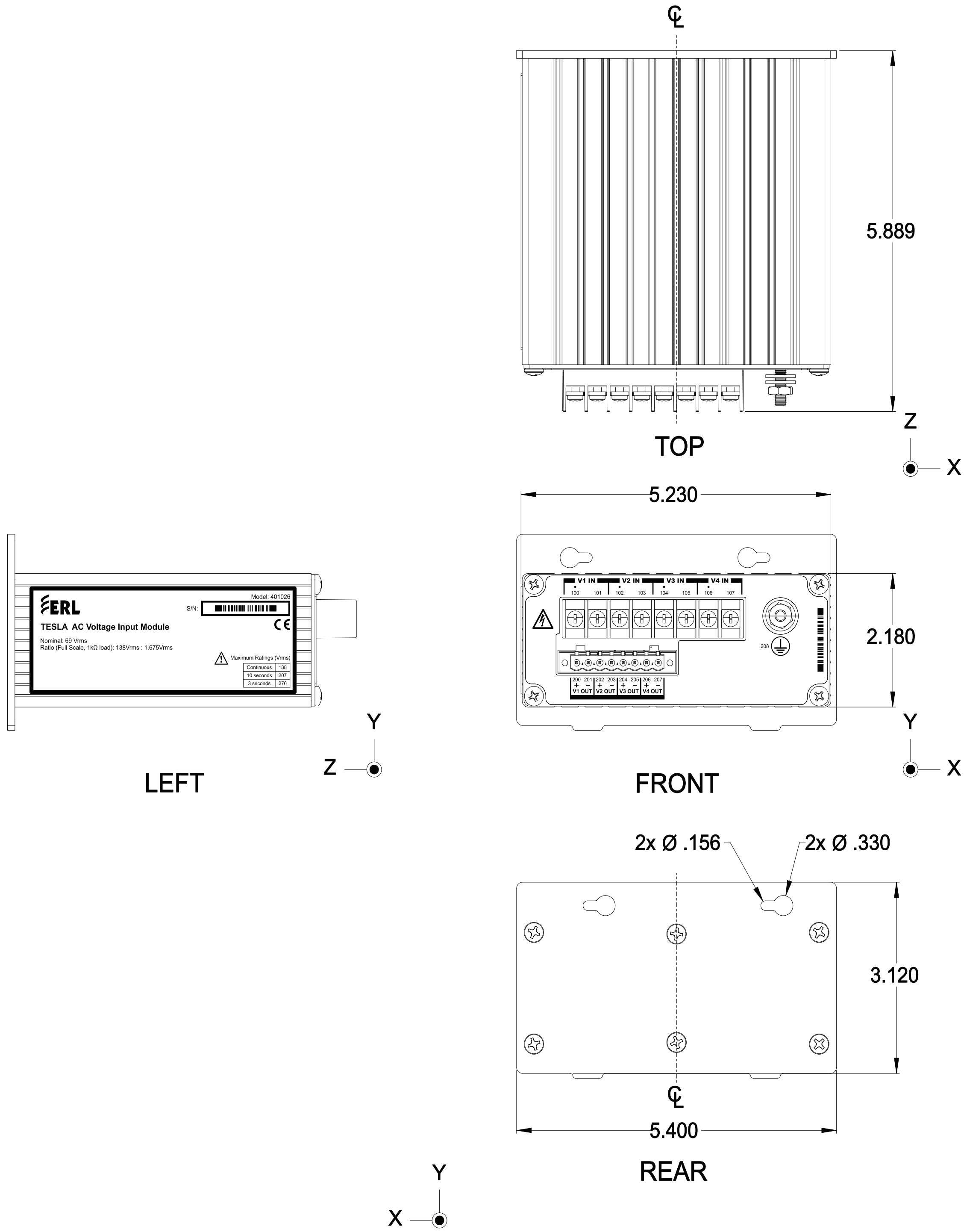


Figure G.10: 600V AC Voltage Input Module Model 401028 - Rack Mount

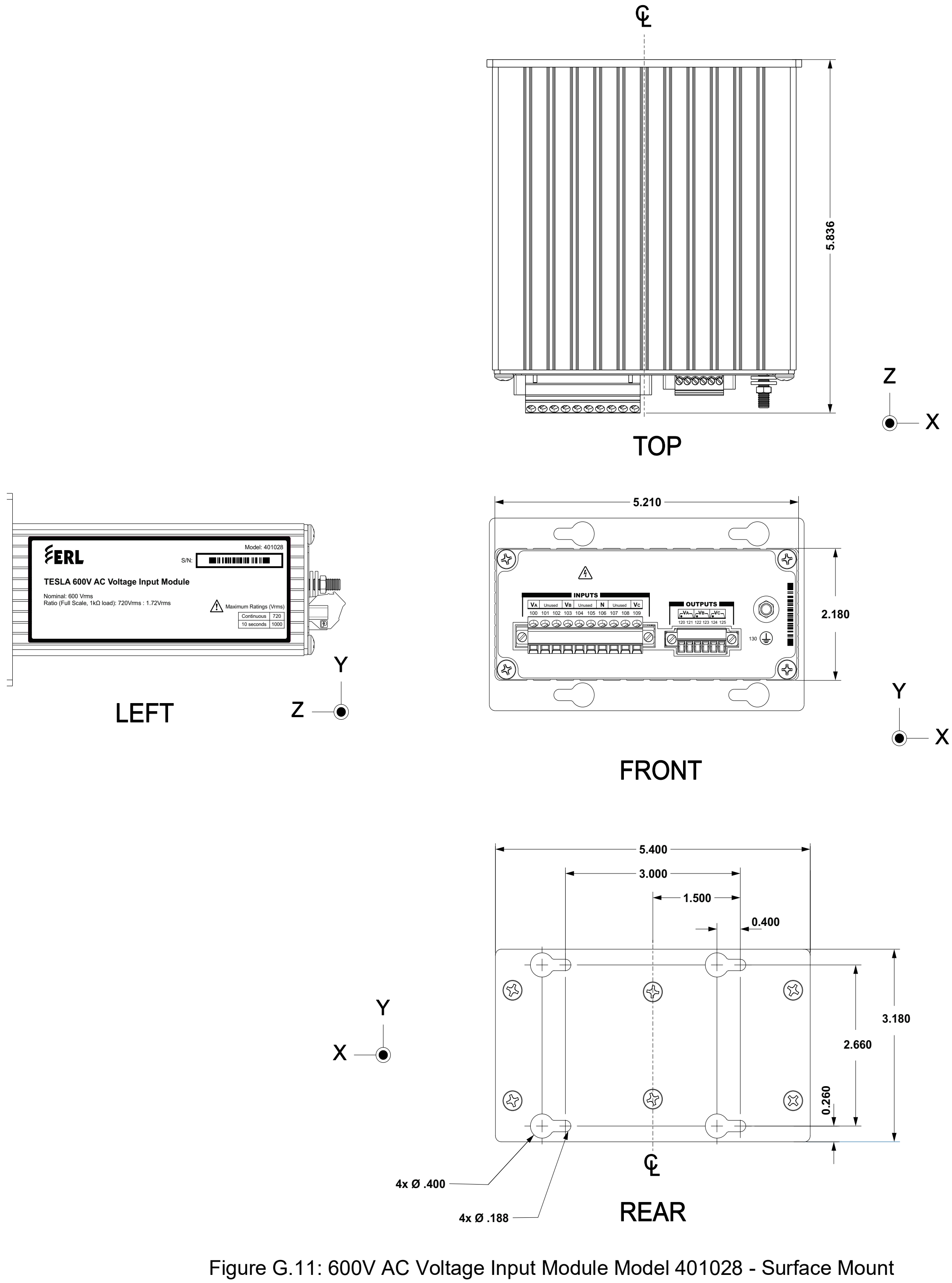


Figure G.11: 600V AC Voltage Input Module Model 401028 - Surface Mount

G.3 AC Current Input Module

The AC Current Input Module provides 4 channels of isolation and scaling for standard secondary current signals. Inputs are AC coupled through transformers. Modules are available with 1A, 5A or both 1A and 5A inputs. See Table G.4: AC Current Input Modules for the modules available to order. The thermal withstand current on the inputs varies from 40x nominal to 100x nominal.

For modules with a user selectable nominal input rating, the selection is made by connecting the to either the 1A terminal or the 5A terminal on the input connector. The selection is indicated in Control Panel by selecting either the 1Aac or the 5Aac module type from the module type pulldown menu.

Output from the module is scaled to connect directly to the TESLA's analog input terminals. Due to impedance matching requirements, module channels cannot be connected to more than one TESLA input channel.

The Full Scale rating of the module indicates the maximum current that can be measured before the output exceeds the input rating of the TESLA. The Full Scale rating is either fixed or user selectable for each module as shown in Table G.4: AC Current Input Modules. For modules with a fixed Full Scale rating, Control Panel automatically selects the correct Full Scale setting.

For modules with a user selectable Full Scale rating, the selection is made on the module by changing the shunt resistor (labeled "R_{SH}" on the module) on the output connector as shown in Table G.6: Full Scale Rating Adjustment. The Full Scale rating must also be correctly entered in Control Panel to match the R_{SH} installed. The Full Scale rating of the module is shipped as 20x, with a 1.5kΩ resistor installed. To change the input module to a Full Scale Rating of 40x, remove the 1.5kΩ resistor. To change the input module to a Full Scale Rating of 10x, replace the 1.5kΩ resistor with a wire jumper. See Figure G.12: Adjusting the Full Scale Rating,which shows the factory default 20x Full Scale rating with 1.5kΩ resistor installed.

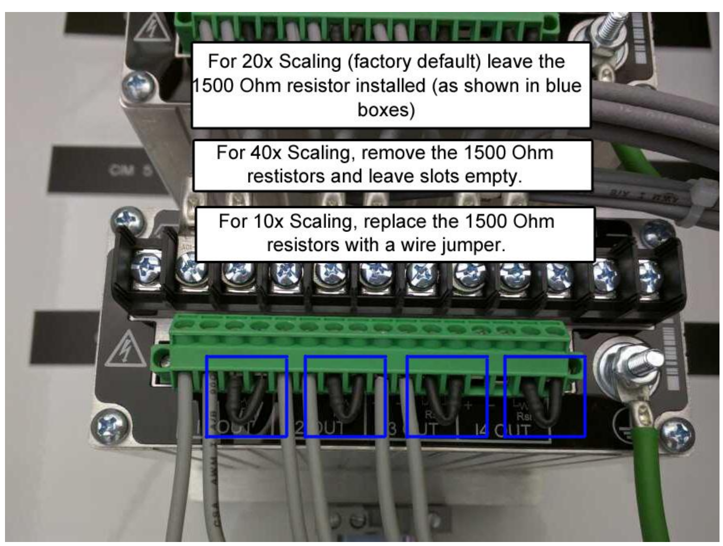


Figure G.12: Adjusting the Full Scale Rating

Table G.4: AC Current Input Modules						
Module Type in TESLA Control Panel	**Nominal (In)**	**Full Scale**	**Thermal Withstand (1s)**	**Mounting Style**	**Case Material**	**Figure**
401021 $1A_{AC}$	1A	20x I_N	100x I_N	DIN	Plastic	Figure G.13:
401014 $5A_{AC}$	5A	20x I_N	40x I_N	DIN	Plastic	Figure G.13:
110739 5A Himax	5A	20x I_N	40x I_N	DIN	Plastic	Figure G.13:
401025 $1A_{AC}$ or 401025 $5A_{AC}$	User selectable: 1 A or 5 A	User selectable: 10x/20x/40x I_N	100x I_N	DIN/Surface	Metal	Figure G.14:
401025 $1A_{AC}$ or 401025 $5A_{AC}$	User selectable: 1 A or 5 A	User selectable: 10x/20x/40x I_N	100x I_N	Rack	Metal	Figure G.15:
401025 $1A_{AC}$ or 401025 $5A_{AC}$	User selectable: 1 A or 5 A	User selectable: 10x/20x/40x I_N	100x I_N	Surface	Metal	Figure G.16:
401025 $1A_{AC}$ or 401025 $5A_{AC}$	User selectable: 1 A or 5 A	User selectable: 10x/20x/40x I_N	100x I_N	DIN2	Metal	Figure G.17:

Table G.5: AC Current Input Module Ratings	
Module Type in TESLA Control Panel	**Ratings**
Model 401021 $1A_{AC}$ or Model 401014 $5A_{AC}$ or Model 110739 5A Himax	Nominal In: 1 A_{RMS} or 5 A_{RMS} (order option) Continuous: 4x I_N Full scale: 20x I_N Thermal withstand: 40x for 1 second Burden: 0.25 VA @ 5A, 0.05 VA @ 1A
401025 $1A_{AC}$ or 401025 $5A_{AC}$	Nominal In: 1 A_{RMS} and 5 A_{RMS} (connection option) Continuous: 4x I_N Full scale: user configurable 10x, 20x or 40x I_N Thermal withstand: 50x I_N for 3 seconds, 100x I_N for 1 second Burden: 1A Input: <0.07VA @ In, 5A Input: <0.25VA @ In

Table G.6: Full Scale Rating Adjustment	
Full Scale	**Shunt Resistor (R_{SH})**
10x I_N	R_{SH} = 0 Ω (short/jumper)
20x I_N	R_{SH} = 1500 Ω (default)
40x I_N	R_{SH} = open (empty)

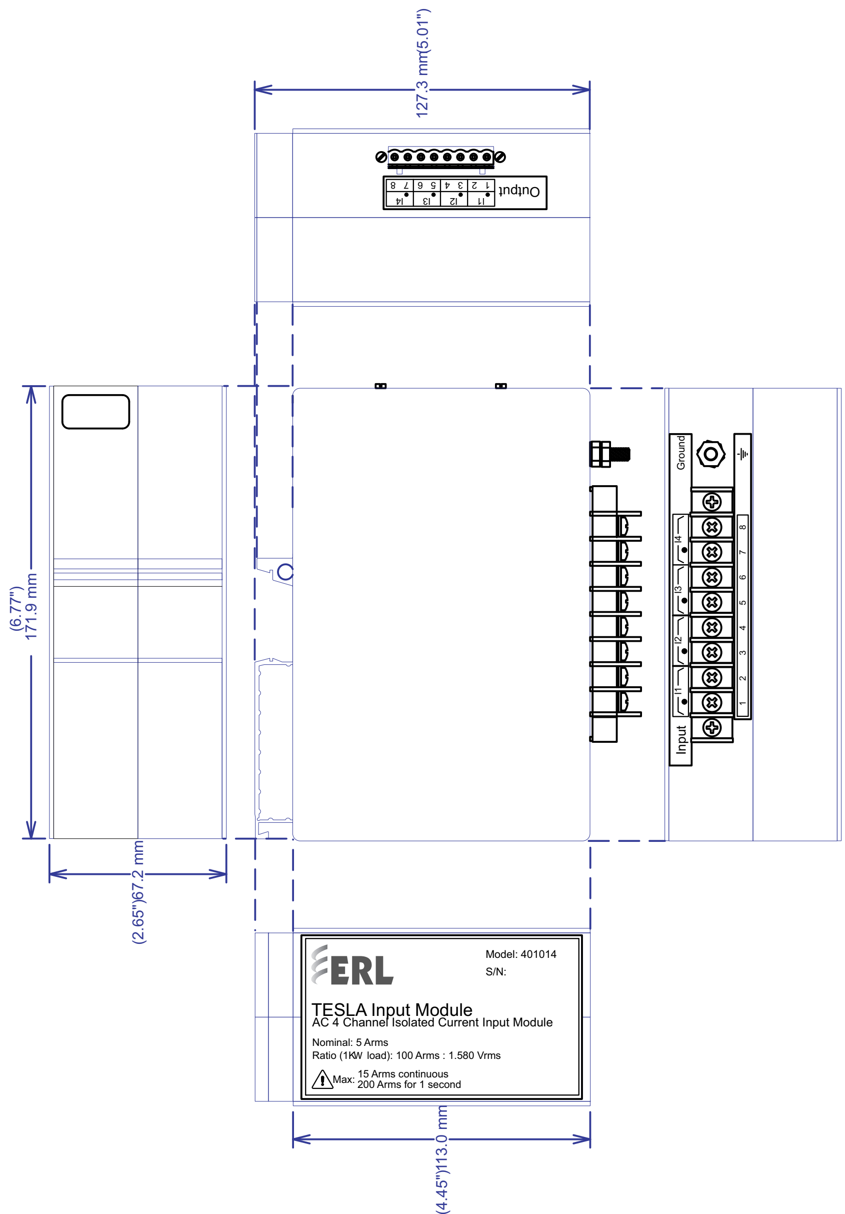


Figure G.13: AC Current Input Module Models 401021, 401014, 110739

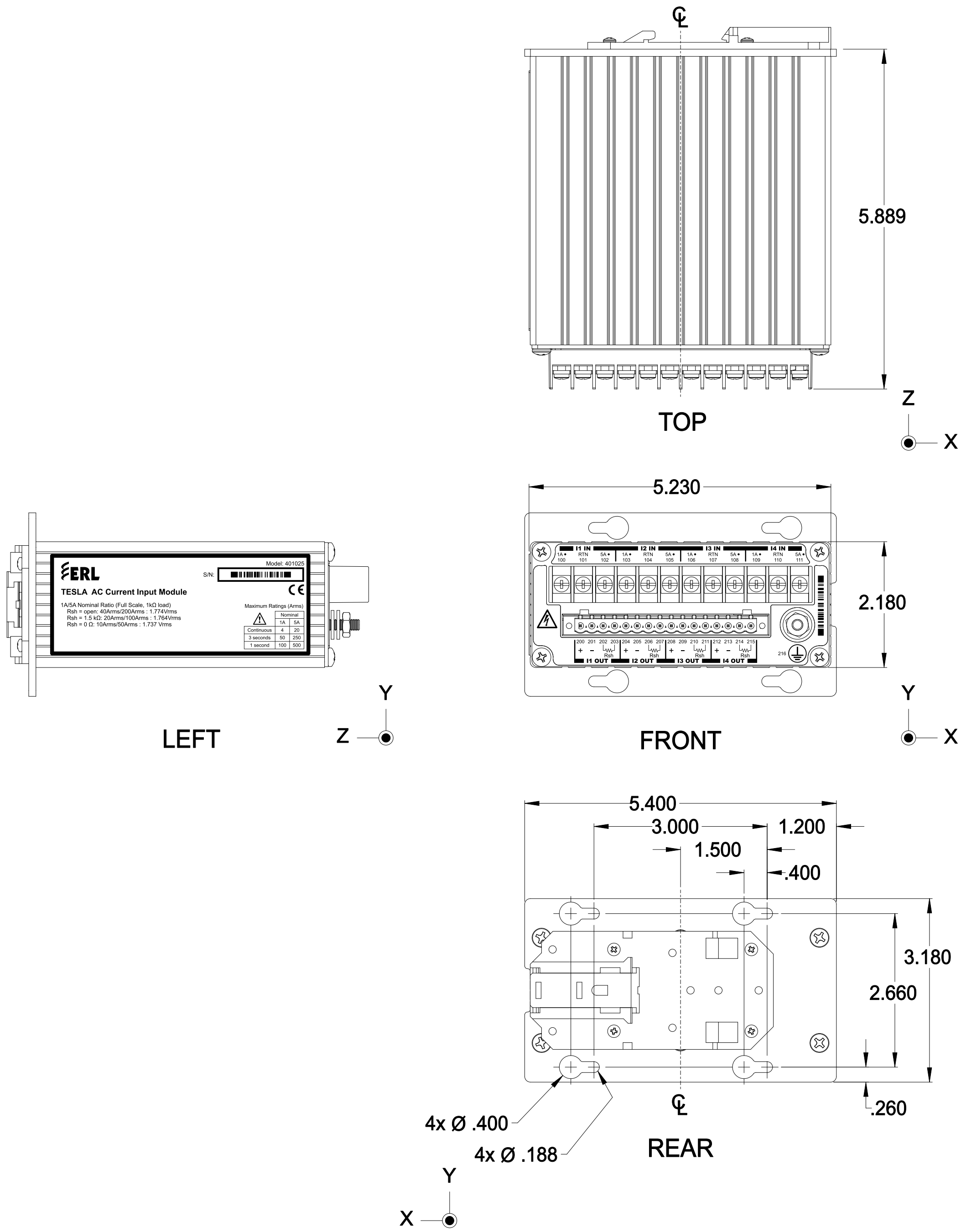


Figure G.14: AC Current Input Module Model 401025 - DIN/Surface Mount

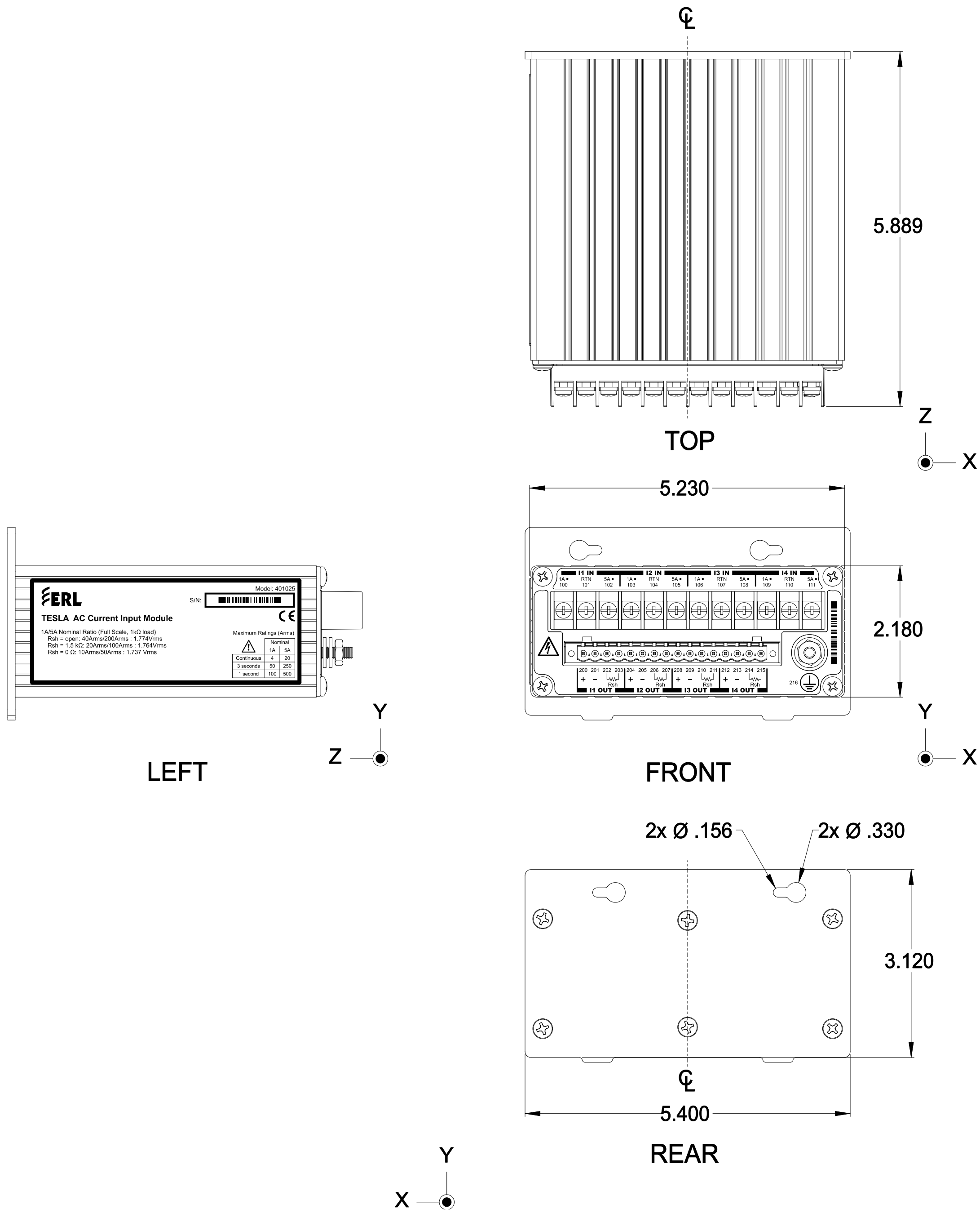


Figure G.15: AC Current Input Module Model 401025 - Rack Mount

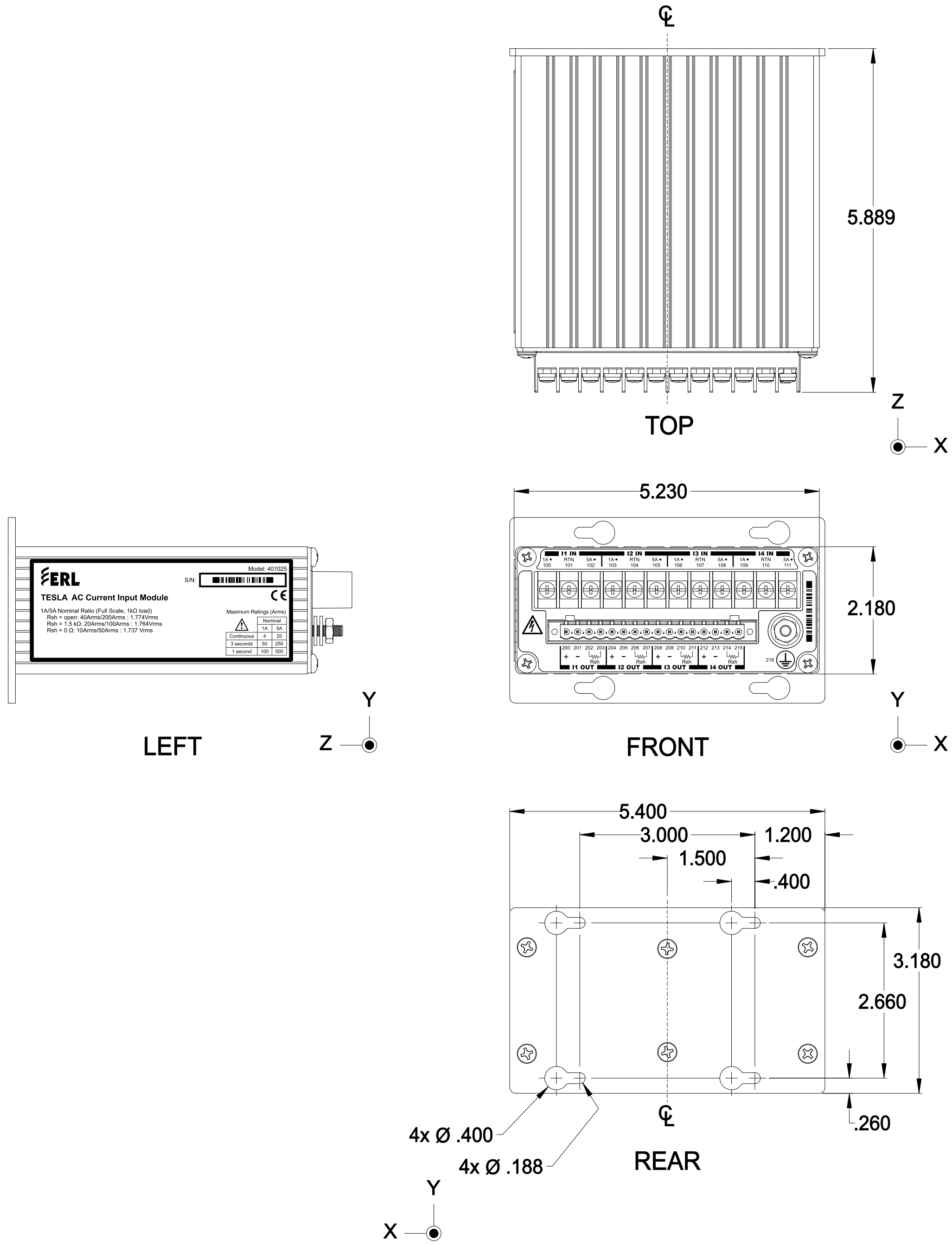


Figure G.16: AC Current Input Module Model 401025 - Surface Mount

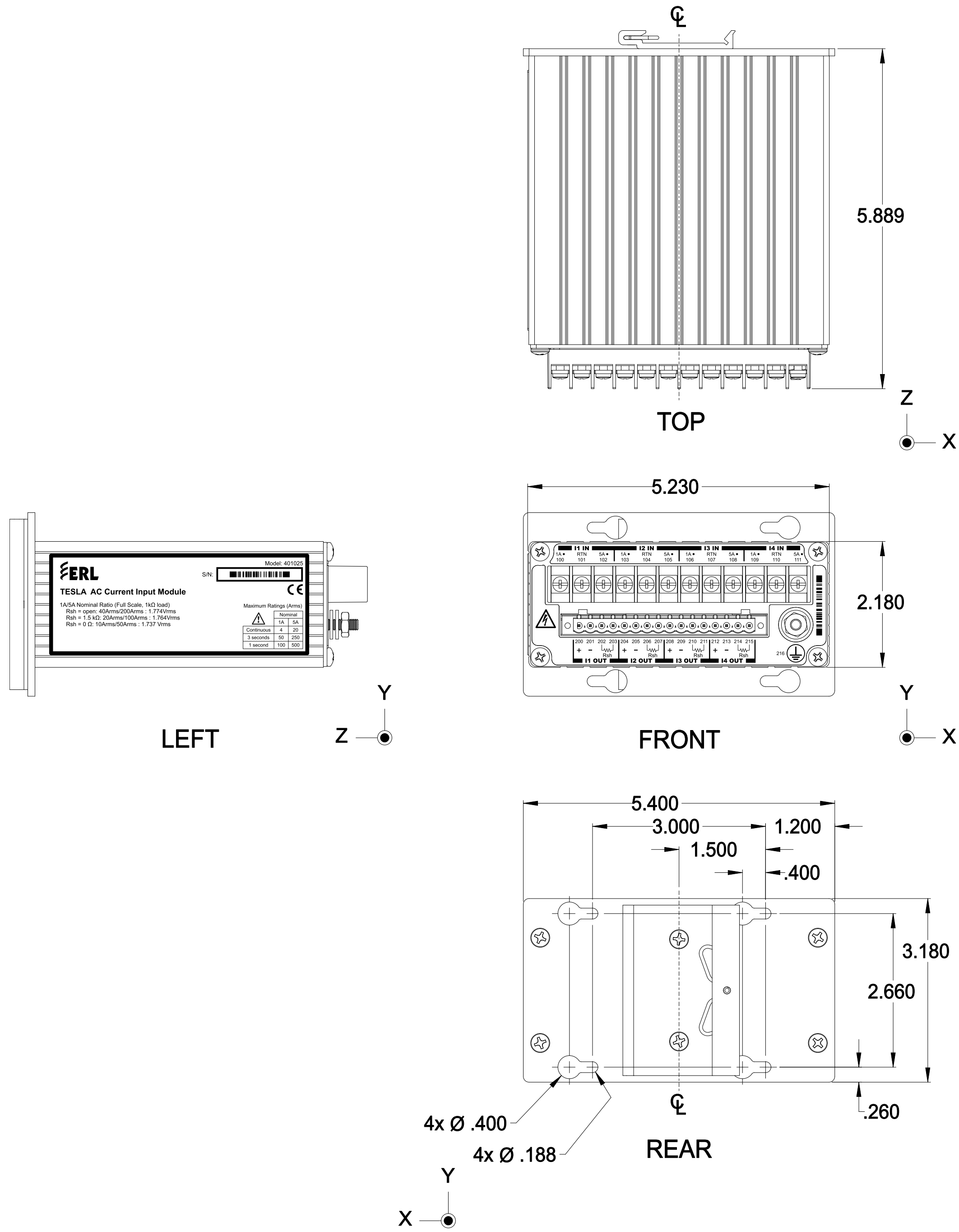


Figure G.17: AC Current Input Module Model 401025 - DIN Mount

G.4 Split Core CT

The Split Core CT is designed to clamp around the secondary circuit wires from the primary current transformers. It is intended for situations where an outage is not possible to connect an in-line CT.

The Split Core CT has the same characteristics as the standard AC Current Input Module. It is available in 1A nominal and 5A nominal versions. There are 1A and 5A variants with a dynamic range that can pass 20x nominal currents continuously and another 5A variant that can pass 40x nominal currents continuously. The outputs from the CT are scaled and impedance matched to connect directly to the TESLA's analog input connectors. Due to impedance matching requirements, the CT cannot be connected to more than one TESLA input channel. The Split Core CT can be located up to 1220 meters (4000 feet) from the TESLA.

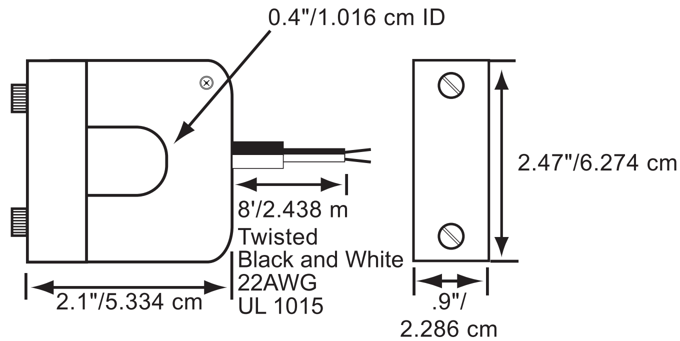


Figure G.18: Split Core CT (20x In models)

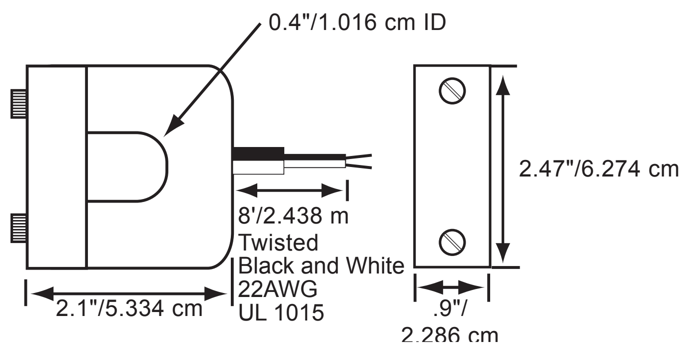


Figure G.19: Split Core CT (40x In model)

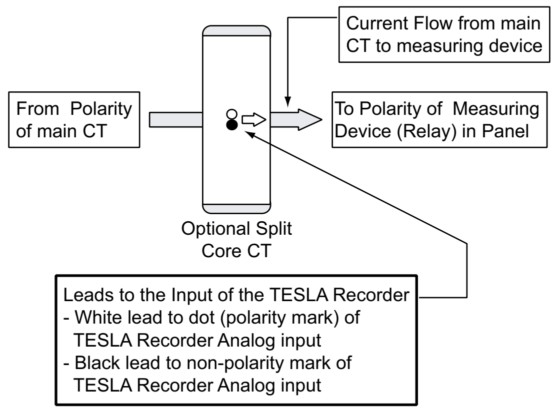


Figure G.20: Split Core CT Connection

Table G.7: Split Core CT Input Module Ratings

Specs	**Model 401013 (5A)**	**Model 401017 (1A)**	**Model 401013-2 (5A)**
Nominal Current	I_N = 5 A_{RMS}	I_N = 1 A_{RMS}	I_N = 5 A_{RMS}
Full Scale/Continuous	3x I_N = 15 A_{RMS}	3x I_N = 3 A_{RMS}	4x I_N = 20 A_{RMS}
Maximum Over-scale	20x I_N = 100 A_{RMS} for 1 second (no distortion)	20x = 20 A_{RMS} for 1 second (no distortion)	40x = 200 A_{RMS} I_N for 1 second (no distortion)
Thermal Rating	80x = 400 A_{RMS} for 1 second	400x = 400 A_{RMS} for 1 second	100x I_N = 500 A_{RMS} for 1s 50x I_N = 250 A_{RMS} for 3s
Burden	<0.25 VA @ 5 A_{RMS}	<0.1 VA @ 1 Arms	<0.15 VA @ 5 A_{RMS}
Ratio (1kΩ load)	15.8 mV/A	79mV/A	8.84 mV/A
Ratio/Linearity Accuracy	0.5 % full scale, ± 0.5% range		0.5% of reading from 0.2 to 20X I_N
Phase Displacement or Shift	0.25° or less @ 60Hz		0.5 degrees from 0.2 to 8X I_N
Phase Connection Relationship	White wire positive with arrow towards source of current		

G.5 AC/DC Input Modules

G.5.1 AC/DC Input Module Model 401016

The AC/DC Input Module (Model 401016) provides DC-coupled isolation and scaling for four independent DC or AC voltage or current channels. DC module channels have a DC to 2 kHz bandwidth, but the bandwidth may be limited by the recorder's input filters, depending on the sample rate. Externally mounted resistors set the input type and full scale range.

Output from the module is scaled to connect directly to the TESLA's analog input terminals. Due to impedance matching requirements, module channels cannot be connected to more than one TESLA input channel.

Input and Range Configuration

Resistors mounted on each channels input connector set the channel's input range. Up to three resistors are used, depending on the type and level of the signal to be applied.

The input signal is applied to low or high range terminals, as appropriate for the selected input range.

The following tables give resistor values and wiring examples for different applications. For applications that are not in these tables, contact ERLPhase.

All resistors must be rated for ¼ watt or more, unless otherwise specified. Unless otherwise noted, the R_{IN} resistor must be rated to handle the full input voltage, which may require a physically larger resistor be used. This is generally true of any application that has an input in excess of 50 V peak.

The resistor values specified are precision values as per the E48 standard series of resistance values in a decade. See the section “Standard Series of Values in a Decade” on page Appendix G-32 for the full table of standard values. It is possible to use other available values, although range and resolution may be compromised. Always select R_{IN} of equal or greater value to that shown, and select R_{FB} of equal or lesser value to that shown.

The Vishay CCF-2 series resistors in ±1% precision, or equivalent, are recommended for this application. These metal film flameproof resistors are rated for industrial power applications at up to 2 Watts dissipation and up to 350 Volt drop. Values of 4.99 Ω to 1 MΩ are available in this series - for higher values, use two resistors of appropriate value in series.

Table G.8: AC/DC Input Module 401016 Model Ratings

Configured mode	Ratings	
Model 401016 Voltage Mode	Low range:0.1 to 200 V_{DC} full scale 0.1 to 150 V_{RMS} full scale High range: 350 V to 880 V_{DC} full scale 200 V to 600 V_{RMS} full scale	Ratio (1 kΩ load): Dependant on configuration Input Impedance: Dependant on configuration Power Supply: 100-120V_{AC} ±10% @ 50/60Hz 48-250V_{DC} ±20%. Channel to ground isolation: 1500 V Channel to channel isolation: 1500 V Dimensions LxWxH: 172mm x 113mm x 67.2mm
Model 401016 Current Mode	Direct input from transducers: 1 to 500 mA_{DC} full scale AC or DC from high current shunts (mV)0.1 to 1000 mV (AC or DC) across the shunt	

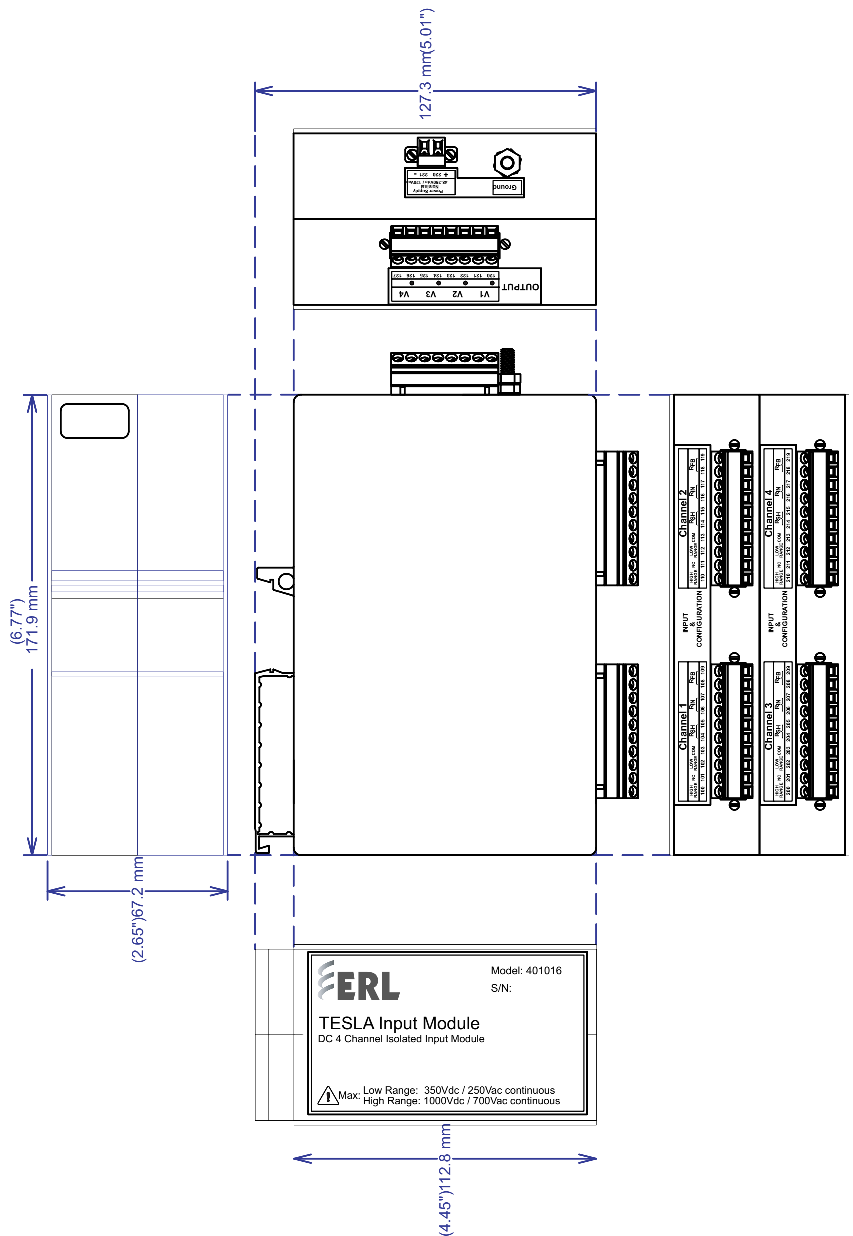
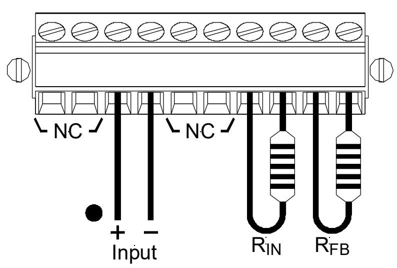
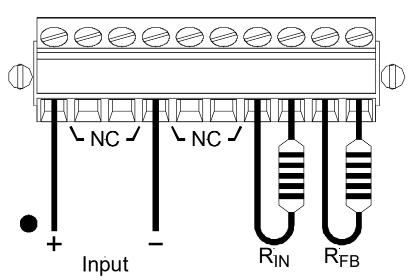


Figure G.21: DC Input Module Model 401016

The Max ratings shown in Figure G.21 are the maximum continuous voltage rating of the module.

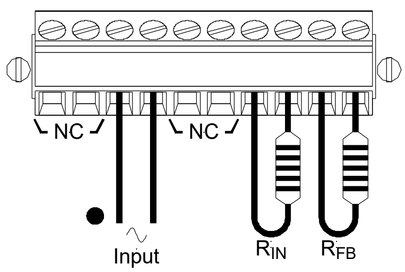
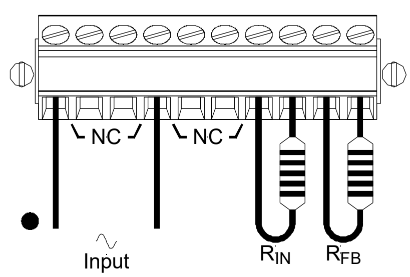
The maximum supported full scale voltages are less than the Max rating value and can be found in the DC Voltage Input table.

> In the following tables, a resistance of 0 Ω is referring to the use of a jumper, *not* a 0 Ω resistor.

DC Voltage Input	**Full Scale (V dc)[a]**	**Shunt Resistance R_{SH} (Ω)**	**Input Resistance R_{IN} (Ω)**	**Feedback Resistance R_{FB} (Ω)**	**Input Impedance (Ω ±10%)**
Low Range **0.1 V_{DC} to 200 V_{DC} FS**	± 0.1		332 Ω	open	10 kΩ
	± 0.2		0 Ω	422 kΩ	10 kΩ
	± 0.5		0 Ω	100 kΩ	10 kΩ
	± 1		0 Ω	40.2 kΩ	10 kΩ
	± 2		0 Ω	13.3 kΩ	10 kΩ
	± 5		1.40 kΩ	0 Ω	11 kΩ
	± 10		13.3 kΩ	0 Ω	22 kΩ
	± 20		38.3 kΩ	0 Ω	47 kΩ
	± 25		51.1 kΩ	0 Ω	60 kΩ
	± 50		121 kΩ	0 Ω	120 kΩ
	± 100		287 kΩ 1/2 W	0 Ω	240 kΩ
	± 150		511 kΩ 1 W	0 Ω	350 kΩ
	± 200		825 kΩ 1 W	0 Ω	450 kΩ
High Range **350 V_{DC} to 880 V_{DC} FS**	± 350		0 Ω	10.0 kΩ	1.5 MΩ
	± 500		0 Ω	3.48 kΩ	1.5 MΩ
	± 880		1 MΩ 2W	0 Ω	2 MΩ

a. The ± symbol indicates that the input supports reversed polarity.
For example, the ±880V DC rating means that the input can accept voltages in the range 0V to 880V or -880V to 0V. It does not mean that the input can accept a differential voltage of 1760V_{DC}.

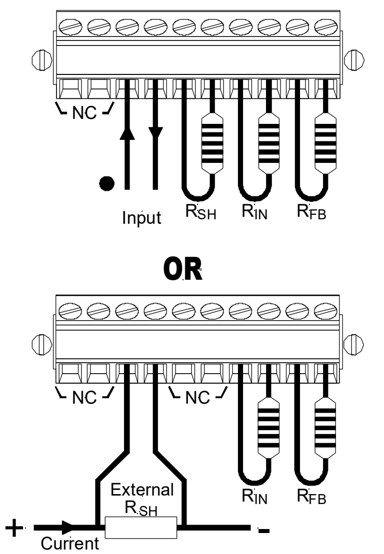
AC Voltage Input

	Full Scale (V_{RMS})	Shunt Resistance R_{SH} (Ω)	Input Resistance R_{IN} (Ω)	Feedback Resistance R_{FB} (Ω)	Input Impedance ($\Omega \pm 10\%$)
Low Range **0.1 V to 150 V_{RMS} FS**	0.1		0 Ω	1.00 MΩ	10 k Ω
	0.2		0 Ω	237 kΩ	10 k Ω
	0.5		0 Ω	64.9 kΩ	10 k Ω
	1		0 Ω	23.7 kΩ	10 k Ω
	2		0 Ω	6.19 kΩ	10 k Ω
	5		6.19 kΩ	0 Ω	16 k Ω
	10		23.7 kΩ	0 Ω	33 k Ω
	20		59.0 kΩ	0 Ω	66 k Ω
	50		178 kΩ 1/2 W	0 Ω	160 k Ω
	100		464 kΩ 1 W	0 Ω	320 k Ω
	150 (for 69 V)		909 kΩ 2 W	0 Ω	490 k Ω
High Range **200 V to 600 V_{RMS} FS**	200		0 Ω	15.4 kΩ	1.5 M Ω
	250 (for 120 V)		0 Ω	9.53 kΩ	1.5 M Ω
	500 (for 240 V)		121 kΩ	0 Ω	1.6 M Ω
	600		750 kΩ 1 W	0 Ω	1.9 M Ω

DC Current Input

(External Shunt Optional)

1 mA to 500 mA_{DC} FS



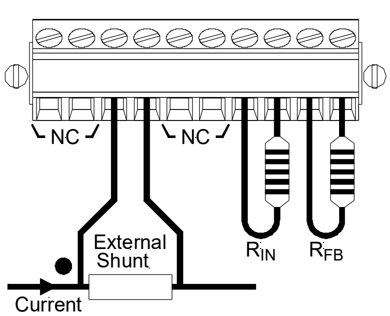
Full Scale (mA_{DC})	Shunt Resistance R_{SH} (Ω)	Input Resistance R_{IN} (Ω)	Feedback Resistance R_{FB} (Ω)	Full Scale Voltage Drop (V)
1	100 Ω	332 Ω	open	0.1
2	100 Ω	0 Ω	422 kΩ	0.2
5	100 Ω	0 Ω	100 kΩ	0.5
10	100 Ω	0 Ω	40.2 kΩ	1.0
20	100 Ω	0 Ω	13.3 kΩ	2.0
25 (for 4-20 mA)	100 Ω	0 Ω	8.25 kΩ	2.5
50	10 Ω	0 Ω	100 kΩ	0.5
100	1 Ω	332 Ω	Open	0.1
200	1 Ω	0 Ω	422 kΩ	0.2
500	1 Ω 1/2 W	0 Ω	100 kΩ	0.5

External shunt with value of R_{SH} may be used as shown instead of R_{SH} on the terminal block.

AC Current Input

(with External Shunt)

0.1 V to 1 V_{RMS} FS



Full Scale (V_{RMS}) output of shunt	Shunt Resistance R_{SH} (Ω)	Input Resistance R_{IN} (Ω)	Feedback Resistance R_{FB} (Ω)	Input Impedance (Ω ±10%)
0.1		0 Ω	1.00 MΩ	10 kΩ
0.2		0 Ω	237 kΩ	10 kΩ
0.5		0 Ω	64.9 kΩ	10 kΩ
1.0		0 Ω	23.7 kΩ	10 kΩ

Standard Series of Values in a Decade

The following tables show the standard values of resistance available in a decade. The lower numbered series are more common and easier to obtain, while the higher numbered series provide more resolution. In general, it is best to use the lowest numbered series which provides acceptable resolution, since this will be the easiest and least expensive to obtain.

Most often, distributors stock ±2% and ±5% resistors in the E24 series, 1% resistors in the E96 series, and ±0.1%, ±0.2% and ±0.5% in the E192 series.

The values are not linear, but are instead approximately equal percentages apart from each other. Each value is related to the next by a ratio of approximately the Nth root of 10, where "N" is the series number (3 to 192).

E24, E12, E6 and E3 Series of Resistor Values (generally used for ±2% and ±5% resistors)			
E24	**E12**	**E6**	**E3**
10	10	10	10
11			
12	12		
13			
15	15	15	
16			
18	18		
20			
22	22	22	22
24			
27	27		
30			
33	33	33	
36			
39	39		
43			
47	47	47	47
51			
56	56		
62			
68	68	68	
75			
82	82		
91			

E192, E96 and E48 Series of Resistor Values (E96 generally used for ±1% resistors, E192 generally used for ±0.1%, ±0.2% and ±0.5% resistors)											
E192	E96	E48	E192	E96	E48	E192	E96	E48	E192	E96	E48
100	100	100	178	178	178	316	316	316	562	562	562
101			180			320			569		
102	102		182	182		324	324		576	576	
104			184			328			583		
105	105	105	187	187	187	332	332	332	590	590	590
106			189			336			597		
107	107		191	191		340	340		604	604	
109			193			344			612		
110	110	110	196	196	196	348	348	348	619	619	619
111			198			352			626		
113	113		200	200		357	357		634	634	
114			203			361			642		
115	115	115	205	205	205	365	365	365	649	649	649
117			208			370			657		
118	118		210	210		374	374		665	665	
120			213			379			675		
121	121	121	215	215	215	383	383	383	681	681	681
123			218			388			690		
124	124		221	221		392	392		698	698	
126			223			397			706		
127	127	127	226	226	226	402	402	402	715	715	715
129			229			407			723		
130	130		232	232		412	412		732	732	
132			234			417			741		
133	133	133	237	237	237	422	422	422	750	750	750
135			240			427			759		
137	137		243	243		432	432		768	768	
138			246			437			777		
140	140	140	249	249	249	442	442	442	787	787	787
142			252			448			796		
143	143		255	255		453	453		806	806	
145			258			459			816		
147	147	147	261	261	261	464	464	464	825	825	825
149			264			470			835		
150	150		267	267		475	475		845	845	
152			271			481			856		
154	154	154	274	274	274	487	487	487	866	866	866
156			277			493			876		
158	158		280	280		499	499		887	887	
160			284			505			898		
162	162	162	287	287	287	511	511	511	909	909	909
164			291			517			920		
165	165		294	294		523	523		931	931	
167			298			530			942		
169	169	169	301	301	301	536	536	536	953	953	953
172			305			542			965		
174	174		309	309		549	549		976	976	
176			312			556			988		

G.5.2 AC/DC Input Module Model 401027

The AC/DC Input Module (Model 401027) provides DC-coupled isolation and scaling for three independent DC or AC voltage or current channels. AC/DC Input Module channels have a DC to 2 kHz bandwidth, but the bandwidth may be limited by the recorder's input filters, depending on the sample rate. Externally mounted shunt resistors are required for current measurements. Output from the module is scaled to connect directly to the TESLA's analog input terminals. Due to impedance matching requirements, module channels cannot be connected to more than one TESLA input channel.

In order to configure the AC/DC Input Module (Model 401027) a PC software tool, available on the ERLPhase website, must be installed. This AC/DC Input Module Configurator Tool is used for configuring each the channels of the module for use with Voltage or Current and AC or DC. It also provides visual guidance for wiring of the Module. A standard USB cable with a USB-B connector on the AC/DC Input Module end is required for communication between the computer running the AC/DC Input Module Configurator Tool and the module.

When the AC/DC front panel LED is:

- Green - the module is ready to use
- Red - the module is not ready to use.

Power Supply

A wide range power supply is standard. The nominal operating range is 48 - 250 V_{DC}, 100 - 120 V_{AC}, 50/60 Hz. To protect against a possible short circuit in the supply use an in-line fuse or circuit breaker. If a fuse is chosen it must be a slow-blow 5 A, 250 V_{AC}, in-line fuse (T 5 A 250 V). If a circuit breaker is chosen it must be a 5 A, 250 V_{AC}, single-pole breaker. The fuse or circuit breaker must be installed on the AC LINE or DC POSITIVE connection.

Wiring

AC/DC Output Wiring shall use Belden 9388 shielded cable, or better. Drain wire shall be securely fastened to case ground at both the AC/DC Input Module module and the TESLA recorder end of the cable. The cable between the AC/DC module and the recorder shall be limited to a maximum length of 10 meters (33 feet).

AC/DC Power and Safety Ground cable shall be bundled with the signal cable to connect power and Protective Earth from the recorder inputs to the AC/DC Input Module. NO OTHER Protective Earth connections shall be made to the AC/DC Input Module to maintain the star grounding configuration. The cable between the AC/DC module and the recorder shall be limited to a maximum length of 10 meters (33 feet).

AC/DC Input Wiring may use shielded cables for improved performance. If used, shields shall only be connected at the AC/DC Input Module end of the cable.

Software Configuration

To configure the AC/DC Input Module, connect power to the unit and connect it to a PC using a USB cable with a type B end to connect to the AC/DC Input Module. Open the AC/DC Input Module Configurator Tool on the PC. Once the software has indicated that the module is detected (module must be powered and connected to PC), configuration of the unit may begin.

i. Select VOLTAGE or CURRENT mode.

ii. Select AC or DC operation

iii. For Voltage mode, enter the maximum FULL SCALE voltage you wish to record:

1. For AC enter the maximum RMS value
2. For DC enter the maximum positive or negative value
3. NOTE - The Voltage entered must be between 0.1V and 600V

iv. For Current mode, enter the maximum FULL SCALE current you wish to record:

1. For AC enter the maximum RMS value
2. For DC enter the maximum positive or negative value
3. NOTE - The Current entered must be between 1mA and 10A
4. Choose and enter value of the external shunt resistor (the configurator will recommend a range)

The existing configuration of the unit is retrieved and displayed upon initial connection to the PC.

The user can undo all changes by pressing the ↶ button, retrieving the existing configuration from the unit.”

When the configuration is complete, click the ⇩ button to send the configuration to the module.

NOTE: The FULL_SCALE voltage, whether directly entered for Voltage operation, or indirectly calculated for Current operation must be between 0.1V and 600V.

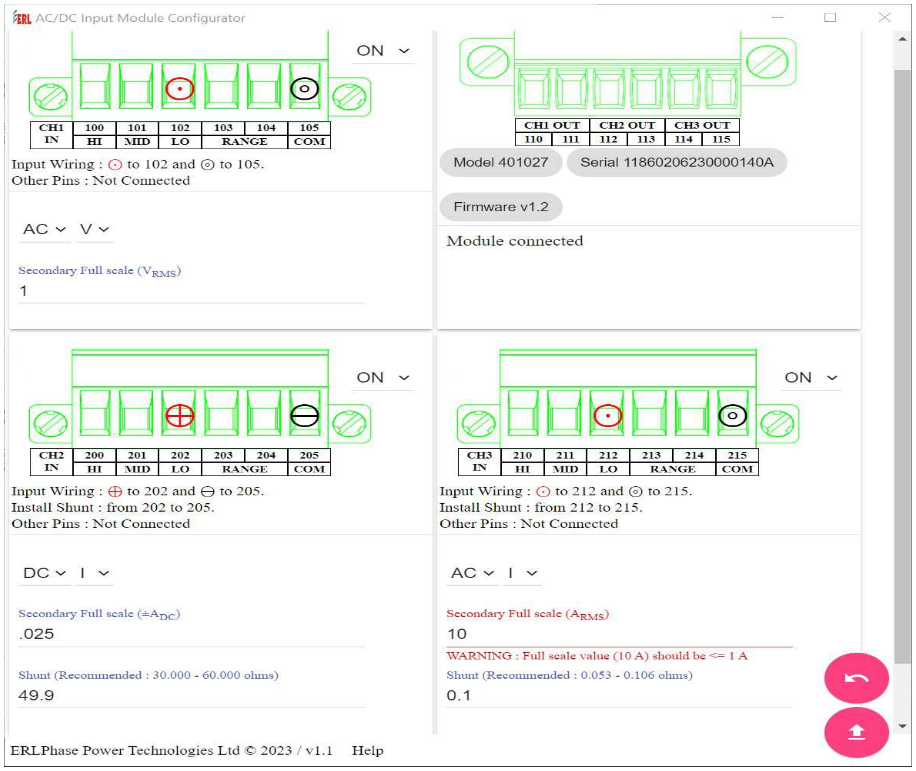


Figure G.22: AC/DC Input Module Configurator tool

Configurator Specified Input Wiring

Each AC/DC Input Module input channel must be wired consistently with the configuration loaded into the module. The module requires different wiring configurations based on Current or Voltage, AC or DC and Shunt Resistor selections. The AC/DC Input Module Configurator software displays a wiring diagram based on the channel configuration. Input wiring must be completed according to this diagram. An example Configurator screen is shown in Figure G.22.

Connector pins without connections MUST be left Not Connected (NC**)**

Configurator Shunt Selection

The configurator will recommend a shunt resistance range.

Once you choose a shunt resistance, the tool will recommend a minimum Wattage based on 50% power dissipation at maximum specified current.

Operating outside of the recommended range will be allowed by the software, but it will either generate a WARNING or an ERROR. See definitions of WARNINGs and ERRORs below.

AC/DC Input Module Model 401027 Ratings

Table G.9: AC/DC input module (Model 401027) ratings

Signal Input Ratings with TESLA 1kΩ load on AC/DC outputs					
AC Voltage (V_{RMS})					
Input Pin	HI	MID	HI	MID	LO
Range Link	Shorted	Shorted	Not Connected	Not Connected	Not Connected
Maximum Full Scale / Continuous Rating (note 1)	600	116	58.1	10.2	1.1
10 seconds Thermal Rating	800	400	800	400	50
DC Voltage (V_{DC})					
Input Pin	HI	MID	HI	MID	LO
Range Link	Shorted	Shorted	Not Connected	Not Connected	Not Connected
Maximum Full Scale / Continuous Rating (note 1)	-600 to 600	-164 to 164	-82.1 to 82.1	-14.4 to 14.4	-1.56 to 1.56
10 seconds Thermal Rating	800	400	800	400	50
AC Current (A_{RMS})					
Input Pin	LO				
Range Link	Not Connected				
Maximum Full Scale / Continuous Rating (note 1)	10.0				
10 seconds Thermal Rating	note 2				
DC Current (A_{DC})					
Input Pin	LO				
Range Link	Not Connected				
Maximum Full Scale / Continuous Rating (note 1)	-10.0 to 10.0				
10 seconds Thermal Rating	note 2				

Power Input	
Range	48 - 250 V_{DC}, 100 - 120 V_{AC}
Tolerance	DC = +20% / -10%, AC = ± 10%
Burden (VA)	10 VA

NOTES:

1. The table indicates the maximum Full Scale setting allowed. The desired Full Scale is entered by the user in the “Secondary Full Scale” input field in the Configurator tool.

2. It is the user’s responsibility to choose a shunt resistor capable of meeting the required Thermal Rating

Attempting to configure the unit outside of these ranges will result in ERRORS or WARNINGS in the configurator tool.

ERRORS will need to be fixed before you will be able to program the unit.

WARNINGS indicate that you are operating outside of the units ratings so performance is NOT guaranteed. You will still however be able to program the unit.

Table G.10: AC/DC Input Modules

Module Type in TESLA Control Panel	Channels	Mounting Style	Case Material	Figure
401027 DC	3	Rack	Metal	Figure G.23:
401027 DC	3	Surface	Metal	Figure G.24:
401027 DC	3	DIN	Metal	Figure G.25:

AC/DC Input Module Model 401027 Drawings

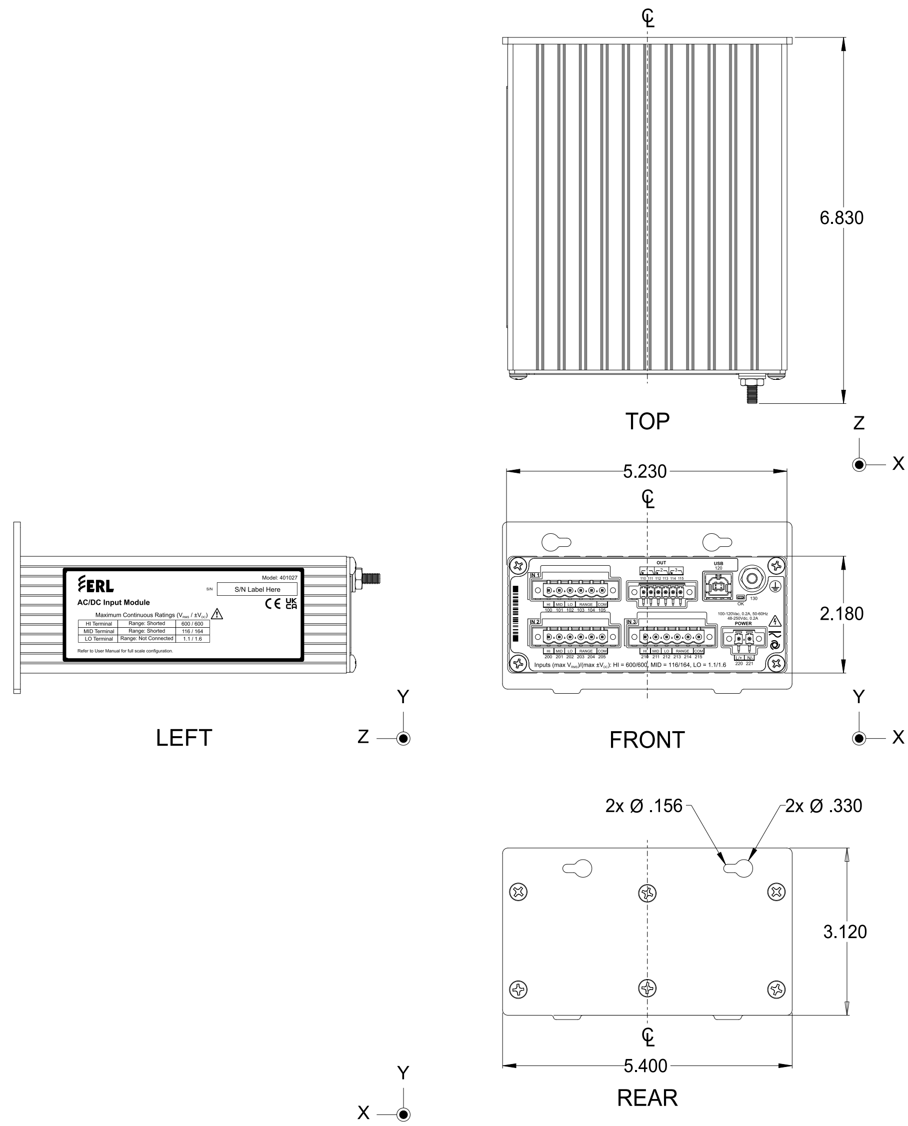


Figure G.23: Module 401027 - Rack Mount

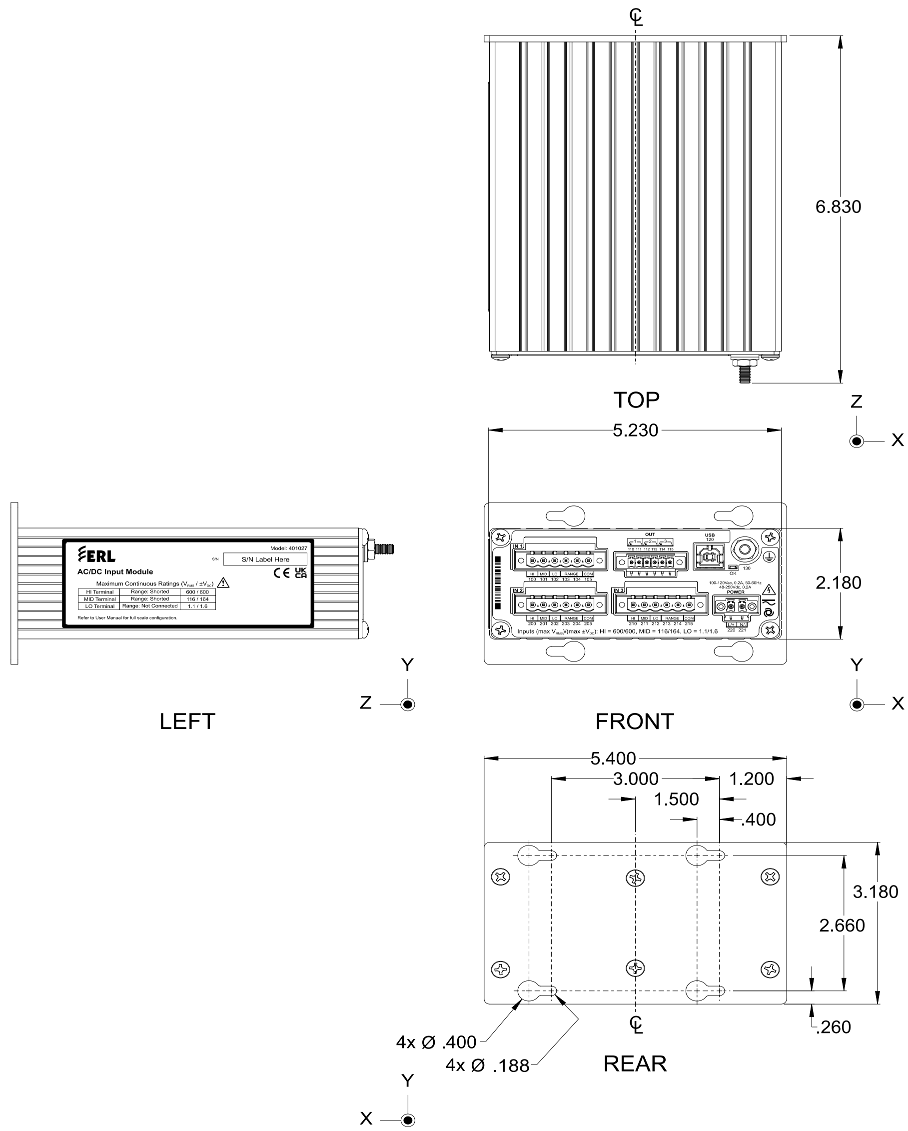


Figure G.24: Model 401027 - Surface Mount

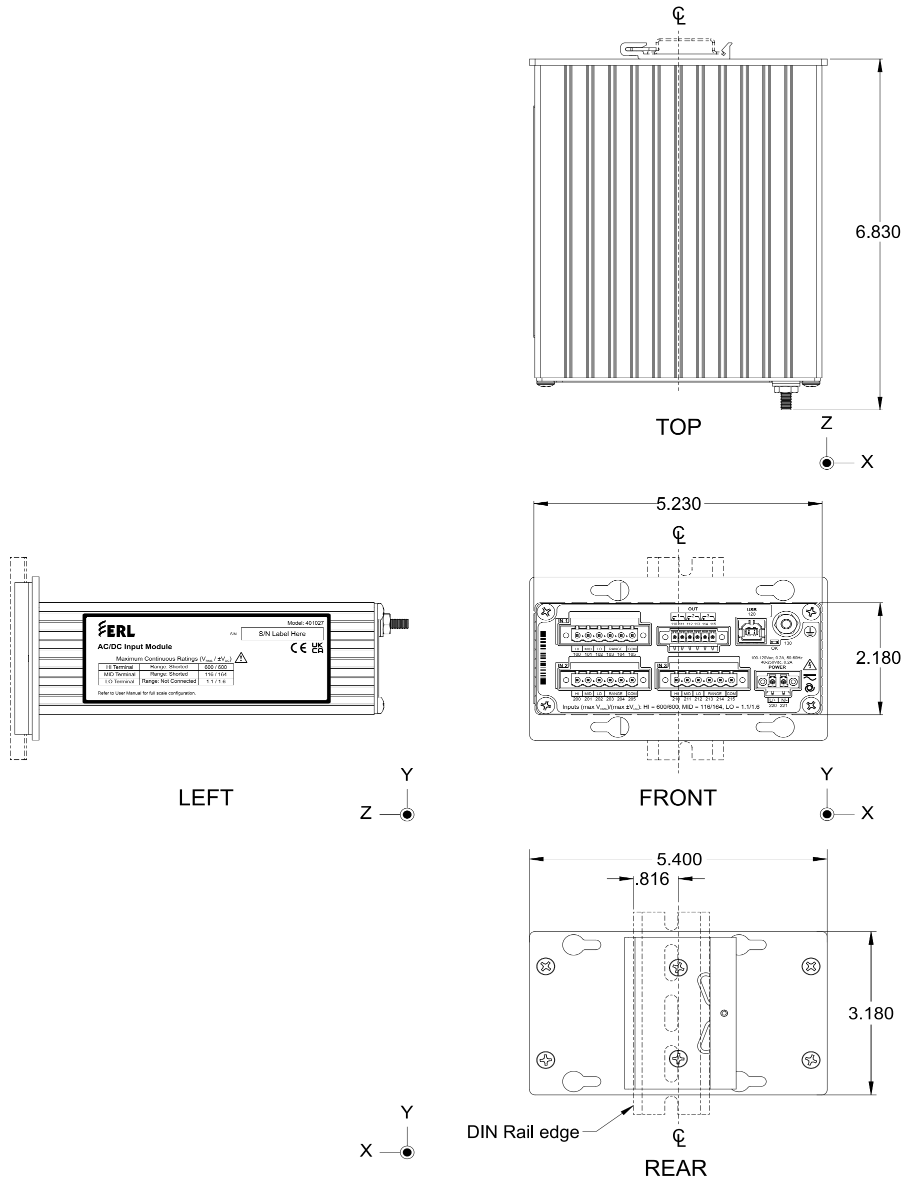


Figure G.25: Model 401027 - DIN Mount

G.5 Weight of Input Modules

The approximate weight of each input module type is shown in the table below:

Table G.9: Approximate weight of input modules

Module Type	Weight grams / lbs
Current input module (model 401021 1A / model 401014 5A)	580 / 1.28
Voltage input module (model 401006)	494 / 1.09
AC/DC input module (model 401016)	540 / 1.19
Rack-mount AC/DC input module (model 401027)	1096 / 2.42
Split-core CT (model 401017 1A)	161.6 / 0.35
Split-core CT (model 401013 5A)	159.8 / 0.35
Split-core CT (model 401013-2 5A)	273.4 / 0.60
Rack-mount current module (model 401025)	1088 / 2.40
Rack-mount voltage module (model 401026)	998 / 2.20
Rack-mount voltage module (model 401028)	1052 / 2.32

Appendix H TESLA Handling and Disposition

Unpacking

To unpack a TESLA System Unit

- Open the bottom of the box.
- Place the box on the floor or a secure table.
- Lift the box off of the unit leaving the TESLA and packing material standing intact.
- Remove the packing material from the TESLA.
- Dispose of the packing materials and box in a manner consistent with local waste disposal procedures and regulations. We recommend recycling the box.

Long Term Storage

For long term storage:

- Store the TESLA system unit in original packing container.
- Protect any of the components not in original packing from dust accumulation and moisture.
- Store all components indoors and protect from moisture accumulation.

Final Disposition

Regulations governing disposal of electronics are rapidly being adopted and are constantly changing. We recommend that local electronics disposal regulations be reviewed prior to disposal of a TESLA system when it has reached the end of its useful life. The TESLA system unit contains a battery that should be disposed of separately and may contain other electronic components that are potentially subject to specific disposal instructions. Use a local electronics recycler who is familiar with local regulations.

Appendix I TESLA 4000-A Drawings

This appendix contains the mechanical drawings for the TESLA 4000-A.

TESLA 4000-A Mechanical Overview

TESLA 4000-A Rear Panel View - Non-redundant Configuration

TESLA 4000-A Rear Panel View - Redundant Configuration

TESLA 4000-A AC Input Module Connection Model 401025/401026

TESLA 4000-A AC Input Module Connection Model 401006/401014

TESLA 4000-A 600 VAC Input Module Connection Model 401028

TESLA 4000-A DC Input Module - Model 401027 Connection Diagram

TESLA 4000-A DC Input Module - Model 401016 Connection Diagram

TESLA 4000-A Split Core Connection

Electronic versions of the drawings in both PDF and DWG formats are available. Contact ERLPhase Customer Support to request the drawings. The PDF documents are scaled for 11" x 17" printing for improved readability.

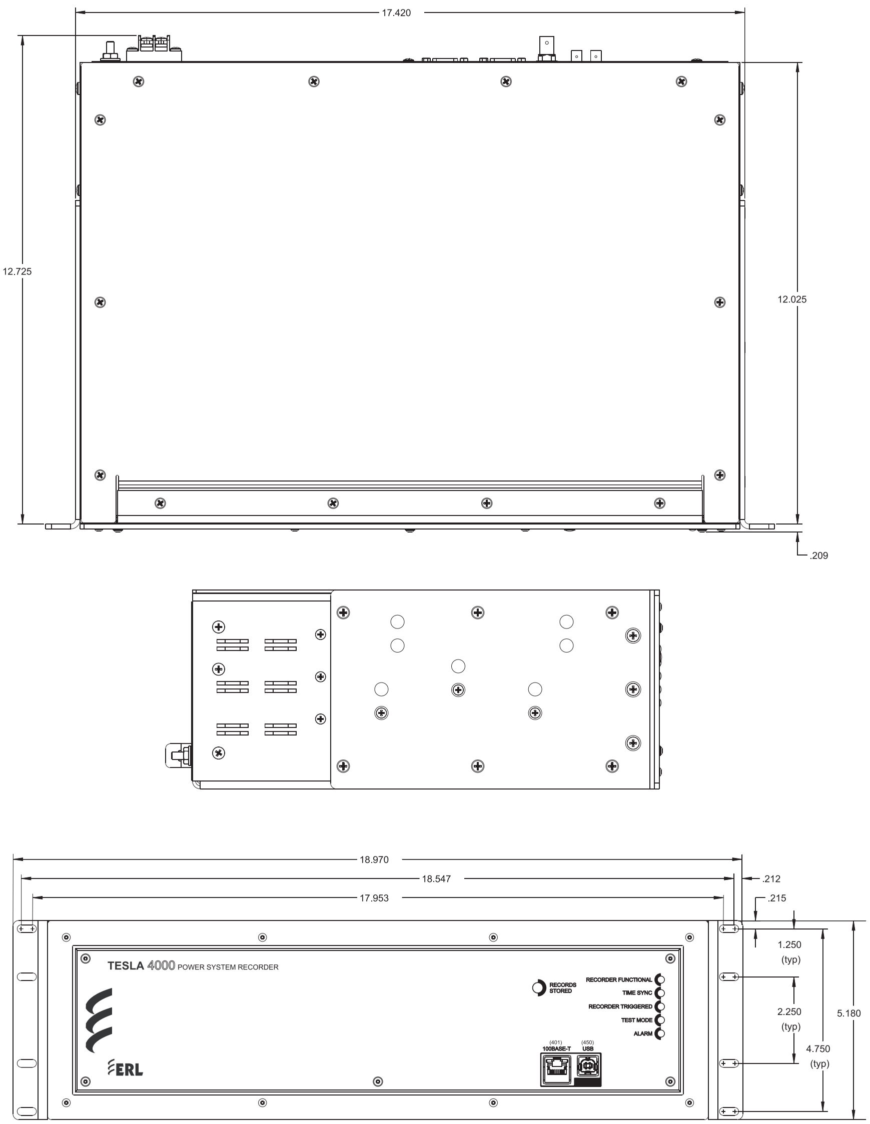


Figure I.1: Mechanical Drawings

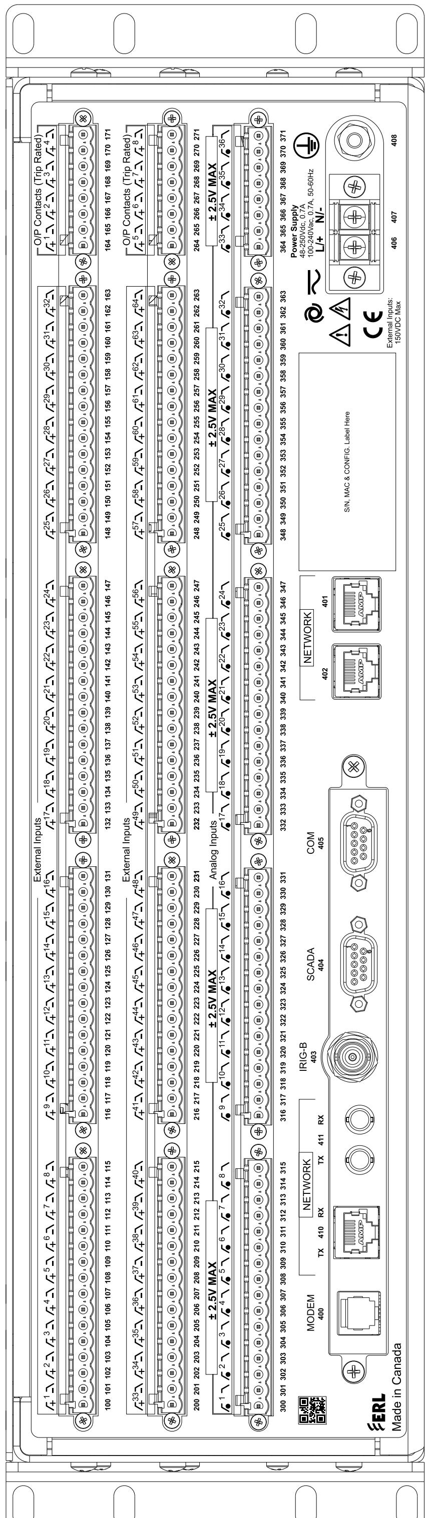


Figure I.2: Rear View - Non-redundant configuration

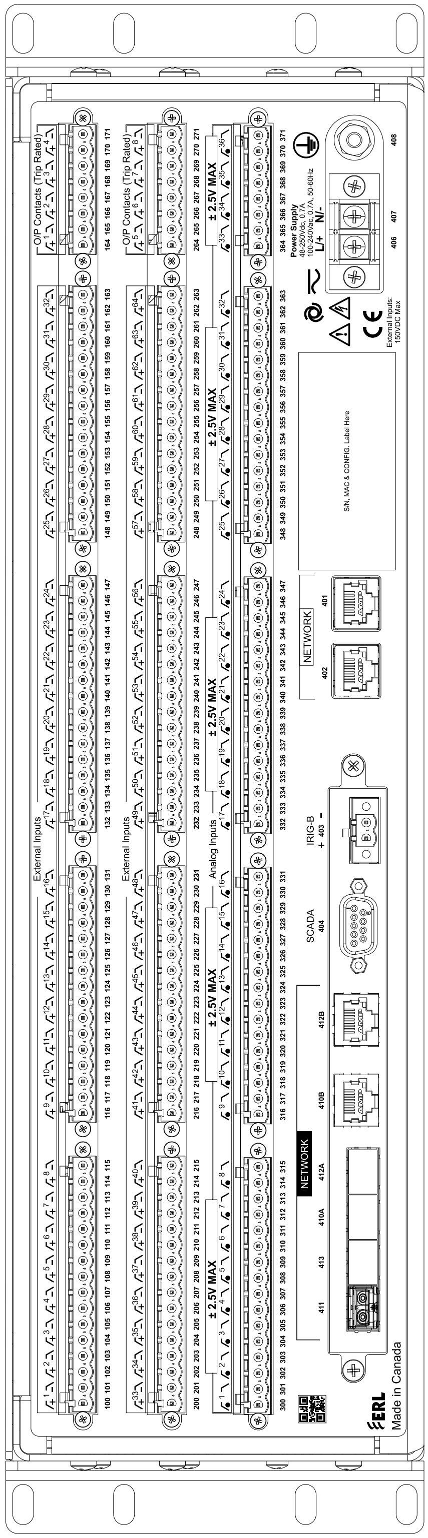


Figure I.3: Rear View - Redundant configuration

Not all ordering configurations shown in the Rear View drawings.

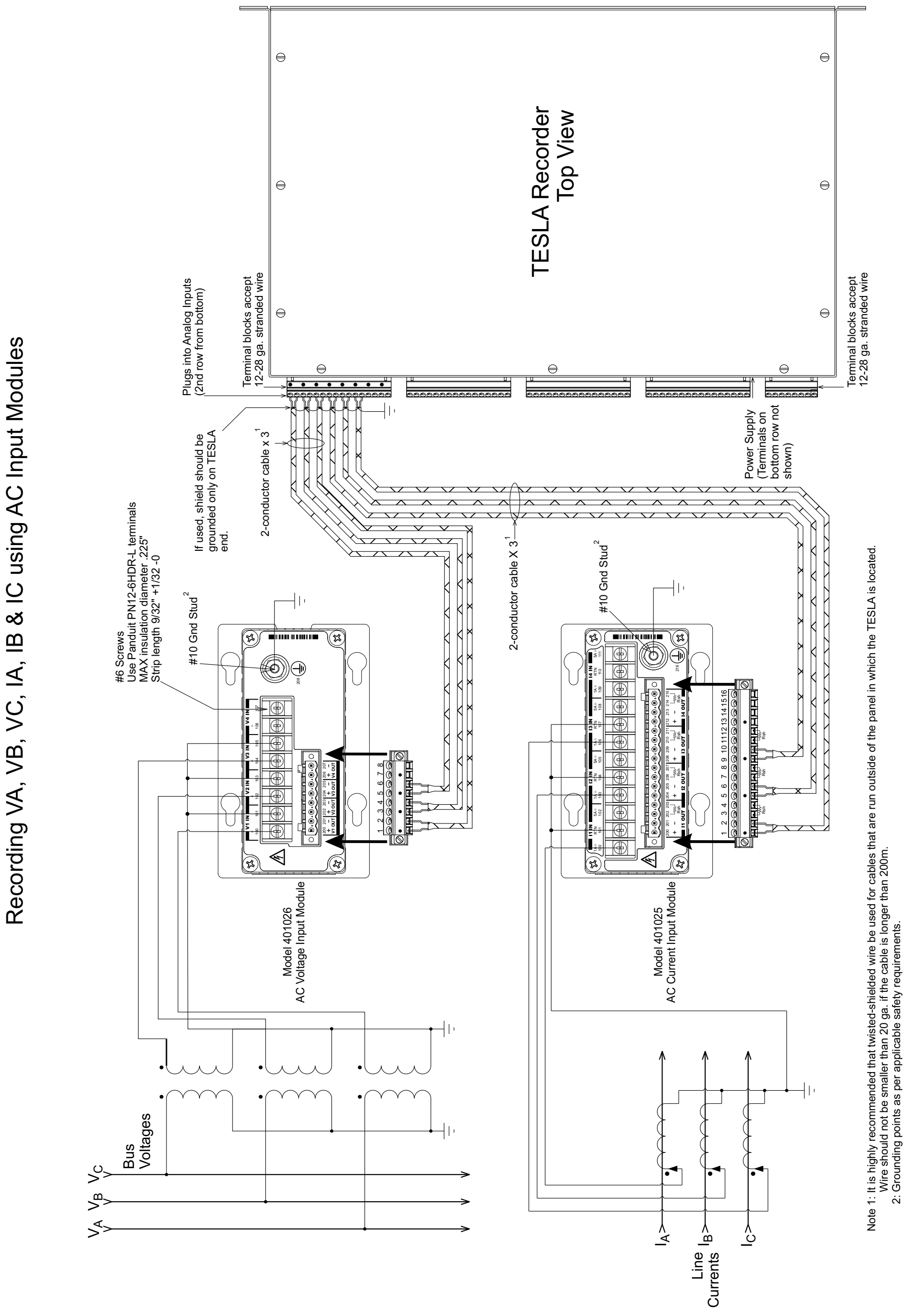


Figure I.4: TESLA 4000-A AC Input Module Connection Diagram – Model 401025/ 401026

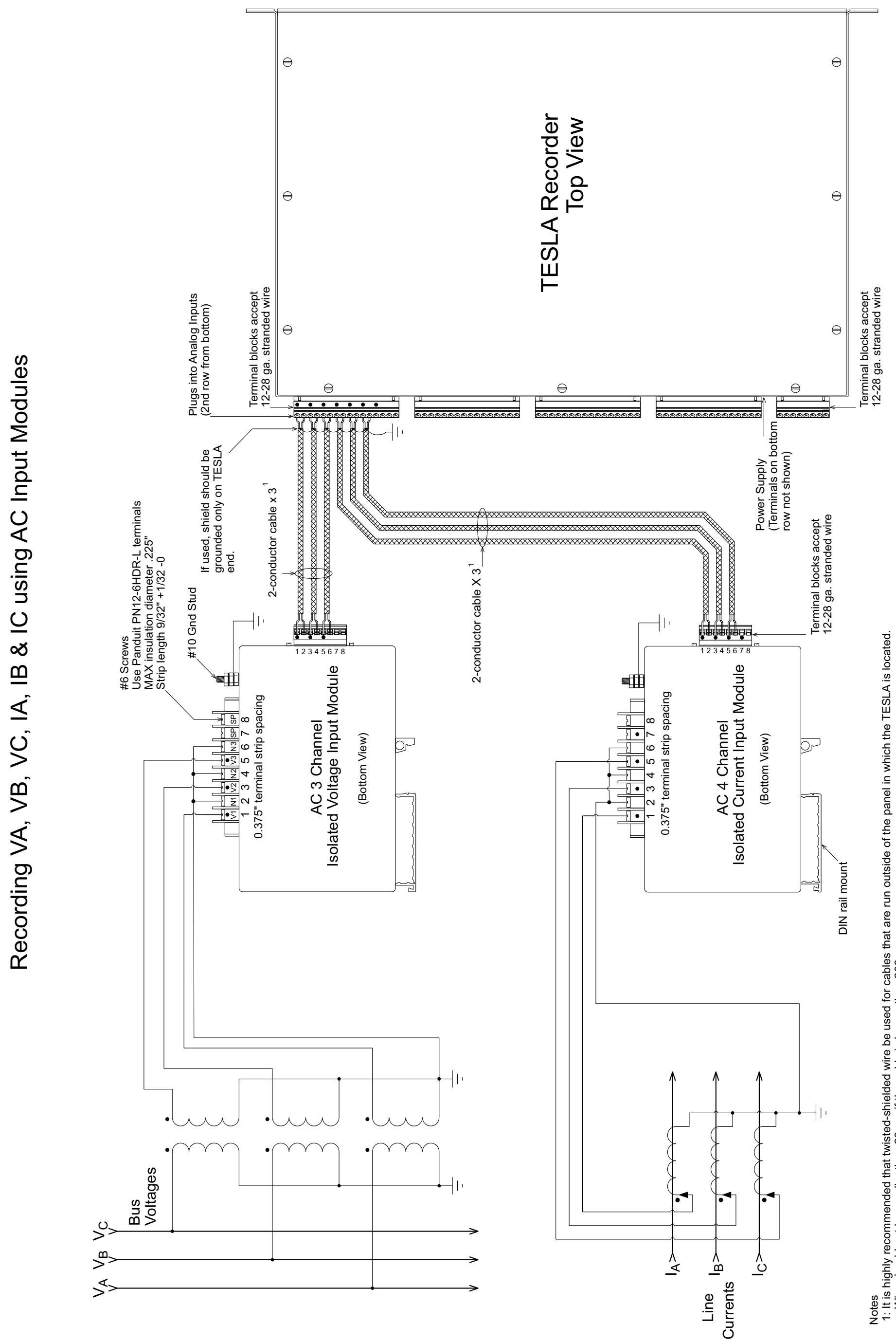


Figure I.5: TESLA 4000-A AC Input Module Connection Diagram - Model 401006/ 401014

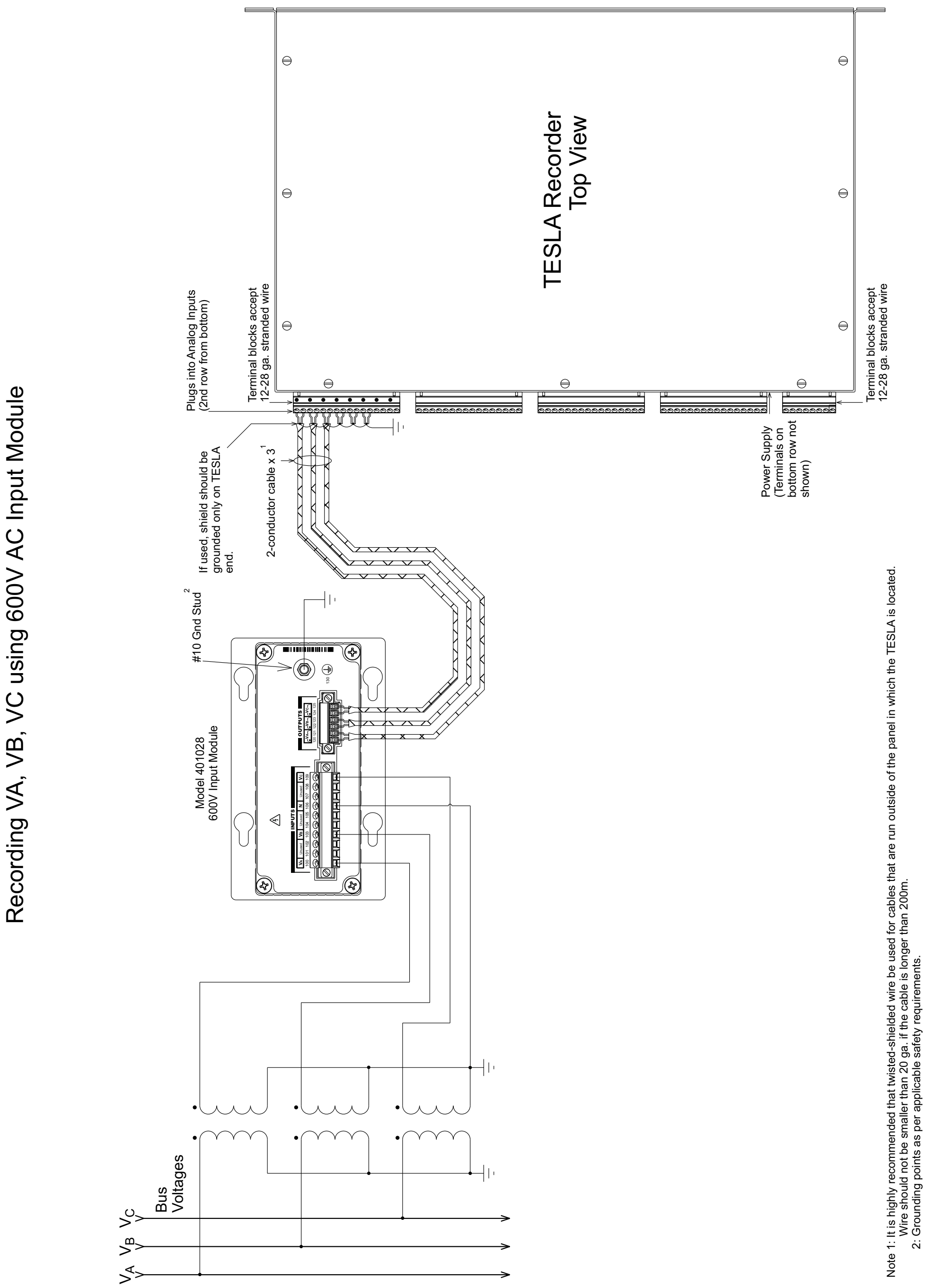


Figure I.6: TESLA 4000-A 600 VAC Input Module Connection Model 401028

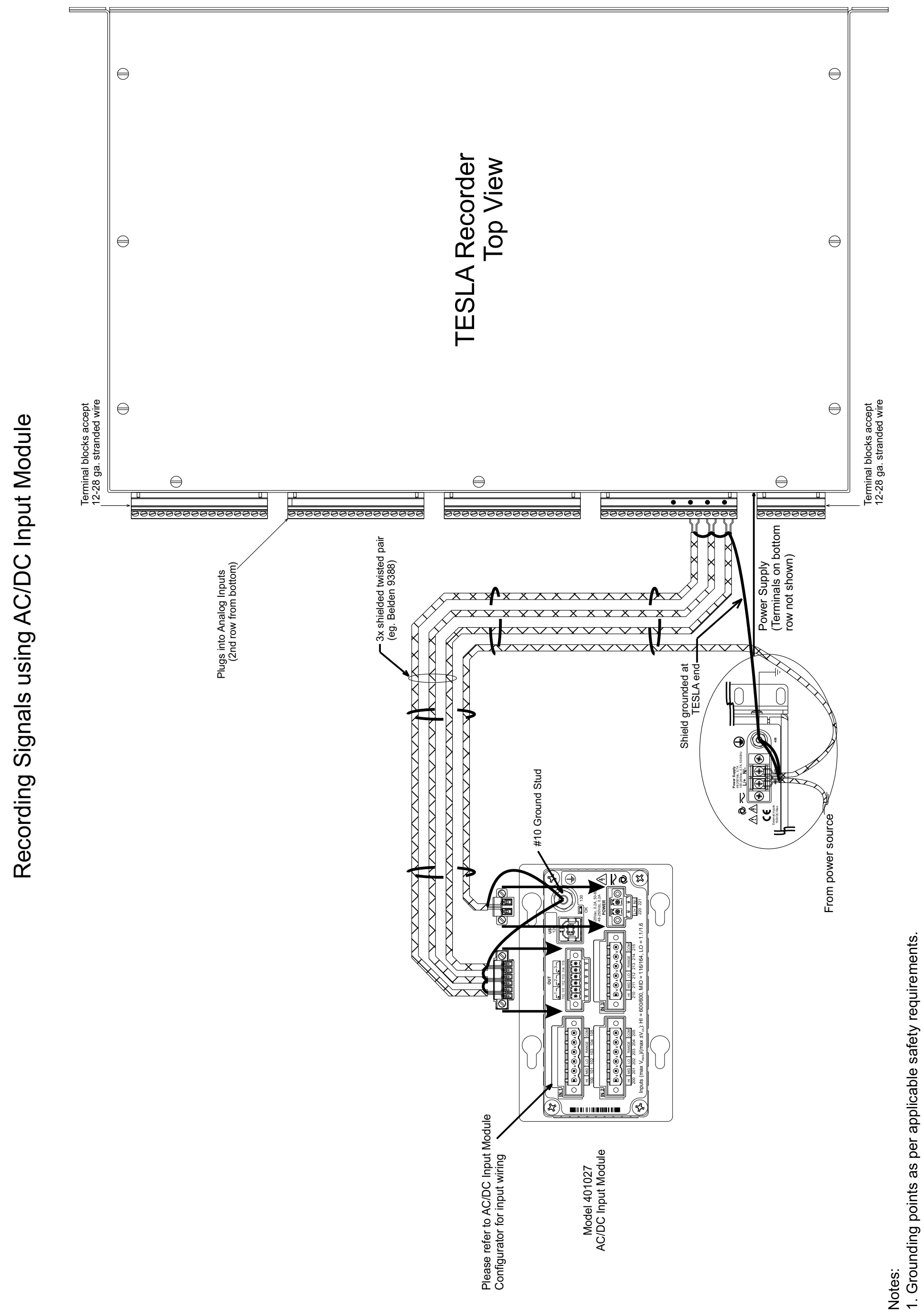


Figure I.7: TESLA 4000-A DC Input Module - Model 401027 Connection Diagram

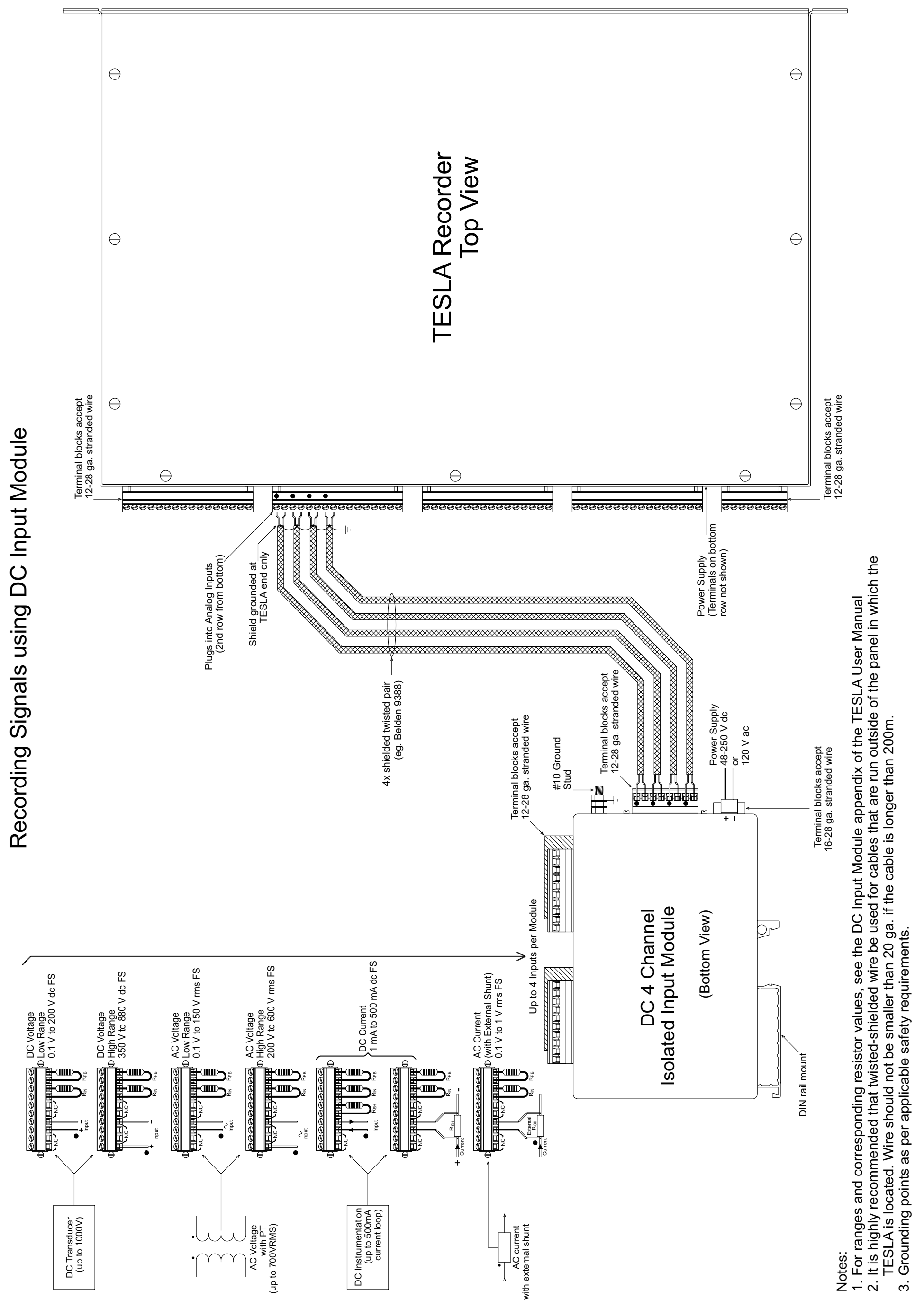


Figure I.8: TESLA 4000-A DC Input Module - Model 401016 Diagram

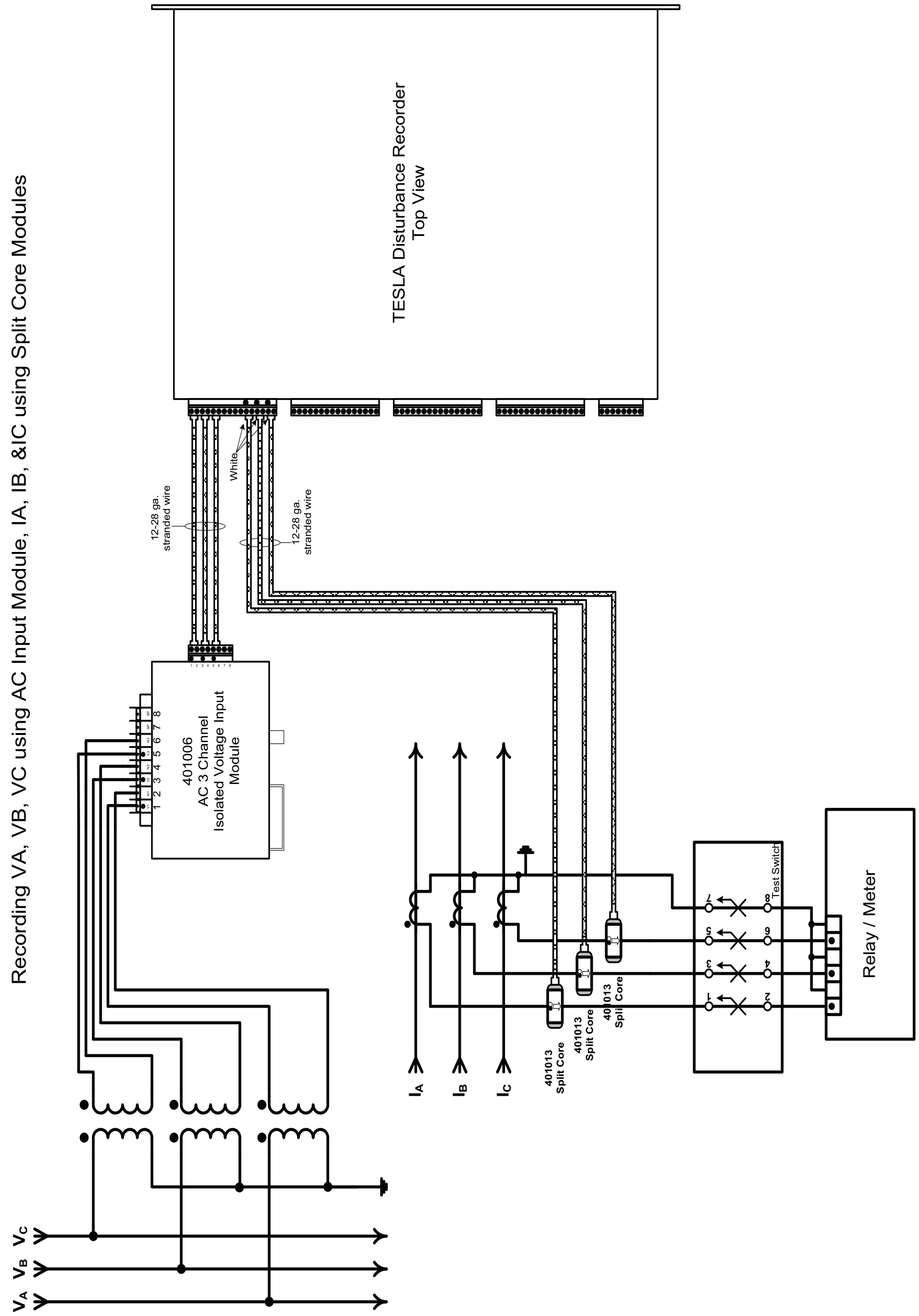


Figure I.9: TESLA 4000-A Split Core Connection

Appendix J IEC 61850 Conformance Statements and Data Mapping Specification

J.1 Protocol Implementation Conformance Statement (PICS)

Protocol Implementation Conformance Statement

for the IEC 61850 interface in TESLA 4000-A

Document Version[1]: D05517R01.00

Date: 2022-07-12

ICS Template version 2.3

UCA International Users Group

Testing Sub Committee

1. The version shown in the user manual differs slightly in formatting to the official released version.

PICS Template for Server Ed2

General

The following ACSI conformance statements are used to provide an overview and details about TESLA 4000-A, with firmware v1.0:

- ACSI basic conformance statement
- ACSI models conformance statement
- ACSI service conformance statement

The statements specify the communication features mapped to IEC 61850-8-1 and IEC 61850-9-2.

ACSI basic conformance statement

The basic conformance statement is defined in Table J.1, “Basic conformance statement”.

Table J.1: Basic conformance statement

		Client/ Subscriber	Server/ Publisher	Value/ Comments
Client-Server roles				
B11	**Server** side (of TWO-PARTY-APPLICATION-ASSOCIATION)	-	YES	
B12	**Client** side of (TWO-PARTY-APPLICATION-ASSOCIATION)		-	
SCSMs supported				
B21	**SCSM**: IEC 61850-8-1 used		YES	
B22	**SCSM**: IEC 61850-9-1 used	-	-	Deprecated Ed2
B23	**SCSM**: IEC 61850-9-2 used	-	-	
B24	**SCSM**: other		NO	
Generic substation event model (GSE)				
B31	**Publisher** side	-	YES	
B32	**Subscriber** side	YES	-	
Transmission of sampled value model (SVC)				
B41	**Publisher** side	-		
B42	**Subscriber** side		-	
– = not applicable YES = supported NO or empty = not supported				

ACSI Models Conformance Statement

The ACSI models conformance statement is defined in Table J.2, “ACSI models conformance statement”.

Table J.2: ACSI models conformance statement

		Client/ Subscriber	Server/ Publisher	Value/ Comments
If **Server** side (B11) and/or **Client** side (B12) supported				
M1	Logical device		YES	c1
M2	Logical node		YES	c1
M3	Data		YES	c1
M4	Data set		YES	c2
M5	Substitution		NO	
M6	Setting group control		NO	
	Reporting			
M7	Buffered report control		YES	
M7-1	sequence-number		YES	
M7-2	report-time-stamp		YES	
M7-3	reason-for-inclusion		YES	
M7-4	data-set-name		YES	
M7-5	data-reference		YES	
M7-6	buffer-overflow		YES	
M7-7	entryID		YES	
M7-8	BufTm		YES	
M7-9	IntgPd		YES	
M7-10	GI		YES	
M7-11	conf-revision		YES	
M8	Unbuffered report control		YES	
M8-1	sequence-number		YES	
M8-2	report-time-stamp		YES	
M8-3	reason-for-inclusion		YES	
M8-4	data-set-name		YES	
M8-5	data-reference		YES	
M8-6	BufTm		YES	
M8-7	IntgPd		YES	
M8-8	GI		YES	
M8-9	conf-revision		YES	

Table J.2: ACSI models conformance statement				
		Client/ Subscriber	**Server/ Publisher**	**Value/ Comments**
	Logging		NO	
M9	Log control		NO	
M9-1	IntgPd		NO	
M10	Log		NO	
M11	Control		YES	
M17	File Transfer		YES	
M18	Application association		YES	c1
M19	GOOSE Control Block	YES	YES	
M20	Sampled Value Control Block			
c1 Server must be Y if B11=Yes; Client must be Y if B12=Y c2 Server must be Y if M7-Y or M8=Y or M9=Y or M19=Y or M20=Y				
If **GSE** (B31/32) is supported				
M12	GOOSE	YES	YES	
M13	GSSE			Deprecated Ed2
If **SVC** (B41/42) is supported				
M14	Multicast SVC			
M15	Unicast SVC			
For all IEDs				
M16	Time		YES	
YES = service is supported NO or empty = service is not supported				

ACSI Service Conformance Statement

The ACSI service conformance statement is defined in Table I.3 ACSI service Conformance statement (depending on the statements in Table J.1, "Basic conformance statement" and Table J.2, "ACSI models conformance statement").

Table J.3: ACSI service Conformance statement

	Ed.	Services	AA: TP/MC	Client (C)	Server (S)	Comments
Server: if B11=Y or B12=Y						
S1	1,2	GetServerDirectory (LOGICAL-DEVICE)	TP		YES	
Application association: if B11=Y or B12=Y						
S2	1,2	Associate			YES	
S3	1,2	Abort			YES	
S4	1,2	Release			YES	
Logical device: if M1=Y						
S5	1,2	GetLogicalDeviceDirectory	TP		YES	
Logical node: if M2=Y						
S6	1,2	GetLogicalNodeDirectory	TP		YES	
S7	1,2	GetAllDataValues	TP		YES	
Data: if M3=Y						
S8	1,2	GetDataValues	TP		YES	
S9	1,2	SetDataValues	TP		NO	
S10	1,2	GetDataDirectory	TP		YES	
S11	1,2	GetDataDefinition	TP		YES	
Data set: if M4=Y						
S12	1,2	GetDataSetValues	TP		YES	
S13	1,2	SetDataSetValues	TP		NO	Deprecated in Ed2
S14	1,2	CreateDataSet	TP		NO	
S15	1,2	DeleteDataSet	TP		NO	
S16	1,2	GetDataSetDirectory	TP		YES	

Table J.3: ACSI service Conformance statement

	Ed.	Services	AA: TP/MC	Client (C)	Server (S)	Comments
Substitution: if M5=Y						
S17	1,2	SetDataValues	TP		NO	

Setting group control: if M6=Y						
S18	1,2	SelectActiveSG	TP		NO	
S19	1,2	SelectEditSG	TP		NO	
S20	1,2	SetEditSGValues	TP		NO	
S21	1,2	ConfirmEditSGValues	TP		NO	
S22	1,2	GetEditSGValues	TP		NO	
S23	1,2	GetSGCBValues	TP		NO	

Reporting: If M7=Y or M8=Y						
Buffered report control block (BRCB); If M7=Y						
S24	1,2	Report	TP		YES	
S24-	1,2	data-change (dchg)			YES	
S24-	1,2	quality-change (qchg)			YES	
S24-	1,2	data-update (dupd)			YES	
S25	1,2	GetBRCBValues	TP		YES	
S26	1,2	SetBRCBValues	TP		YES	
Unbuffered report control block (URCB) If M8=Y						
S27	1,2	Report	TP		YES	
S27-	1,2	data-change (dchg)			YES	
S27-	1,2	quality-change (qchg)			YES	
S27-	1,2	data-update (dupd)			YES	
S28	1,2	GetURCBValues	TP		YES	
S29	1,2	SetURCBValues	TP		YES	

Logging: If M9=Y or M10=Y						
Log control block; If M9=Y						
S30	1,2	GetLCBValues	TP		NO	
S31	1,2	SetLCBValues	TP		NO	
Log; If M10=Y						
S32	1,2	QueryLogByTime	TP		NO	

Table J.3: ACSI service Conformance statement						
	Ed.	**Services**	**AA: TP/MC**	**Client (C)**	**Server (S)**	**Comments**
S33	1,2	QueryLogAfter	TP		NO	
S34	1,2	GetLogStatusValues	TP		NO	

Generic substation event model (GSE): If M19=Y						
GOOSE						
S35	1,2	SendGOOSEMessage	MC		YES	
GOOSE-CONTROL-BLOCK						
S36	1,2	GetGoReference	TP		NO	
S37	1,2	GetGOOSEElementNumber	TP		NO	
S38	1,2	GetGoCBValues	TP		YES	
S39	1,2	SetGoCBValues	TP		YES	
GSSE						
S40	1	SendGSSEMessage	MC	-	-	Deprecated in Edition 2
GSSE-CONTROL-BLOCK						
S41	1	GetReference	TP	-	-	Deprecated in Edition 2
S42	1	GetGSSEElementNumber	TP	-	-	Deprecated in Edition 2
S43	1	GetGsCBValues	TP	-	-	Deprecated in Edition 2
S44	1	SetGsCBValues	TP	-	-	Deprecated in Edition 2

Transmission of sampled value model (SVC): If M20=Y						
Multicast SV						
S45	1,2	SendMSVMessage	MC		NO	
Multicast Sampled Value Control Block						
S46	1,2	GetMSVCBValues	TP		NO	
S47	1,2	SetMSVCBValues	TP		NO	
Unicast SV						
S48	1,2	SendUSVMessage	TP		NO	
Unicast Sampled Value Control Block						
S49	1,2	GetUSVCBValues	TP		NO	
S50	1,2	SetUSVCBValues	TP		NO	

Table J.3: ACSI service Conformance statement

	Ed.	Services	AA: TP/MC	Client (C)	Server (S)	Comments
Control: If M11=Y						
S51	1,2	Select			NO	
S52	1,2	SelectWithValue	TP		NO	
S53	1,2	Cancel	TP		NO	
S54	1,2	Operate	TP		YES	
S55	1,2	CommandTermination	TP		NO	
S56	1,2	TimeActivatedOperate	TP		NO	

File transfer: If M17=Y						
S57	1,2	GetFile	TP		YES	
S58	1,2	SetFile	TP		NO	
S59	1,2	DeleteFile	TP		NO	
S60	1,2	GetFileAttributeValues	TP		YES	
S61	1,2	GetServerDirectory (FILE-SYSTEM)	TP		YES	

Time						
T1	1,2	Time resolution of internal clock			24 (60ns)	Nearest negative power of 2^{-n} in seconds (number 0..24)
T2	1,2	Time accuracy of internal clock			T1	TL (ms)(low accuracy), T3 <7 (c1) T0 (ms)(<=10ms), 7 <= T3 < 10 (c1) T1 (µs)(<=1ms), 10<= T3 < 13 T2 (µs)(<=100µs), 13 <= T3 < 15 T3 (µs)(<=25µs), 15 <= T3 < 18 T4 (µs)(<=4µs), 18 <= T3 < 20 T5 (µs)(<=1µs), 20 <= T3 < 25
T3	1,2	Supported TimeStamp resolution	-		10 (1 ms)	Nearest value of 2^{-n} in seconds (number 0...24)
c1 TL may only be specified for Ed2. If Ed1 has accuracy which is better than 1 second but is not T1 then declare T0.						

J.2 Model Implementation Conformance Statement (MICS)

Model Implementation Conformance Statement (MICS)

for the IEC 61850 Edition 2 server interface in TESLA 4000-A

Document Version[1]: D05516R01.10

Date: 2025-01-07

Based upon

UCA International Users Group
Testing Sub Committee

MICS template for Server Test Procedures First edition and Edition 2 servers
Template version 1.2

1. The formatting of the official version of this document differs slightly from the version shown here in the user manual, but the content is the same.

Introduction

This model implementation conformance statement is applicable for TESLA 4000-A, with firmware v1.2:

This MICS document specifies the modeling extensions compared to IEC 61850 Edition 2. For the exact details on the standardized model please compare the ICD substation configuration file: “ERLPhaseTESLA4006v1.01.03”, version 1.01 revision 3.

Table J.4, “Logical Nodes List” contains the list of implemented logical nodes.

Logical Nodes List

The following table contains the list of logical nodes implemented in the device:

Table J.4: Logical Nodes List
L: System Logical Nodes
LPHD (Physical device information)
LLN0 (Logical node zero)
LGOS (GOOSE Subscription)
LTMS (Time source status)
LCCH (Physical communication channel supervision)
R: Logical nodes for protection related functions
RDRE (Disturbance recorder function)
RADR (Disturbance recorder channal analog)
RBDR (Disturbance recorder channal binary)
RFLO (Fault Locator)
G: Logical Nodes for generic references
GGIO (Generic process I/O)
M: Logical Nodes for metering and measurement
MSQI (Sequence and Imbalance)
MMXN (Non-phase-related measurement)

Logical Node Extensions

The following table uses:

- M: Data is mandatory in the IEC 61850-7-4 Ed.2.
- O: Data is optional in the IEC 61850-7-4 Ed.2 and is used in the device.
- E: Data is an extension to the IEC 61850-7-4 Ed.2.

Extended Logical Nodes

The following logical nodes have been extended with extra data. All extra data has been highlighted in the tables and marked as “E” (Extended).

VIGGIO – Virtual Input LN

GGIO class				
Name	**Description**			
VIGGIO	Virtual Input LN for GOOSE subscription. 256 LNs provided, indexed VIGGIO1 – VIGGIO256.			
Data object name	**Common data class**	**Explanation**	**M/O/C/E**	**Remarks**
Data objects				
Common Logical Node Information				
Beh	ENS	Behaviour	M	
Status Information				
Ind1	SPS	General indication (binary input)	O	
IntIn1	INS	Integer status input	O	
PosMir	DPS	Double-point status input	E	

J.3 TISSUES Implementation Conformance Statement (TICS)

Introduction

This document provides a template for the Tissues conformance statement. According to the UCA IUG QAP the Tissue conformance statement is required to perform a conformance test and is referenced on the certificate.

This document is applicable for TESLA 4000-A with firmware v1.0.

Document Version[1]: D05519R01.00
Date: 2022-07-12

Mandatory Edition 2 Tissues

Below tables give an overview of the applicable mandatory Tissues. Items in *italic* are brief interpretations provided by the UCA International Users Group to aid in interpretation and is not normative. The original TISSUE should consulted for details of changes.

Table J.5: Mandatory Edition 2 Tissues

Tissue	Description	Implemented Y/na
Part 6		
658	Tracking related features *EntryID and CST missing, these are checked by schema*	na
663	FCDA element cannot be a “functionally constrained logical node” *doName now mandatory in FCDA element,* *SCT: refuse to make empty doName? ICT: Refuse SCD*	Y
668	Autotransformer modeling *Autotransformer model in substation section has changed*	na
687	SGCB ResvTms *SettingControl has added attribute resvTms* *see also TISSUE 845*	na
719	ConfDataSet - maxAttributes definition is confusing *maxAttributes now means max count of FCDA in dataset*	Y
721	Log element name *LN0/Log now has optional attribute “name”*	na
768	bType VisString65 is missing *VisString65 added as SCL BasicType*	na
779	object references *“@” as first character in object references now allowed*	na
788	SICS S56 from optional to mandatory *SICS S56=”Interpret IED capabilities and prohibit unsupported usage”*	na

1. The formatting of the official version of this document differs slightly from the version shown here in the user manual, but the content is the same.

Table J.5: Mandatory Edition 2 Tissues

Tissue	Description	Implemented Y/na
789	ConfLdName as services applies to both server and client *Many changes made to Services section*	na
804	valKind and IED versus System configuration *valImport missing/false DAI means ICT shall ignore value in SCD and SCT shall not change from ICD/IID value. Instance section inherits from DA/BDA element.*	na
806	Max length of log name inconsistent between -6 and -7-2 *LogControl.logName and Log.name restricted to 32 chars*	na
807	Need a way to indicate if “Owner” present in RCB *Services/ReportSettings@owner added*	Y
823	ValKind for structured data attributes *valKind is prohibited on structured attributes*	Y
824	Short addresses on structured data attributes *sAddr is now allowed for structured attributes*	na
825	Floating point value *Server shall support <Val> with exponential notation*	na
845	SGCB ResvTms *Services/SettingGroups/SGEdit added attribute resvTms* *Services/SettingGroups/ConfSG added attribute resvTms* *See also TISSUE 687*	na
853	SBO and ProtNs *DA[@name=SBO] element shall have ProtNS element*	na
855	Recursive SubFunction *Substation section extension must be tolerated*	na
856	VoltageLevel frequency and phases *Substation section extension must be tolerated*	na
857	Function/SubFunction for ConductingEquipment *Substation section extension must be tolerated*	na
886	Missing 8-1 P-types *“tP_IP_UDP_PORT” and “tP_IP_TCP_PORT” added*	na
901	tServices as AP or as IED element *Rules for contents of AP/Server/Services are now defined*	Y
936	SupSubscription parameter usage is difficult *SupSubscription “max” replaced by “maxGo” and “maxSv”*	Y
1147	tServices - FileHandling not consistent with -7-2 *Services/FileHandling now means only support for GetFile and GetFileAttributeValues and NOT SetFile/DeleteFile*	Y
1185	Valkind value Conf for EX FC data *valKind=Conf is allowed for dataNs*	na
1284	SCSM mapping may require a communication section in an ICD file *Server IEDs supporting client/server associations to 61850-8-1 shall include a <Communication> section*	Y

Table J.5: Mandatory Edition 2 Tissues

Tissue	Description	Implemented Y/na
1328	Limitation on the size of data type templates identifiers *Identifer now limited to 255 characters*	Y
1395	Client LN attributes *ReportControl/RptEnabled/ClientLN@ldInst shall be “LD0” for pure clients (without any Logical Devices)*	na
1402	ExtRef during engineering *an ExtRef.intAddr attribute value unequal to empty string (pre-scribed or filled by the IED tool) is the flag indicating that the ExtRef shall not be deleted by the system tool. The system tool can however remove the link to the source IED* <<applicable for SCL tool test>>	na
1415	SICS-S110 IID import mandatory for Edition2 *only the import of data model modifications and CF value changes is mandatory for system tool* <<applicable for SCL tool test>>	na
1419	Support of ldName on other IEDs *SICS I212 is now mandatory*	Y
1444	Need to support fixed and SCT controlled Datasets *Services/xxxSetttings@datSet=fix now means “data set pointed by Control Block cannot be altered from ICD/IID* value <<appli-cable for SCL tool test>>	na
1445	ConfReportControl and a fixed ReportSettings *Control block capabilities must be consistent* *<<applicable for SCL tool test>>*	na
1450	originalSclXxx computation rules *Ed2 ICD/IID files specifying SCL@version=2007 SHALL include originalSCLVersion=2007 and originalSCLRevision as attributes of the <IED>element*	Y
1485	Need to supercede Tissue 1398 to clarify SCT behavior *Same as TISSUE 1450 <<applicable for SCL tool test>>*	na
Part 7-1		
828	Data model namespace revision IEC 61850-7-4:2007[A] *Both 2007 and 2007A are allowed for namespace name*	Y
948	Enumeration (string) values format *Enums are limited to 127 characters from Basic-Latin and Latin-1 character sets*	Y
1151	simulated GOOSE disappears after 1st appearance when LPHD.Sim = TRUE *New LGOS state machine defined, but TISSUE is not IntOp2, therefore TISSUE is optional if LGOS is used*	Y
1396	The use and configuration flow of LGOS is unclear *If Services/SupSubscription@maxGo > 1 then at least 1 LGOS must exist.* *If maxGo > count(LGOS) then SCT can create additional LGOS.*	Y

Table J.5: Mandatory Edition 2 Tissues

Tissue	Description	Implemented Y/na
1447	Restriction on ENUMtypes in SCL *If a ENUM DA limits write or configuration to a subset, then that subset must be declared*	na
1457	Multiple DOI nodes with the same name *LN can have no more than one DOI with same name*	Y
1468	Re-use DO from other LN *allow standard or private dataNs*	na
1491	CmdBlk blocks itself? *The data CmdBlk shall have no effect on the controllable data Mod or CmdBlk*	na
1495	GetVariableAccessAttributes error code *Return MMS error access/object-non-existent if the object does not exist*	Y
Part 7-2		
728	BRCB: could PurgeBuf be set when RptEna=TRUE? *PurgeBuf while RptEna=true is prohibited*	Y
778	AddCause values – add value not-supported *Align 7-2 with 8-1 (nothing new to 8-1)*	na
780	What are unsupported trigger option at a control block? *All control blocks must support all trigger options*	Y
783	TimOper Resp- ; add Authorization check *Clarifies Time-Operated Controls*	na
786	AddCause values 26 and 27 are switched *Annex B.2 has wrong AddCause values*	na
820	Mandatory ACSI services (use for PICS template) *Model entries M18 (Application Association), M19 (GCB), M20 (SVCB) are new. Services S17 (Substitution) and S61 (Get-ServerDirectory) are new. Services S1, S3, S4, S5, S6, S8, S16, S18, S23, S36, S37, S41, S42 are changed.*	Y
858	typo in enumeration ServiceType *Tracking serviceType now has GetLogicalNodeDirectory*	na
861	dchg of ConfRev attribute *Clarifies (tracking) BTS.confRev is AFTER BRCB change*	na
1050	GTS Phycomaddr definition in SCL *(Tracking) GTS needs a special structure for SCL*	na
1071	Length of DO name *Private DO name length shall be <=12 including instance*	Y
1127	Missing owner attribute in BTS and UTS *NSD files for 61850-7-3 show owner in (tracking) BTS/UTS*	na
1202	GI not optional *GI support is mandatory for both URCB and BRCB*	Y
1232	EntryID needs clarification *Segments of a report shall have same identifiers*	Y

Table J.5: Mandatory Edition 2 Tissues

Tissue	Description	Implemented Y/na
1242	NTS definition *NTS.resv have been added*	na
1307	Segmented report with Buffer overflow *Segments of a report shall have identical buf-overflow value*	Y
1428	MTS and NTS should use svOptFlds *MTS.optFlds and NTS.optFlds now have bType=SvOptFlds*	na
1630	Attributes in CDC=LTS do not match 8-1 definition *Order of attributes in LTS changed to:* *logEna, logRef, datSet, oldEntrTm, newEntrTm, oldEnt, newEnt, trgOps, intgPd*	na
Part 7-3		
697	persistent command / PulseConfig *PulseConfig adds enum “persistent-feedback”* *DPC.cmdQual==”persistent” is conditionally allowed*	na
698	Wrong case is BAC.dB attribute *attribute renamed from “dB” to “db”*	na
711	blkEna freeze data update while setting its quality to operater-Blocked *Mode=Blocked shall not cause q.operatorBlocked*	na
722	Units for 'h' and 'min' not in UnitKind enumeration. *New unit enums 84=hours, 85=minutes*	na
919	Presence Condition for sVC *svC may be valKind=Conf in ICD file*	na
925	Presence of i or f attribute - Problem with writing *New constructed attribute class "AnalogueValueCtl"*	na
926	Presence Conditions within RangeConfig *All or none of hhLim+hLim+lLim+llLim shall be present*	Y
954	Data attributes with FC=CF should have trgOp=dchg *Some INS and HST and CSG attributes missing dchg*	Y
1078	CMV.t update if rangeAng changed *Add rangeAng to“reasons-to-update-timestamp-of-CMV”*	na
1565	db = 0 behaviour *db=0 not longer suppresses reporting*	Y
1578	dataAttribute NameSpace content *Attributes with FC=EX must be initialized in ICD/IID file*	Y
Part 7-4		
671	mistake in definition of Mod & Beh *Beh=on, q=test should be “Processed as valid”*	Y
674	CDC of ZRRC.LocSta is wrong *ZRRC LocSta should be CDC=SPC*	na
676	Same data object name used with different CDC *LCCH.Fer renamed to FerCh, LCCH.RedFer to RedFerCh*	na

Table J.5: Mandatory Edition 2 Tissues

Tissue	Description	Implemented Y/na
677	MotStr is used with different CDC in PMMS and SOPM LN classes *Rename SOPM.MotStr to MotStrNum*	na
679	Remove CycTrMod Enum *Enum is no longer used, use TrMod instead*	na
680	SI unit for MHYD.Cndct *Change unit from S/cm^2 to S/m*	na
681	Enum PIDAlg *Typographical error, invalid XML syntax*	na
682	ANCR.ParColMod *ParColMod enum values text have changed*	na
683	Enum QVVR.IntrDetMth *IntrDetMth enum values text have changed*	na
685	Enum ParTraMod *ParTraMod enum values text have changed*	na
686	New annex H - enums types in XML *Many changes have been made to enumeration names*	Y
694	Data object CmdBlk *CmdBlk semantics have changed*	na
696	LSVS. St (Status of subscription) *LSVS. St is now mandatory*	na
712	interpretation of quality operatorBlocked *Mode and Behavior semantics have changed*	na
713	DO Naming of time constants in FFIL *Many DO names in FFIL have changed*	na
714	Enums for ShOpCap and SwOpCap *Type for YPSH.ShOpCap and XSWI.SwOpCap have changed*	na
715	RBDR.ChNum1 *RBDR.ChNum1 changes from optional to conditional*	na
716	TAXD text for condition *TAXD.SmRte condition for inclusion has changed*	na
724	ANCR.Auto *ANCR.Auto changes from mandatory to optional*	na
725	Loc in LN A-group *Loc changes to optional, LocKey/LocSta conditions change*	na
734	LLN0.OpTmh vs. LPHD.OpTmh *LLN0.OpTmh deleted, LPHD.OpTmH added as conditional*	na
736	PFSign *MMXU.PFSign enum is extended with 3=Excitation*	na
742	GAPC.Str, GAPC.Op and GAPC.StrVal *Objects have instance indicator removed (ex, Str1 to Str)*	na

Table J.5: Mandatory Edition 2 Tissues

Tissue	Description	Implemented Y/na
743	CCGR.PmpCtl and CCGR.FanCtl *Object have instance indicator added (ex:PmpCtl to PmpCtl1)*	na
744	LN STMP, EEHealth and EEName *Removed STMP.EEHealth and STMP.EEName*	na
772	LPHD.PwrUp/PwrDn should be transient *These objects are now transient*	na
773	Loc, LocKey and LocSta YPSH and YLTC *Add Loc, LocKey and LocSta in YLTC and YPSH (optional)*	na
774	ITCI.LocKey *Add ITCI.LocKey as optional*	na
776	LPHD.OutOv/InOv and LCCH.OutOv/InOv *Clarified: stays true until buffer space again available*	na
800	Misspelling in CSYN *CSYN.VInvTmms renamed to CSYN.VIntvTmms*	na
802	CCGR and Harmonized control authority *Add Loc, LocKSta to every controllable LN (e.g. FSPT)*	na
808	Presence condition of ZMoT.DExt and new DOs *Change ZMOT.DExt to optional; add TotThmSt and MotSt*	na
831	Setting of ConfRevNum in LGOS *Add RxConfRevNum to LGOS*	na
838	Testing in Beh=Blocked *Change sematic of Beh=Blocked to allow controls to be acknowledged even when LN is blocked.*	na
844	MFLK.PhPiMax, MFLK.PhPiLoFil, MFLK.PhPiRoot DEL->WYE *Change these NFLK objects from cdc=DEL to cdc=WYE*	na
877	QVUB -settings should be optional *Change QVUB.UnbDetMth and QVUB.StrVal to optional*	na
908	ARIS.StrSeq – transient *Change ARIS.StrSeq to transient*	na
909	Remove ANCR.ColOpR and ColOpL *Replace ANCR.ColOpR and ANCR.ColOpL with ANCR.Col-Chg. Add YEFN.ColChg*	na
912	Clarification of PwrRtg/VARtg *Change many DOs in YPTR, and ZGEN, see name space 2007A2.nsd for final result*	na
920	Resetable Counter is NOT resetable *Change GGIO.CntRs to CntVal; Same for FCNT*	na
932	Rename AVCO.SptVol to AVCO.VolSpt	na
933	Presence of LCCH.RedFerCh and RedRxCnt *Change the presence condition of LCCH.RedChLiv*	na
939	Change CDC for ANCR.FixCol *Change ANCR.FixCol from APC to ASG*	na

Table J.5: Mandatory Edition 2 Tissues

Tissue	Description	Implemented Y/na
991	LGOS: GoCBRef should be mandatory *LGOS.GoCBRef is mandatory*	Y
1007	PTRC as fault indicator - Update of description required *PTRC.Tr and Op and Str conditional (at least 1 of group)*	na
1044	TapChg in AVCO *AVCO.TapChg is now optional*	na
1077	Rename DOnames within LTIM *LTIM.TmChgDayTm, changed to TmChgDay;* *LTIM.TmChgStdTm changed to TmChgStd*	na
1256	New DO for LTIM to set time “manually” *Add LTIM.TmSet*	na
1331	Mod, Beh and Health with q=TEST, client can't receive their states *Mod while in Blocked will always be processed*	Y
1426	Add two DO for leap seconds in LTIM *LTIM.Leap added,*	na
1456	Annex A and Mod/Beh/Health *Mod.stVal writes always igore test bits in controls*	Y
1568	ISAF.AlmReset ->transient *Change ISAF.AmlReset to transient*	na
Part 8-1		
770	GoID type mitmatch 18.1.1 and 18.1.2.5.2 *GoID string length is now 129*	Y
784	Tracking of control (CTS) *Tracking CTS has been added*	na
817	Fixed-length GOOSE float encoding *GOOSE float is encoded Tag-0x87, length=5, first octet=8*	na
827	Mandatory ACSI services (Part of 7-2 TISSUE resolution) *Change Table 111 (ServicesSupported): Add initiate, abort, and release. Change conditions for defineNamedVariables.*	Y
834	File dir name length 64 *Filename length changed from 32 to 64*	na
951	Encoding of Owner attribute *xRCB.owner is encoded as 4 octets(IPv4) or 16 octets(IPv6)*	na
1040	More associate error codes *3 additional associate error codes added*	Y
1178	Select Response+ is non-null value *Response to SBO read should be <CO_CtrlObjectRef>*	na
1324	The response- for DeleteNamedVariableList is not defined *numDeleted=0; error=service/object-constraint-conflict*	na
1345	Fixed-length GOOSE ASN.1 length encoding *GOOSE publisher shall always encode minimum size legth field*	na

Table J.5: Mandatory Edition 2 Tissues

Tissue	**Description**	**Implemented Y/na**
1441	Optonal fields in buffered reports *Writing BRCB.optFld shall not cause a purgeBuf operation*	Y
1442	Journal variableTag for ReasonCode *Example in the standard is incorrect*	na
1453	Purge buffer on write to BRCB *PurgeBuf only occurs if different value is written*	Y
1454	Reports can be transmitted before write (RptEna=true) is confirmed	na
1495	GetVariableAccessAttributes error code *Return MMS error access/object-non-existent if the object does not exist*	Y
1500	the response for DeleteNamedVariableList with a non-existent LN is not specified *CreateDataSet/DefineNamedVariableList specifying a non-existing LD/LN shall fail with access/object-non-existent*	na
1626	PICS for Information Report is incorrect MMS ServicesSupported "informationReport" should be optional for servers because they never receive InformationReport request. It is only required for clients which process reports or control command-termination	Y

J.4 Protocol Implementation eXtra Information for Testing (PIXIT)

Protocol Implementation eXtra Information for Testing (PIXIT) for the IEC 61850 Edition 2 server interface in
TESLA 4000-A

Document Version[1]: D05518R01.00
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Based Upon UCAIug Server PIXIT
Template version 20

1. The formatting of the official version of this document differs slightly from the version shown here in the user manual, but the content is the same.

PIXIT for Server

Introduction

This document specifies the protocol implementation extra information for testing (PIXIT) of the IEC 61850 interface in TESLA 4000-A with firmware version v1.0.

Together with the PICS and the MICS the PIXIT forms the basis for a conformance test according to IEC 61850-10. The PIXIT entries contain information which is not available in the PICS, MICS, TICS documents or SCL file.

Each table specifies the PIXIT for applicable ACSI service model as structured in IEC 61850-10. The “Ed” column indicates if the entry is applicable for IEC 61850 Edition 1 and/or Edition 2. A hyphen (“-”) in the Ed column indicates the PIXIT entry is not applicable for any version.

PIXIT for DOCUMENTATION

ID	Ed	Description	Value / Clarification
Do1	2	How to expose required firmware versions not present in the datamodel	Firmware version and ICD file compatibility listed in the firmware release notes.

PIXIT for ASSOCIATION MODEL

ID	Ed	Description	Value / Clarification
As1	1	Maximum number of clients that can set-up an association simultaneously	4
As2	1,2	TCP_KEEPALIVE value. The recommended range is 1...20s	5 seconds
As3	1,2	Lost connection detection time	20 seconds
As4	-	Authentication is not supported yet	
As5	1,2	What association parameters are necessary for successful association: Called value: Calling values:	Transport selector Y Session selector Y Presentation selector Y AP Title N AE Qualifier N other Transport selector Y Session selector Y Presentation selector Y AP Title N AE Qualifier N other
As6	1,2	If association parameters are necessary for association, describe the correct Called values: e.g. Calling parameters: e.g.	Transport selector 0001 Session selector 0001 Presentation selector 00000001 other Transport selector 0001 Session selector 0001 Presentation selector 00000001 other
As7	1,2	What is the maximum and minimum MMS PDU size	Max MMS PDU size 32,000 Min MMS PDU size 1,300
As8	1,2	What is the maximum start up time after a power supply interrupt	180 seconds
As9	1,2	Does this device function only as test equipment? (test equipment need not have a non-volatile configuration; but it cannot be part of the substation automation system)	N

PIXIT for SERVER MODEL

ID	Ed	Description	Value / Clarification
Sr1	1,2	Which analogue value (MX) quality bits are supported (can be set by server)	Validity: Y Good, Y Invalid, Y Reserved, Y Questionable Detail Quality: Y Overflow Y OutofRange Y BadReference Y Oscillatory Y Failure Y OldData Y Inconsistent Y Inaccurate Miscellaneous: Y Source Y Test N OperatorBlocked Reserved is treated as invalid
Sr2	1,2	Which status value (ST) quality bits are supported (can be set by server)	Validity: Y Good, Y Invalid, Y Reserved, Y Questionable Detail Quality: Y BadReference Y Oscillatory Y Failure Y OldData Y Inconsistent Y Inaccurate Miscellaneous: Y Source Y Test N OperatorBlocked Reserved is treated as invalid
Sr3	-	What is the maximum number of data object references in one GetDataValues request	Deprecated
Sr4	-	What is the maximum number of data object references in one SetDataValues request	Deprecated
Sr5	1	Which Mode values are supported [a]	On Y [On-Blocked] N Test Y Test/Blocked N Off N

a. IEC 61850-6:2009 clause 9.5.6 states that if only a subrange of the enumeration value set is supported, this shall be indicated within an ICD file by an enumeration type, where the unsupported values are missing

PIXIT for DATA SET MODEL

ID	Ed	Description	Value / Clarification
Ds1	1	What is the maximum number of data elements in one data set (compare ICD setting)	128
Ds2	1	How many persistent data sets can be created by one or more clients (this number includes predefined datasets)	CreateDataSet not supported.
Ds3	1	How many non-persistent data sets can be created by one or more clients	CreateDataSet not supported.

PIXIT for SUBSTITUTION MODEL

ID	Ed	Description	Value / Clarification
Sb1	1	Are substituted values stored in volatile memory	Not Supported

PIXIT for SETTING GROUP CONTROL MODEL

ID	Ed	Description	Value / Clarification
Sg1	1	What is the number of supported setting groups for each logical device	Not Supported
Sg2	1,2	What is the effect of when and how the non-volatile storage is updated (compare IEC 61850-8-1 §16.2.4)	Not Supported
Sg3	1	Can multiple clients edit the same setting group	Not Supported
Sg4	1	What happens if the association is lost while editing a setting group	Not Supported
Sg5	1	Is EditSG value 0 allowed	Not Supported
Sg6	2	When ResvTms is not present how long is an edit setting group locked	Not Supported

PIXIT for REPORTING MODEL

ID	Ed	Description	Value / Clarification
Rp1	1	The supported trigger conditions are (compare PICS)	integrity Y data change Y quality change Y data update Y general interrogation Y Trigger option Data Update (dupd) is supported by the IED. However data model doesn't contain any CDC DA with trigger dupd=true.Therefore, such an event will not be possible to generate.
Rp2	1	The supported optional fields are	sequence-number Y report-time-stamp Y reason-for-inclusion Y data-set-name Y data-reference Y buffer-overflow Y entryID Y conf-rev Y segmentation Y
Rp3	1,2	Can the server send segmented reports (when not supported the device shall refuse an association request with a smaller than minimum PDU size)	Y
Rp4	1,2	Mechanism on second internal data change notification of the same analogue data value within buffer period (Compare IEC 61850-7-2 §14.2.2.9)	Send report immediately
Rp5	1	Multi client URCB approach (compare IEC 61850-7-2:2003 §14.2.1)	Each URCB is visible to all clients
Rp6	-	What is the format of EntryID	Deprecated
Rp7	1,2	What is the buffer size for each BRCB or how many reports can be buffered	Buffer size is 50,000 bytes for each BRCB
Rp8	-	Pre-configured RCB attributes that are dynamic, compare SCL report settings	Deprecated
Rp9	1	May the reported data set contain: - structured data objects - data attributes	 Y Y
Rp10	1,2	What is the scan cycle for binary events. Is this fixed, configurable?	3 ms Fixed
Rp11	1	Does the device support to pre-assign a RCB to a specific client in the SCL	N

ID	Ed	Description	Value / Clarification
Rp12	2	After restart of the server is the value of ConfRev restored from the original configuration or retained prior to restart	Restored from original configuration
Rp13	1,2	Does the server accept any client to configure / enable a BRCB with ResvTms=-1? What fields are used to do the identi-fication?	N
Rp14	1,2	When BRCB.ResvTms is exposed, what is the default value for BRCB.ResvTms if client does not write (must be > 0) When BRCB.ResvTms is not exposed, what is the internal reservation time-(must be >= 0)	N/A 0 seconds
Rp15	2	Is data model db=0 supported Value/ Clarification	Y

PIXIT for LOGGING MODEL

ID	Ed	Description	Value / Clarification
Lg1	1,2	What is the default value of LogEna (Compare IEC 61850-8-1 §17.3.3.2.1, the default value should be FALSE)	Not Supported
Lg2	-	What is the format of EntryID	Deprecated
Lg3	1,2	Are there multiple Log Control Blocks that specify the Journaling of the same MMS NamedVariable and TrgOps and the Event Condition (Compare IEC 61850-8-1 §17.3.3.3.2)	Not Supported
Lg4	-	Pre-configured LCB attributes that cannot be changed online	Deprecated, the information is already available in SCL
Lg5	1	Which TrgOps are supported for logging (note Ed2 and up requires support for all TrgOps)	Not Supported

PIXIT for GOOSE PUBLISH MODEL

ID	Ed	Description	Value / Clarification
Gp1	1,2	Can the test (Ed1) / simulation (Ed2) flag in the published GOOSE be set	N
Gp2	1	What is the behaviour when the GOOSE publish configuration is incorrect	NdsCom=T DUT keeps GoEna=F
Gp3	1,2	Published FCD supported common data classes are	SPS, ENS, ACD, LPL, DPS, ACT, INS, SPC Arrays are not supported
Gp4	1,2	What is the maximum value of TAL (maxTime) Is it fixed or configurable	Configurable MaxTime 120,000ms
Gp5	1,2	What is the fastest retransmission time	2 ms
Gp6	-	Can the GOOSE publish be turned on / off by using SetGoCBValues(GoEna)	Deprecated See PICS - SetGoCBValues
Gp7	1,2	What is the initial GOOSE sqNum after restart	sqNum = 0
Gp8	1	May the GOOSE data set contain: - structured data objects (FCD) - timestamp data attributes	 Y Y
Gp9	1,2	Does Server or ICT refuse GOOSE payload dataset length greater than SCSM supports?	Y – ICT refuses

PIXIT for GOOSE SUBSCRIBE MODEL

ID	Ed	Description	Value / Clarification
Gs1	1,2	What elements of a subscribed GOOSE message are checked to decide the message is valid and the allData values are accepted? If yes, describe the conditions. Notes: • the VLAN tag may be removed by an Ethernet switch and shall not be checked • the simulation flag shall always be checked (Ed2)	Y destination MAC address Y APPID Y gocbRef Y timeAllowedtoLive N datSet N goID N T Y stNum N sqNum Y simulation / test Y confRev Y ndsCom Y numDatSetEntries Yout-of-order dataset members
Gs2	1,2	When is a subscribed GOOSE marked as lost (TAL = time allowed to live value from the last received GOOSE message)	message does not arrive by 2x TAL
Gs3	1,2	What is the behaviour when one or more subscribed GOOSE messages is not received or syntactically incorrect (missing GOOSE)	Syntactically incorrect messages (incorrect stNum increment) received within the TAL are discarded, message will be processed after TAL expires and syntactically correct message is not received.
Gs4	1,2	What is the behaviour when a subscribed GOOSE message is out-of-order	Older messages are discarded
Gs5	1,2	What is the behaviour when a subscribed GOOSE message is duplicated	First message will process and second message will discard.
Gs6	1	Does the device subscribe to GOOSE messages with/without the VLAN tag	Y, with the VLAN tag Y, without the VLAN tag
Gs7	1	May the GOOSE data set contain: - structured data objects (FCD) - timestamp data attributes	 Y Y
Gs8	1,2	Subscribed FCD supported common data classes are	SPS, ENS, DPS, INT, ACD, ACT, SEC Arrays are not supported
Gs9	1,2	Are subscribed GOOSE with test=T (Ed1) / simulation=T (Ed2) accepted in test/simulation mode	Y
Gs10	1,2	Max number of dataset members	Fixed at 128
Gs11	1	Is Fixed-length encoded GOOSE supported	Y
Gs12	2	Is IEC 62351-9 security supported	N

PIXIT for GOOSE PERFORMANCE

ID	Ed	Description	Value / Clarification	
Gf1	1,2	Performance class	P2 = 10 ms P3 = 20 ms	
Gf2	1,2	GOOSE ping-pong processing method	Scan cycle based	
Gf3	1,2	Application logic scan cycle (ms)	Max.	4ms (GOOSE PUB) 100us (GOOSE SUBS)
			Min.	100us (GOOSE PUB) 100us (GOOSE PUB)
Gf4	1	Maximum number of data attributes in GOOSE dataset (value and quality has to be counted as separate attributes)	Such that dataset does not exceed GOOSE: 1000 Bytes	

PIXIT for CONTROL MODEL

ID	Ed	Description	Value / Clarification
Ct1	1	What control models are supported (compare ICD file enums for Ed2)	Dons: Y SBOns: N DOes: N SBOes: N
Ct2	1,2	Is the control model fixed, configurable and/or dynamic	Fixed
Ct3	-	Is TimeActivatedOperate supported (compare PICS or SCL)	Deprecated
Ct4	-	Is “operate-many” supported (compare sboClass)	Deprecated, see sboClass in datamodel (ICD)
Ct5	1	Will the DUT activate the control output when the test attribute is set in the SelectWithValue and/or Operate request (when N test procedure Ctl2 is applicable)	Yes, only for Mode control
Ct6	-	What are the conditions for the time (T) attribute in the SelectWithValue and/or Operate request	Deprecated
Ct7	-	Is pulse configuration supported (compare pulseConfig)	Deprecated
Ct8	1	What is the behaviour of the DUT when the check conditions are set Is this behaviour fixed, configurable, online changeable	Check conditions are not checked.

ID	Ed	Description	Value / Clarification
Ct9	1,2	Which additional cause diagnosis are supported	N Unknown N Not-supported N Blocked-by-switching-hierarchy N Select-failed N Invalid-position N Position-reached N Step-limit N Blocked-by-Mode N Blocked-by-process N Blocked-by-interlocking N Blocked-by-synchrocheck N Command-already-in-execution N Blocked-by-health N 1-of-n-control N Abortion-by-cancel N Time-limit-over N Abortion-by-trip N Object-not-selected **Edition 1 specific values:** N Parameter-change-in-execution (Ed1 semantics) **Edition 2 specific values:** N Object-already-selected N No-access-authority N Ended-with-overshoot N Abortion-due-to-deviation N Abortion-by-communication-loss N Blocked-by-command N None N Locked-by-other-client N Parameter-change-in-execution (Ed2 semantics)
Ct10	1,2	How to force a “test-not-ok” respond with SelectWithValue request	Not Supported
Ct11	1,2	How to force a “test-not-ok” respond with Select request	Not Supported
Ct12	1,2	How to force a “test-not-ok” respond with Operate request	Not supported
Ct13	1,2	Which origin categories are supported / accepted	Y bay-control Y station-control Y remote-control Y automatic-bay Y automatic-station Y automatic-remote Y maintenance Y process
Ct14	1,2	What happens if the orCat value is not supported or invalid	DOns: Operate response-

ID	Ed	Description	Value / Clarification
Ct15	1,2	Does the IED accept a SelectWithValue / Operate with the same control value as the current status value Is this behaviour configurable	DOns: N Configurable: N
Ct16	1	Does the IED accept a select/operate on the same control object from 2 different clients at the same time	DOns: N
Ct17	1	Does the IED accept a Select/SelectWith-Value from the same client when the control object is already selected (Tissue #334)	Not Suported
Ct18	1	Deprecated	
Ct19	-	Can a control operation be blocked by Mod=Off or [On-] Blocked (Compare PIXIT-Sr5)	Deprecated
Ct20	1,2	Does the IED support local / remote operation	N
Ct21	1,2	Does the IED send an InformationReport with LastApplError as part of the Operate response- for control with normal security	DOns: N
Ct22	2	How to force a “parameter-change-in-execution”	Not Supported
Ct23	1,2	How many SBOns/SBOes control objects can be selected at the same time?	Not Supported
Ct24	1,2	Can a controllable object be forced to keep its old state e.g. Internal Controllable Objects may not be accessible to force this, whereas a switch like Circuit Breaker outside the DUT can?	N
Ct25	1,2	When CDC=DPC is supported, is it possible to have DPC (Controllable Double Point) go to the intermediate state? (00)	N/A
Ct26	1,2	Name an enhanced security point (if any) with a finite operate timeout specify the timeout (in milliseconds)	Ld/Ln.DataObject, xxx or No DOes points have timeout DOes: No SBOes: No
Ct27	2	Does the IED support control objects with external signals?	DOns: N SBOns: N DOes: N SBOes: N
Ct28		Deprecated, kept as placeholder	

PIXIT for TIME SYNCHRONIZATION MODEL

ID	Ed	Description	Value / Clarification
Tm1	1	What time quality bits are supported (may be set by the IED)	Y LeapSecondsKnown Y ClockFailure Y ClockNotSynchronized
Tm2	1,2	Describe the behaviour when all time server(s) cease to respond What is the time server lost detection time	Assert CNS after lost detection time SNTP: Configurable “Poll Interval” + 5*”Timeout Interval”
Tm3	1,2	How long does it take to take over the new time from time server	From ‘no sync’ to ‘SNTP sync’: it takes approximately 5 seconds For the same SNTP time master time adjustment: it takes “Poll Interval” + 5*”Timeout Interval” to get the new time from the same time server.
Tm4	1,2	When is the time quality bit “Clock-Failure” set	Bit is set, when no IRIG-B, SNTP or PTP is detected Note: For Ed2 and up, CNS is set according to PIXIT Tm2
Tm5	1	When is the time quality bit “Clock not Synchronized” set	Bit is set, when No IRIG-B, SNTP or PTP is detected Unlocked IRIG-B is detected Note: For Ed2 and up, CNS is set according to PIXIT Tm2
Tm6	-	Is the timestamp of a binary event adjusted to the configured scan cycle	Deprecated
Tm7	1	Does the device support time zone and daylight saving	Y
Tm8	1,2	Which attributes of the SNTP response packet are validated	N Leap indicator not equal to 3 N Mode is equal to SERVER N OriginateTimestamp is equal to value sent by the SNTP client as Transmit Timestamp N RX/TX timestamp fields are checked for reasonableness Y SNTP version 3 and/or 4 N other (describe)
Tm9	1,2	Do the COMTRADE files have local time or UTC time and is this configur-able	COMTRADE files are not supported on the IED. Native Records may be converted to COMTRADE via software tools. It is configurable to display either Local or UTC time.

PIXIT for FILE TRANSFER MODEL

ID	Ed	Description	Value / Clarification
Ft1	1	What is the structure of files and directories Where are the COMTRADE files stored Are COMTRADE files zipped and what files are included in each zip file	Flat file system with pseudo folders (Ed2) COMTRADE files are not stored on the IED.
Ft2	1,2	Directory names are separated from the file name by	“/”
Ft3	1	The maximum file name size including path (recommended 64 chars)	64 chars
Ft4	1,2	Are directory/file name case sensitive	Y
Ft5	1,2	Maximum file size for SetFile	SetFile Not Supported
Ft6	1	Is the requested file path included in the MMS fileDirectory respond file name	Y But client is not allowed to use any path names that contain anything other than “/”. In that case Server will return response with zero files. (Ed2: always complete path)
Ft7	1	Is the wild card supported in the MMS fileDirectory request	Yes, wild card = *
Ft8	1,2	Is it allowed that 2 clients get a file at the same time	Y same file Y different files
Ft9	1,2	Which files can be deleted	Delete files not supported
		<additional items>	

PIXIT for SERVICE TRACKING MODEL

ID	Ed	Description	Value / Clarification
Tr1	2	Which ACSI services are tracked by LTRK.GenTrk	Not Supported

J.5 Data Mapping Specifications

TESLA 4000-A Logical Devices

The TESLA 4000-A Recorder has the following IEC 61850 logical devices defined in its ICD file:

- LD0 - Root Logical Device
- RCD - Recorder Triggers
- MEAS- Measurements
- SYS - System Info
- FLTL - Fault Locators
- DVI - Digital Virtual Inputs

TESLA 4000-A Logical Nodes

The following table, Table J.6: TESLA 4000-A Logical Nodes, defines the list of logical nodes (LN) which belong to the TESLA 4000-A logical devices.

Table J.6: TESLA 4000-A Logical Nodes

LD Name	LN Name	LN Description	Comments
LD0	LLN0	Common LN	
LD0	LPHD	Physical Device LN	
RCD	DFRRDRE	Digital Fault Record Status	
RCD	GRTGGIO1	Group Record Trigger Channel	Group Record Trigger Inputs and Output
RCD	ANALOGRADR1 . . . ANALOGRADR36	Disturbance Recorder Channel Analog	Trigger Status of Analog Channels 1 to 8/12/18/36
RCD	SUMRADR37 . . . SUMRADR84	Disturbance Recorder Channel Analog	Trigger Status of Summation Channels 1 to 48
RCD	SEQRADR85 . . . SEQRADR108	Disturbance Recorder Channel Analog	Trigger Status of Sequence Channels 1 to 24
RCD	WVARRADR109 . . . WVARRADR126	Disturbance Recorder Channel Analog	Trigger Status of Watt/Var Channels 1 to 18

Table J.6: TESLA 4000-A Logical Nodes

LD Name	LN Name	LN Description	Comments
RCD	IMPRADR127 . . . IMPRADR144	Disturbance Recorder Channel Analog	Trigger Status of Impedance Channels 1 to 18
RCD	FREQRADR133 . . . FREQRADR144	Disturbance Recorder Channel Analog	Trigger Status of Frequency Channels 1 to 12
RCD	PFRADR145 . . . PFRADR162	Disturbance Recorder Channel Analog	Trigger Status of PF Detectors 1 to 18
RCD	LOGICRBDR1 . . . LOGICRBDR30	Disturbance Recorder Channel Binary	Trigger Status of Logic Channels 1 to 30
RCD	DIGRBDR31 . . . DIGRBDR94	Disturbance Recorder Channel Binary	Trigger Status of Digital (External Input) Channels 1 to 32/64
MEAS	ANLMAGMMXN1 . . . ANLMAGMMXN36	Non phase related measurement	Magnitude of Analog Channels 1 to 8/12/18/36
MEAS	SUMMAGMMXN37 . . . SUMMAGMMXN84	Non phase related measurement	Magnitude of Summation Channels 1 to 48
MEAS	WVARMMXN85 . . . WVARMMXN102	Non phase related measurement	Watt/Var Channels 1 to 18
MEAS	IMPMMXN103 . . . IMPMMXN120	Non phase related measurement	Impedance Channels 1 to 18
MEAS	FREQMMXN121 . . . FREQMMXN132	Non phase related measurement	Frequency Channels 1 to 12

Table J.6: TESLA 4000-A Logical Nodes

LD Name	LN Name	LN Description	Comments
MEAS	PFMMXN133 . . . PFMMXN150	Non phase related measurement	Power Factor Channels 1 to 18
MEAS	SEQMSQI1 . . . SEQMSQ24	Sequence and imbalance	Sequence Channels 1 to 24
MEAS	ANLANGGGIO1 . . . ANLANGGGIO36	Generic process I/O	Angle of Analog Channels 1 to 8/12/18/36
MEAS	SUMANGGGIO37 . . . SUMANGGGIO84	Generic process I/O	Angle of Summation Channels 1 to 48
SYS	OCGGIO1	Generic process I/O	Output contact status
SYS	TMSRCLTMS1		Time Source status
SYS	LGOS1 . . . LGOS32	GOOSE Subscription Supervision	One LGOS LN is included per GOOSE Control Block which is subscribed to. See “Subscription Supervision via LGOS” on page 19-4.
SYS	P401LCCH1, P402LCCH2, P410LCCH3, P411LCCH4, P412LCCH5, P413LCCH6	Physical communication channel supervision	Physical port communication status
FLTL	RFLO1 . . . RFLO10	Fault locator	Fault Locators 1 to 10
DVI	VIGGIO001 . . . VIGGIO256	Generic process I/O	Multi-purpose external GOOSE Virtual Inputs. Total of 256 GOOSE Virtual Inputs

Logical Node Specifications

The following tables provide information on each of the TESLA 4000-A logical nodes.

Note:

Common Logical Node information is not shown in the following Logical Node descriptions. Only the data provided from the TESLA 4000-A application to the IEC 61850 stack are described

Logical Device: RCD

DFRRDRE1			
Logical Node	**Description**	**Data Name**	**Comments**
DFRRDRE1	Recorder status information	ST$RcdMade$stVal ST$FltNum$stVal ST$RcdStr$stVal ST$MemUsed$stVal	Indicates Records stored on IED Number of Records stored on IED Indicates that Recording is in progress Indicates percentage of memory used

GRTGGIO1			
Logical Node	**Description**	**Data Name**	**Comments**
GRTGGIO1	Group Record Trigger Inputs and output	ST$IntIn1$stVal ..... ST$IntIn7$stVal ST$ISCSO1$stVal	GRT input 1 to 7, GRT output 1

ANALOGRADR1 … ANALOGRADR36			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
ANALOGRADR1 . . . ANALOGRADR36	Trigger status of analog channel 1 . . . Trigger status of analog channel 36	ST$ChTrg$stVal	

SUMRADR37 … SUMRADR84			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
SUMRADR37 . . . SUMRADR84	Trigger status of summation channel 1 . . . Trigger status of summation channel 48	ST$ChTrg$stVal	

SEQRADR85 … SEQRADR108			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
SEQRADR85 . . . SEQRADR108	Trigger status of sequence channel 1 . . . Trigger status of sequence channel 24	ST$ChTrg$stVal	

WVARRADR109 … WVARRADR126			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
WVARRADR109 . . . WVARRADR126	Trigger status of watt/var channel 1 . . . Trigger status of watt/var channel 18	ST$ChTrg$stVal	

IMPRADR127 … IMPRADR144			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
IMPRADR127 . . . IMPRADR144	Trigger status of impedance channel 1 . . . Trigger status of impedance channel 18	ST$ChTrg$stVal	

FREQRADR145 ... FREQRADR156			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
FREQRADR145 . . . FREQRADR156	Trigger status of frequency channel 1 . . . Trigger status of frequency channel 12	ST$ChTrg$stVal	

PFRADR157 … PFRADR174			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
PFRADR157 . . . PFRADR174	Trigger status of PF detector 1 . . . . Trigger status of PF detector 18	ST$ChTrg$stVal	

LOGICRBDR1 … LOGICRBDR30			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
LOGICRBDR1 . . . LOGICRBDR30	Trigger status of logic channel 1 . . . Trigger status of logic channel 30	ST$ChTrg$stVal	

DIGRBDR31 … DIGRBDR94			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
DIGRBDR31 . . . DIGRBDR94	Trigger status of External Input channel 1 . . . Trigger status of External Input channel 64	ST$ChTrg$stVal	

Logical Device MEAS

ANLMAGMMXN1 … ANLMAGMMXN36			
Logical Node	**Description**	**Data Attributes**	**Comments**
ANLMAGMMXN1 . . . ANLMAGMMXN36	Magnitude of analog channel 1 . . . Magnitude of analog channel 36	MXAmpmag MX$Volt$mag	Current input magnitude in A, Voltage input magnitude in V **Note:** Logical node will only use one of the two data attribute types, depending on channel configuration.

SUMMAGMMXN37 … SUMMAGMMXN84			
Logical Node	**Description**	**Data Attributes**	**Comments**
SUMMAGMMXN37 . . . SUMMAGMMXN84	Magnitude of summation channel 1 . . . Magnitude of summation channel 48	MXAmpmag MX$Volt$mag	Current input magnitude in A, Voltage input magnitude in V

WVARMMXN85 … WVARMMXN102			
Logical Node	**Description**	**Data Attributes**	**Comments**
WVARMMXN85 . . . WVARMMXN102	Watt/Var channel 1 . . . Watt/Var channel 18	MX$Watt$mag, MX$VolAmpr$mag MX$VolAmp$mag	Magnitude in W, Magnitude in VAR Magnitude in VA **Note:** Logical node will only use one of the three data attribute types, depending on channel configuration.

IMPMMXN103 … IMPMMXN120			
Logical Node	**Description**	**Data Attributes**	**Comments**
IMPMMXN103 . . . IMPMMXN120	Impedance channel 1 . . . Impedance channel 18	MXImpcVal$mag MX$Imp$cVal$ang	Impedance in polar form.

FREQMMXN121... FREQMMXN132			
Logical Node	**Description**	**Data Attribute**	**Comments**
FREQMMXN121 . . . FREQMMXN132	Frequency channel 1 . . . Frequency channel 12	MXHzmag	In Hz

PFMMXN133 … PFMMXN150			
Logical Node	**Description**	**Data Attribute**	**Comments**
PFMMXN133 . . . PFMMXN150	Power factor channel 1 . . . Power factor channel 18	MX$PwrFact$mag	0 < PF < 1

SEQMSQI1 … SEQMSQI24			
Logical Node	**Description**	**Data Attributes**	**Comments**
SEQMSQI1 . . . . SEQMSQI24	Sequence channel 1 . . . . Sequence channel 24	MX$SeqA$c1$cVal$mag MX$SeqA$c1$cVal$ang MX$SeqA$c2$cVal$mag MX$SeqA$c2$cVal$ang MX$SeqA$c3$cVal$mag MX$SeqA$c3$cVal$ang MX$SeqV$c1$cVal$mag MX$SeqV$c1$cVal$ang MX$SeqV$c2$cVal$mag MX$SeqV$c2$cVal$ang MX$SeqV$c3$cVal$mag MX$SeqV$c3$cVal$ang	Current positive sequence magnitude Current positive sequence angle Current negative sequence magnitude Current negative sequence angle Current zero sequence magnitude Current zero sequence angle Voltage positive sequence magnitude Voltage positive sequence angle Voltage negative sequence magnitude Voltage negative sequence angle Voltage zero sequence magnitude Voltage zero sequence angle

ANLANGGGIO1 … ANLANGGGIO36			
Logical Node	**Description**	**Data Attribute**	**Comments**
ANLANGGGIO1 . . . ANLANGGGIO36	Angle of analog channel 1 . . . Angle of analog channel 36	MX$AnIn1$mag	In degrees

SUMANGGGIO37 … SUMANGGGIO84			
Logical Node	**Description**	**Data Attribute**	**Comments**
SUMANGGGIO37 . . . SUMANGGGIO84	Angle of summation channel 1 . . . Angle of summation channel 48	MX$AnIn1$mag	In degrees

Logical Device: SYS

OCGGIO1			
Logical Node	**Description**	**Data Attributes**	**Comments**
OCGGIO1	Output Contacts	ST$Ind1$stVal . . . ST$Ind8$stVal	Output contact 1 . . . Output contact 8

TMSRCLTMS1			
Logical Node	**Description**	**Data Attribute**	**Comments**
TMSRCLTMS1	Time Source Status	ST$TmSrc$stVal ST$TmSyn$stVal	Time source type (RTC, IRIG, PTP, SNTP) Synchronization status

LGOS1...LGOS32			
Logical Nodes	**Description**	**Data Attributes**	**Comments**
LGOS1 . . . LGOS32	GOOSE Subscription Supervision	ST$NdsCom$stVal STStstVal ST$SimSt$stVal ST$LastStNum$stVal ST$ConfRevNum$stVal SP$GoCBRef$setSrcRef	Subscription needs commissioning Status of the subscription Status showing if simulated GOOSE are accepted Last state number received Expected configuration revision number Reference to the subscribed GOOSE control block **Note:** One LGOS LN is included per GOOSE Control Block which is subscribed to. See "Subscription Supervision via LGOS" on page 19-4

P401LCCH1... P413LCCH6			
Logical Node	**Description**	**Data Attributes**	**Comments**
P401LCCH1	Port 401 communication status	ST$ChLiv$stVal	Response Time: True to false (up to 61 seconds); Fault to True (up to 3 seconds).
P402LCCH2	Port 402 communication status	ST$ChLiv$stVal	Response Time: True to false (up to 61 seconds); Fault to True (up to 3 seconds).

P410LCCH3	Port 410 communication status/PRP redundancy port 412 communication status	ST$ChLiv$stVal / ST$RedChLiv$stVal	Response Time: True to false (up to 130 seconds); Fault to True (up to 60 seconds).
P411LCCH4	Port 411 communication status	ST$ChLiv$stVal	Response Time: True to false (up to 130 seconds); Fault to True (up to 60 seconds).
P412LCCH5	RSTP redundancy port 412 communication status	ST$ChLiv$stVal	Response Time: True to false (up to 130 seconds); Fault to True (up to 60 seconds).

Logical Device: FLTL

FLTLOCRFLO1...FLTLOCRFLO10			
Logical Nodes	**Description**	**Data Attribute**	**Comments**
RFLO1 . . . RFLO10	Fault locator 1 . . . Fault locator 10	MX$FltZ$cVal$mag MX$FltZ$cVal$ang MX$FltDiskm	Fault impedance magnitude Fault impedance angle Fault location

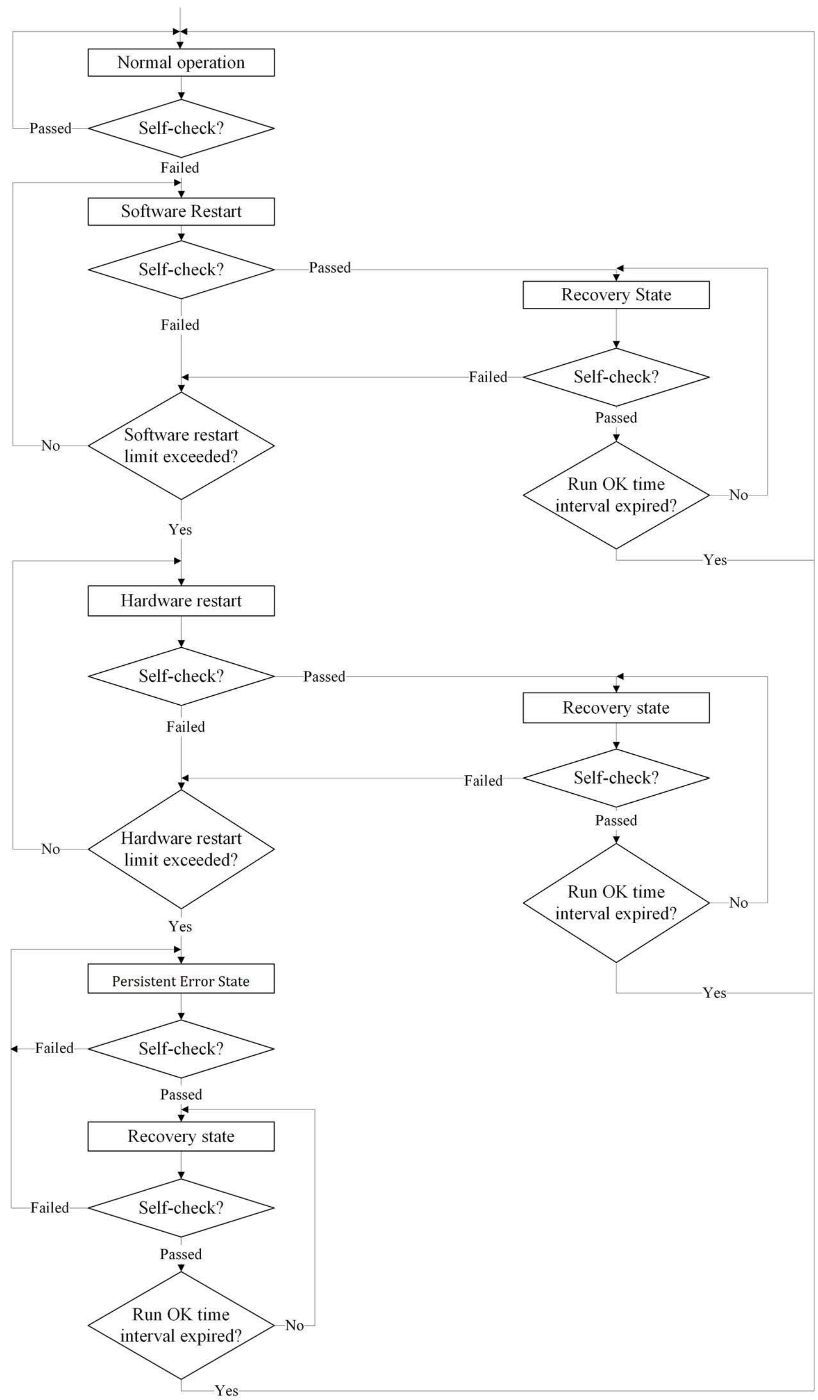
Logical Device: DVI

VIGGIO001...VIGGIO256			
Logical Nodes	**Description**	**Data Attributes**	**Comments**
VIGGIO001 . . . VIGGIO256	Multi-purpose external GOOSE Virtual Inputs for high/low speed recording triggers, Logic inputs and Digital recording channels	ST$Ind1$stVal	

Appendix K TESLA Self-Check and Recovery

The purpose of this Appendix is to provide a detailed description of the TESLA Self-Check and Recovery process.

Self-check and Recovery Flowchart



Self-Check and Recovery Description

When the supervisory software detects an issue for a first time, it makes an attempt to correct the issue through a software restart. The software restart takes place quickly and does not activate any external indications. If the issue persists after the first software restart, the supervisory software initiates two more software restarts in attempt to correct the issue.

If the issue persists after three software restarts, the supervisory software initiates a hardware reset in an attempt to correct the issue. A hardware reset takes approximately a minute and a half to complete. Refer to the Table 16.1:Recorder States and State Indicators for the hardware reset indications and guidance on maintenance actions to take.

If the problem is not cleared after four consecutive hardware resets initiated by the supervisory software, the unit enters the Persistent Error state. In this state, the recorder activates its Persistent Error state indication and stops initiating hardware resets to avoid interfering with issue investigation. Refer to the Table 16.1:Recorder States and State Indicators for the Persistent Error state indication and guidance on maintenance actions to take.

If the Supervisory software subsequently determines that the problem has been cleared, it automatically returns the unit to its normal operating state and clears the failure indication.

If the supervisory software is not able to function properly, the hardware watchdog initiates unit reboot. If the supervisory software issue is not corrected after the first watchdog initiated reboot, the watchdog initiates four more unit reboots and then activates Persistent Error state indication. Refer to the Table 16.1:Recorder States and State Indicators for the Persistent Error state indications and guidance on maintenance actions to take.

Appendix L IEEE 1686-2013 Table of Compliance

Clause Number	Clause/Subclause Title	Status	Comment
5	IED cyber security features	Acknowledge	
5.1	Electronic access control	Acknowledge	
5.1.2	Password defeat mechanisms	Comply	
5.1.3	Number of individual users	Exceed	Number of individual users is 32
5.1.4	Password construction	Comply	
5.1.5	IED access control	Acknowledge	
5.1.5.1	Authorization levels by password	Comply	
5.1.5.2	Authorization using role-based access control (RBAC)	Exception	IED doesn't allow for user-defined roles. IED complies with IEC 62351-8 RBAC model. 6 pre-defined and 4 default roles are supported. See User Manual for details.
5.1.6	IED main security functions	Comply	
5.1.6 a)	View data	Comply	
5.1.6 b)	View configuration settings	Comply	
5.1.6 c)	Force values	Comply	
5.1.6 d)	Configuration change	Comply	
5.1.6 e)	Firmware change	Comply	
5.1.6 f)	ID/password or RBAC management	Comply	User-defined roles are not supported.
5.1.6 g)	Audit trail	Comply	
5.1.7	Password display	Comply	
5.1.8	Access timeout	Exceed	Inactivity timeout range is between 1min to 120min.
5.2	Audit trail	Acknowledge	
5.2.2	Storage capability	Comply	
5.2.3	Storage record	Comply	
5.2.3 a)	Event record number	Comply	
5.2.3 b)	Time and date	Comply	
5.2.3 c)	User identification	Comply	

Clause Number	Clause/Subclause Title	Status	Comment
5.2.3 d)	Event type	Comply	
5.2.4	Audit trail	Exception	
5.2.4 a)	Log in	Comply	
5.2.4 b)	Manual log out	Comply	
5.2.4 c)	Timed log out	Comply	
5.2.4 d)	Value forcing	Comply	
5.2.4 e)	Configuration access	Comply	
5.2.4 f)	Configuration change	Comply	
5.2.4 g)	Firmware change	Comply	
5.2.4 h)	ID/password creation or modification	Comply	
5.2.4 i)	Password deletion	Comply	
5.2.4 j)	Audit log access	Comply	
5.2.4 k)	Time/date change	Exception	Time/date changes are not captured in audit trail
5.2.4 l)	Alarm incident	Comply	
5.3	Supervisory monitoring and control	Acknowledge	
5.3.2	Events	Comply	
5.3.3	Alarms	Exception	
5.3.3 a)	Unsuccessful login attempt	Comply	
5.3.3 b)	Reboot	Comply	
5.3.3 d)	Attempted use of unauthor-ized configuration software	Comply	
5.3.3 d)	Invalid configuration or firm-ware download	Comply	
5.3.3 e)	Unauthorized configuration or firmware file	Comply	
5.3.3 f)	Time signal out of tolerance	Exception	Out of tolerance time signal alarms are not captured in audit trail
5.3.3 g)	Invalid field hardware changes	Comply	Feature not offered in this product
5.3.4	Alarm point change detect	Comply	
5.3.5	Event and alarm grouping	Comply	Supervisory system upon the occurrence of events and alarms is not supported

Clause Number	Clause/Subclause Title	Status	Comment
5.3.6	Supervisory permissive control	Exception	Feature is implemented for Remote Firmware Update only
5.4	IED cyber security features	Acknowledge	
5.4.1	IED functionality compromise	Comply	Ports and services are listed in User Manual
5.4.2	Specific cryptographic features	Exception	
5.4.2 a)	Web-server functionality	Comply	Feature not offered in this product
5.4.2 b)	File transfer functionality	Exception	FTP protocol is used for file transfer
5.4.2 c)	Text-oriented terminal connections	Comply	Feature not offered in this product
5.4.2 d)	SNMP network management	Comply	Feature not offered in this product
5.4.2 e)	Network time synchronization	Exception	SNTP protocol is used
5.4.2 f)	Secure tunnel functionality	Comply	Feature not offered in this product
5.4.3	Cryptographic techniques	Comply	Implemented cryptographic techniques are based on NIST Computer Security Division recommendations.
5.4.4	Encrypting serial communications	Exception	Data encryption for remote serial communication is not supported
5.4.5	Protocol-specific security features	Comply	
5.5	IED configuration software	Acknowledge	
5.5.1	Authentication	Exception	Feature is not supported
5.5.2	Digital signature	Comply	Digital signatures are used in the configuration and firmware download files
5.5.3	ID/password control	Exception	Feature is not supported
5.5.4	ID/password controlled features	Exception	
5.5.4.1	View configuration data	Exception	Feature is not supported
5.5.4.2	Change configuration data	Exception	Feature is not supported
5.5.4.2 a)	Full access	Exception	Feature is not supported
5.5.4.2 b)	Change tracking	Exception	Feature is not supported
5.5.4.2 c)	Use monitoring	Exception	Feature is not supported
5.5.4.2 d)	Download to IED	Exception	Feature is not supported

Clause Number	Clause/Subclause Title	Status	Comment
5.6	Communications port access	Exception	Not all ports and services can be disabled
5.7	Firmware quality control	Comply	

Appendix M Credential Character List

Table M.1: Alphabetic Characters

Character	ASCII Decimal	Description	Character	ASCII Decimal	Description
A	65	Uppercase A	a	97	Lowercase a
B	66	Uppercase B	b	98	Lowercase b
C	67	Uppercase C	c	99	Lowercase c
D	68	Uppercase D	d	100	Lowercase d
E	69	Uppercase E	e	101	Lowercase e
F	70	Uppercase F	f	102	Lowercase f
G	71	Uppercase G	g	103	Lowercase g
H	72	Uppercase H	h	104	Lowercase h
I	73	Uppercase I	i	105	Lowercase i
J	74	Uppercase J	j	106	Lowercase j
K	75	Uppercase K	k	107	Lowercase k
L	76	Uppercase L	l	108	Lowercase l
M	77	Uppercase M	m	109	Lowercase m
N	78	Uppercase N	n	110	Lowercase n
O	79	Uppercase O	o	111	Lowercase o
P	80	Uppercase P	p	112	Lowercase p
Q	81	Uppercase Q	q	113	Lowercase q
R	82	Uppercase R	r	114	Lowercase r
S	83	Uppercase S	s	115	Lowercase s
T	84	Uppercase T	t	116	Lowercase t
U	85	Uppercase U	u	117	Lowercase u
V	86	Uppercase V	v	118	Lowercase v
W	87	Uppercase W	w	119	Lowercase w
X	88	Uppercase X	x	120	Lowercase x
Y	89	Uppercase Y	y	121	Lowercase y
Z	90	Uppercase Z	z	122	Lowercase z

Table M.2: Numeric Characters

Character	ASCII Decimal	Description
0	48	Zero
1	49	One
2	50	Two
3	51	Three
4	52	Four
5	53	Five
6	54	Six
7	55	Seven
8	56	Eight
9	57	Nine

Table M.3: Special Characters

Character	ASCII Decimal	Description
!	33	Exclamation mark
“	34	Quotation mark
#	35	Number sign
$	36	Dollar sign
&	38	Ampersand
‘	39	Apostrophe
(	40	Left parenthesis
)	41	Right parenthesis
*	42	Asterisk
+	43	Plus sign
,	44	Comma
-	45	Hyphen-minus
.	46	Full stop
/	47	Slash (Solidus)
:	58	Colon
;	59	Semicolon
<	60	Left-than sign

<table>
<tr><th colspan="3">Table M.3: Special Characters</th></tr>
<tr><td>=</td><td>61</td><td>Equal sign</td></tr>
<tr><td>></td><td>62</td><td>Greater-than sign</td></tr>
<tr><td>?</td><td>63</td><td>Question mark</td></tr>
<tr><td>@</td><td>64</td><td>At sign</td></tr>
<tr><td>[</td><td>91</td><td>Left Square Bracket</td></tr>
<tr><td>]</td><td>93</td><td>Right Square Bracket</td></tr>
<tr><td>^</td><td>94</td><td>Circumflex accent</td></tr>
<tr><td>_</td><td>95</td><td>Underscore</td></tr>
<tr><td>|</td><td>124</td><td>Vertical bar</td></tr>
<tr><td>{</td><td>123</td><td>Left Curly Bracket</td></tr>
<tr><td>}</td><td>125</td><td>Right Curly Bracket</td></tr>
<tr><td>~</td><td>126</td><td>Tilde</td></tr>
</table>

Appendix N Declaration of Conformity

DECLARATION OF CONFORMITY

We,

ERLPhase Power Technologies Ltd.
74 Scurfield Blvd.
Winnipeg, Manitoba, Canada
R3Y 1G4
Ph: 204-477-0591
Fax: 204-478-1697

declare under our sole responsibility that the product

TESLA 4000 Power System Recorder

is in conformity with the applicable requirements of the following documents

2014/35/EU **SI 2016/1101**	**Low Voltage Directive** IEC 60255-27:2013 Measuring relays and protection equipment - Part 27: Product safety requirements
2014/30/EU **SI 2016/1091**	**Electromagnetic Compatibility Directive** **EMC Regulations 2016** IEC 60255-26:2013 Measuring relays and protection equipment - Part 26: Electromagnetic compatibility requirements
2015/863/EU **SI 2012/3032**	**Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive** BS EN IEC 63000:2018

I hereby declare that the equipment named above has been designed to comply with the relevant sections of the above referenced specifications. The unit complies with all applicable essential requirements of the directives.

Signed by:

Name: Andy Perreault
Position: Research and Development Manager
Signed at: Winnipeg, Manitoba, Canada
Date: March 4, 2024

ERLPhase Document Number: D04050R03.00

Index