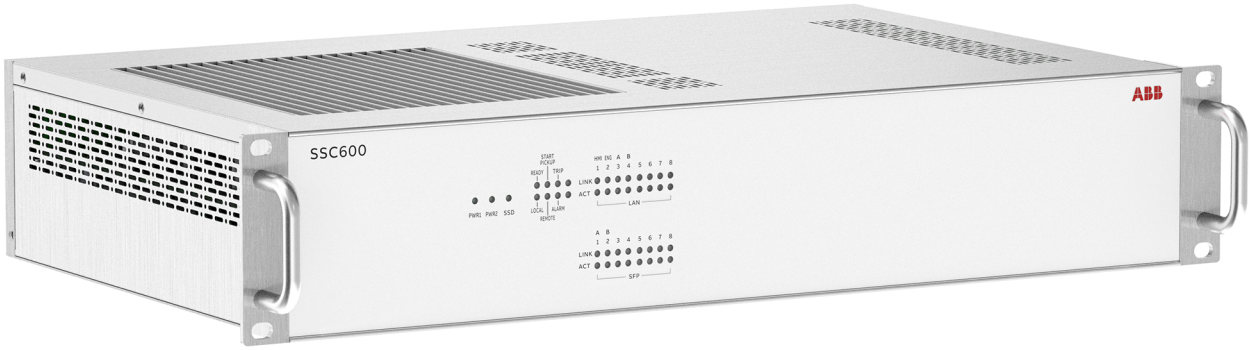
ABB ABILITY™ SMART SUBSTATION CONTROL AND PROTECTION FOR ELECTRICAL SYSTEMS

SSC600 and SSC600 SW

Engineering Manual



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This product complies with following directive and regulations.

Directives of the European parliament and of the council:

- Electromagnetic compatibility (EMC) Directive 2014/30/EU
- Low-voltage Directive 2014/35/EU
- RoHS Directive 2011/65/EU

UK legislations:

- Electromagnetic Compatibility Regulations 2016
- Electrical Equipment (Safety) Regulations 2016
- The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

These conformities are the result of tests conducted by the third-party testing in accordance with the product standard EN / BS EN 60255-26 for the EMC directive / regulation, and with the product standards EN / BS EN 60255-1 and EN / BS EN 60255-27 for the low voltage directive / safety regulation.

The product is designed in accordance with the international standards of the IEC 60255 series.

Contents

1 Safety information

Dangerous voltages can occur on the connectors, even though the auxiliary voltage has been disconnected.

Non-observance can result in death, personal injury or substantial property damage.

Only a competent electrician is allowed to carry out the electrical installation.

National and local electrical safety regulations must always be followed.

The frame of the device has to be carefully earthed.

The device contains components which are sensitive to electrostatic discharge. Unnecessary touching of electronic components must therefore be avoided.

Whenever changes are made in the device, measures should be taken to avoid inadvertent tripping.

2 Introduction

ABB Ability™ Smart Substation Control and Protection for electrical systems SSC600 is a Smart Substation device designed for protection, control, measurement and supervision of utility substations and industrial switchgear and equipment. The design of the device has been guided by the IEC 61850 standard for communication and interoperability of substation automation devices. It is fully integrable with Relion series IEDs for creating a complete solution. Optional functionality is available at the time of order for both software and hardware, for example, special application packages and additional communication modules.

Figure 1: SSC600

2.1 This manual

The engineering manual contains instructions on how to engineer the device using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert device to the project structure. The manual also recommends a sequence for engineering of protection and control functions, WHMI functions as well as communication engineering for IEC 61850 and other supported protocols.

2.2 Intended audience

This manual addresses system and project engineers involved in the engineering process of a project, and installation and commissioning personnel, who use technical data during engineering, installation and commissioning, and in normal service

The system engineer must have a thorough knowledge of the application, protection and control equipment and the configured functional logic in the device. The installation and commissioning personnel must have a basic knowledge of handling electronic equipment.

2.3 Product documentation

2.3.1 Product documentation set

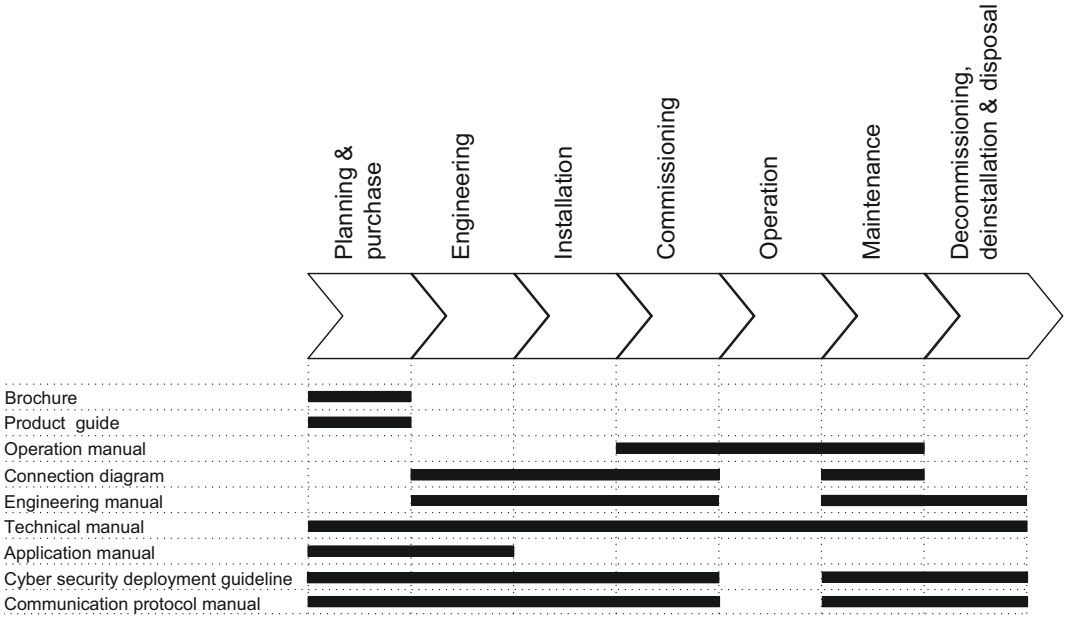


Figure 2: The intended use of documents during the product life cycle

Product series- and product-specific manuals can be downloaded from the ABB Web site.

2.3.2 Document revision history

Document revision/date	Product series version	History
A/2019-05-13	1.0	First release
B/2020-03-23	1.0 FP1	Content updated
C/2021-11-26	1.0 FP3	Content updated
D/2022-02-14	1.0 FP3	Content updated
E/2022-12-01	1.0 FP4	Content updated
F/2022-12-14	1.0 FP4	Content updated
G/2023-04-17	1.0 FP4	Content updated
H/2024-12-13	1.5	Content updated

Download the latest documents from the ABB Web site *go.abb/digitalsubstations*.

2.3.3 Related documentation

Product series- and product-specific manuals can be downloaded from the ABB Web site *go.abb/digitalsubstations*.

2.4 Symbols and conventions

2.4.1 Symbols

The warning icon indicates the presence of a hazard which could result in electrical shock or other personal injury.

The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.

The information icon alerts the reader of important facts and conditions.

The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

Although the warning hazards are related to personal injury, it is necessary to understand that under certain operational conditions, operation of damaged equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

2.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Menu paths are presented in bold.

  Select **Main menu/Settings**.
- Parameter names are shown in italics.

  The function can be enabled and disabled with the *Operation* setting
- Parameter values are indicated with quotation marks.

  The corresponding parameter values are "On" and "Off".
- Input/output messages and monitored data names are shown in Courier font.

  When the function starts, the START output is set to TRUE.
- This document assumes that the parameter setting visibility is "Advanced".

2.4.3 Functions, codes and symbols

All available functions included in the IED are listed in the tables below. Available functions depend on the chosen product options.

Table 1: Protection functions

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	3I>	51P-1	LD0	PHLPTOC
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	3I>>	51P-2	LD0	PHHPTOC
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	3I>>>	50P	LD0	PHIPTOC
Three-phase directional overcurrent protection, low stage	DPHLPDOC	3I> ->	67P/51P-1	LD0	DPHLPTOC DPHLRDIR
Three-phase directional overcurrent protection, high stage	DPHHPDOC	3I>> ->	67P/51P-2	LD0	DPHHPTOC DPHHRDIR
Non-directional earth-fault protection, low stage	EFLPTOC	Io>	51G/51N-1	LD0	EFLPTOC
Non-directional earth-fault protection, high stage	EFHPTOC	Io>>	51G/51N-2	LD0	EFHPTOC
Non-directional earth-fault protection, instantaneous stage	EFIPTOC	Io>>>	50G/50N	LD0	EFIPTOC
Directional earth-fault protection, low stage	DEFLPDEF	Io> ->	67G/N-1 51G/N-1	LD0	DEFLPTOC DEFLRDIR
Directional earth-fault protection, high stage	DEFHPDEF	Io>> ->	67G/N-1 51G/N-2	LD0	DEFHPTOC DEFHRDIR
Admittance-based earth-fault protection	EFPADM	Yo> ->	21YN	LD0	EFPADM
Wattmetric-based earth-fault protection	WPWDE	Po> ->	32N	LD0	WRDIR WPSDE WMMXU
Transient/intermittent earth-fault protection	INTRPTEF	Io> -> IEF	67NTEF/NIEF	LD0	INTRPTEF
Negative-sequence overcurrent protection	NSPTOC	I2>	46M	LD0	NSPTOC
Phase discontinuity protection	PDNSPTOC	I2/I1>	46PD	LD0	PDNSPTOC
Residual overvoltage protection	ROVPTOV	Uo>	59G/59N	LD0	ROVPTOV
Three-phase undervoltage protection	PHPTUV	3U<	27	LD0	PHPTUV
Three-phase overvoltage protection	PHPTOV	3U>	59	LD0	PHPTOV
Positive-sequence undervoltage protection	PSPTUV	U1<	27PS	LD0	PSPTUV
Negative-sequence overvoltage protection	NSPTOV	U2>	59NS	LD0	NSPTOV
Frequency protection	FRPFRQ	f>/f<,df/dt	81	LD0	FRPTRC FRPTOF FRPTUF FRPFRC

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
Distance protection	DSTPDIS	Z<	21P, 21N	LD0	GFCPDIS GFCRDIR DST1PDIS DST2PDIS DST3PDIS DST4PDIS DST5PDIS DSTRDIR GFC1RFRC GFC2RFRC GFC3RFRC
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	3Ith>F	49F	LD0	T1PTTR
Three-phase thermal overload protection, two time constants	T2PTTR	3Ith>T/G/C	49T/G/C	LD0	T2PTTR
Negative-sequence overcurrent protection for ma- chines	MNSPTOC	I2>M	46M	LD0	MNSPTOC
Loss of load supervision	LOFLPTUC	3I<	37	LD0	LOFLPTUC
Motor load jam protection	JAMPTOC	Ist>	50TDJAM	LD0	JAMPTOC
Motor start-up supervision	STTPMSU	Is2t n<	49,66,48,50TDLR	LD0	STTPMSS STTPMRI
Phase reversal protection	PREVPTOC	I2>>	46R	LD0	PREVPTOC
Thermal overload protection for motors	MPTTR	3Ith>M	49M	LD0	MPTTR
Stabilized and instantaneous differential protection for two-winding transformers	TR2PTDF	3dI>T	87T	LD0	TR2PTRC TR2LPDIF TR2H2PHAR TR2H5PHAR TR2HPDIF
Numerically stabilized low-impedance restricted earth-fault protection	LREFPNDF	dIoLo>	87NLI	LD0	LREFPDIF LREFPHAR
Circuit breaker failure protection	CCBRBRF	3I>/Io>BF	50BF	LD0	CCBRBRF
Three-phase inrush detector	INRPHAR	3I2f>	68HB	LD0	INRPHAR
Switch onto fault	CBPSOF	SOTF	SOTF	LD0	CBPSOF
Master trip	TRPPTRC	Master Trip	94/86	LD0	TRPPTRC
Arc protection	ARCSARC	ARC	AFD	LD0	ARCSARC ARC1PIOC ARC2PIOC ARCPTRC
Multipurpose protection	MAPGAPC	MAP	MAP	LD0	MAPGAPC
Load-shedding and restoration	LSHDPFRQ	UFLS/R	81LSH	LD0	LSHDPTRC LSHDPTOF LSHDPTUF LSHDPFRC
Fault locator	SCEFRFLO	FLOC	FLOC	LD0	SCEFRFLO SCEFZLIN SCEF2ZLIN SCEF3ZLIN

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
					FLORFRC
Reverse power/directional overpower protection	DOPPDPR	P>/Q>	32R/32O	LD0	DPPDOP DOPMMXU
Three-phase underimpedance protection	UZPDIS	Z>G	21G	LD0	UZPDIS UZMMXU
Multifrequency admittance-based earth-fault protection	MFADPSDE	Io> ->Y	67NYH	LD0	MFADPSDE MFADRDIR
Busbar differential protection	BBPBDF	3Id/I	87BL	LD0	BBPTRC ZNAPDIF ZNBPDIF ZNCZPDIF SFAPDIF SFBPDIF BBCCSPVC
Busbar zone selection	ZNRSRC	ZNRSRC	ZNRSRC	LD0	ZNRSRC
Load blinder	LBRDOB	LB	21LB	LD0	LBRDOB LBMMXU
Three-phase overload protection for shunt capacitor banks	COLPTOC	3I> 3I<	51,37,86C	LD0	COL1PTOC COLPTUC COL2PTOC
Current unbalance protection for shunt capacitor banks	CUBPTOC	dI>C	60N	LD0	CUB1PTOC CUB2PTOC
Three-phase current unbalance protection for shunt capacitor banks	HCUBPTOC	3dI>C	60P	LD0	HCUB1PTOC HCUB2PTOC
Shunt capacitor bank switching resonance protection,current based	SRCPTOC	TD>	55ITHD	LD0	SRC1PTOC SRC2PTOC
Anomaly detector	ANOGAPC	ANOGAPC	ANOGAPC	LD0	ANOGAPC

Table 2: Interconnection functions

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
Directional reactive power undervoltage protection	DQPTUV	Q> ->,3U<	32Q,27	LD0	DQPTUV DQPDOP DQMMXU
Low-voltage ride-through protection	LVRTPTUV	U<RT	27RT	LD0	LVRTPTUV

Table 3: Power quality functions

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
Current total demand distortion	CMHAI	PQM3I	PQM3I	CMHAI	CMHAI
Voltage total harmonic distortion	VMHAI	PQM3U	PQM3V	VMHAI	VMHAIVMHAI
Voltage variation	PHQVVR	PQMU	PQMV	PHQVVR PH2QVVR	PHQVVR PH2QVVR

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
				PH3QVVR QVVRQRC QVV2RQRC QVV3RQRC	PH3QVVR QVVMSTA QVV2MSTA QVV3MSTA
Voltage unbalance	VSQVUB	PQUUB	PQVUB	-	-

Table 4: Control functions

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
Circuit-breaker control	CBXCBR	I <-> O CB	I <-> O CB	CTRL	CBCSWI CBCILO CBXCBR
Disconnector control	DCXSWI	I <-> O DCC	I <-> O DCC	CTRL	DCCSWI DCCILO DCXSWI
Earthing switch control	ESXSWI	I <-> O ESC	I <-> O ESC	CTRL	ESCSWI ESCILO ESXSWI
Disconnector position indication	DCSXSWI	I <-> O DC	I <-> O DC	CTRL	DCSXSWI
Earthing switch indication	ESSXSWI	I <-> O ES	I <-> O ES	CTRL	ESSXSWI
Emergency start-up	ESMGAPC	ESTART	ESTART	LD0	ESMGAPC
Autoreclosing	DARREC	O -> I	79	LD0	DARREC
Tap changer position indication	TPOSYLTC	TPOSM	84M	LD0	TPOSYLTC
Tap changer control with voltage regulator	OLATCC	COLTC	90V	LD0	OLATCC
Synchronism and energizing check	SECRSYN	SYNC	25	LD0	SECRSYN

Table 5: Condition monitoring and supervision functions

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
Circuit-breaker condition monitoring	SSCBR	CBCM	CBCM	LD0	SSCBR1 SPH1SCBR SPH2SCBR SPH3SCBR SSOPM SSIMG
Runtime counter for machines and devices	MDSOPT	OPTS	OPTM	LD0	MDSOPT
Fuse failure supervision	SEQSPVC	FUSEF	VCM, 60	LD0	SEQSPVC

Table 6: Measurement functions

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
Disturbance recorder	RDRE	DR	DFR	LD0	DR_LLN0 DR_LPHD

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
					RDRE RBDR
Fault record	FLTRFRC	FAULTREC	FAULTREC	LD0	FLTRFRC
Three-phase current measurement	CMMXU	3I	3I	LD0	CMMXU CAVMMXU CMAMMXU CMIMMXU
Sequence current measurement	CSMSQI	I1, I2, I0	I1, I2, I0	LD0	CSMSQI
Residual current measurement	RESCMMXU	Io	In	LD0	RESCMMXU RCAVMMXU RCMAMMXU RCMIMMXU
Three-phase voltage measurement	VMMXU	3U	3V	LD0	VMMXU VAVMMXU
Residual voltage measurement	RESVMMXU	Uo	Vn	LD0	RESVMMXU RVAVMMXU RVMAMMXU RVMIMMXU
Sequence voltage measurement	VSMSQI	U1, U2, U0	V1, V2, V0	LD0	VSMSQI
Three-phase power and energy measurement	PEMMXU	P, E	P, E	LD0	PEMMXU PEMMTR PEAVMMXU PEMAMMXU PEMIMMXU
Frequency measurement	FMMXU	f	f	LD0	FMMXU

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
IEC 61850-9-2 LE sampled value receiving	SVRECEIVE_LE	SVRECEIVE_LE	SVRECEIVE_LE	SMVRECEIVEMU01 – SMVRECEIVEMU30	I10ATCTR37 I10BTCTR38 I10CTCTR39 I10NTCTR40 U10ATVTR37 U10BTVTR38 U10BTVTR39 U10NTVTR40
IEC 61869-9 sampled value receiving	SVRECEIVE_61869	SVRECEIVE_61869	SVRECEIVE_61869	SV61869RECEIVEMU01 – SV61869RECEIVEMU30	I01ATCTR1–I10ATCTR37 I01BTCTR2–I10BTCTR38 I01CTCTR3–I10CTCTR39 I01NTCTR4–I10NTCTR40 U01ATVTR1-U10ATVTR37 U01BTVTR2-U10BTVTR38 U01CTVTR3-U10CTVTR39 U01NTVTR4-U10NTVTR40

Table 7: Other functions

Function	IEC 61850	IEC 60617	ANSI	Logical device	Logical nodes
Minimum pulse timer	TPGAPC	TP	TP		TPGAPC
Minimum pulse timer (second resolution)	TPSGAPC	TPS	TPS		TPSGAPC
Minimum pulse timer minute resolution)	TPMGAPC	TPM	TPM		TPMGAPC
Pulse timer	PTGAPC	PT	PT		PTGAPC
Time delay off	TOFGAPC	TOF	TOF		TOFGAPC
Time delay on	TONGAPC	TON	TON		TONGAPC
Set-reset	SRGAPC	SR	SR		SRGAPC
Move	MVGAPC	MV	MV		MVGAPC
Generic control point	SPCGAPC	SPC	SPC		SPCGAPC
Analog value scaling	SCA4GAPC	SCA4	SCA4		SCA4GAPC
Integer value move	MVI4GAPC	MVI4	MVI4		MVI4GAPC
Voltage switch	VMSWI	VSWI	VSWI		VMSWI
Current switch	CMSWI	CMSWI	CMSWI		CMSWI
Current sum	CMSUM	CSUM	CSUM		SIL1TCTR SIL2TCTR SIL3TCTR SRESTCTR

3 IED system engineering process

PCM600 is used for various tasks in the protection IED system engineering process.

- IED engineering management
  - Organizing the bay protection IEDs and Smart Substation IEDs in the structure of the substation by defining voltage levels and bays below the substation. PCM600 manages the project.
  - Configuring the protection and control functions by using the Application Configuration tool.
  - Configuring the parameters and setting values for the IED itself and for the process functions by using the Parameter Setting tool.
  - Drawing single-line diagrams and making links to dynamic process values by using Graphical Display Editor. The single-line diagrams are displayed in the WHMI of SSC600.
  - Configuring connections between the application configuration function blocks and physical hardware inputs and outputs by using the Signal Matrix tool or the Application Configuration tool.
- Communication management
  - IEC 61850 station communication engineering is done using the internal IEC 61850 Configuration tool or any IEC 61850 system engineering tool. PCM600 interacts with external system engineering tools by importing and exporting SCL files.
  - Configuring the GOOSE receiving data connections to the IED application configuration function blocks by using the Application Configuration tool and the Signal Matrix tool.
  - Configuring the sampled values (process bus) between the devices using the Application Configuration tool and IEC 61850 Configuration tool.
- Record management
  - Generating overviews on the available (disturbance) recordings in all connected IEDs by using the Disturbance Handling tool.
  - Manually reading the recording files (in the COMTRADE format) from the IED system by using the Disturbance Handling tool or automatically by using the PCM600 Scheduler.
  - Managing recording files with the Disturbance Handling tool.
  - Creating recording file content overview reports for fast evaluation with assistance of the Disturbance Handling tool.
  - Using the Fault Record tool to read fault records from the IED, save records to a PC and clear old records.
- Service management
  - Monitoring the selected signals of a IED for commissioning or service purposes by using the Signal Monitoring tool and Event Viewer tool (including audit trail).

There are also additional functions for managing projects and organizing user rights.

- PCM600 user management

- Organizing users regarding their rights, profiles and passwords to use different tools and functions in the tools.
- Defining allowed activities for user profiles to use tools in PCM600.

Once the engineering of the IED is finished, the results must be written to the IED.

The connection between the physical IED and PCM600 is established via an Ethernet link on the local / remote or rear port on the IED.

3.1 Monitoring and control system structure

The monitoring and control system for electrical substations contains a number of IEDs for various purposes.

The maximum size of a project is 180 IEDs. However, in order to maintain good performance and usability of the tool, it is recommended to divide one big project into multiple smaller PCM600 projects.

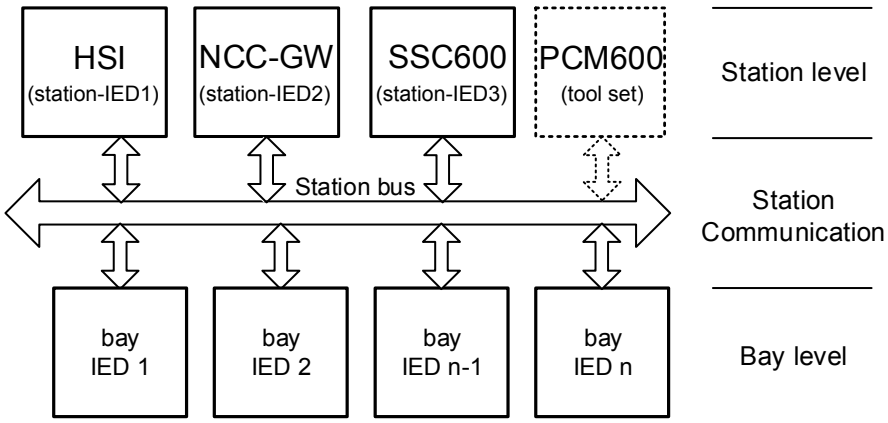


Figure 3: Principle structure of a monitoring and control system for a substation

The monitoring and control system can be divided into three main parts.

- Bay level IEDs
- Station communication
- Station level IEDs

All three parts require specific engineering and configuration.

A plant structure is used to identify each IED in its location within the substation organization. The plant structure is a logical image of the substation and the bays within the substation. The organization structure for the IEDs may differ from the structure of the primary equipment in the substation.

In PCM600 it is possible to set up a hierarchical structure of five levels for the IED identification.

- Project
- Substation = name of the substation
- Voltage level = identifies to which grid type or part the IED belongs in the substation
- Bay = bay within the voltage level

- IED = the selection of the IED that is used in the bay; it is possible to insert several IEDs within a bay, for example, one control IED and two protection IEDs

Normally SSC600 should be inserted to station level, as an station level device.

3.2 Workflow

Workflow for station level device SSC600 is similar to conventional bay level IEDs.

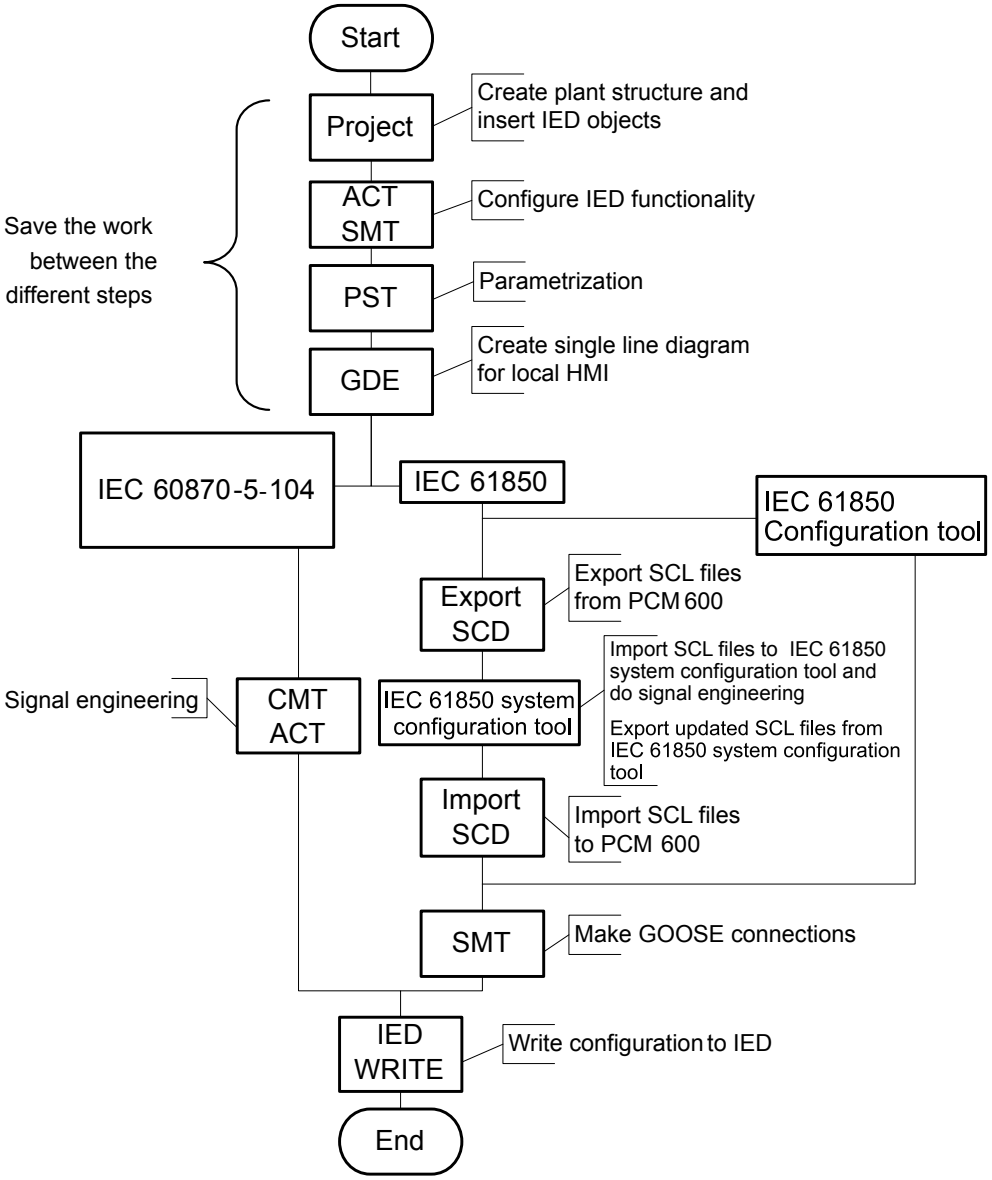


Figure 4: IED engineering workflow proposal based on practical experience and dependencies of the steps

It is possible to follow a different sequence based on the information available at the time when the project is started. This means that several iterations may be needed to complete the project.

Setting up a PCM600 project

- The plant structure is built according to the substation structure.

  The maximum size of a project is 180 IEDs. However, in order to maintain good performance and usability of the tool, it is recommended to divide one big project into multiple smaller PCM600 projects.
- To add an IED to a project, a suitable Connectivity package is needed. IEDs can be added either while connected or disconnected or through other means such as an IED template.
- IED objects are uniquely named within the PCM600 project.

Application configuration in the Application Configuration tool

- Protection and control functions can be configured as needed.
- The configuration made in the Application Configuration tool is saved to make the interfaces and signals available for other engineering tools within PCM600, for example, for the Parameter Setting tool.

Parameter setting and configuration in the Parameter Setting tool

- Configuration parameters such as CT and VT conversion values of the transformer module are checked by the tool.
- If needed, the setting values are checked and adjusted with the Parameter Setting tool.

Single-line diagram configuration in Graphical Display Editor

- It is possible to create a single-line diagram for the switching devices for multiple feeders in the substation.
- Measurements can be included when needed.
- The dynamic elements are linked to the functions created in the Application Configuration tool; for example, a breaker object is linked to the circuit breaker control function.

Engineering

- The LED behavior is defined with Parameter Setting.
- The LEDs are configured with Application Configuration.

Communication protocol engineering

- The communication engineering details are protocol-dependent.
- The connectivity package creates the IEC 61850 configuration for vertical communication automatically and it is directly suitable, in most cases, for IEC 61850 client configuration. Either IEC 61850 Configuration tool or any IEC 61850 system configuration tool is needed for configuring horizontal and vertical communication.
- The Communication Management tool is used for other protocols; for example Modbus.

The IED restarts automatically when writing an IED configuration where changes have been made. It is not possible to communicate with the IED during restart.

4 PCM600 tool

Protection and Control IED Manager PCM600 offers all the necessary functionality to work throughout all stages of the IED life cycle.

- Planning
- Engineering
- Commissioning
- Operation and disturbance handling
- Functional analysis

The whole substation can be controlled and different tasks and functions can be performed with the individual tool components. PCM600 can operate with many different topologies, depending on the customer needs.

PCM600 is used to conduct complete engineering and configuration activities needed for the bay level IEDs.

Connectivity Packages are separate software packages that provide type and version information to PCM600. Further Connectivity Packages assist the tool with communications.

PCM600 uses IEC 61850 over Ethernet to communicate with bay devices. This communication allows PCM600 to configure and monitor the devices. In addition to IEC 61850 the devices have optional communications protocols and hardware to connect to station engineering tools. PCM600 provides the ability to export the configuration of the devices or an entire substation in a standard file format which enables station engineering in separate IEC 61850 System Configuration tools.

A PC with PCM600 can be connected to any 615 series protection IED and SSC600 within a station by using the Ethernet connection. The connection can also be used for service and maintenance purposes. In addition, the connection is used to handle disturbance records from the IEDs.

The modern-day IEDs are designed using the concept of the IEC 61850 standard. This is primarily in regards to how functions within the IEDs are modelled and how the IED is represented in the substation. See the IEC 61850 parameter list for the list of logical nodes available in the IED and observe how they follow the structure and rules as defined in part 7 of the standard.

The engineering of the used communication protocols is a separate task and an addition to the engineering of protection and control functions.

PCM600 can be used for different purposes throughout the IED life cycle. A set of special tools is available for different applications.

The applications can be organized into groups.

- IED system engineering
- Communication engineering
- Record management
- Device monitoring and diagnostic

For more information, see PCM600 documentation.

4.1 Connectivity packages

A connectivity package is a software component that consists of executable code and data which enables system tools to communicate with a IED. Connectivity packages are used to create configuration structures in PCM600. The latest PCM600 and connectivity packages are backward compatible with older IED versions.

A connectivity package includes all of the data which is used to describe the IED, for example, it contains a list of the existing parameters, data format used, units, setting range, access rights and visibility of the parameter. In addition, it contains code which allows software packages that consume the connectivity package to properly communicate with the IED. It also allows for localization of text even when its read from the IED in a standard format such as COMTRADE.

Update Manager is a tool that helps in defining the right connectivity package versions for different system products and tools. Update Manager is included with products that use connectivity packages.

4.2 PCM600 and IED connectivity package version

- PCM600 2.9 Hotfix 20181219 or later
- SSC600 Connectivity Package Ver 1.5 or later

For configuring R-SV, PCM600 version 2.13 or later is required.

Download connectivity packages from the ABB Web site *go.abb/digitalsubstations* or directly with the Update Manager in PCM600.

4.2.1 Installing connectivity packages

- Install connectivity packages either by running the installer which can be downloaded on the ABB Web site or by using Update Manager when a network connection is available.

Download connectivity packages from the ABB Web site *go.abb/digitalsubstations* or directly with Update Manager in PCM600.

4.2.1.1 Installing connectivity packages by using the connectivity package installer

1. Close PCM600.
2. Run the **ABB IED Connectivity Package SSC600 Ver. n.msi** installer. (n = version number)
3. To install the connectivity package, follow the steps in the connectivity package installation wizard.

4.2.1.2 Installing connectivity packages by using the Update Manager

1. In PCM600, click Help and select Update Manager. Run the Update Manager with administrator rights.

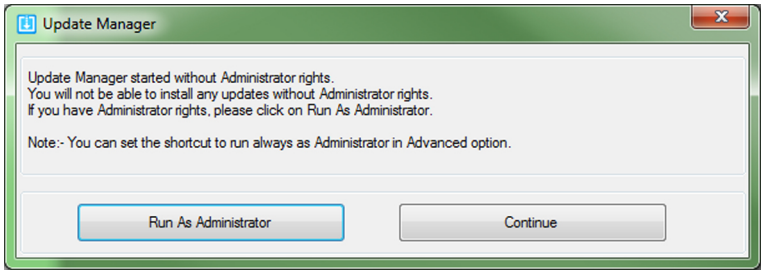


Figure 5: Running the Update Manager as an administrator

2. Select Get Connectivity Packages from menu on the left column.
3. Select all the required connectivity packages.
4. Click Download and Install.

   The status bar shows the installation status.

4.2.2 Activating connectivity packages

The IED connectivity package has to be installed before it can be activated in the Update Manager.

1. Select Manage Connectivity Packages from the menu on the left column to access the installed connectivity packages.
2. Browse the tree structure to find the correct product.
3. Select the connectivity package version from the drop-down list beside the product name.

Always use the latest version of the connectivity package.

4. Click Apply to activate the connectivity package.

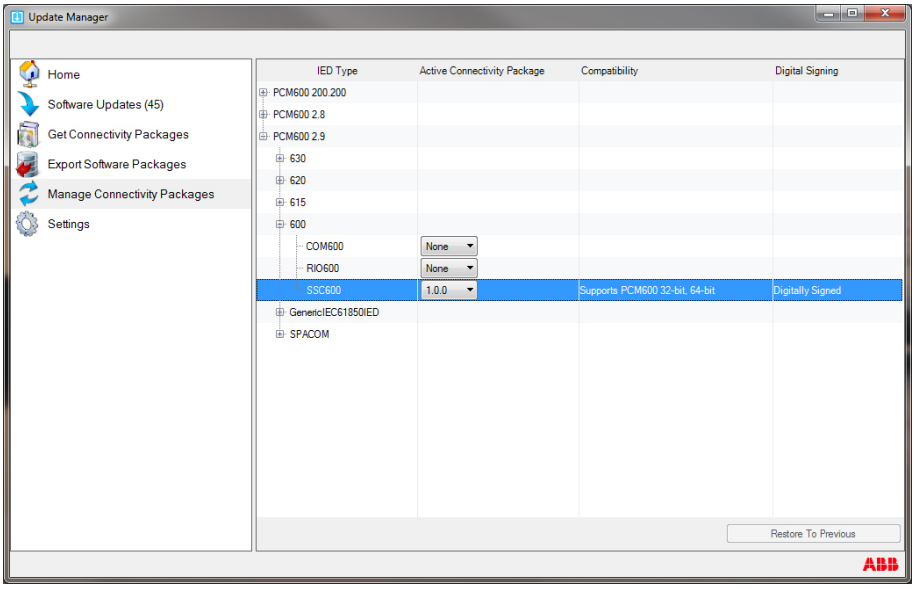


Figure 6: Selecting the connectivity package versions

PCM600 recognizes the installed connectivity packages during start-up, and the corresponding IED types are available in PCM600 when starting a new project.

4.3 PCM600 projects

A typical project in PCM600 contains a plant structure including one or several IED objects, where each IED object contains the engineering data created or modified using the different PCM600 tools.

Several projects can be created and managed by PCM600, but only one project can be active at a time.

Regardless the protocol used in installation for each project, the IEC 61850 version must be selected when adding the first IED to plant structure. After the initial selection, all IEDs in plant structure use the selected version, either Edition 1 or Edition 2. In case the IEC 61850 is not used for station bus, the default version can be applied. By default, the IEC 61850 version of PCM600 is Edition 1. The IED's IEC 61850 version is by default Edition 2.

With PCM600, it is possible to do various tasks.

- Open existing projects
- Import projects
- Create new projects
- Export projects
- Delete projects
- Rename projects
- Copy and paste projects

The extension of the exported project file is .pcmp. The files are only used for exporting and importing projects between PCM600s.

4.4 Technical key

Both a physical IED and an IED object in PCM600 have a technical key. The technical key in the IED and PCM600 must be the same, otherwise it is not possible to download a configuration.

Each IED in a PCM600 project must have a unique technical key. Therefore, it is not possible to set the same technical key for several IEDs in the same PCM600 project.

The IED is delivered with a factory default technical key. The validation of the technical keys between PCM600 and the IED does not occur if the IED contains the factory default technical key.

The technical key property in PCM600 corresponds to the IED name attribute in SCL files. Avoid changing the IED name attribute outside PCM600, because data in PCM600 may get lost when importing the SCL files.

The technical key must be the same for the communication between the IED and PCM600. The technical key can be read from the IED and updated to PCM600, or the PCM600 technical key can be written to the IED. Alternatively, a user-defined technical key can be defined.

When writing a configuration to the IED, PCM600 checks for a mismatch between the IED object and the physical IED technical key.

Ensure that the IED object in PCM600 has the same IP address as the physical IED that is intended to be connected through the technical key concept.

Change the technical key for an IED object in the Object Properties dialog box in PCM600.

4.4.1 IEC 61850 naming conventions to identify an IED

This section is only valid when the IEC 61850 standard is used for station bus communication. The IEC 61850 naming conventions to identify an IED are only valid when the IEC 61850 standard is used for station bus communication. According to the IEC 61850-6, the SCL model allows two kinds of project designations in the object properties: a technical key and a user-oriented textual designation.

- Technical key is used in engineering drawings and for signal identifications. This is contained in the attribute name as an identification of each object. If the value is used as a reference to an object, it is contained in an attribute name starting with a string denoting the reference target object type and ending with the string Name. The technical key is used within SCL for referencing to other objects. The name is a relative identification within a hierarchy of objects. The maximum characters allowed for a technical key is 28 for IEC 61850 Edition 1 and 60 for Edition 2 projects.
- User-oriented textual designation is contained in the desc attribute. Attributes are not allowed to contain carriage return, line feed, tab, greater than, less than, double quotes or ampersand characters. The semantics of desc must also be relative within an object hierarchy. The maximum length is 100.

PCM600 takes care of these two possibilities. The two possible signal designations are available per object in the Object Properties for all the hierarchical levels beginning with the station as the highest level.

The technical key is automatically generated based on the rules and type specifications of IEC 61346 and the extended definitions assigned for substations by a technical committee. The technical key is shown in the Object Properties dialog box under SCL Technical Key or Technical Key.

The user-oriented textual designation is visible in the Plant structure view for each object. It is the name given by default or changed by using the Rename function.

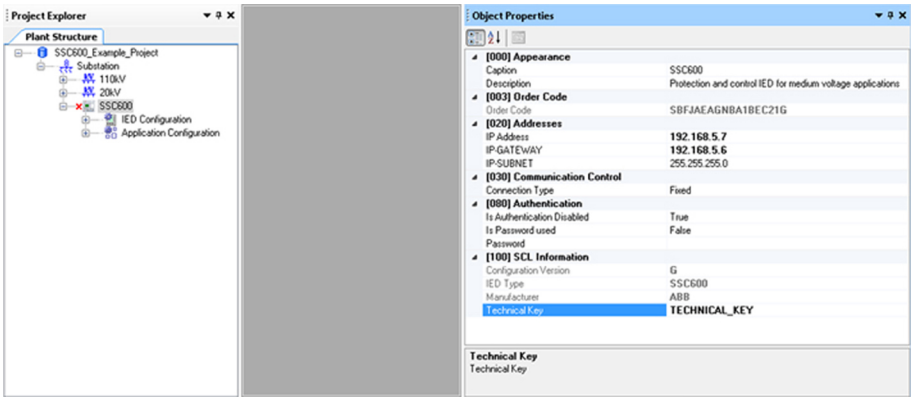


Figure 7: PCM600: IEC 61850 signal designation concept

4.4.2 Setting the technical key

The maximum length of technical key is 28 characters for Edition 1 and 60 characters for Edition 2.

1. In the Plant Structure view, right-click the IED and select Set Technical Key in IED.

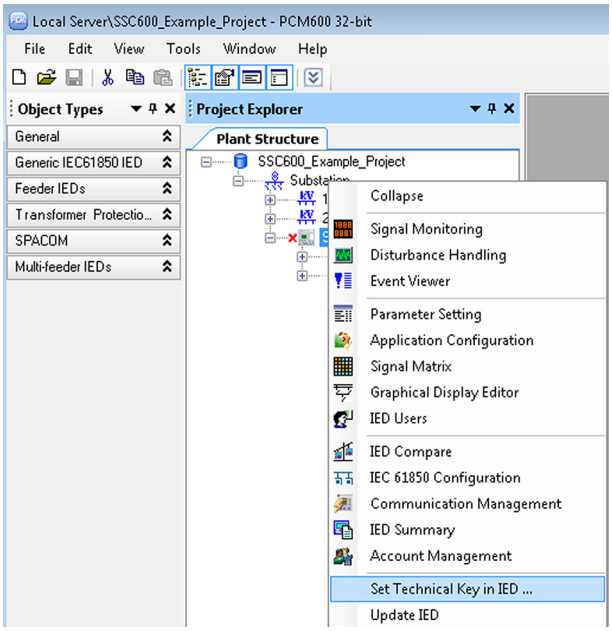


Figure 8: PCM600: Setting the technical key on the IED level

A dialog box opens to inform about the technical key concept.

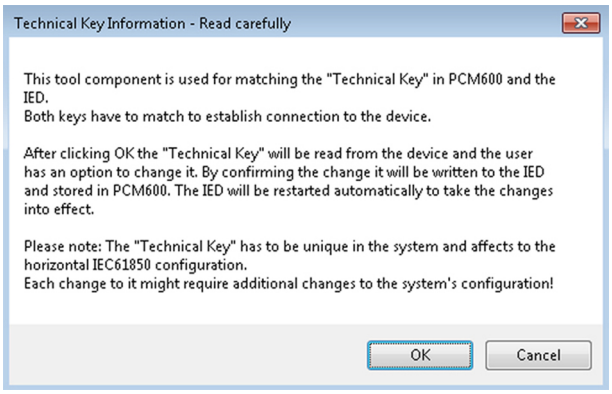


Figure 9: Technical key information

2. Click OK.

   The technical key is read from the IED and the Set Technical Key dialog box opens.

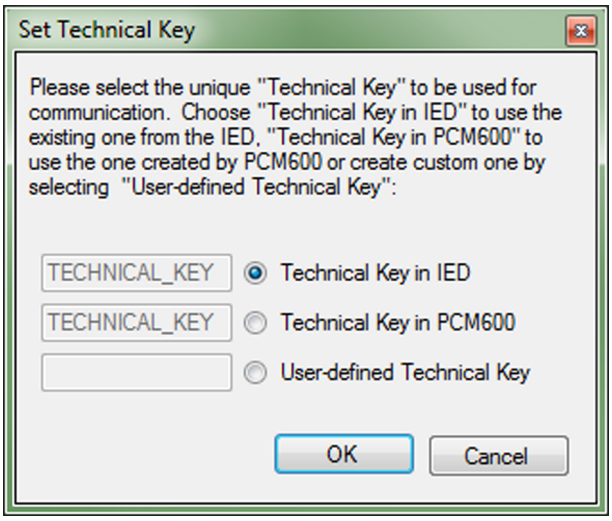


Figure 10: Setting the technical key

3. In Set Technical Key dialog box, select the technical key to be used. There are three alternatives.
   - Use the existing technical key in the IED
   - Use the existing technical key defined for the IED object in PCM600
   - Set a user-defined technical key, which changes the technical key for both the physical IED and IED object in PCM600

4. Click OK to confirm the selection.

It is not possible to set a user-defined name or select the Technical key in IED if the value is the same as already given to another IED object in the PCM600 project. An error message is displayed if this happens.

4.5 Communication between PCM600 and the IED system

The communication between the IED system and PCM600 is independent of the used communication protocol within the substation or to the NCC.

All communication is done over Ethernet using either IEC 61850 or FTPS/HTTPS protocol.

SSC600 has multiple Ethernet connectors for communication. The Ethernet connector can be used for communication with PCM600.

When an Ethernet-based station protocol is used, the same Ethernet port and IP address can be used for PCM600 communication.

Two basic variants have to be considered for the connection between PCM600 and the IED system.

- Direct point-to-point link between PCM600 and the IED system's local port / remote port
- Indirect link via station LAN or from remote via network

1. If needed, the IP address for the IED system is set.
2. A PC or workstation is set up for a direct link (point-to-point), or the PC or workstation is connected to the LAN/WAN network.
3. The IED system' IP addresses in the PCM600 project are configured for each IED to match the IP addresses of the physical IEDs.
4. Technical keys of the IEDs in PCM600 project are configured for each protection IED to match the technical keys of the physical IEDs.

For successful protection IED engineering and usage, check the workstation firewall TCP and UDP port configurations, especially for IEC 61850 and FTP. Other protocols are not used for engineering and/or they are optional.

Table 8: Ports that must be open in the firewall for different protocols

Protocol	TCP port
File Transfer Protocol (FTPS)	21
IEC 61850	102
Web server HTTPS	443
Device management server HTTPS	5001

4.5.1 Setting up IP addresses

The IP address and the corresponding subnet mask can be set via WHMI for Ethernet interfaces in the IED. Each Ethernet interface has a default factory IP address when the complete IED is delivered.

The IED's local port IP address is fixed to “192.168.0.254” and it cannot be modified.

The IED's remote port IP address is fixed to “192.168.1.254” and it cannot be changed.

1. Set the IP address for the IED's port and the corresponding subnet mask via the WHMI path **Configuration/Communication/Ethernet**.

Table 9: Default IP addresses and corresponding subnet masks

Port	IP address	Subnet mask
Rear port	192.168.2.10	255.255.255.0
Local port	192.168.0.254	
Remote port	192.168.1.254	
Service port	192.168.3.10	255.255.255.0
Protection communication port	192.168.4.10	255.255.255.0

Communication fails if the IP addresses of the local / remote and the rear port belong to the same subnet.

When using redundant Ethernet (PRP), configure all devices in the network before connecting cables to ports LAN A and LAN B. Avoid using the LAN A or LAN B ports on redundant communication modules while changing the Switch mode parameter.

4.6 IED Update

The firmware update tool is used for patching the IED firmware and for adding or replacing additional languages to the IED. Update packages are provided by Customer Support. The update tool can be used either locally or remotely.

It is recommended to take a backup of the IED configuration before starting the update. This can be done by using the Read from IED function from the IED context menu in PCM600. The user needs to be authorized before using the tool. User credentials are asked if the default administrator password has been changed. User with System Update right (refer to table Default roles-to-rights in the Cyber Security Deployment Guideline) credentials are needed for authorization.

4.6.1 Prerequisites for updates

Use of the local port/remote port is recommended when updating locally. Remove the IED from the network especially with redundant network topologies (PRP).

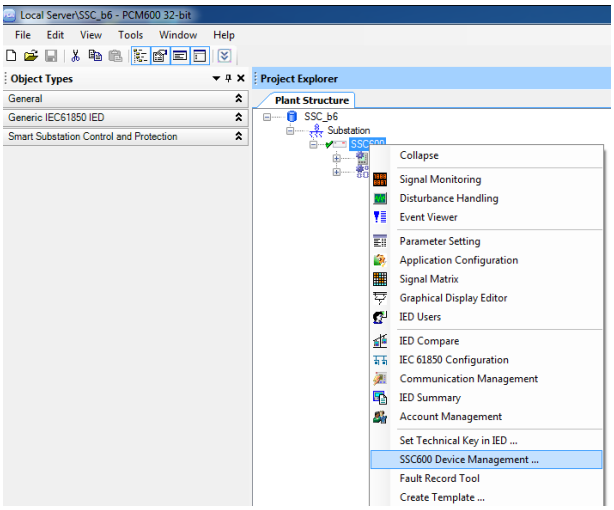
4.6.2 SSC600 Device Management

This tool is used for multiple purposes: Factory reset, Firmware upgrade and License update.

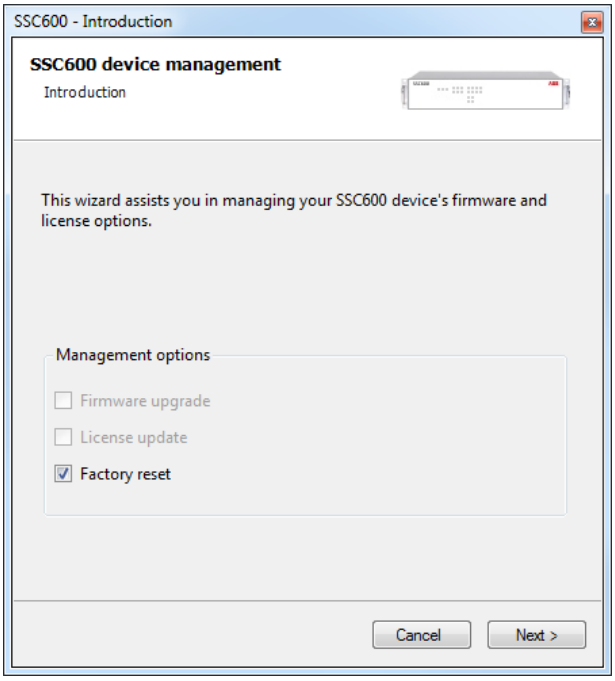
4.6.2.1 Restoring factory settings

In case of configuration data loss or any other file system error that prevents the protection device from working properly, the whole file system can be restored to the original factory state. All default settings and configuration files stored in the factory are restored. Only a user with System Update right (refer to table Default roles-to-rights in the Cyber Security Deployment Guideline) (e.g. ADMINISTRATOR) can restore the *factory* settings.

1. In the **Plant Structure** view, right-click the device and select **SSC600 Device Management**.



2. Select **Factory reset** and click **Next**.



3. Click **Reset**.

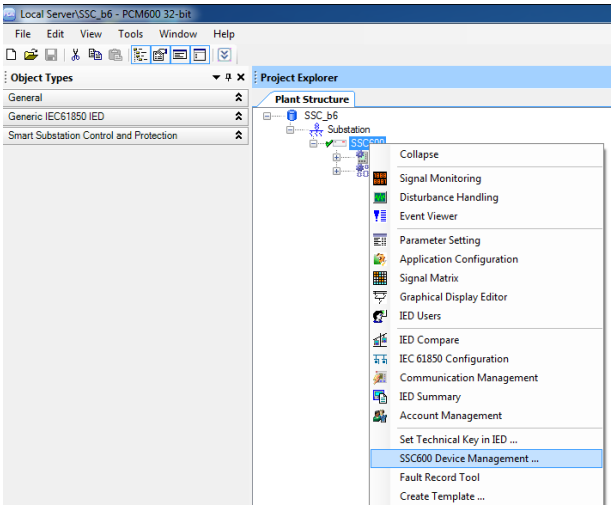
4. Click **Finish**.

The protection device restores the factory settings and restarts. Restoring takes 1...3 minutes. Confirmation of restoring the factory settings is shown on the display a few seconds, after which the device restarts.

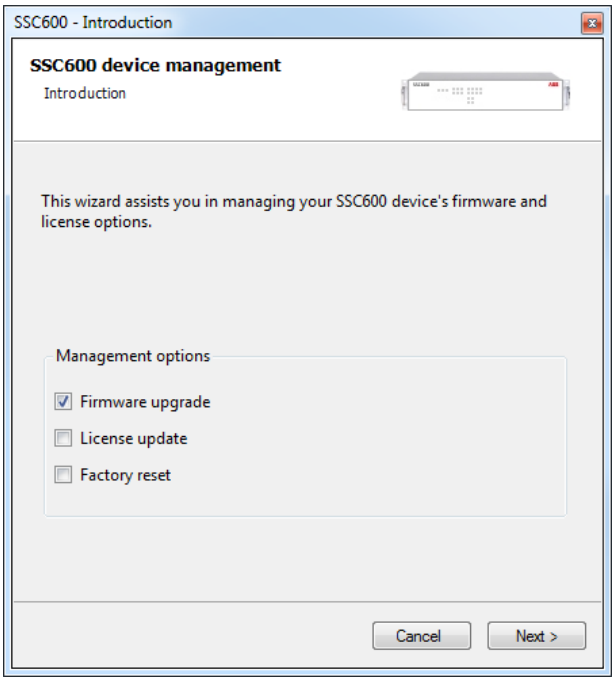
Avoid the unnecessary restoring of factory settings, because all the parameter settings that are written earlier to the device will be overwritten with the default values. During normal use, a sudden change of the settings can cause a protection function to trip.

4.6.2.2 Firmware upgrade

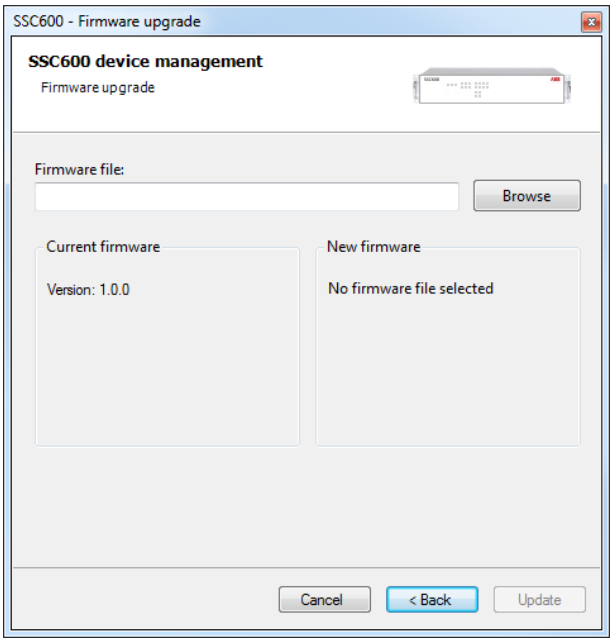
1. In the **Plant Structure** view, right-click the device and select **SSC600 Device Management**.



2. Select **Firmware upgrade** and click **Next**.



3. Update Firmware file.



4.6.2.3 License management

1. In the **Plant Structure** view, right-click the device and select **SSC600 Device Management**.

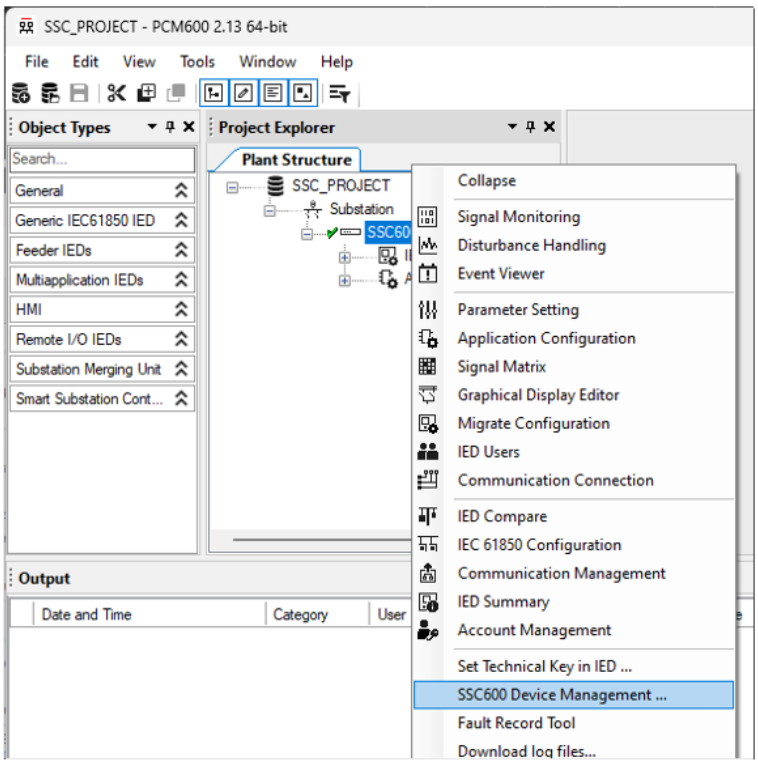


Figure 11: Selecting SSC600 Device Management

2. Select **License management** and click **Next**.

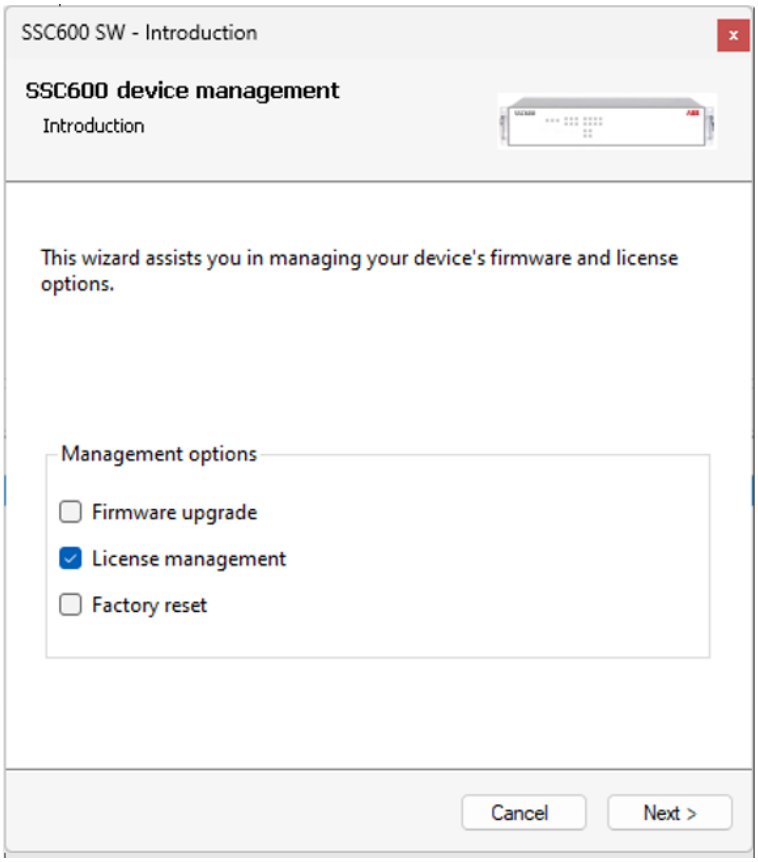


Figure 12: Selecting License management

3. Click **Next**.

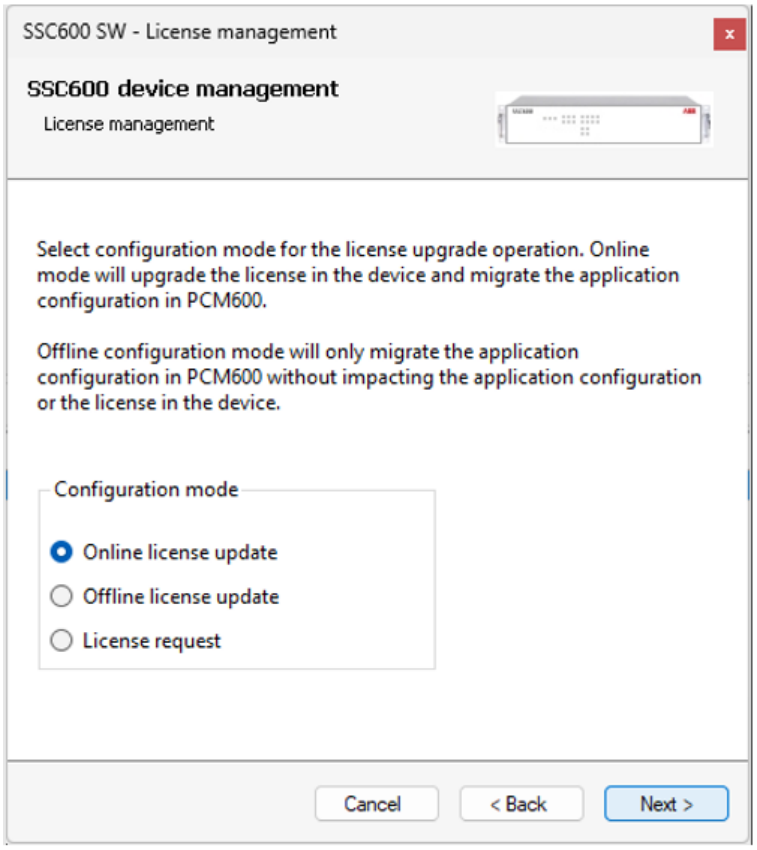


Figure 13: Configuration mode for the license upgrade operation

4. Click **Next** in Order code selection window.

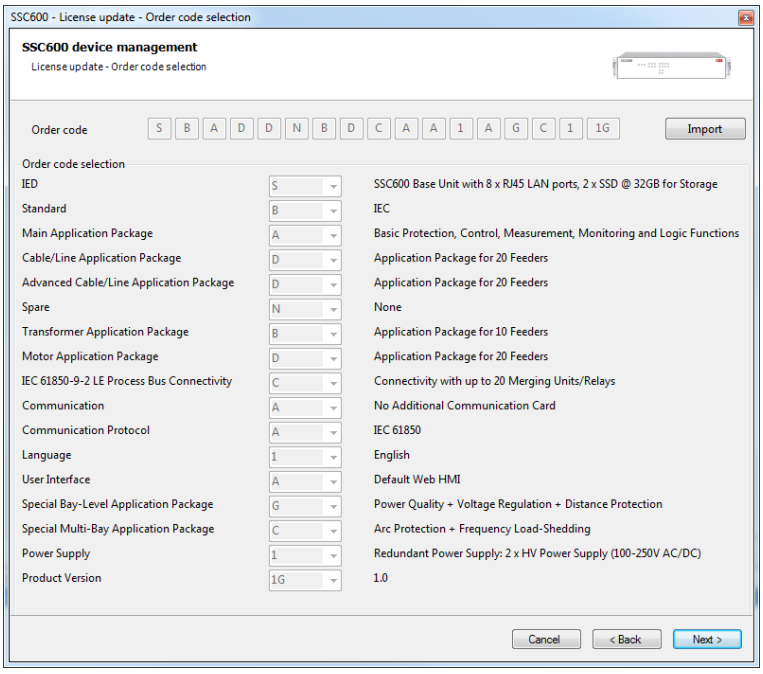


Figure 14: Order code selection window

5. Summary window tells if application changes are needed. If changes are needed, follow instructions. If changes are not needed, click **Finish**.

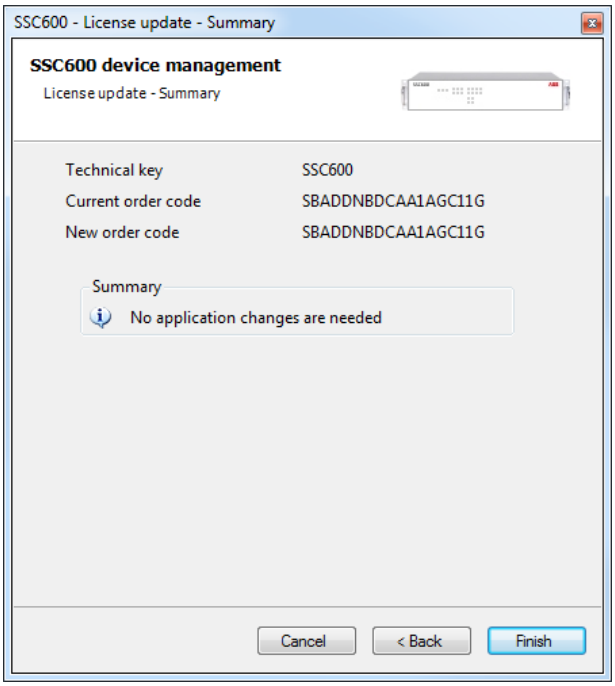


Figure 15: Summary window

4.6.2.4 License request

1. In the **Plant Structure** view, right-click the device and select **SSC600 Device Management**.

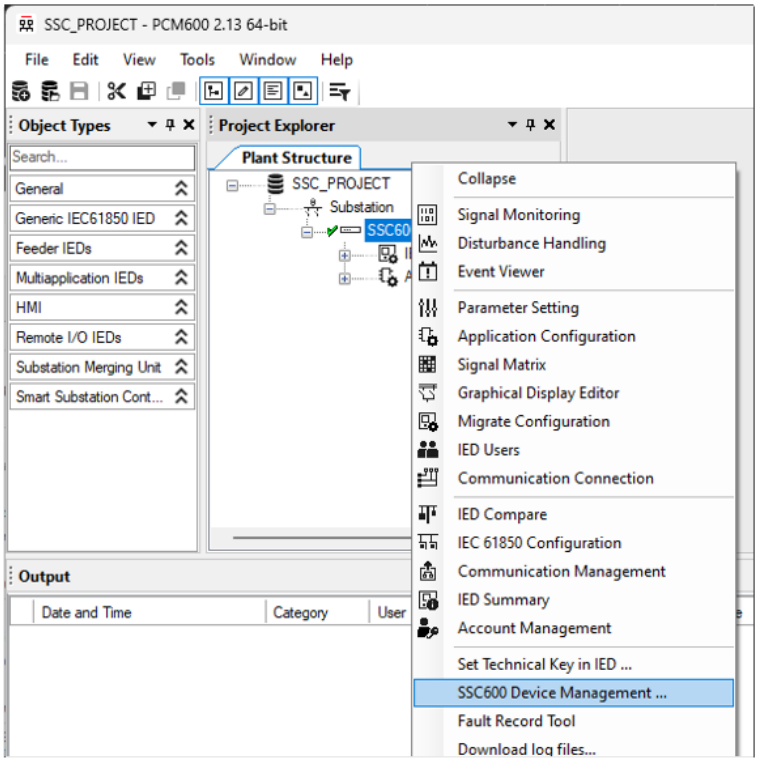


Figure 16: Selecting SSC600 Device Management

2. Select **License management** and click **Next**.

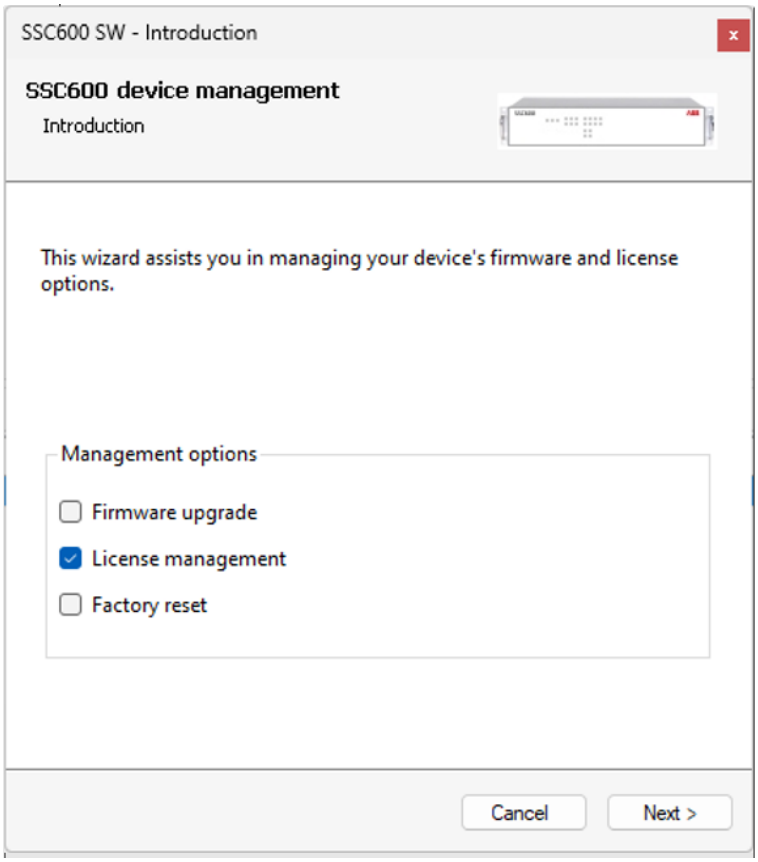


Figure 17: Selecting License management

3. Select **License request** and click **Next**.

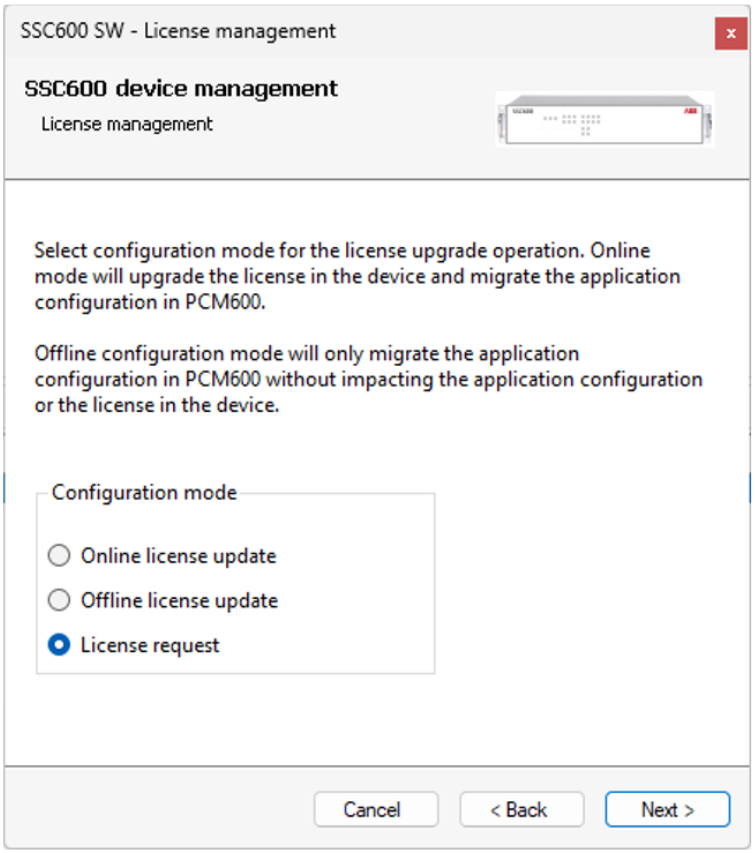


Figure 18: Selecting License request

4. Click **Finish**.

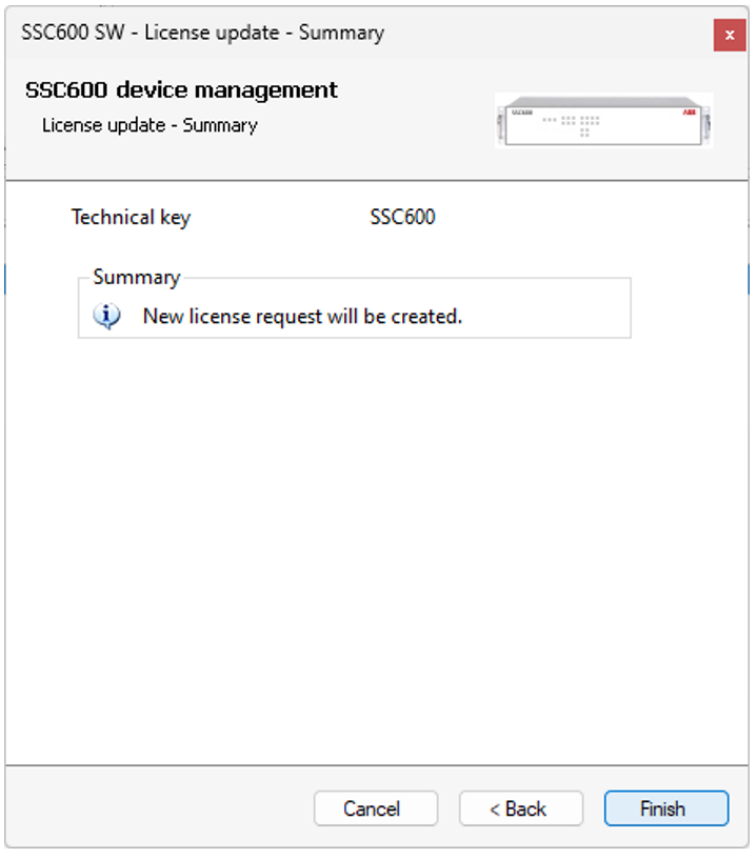


Figure 19: Creating a new license request

5. Save the JSON-based license request file with the file saving dialog that appears.

5 Setting up a project

5.1 Creating a new project

1. Start PCM600
2. To see the projects that are currently available in the PCM databases, select **File/ Open/Manage Project** on the menu bar.
   The **Open/Manage Project** window is displayed.
3. Click Projects on my computer.
4. Click New Project.
5. If there are currently projects or object tools open, a confirmation dialog box opens.
   Click Yes to close the open projects. A Create New Project dialog box opens.

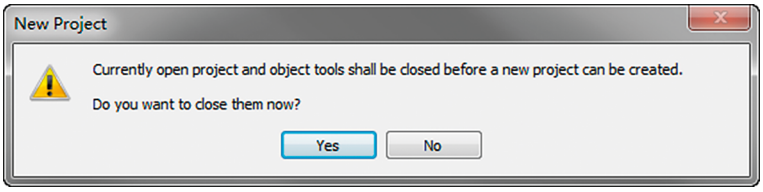


Figure 20: New Project dialog box

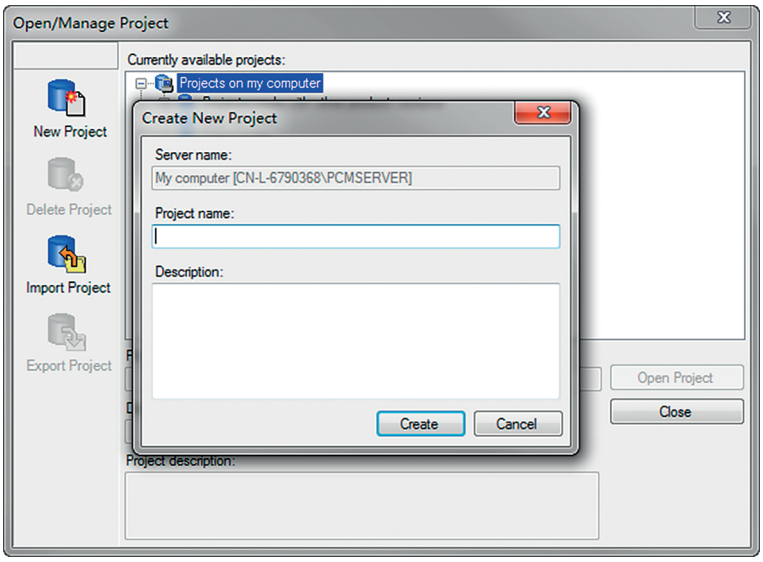


Figure 21: Creating a new project

6. In the Project Name box, give a name for the project.

The project name must be unique.

7. Optionally, write a description of the project in the Description box.
8. Click Create.

PCM600 sets up a new project that is listed under Projects on my computer.

5.2 Building the plant structure

Building a plant structure is useful when a complete grid with an essential number of IEDs has to be built.

1. Create a new plant structure in one of the alternative ways.
   - Right-click the Plant Structure view, point to New and select Create from Template.
   - Right-click the Plant Structure view, point to New and select General and select the element either IED Group or Substation.
2. On the View menu, select Object Types.
3. Select the needed elements and drag them into the plant structure.

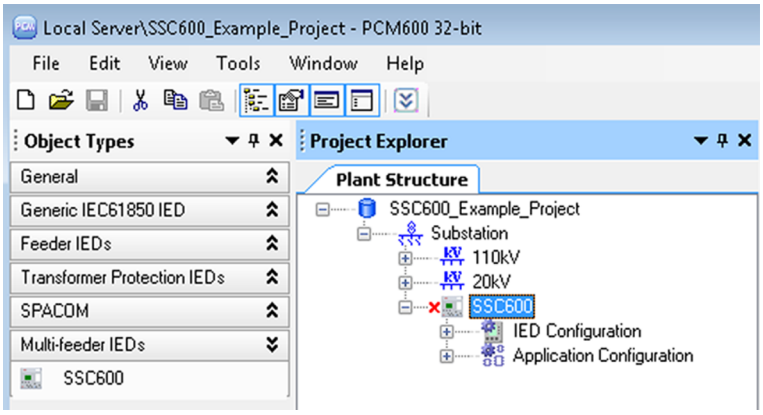


Figure 22: The start of a project with IEDs placed but not renamed

4. Rename each level in the structure by the names/identifications used in the grid.
   - Right-click the level and select Rename.
   - Rename the levels in the Object Properties view.

5.3 Inserting an IED

In plant structure SSC600 unit can be placed on multiple different locations, depending on the application: substation, voltage level or bay.

The bay level IEDs or Merging Units that send measurements to SSC600 need to be instantiated to the plant structure to corresponding bay nodes.

It is possible to do various tasks in the plant structure.

- Insert either offline or online IED

- Import a template IED that is available in the template library as a .pcmt file
- Import a preconfigured IED available as a .pcmi file

PCM600 uses two kinds of IED files: .pcmt and .pcmi. Both files include the complete IED configuration but their usage differs. The .pcmt files are always accessed through the PCM600 template manager while the .pcmi files are meant for sharing the IED instances between different PCM600 users enabling quick import/export directly from the plant structure context menu.

IEC 61850 Edition 1 and Edition 2 IEDs cannot be used simultaneously in the same PCM600 project. The first inserted IED determines the IEC 61850 version for the whole project.

5.3.1 Inserting an IED in online mode

To set up an IED online, the IED must be connected to PCM600.

When the IED is already connected to PCM600, PCM600 can read the order number directly from the IED. It is possible to read the full configuration from the IED by using the Read from IED function.

1. In the Plant Structure view, right-click the bay, point to New, point to the IED application area such as Motor Protection IEDs and select the IED type to be inserted.

   Alternatively, drag an IED from the Object Types view to the bay level.

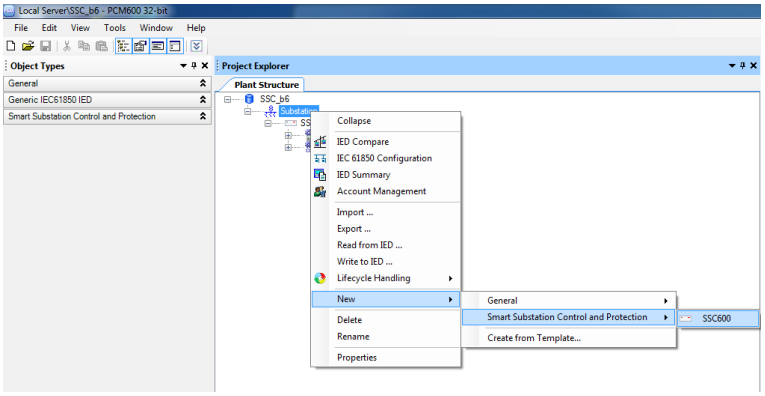


Figure 23: Selecting the IED type

2. On the Configuration mode selection page, select Online Configuration and click Next.

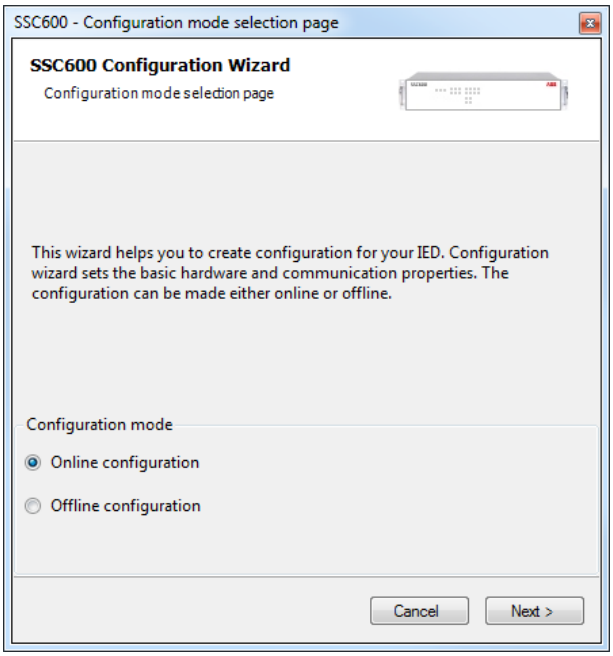


Figure 24: Configuration mode selection

3. On the Communication protocol selection page, select the communication protocol from the IED protocol list and click Next.

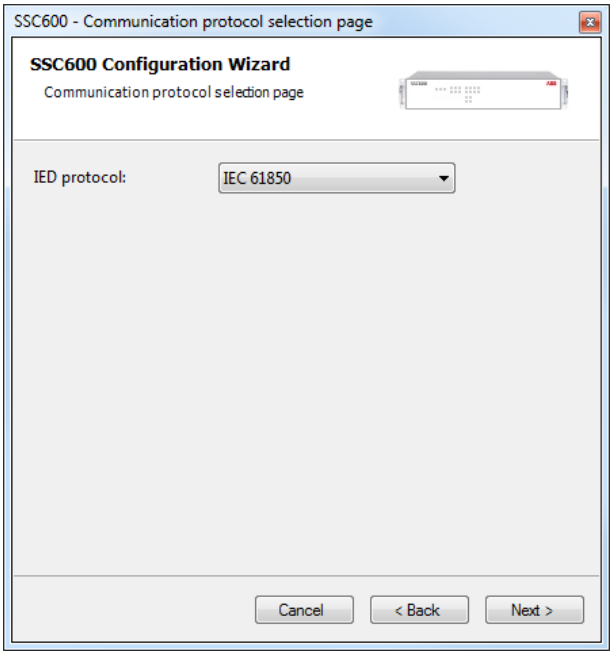


Figure 25: Communication protocol selection

4. On the IEC61850 communication protocol page, select the port from the Port list.
   - If the rear port is selected, type the correct IP address (of the physical IED to be configured) to the IP address box.

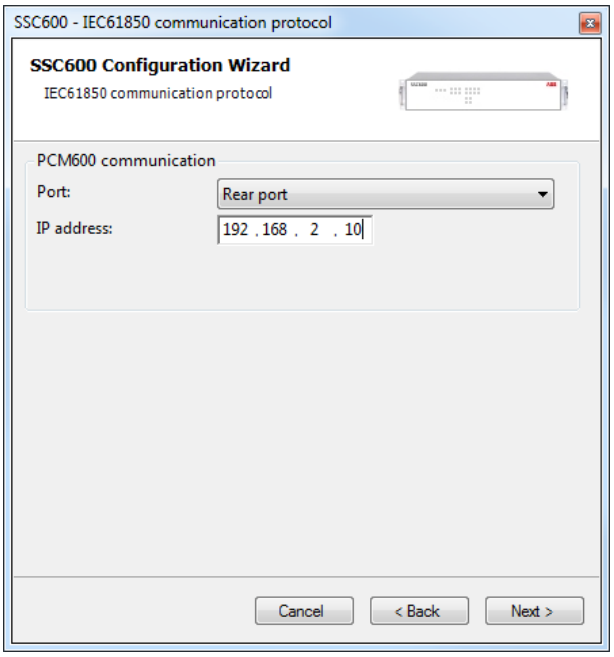


Figure 26: Communication port and IP address

Communication configuration is now defined.

5. Click Next to scan/read the order code of the IED.

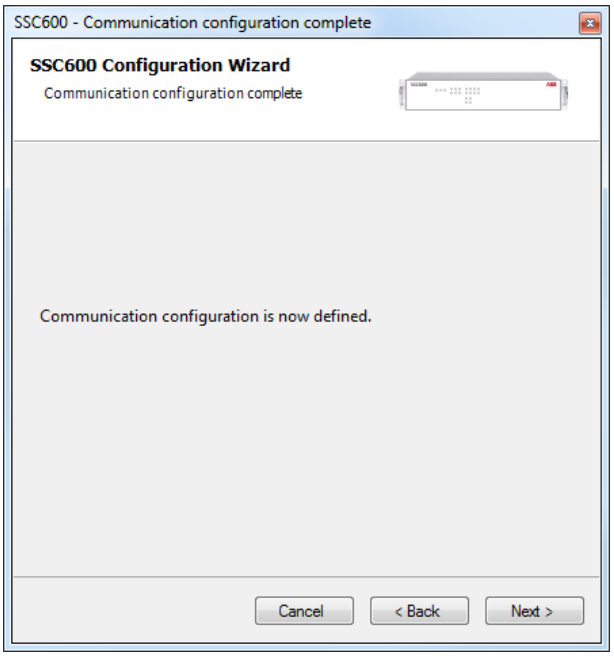


Figure 27: Configuration complete

6. On the Order code detection page, click Next.

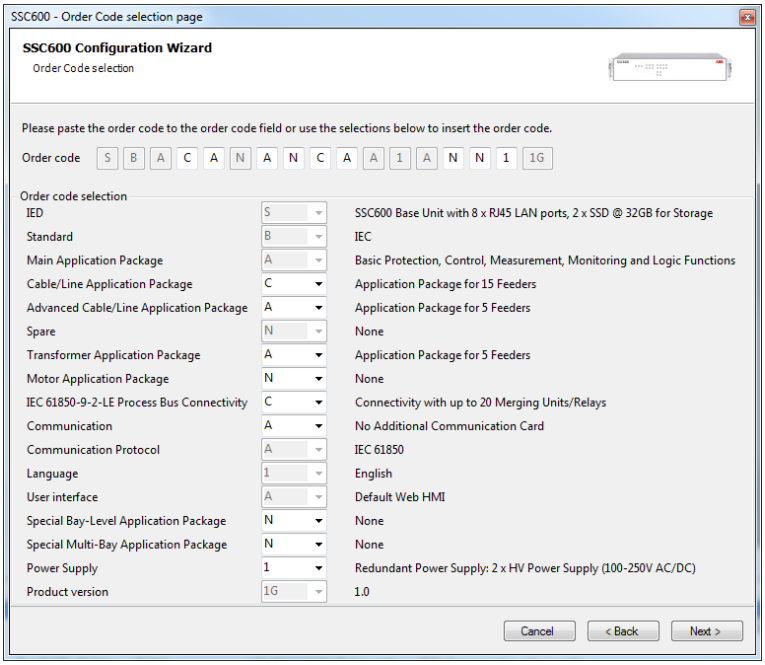


Figure 28: Order code detection

7. On the Configuration selection page, select the configuration type and click Next.

   - Select Empty Configuration to create an empty configuration.
   - Select Example Configuration to import any existing example configuration.

     Click Browse to select the .pcmi/.pcmt file that has the example configuration.

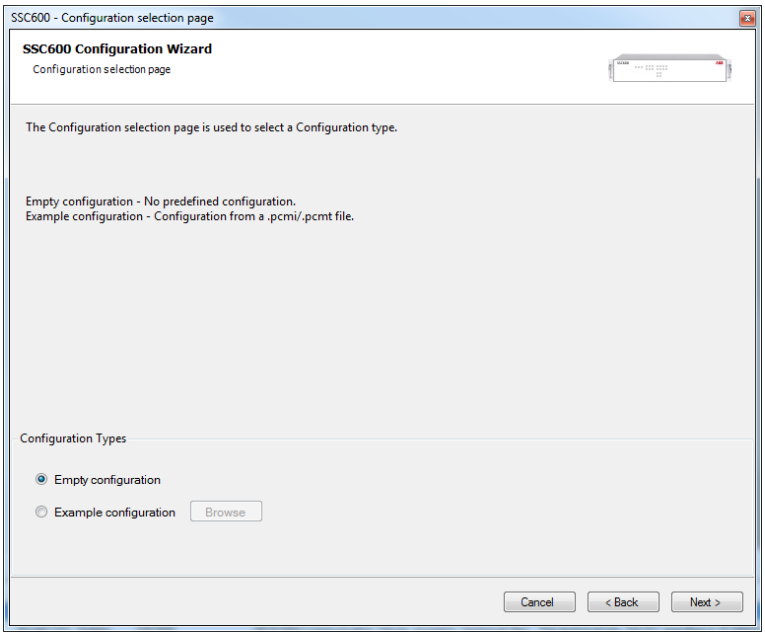


Figure 29: Configuration selection page

8. On the Version selection page, select the IEC 61850 version and click Next.

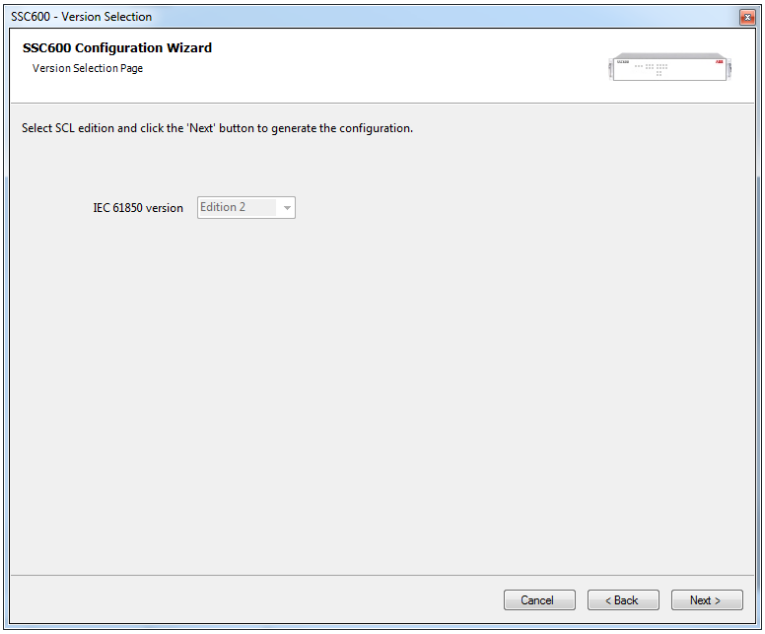


Figure 30: Version selection page

Regardless of the protocol used in the installation for each project, the IEC 61850 version must be selected when adding the first IED to the plant structure. After the initial selection all IEDs in the plant structure use the selected version, either Edition 1 or Edition 2.

9. The Setup complete page shows the summary of the IED's IED type, version, IP address and the selected order number. Click Finish to confirm the configuration and conduct the insertion.

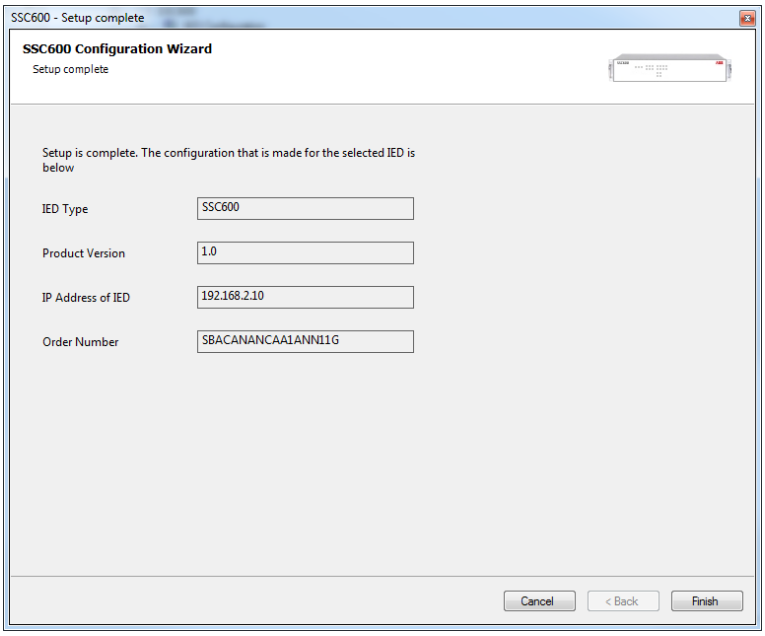


Figure 31: Setup complete

To cancel the insertion, click Cancel.

If an error is found on the Setup Complete Page, it is not possible to go back and make modifications. If an error is detected, cancel the insertion by clicking Cancel and insert the IED again.

10. From the Plant structure view, check that PCM600 has turned online the IED that was inserted to the bay level.

Data cannot be scanned from the IED and proceeding is prevented if the IED is not online or if the IP address is not correct.

5.3.2 Inserting an IED in offline mode

When the IED is not available or is not connected to PCM600, engineering can be done offline. The offline configuration in PCM600 can be written to the IED later when it is connected.

Working in the offline mode has an advantage compared to online mode in that the preparation for the configuration can be started even though the IED is not available.

1. In the **Plant Structure** view, right-click the bay, point to **New**, point to the IED application area such as Feeder IEDs and select the IED type to be inserted.

   Alternatively, drag an IED from the Object Types view to the bay level.

2. On the Configuration mode selection page, select Offline Configuration and click Next.

   Setting up an IED in the offline mode is similar as in the online mode; however, with the offline mode it is not necessary to type the correct IP address in the Communication port and IP address dialog box.

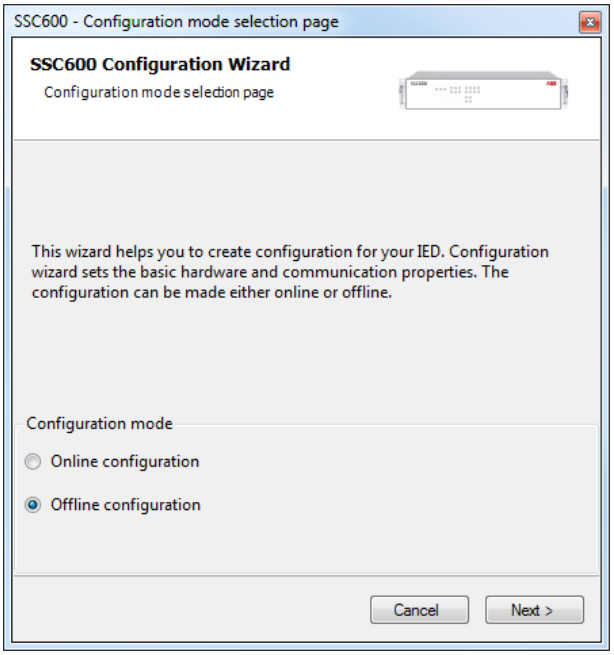


Figure 32: Configuration mode selection wizard

3. On the Order Code selection page, select the correct order codes and click Next.

Ensure that the order code is correct. PCM600 verifies later that the order code matches with the IED. If the order code digits related to the configuration, I/O or version do not match with the IED, PCM600 does not allow writing the configuration to the device. If other digits in the order code do not match, PCM600 informs about the mismatch with a dialog.

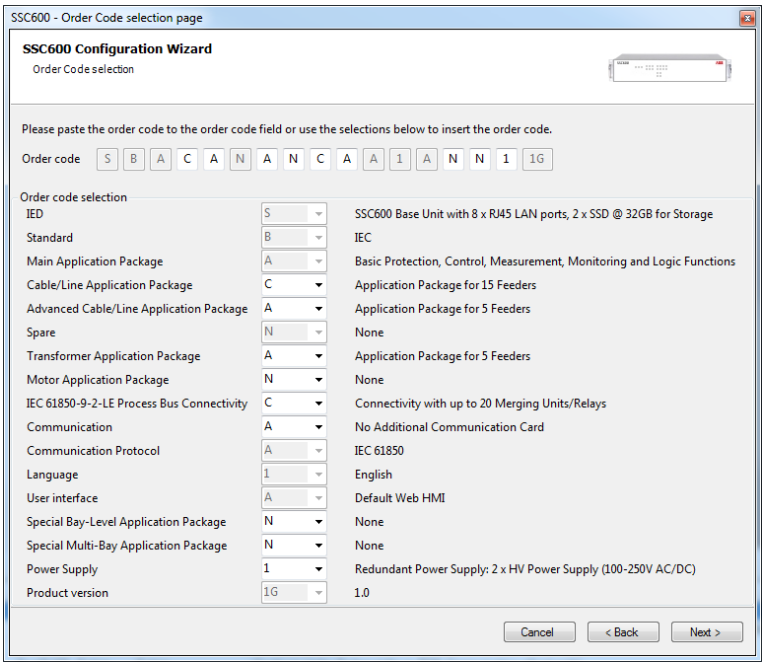


Figure 33: Order code selection

4. On the Configuration Selection Page, select the configuration type and click Next.
   - Select Empty configuration to create an empty configuration.
   - Select Example configuration to import any existing example configuration.

     Click Browse to select the .pcmi/.pcmt file that has the example configuration.
   - Select Standard configuration to generate a default configuration.
5. On the Version Selection page, select the IEC 61850 version and click Next to generate the functions.
6. The Setup Complete Page shows the summary of the IED type, version, IP address and the selected order number. Click Finish to confirm the configuration and conduct the insertion.

5.3.3 Inserting an IED from the template directory

IED templates can be used for replicating IEDs with same order code in PCM600 projects. Template includes IED application configuration, graphical display configuration (single-line diagram), communication protocol mappings and parameters. An IED in the plant structure can be exported as a template (.pcmt file). The template library can be built from all the exported IED templates.

It is also possible to insert an IED from the template library to create a new IED in the plant structure. After a template IED has been imported, the IP address, the Caption in IED's Object Properties and the Technical Key that corresponds to the physical IED have to be changed.

A template IED can be inserted only when the bay is selected in the plant structure.

1. In the Plant structure view, select the bay, right-click, point to New and select Create from template.
   The Create New Object from Template dialog box opens.

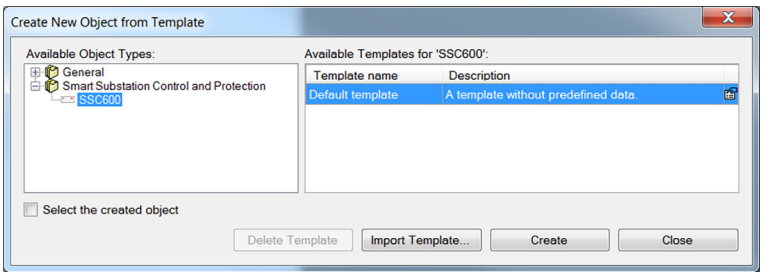


Figure 34: PCM600: Selecting an IED from the template library

2. Select the IED from the list of available IEDs.
3. Click the icon on the right column in the list of available templates.
   The Template Properties dialog box opens.

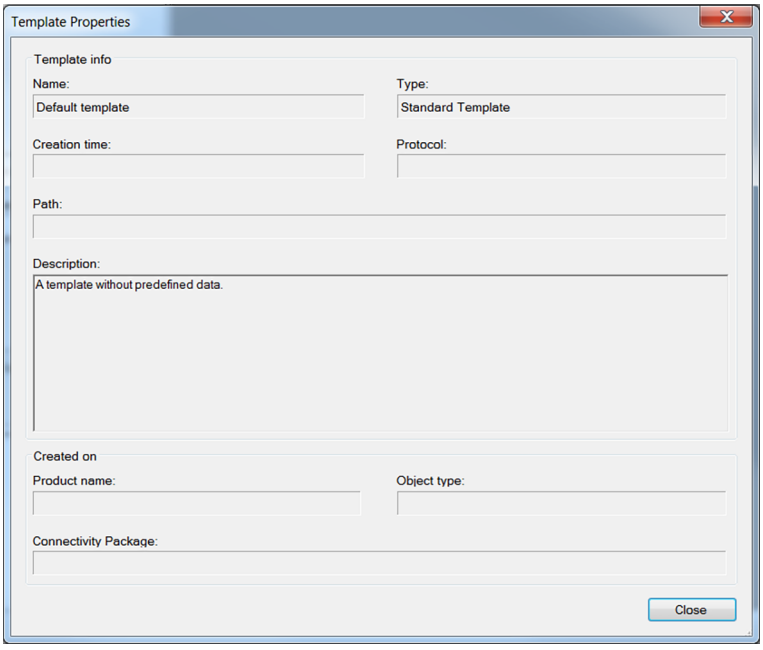


Figure 35: PCM600: Template information

4. Check and verify the template information and click Close to close the dialog box.

   The Create New Object from Template dialog box is displayed.

5. Delete, import or create a template by clicking the corresponding button.

   - To delete the selected template, click Delete Template.
   - To import a template from the selection window, click Import Template.
   - To insert the selected IED to the bay, click Create.

   It is possible to insert more than one IED from the Create New Object from Template dialog box. The dialog box remains open until Close is clicked .

6. Click Close when finished.

5.3.4 Inserting an IED by importing a .pcmi file

It is possible to create a new IED object in the plant structure by importing a .pcmi file.

1. In the Plant Structure view, right-click the bay and select Import.

   A .pcmi file can be imported only when the bay is selected in the plant structure.

2. In the Import dialog box, select the .pcmi file to be imported and click Open. After importing, the IED object is created in the plant structure.

After the .pcmi file has been imported, the IP address, the name and the technical key that correspond to the physical IED have to be changed.

5.4 Setting the IED IP address in a project

The IP address and subnet mask of the IED object in PCM600 must match the local / remote and rear port of the IED (physical IED) to which the PC is connected. The IP address of the IED can only be set via the WHMI or Parameter Setting tool in PCM600. The PC and IED need to be on the same subnet.

There are two alternatives to set the IP address of an IED object in PCM600.

- On the first page of the wizard when including a new IED into a project.
- In the IP address box of the IED's Object Properties dialog box.

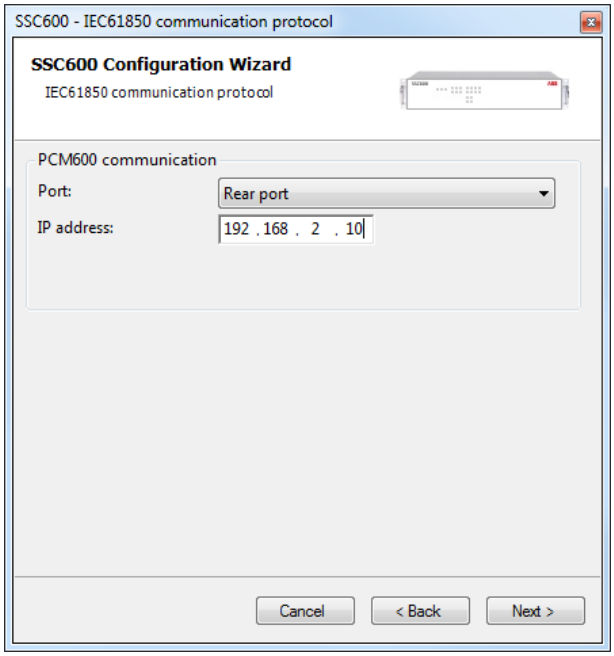


Figure 36: Alternative 1: Setting the IP address on the first wizard page

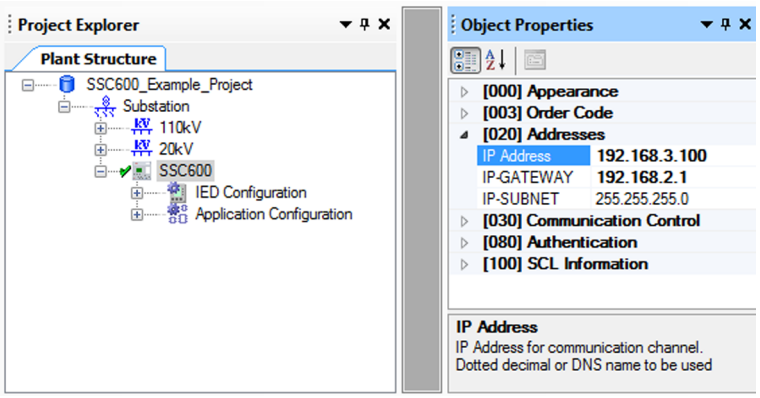


Figure 37: Alternative 2: Setting the IP address in IED's Object Properties dialog box

Choosing between the two ways depends on when the IP address is set. Typing the IP address via the IED's Object Properties dialog box is possible at any time while entering it via the configuration wizard can only be done when adding the IED object.

1. In the Plant Structure view, select the IED to which the IP address is to be entered.

2. On the View menu, select Object Properties.
   Object Properties dialog box is opened.
3. Type in the IP address to the IP Address row.

5.4.1 Selecting communication port for configuration

When a IED is configured to a PCM600 project, the connection between the IED and the tool can be established using a point-to-point link between the IED local port / remote port and the computer or by connecting the computer to the IED rear port over an Ethernet station bus. In PCM600, the local, remote or rear communication port can be selected from the project structure.

When using the local port / remote port, DHCP server functionality must be activated in the computer network adapter settings to get the IP address from the IED. Alternatively, the computer network adapter IP address can be set manually to the same subnet range as the local port / remote port.

Figure 38: Communication port options

- Check that the settings are correct to ensure successful configuration access to the IED.
  - Computer port settings must match IED settings (IP address, subnet mask, DHCP).
  - Any fire wall in the computer or in the network must pass required communication services.
  - When using the local port / remote port and switching the connection from the computer to another IED, it takes some time before the computer refreshes the IED's MAC address for local port / remote port IP address automatically. The MAC address can also be reset manually by clearing the computer ARP table.

5.4.2 Importing a SSC600 protection device in a COM600S project

1. Create a PCM600 project including several IEDs.

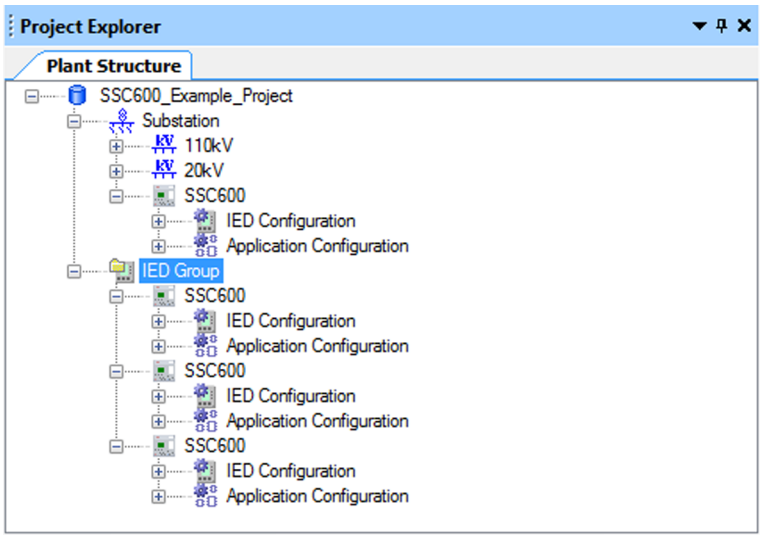


Figure 39: Creating a PCM600 project including several IEDs

2. Export the SCD file from PCM600.
   In the Plant structure view, select the substation, right-click and select Export.

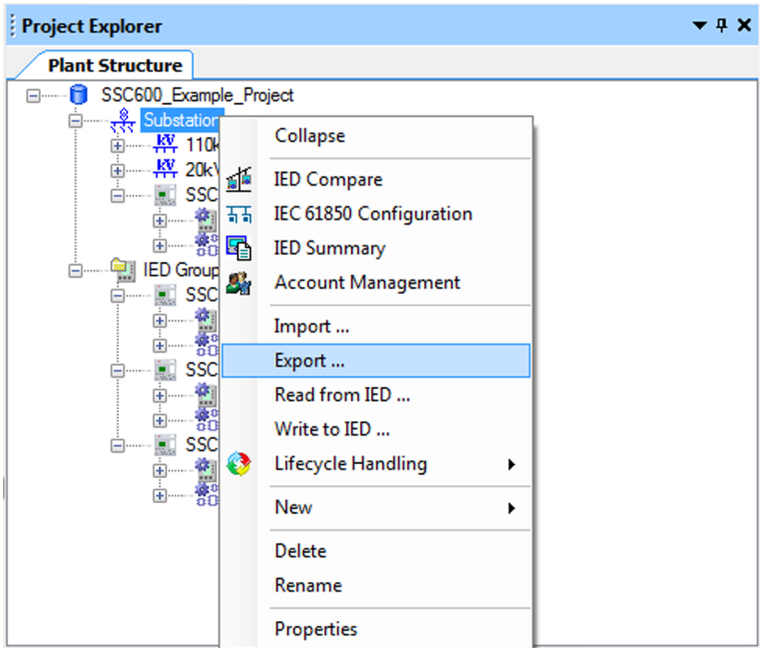


Figure 40: Exporting SCD file from PCM600 and importing it to SAB600

3. Import the SCD configuration into the SAB600 project. In the Project Explorer view, right-click the IEC61850 OPC Server object and select SCL Import.

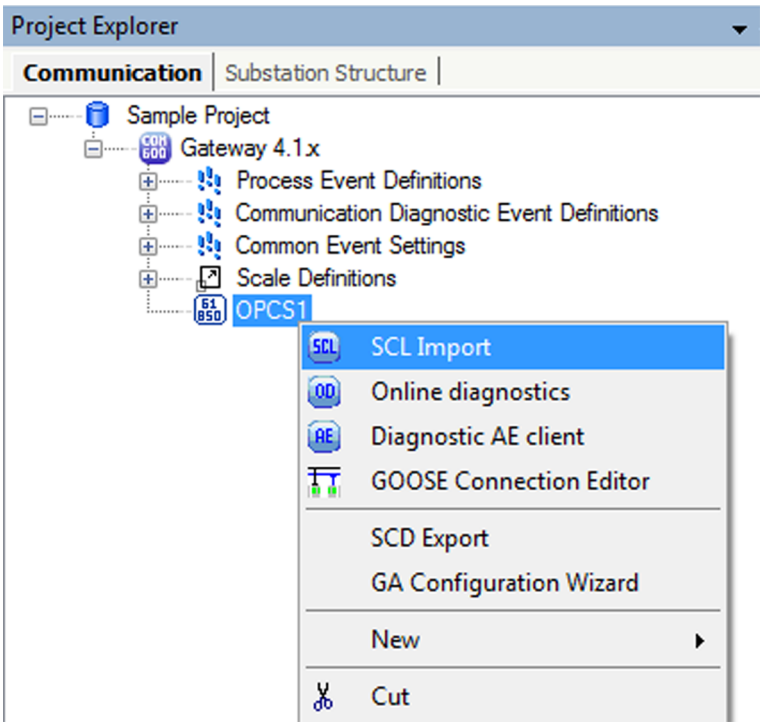


Figure 41: Importing the SCD configuration into the SAB600 project

4. In the SCL Import view, click Select File to select the SCD file exported from PCM600.

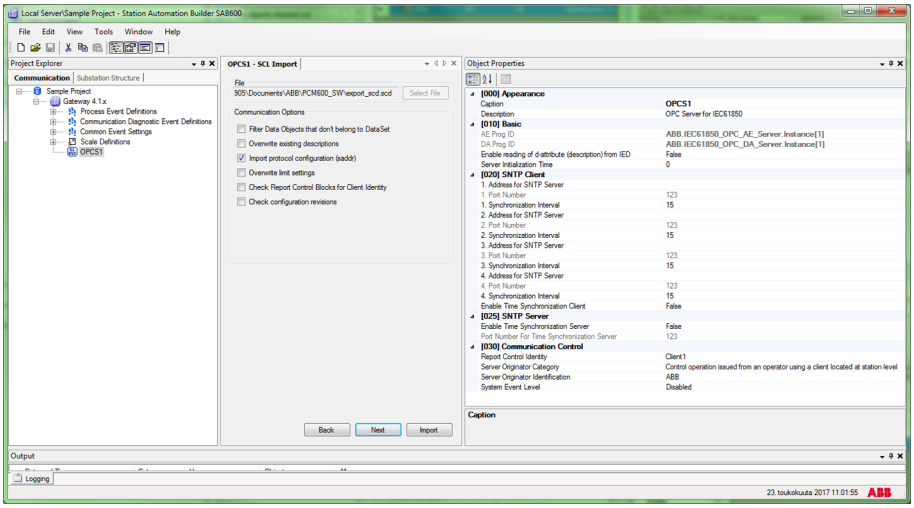


Figure 42: Creating a new IED into SAB600 project

5. Check the default settings in the SCL Import view and change the settings if they are not suitable.

   The default settings in the SCL Import dialog should be correct in most cases.

6. Click Import to import the SCD file.

7. Check the IP address on the IEC 61850 subnetwork and change it if needed.

   When the SCD file is directly exported from PCM600, it uses the IP address of the PCM600 computer, not the COM600S.

The communication towards the IED is now ready. For information on how to finalize the single-line diagram and enable parameter setting through COM600S HMI, see COM600S documentation.

5.5 Using the WHMI

As secure communication is enabled by default, the WHMI must be accessed from a Web browser using the HTTPS protocol.

To establish a remote WHMI connection to the IED, contact the network administrator to check the company rules for IP and remote connections.

Disable the Web browser proxy settings or make an exception to the proxy rules to allow the protection IED's WHMI connection, for example, by including the IED's IP address in **Internet Options/ Connections/LAN Settings/Advanced/Exceptions**.

For more information on the WHMI, see the operation manual.

5.6 Managing IED users

IED user passwords can be changed in WHMI and using the IED Users tool in PCM600.

Remote passwords can be changed via WHMI or with PCM600.

Use the IED Users tool in PCM600 to change the passwords. Select **Tools/IED Users** to start the tool. This tool cannot be used to add or change users.

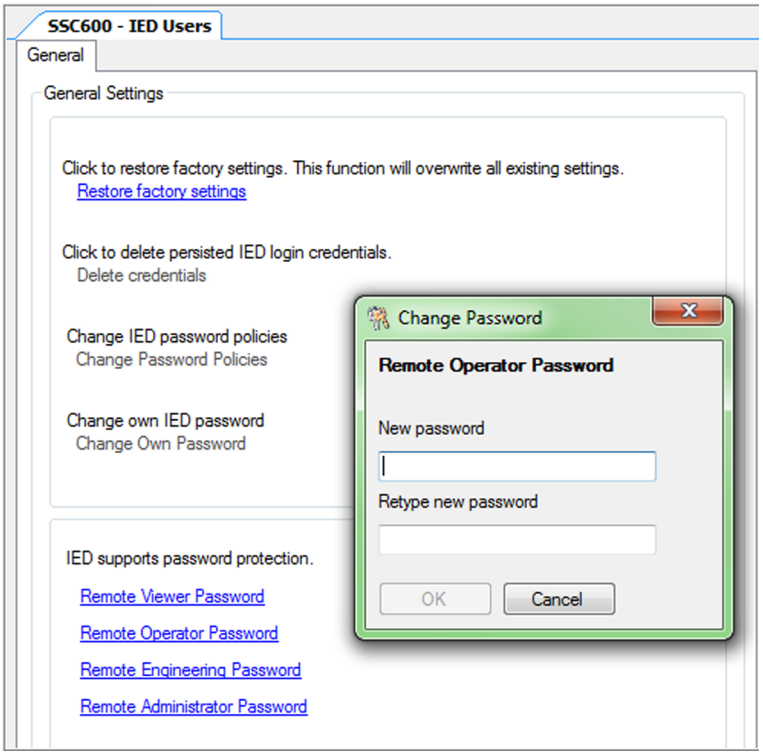


Figure 43: Changing the password using the IED User Management tool

If the PCM600 authentication has been enabled in PCM600 System Settings, a IED user can be linked to the current PCM600 user by selecting the Remember me check box in the Login dialog. After that, the user credentials are no longer asked at tool communication as logging in PCM600 also provides the authentication credentials to the IED.

When communicating with the IED with PCM600 tools and with the IED authentication enabled, the IED username and password must be given when prompted.

5.7 PCM600 project's IEC 61850 version identification

The IEC 61850 version of a PCM600 project can be identified from the Object Properties pane of the project.

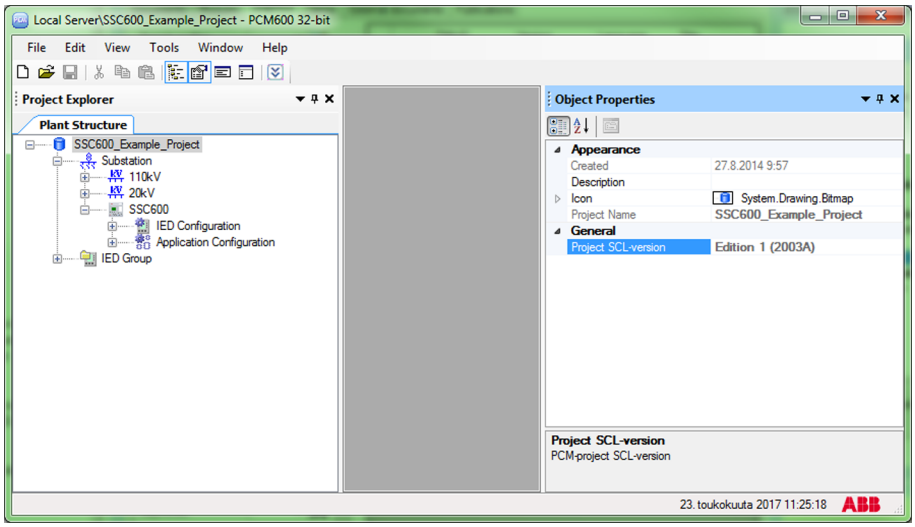


Figure 44: Project's IEC 61850 version

To change the IEC 61850 version Edition 1 of an IED to Edition 2, the configuration has to be written to the IED from a PCM600 project that has the IEC 61850 version Edition 2. A dialog box notifies on the difference of the versions.

6 Protection and control engineering

6.1 Application Configuration tool

Application Configuration tool is used to modify an application configuration for a IED and is based on IEC 61131-3 Function Block Diagrams.

The function blocks are dedicated to different functions.

- Control related functions
- Protection related functions
- Monitoring functions
- Communication

For more information on the function blocks, see the technical manual.

Most function blocks are mapped as logical nodes according to the IEC 61850 standard. See the IEC 61850 parameter list for more information.

If a function block is removed with Application Configuration, the function related data disappears from the menus as well as from the IEC 61850 data model, with the exception of some basic function blocks, which are mandatory and thus cannot be removed from the IED configuration by removing them from the Application Configuration.

Other function blocks are not mapped as logical nodes; for example, logical gates.

The basic features of Application Configuration tool include the ability to organize a configuration into several MainApplications as well as providing different application programming features.

- Organize an application configuration
  - Organize an application configuration into a number of logical parts (MainApplication)
  - Organize a MainApplication over a number of pages
- Features for programming an application configuration
  - Insert function blocks, make connections and create variables
  - Calculate the execution order automatically by clicking Calculate execution order on the toolbar.
  - Document the application configuration: such as, make printouts
  - Save application configurations as templates in an application library to reuse them in other IEDs (Function blocks and related logic can be fully or partially reused depending on the functionality available in other IED)
  - Validate the application configuration during the configuration process on demand and while writing the application configuration to the IED

For instructions on how to perform the different tasks in PCM600, see PCM600 online help.

6.1.1 Main applications

It is recommended to use different MainApplications for functionalities focusing on different Bays (e.g. different MainApplication for the protection application for Bay J01 and different for Bay J02).

The name of the Main Application should start with the technical key of the corresponding Bay.

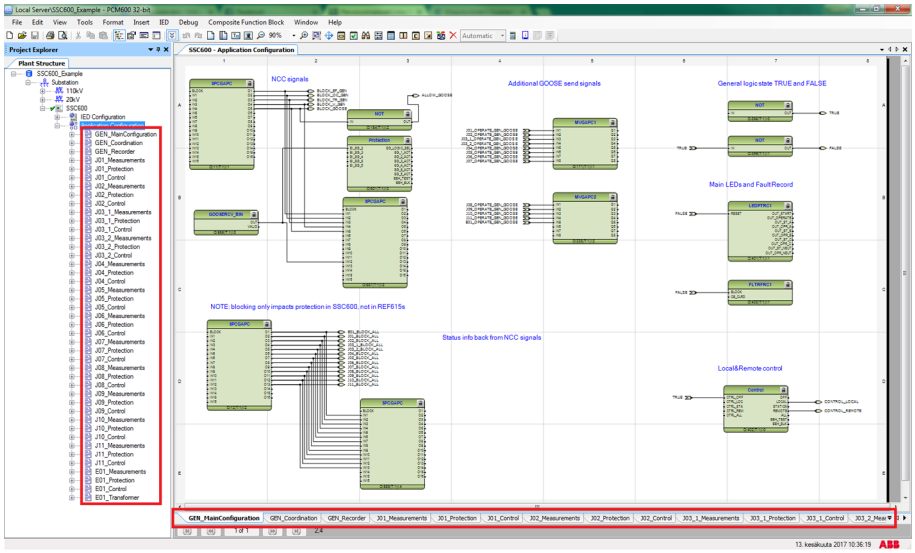


Figure 45: Main Applications

6.1.2 Function blocks

Function blocks are the main elements of an application configuration. They are designed for a various number of functions and organized into groups according to type. The different function block types are shown in the Object Types view. Function block data can be modified with the Application Configuration tool.

- User-defined names can be given for function blocks and signals.

  Signals that have a user-defined name created with the Application Configuration tool are only visible in the Parameter Setting tool if the IED configuration is written to the IED and read back to PCM600. Otherwise, the default signal name is shown in the Parameter Setting tool.

  If possible, set the user-defined name to a signal before connecting the signal to other function blocks.

- IEC 61850, ANSI or IEC 60617 symbol standard can be set.
- IEC or ANSI naming style can be set.
- Function blocks can be locked.
- Visibility for execution order, cycle time and instance number can be set.
- Signals can be managed.
- Boolean inputs and outputs can be inverted.

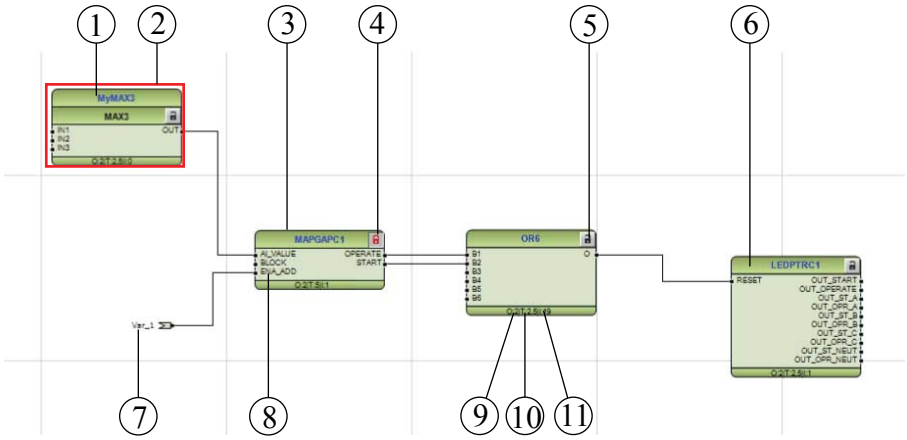


Figure 46: Application Configuration tool: function block overview

1	User-defined function block name
2	Function block, selected (red)
3	Function block name
4	Function block, locked
5	Function block, unlocked
6	Programmable virtual LED
7	User-defined input variable
8	User-defined signal name
9	Execution order
10	Cycle time
11	Instance number

6.1.3 Signals and signal management

The function block has a set of input and output signals. The placement of function block signals is from left to right. Input signals are placed on the left and output signals on the right.

Function blocks can contain more signals than needed in that application part. Unused signals can be hidden to get a clear picture.

Signals are located up and down on both sides of the middle position. When there is space left, some signals may be moved up or down for better visibility and connection routing.

Boolean input and output signals may need to be inverted to fulfil the logic. The Application Configuration tool supports the adding of inversion logic to a binary signal.

All input signals have a default value that is used when the signals are not connected in the configuration.

6.1.4 Function block execution parameters

Three function block execution parameters have an influence on the runtime execution of the function block within the application configuration.

- Execution order
- Cycle time
- Instance number

Each time a new function block is inserted, these parameters are shown in the Function Block Instance dialog box in the Application Configuration tool. The three parameters are selectable and not selectable depending on the function block type. The cycle time is predefined to one value. The instance number is a counter for the total possible number of function blocks of that type used within the application configuration.

The Execution Order and Instance Number are a combination that is predefined within a product. It is possible to select a pair out of the list.

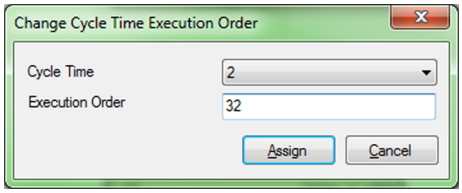


Figure 47: Application Configuration tool: an example of function block organization parameters

The Cycle Time is automatically set and it cannot be modified.

To automatically calculate the execution order, click Calculate Execution Order on the tool bar.

6.1.5 Execution order and feedback loops

It is possible to draw multi-layer configuration logic that contains feedback loops with the Application Configuration tool. The execution order of logic functions is calculated automatically in the Application Configuration tool, but the execution order can also be set manually. If the automatically calculated value causes the function to be executed one task cycle time after the other logic functions in the same loop, the execution order number can be set manually to prevent delays, for example, in output activation.

To perceive accurate time stamps from binary input signals to function blocks, direct logic connection should be used in the Application Configuration tool. Due to internal execution order, time stamps may not be accurate if additional logic is used to connect priority signals to function blocks.

Example shows a simple situation where the execution order causes one cycle time delay if the NOT port is executed in the order determined by the automatic calculation.

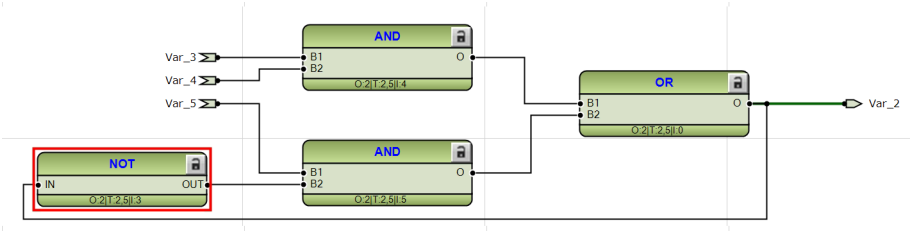


Figure 48: Feedback loop situation with automatically calculated execution orders

By setting a smaller execution number than in the AND port to where the NOT port is connected, it is possible to fix the execution order of all functions in a loop so that they are handled in the same task.

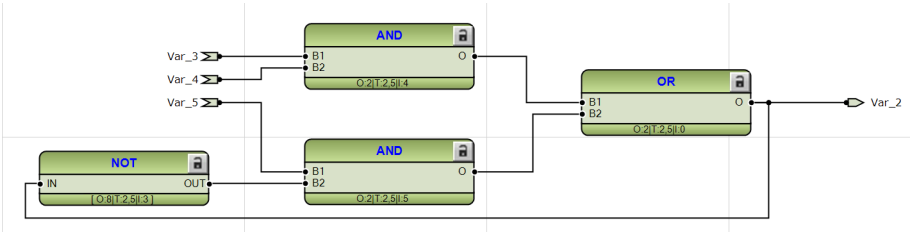


Figure 49: Feedback loop situation with manually fixed execution order for NOT port

Execution number can be changed by right-clicking the function and selecting **Change CycleTime ExecOrder**.

After manually defining the execution number, the function is no longer part of the automatic execution order calculation. The function can be included back to the automatic calculation by right-clicking the function and selecting **Include FB in calculation**.

6.1.6 Configuration parameters

Configuration parameters can be viewed and set with the Parameter Setting tool.

6.1.7 Connections and variables

A connection is the link or "wire" between function block outputs and inputs.

There are rules and methods for making connections.

- Drag a line between two signals
- Link two signals by using variables

It is possible to search and replace variable names in Application Configuration tool.

Connect the variables to a destination, for example to a function block or a hardware output channel. The connectivity package automatically removes the orphan variables which are not connected to any destination.

Connection validation

A connection is only useful or even possible between two signals of the same base attribute type.

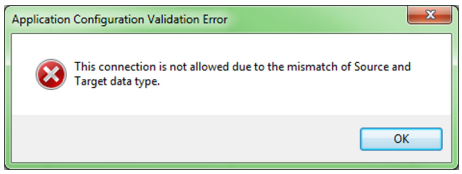


Figure 50: Application Configuration tool: an error message of a signal mismatch for a connection

6.1.8 Online monitoring

The online monitoring enables the continuous monitoring of the signal or channel values in the configuration. In the “Online monitoring” mode, the configuration cannot be edited in the Application Configuration tool.

Online monitoring can be started by clicking the Work online button in the toolbar. If the application configurations in the IED and PCM600 are the same, the online monitoring starts. The online monitoring ends and the tool returns to the configuration mode if the Work Offline button is clicked.

Online monitoring cannot be started if the application configuration in IED and PCM600 are different.

In some cases when the function block input is directly mapped to the function block output, the input is internally forced to the correct value depending of the function block's settings. This kind of function block design is present in control blocks, setting group handling and tap changer.

6.1.9 Validation

Validation checks the application configuration for errors based on the rules that govern the creation of the application at three different times.

- During the logic creation, while making a connection or placing a function block
- On demand by starting the validation
- When writing the application configuration to the IED

6.1.9.1 Validation when creating an application configuration

Validation is made when creating the application configuration.

- A connection between two input or two output signals is not possible
- A connection between two different data types is not possible: for example, from a binary output to an analog input

6.1.9.2 Validation on demand

The validity of an application configuration can be checked by clicking **Validate Configuration** in the toolbar. The Application Configuration tool checks the application configuration for formal correctness. The found problems are divided into warnings and errors.

- Warnings, marked with a yellow warning icon
  - Example: a variable connected to an output signal that is not connected
  - Example: if an output from a user connects an output from a higher execution order function is connected to inputs of lower execution order function
- Errors, marked with a red circle with a cross
  - Example: unconnected hardware output

Warnings do not prevent writing to the IED. However, errors must be corrected before writing the application configuration to the IED. The application configuration can be saved and the Application Configuration tool can be closed with open errors, but the application configuration cannot be written to the IED.

These problems are listed in the **Output** view under the **Application Configuration** tab. Double-clicking the error or warning row navigates to the **MainApplication/ Page/Area**, where the problem was identified.

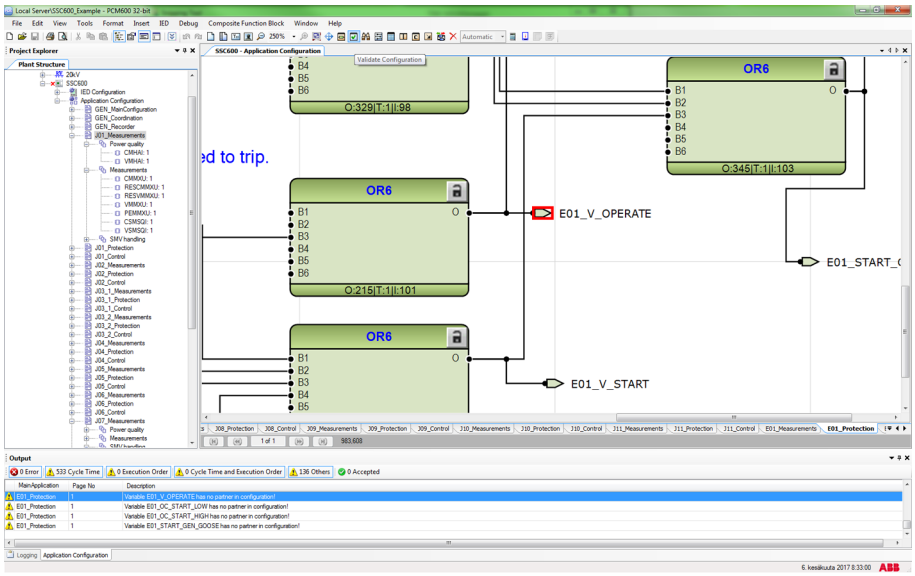


Figure 51: Application Configuration tool: validation on demand

6.1.9.3 Validation when writing to the IED

When writing the application configuration to the IED, an automatic validation is performed. The validation is the same as the manually demanded validation. Errors abort the writing.

6.1.9.4 Load estimation

SSC600 has limited amount of resources to ensure stability of the protection and control application. In-built tool estimates the configuration load and ensures that too big applications can't be created. When modifying the **Application**

Configuration, the estimated load can be found from the PCM600 Output Window. If the estimated load exceeds 100%, it is not possible to write the configuration to the device.

As long as the amount of received IEC 61850-9-2LE streams is 20 or less, SSC600 can manage all feasible protection applications. When amount of received streams get closer to 30, the amount of available protection function instances is limited. Even with 30 streams normal protection applications are still possible. For example busbar differential protection, backup current/voltage protection and circuit breaker failure protection in the same application.

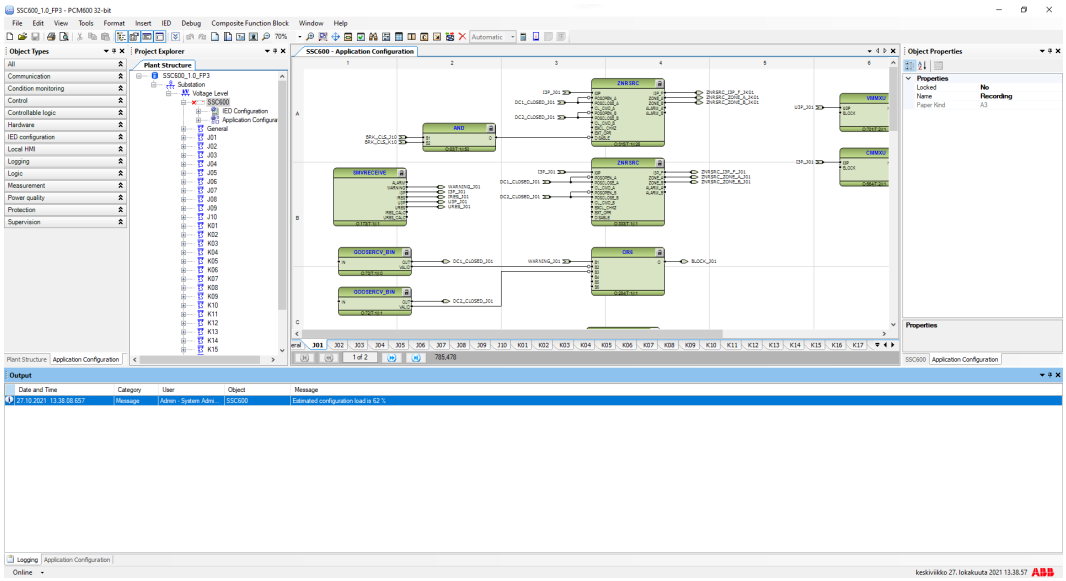


Figure 52: Example of PCM600 output window informing about the load estimation

6.2 Parameter Setting tool

Configuration parameters and settings parameters can be changed with the WHMI or with the Parameter Setting tool in PCM600.

Some parameters are only visible in the Parameter Setting tool and some only in WHMI.

A common writing from PCM600 to the IED, where parameters are changed in the Parameter Setting tool, overwrites any parameter changes made locally with WHMI.

All variables listed and displayed in the parameter list can be sorted into two groups.

- Configuration parameters
- Setting parameters

6.2.1 Configuration parameter

Configuration parameter specifies the operation mode of an application function or of the IED. These are basic configurations that are normally configured only once and then not modified again. The IED configures itself during startup according to the given configuration parameter values.

6.2.2 Setting parameter

Setting parameter (short form: “setting”) is a parameter that can be changed in the IED at runtime.

6.2.3 Setting group

Nearly all settings used by the IED for protection application functions are organized into a group of settings. Up to six setting groups can be configured with different values.

The IED supports the selection of a setting group at runtime.

6.2.4 Parameter import and export

The parameter export and import function can be utilized when the IED's parameters are set using the PCM600. The IED settings engineered with PCM600 can be exported to XRIO files.

The exporting and importing of settings is sensitive to the IED's content. Settings are exported and imported for one IED at a time. The export files of a specific IED can be exchanged between PCM600 and the actual physical IED. To avoid errors and to efficiently manage the exporting and importing of settings, for example, in a substation with several IEDs, ensure that the names of the export files identify the IED to which the file should be imported.

The parameter import/export functionality is available via the File menu when the Parameter Setting tool is open.

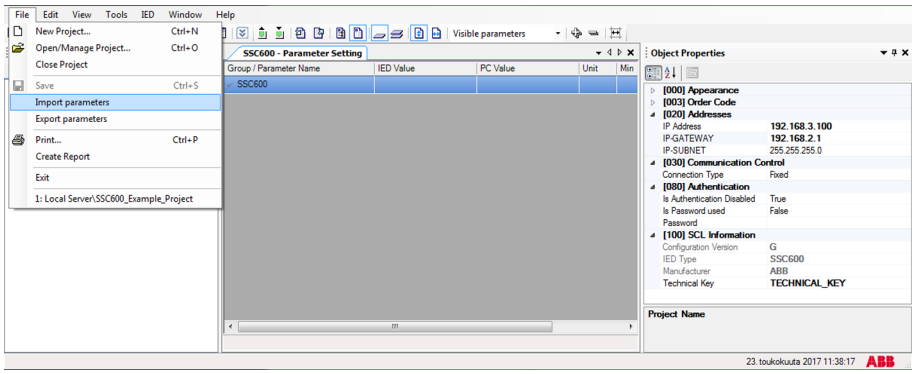


Figure 53: Parameter import/export

6.2.5 Parameter organization

The organization of parameters into a tree structure becomes visible in the Plant Structure by expanding the setting tree.

6.3 Signal Matrix tool

The Signal Matrix tool is used to make cross-references for the GOOSE signal input engineering.

The Application Configuration tool is used for adding or removing function blocks, for example, GOOSE receiving function blocks.

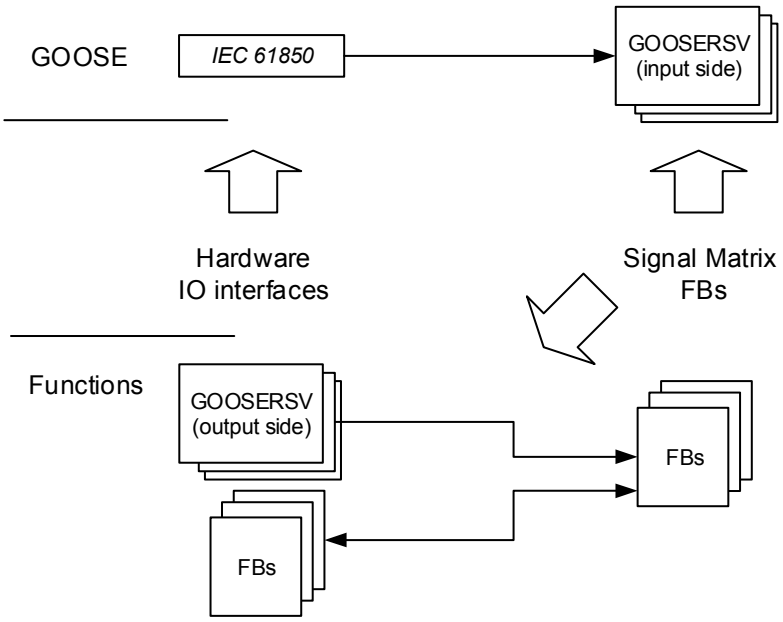


Figure 54: Signal Matrix: operation principles

Glue logic means inserting a logical gate (OR and AND blocks) between the function blocks and the binary output channel. This can be engineered with the Signal Matrix tool.

Connections made with the Signal Matrix tool are automatically also shown in the Application Configuration tool.

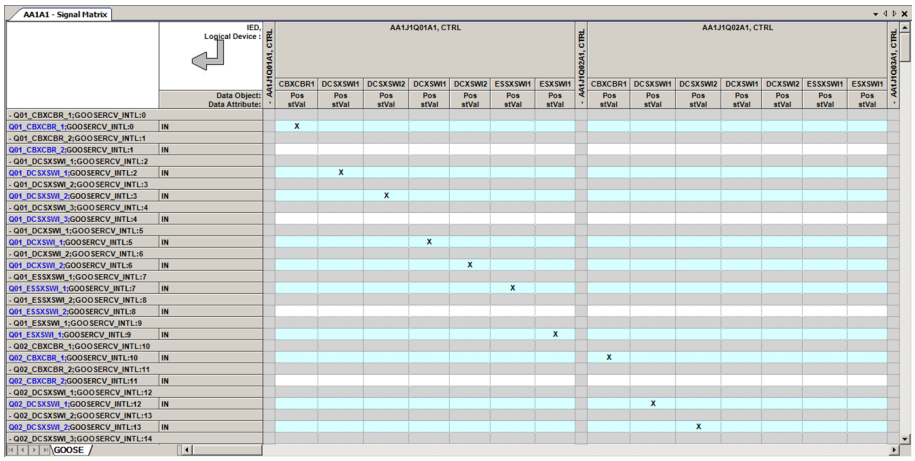


Figure 55: Signal Matrix: a connection between binary input channels to binary input signals

6.4 Fault Record tool

The Fault Record tool is used for reading the fault records from the IED and it is included in the connectivity packages. The tool makes analyzing the fault records easier by showing them separately in their own user control components. It also includes save, copy and clear functions where all the fault records are saved or copied in text format for later viewing or cleared from the IED or the tool.

The fault record is saved to a local PC with the default name FaultRecords.txt. Revise the file name before saving to avoid overriding the old record.

6.4.1 Opening and closing Fault Record tool

To open the Fault Record tool, right-click an IED node in the PCM600 project tree and select **Fault Record Tool**.

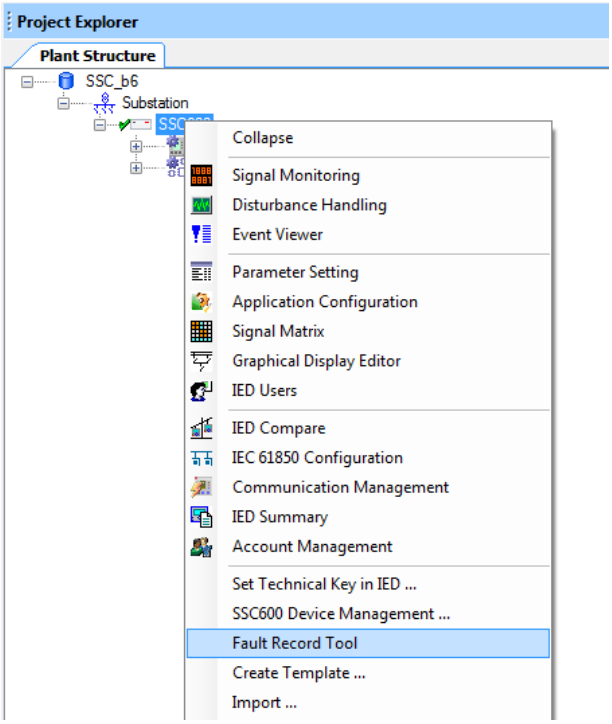


Figure 56: Opening the Fault Record tool

- To close the Fault Record tool, click the Close button in the tool. The Fault Record tool runs in the same process as PCM600 but in a separate window. Multiple instances of the tool can be run at the same time. Any open tool instances are closed without confirmation when PCM600 is closed.

The Fault Record tool is a connectivity package tool. The main functionality is divided into three parts: reading the fault record parameters from the IED, displaying their names, values and units on the user interface and saving them to a text file. It is also possible to clear all the fault records from both the tool and the IED and copy the fault records either individually or all at once to a word processor.

6.4.2 Fault Record tool interface

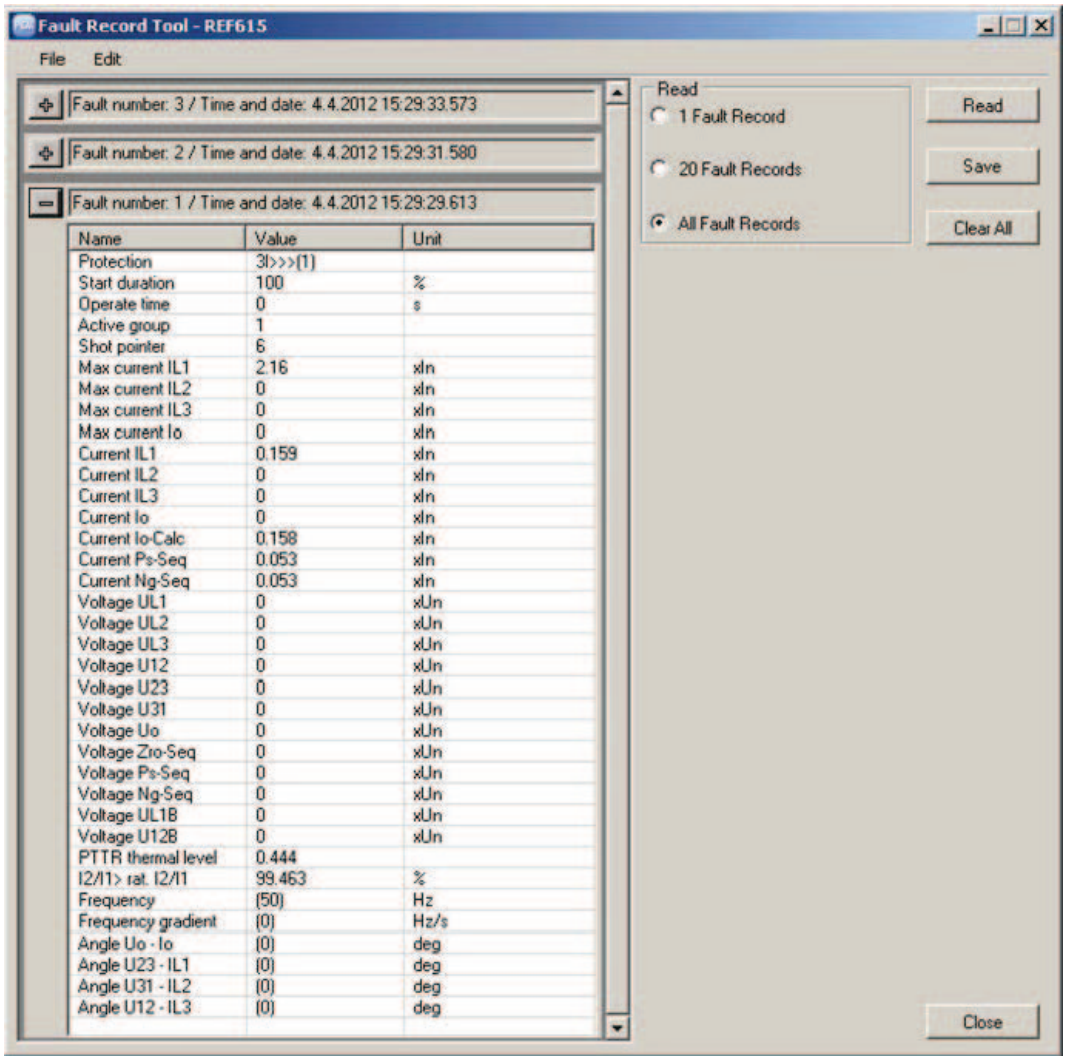


Figure 57: Fault record tool

Table 10: Available actions on the user interface

Action	Description
Read	Clicking **Read** reads all available fault records from the protection relay into the tool. One fault record, 20 fault records or all fault records can be read. The **Read** button opens up a progress bar to indicate an ongoing read operation. Clicking **Cancel** on the Read progress bar cancels the read operation. On operation completion, the available fault records are shown in the record grid. Click the **+** icon to expand and view record details.
Save	Clicking **Save** saves the fault records on the local machine as .txt file.
Clear	A record can be cleared from either the Fault record tool, the protection relay or both. Before deleting the records, a confirmation dialog box is shown.

Table continues on the next page

Action	Description
Close	Clicking **Close** closes this instance of the Fault Record tool. All open instances are closed when PCM600 is closed.
File	**File** menu for **Save** and **Exit** actions.
Edit	**Copy All** in the **Edit** menu allows to copy all the fault records which can then be pasted to a word processor and saved on the local machine without having to save the records as a .txt file. Additionally the user can select any particular fault record and right-click to copy the selected record.

6.5 IED Compare

IED Compare is used to compare the IED configuration of two same type of IEDs. It generates a text report which lists the differences in the IED configuration. IED Compare provides an option to compare an IED configuration stored in PCM600, IED or pcmi file. IED Compare can compare certain types of IED configurations and parameters.

- Application configuration
- Display configuration
- GOOSE receive configuration
- Parameters

Application comparison also compares the system function blocks.

Display comparison compares two display pages with a delta of two pixels.

Detailed instructions are shown in PCM600 documentation.

6.5.1 Starting IED Compare

- Start IED Compare in the context menu in plant structure.
  a) In the PCM600 plant structure, right-click Substation, Voltage level, Bay or IED.
  b) Select IED Compare.
- Start IED Compare from the PCM600 main menu.
  a) Select Substation, Voltage level, Bay or IED in the PCM600 plant structure.
  b) On the PCM600 menu bar, point to Tools and select IED Compare.

6.5.2 IED Compare tool interface

The comparison report shows differences in the configuration of two IEDs. Hardware, application, display, GOOSE and parameter configuration differences are grouped and listed under the corresponding headings.

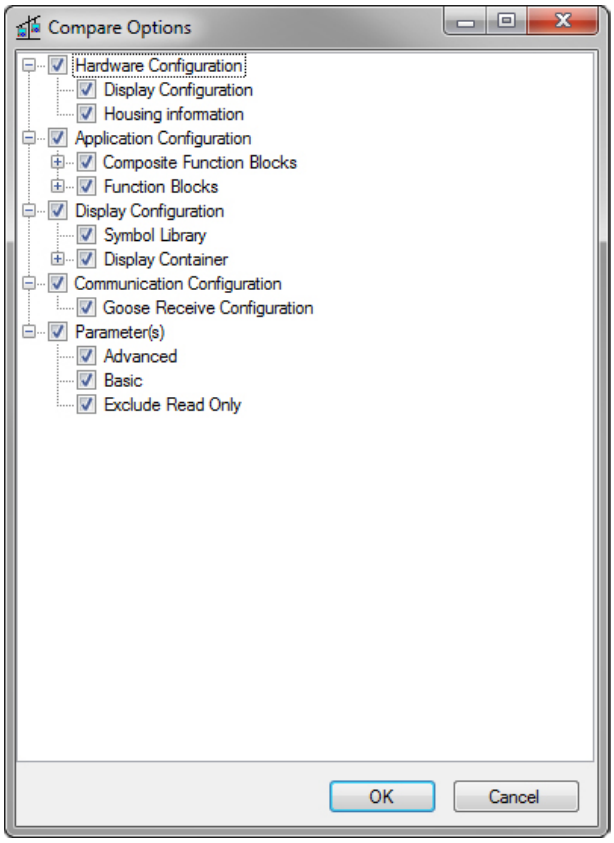


Figure 58: Compare options

Each configuration group can be expanded or collapsed by clicking the plus (+) or minus (-) button next to it in the result grid.

The reports must be read from left to right row-wise.

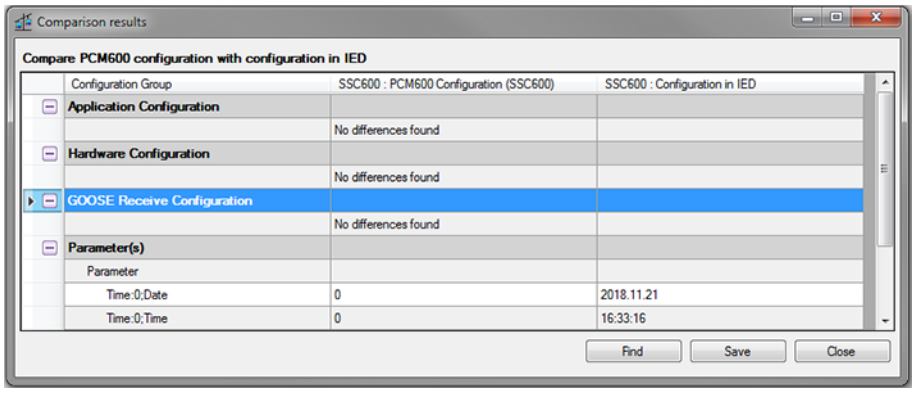


Figure 59: Compare report

Table 11: Acronyms used in a report

Acronym	Description
DA	Data attribute
DO	Data object
IED	Intelligent electronic device
LN	Logical node
SIG	Signal

6.6 Protection and control blocking examples

All of the IED's logical nodes are set with Test mode. Test mode is selected through one common parameter via the HMI path Tests/IED test. By default, Test mode can only be set locally through LHMI. Test mode is also available via IEC 61850 communication (LD0.LLN0.Mod).

Table 12: Test mode

Test mode	Description	Protection BEH_BLK
Normal mode	Normal operation.	FALSE
IED blocked	Protection working as in "Normal mode" but ACT configuration can be used to block physical outputs to process. Control function commands blocked.	TRUE
IED test	Protection working as in "Normal mode" but protection functions are working in parallel with test parameters.	FALSE
IED test and blocked	Protection working as in "Normal mode" but protection functions are working in parallel with test parameters. ACT configuration can be used to block physical outputs to process. Control function commands blocked.	TRUE

The mode of all logical nodes located under CTRL logical device are set with Control mode. Control mode is selected via the HMI or PCM600 path Configuration/Control/General. By default, Control mode can only be set locally through LHMI. Control mode inherits its value from Test mode but Control mode "On", "Blocked" and "Off" can also be independently set. Control mode is also available via IEC 61850 communication (CTRL.LLN0.Mod).

Table 13: Control mode

Control mode	Description	Control BEH_BLK
On	Normal operation.	FALSE
Blocked	Control function commands are blocked.	TRUE
Off	Control functions disabled.	FALSE

According to IEC 61850, the physical outputs to process should be blocked when device is set to blocked or test blocked mode. The usage depends heavily on the actual ACT configuration. In the protection blocking example the main trip from TRPPTRC1 is blocked, and in the control blocking example the CBXCBR1 is blocked. Both comply to the IEC 61850. In real applications some of PTRC's might also be used for signaling purposes (GOOSE) and blocking and interlocking via IO.

6.6.1 Protection blocking example

The physical outputs to process can be blocked with "IED blocked" and "IED test and blocked" modes. If physical outputs need to be blocked, the application configuration must block signals or function blocks that affect primary apparatuses. Blocking scheme needs to use BEH_BLK output of PROTECTION function block.

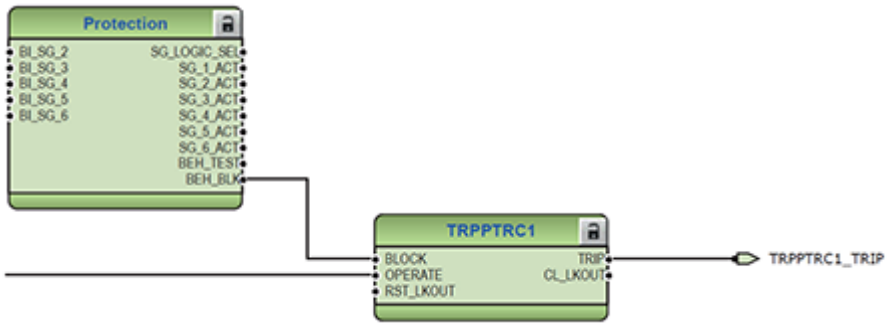


Figure 60: Master trip TRPPTRC blocked using Protection function block BEH_BLK output

6.6.2 Control blocking example

The physical outputs to process can be blocked with "Blocked" mode. If physical outputs need to be blocked, the application configuration must block signals or function blocks that affect primary apparatuses. Blocking scheme needs to use BEH_BLK output of CONTROL function block.

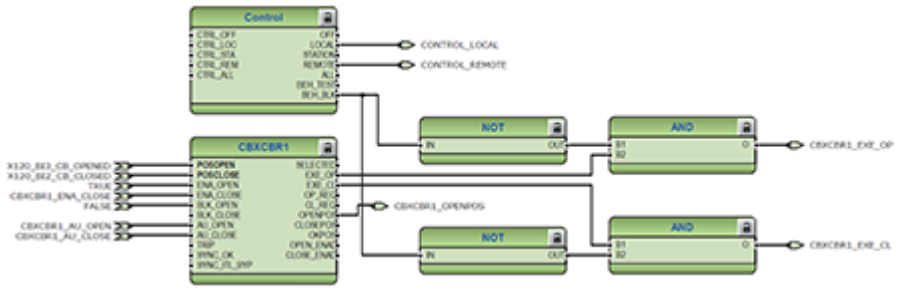


Figure 61: Circuit breaker control CBXCBR1 blocked using Control function block BEH_BLK output

7 WHMI engineering

For information on LED operation modes supported by the IED, see the technical manual.

7.1 Single-line diagram engineering

A single-line diagram of the IED can be designed by using the Graphical Display Editor tool of PCM600. The single-line diagram is modelled according to the IEC 61850 standard in the Graphical Display Editor.

7.1.1 Diagrams in Graphical Display Editor

The Graphical Display Editor is used for various tasks.

- Creating HMI display raster layouts
- Adding static text
- Adding measurands
- Adding busbars
- Adding symbols onto display page
- Drawing lines (creating a link)
- Adding buttons to control ACT application with SPCGGIO

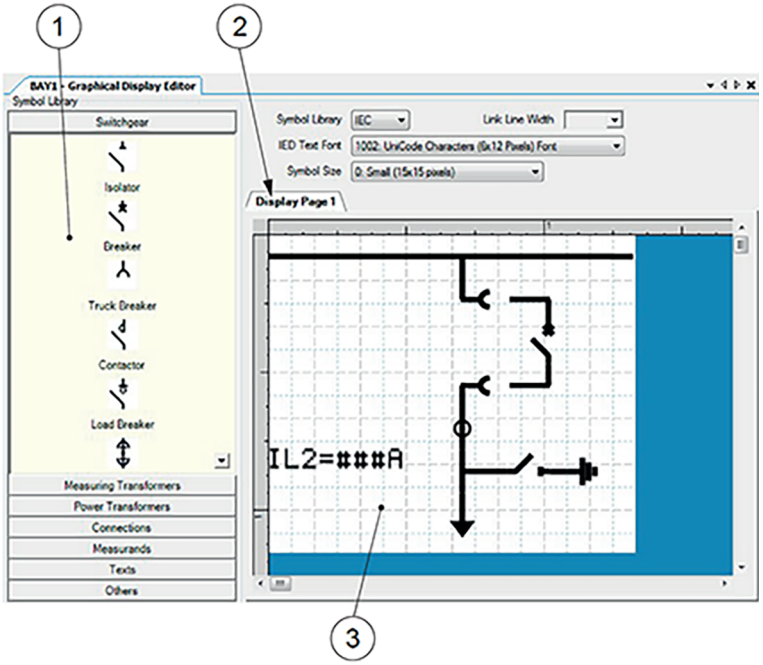


Figure 62: Graphical Display Editor: active view

1	Symbol library window
2	HMI display page
3	IED HMI display window

The Graphical Display Editor has a stationary symbol library window on the left side of the view. The window is empty when no page exists for the IED. A default single-line diagram presentation is displayed if standard configurations are used.

Additional single-line diagram HMI display pages can be added or removed with the Add Display Page or Remove Display Page commands in the Graphical Display Editor menu.

7.1.1.1 Display window and sequence order

The HMI pages are handled according to rules.

- SSC600 supports single-line diagram for a substation up to 30 bays
- Measurements and the single-line diagram can be displayed on the page in any possible order and placement.
- All symbol objects, for example apparatus and measurement, on the HMI page must be linked to the correct function block in the application configuration to present the correct process values.

7.1.1.2 Symbol library

The Symbol Library view contains panes that include drawing symbols or elements for creating a single-line diagram, measurements and texts onto a page. Panes can be opened by clicking the name bar of the selected element.

The library shows the symbols either in the ANSI standard or IEC standard. The standard is selected from the list located on top of the window.

When changing to another library standard, Graphical Display Editor changes the symbols according to the selected new standard and redraws the single-line diagram in the window.

To change the symbol format used in the IED, select Main menu/ Configuration/HMI/SLD symbol format and choose IEC or ANSI.

To become familiar with the available symbols, select the different panes and their symbols.

7.1.1.3 Supported single-line diagram symbols

Description	IEC representation	ANSI representation
Disconnector – Intermediate position		
Disconnector – Open position		
Disconnector – Closed position		
Disconnector – Bad (faulty) position		
Circuit breaker – Intermediate position		
Circuit breaker – Open position		
Circuit breaker – Closed position		
Circuit breaker – Bad (faulty) position		
Truck – Intermediate position		
Truck – Open position		
Truck – Closed position		

Table continues on the next page

Description	IEC representation	ANSI representation
Truck – Bad (faulty) position		
Contactor – Intermediate position		
Contactor – Open position		
Contactor – Closed position		
Contactor – Bad (faulty) position		
Load Breaker – Intermediate position		
Load Breaker – Open position		
Load Breaker – Closed position		
Load Breaker – Bad (faulty) position		
Disconnecting truck – Intermediate position		
Disconnecting truck – Open position		
Disconnecting truck – Closed position		
Disconnecting truck – Bad (faulty) position		
Current transformer		
Voltage transformer 2 windings		
Voltage measurement truck – Intermediate position		
Voltage measurement truck – Open position		

Table continues on the next page

Description	IEC representation	ANSI representation
Voltage measurement truck – Closed position		
Voltage measurement truck – Bad (faulty) position		
Current sensor		
Voltage sensor		
Transformer 2 windings		
Transformer 3 windings		
Autotransformer		
Tap changer		
Transformer 2 windings with earth		
In-feeder		
Out-feeder		
Earth symbol		
Button		
Capacitor		
Motor		
Generator		
Fuse		

Table continues on the next page

Description	IEC representation	ANSI representation
Resistor		
Earthing transformer		
Petersen coil		
Power factor controller		

7.1.1.4 HMI display raster layout and text font selection

The raster on the page changes from symbol presentation to text presentation when a text object is selected and vice versa.

Raster and shown symbols are only visible in the GDE tool, WHMI has different SVG symbols.

The visible display for a single-line diagram is organized in a raster of 9 x 7 (columns x rows). Each symbol (presented in 15 x 15 pixels) included in the drag-and-drop method must be dropped into a raster box.

The description text for an apparatus object can be placed in all four directions around the symbol. The description is part of the apparatus object. It is possible to place the symbols without the assistance of Snap to Grid and manually change the position coordinates.

7.1.1.5 Text handling

The display switches when text is selected in a display of 22 x 9 (columns x rows). One display box holds one character. A text element must be placed in the position of the display.

The name and the unit of a measurement or text symbol can be changed by double-clicking the symbol or via the Object Properties view.

Selecting and toggling Show Texts using the IED fonts can be used to preview the single-line diagram to see how it is presented in the real HMI display.

7.1.1.6 Adding select buttons

1. Drag a **Select Button** object into a raster box.

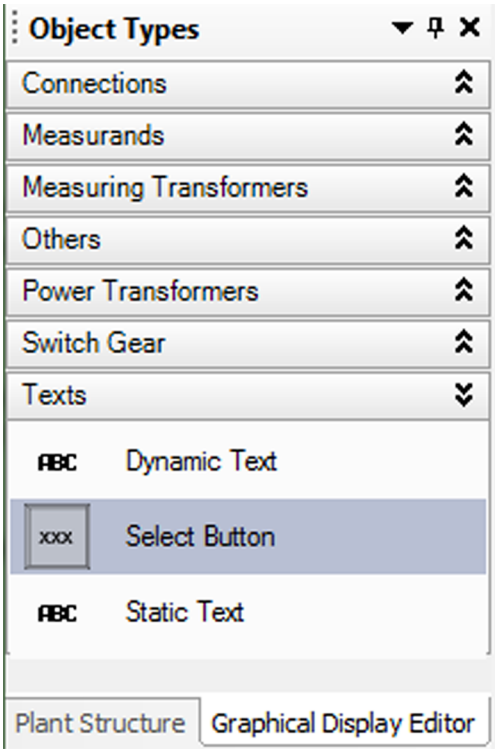


Figure 63: Select button

2. Right-click the select button symbol, point to **Select Input Signal** and select the input signal from the list.

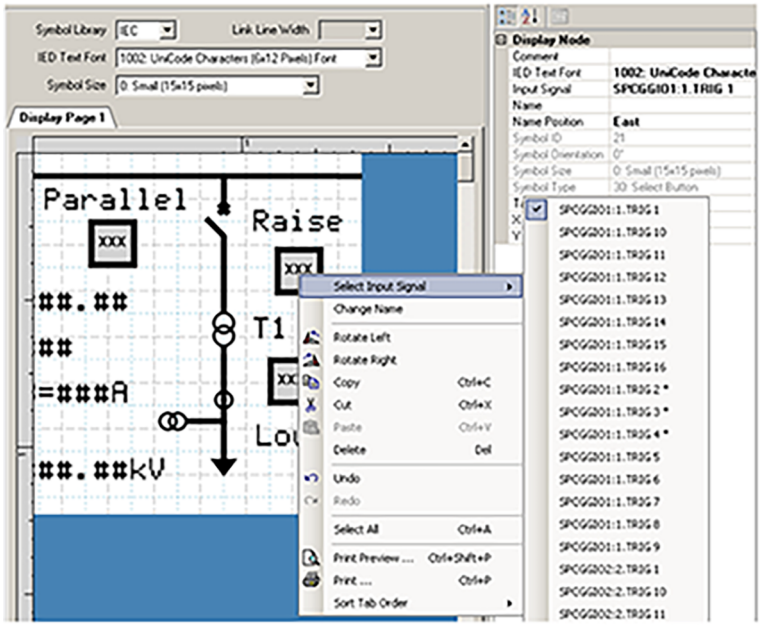


Figure 64: Selecting input signal

7.1.1.7 Adding a measurand

1. Drag a **Measurand** object into a raster box.

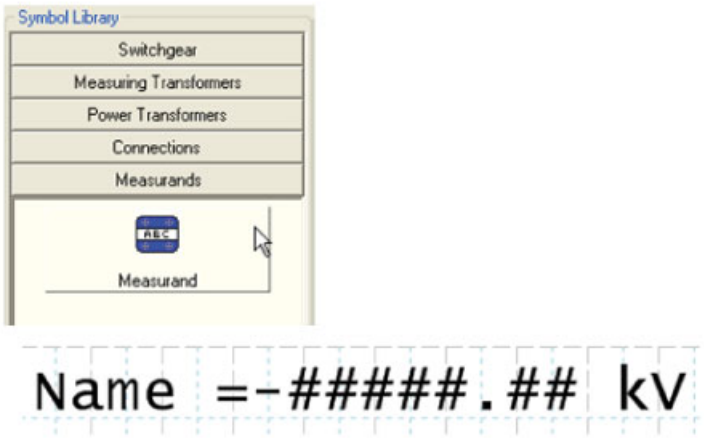


Figure 65: Adding a measurand object to an WHMI view

2. In the **Objects Properties** view, edit the name, unit and the number of decimals.
   Unit text specifies the default text used for the measurement's unit. If the Unit text is empty in the Graphical Display Editor, no unit is shown. If the Unit text is not empty, the unit in the IED is updated dynamically based on the signal it is connected to. The Scale factor parameter is not used.

Uncheck the option **Place Symbol at available space** in the Graphical Display Editor menu to allocate more space for symbols near measurands.

7.1.1.8 Adding a busbar

1. Add at least two Busbar Junction elements from the Symbol Library to the display page.
2. Select the Busbar Junction and use the rotate command from the toolbar to ensure that the busbar ends to the margin.

3. Add links between the busbar junctions.

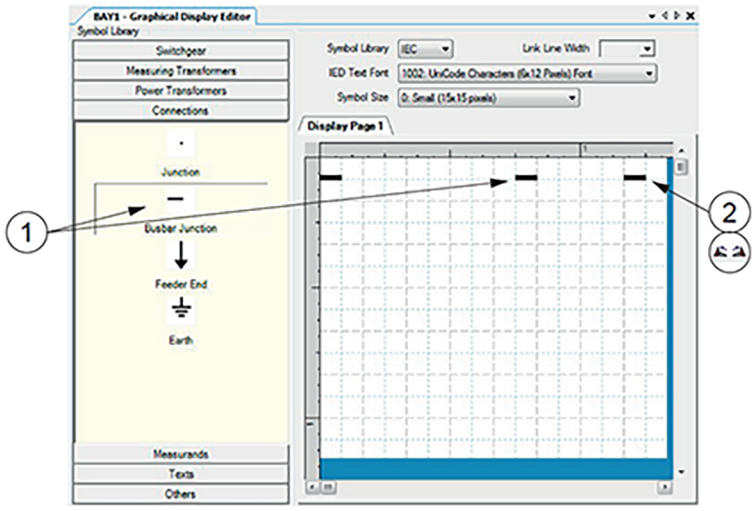


Figure 66: Graphical Display Editor: drawing a busbar and placing busbar junctions

1	Busbar junction
2	Rotate command

4. Add a link between one busbar junction point and the corresponding symbol or junction point.

Only horizontal busbars are supported by SSC600 WHMI.

7.1.1.9 Adding symbols into a display page

1. Prepare the body of the single-line diagram by locating symbols to the wanted positions on the display.
2. Drag the apparatus or transformer symbols into a raster box.
3. Drag the connection symbols into a raster box.
4. Place the junction points.

   Do not connect two symbols directly to each other. Instead, add a junction between them.

5. Use the X and Y coordinates in the Object Properties window to adjust the placement of symbols in the single-line diagram.

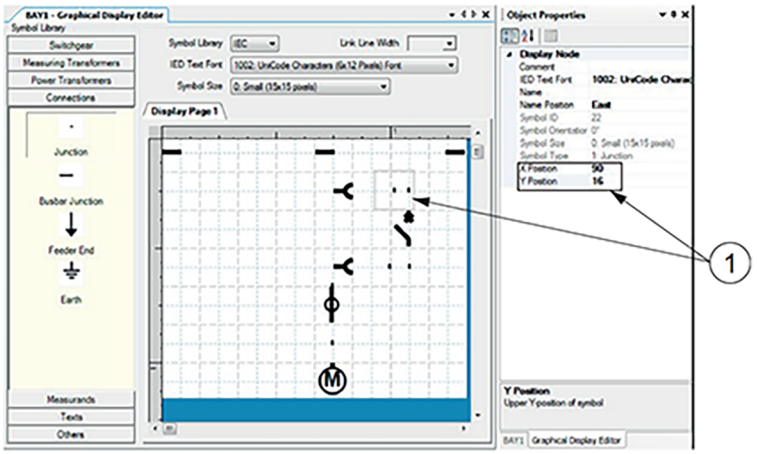


Figure 67: Graphical Display Editor: adding single-line diagram symbols into a display page

1	X and Y coordinates

7.1.1.10 Drawing lines to create links

After the apparatus symbols are placed, lines can be drawn to create links.

1. To draw a line, point to the center of the connection point which is visible in two circles at the end points of a line.
2. Drag the pointer to the destination connection point. Center the pointer again and release to draw the line.

3. Draw all the necessary line elements.

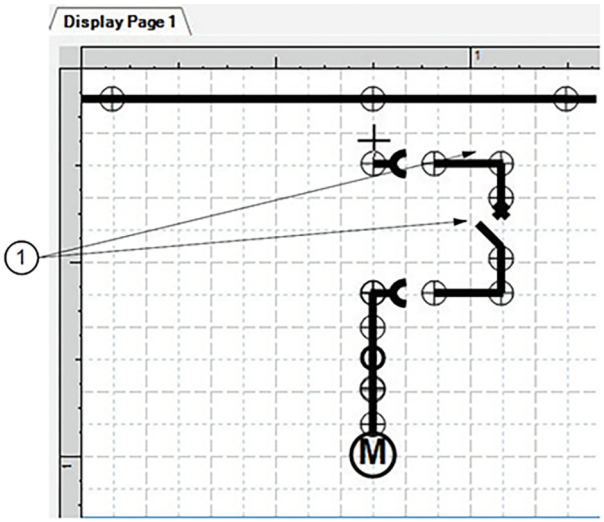


Figure 68: Graphical Display Editor: drawing a line between symbols

1 Line draw icon used for drawing lines between symbols

7.1.2 Object configuration engineering

A view with a single-line diagram and measurements contains active living objects. The object values are updated by the IED periodically (measurement) or in case of an event.

Once the symbols are placed on the HMI page, they must be linked to the corresponding function block in the application configuration, which protects or controls the object that the symbol on the HMI page represents.

7.1.2.1 Linking process objects

To describe a process object within an IED, it needs to be established in the application configuration, configured when given the parameters by the Parameter Setting tool and linked to be displayed in the HMI.

Three tools are involved in the described steps.

- Application Configuration tool for programming the application function block for the apparatus and measurements
- Parameter Setting tool for adapting the settings and configuration parameters of the application function block
- Graphical Display Editor for establishing the link to update the selected data attribute in the HMI of the application function block

The needed information is delivered with switch controller (of type CSWI) for an apparatus and all the configured function blocks with measurements (of type MMXU) for the measurements

1. Right-click the apparatus symbol and select Select Input Signal.

   A list of engineered switch control application function blocks opens.
2. Select the switch control application function block that corresponds to the selected apparatus.
3. Right-click the measurement symbol and select Select Input Signal. A list of the engineered measurement application function blocks opens.
4. Select the measurement application function block that corresponds to the selected symbol.

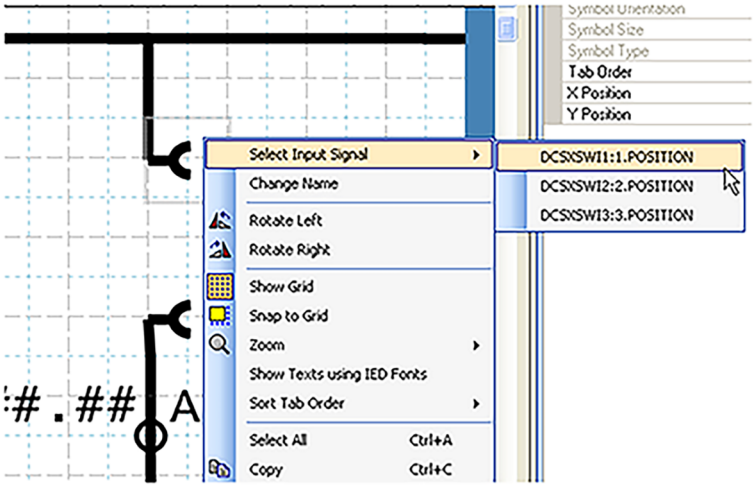


Figure 69: Graphical Display Editor: input signal selection

The ordering number in the selection window of the process objects corresponds to the number given in the Parameter Setting tool tree and to the application function block in the Application Configuration tool. Only the apparatus and measurements that are configured in the application configuration program are displayed.

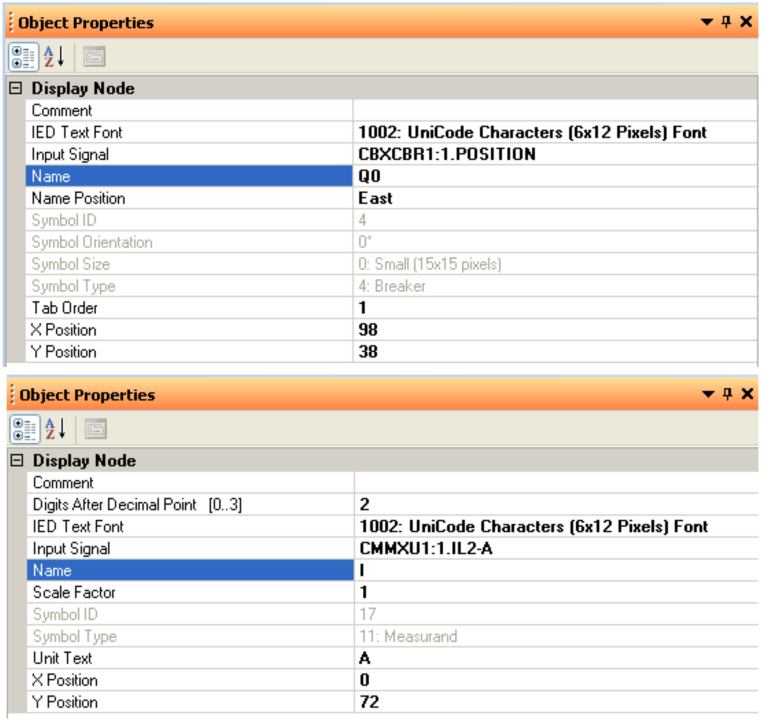


Figure 70: Graphical Display Editor: object properties view for text insertion

7.1.2.2 Creating a complete HMI display page

1. Make a sketch of how to present the single-line diagram.
2. Place the apparatus, transformer and other symbols that are needed for the single-line diagram into the raster boxes.
3. Add Junction points where needed.
4. Link the apparatus symbols with line elements.
5. In the Object Properties view, adjust the text symbols while writing to north, east, south or west.
6. Place measurements when needed.
7. Edit the name, unit and the number of the measurements' decimals.
8. Select each object that has a dynamic link and make the link to the corresponding process object.

9. Check that the correct function block is selected.
   Function blocks of the same type can have different instance numbers.

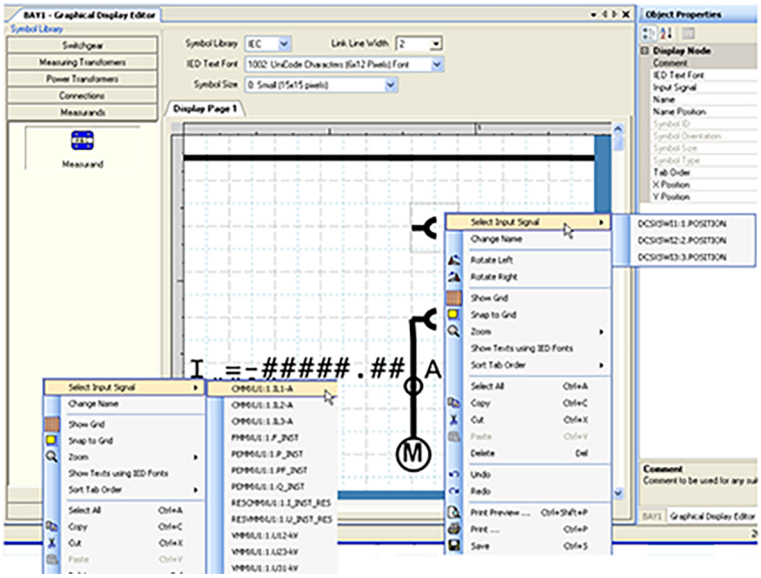


Figure 71: Graphical Display Editor: establishing a dynamic object link

10. Ensure that all links are done.
11. Save the complete picture.
12. Write to the IED.
13. Validate the single-line diagram on the IED.

8 IEC 61850 Engineering

The international IEC 61850 standard defines a framework for substation communications networks and systems. The standard consists of several parts ranging from the requirements on substation automation systems to the details of a communication protocol. Its main goal is interoperability; the ability for IEDs from one or different manufacturers to exchange information and use the information for their own functions.

IEC 61850 standard for communication networks and systems in substations has been out since 2005 and used successfully in ABB products. IEC 61850 standard is updated with a new version, Edition 2. Edition 2 extends to new application areas in transmission and distribution power systems and also defines a new functionality to Edition 1 functionality. This product series supports both versions of IEC 61850, Edition 1 and Edition 2.

Edition 2 is a new version of IEC 61850 standard and it adds new functionality which is not supported by the Edition 1 devices. Therefore it is recommended to always use the same standard version in all devices and not to mix different versions in the same project.

A major difference between the other communication protocols applied in substation automation and IEC 61850 is that the latter is not only a communication protocol, but a whole framework for specifying, engineering and operating substation automation systems. The communication part covers the connection between the IEDs and the substation clients, for example, SCADA and gateways.

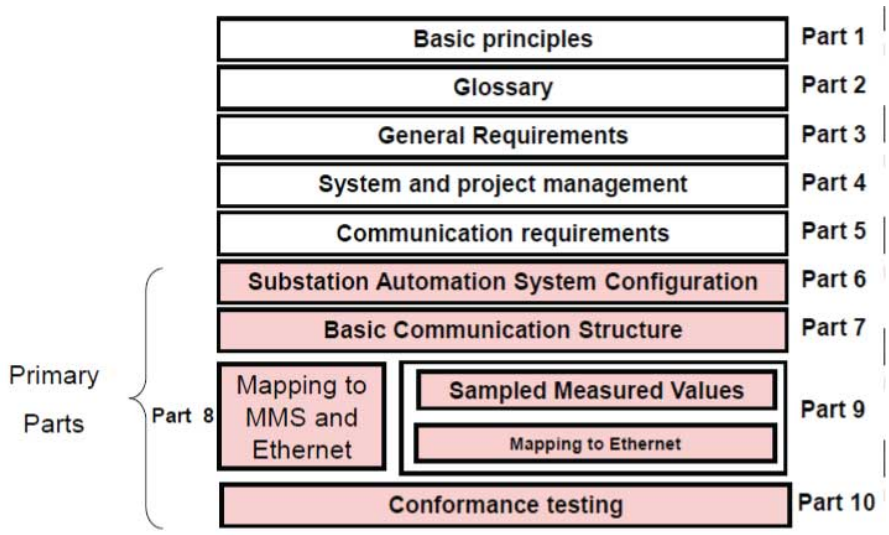


Figure 72: Structure and parts of the IEC 61850 standard

The IEC 61850 standard specifies an expandable object-oriented data model and wide set of protocol services for substation automation (standard parts 7-x). The standard does not specify any protection or control functions, but specifies how the functions expose their information to a communication network.

The standard supports free allocation of functions to devices. With efficient communication facilities, the functions can be located anywhere in the system, that

is, an interlocking function can reside in the IED or on the station level. Additionally, the standard is open for different system implementations, that is, different integration levels and allocation of functions to different devices is supported.

The standard also defines an XML description language for substation automation systems. The language facilitates efficient integration of devices into systems in an automated fashion. Additionally the standard supports a comprehensive and consistent system definition and engineering, which makes not only the devices, but also their tools and systems interoperable (standard part 6).

The standard uses Ethernet and TCP/IP for communication. Since Ethernet and TCP/IP are widely accepted and used, the application of these technologies provide a broad range of features from mainstream communication (standard parts 8-1, 9-2).Communication profiles in IEC 61850 can be divided to vertical and horizontal. The vertical profile uses MMS over TCP/IP and vertical communication Layer 2 Ethernet multicast messages. The standard separates the functionality represented by the data model and the related communication services from the communication implementation thus being open for possible new communication concepts in the future.

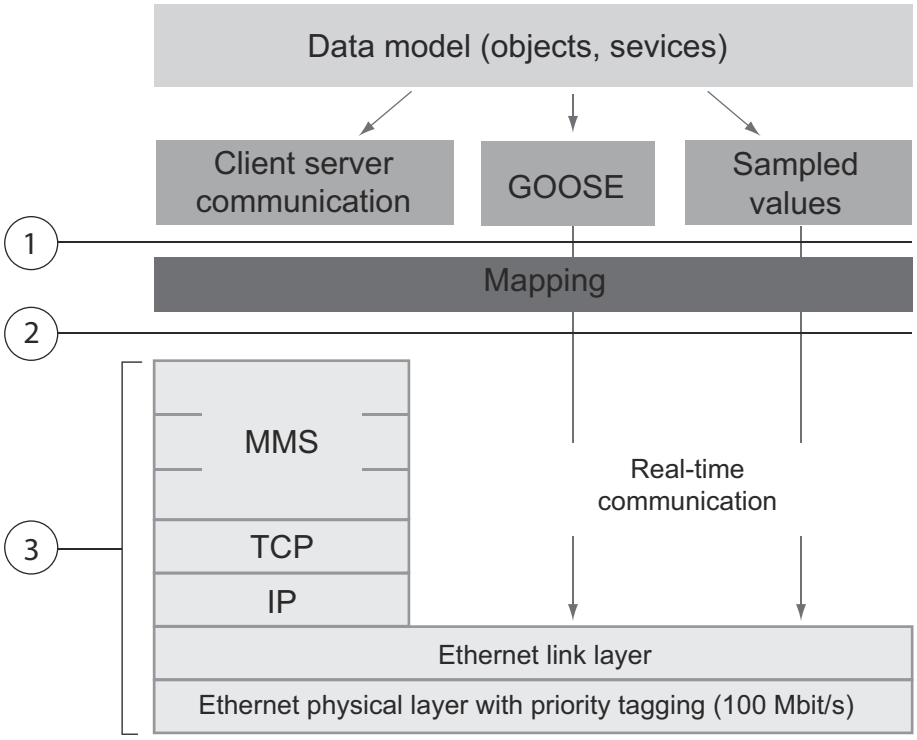


Figure 73: Communication stacks and mapping used in IEC 61850

1	Abstract communication services interface (ACSI)
2	Stack interface
3	ISO/OSI stack

8.1 IEC 61850 Overview

8.1.1 IEC 61850 interface in the IED

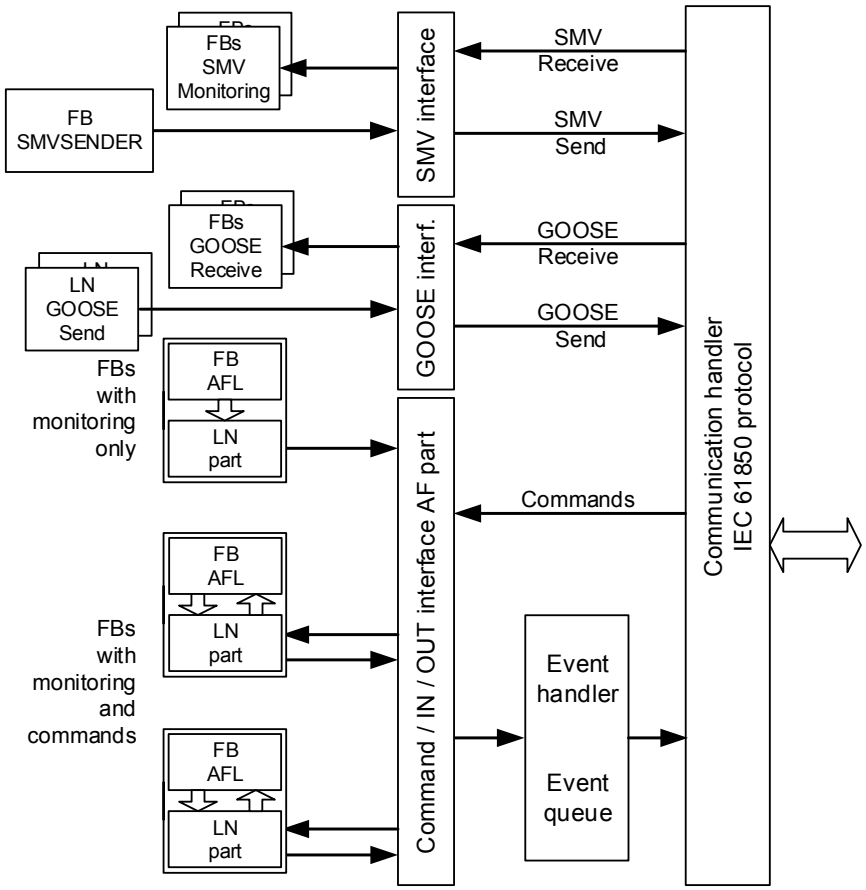


Figure 74: IEC 61850 communication interface principle

IEC 61850 provides a method for identifying all signals that belong to a function. These signals are identified through the logical nodes representing the functions. All signal information for commands and monitoring are available in logical nodes.

Whenever a function block is instantiated in the Application Configuration tool, PCM600 automatically generates the corresponding logical node data.

8.1.2 Station configuration description file types

The IEC 61850 standard defines SCL file types in the sequence of engineering. These files have a different definition, which is explained in IEC 61850-6. Three of the file types are used in the engineering process for an IED.

- ICD = IED capability description
  - Capability description of the IED in logical nodes and their data. No information about, for example, the communication configuration is included.

  - An IED is already extended by default data sets and report control blocks. They are predefined by ABB. Changes or additional data sets, for example, have to be done with IEC 61850 Configuration tool or any IEC 61850 system configuration tool.
- SCD = Station configuration description
  - A complete configuration description of all IEDs in a station and the full engineering of process signals and communication structure is included. This includes all the needed data sets and control blocks.
- CID = Configured IED description
  - The CID file contains the information needed for configuring one specific IED. The CID file contains the complete configuration description of one specific IED. This includes the configured IED name, communication part, data sets and all control blocks.
- IID = Instantiated IED description
  - The IID file contains a complete IED configuration, like the CID file. The IID file can include references to other devices which are not present in the file. The IID file is meant for transferring configuration data from IED configuration tool to a system configuration tool.

The uploading of IEC 61850 communication configuration is not supported when reading a configuration from an online IED. The PCM600 project works as a repository for the IEC 61850 configuration.

8.1.3 IEC 61850 engineering process

The IEC 61850 standard defines how information is communicated in a substation. The information communication can be divided into different parts.

- Description of the substation part, including the used logical nodes
- Description of the IEDs with their logical nodes
- Description of the communication network
- Description of the engineering process

When exporting an SCL file from PCM600, the tool builds a default substation structure and creates default data sets and control blocks for vertical communication between the substation client and IEDs. For more information, see the IEC 61850 standards.

In the following example, system configuration is done with PCM600 and any IEC 61850 system configuration tool. Another option is to use the IEC 61850 Configuration tool inside PCM600. In that case the SCL file export and import operations (steps 1 and 3) are not needed.

1. SCL files are exported from PCM600. In this case, a SCD file. It is also possible to export other SCL file types.
2. Horizontal and vertical communication is configured using the station configuration tool, for example, IEC 61850 Configuration tool or any IEC 61850 system configuration tool.
3. SCL files are imported to a PCM600 project. In this case, it is the updated SCD file.

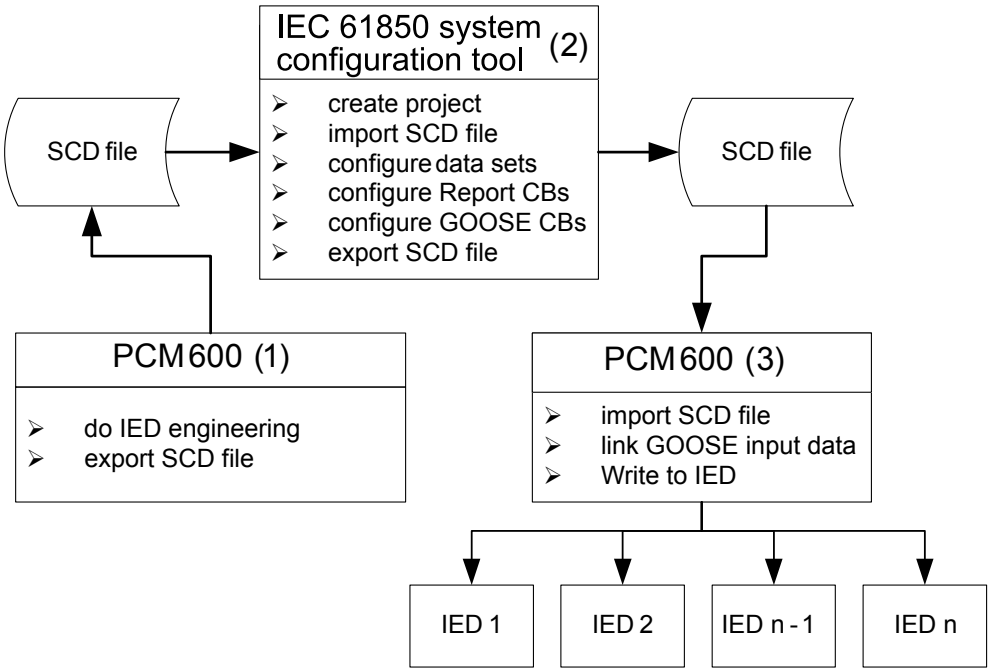


Figure 75: IEC 61850: signal engineering procedure flow when a complete station is exported as a SCD file

8.2 SSC600 data model

8.2.1 Product series implementation

The Smart Substation Control and Protection device has been fully designed according to IEC 61850. This means that the functionality of the protection device is represented in a data model in accordance with the standard and the protection devices support a wide range of the services provided by the standard.

- Process data: monitoring of statuses and measurements
- Application data: protection activation, tripping, fault recordings
- Disturbance records
- Control commands
- Protection settings
- Settings and setting groups
- Configuration data
- Diagnostics and self-supervision
- Fast horizontal communication between devices
- Time synchronization
- File transfer

As this series of IEDs supports both versions of IEC 61850, Edition 1 and Edition 2, there are small differences with IEC 61850 data model depending of the used version. Generally the IED's protection and control functionality is independent

of the IEC 61850 version used. Any differences between data model versions are documented.

If the protection IED is ordered with no Ethernet communication interface, the local port / remote port on the device still works according to IEC 61850. All settings and configurations are changed with IEC 61850 services using PCM600 via the local / remote Ethernet port of the LHMI. Without the rear Ethernet option, station communication is not available.

8.2.2 Information model

The protection IED is fully modelled according to the IEC 61850 standard. The data model can include up to four logical devices where different logical nodes representing protection and control functionality are located. Depending of the selected functionality in the protection IED, different configurations have different set of logical devices and logical nodes. Data models also include full modelling and functionality of setting, setting groups and configuration according to the IEC 61850 concept.

- Control logical device, CTRL
- Disturbance recorder logical device, DR
- Protection logical device, LD0

All generic functionality, such as modelling of physical inputs and outputs as well as the alarming LED functionality, resides under logical device LD0. A full description of the protection IED's data model is available in the parameter list.

During system engineering in the system configuration tool, do not delete or rename logical devices, logical nodes, data objects or data attributes in the IEC 61850 data model.

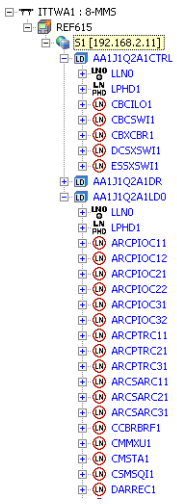


Figure 76: Example of an IEC 61850 data model of a protection IED

In the IEC 61850 standard, communication services are configured through a number of data structures including data sets, report control blocks, GOOSE control blocks and setting group control blocks. As these data structures pertain to the entire logical device, the standard indicates that they are to be modeled under LLN0, which is a special logical node that describes the common functionality of the logical device. All these data structures are located in logical device LD0 logical node LLN0.

The full data model can be exported from PCM600 in the form of a SCL file, which is defined in part 6 of the standard.

8.2.3 Vertical and horizontal communication

The protection relays are capable of vertical communication between the protection relay and monitoring and control systems (clients) such as ZEE600. Each protection relay can communicate to five separate clients to receive events, read or write data (an active PCM600 connection is considered to be a client). The protection relay can report data in either buffered or unbuffered mode and execute direct or select-before-operate control sequences according to the control commands sent by the client.

The protection relays are also capable of horizontal or peer-to-peer communication. They can be programmed to publish (send) and subscribe (receive) information according to IEC 61850-8-1, but only receive according to IEC 61850-9-2LE

IEC 61850 standard Edition 2 increased several identification string lengths which affect communication engineering and interoperability. The table lists identification length values to be considered especially with third party tools. ABB tools generally check the length values.

Table 14: Identification lengths in IEC 61850 versions

Object	Edition 1 length	Edition 2 length	Description
IED name	28 (32-4)	60 (64-4)	Excluding the longest LD name length of 4 characters
Report control block name	14	30	Without a two digit RCB instance number
Data set name	32	32	
RptID	65	129	Report Identifier
GoID	65	129	GOOSE Identifier
MSVID	65	65	Multicast Sampled Value Identifier (length as in 61850-9-2 LE)

Table 15: Number of control block data sets and size of data sets

Control Block	Maximum data sets	Maximum length of data set	Description
GoCB	40	20 attributes	
RCB	100	Edition 1: 255 attributes Edition 2: 100 data objects	

8.2.4 Writing communication configuration to the IED

IEC 61850 communication depends on the proper communication configuration in all IEDs that communicate via IEC 61850.

It is possible to make a configuration change in one IED, without affecting the horizontal communication (GOOSE or IEC 61850-9-2 LE) engineering between IEDs. For example, when the Application Configuration tool configuration is changed, but no changes are done to the instantiation or deletion of functions that represent a logical node.

When a changed configuration is written to the IED, the horizontal communication configuration needs to be updated.

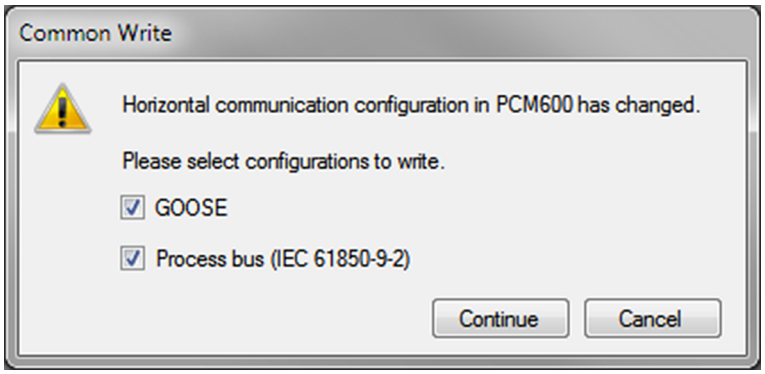


Figure 77: Updating the communication configuration in the IED with the configuration made in PCM600

1. Select which configuration part to include in writing.
   - Select GOOSE to update the GOOSE configuration part in the IED.
   - Select Process bus (IEC 61850-9-2) to update the IEC 61850-9-2 configuration part in the IED.
2. Select whether or not to update the configuration.
   - Click Continue to update the selected communication configuration part(s) in the IED. The options can be left unselected. In this case, other parts of the configuration are updated.
   - Click Cancel to cancel the whole writing operation.

8.2.4.1 Predefined vertical communication data sets

In vertical communications, the protection IED can generate events that are automatically reported to any listening clients. These communications are configured via a series of predefined data sets and corresponding report control blocks. The data sets are used to configure what data is sent and the report control block is used to configure when data is sent.

The IED connectivity package includes predefined data sets and control blocks for vertical MMS event reporting. These data sets are used in predefined reporting control blocks for five clients. The selected data in the data sets is suitable to most of the different applications and the selected default data automatically considers the used protection IED type and options.

The data sets and report control blocks can be modified using the IEC 61850 Configuration tool or any IEC 61850 system configuration tool, however, this should only be done by individuals that are extremely familiar with both the protection IEDs and IEC 61850. Inappropriate modifications can result in misoperation of the protection IED.

- StatIed – generic status information of IEDs

- StatIo – inputs, outputs, LEDs
- StatUrg – measurement limit supervision, control feedback
- StatNrml – protection start and trip signals, autoreclosing status
- StatDR – digital fault recorder status
- MeasReg – registered measurement values at faults
- MeasFlt – measurements

When function blocks are added to or removed from a IED configuration also the default data sets and the content of data sets are automatically modified to follow the IED data model. If all data does not fit into one data set, two data sets with suffixes "A" and "B" are created.

The protection IEDs support both buffered and unbuffered event reporting. In the predefined configuration all report control blocks are configured to use buffered reporting. The benefit of buffered reporting is that it buffers events during communication breaks and thus no events are lost. Further, a single data set can only be used by one report control block and the same data set entry cannot be used in different event reporting data sets.

The default values for the data sets and control blocks are suitable for most applications. The protection IED allows free renaming and editing of report control blocks and data sets. Only users who have an in-depth understanding of the protection IED and IEC 61850 should modify the default configuration. Description of data in default data sets is available in the parameter list.

Vertical communication protocols rely on the data sets for event generation. Modification of the default configuration have an impact on vertical communication.

It is not recommended to mix seldom updated status data (FC=ST) and frequently updated measurement data (FC=MX) in the same data set to minimize the bandwidth consumption in the network and to avoid unnecessary publishing of unchanged status data.

The protection IED does not support defining data on data attribute level for data sets used for vertical reporting. Only data object level is allowed.

8.2.4.2 Predefined horizontal communication data set

In horizontal communication the user normally has to engineer IEC 61850-8-1 GOOSE data sets. When IEC 61850-9-2 is used, the connectivity package automatically creates a data set including data as defined in 9-2 LE: four currents and four voltages with quality attributes.

It is not allowed to engineer or modify the predefined 9-2 LE data set. Together with the 9-2 LE data sets the connectivity package also creates a default sampled measurement value control block. The SVCB configuration needs to be finalized in the tool before connecting the sent 9-2 data to the receiver IEDs.

8.2.4.3 Vertical communication diagnostic counters

The IEC 61850 data model of the IEDs includes a logical node LD0.MMSLPRT1 for IEC 61850 vertical communication diagnostic. The counters are available via the HMI or PCM600 path **Monitoring/Communication/MMSLPRT1**.

Table 16: Diagnostic data objects

Data object	Description	Diagnostic information
SucConnCnt	Successful connections	Number of succeeded client connection attempts
FailConnCnt	Failed connections	Number of failed client connection attempts
ConcCnt	Concludes	Number of session concludes
TxAbtCnt	Sent aborts	Number of association aborts sent by server
RxAbtCnt	Received aborts	Number of received association aborts by server
TxRejCnt	Sent rejects	Number of sent rejects by server
RxRqCnt	Received request	Number of received client requests
FailRqCnt	Failed requests	Number of failed client requests
SucReadCnt	Reads	Number of variable reads
FailReadCnt	Failed reads	Number of failed variable reads
SucWrCnt	Writes	Number of succeeded variable writes
FailWrCnt	Failed writes	Number of failed variable writes
InfRepCnt	Reports	Number of sent reports
ActConnCnt	Active connections	Number of active client connections

It is possible to reset the vertical diagnostics counters via **Monitoring/Communication/MMSLPRT1/Reset counters** and via the IEC 61850 communication by writing `TRUE` to the *RsCnt.Oper.ctlVal* attribute under MMSLPRT1.

GOOSE communication has its own diagnostic counters. See the Diagnostic counters chapter in this manual for information on diagnostic counters used in GOOSE communication.

8.2.4.4 Parameter setting and disturbance recorder

The IED's protection function settings and parameters can be set and the active setting groups changed by IEC 61850 client using the standard IEC 61850 services.

The disturbance recorder files in COMTRADE format are retrieved from the **\COMTRADE** and **\LPD\COMTRADE** directories by using PCM600 or any other client supporting IEC 61850 file transfer service or FTP.

When setting the parameter **Configuration/Communication/MMSLPRT1/Unit mode** to “Primary”, the values sent over IEC 61850 are scaled according to the CT and VT settings. Restart the protection relay after changing the parameter. This feature is needed if the SCADA system or substation gateway does not handle scaling from nominal values.

8.3 Configuring GOOSE with PCM600

8.3.1 GOOSE communication

GOOSE is used in substation automation for fast horizontal communication between the protection relays. GOOSE can be used for direct data exchange, for example, of interlocking and blocking information between protection relays. According to the IEC 61850-8-1 standard, GOOSE uses a publisher/subscriber profile in which information is shared from one device to one or several devices by using Ethernet multicast messages. A message is an image of a sent IEC 61850 data set that is defined in the configuration.

The protection relay can send any type of status or measurement data in the GOOSE messages from its IEC 61850 data model. The status data response time, that is, the time it takes for the application to handle a received GOOSE message and to send the concerned data back to the network, is below 3 ms. The response time fulfils the Type 1A, Class P2/3 requirements of the standard.

When the protection relay is configured to send measurements, the analog, integer or counter type data should be placed in its own data set to minimize the bandwidth consumption in the network and to avoid unnecessary publishing of unchanged status data. The triggering of analog data sending is controlled by deadband handling, zeropoint clamping and limit supervision.

The GOOSE communication configuration consists of the protection relays' GOOSE control block, data set and GOOSE input configuration. The result of the configuration work is a system configuration which is used for the protection relays. The used files in the workflow are IEC 61850 standard format SCL files.

8.3.1.1 GOOSE transport

GOOSE messages are sent connectionless in Ethernet multicast frames using VLAN and priority tagging (802.1Q) over a LAN.

8.3.1.2 Routable GOOSE

R-GOOSE is GOOSE data sent over a WAN. R-GOOSE can be used for wide area protection and control applications. R-GOOSE follows the principles and configuration of GOOSE extending the transport medium to allow routing over IP networks. R-GOOSE messages are sent connectionless using IP multicast and UDP. R-GOOSE uses IGMPV3 to allow routers to determine the routing path through the network.

8.3.1.3 Configuring GOOSE communication

Configure GOOSE by using the IEC 61850 Configuration tool in PCM600 or by using any IEC 61850 system configuration tool. PCM600 interacts with IEC 61850 system configuration tools by importing and exporting SCL files.

8.3.2 GOOSE publishing properties

GOOSE data is transmitted event based and at regular intervals. Peer devices can determine the state of the communications by listening for the transmissions. When the data values change, the data is transmitted at an increased frequency to ensure the timeliness of its reception. The transmission then gradually tapers off to the original frequency with the new data.

In GOOSE, data sending is based on data sets and GOOSE control blocks. The data set defines what device data is used in GOOSE service and sent to local Ethernet subnetwork in a GOOSE message. The GOOSE control block links the data set and its attributes to actual data.

8.3.3 Configuring GOOSE with the IEC 61850 Configuration tool

See detailed descriptions of the steps in corresponding chapters.

1. Add devices to a PCM600 project.
2. Engineer the GOOSE connections between the devices.
   a) Define the published GOOSE data and control blocks.
   b) Define the subscribing IEDs for the GOOSE data.
3. Engineer the IED applications with GOOSE inputs.

8.3.3.1 Defining IEDs and starting the IEC 61850 Configuration tool

Use PCM600 to define the substation and the IEDs. Before starting the system engineering, configure the IED settings and logic in PCM600.

For more information, see PCM600 documentation.

1. Create a PCM600 project with all the needed IEDs.

If the substation includes third party IEDs requiring configuring for horizontal GOOSE communication, instantiate a generic IEC 61850 IED under the substation in the plant structure and import the SCL files (ICD/CID) holding the information on those IEDs. The third party IEDs have separate tools for creating the ICD/CID/SCD file.

2. Start the IEC 61850 Configuration tool.

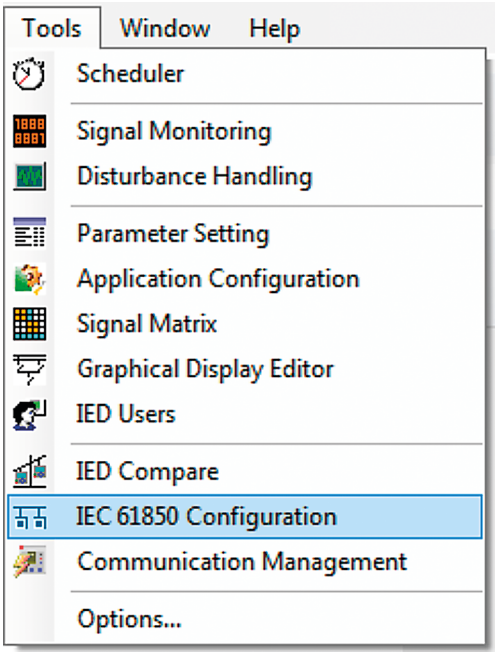


Figure 78: Starting IEC 61850 Configuration

8.3.3.2 Configuring a GOOSE publisher with the IEC 61850 Configuration tool

To control the GOOSE data publishing, such as addressing, every publisher IED must have at least one data set for GOOSE data and one GOOSE control block.

1. Group the data to a data set sent to IEC 61850 station bus.
2. Define the GOOSE control block.

The IED can send single binary, double binary, integer and floating point data values with a quality attribute. A quality attribute is used at the receiver side to check data validity.

Creating a GOOSE data set with the IEC 61850 Configuration tool

The sending data set is defined with the GOOSE control block. With the IEDs of this product series, the sending GOOSE data set can have a maximum of 20 data attributes to minimize the message-handling load in the receiving and sending IEDs.

All data sets must be configured under the logical node LLN0 and must be provided with names unique within the IED. The IEDs allow a maximum of four GOOSE control blocks, which effectively limits the IED to four data sets for GOOSE, as there is a one-to-one correspondence between the GOOSE control blocks and GOOSE data sets. Typically, it is sufficient to define a single data set and control block for an application. However, it is recommended to use a separate data set and corresponding control block for analog values.

1. Select the target IED in the Plant Structure view.

2. Select GOOSE Communication in the drop-down box on the toolbar.

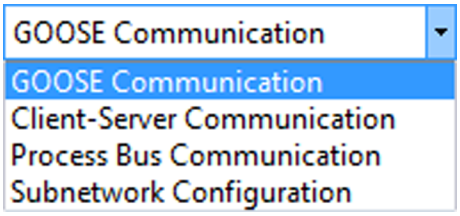


Figure 79: Selecting GOOSE communication

3. Select the **Data Sets** tab.
4. To add a new data set, right-click the area containing the data set names and select **New**.
5. Define the LN where the data set is to be placed (accept preselected “LD0/LLN0”) and give the data set a unique name.

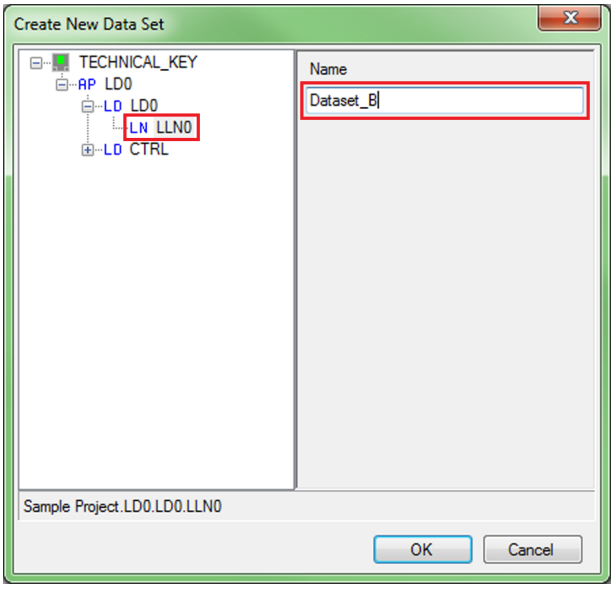


Figure 80: Naming the data set

A maximum of 80 data attributes can be added to IED's GOOSE data sets. Recommendation is to divide attribute amount to 20 per GOOSE data set, for maximum performance in sender/receiver. After creating the GOOSE data sets, define the data set entries (data attributes or data objects) for the data sets.

After creating the GOOSE data sets, define the data set entries (data attributes or data objects) for the data sets.

If quality data attributes are added to a data set, they must be located after the status value of the corresponding data object.

The received GOOSE data set can contain signals on the data attribute or data object level. Data object level GOOSE entries can only be received of the following CDC types: SPS, SPC, ACD, ACT, DPS, DPC, INC, INS, ENC and ENS. Other CDC types can be connected to application only when dataset is defined in attribute level.

Defining GOOSE data set entries with the IEC 61850 Configuration tool

1. Select the **Data Sets** tab.
2. Right-click a data set and select **Details** to add data attributes.

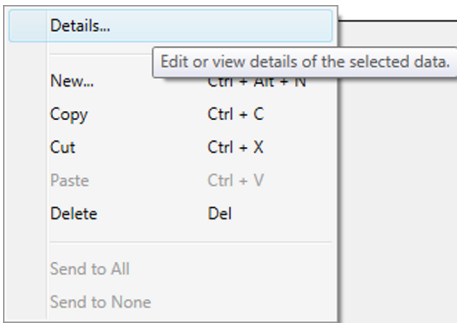


Figure 81: Opening Details

3. In the **Data Set Entry** window, select the data attribute or data object present in the data set.
   - Click **Append selected** to add the data to the end of the data set. To add a data object level entry, select it from the FC section. To add a data attribute level entry, select it from the DA section
   - Click **Insert selected** to add the data above the selected row in the data set entries list.
   - To remove a data from the data set, select the data in the data set entries pane and click **Remove selected.**

   A maximum of 80 data attributes can be added total to IED's GOOSE data sets. Recommendation is to divide attribute amount to 20 per GOOSE data set, for maximum performance in sender/receiver.

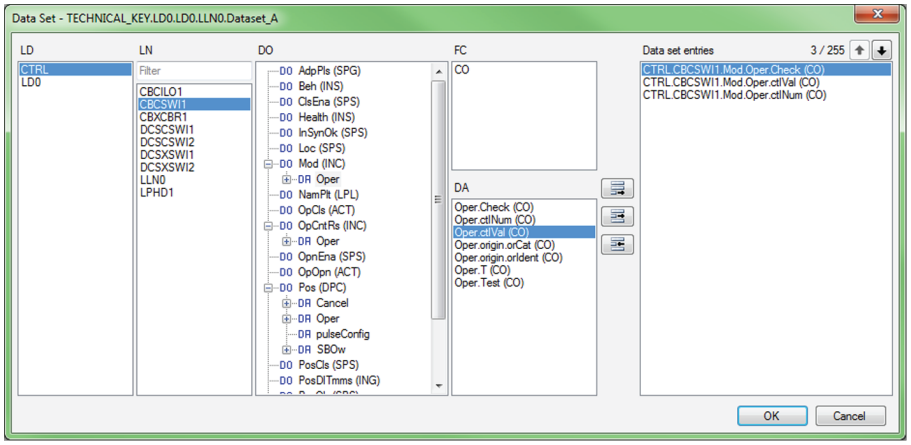


Figure 82: Adding data set entries

If a data set has quality attributes, the attributes must be located after the status value of the same data object.

The data attribute entries are single data, such as stVal and q. Data set entries can be also defined on the data object level. Data object level GOOSE entries can only be received of the following CDC types: SPS, SPC, ACD, ACT, DPS, DPC, INC, INS, ENC and ENS.

Some merging units (for example ABB 615 series ver. 5.0 or earlier) do not support the data object level GOOSE entries. This limitation must be considered when configuring the whole system consisting of different product versions.

After defining the data entries for the data sets, configure the GOOSE control block properties.

Configuring a GOOSE control block with the IEC 61850 Configuration tool

1. Select the IED in the **Plant Structure** view.
2. Select the **GOOSE Controls** tab in the tool pane.
3. To add a new data set, right-click the area containing the data set names and select **New**.

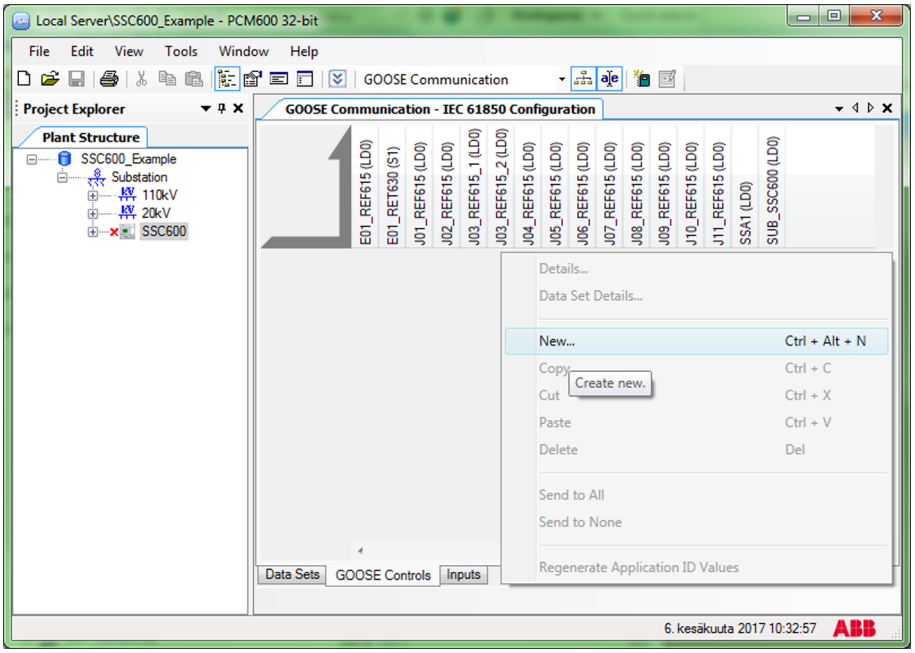


Figure 83: Creating a new GOOSE control block

4. Browse to LLN0 under LD0 to define where the GOOSE control block is to be placed.

5. Give a unique name to the GOOSE control block. 1MRS756475 N Section 5 GOOSE 615.

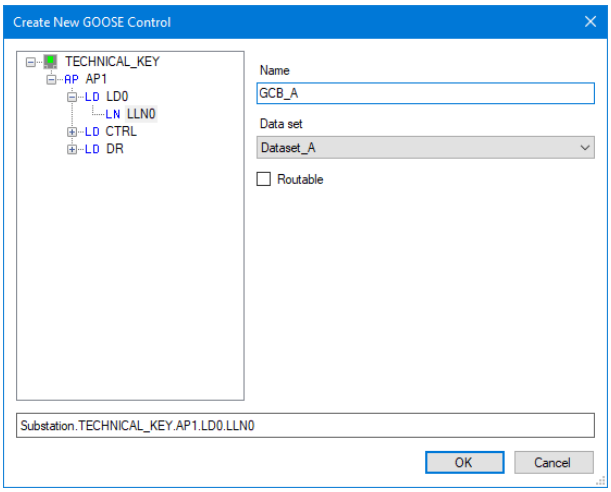


Figure 84: Naming a GOOSE control block

6. In the Data set drop-down list, select the previously created data set to link with the GCB.
7. If creating a R-GOOSE control block check the Routable checkbox.

8. Edit the properties and addresses of the created GOOSE control block. Edit at least MAC Address and App ID.

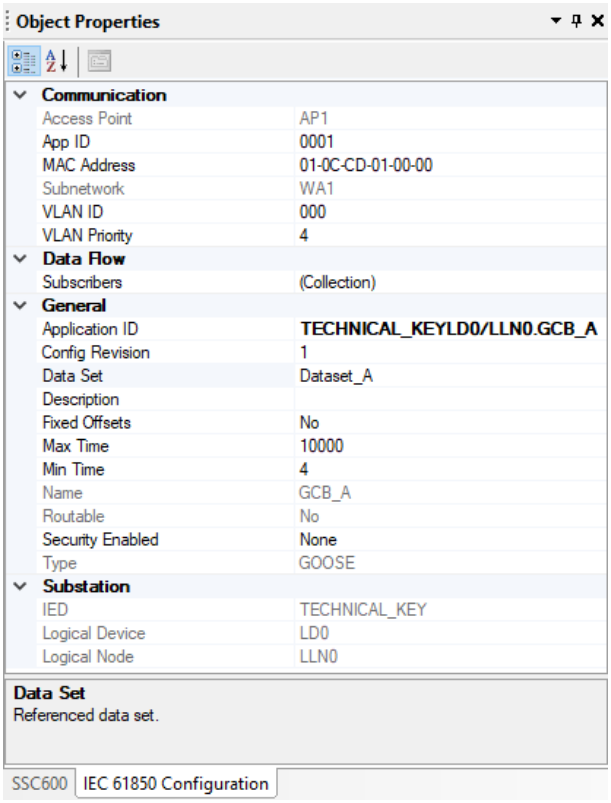


Figure 85: GOOSE control block properties

Table 17: GOOSE control block properties

GoCB attribute	Description
App ID	Application identifier. A hexadecimal value for the published GoCB. It needs to be a unique value within the system. Value range is 0000...3FFF.
MAC Address	Multicast destination MAC address. A multicast addressing scheme is used when sending GOOSE messages. A multicast address can be shared by several GoCBs. To allow multicast message filtering in receiving devices it is recommended to use unique addresses. Value range is 01-0C-CD-01-00-00...01-0C-CD-01-01-FF.
VLAN ID	The VLAN group can be used when configuring the Ethernet network topology's virtual LANs for routing and segmenting. Configuration is done in managed Ethernet switches. If static VLAN identifiers are defined, it also affects the switch port configuration. Value “000” indicates a non-configured VLAN; in this case, switches do not filter these messages on a port basis. This is recommended if there is no need to

Table continues on the next page

GoCB attribute	Description
	split the logical network. The VLAN identifier is a three-character hexadecimal value. Value range is 000...FFF.
VLAN Priority	Used in networks supporting VLANs. The priority is used with network switches. Default value is 4. Value range is 0...7.
Application ID	GOOSE control block identifier. A unique identification string of max 64 characters for each GoCB in the system. By default, it is the GoCB identification in the device data model. It is recommen ded to use unique identifiers. Default value is GoCB IEC 61850 path name.
Config Revision	Configuration revision. An integer value indicating the revision of the GOOSE configuration. Sent in every GOOSE message. Receivers check the value to detect configuration mismatches. Both sender and the receiver must use the same configuration revision. Updated automatically by configuration tools when the referenced data set is changed.
Data Set	Data content sent in the GOOSE message.
Fixed Offsets	Not applicable.
Max Time	Background "heartbeat" send cycle time in milliseconds. The device resends the latest data with the heartbeat cycle when no data changes. Communication supervision is based on this idle sending mechanism. Default value 10000 ms.Value range is 1000…60000 ms.
Min Time	Maximum response time to data changes in milliseconds. In the device, the value is always 4 ms for sent data. Not applicable.
Security Enabled	Not applicable.

Max Time is configurable. Min Time is not.

The multicast MAC address is usually unique. App ID must be unique.

R-GOOSE shares the properties of GOOSE for configuration with the exception of Multicast address. The multicast destination MAC address is calculated from the R-GOOSE IP address. In addition to GOOSE, the following R-GOOSE specific communication properties need to be configured.

Table 18: R-GOOSE control block attributes

GoCB attribute	Description
Class of Traffic	Class of traffic for IPv4. Specifies the Type of Service field of the IPv4 header (DSCP high 6 bits and ECN low 2 bits). Defines the requested routing service for the message to allow routing prioritizing in the network routing devices. Default 0 equals best effort service.
IGMPv3 Address	Source IPv4 address of R-GOOSE message. Unicast IPv4 address used for IGMPv3 subscription. Used for source specific multicast filtering to allow subscription to R-GOOSE from only specified sources. It is recommended to use the device IP address.
IP Address	UDP/IPv4 destination address of R-GOOSE message. Must be an IP multicast address conforming to RFC 5771 (Class D, 224.0.0.0/4, leading bits 1110).

8.3.3.3 Configuring a GOOSE subscriber with the IEC 61850 Configuration tool

The IED application can receive and use single binary, double binary, integer and floating point values with attached quality information. A quality attribute is received and processed automatically.

8.4 Process bus and IEEE 1588 time synchronization

8.4.1 Sampled measured values and IEEE 1588 v2 time synchronization

The IED supports IEC 61850 process bus with IEC 61850 9-2 LE or IEC 61869-9 sampled values of analog neutral and phase voltages. Receiving of sampled values of analog neutral and phase currents is supported in addition to the voltages. The neutral voltage is derived from the phase voltages when there is no physical neutral voltage input available in the IED. The SSC600 supports receiving sampled measured values from up to 30 bay level IEDs or Merging Units. IEDs with process bus based applications use IEEE 1588 v2 Precision Time Protocol (PTP) according to IEEE C37.238-2011 Power Profile or IEC 61850-9-3 Power Utility Profile for high accuracy time synchronization.

The IED can receive sampled values measurements as either IEC 61850-9-2 LE using the SVRECEIVE_LE function or IEC 61869-9 using the SVRECEIVE_61869 function. The selection is done based on the sending IEDs capabilities.

Only IEC 61850-9-2 LE with SVRECEIVE_LE or IEC 61869-9 with SVRECEIVE_61869 can be used within an application. Mixed application is not supported.

In addition to the process bus, the IED supports forwarding the received sampled values as routable sampled values over the protection communication port. The devices on the protection communication port that produce or consume the routable SV measurements should be synchronized to the same IEEE 1588 v2 grandmaster clock.

IEC 61869-9 receiving supports up to 32 measurements in a dataset for a single SMV stream with 2 samples (2 ASDUs) in a single ethernet packet and 4800 samples per second sampling frequency.

8.4.2 System building

Redundant Ethernet topologies (PRP) are recommended to be used in the sampled measured values applications and with GOOSE to ensure the highest availability.

8.4.2.1 Parallel redundancy protocol PRP

PRP topology presented here is a reference system for process bus usage with proper switches supporting IEEE 1588 v2. This topology includes duplicated star networks which are in PRP called LAN A and LAN B. IEEE 1588 v2 clock masters are connected to the network utilizing Ethernet switches. Ethernet switches filter out IEC 61850-9-2 LE traffic from the IEEE 1588 v2 clock masters. PRP LAN A is presented with dark blue lines and LAN B with light blue.

It is important in PRP not to connect LAN A and LAN B anywhere else than to end devices supporting PRP. Otherwise Ethernet communication is disturbed and might not work. All devices connected to both LAN A and LAN B must support the PRP protocol. Single attached nodes can be connected directly to LAN A or LAN B in which case there is no redundancy for this node or with a separate redundancy box (RedBox).

Do not mix different PRP LANs. Ensure that the LAN A port is always connected to LAN A only and the LAN B port is connected to LAN B.

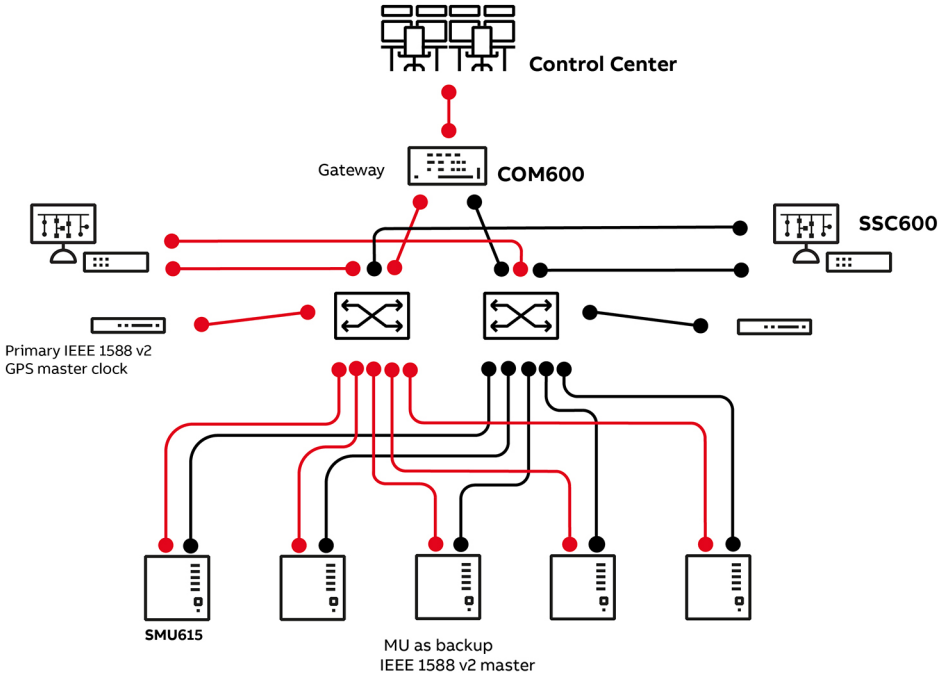


Figure 86: PRP solution

8.4.2.2 Performance optimization

- The SMV messages should be filtered out from the local subnetwork part not using these, because they cause high traffic in the network. Otherwise they reach also those network devices that do not subscribe the SMV messages. Managed Ethernet switches can be configured to perform the filtering operation.
- IEEE 1588 v2 network devices complying with Power Profile are highly recommended to simplify the settings and to ensure compatibility. Power Profile recommends implementation according to the one-step mode.
- It is recommended to use IEEE 1588 v2 devices with the same clock mode (onestep or two-step) within one network. Ethernet switches performing one-step to two-step conversions should be avoided due to additional inaccuracy.
- The SSC600 requires 1GBit ethernet connection, since it can receive SMV from up to 30 IEDs or MU. The sender side devices can be 100MBit.

8.4.2.3 Requirements for third party devices

System and setting requirements

- Support for the IEEE 1588 v2 time synchronization
- Preferably IEEE 1588 v2 according to the Power Profile and implementation according to the one-step mode
- All network devices between the IEEE 1588 v2 clock master and the IED must support IEEE 1588 v2

Ethernet switch requirements

- Support for the IEEE 1588 v2 transparent-clock operation mode to enable accurate time synchronization in the system
- Preferably managed switch capabilities for SMV filtering and VLAN to restrict the flow of SMV only to devices using it

In order to get maximum throughput, we recommend that the Ethernet Switches which are supporting hardware time stamping for PTP IEEE 1588 V2 are used.

ABB Ethernet Switches such as AFS 665/677 are good choices to get full functionality out of SSC600 devices. AFS660 can be used too but it doesn't have gigabit ports so the fiber optic card of SSC600 cannot be used. E.g. AFS675 is not supporting hardware time stamping so it is not recommened to use with SSC600.

ABB AFS677 Ethernet Switch is tested in our factory lab and it supports 20 SMV streams very well with IEEE 1588-time synch.

AFS677 switch time sync in details:

- PTP IEEE 1588 v1/v2 Boundary and Transparent Clock hardware time stamping with accuracies of 30ns
- IEEE 1588 Power Profile (C37.238-2011)
- SNTP server e.g. for COM600

Realtime clock with energy buffer.

Summary:

The following switches support PTP with HW time stamping.

- AFS677
- AFS660/665-S
- AFS660-C

AFS650/655 and AFS670/675 support ‘PTP simple mode’ only, i.e. they can derive the local time from PTP signal, but they don’t support Boundary Clock or Transparent Clock function (i.e. they have no HW timestamp) See the table below.

It is hereby stated that the below listed ABB products are in accordance with the corresponding Hirschmann versions.

- **ABB naming -> Hirschmann naming**
- AFS650-xxx -> RSR20-xxx
- AFS655-xxx -> RSR30-xxx
- AFS670-xxx -> MACH1020-xxx
- AFS675-xxx -> MACH1030-xxx
- AFS677-xxx -> MACH1040-xxx
- AFF650-xxx -> EAGLE20-xxx
- AFF 660/65xx -> EAGLE30-xxx
- AFS660-Cxx -> RSPS2x-xx
- AFS660-Sxx -> RSP20-xx
- AFS665-Sxx -> RSP30-xx
- AFS660-Bxx -> RSPL20-xx
- AFS665-Bxx -> RSPL30-xx

Table 19: Managed Ethernet switches

Type	Manufacturer	Assembly	Number of ports	HSR Redbox	PRP Redbox	RSTP	SNTP	PTPv2	Station bus	Process bus
AFS670	ABB	19'	up to 24	No	No	Yes	Yes	No	Yes	No
AFS675	ABB	19'	up to 28	No	No	Yes	Yes	No	Yes	No
AFS677	ABB	19'	16	No	No	Yes	Yes	Yes	Yes	Yes
AFS660B	ABB	DIN Rail	8	No	No	Yes	Yes	No	Yes	No
AFS665B	ABB	DIN Rail	10	No	No	Yes	Yes	No	Yes	No
AFS660C	ABB	DIN Rail	6	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AFS660S	ABB	DIN Rail	6	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AFS665S	ABB	DIN Rail	11	Yes	Yes	Yes	Yes	Yes	Yes	Yes

In addition to the above switch models, the following switches has been used successfully in ABB test environment:

- RUGGEDCOM RST2228
- RUGGEDCOM RS950G
- Cisco IE4010
- Moxa PT-G7728
- Moxa EDR-G9010

IEEE 1588 v2 master clock requirements

- Support for IEEE 1588 v2 Grand Master operation mode
- Clock accuracy of ±1 µs or better to enable accurate enough sampled measured values

Accurate time synchronization is essential for working centralized protection and control system. Here is a reference list of GPS clock masters, that ABB has used successfully together with SSC600:

- Meinberg Lantime M3000 (GPS)
- MEINBERG LANTIME M600/GPS
- Meinberg LANTIME M1000
- Tekron NTS 03-G+
- TTM 01-G

More GPS clocks will be added as soon as there is a reference that they work reliably with the SSC600 system.

8.4.3 SMV system configuration

SSC600 based solution requires that separate SMV sender IEDs or Merging Units are installed in the substation. The requirements for the SMV sender devices are as defined in Chapter 8.5.4.

SMV system configuration of the SMV sender IED

The SMVSENDER function block must be added to the ACT configuration of the SMV sender IED to activate SMV sending. By doing this the sampled value control block and the related data set are automatically added to the IED configuration when using IEC 61850-9-2 LE. SVCB and the data set are defined by 9-2 LE in which the data set consists of four currents and four voltages with quality attributes. IED sends the residual voltage as a calculated value when there is no physical neutral voltage input available in the IED. IEC 61850-9-2 LE defines a sample rate of 4000 samples per second in 50 Hz system. When using IEC 61869-9, the data set is not

fixed, and the correct number of channels and their use should be checked from the IED manual(s) and/or configurations. For IEC 61869-9 the sample rate is always 4800 samples per second.

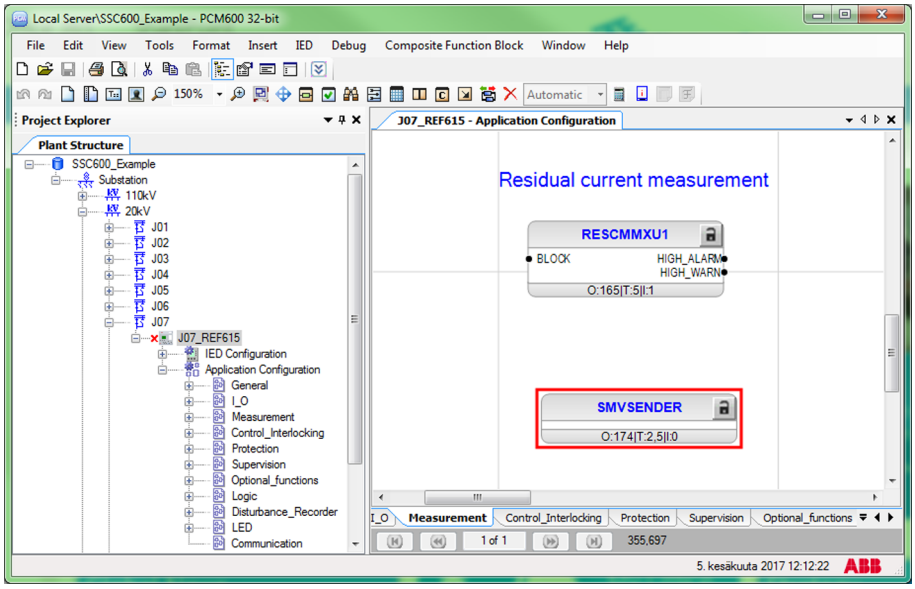


Figure 87: Adding an SMVSENDER block in the Application Configuration tool of the SMV sender IED

The default data set for SMV sending is fixed and should not be modified.

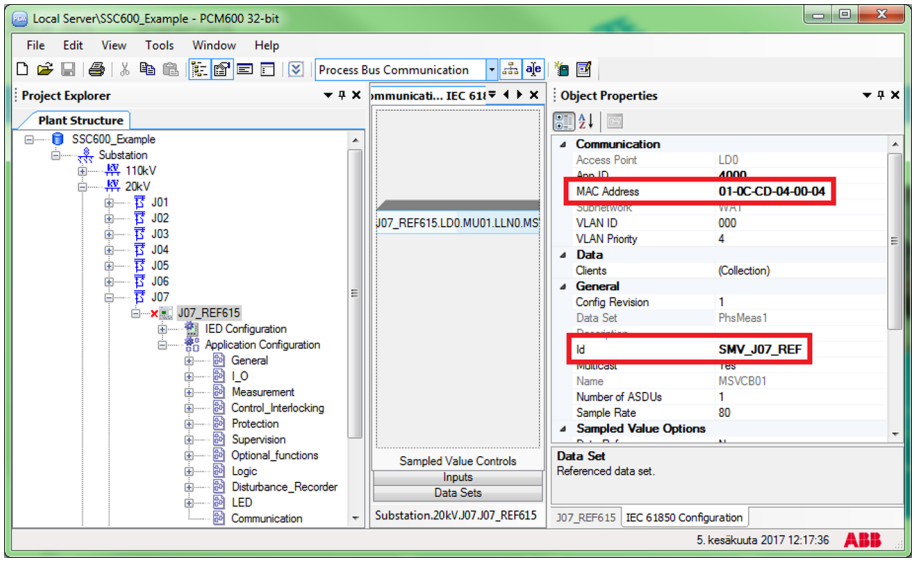


Figure 88: Setting svID and MAC address of SMV stream of the SMV sender IED

SMV system configuration of SSC600

The SSC600 specific item in terms of engineering is the receiving of SMV. In ACT, one SVRECEIVE_LE or SVRECEIVE_61869 function is needed for every received SMV

stream. SVRECEIVE_LE has group signal outputs for phase and residual currents and voltages, which can be connected as inputs to other functions.

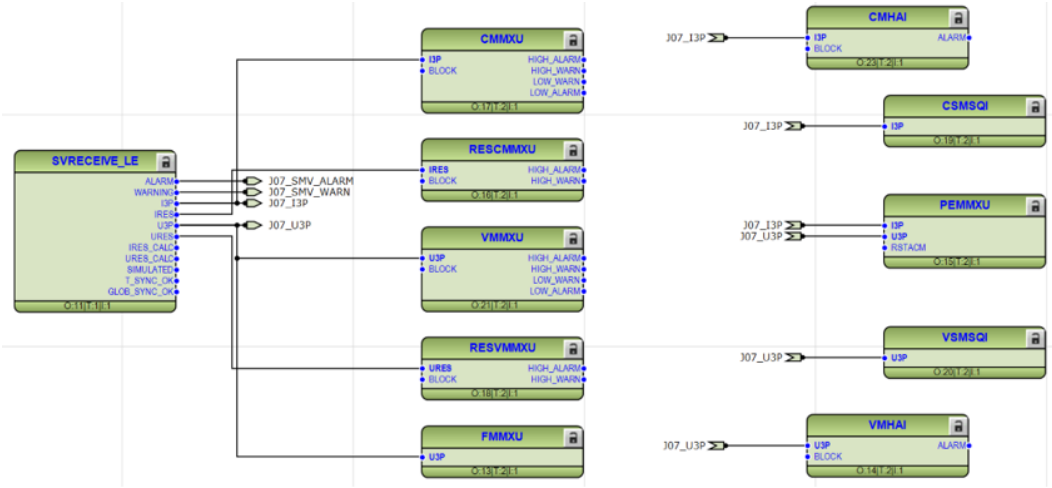


Figure 89: SVRECEIVE_LE function of SSC600

For SVRECEIVE_61869, separate ILTCTR, UTVTR and RESTCTR preprocessing functions are required for mapping the received samples to measurements usable in application. SVRECEIVE_61869 output channels represent the measurements received in SMV frame dataset. 1st measurement with quality in dataset is mapped to output CH1, 2nd to CH2 and so on up to CH32.

Special care should be taken when configuring the channel mappings to preprocessing functions to get correct measurements to application.

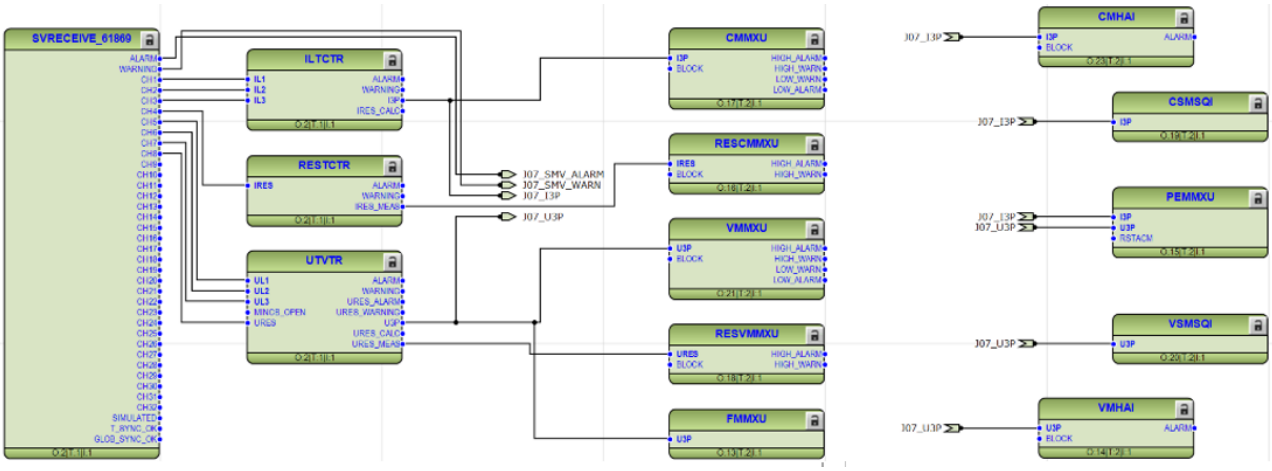


Figure 90: Example SVRECEIVE_61869 function of SSC600 receiving a 9-2LE dataset

The selection of which SMV stream to receive is done in the Signal Matrix Tool.

1. Select **SSC600** in the plant structure.
2. Right click and select **Signal Matrix**.
3. Map the SMV receive function instance(s) to the corresponding sender IED(s).

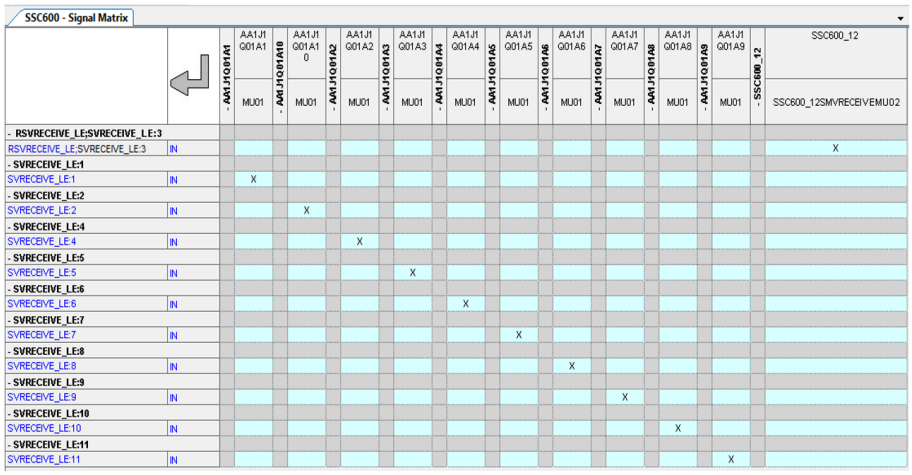


Figure 91: Mapping the SMV senders to SVRECEIVE_LE blocks

Due to the high time accuracy requirement of SMV the used time synchronization method must be IEEE 1588 v2. PTP priorities of IEDs and other IEEE 1588 v2 devices in the network need to be configured properly (smaller value means highest priority) for best master clock algorithm in 1588. External accurate master clocks must be set with highest priority and if the IED is selected as backup, master clock priorities should be set accordingly in all IEDs.

Some network routers can block 1588 traffic. Check that all devices using 1588 time synchronization utilize the same master clock.

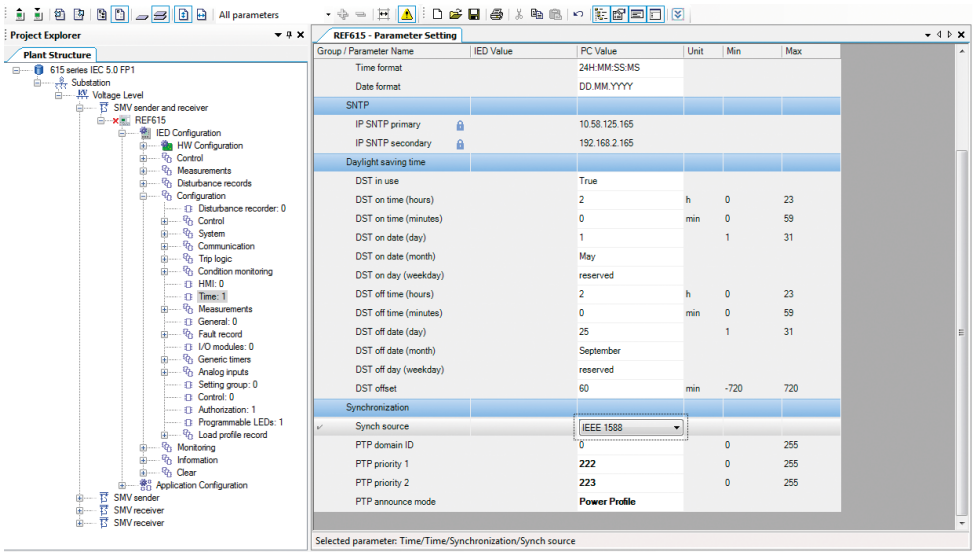


Figure 92: Time synchronization source

SMV data set and SVCB should not be manually added or removed with other tools.

8.4.3.1 Configuring SMV with the IEC 61850 Configuration tool

After you have added all SMV senders (all 615 series relays or MUs) to the PCM600 project, you need to configure SSC600 to receive streams from all those devices using the **IEC 61850 Configuration tool**. You see all senders and receivers in the window when you select substation node in the Plant Structure.

1. Start the IEC 61850 Configuration tool.
2. Select **Process Bus Communication** in the drop-down box on the toolbar.

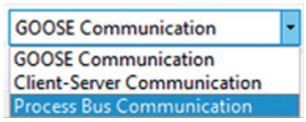


Figure 93: Selecting Process Bus Communication

3. The SMV sender and SMV receiver IEDs become visible. Edit the properties and addresses of the sampled value control block.

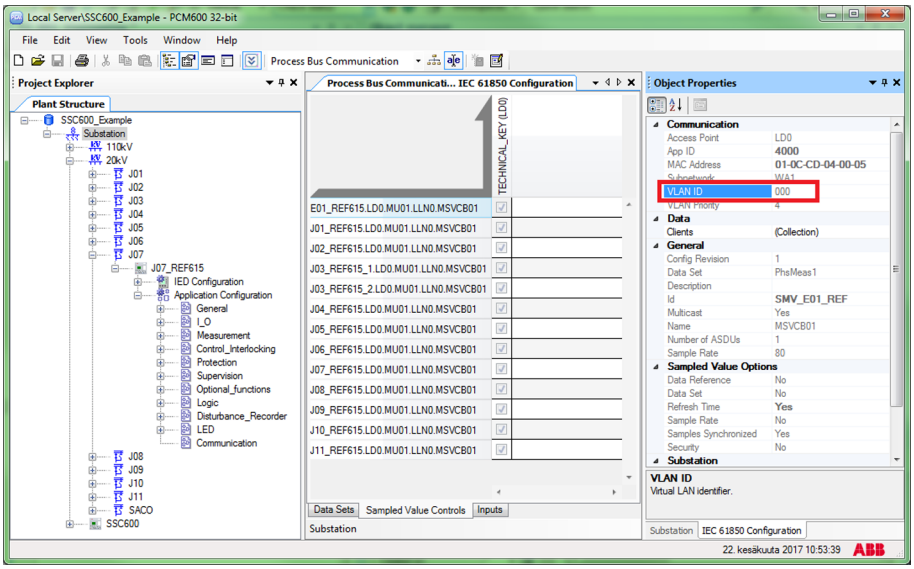


Figure 94: Changing the VLAN ID

Some switches do not support multicast filtering with VLAN value “0” because it means “no VLAN” and VLAN 1 has special purpose as management VLAN for switches. Recommended value for VLAN is 2...1001.

Use a unique multicast address for each SVCB. The address range for sampled values multicast addresses is 01-0C-CD- 04-00-00...01-0C-CD-04-FF-FF.

4. Connect the SMV sender to the receivers.

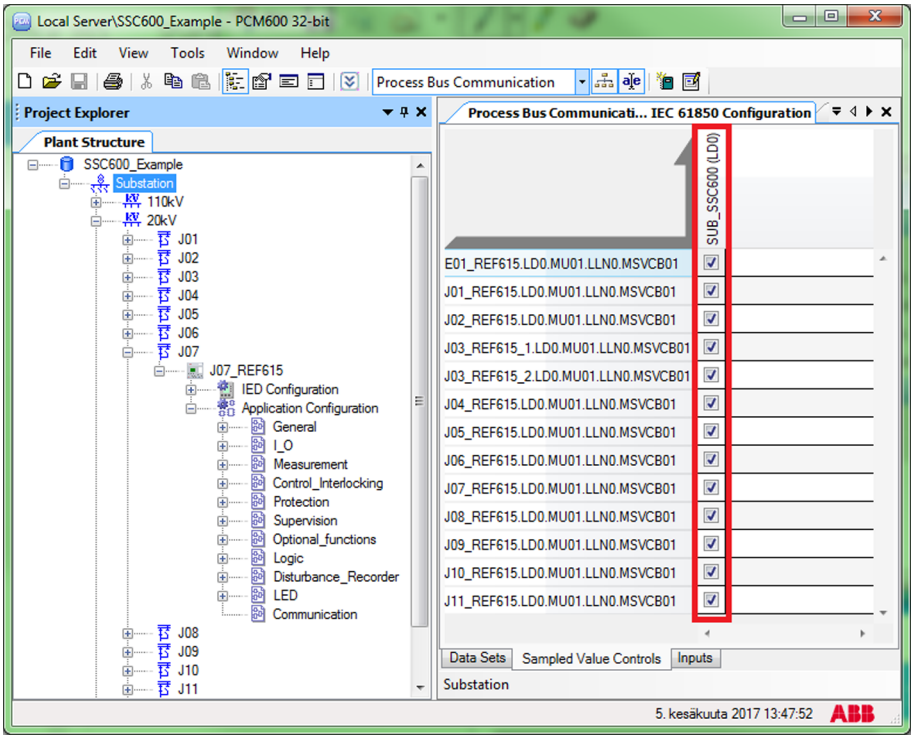


Figure 95: IEC61850 Configuration and SMV Control selection for SSC600

If the configuration is updated in a manner that affects the Conf.Rev value of SVCB, configurations of both SMV sender and all receivers must be rewritten from PCM600.

5. In PCM600, select **Write to IED.**

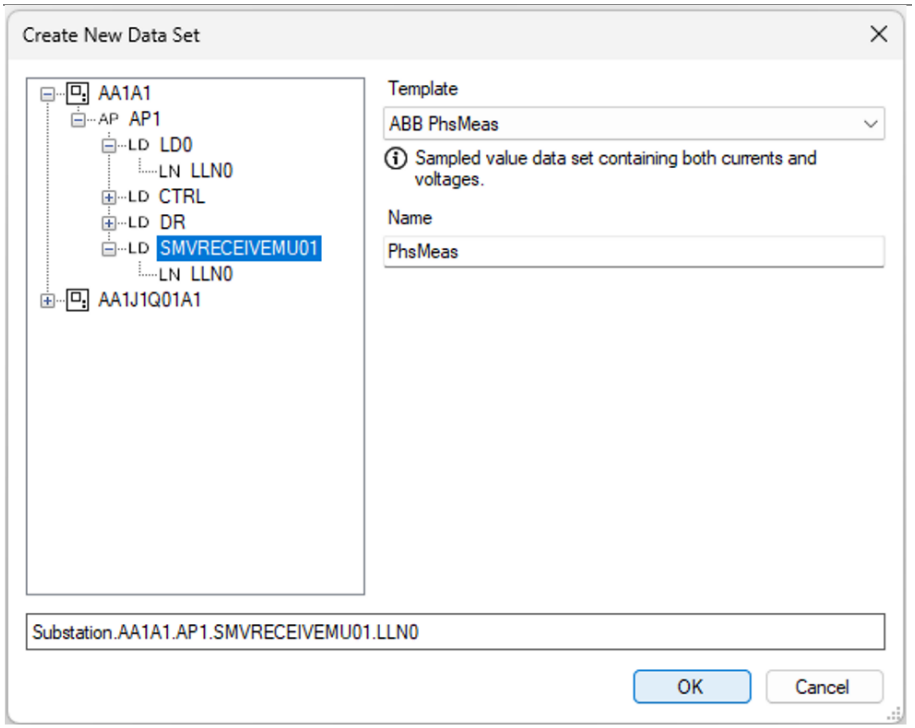
8.4.3.2 Configuring Routable SMV sending with PCM600

R-SMV can be sent with dataset including measurements from a single received SMV from within a single logical device. The dataset configuration needs to be verified by user to reflect the received dataset. This is especially true for IEC 61869-9 datasets where the sent dataset current and voltage phases and measurement points need to be in line with the received dataset. This is important for the device receiving the R-SMV to be able to process the dataset correctly. The R-SMV dataset is sent as a copy of the received dataset values with no processing done to the values.

After all SVRECEIVE_LE connections have been added, the R-SMV sending can be configured.

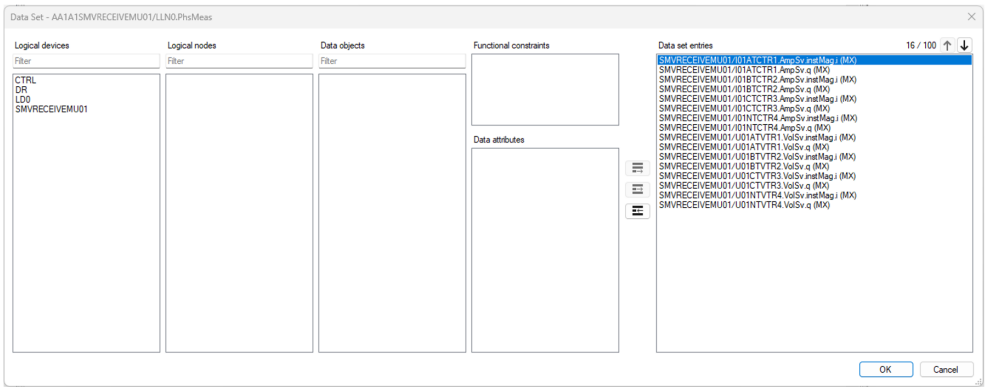
1. Open the IEC 61850 configuration tool in PCM.
2. Select **Process Bus Communication** in the drop-down box on the toolbar.
3. Make sure that the **Data Sets** tab is active.
4. Create new data set from the SMVRECEIVE LD.
   a) Right click inside the **IEC 61850 Configuration tool** window.
   b) Select **new** in the context menu.
   c) Select the correct SMVRECEIVE LD item in the left-hand side tree.

d) Select the **ABB PhsMeas** from the template drop-down.



e) Press **OK**.

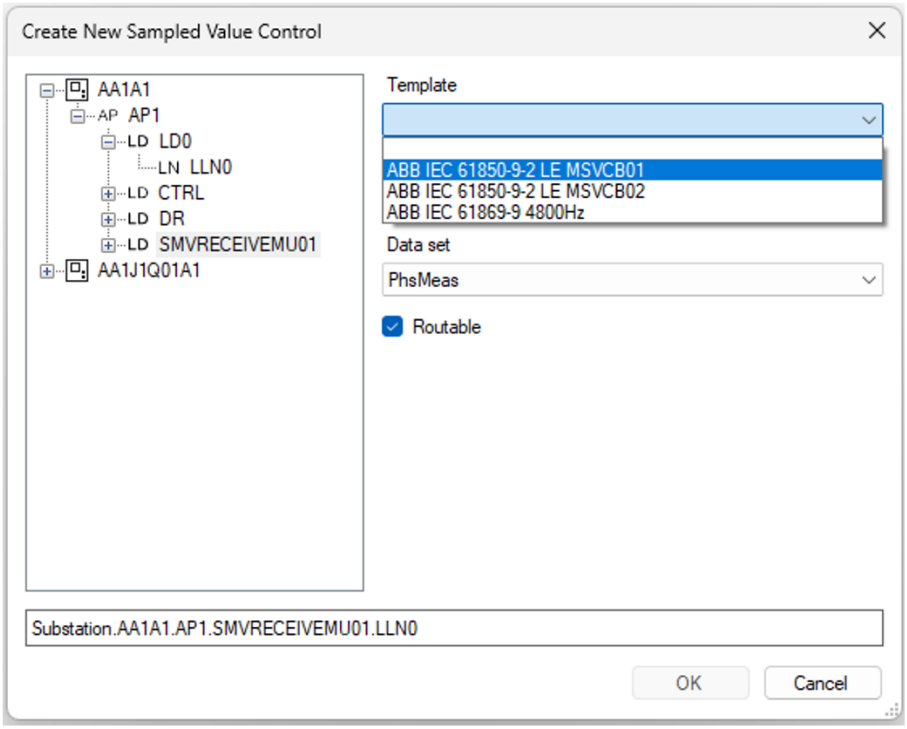
f) Check the data set entries.



g) Press **OK**.

5. Switch to the **Sampled Value Controls** tab.

6. Create a new Sampled Value Control.



   a) Right click inside the **IEC 61850 Configuration tool** window.
   b) Select **new** in the context menu.
   c) Select the SMVRECEIVE LD item that was used in the previous step.
   d) Select one of the ABB 9-2 LE templates from the drop down.
   e) Make sure that the **Name** attribute is unique for the SSC600.
   f) Make sure that the **Routable** checkbox is selected.
   g) Press **OK**.
7. Configure R-SMV settings.
   a) **VLAN**, **App ID** and **Sampled Value ID** should be configured according to the same rules as for regular SMV streams.
   b) Set **IGMPv3 Address** to a valid unicast IP address.
   c) Set **IP address** to a unique UDP multicast address.
8. In PCM600, select **Write to IED**.

Valid UDP multicast address range is 224.0.0.0 - 239.255.255.255.
Valid unicast address range is 0.0.0.0 – 223.255.255.255.

Configuring the R-SMV reception is done the same way as for regular SMV.

Communication	
Access Point	AP1
App ID	4001
Class of Traffic	0
IGMPv3 Address	0.0.0.0
IP Address	0.0.0.0
Subnetwork	WA1
VLAN ID	000
VLAN Priority	4
Data Flow	
Subscribers	(Collection)
General	
Config Revision	1
Data Set	PhsMeas
Description	
Multicast	Yes
Name	MSVCB01
Number of ASDUs	1
Routable	Yes
Sample Rate	80
Sampled Value ID	**AA1SMVRECEIVEMU0101**
Sampling Mode	Samples Per Period
Security Enabled	None
Sampled Value Options	
Data Reference	No
Data Set	No
Master Clock ID	No
Refresh Time	No
Sample Rate	No
Samples Synchronized	Yes
Security	No
Substation	
IED	AA1A1
Logical Device	SMVRECEIVEMU01
Logical Node	LLN0

Figure 96: Routable SMV settings

8.4.4 Bay level configuration

8.4.4.1 Application configuration of the SMV receiver

The SMV receiver application configuration is done with the Application Configuration tool in PCM600. SMV receive function blocks, SVRECEIVE_LE and SVRECEIVE_61869 are used in receiver application in PCM600 to perform the supervision for the sampled values and to connect the received analog voltage inputs to the application.

The WARNING output of SMV receive should be connected in the SMV applications to perform the necessary actions in case the SMV angle information is out of the accuracy range. Depending on the protection function operation principle, inaccurate angle information is also seen in the related protection function operation inaccuracy.

Additionally, the ALARM output of SMV receive function should be connected to ensure fail-safe operation in all circumstances. The WARNING output is always internally active whenever the ALARM output is active.

WARNING and ALARM information is internally propagated for the measurement functions. Thus, measurement functions are able to update the measured value quality information accordingly without any additional connections.

The receiver activates the SMV receive WARNING and ALARM outputs if any of the quality bits, except for the derived bit, is activated. When the receiver is in the test mode, it accepts SMV frames with test bit without activating the SMV receive WARNING and ALARM outputs.

The SMV receive WARNING in the receiver is activated if the synchronization accuracy of the sender or the receiver is worse than 4 µs. The output is held on for 10 seconds after the synchronization accuracy returns within limits.

The SMV receive ALARM in the receiver is activated if the synchronization accuracy of the sender or the receiver is unknown, worse than 100 ms or two or more consecutive frames are lost. The output is held on for 10 seconds after the synchronization accuracy returns within limits.

The T_SYNC_OK output of the SMV receive function is set when both the sender and receiver have synchronized their clocks to within the accuracy requirements with an IEEE 1588 grandmaster clock.

The GLOB_SYNC_OK output of the SMV receive function is set when both the sender and receiver have synchronized their clocks with a global IEEE 1588 grandmaster clock, such as a GPS clock.

Quality of received SMV is available as outputs in SMV measurement function block and not propagated directly to protection function blocks along with the SMV measurement values. To handle situations where SMV is not available, its quality is not good or there is an issue with time synchronization, the WARNING, ALARM, T_SYNC_OK and GLOB_SYNC_OK outputs of SMV measurement function blocks must be connected to application, for example to block directional protection.

The amount of received SV streams is practically limited to the number of SVRECEIVE functions and the number of TxTR functions. In addition to these, the following restrictions apply:

- Maximum number of received sampled value streams is 30
- Maximum number of measurement channels in one received sampled value stream is 32
- Maximum number of received sampled value channels is 720 (30 streams with 24 channels each)

  Note that all of these are not usable in the application simultaneously because of the limited number of SVRECEIVE functions
- Receiving streams according to IEC 61850-9-2LE and IEC 61869-9 at the same time is not supported.

8.4.4.2 SMV controls

Table 20: Sampled value control attributes

SVCB attribute	Description
Communication	
Access Point	Name of parent access point
App ID	Application identifier. Unique HEX value application identifier for sending the SVCB within the system. Value range for sampled values is 0x4000 to 0x7FFF.
MAC Address	Media access address value. Multicast MAC address to which the data is sent. It is recommended to have a unique address per SVCB. Value range 01-0C-CD-04-00-00 - 01-0C-CD-04-01-FF. Non-routable only.
Class of Traffic	Specifies the TOS field of the IPv4 header.
IGMPv3 Address	Sender IPv4 address. Unicast address used for IGMPv3 subscription. Value range 0.0.0.0 - 223.255.255.255. Routable only.
IP Address	Destination IPv4 address. Multicast address used for UDP destination. Value range 224.0.0.0 - 239.255.255.255. Routable only.
Subnetwork	Name of the subnetwork
VLAN ID	Virtual LAN identifier. Value “000” indicates a nonconfigured VLAN and switches do not filter these messages on a port basis.Value range 000 - FFF. Recommended values are 2 - 1001.
VLAN Priority	Virtual LAN user priority. Used in networks supporting VLANs. The priority is used with network switches. Value range 0 - 7.
General	
Config revision	Configuration revision. Incremented when the referenced dataset is modified. The sender and receiver must both have the same value to ensure configuration version integrity.
Data Set	Referenced dataset of data sent to the network.
Description	Description
Multicast	Defines whether this is a multicast or unicast control block.
Name	Name of control block
Number of ASDUs	Number of application service units sent in single frame.

Table continues on the next page

SVCB attribute	Description
Routable	Defines whether the message can be sent at layer 3 network level.
Sample Rate	Sample rate in units defined by the sampling mode.
Sampled Value ID	Sampled value identifier
Sampling Mode	Sampling mode
Security Enabled	Security option of sampled value message
Sampled Value Options	
Data Reference	Data reference included in message
Data Set	Dataset name included in message
Master Clock ID	Identity of synchronizing master clock included in message
Refresh Time	Time of refresh activity included in message
Sample Rate	Sample rate included in message
Samples Synchronized	Samples synchronized by clock signal included in message
Security	Digital signature included in message

Take care when modifying other than App ID, IGMPv3 Address, IP Address, MAC address, VLAN ID and Sampled Value ID parameters to keep IEC 61850-9-2 compliancy. Others should be set as default.

8.4.4.3 SV delay

The *SV delay* parameter, found via menu path **Configuration/System**, defines how long the receiver waits for the SMV frames before activating the SMVRECEIVE ALARM output. This setting also delays the local measurements of the receiver to keep them correctly time aligned. The *SV delay* values include sampling, processing and network delay.

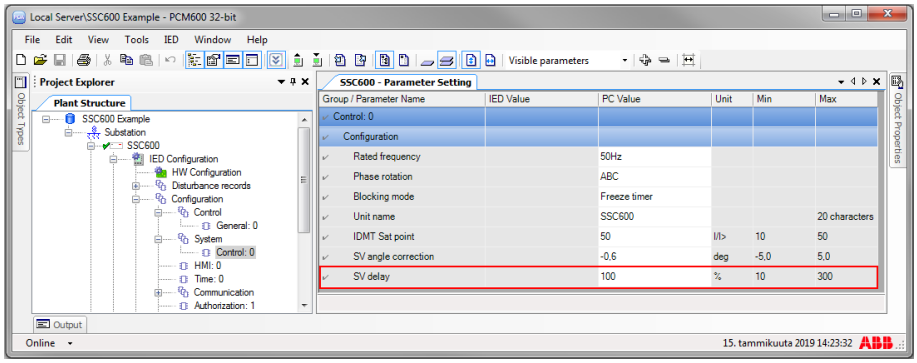


Figure 97: SV Delay

SMVRECEIVE WARNING output is set TRUE if two consecutive frames are lost. ALARM output is set TRUE if three or more frames in a sequence is lost. A single loss of frame is corrected with a zero-order hold scheme, the affect on protection is considered negligible in this case and it does not activate the SMVRECEIVE WARNING or ALARM outputs.

Table 21: Protection delays and network margins for 9-2LE at 50 Hz

SV Delay setting (%)	Ethernet network margin (ms)	Protection delay (ms)
50	0,656	2,606
75	0,984	2,934
100	1,313	3,263
125	1,641	3,591
150	1,969	3,919
200	2,625	4,575
300	3,938	5,888
5000	65,625	67,575

Table 22: Protection delays and network margins for 9-2LE at 60 Hz and IEC 61869-9 at 50 Hz and 60 Hz

SV Delay setting (%)	Ethernet network margin (ms)	Protection delay (ms)
50	0,547	2,497
75	0,82	2,77
100	1,094	3,044
125	1,367	3,317
150	1,641	3,591
200	2,188	4,138
300	3,281	5,231
5000	54,688	56,638

Because *SV delay* impacts directly the protection speed, big values are meant for non-time critical applications, like alarming. Increasing *SV delay* might be necessary for high latency networks for example in case of mobile networks.

When using routable SV, there's additional R-SV delay parameter that can be used to adjust the total network delay and therefore also the protection delay. The formula to calculate the total protection delay using R-SV delay is the following:

$$Delay_{prot} = Delay_{Eth} + 1{,}95\ ms + Delay_{R-SV} + SampleDistance$$

(Equation 1)

Where *Delay*$_{Eth}$ is the Ethernet margin, *Delay*$_{R\text{-}SV}$ is the configured R-SV delay and *SampleDistance* is the SV sample distance in milliseconds. See table below for SV sample distances.

Table 23: SV sample distances

SV Profile	SV sample distance (ms)
9-2LE at 50 Hz	0,250
9-2LE at 60 Hz	0,208
IEC 61869-9 at 50 Hz	0,208
IEC 61869-9 at 60 Hz	0,208

For example, consider the R-SV delay setting of 0,5 ms, the SV delay setting of 100% using IEC 61869-9 at 50 Hz. The total protection delay would be the following:

$$Delay_{prot} = 1{,}094\ ms + 1{,}95\ ms + 0{,}5\ ms + 0{,}208\ ms \approx 3{,}75\ ms$$

(Equation 2)

8.4.4.4 IEEE 1588 v2 parameters and status information

Time

The time parameters are found via menu path **Configuration/Time**.

Table 24: Time parameters

Parameter	Value	Range
Synch source	IEEE 1588	

In IEEE 1588 v2, the PTP domain is a logical grouping of clocks that synchronize to each other using the protocol but that are not necessarily synchronized to clocks in another domain.

Best master clock algorithm

The best master clock algorithm compares data describing two clocks to determine which data describes the better clock. This algorithm is used to determine which of the described clocks in several announce messages received by the local clock port is the best clock.

Time synchronization monitoring values

The time synchronization monitoring values are found via menu path **Monitoring/IED status/Time synchronization.**

Table 25: Time synchronization monitoring values

Description	Value
Sync source	IEEE 1588 slave
Sync status	Up
	Down
Sync accuracy	0...26 bits

Sync accuracy indicates the synchronization accuracy in number of fractional bits.

Sync accuracy can be calculated from the number of bits according to a formula.

Synch_accuracy = 2^-2bits seconds

Table 26: Synch accuracy values and corresponding accuracies

Bits	Accuracy
21	0.5 µs
20	1 µs
19	2 µs
18	4 µs
17	8 µs
11	0.5 ms
10	1 ms
9	2 ms
8	4 ms
7	8 ms
1	0.5 s
0	1 s

The time synchronization accuracy is rounded to the next worse accuracy, for example, if the accuracy is 2..3 ms, it is shown as 8 bits (4 ms).

IEEE 1588 v2 monitoring values

The IEEE 1588 v2 monitoring values are found via menu path **Monitoring/IED status/Time synchronization/IEEE 1588.**

Table 27: IEEE 1588 v2 monitoring values

Description	Value
Grandmaster Identity	

Within a domain, grandmaster is the clock that is the ultimate source of time for clock synchronization using the PTP protocol.

Grandmaster identity indicates the identity of the master clock.

8.4.4.5 Power profile parameters

The IEDs' IEEE 1588 v2 time synchronization complies with the IEEE C37.238-2011 Power Profile or IEC 61850-9-3 Power Utility Profile.

For best interoperability, third party devices in the same IEEE 1588 v2 time domain network must be set according to Power Profile either via the power profile parameter or by individually setting the parameters according to Power Profile.

Table 28: IEEE C37.238-2011 and IEC 61850-9-3 key parameters

Parameter	Value[1]
Delay Mechanism	P2P
VLAN priority	mandatory (default=4)
Ethertype	0x88f7
Announce period	1 s
Sync period	1 s
Pdelay period	1 s
PTP mode	transparent

8.4.4.6 Quality bits in SMV frames

Table 29: Explanation of quality bits

Quality bit	Description
smpSynch	Synchronization accuracy for all channels in the SMV frame. 0: less than 4 µs synchronization accuracy 1: within 4 µs synchronization accuracy
test bit	The sender IED is in test mode.
invalid 01 & bad reference	The sender time synchronization is uninitialized (accuracy unknown).
	The sender has time accuracy less than 100 ms.
invalid 01	The channel is not available.
questionable 11 & inaccurate	The accuracy of the measurement value is inaccurate or not supported.
derived	The channel is derived from other channels, for example, calculated residual voltage.

8.4.5 Engineering verification

This chapter gives a checklist of items to check and confirm during the engineering phase. The complete test specification depends on the network topology and used system components.

[1] Some devices use the standard notation format 2x[s] of IEEE 1588 v2 intervals. The values in this table are in [s] format.

Check the configuration and settings with real system load and topology.

In the Measurement view of the SMV receive, the voltage values in brackets indicate an invalid or a questionable measurement.

Table 30: SMV sender (only in IEDs sending SMV, not in SSC600)

Item	Description	Checked
Missing sender	Disable the SMV sender via Configuration/Communication/ Ethernet/SMVSENDER and verify the expected handling in receivers. In the SMV receives's Measurement view, the voltage values should be in brackets indicating invalid or questionable measurement. If The SMVSENDER is disabled from the LHMI, it can only be enabled from the LHMI. Thus, in this situation a configuration write from PCM600 does not enable the SMVSENDER.	
Internal fault test	Force internal fault in the sender via Tests/IED test and check that the receiving devices behave as expected.	

SMV receive monitored data is available in three locations.

- **Monitoring/I/O status/Analog inputs**
- **Monitoring/IED status/SMV traffic**
- **Monitoring/IED status/SMV accuracy**

Table 31: SMV receive

Item	Description	Checked
WARNING	WARNING (**Monitoring/I/O status/Analog inputs/ Voltage(3U,VT)**) works as specified in the Application Configuration tool. Necessary special handling considered in the Application Configuration tool logics. WARNING is active when the IED starts.	
ALARM	ALARM (**Monitoring/I/O status/Analog inputs/Voltage(3U,VT)**) works as specified in the Application Configuration tool. Necessary special handling considered in the Application Configura-	

Table continues on the next page

Item	Description	Checked
	tion tool logics. ALARM is active when the IED starts.	
Max delay	The maximum delay (**Monitoring/IED status/SMV traffic**) must be in all conditions smaller than the SV Delay parameter (Configuration/System). Larger values indicate configuration problems in the network or the need to change the SV Delay.	
Average delay	The average delay (**Monitoring/IED status/SMV traffic**) variation is small in different network traffic setups. A large variation may indicate configuration problems in the network.	
Measurement	In the SMV receives' Measurement view, the voltage values should be without brackets indicating good status. Brackets indicate questionable or invalid values. The *SMV traffic delay* (**Monitoring/IED status/SMV traffic**) value should be lower than the value of SV Delay (Max 6.48ms).	

Table 32: Time synchronization

Item	Description	Checked
Time quality	Observe the grandmaster accuracy (**Monitoring/IED status/Time synchronization/IEEE 1588**). The accuracy decreases slowly if the GPS antenna is removed. The IED GNRLLTMS1 WARNING signal is activated if the accuracy is not within the specified limits.	
Missing clock	Disable the clock master and check that one IED takes the clock master role.	
PTP priority 1	Compare priorities against the grandmaster's priority. The clock master should have smaller value (bigger priority).	
PTP priority 2	Same as above, but PTP priority 2 handles the selection when PTP priority 1 is the same. Can be used to set pri-	

Table continues on the next page

Item	Description	Checked
	orities to the IEDs in situation when the clock master fails.	
SMV Synch accuracy	The global clock is seen when the clock master is present.	
Local synch accuracy	According to 9-2 LE the synchronization accuracy needs to be better than 4 µs which is the defined supervision limit.[2]	
Max Dev synch Accuracy	According to 9-2 LE the synchronization accuracy needs to be better than 4 µs which is the defined supervision limit.[3]	
Grandmaster	Check the grandmaster monitoring from the master configuration via the HMI path **Monitoring/IED status/Time synchronization/IEEE 1588**. Check that all IEDs are synchronized to same PTP master.	

Table 33: Network

Item	Description	Checked
Max HSR loop size	Maximum supported HSR loop size is 30. Consider applying different topology in case a larger system is needed.	
Interlink port	IEEE 1588 v2 slave devices are not allowed in the interlink port.	
Redundancy	Check the maximum delays in different network setups.	

8.5 Engineering of event reporting with PCM600

The process is similar to 615 series relays, from where the engineering example is.

[2] 4 µs corresponds to approximately 0.07 degrees in 50 Hz systems
[3] 4 µs corresponds to approximately 0.07 degrees in 50 Hz systems

8.5.1 Managing IEC 61850 clients with the IEC 61850 Configuration tool

The default IED SCL contains five default client definitions, “Client1”...”Client5”, which are used by all the RCBs. PCM600 does not show these clients in the plant structure, but the IEC 61850 Configuration tool shows the clients in the client-server communication.

ZEE600 clients can use the client definitions directly. If other clients need to be added to the project, import the ICD file describing the client data model to PCM600.

8.5.1.1 Adding new IEC 61850 clients for the IEC 61850 Configuration tool

Adding a new IEC 61850 client to a PCM600 project is a two-step operation. First, a new generic IEC 61850 IED object must be created under the plant structure and the relevant client ICD or CID file must be imported to the generic IEC 61850 IED.

1. Right-click a bay node in the project plant structure, point to **New**, then point to **Generic IEC61850 IEC** and select **IEC61850 IED.**

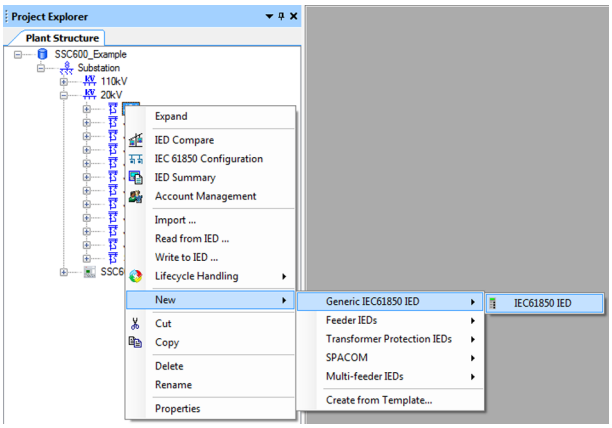


Figure 98: Creating a generic IEC 61850 IED

2. Rename the IED object as “Client_G”.

3. Right-click the **IED** and then select **Import**.

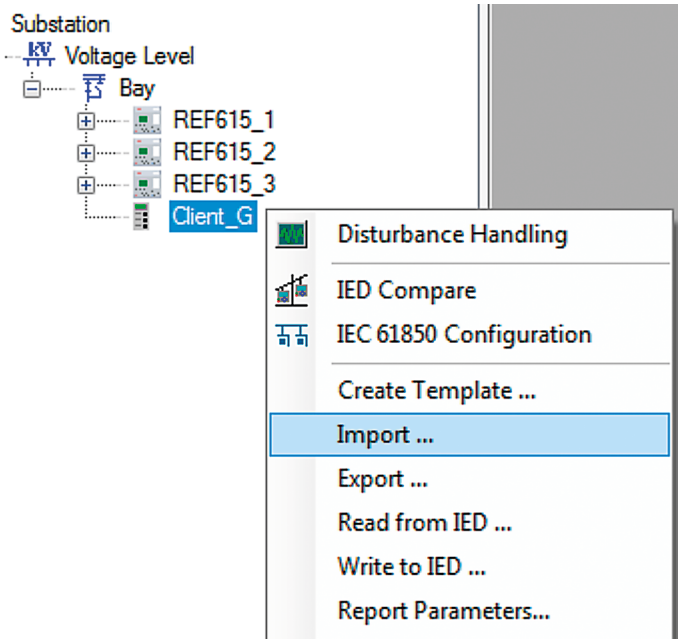


Figure 99: Selecting Import on the shortcut menu

4. Select a valid Client SCL file (ICD or CID) and click **Open** in the file selection dialog box.
5. Select **Ignore PCM Object Type** and then click **Import** in the **SCL Import Options** dialog box.

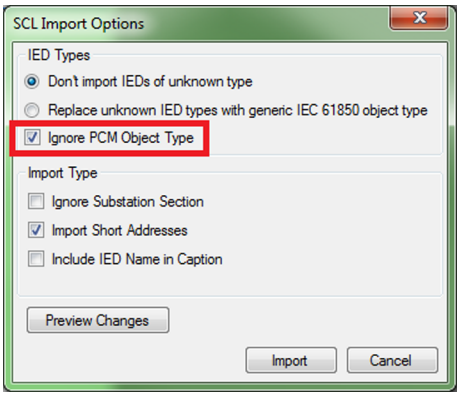


Figure 100: Defining SCL import options

6. Start the IEC61850 Configuration tool and select **Client-Server communication** as engineering mode.

   The newly added client should be present in the Clients column along with other clients in both the Data Set tab and the Report Controls tab.

8.5.2 IEC 61850 Configuration tool user interface

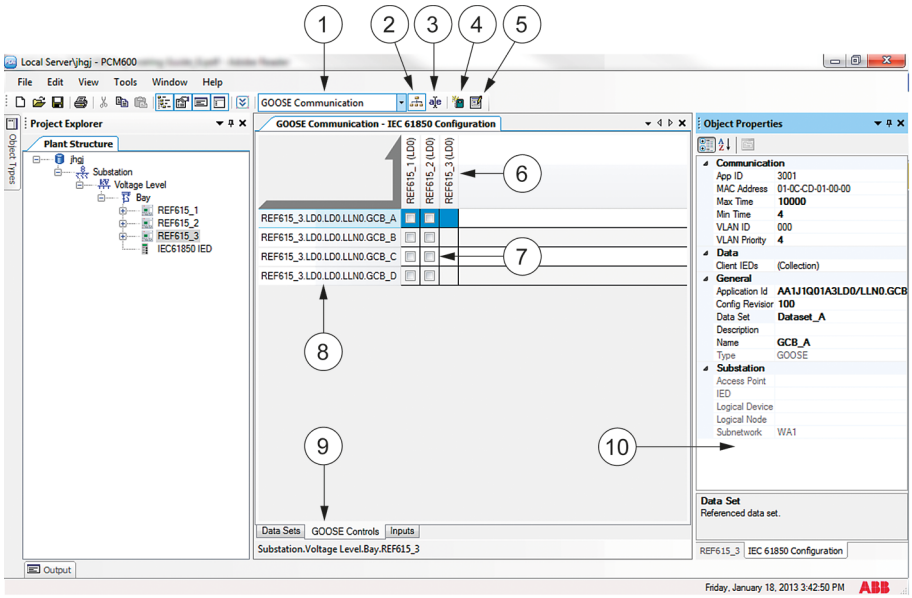


Figure 101: IEC 61850 Configuration tool user interface

1	Engineering mode selection
2	Switch engineering mode on and off
3	Switch IEC 61850 IED naming on and off
4	Create new object
5	Selection details
6	Receiving access points
7	Mapping grid
8	Data to send/receive
9	Engineering type selection
10	Object properties

1. Engineering mode selection

   The communication mode can be selected from the drop-down list on the toolbar. Three modes are available: “GOOSE Communication”, “Client-Server Communication” and “Process Bus Communication”.

2. Switching engineering mode on and off

   The button switches between engineering and view mode. The configuration can be edited only in the engineering mode.

Figure 102: Engineering mode selection button

When the engineering mode is enabled, SCD files from external IEC 61850 engineering tools cannot be imported into PCM600.

3. Switching IEC 61850 IED naming on and off

   The button switches between IEC 61850 and PCM600 IED naming.

4. Create new object.

   The button opens a window to create a new object. The type of object depends on the currently selected engineering type.

5. Selection details

   The button opens the Editor window for the data currently selected in the mapping grid. The same editor can also be opened by double-clicking the data.

6. Receiving access points

   All IEDs that have access points capable of receiving the kind of data according to the currently selected engineering type and engineering mode are displayed as columns in the mapping grid. A check mark in a column means that the access point is receiving the data.

7. Mapping grid

   Mapping grid consists of check boxes for configuring what data is sent to or received by an access point. A check mark in the grid means that the data on the row is sent to the receiver in the column.

8. Data to send/receive

   The data available for sending/receiving in the selected engineering mode and type is displayed as rows in the mapping grid. The data is context-sensitive, with the current selection in the PCM600 plant structure. A check mark in the row means that the data is sent to or received by an access point. Double-click a data to open the data editor.

9. Engineering type selection

   Each engineering mode has several engineering types. Engineering type means the type of data to configure. The types can be selected by clicking the tab page on the bottom of the tool window. The available engineering types depend on the selected engineering mode.

   - Data sets: Create, delete, modify or send data sets
   - GOOSE controls: Create, delete, modify or send GOOSE controls
   - Sampled value controls: Create, delete, modify or send GOOSE controls
   - Report controls: Create, delete, modify or send report controls
   - Inputs: View inputs (external references)

10. Object properties

    The Object Properties window displays the properties of the currently selected data. Different data properties are edited in this window.

8.5.3 Creating data sets with the IEC 61850 Configuration tool

1. Select **Plant Structure** in the **Project Explorer** window.
2. Right-click the IED node.
3. Select **Client-Server Communication** in the drop-down box on the toolbar.

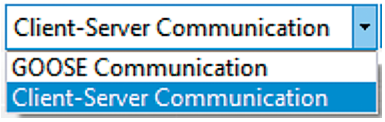


Figure 103: Selecting Client-Server Communication

4. Select the **Data Sets** tab.
5. Right-click the area containing the data set names and select **New** to add a new data set.

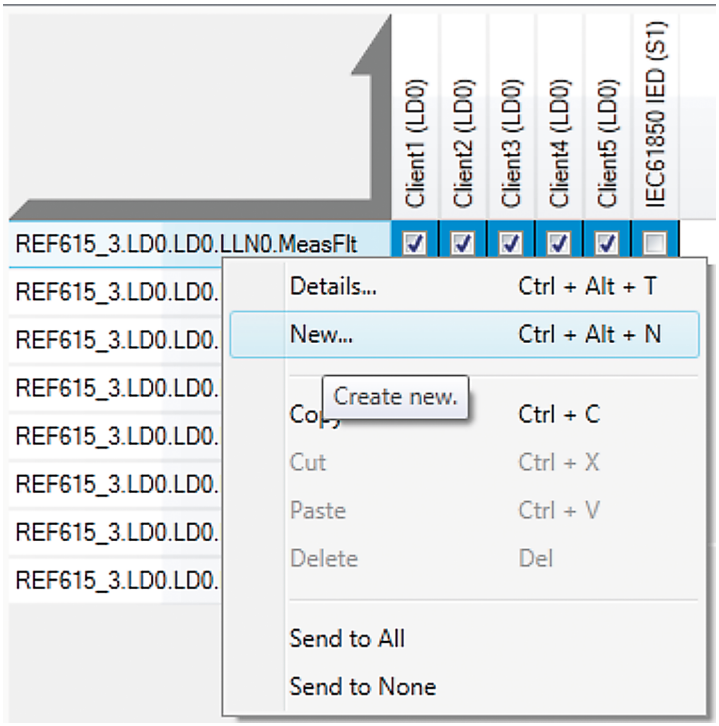


Figure 104: Creating a new data set

6. In the **Create New Data Set** dialog box, define the LN where to place the data set (accept preselected “LD0/LLN0”) and give the data set a unique name.

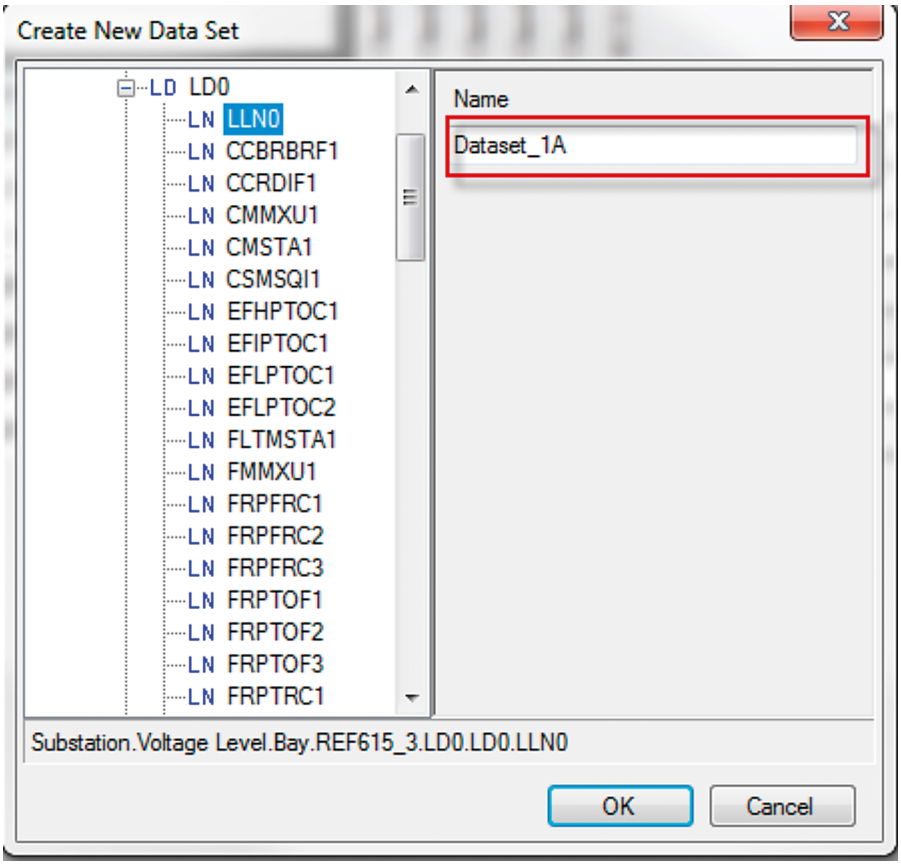


Figure 105: Naming the data set

After creating the GOOSE data sets, define the data set entries (data attributes or data objects) for the data sets.

8.5.3.1 Defining data set entries with the IEC 61850 Configuration tool

1. Select the **Data Sets** tab.

2. Right-click a data set and select **Details** to add data attributes.

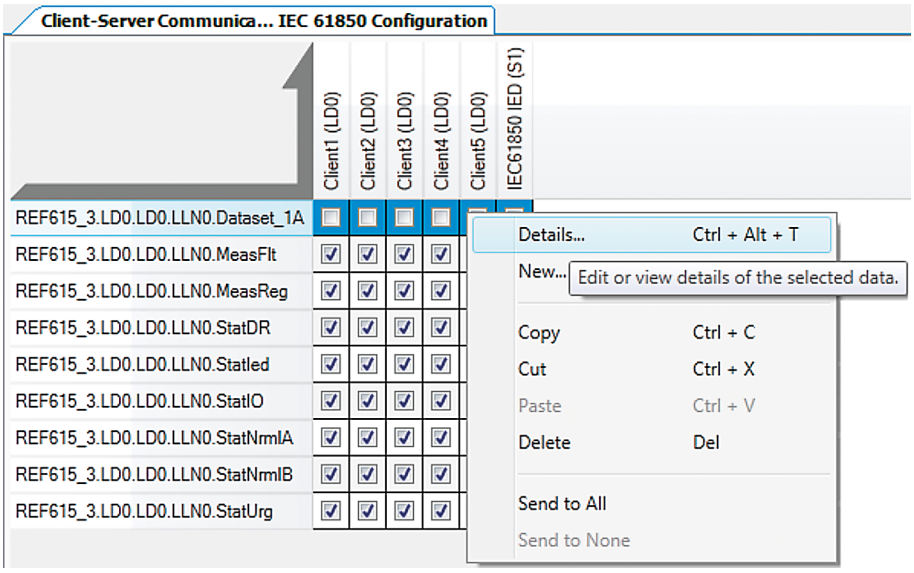


Figure 106: Adding data attributes

3. In the data set entry window, select the data attribute to be contained in the data set.
   - Click **Append selected** to add the data attribute to the end of the data set.
   - Click **Insert selected** to add the data attribute above the selected row in the data set entries list.
   - To remove a data attribute from the data set, select the data attribute in the data set entries pane and click **Removed selected.**

   Reporting datasets can include status and measurement type of data. Also configuration and setting values can be added to datasets in case required.

   Data set entries for vertical reporting are selected using the data object level, and entries for GOOSE using the data attribute or data object level.

   The default data set for SMV sending is fixed and may not be modified.

8.5.4 Creating report control blocks with the IEC 61850 Configuration tool

1. Select the **IED** node in **Plant Structure** in **Project Explorer**.
2. Click the **Report Controls** tab.

3. Right-click the area containing the existing report control blocks and select **New** to add a new report control block.

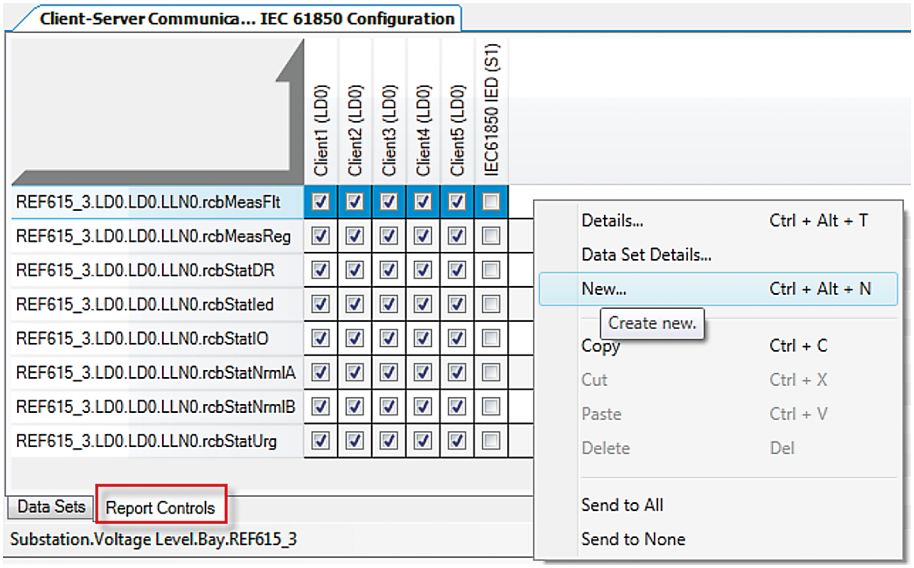


Figure 107: Adding a new report control block

4. Browse to LLN0 under LD0 to define where to place the report control block.
5. Give a unique name to the report control block.

6. In the drop-down list, select the previously created data set to link with the GCB.

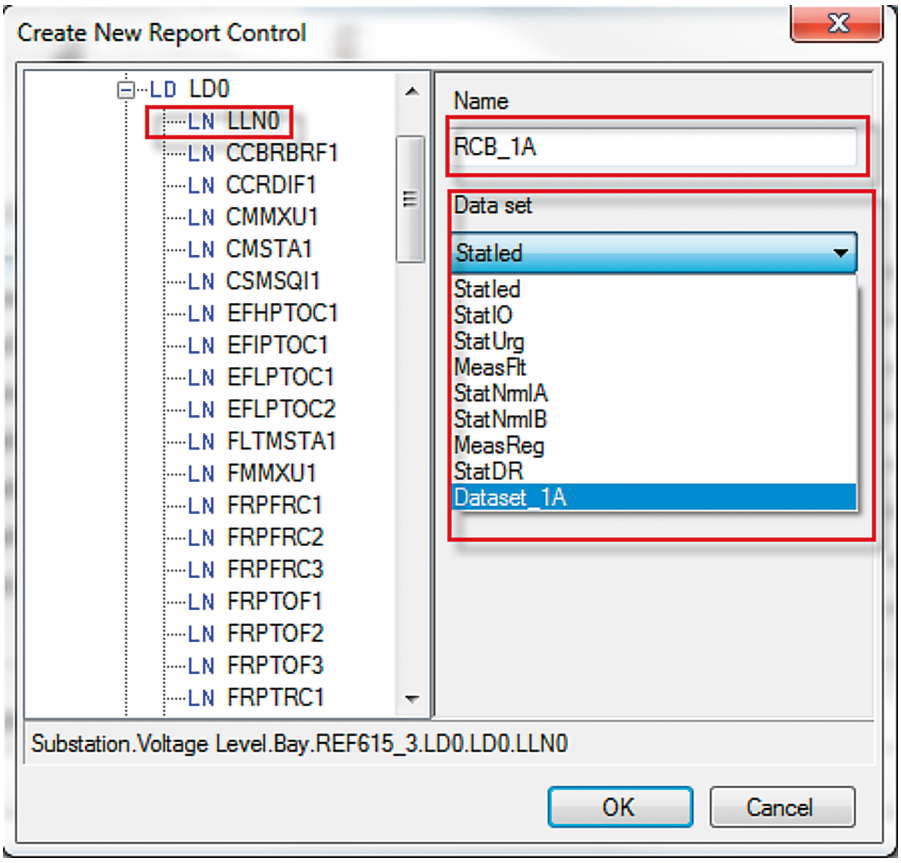


Figure 108: Data set drop-down list

7. Edit the properties and options of the created report control block.

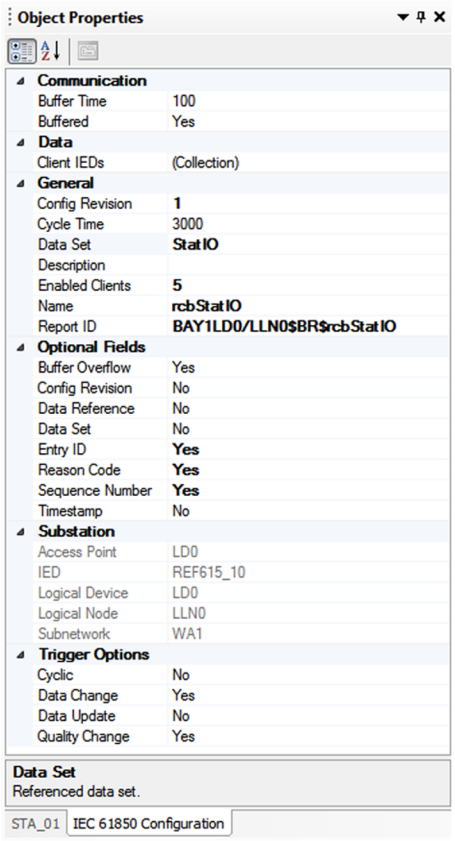


Figure 109: Report control block properties

Data set entries in a data set linked to the GCB can be modified from the **GCB Control Block** tab by selecting the **Data Set Details** in the shortcut menu.

8.5.5 Configuring RCB clients with the IEC 61850 Configuration tool

Add and configure the IEDs before configuring the RCB client. The potential clients and their communication configuration should be known for a successful RCB client configuration.

The RCB name is limited to 14 characters or 30 characters (without two-digit index number) depending on which IEC 61850 version is in use.

1. In the **Plant Structure**, click the IED node which is RCB server.
2. Click **Report Controls** tab.

   The rows of the Report Controls window show RCBs configured for the IED. The columns of the Report Controls window show the RCB clients configured in the PCM600.

3. To add or remove clients for a report control block, click the check-box in the grid, corresponding to the client and RCB.
   Five clients at the maximum can be connected to a RCB.

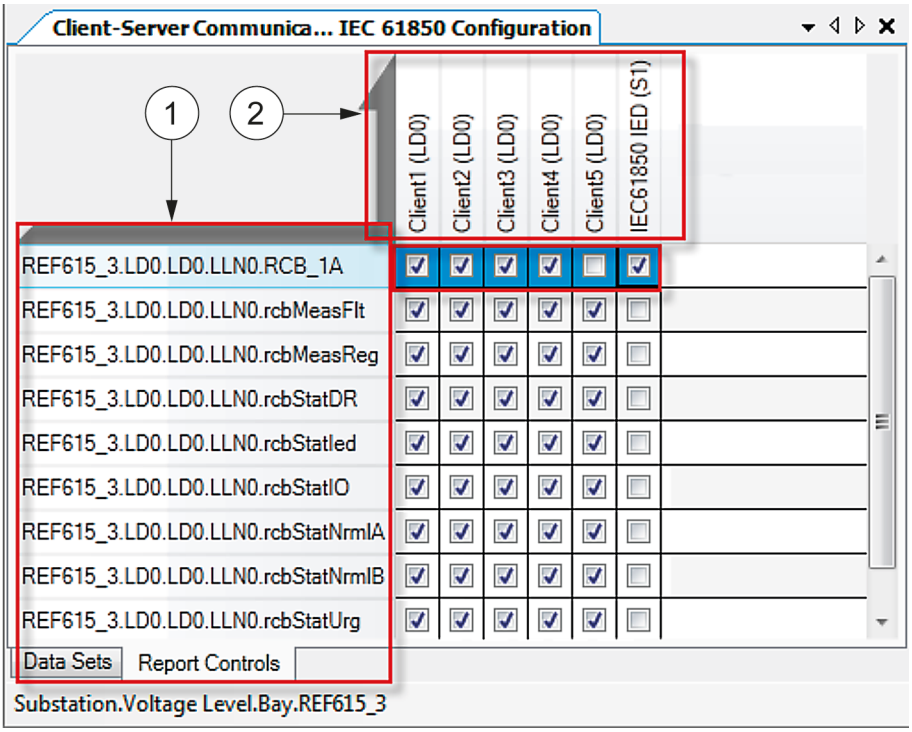


Figure 110: RCB clients

1 RCBs configured for the IED

2 RCB clients

The clients are added or removed automatically to the corresponding data sets in the Data Sets tab. Date sets are based on the configuration done in the Reports Controls tab and vice-versa.

8.5.6 Substation section configuration in the IEC 61850 Configuration tool

The substation topology consists of the substation, voltage level and bay nodes. The bay nodes include also the conducting (primary) equipment, which corresponds to the switches, that is, the circuit breakers, disconnectors, and earth switch, of the configured IED. In addition to the substation topology configuration, logical nodes of the IEDs are mapped to proper objects, for example, to support the automatic bay configuration via SCL files in the SCADA system.

At the moment, the IEC 61850 Configuration tool does not support engineering of the substation section. Instead, for example, IET600 can be used for engineering, if needed.

9 Installation

9.1 Unpacking, inspecting and storing

9.1.1 Removing transport packaging

Devices require careful handling.

1. Examine the delivered products to ensure that they have not been damaged during the transport.
2. Remove the transport packaging carefully without force.

The cardboard packaging material is 100% recyclable.

9.1.2 Inspecting the product

9.1.2.1 Identifying the product

1. Locate the device's order number from the label on side of the device.
2. Compare the order number with the ordering information to verify that the received product is correct.

9.1.2.2 Checking delivery items

- Check that all items are included in the delivery in accordance with the delivery documents.

9.1.2.3 Inspecting the device

Devices require careful handling before installation on site.

- Check the device to see if any damage occurred during transportation.

If the device has been damaged during transportation, make a claim against the transport contractor, and notify the local ABB representative.

9.1.2.4 Returning a device damaged in transit

If damage has occurred during transport, appropriate actions must be taken against the latest carrier. Please inform the nearest ABB office or representative. Notify ABB immediately if there are any discrepancies in relation to the delivery documents.

9.1.3 Storing

If the device is stored before installation, it must be done in the original transport packaging in a dry and dust free place. Observe the environmental requirements stated in the technical manual.

9.2 Mounting

9.2.1 Checking environmental conditions and mounting space

The mechanical and electrical environmental conditions at the installation site must be within the limits described in the technical manual.

- Avoid installation in dusty, damp places.

  Avoid places susceptible to rapid temperature variations, powerful vibrations and shocks, surge voltages of high amplitude and fast rise time, strong induced magnetic fields or similar extreme conditions.
- Check that sufficient space is available.

  Sufficient space is needed at the front and rear of the device to allow access to Ethernet cables and optical fibers to provide sufficient ventilation to the device and to enable maintenance and future modifications.

9.2.2 Mounting the device

The SSC600 provides kits for rack mounting in the chassis.

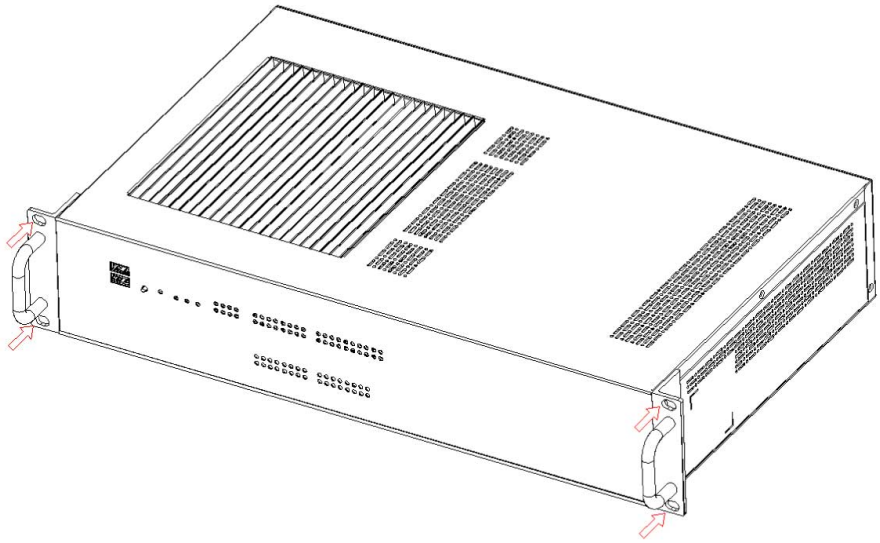


Figure 111: SSC600 product installation on rack location

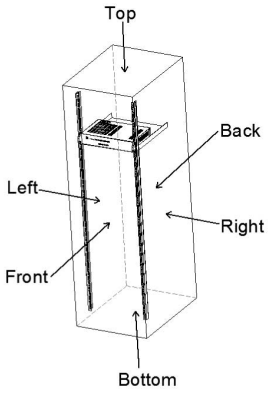


Figure 112: The installation cabinet of SSC600

1. Use the 4 screw holes to mount the SSC600 on the rack.

   The SSC600 can only be used in a standard equipment cabinet with a minimum of 2Us available. The equipment cabinet must satisfy two requirements:

   1. The maximum size of the cooling hole on the top, left, right, front and back is no more than 5mm.
   2. There is no limit on the size of the hole on the bottom.

2. The SSC600 has aluminum fins on the top of the unit as heat-sink. It can generate natural convection for better heat transmission. To have optimal thermal performance, leave 2U (88.9 mm) space above the unit.

9.3 Connecting

9.3.1 Power input

The SSC600 products support single power input AC or DC. Depending on the product, there is either Low Voltage Variant or High Voltage Variant.

Table 34: Power supply

Description	High voltage variant	Low voltage variant
Nominal auxiliary voltage U_n	100...240 VAC 50 and 60Hz	36...72 VDC
	100...240 VDC	
Maximum interruption time in the auxiliary DC voltage without resetting the device	50 ms at U_n	
Auxiliary voltage variation	85...110% of U_n (85...264VAC)	
	80...117% of U_n (80...280 VDC)	
Start-up threshold		
Power consumption	35 W (typical)	
Ripple in the DC auxiliary voltage	Max 10% of the DC value (at frequency of 100 Hz)	
Fuse type		

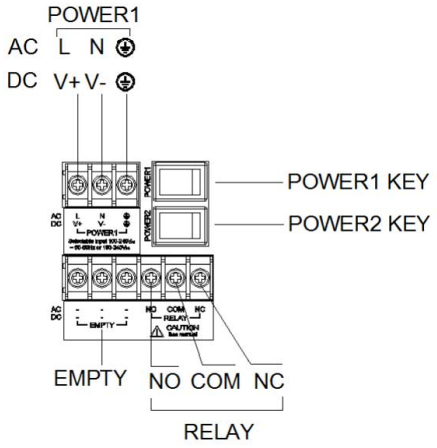


Figure 113: Power1 input location

Table 35: AC/DC power input PIN definition

Pin	Screen printing	Function description
1	L/V+	PWR1 L/PWR1 V+ AC/DC power input PIN Wire size at least 0,75 mm^2 (AWG 20)
2	N/V-	PWR1 N/PWR1 V- AC/DC power input PIN

Table continues on the next page

Pin	Screen printing	Function description
		Wire size at least 0,75 mm^2 (AWG 20)
3		Protective earthing (PE) ⏚ Wire size at least 0,75 mm^2 (AWG 20)

9.4 Installing SSC600 SW

To run the timing critical real-time protection and control with SSC600 SW, it is essential that the used PC hardware has enough resources which can be dedicated for each SSC600 SW virtual machine. SSC600 SW can ensure that it is isolated from other workloads, but the application needs the dedicated resources. Below are the minimum requirements to run SSC600 SW.

In addition to performance related requirements, it's important to ensure that the selected PC hardware is applicable for its environment. For example when installing in substation, external interference should be considered. Especially immunity for EMC is important for robust operation of protection and control. International standards like IEC 61850-3 and IEEE 1613 and related certification helps to select suitable hardware.

The specifications do not consider all the other workloads, like hypervisor, which needs own CPU cores.

Table 36: Minimum requirements to run a single SSC600 SW virtual machine

CPU	At least 4 physical cores for SSC600 SW Speed > 2.2 GHz (nominal frequency) Intel Cache Allocation Technology -support
L3 Cache	At least 8 MiB (reserved for SSC600 SW)
Network	IEEE 1588 HW timestamping 1 GbE for SV/GOOSE, PTP (Reserved for Process bus) 2 physical Ethernet ports
Memory	At least 8 GB RAM (dual-channel) (for SSC600 SW)
Harddisk space	64 GB (for SSC600 SW)
BIOS	Has to have some configurability (for example disabling hyperthreading)

If the used PC hardware includes a separate network interface card, which is cabable to run redundancy protocols with realtime performance (for example PRP or HSR), then SSC600 SW should be configured for non-redundant network.

As a reference, SSC600 SW has been tested successfully in a demanding system with the following hardware:

- Advantech ECU-579
  - Intel(R) Xeon(R) Gold 6208U CPU @ 2.90GHz

  - AQD- D4U16R24-HE 16 G 2400 DDR4 ECC
- Dell PowerEdge XR12 Server
  - Intel Xeon Silver 4314 2.4G, 16C/32T, 10.4GT/s, 24M Cache, Turbo, HT (135W) DDR4-2666
  - 3200MT/s RDIMMs
  - 8 x 8GB RDIMM, 3200MT/s, Single Rank
  - 960GB SSD SATA Mix Use 6Gbps 512 2.5in Hot-plug AG Drive
  - Dual, Hot-plug, Redundant Power Supply (1+1), 1400W
  - Intel X710-T2L Dual Port 10GbE BASE-T Adapter, PCIe Full Height

SSC600 SW is distributed as a complete Virtual Machine. These Virtual Machine packages are downloadable from ABB webpages. There is a separate SW package for each supported virtualization platform. The distributable file is an archived cabinet file (.cab), which needs to be extracted with any available unzipping software. For integrity purposes it is important to verify the digital signature of the .cab files and the SHA256 checksums of the included files before usage.

9.4.1 Hardware configuration

Disable hyper-threading (simultaneous multi-threading/logical processors) and turbo boost. Also enable virtualization support (VMX/VT-X for Intel platforms) in the UEFI (or BIOS) settings. Make sure that the power saving features of the host are disabled. See the hardware vendor documentation for detailed information.

9.4.2 KVM virtualization

Brief instructions on setting up the KVM environment for SSC600 SW. These instructions were tested on Ubuntu 20.04 and 22.04 server installation and on Fedora 36 server installation. The OS specific instructions may or may not apply to other versions or distributions. For instructions on how to set up the Linux distribution, refer to the documentation for the used distribution.

9.4.2.1 SSC600 SW package

The SSC600 SW package contains the SSC600 SW, `ssc600-kvm.xml` virtual machine template, `ptp_status.sh` and `ptp_status.service` for PTP status monitoring, and `ssc600-setup.sh` and `ssc600-startup.service` for configuring L3 cache partitioning and network interrupts. The package also contains `qemu.hook` script for configuring the real-time priorities for the networking tasks for the SSC600 SW.

The SSC600 SW package is distributed as a Windows cabinet file, the `cabextract` utility can be used to extract the files.

9.4.2.2 Host setup

In order to run the SSC600 SW, both hardware and the host OS must be configured so that it will not interfere with the running VM(s) and vice versa. Also the host hardware must be configured to run at a stable rate.

CPU allocation

Before configuring the host, decide how to partition the CPU and L3 cache.

The SSC600 SW requires exclusive access to 4 CPU cores. In addition to this, the emulator and virtual networking require an additional core, and the hardware networking another core. The best results have been seen with the hardware networking interrupts and threads next to the emulator core, and the last virtual CPU next to the emulator core. E.g. networking on core 10, emulator on core 11, and virtual CPU on core 12. By following these instructions optimal CPU core setup is achieved.

L3 partitioning

L3 cache should be partitioned so that virtual CPUs 1 and 2 have a separate 6 MiB or larger last-level cache partition in total.

For checking the L3 cache execute `sudo pqos -D` on the host, and look for the `L3 CAT` and `L3 Cache` sections. They contain the following information

- `Way size` - The size of one single cache block
- `Ways contention bit-mask` - Bit-mask of cache blocks that are shared with peripherals
- `Num ways` - Number of cache blocks

Example output which shows that the L3 can be divided into 20 blocks, each 1310720 bytes (1MB) in size, and the two last blocks are shared with peripherals.

```
 Allocation
  Cache Allocation Technology (CAT)
   L3 CAT
     CDP: unsupported
     Non-Contiguous CBM: unsupported
     I/O RDT: unsupported
     Num COS: 15
     Way size: 1310720 bytes
     Ways contention bit-mask: 0xc0000
     Min CBM bits: 1
     Max CBM bits: 20
Cache information
 L3 Cache
  Num ways: 20
  Way size: 1310720 bytes
  Num sets: 20480
  Line size: 64 bytes
  Total size: 26214400 bytes
```

Install packages

Before proceeding with the host setup, make sure your system is up-to-date. On Ubuntu run `sudo apt update && sudo apt upgrade`. On Fedora run `sudo dnf upgrade --refresh`.

Install Preempt-RT kernel

To be able to meet real-time requirements the host must be running a preempt-RT kernel.

For Ubuntu, get the Xanmod RT or RT-edge kernel. Follow the installation instructions at the *Xanmod homepage*.

For Fedora, follow the instruction at *Fedora copr* for setting up the copr. Install the kernel by running `sudo dnf install kernel-rt-mao`.

Install KVM

On Ubuntu, run

```
sudo apt install qemu-kvm libvirt-daemon-system libvirt-clients
bridge-utils
```

For details, see *Ubuntu help page*.

On Fedora, run

```
sudo dnf -y install bridge-utils libvirt virt-install qemu-kvm
```

and

```
sudo dnf -y install libvirt-devel virt-top libguestfs-tools
guestfs-tools
```

After that, enable and start the libvirtd service

```
sudo systemctl start libvirtd

sudo systemctl enable libvirtd
```

For details, see *Getting started with virtualization (libvirt)*.

Install linuxptp

Install linuxptp and chrony `sudo apt install linuxptp chrony` or `sudo dnf -y install linuxptp chrony`.

Install other utilities

SSC600 SW also requires that the Intel resource management tools are installed.

- On Ubuntu, run `sudo apt install intel-cmt-cat`
- On Fedora, run `sudo dnf -y install intel-cmt-cat`

Install the `cabextract` utility.

- On Ubuntu, run `sudo apt install cabextract`
- On Fedora, run `sudo dnf -y install cabextract`

SSC600 SW services and files

Extract the SSC600 SW package,

```
cd <path to SSC600 SW package>
cabextract <SSC600 SW package>
cd virtual_products/
```

and copy the services and scripts to their proper locations,

```
chmod +x *.sh
sudo cp *.sh /usr/sbin/
sudo cp *.service /etc/systemd/system
```

and update the systemd services

```
sudo systemctl daemon-reload
```

When starting up the VM, the emulator sets up tasks for the virtual networking layer. These tasks need to be run with real-time scheduler in order to avoid unwanted latencies in the Ethernet frames. This is handled by the provided script *qemu.hook* (../template/kvm/qemu.hook). This file should be copied to the libvirt hook folder and renamed to *qemu*. Default location for the hook scripts is */etc/libvirt/hooks/*. Make sure that the file has the correct ownership and that it is executable.

```
sudo mkdir /etc/libvirt/hooks/qemu
chmod +x qemu.hook
sudo cp qemu.hook /etc/libvirt/hooks/qemu
```

Extract the SSC600 SW disk image and copy it to the libvirt storage location, default is */var/lib/libvirt/images*

```
gunzip ssc600_disk.img.gz
sudo cp ssc600_disk.img
/var/lib/libvirt/images/ssc600_disk.img
```

Host tuning

For the SSC600 SW to be able to meet real-time performance, the host system must be isolated from the virtual machines. The host OS is also responsible for controlling CPU performance. This requires setting kernel parameters and configuring sysctls and module parameters.

On Ubuntu, the kernel options can be changed by appending to **GRUB_CMDLINE_LINUX_DEFAULT** in */etc/default/grub*. After editing the file, run `sudo update-grub`.

On Fedora, the `grubby` command is used to update kernel parameters using `sudo grubby --args='<kernel parameters>' --update-kernel=<kernel name>`. The kernel name can be `ALL` for all installed kernels or a specific kernel version. The installed kernels can be listed using `sudo grubby --info=ALL`.

The parameters and services listed below are not all available on all kernel versions/builds and distributions. The commands given may produce errors on some setups.

Host kernel isolation parameters

- `isolcpus` - List of CPUs to isolate (deprecated, according to documentation cpusets is the new way, but this does not work with early kernel threads etc.)
- `irqaffinity` - List of CPUs that can be used for interrupts
- `skew_tick=1` - Offset periodic timer tick between CPU cores
- `threadirqs` - Create separate interrupt handler threads. Allows isolating interrupt handlers to specific CPU cores
- `rcu_nocbs` - List of CPUs to exclude from RCU callbacks
- `rcu_nocb_poll` - Use polling in RCU kernel threads instead of triggering from the CPUs listed in `rcu_nocbs`

Host kernel performance parameters

- `idle=poll` - Use polling when the CPU core is idle
- `nohz=on` - Enable nohz mode
- `nohz_full` - List of CPUs to disable the periodic kernel tick and RCU callbacks from
- `noht` - Disable hyperthreading
- `intel.max_cstate=0, intel_idle.max_cstate=0, processor.max_cstate=0, processor_idle.max_cstate=0` and `intel_pstate=disable` - Disables various performance tunings on Intel platforms
- `rdt=cmt,l3_cat,l3_cdp,mba` - Enable the Intel L3 cache and memory bandwidth resource control
- `selinux=0` - Disable SELinux. Does not work well with virtualization or timing requirements
- `audit=0` - Disable kernel auditing

Other parameters

Not strictly necessary, but may be needed in some cases depending on the hardware and virtual machine setup.

- `iomem=relaxed` - Disable strict MMIO memory access checking from userspace
- `intel_iommu=on` and `iommu=pt`- Enables pass-through mode for PCI/PCIe devices on Intel platform

Example kernel commandline, which leaves the host (including interrupts) running on cores 0-3, and cores 4-15 isolated from the host:

```
idle=poll iomem=relaxed intel.max_cstate=0
intel_idle.max_cstate=0 processor.max_cstate=0
processor_idle.max_cstate=0 intel_pstate=disable isolcpus=4-15
irqaffinity=0-3 rcu_nocbs=4-15 rcu_nocb_poll intel_iommu=on
iommu=pt skew_tick=1 nohz=on nohz_full=4-15 threadirqs
preempt=full rdt=cmt,l3_cat,l3_cdp,mba selinux=0 audit=0
```

Kernel/module parameters

Edit or create */etc/modprobe.d/qemu-system-x86.conf* and add the below:

```
options kvm_intel nested=1 enable_apicv=n ple_gap=0 ple_window=0

options vhost_net experimental_zcopytx=1
```

Edit */etc/sysctl.conf* and add the below:

```
vm.nr_hugepages = 13312
```

```
kernel.nmi_watchdog=0
kernel.sched_rt_runtime_us=-1
```

Services and timers

Some services might cause latency peaks when executed. At least the following services must be disabled. Depending on the Linux distribution and installed software, there might be additional services that must be also disabled.

`fwupd-refresh` service and timer: `sudo systemctl disable fwupd-refresh.service && sudo systemctl disable fwupd-refresh.timer && sudo systemctl stop fwupd-refresh.timer`

`irqbalance` service: `sudo systemctl stop irqbalance && sudo systemctl disable irqbalance`

`ondemand` service sets CPU governor to powersave after a while. Disable it: `sudo systemctl disable ondemand`

If cockpit is installed, make sure the performance monitoring is disabled.

```
sudo systemctl disable pmie.service
sudo systemctl disable pmie_farm.service
sudo systemctl disable pmie_check.timer
sudo systemctl disable pmie_daily.timer
sudo systemctl disable pmie_farm_check.timer

sudo systemctl stop pmie.service
sudo systemctl stop pmie_farm.service
sudo systemctl stop pmie_daily.timer
sudo systemctl stop pmie_check.timer
sudo systemctl stop pmie_farm_check.timer
```

Management interface

For the management interface / web interface access, a virtual bridge can be used. Configuration for this depends on the network manager that is used. An example for netplan can be seen below which creates a bridge called mgmt-bridge on network interface enp4s0 with IP 192.168.0.2 for the host.

```
network:
 ethernets:
  enp4s0:
   dhcp4: false
 version: 2

bridges:
 mgmt-bridge:
   interfaces: [ enp4s0 ]
```

```
    dhcp4: false
    addresses:
     - 192.168.0.2/24
    gateway4: 192.168.0.1
```

`sudo netplan try` takes the new configuration into use, asking the user to verify the configuration. It is useful if the command is run remotely.

For NetworkManager the bridge can be setup with the following commands

```
sudo nmcli connection add type bridge autoconnect yes con-name
mgmt-bridge ifname mgmt-bridge
sudo nmcli connection modify mgmt-bridge ipv4.addresses
192.168.0.2/24 ipv4.method manual
sudo nmcli connection modify mgmt-bridge ipv4.gateway 192.168.0.1
sudo nmcli connection del enp4s0
sudo nmcli connection add type bridge-slave autoconnect yes con-
name enp4s0 ifname enp4s0 master mgmt-bridge
sudo nmcli connection up mgmt-bridge
```

Process bus

The real-time application requires low-latency networking for the process data. For this, the interrupts and interrupt handlers must be isolated to their own CPU core. The `ssc600-setup.sh` script can be used for configuring these.

SSC600 SW script

The convenience script [ssc600-setup.sh](../template/kvm/ssc600-setup.sh) and accompanying service [ssc600-startup.service](../template/kvm/ssc600-startup.service) can be used to configure the L3 cache partitioning, the process bus interrupts affinity, as well as the [miscellaneous settings](#miscellaneous-settings). Run `sudo systemctl edit ssc600-startup.service` to configure the script.

For example, for changing the network interfaces to `ens4` and `ens5`, add the `[Service]` section and the `Environment=NICS="ens4 ens5"` lines as below.

```
### Editing /etc/systemd/system/ssc600-startup.service.d/
override.conf
### Anything between here and the comment below will become the
new contents of the file

[Service]
Environment=NICS="ens4 ens5"

### Lines below this comment will be discarded

### /etc/systemd/system/ssc600-startup.service
# [Unit]
# Description=Runs SSC600 related startup actions
```

```
# After=network.target
#
# [Service]
# Type=oneshot
# RemainAfterExit=true
# ExecStart=/usr/sbin/ssc600-setup.sh
# StandardOutput=journal
# #User=root
#
# # Override the below using `systemctl edit ssc600-
startup.service`
# # CPU cores to use for host system
# Environment=NON_RT_CORES=f
# # L3 partition for the system
# Environment=NON_RT_CACHE=0x1ff
# # L3 partitioning for the SSC600 SW
# Environment=RT_CORES='13-14'
# Environment=RT_CACHE=0xe00
# # CPU core for the process bus(es)
# Environment=CPUMASK="400"
# # Process bus interface(s)
# Environment=NICS="enp4s0 enp5s0"
#
# [Install]
# WantedBy=multi-user.target
```

Enable and run with

```
sudo systemctl enable ssc600-startup.service
sudo systemctl start ssc600-startup.service
```

Time synchronization

Host clocks should be synchronized using PTP with a NIC that supports hardware timestamping. If the used NIC is not the same as that used for the process communication, the PTP hardware clock of the process bus NIC must be synchronized with phc2sys. For instance, if enp4s0 is used for PTP synchronization and enp5s0 is used for process communication, the PTP HW clock of enp5s0 must be synchronized with the PTP HW clock of enp4s0: `phc2sys -c enp5s0 -s enp4s0 -O 0`

If ptp4l is setup to run on multiple interfaces, and phc2sys is run with the auto-configuration option, no extra phc2sys instance is required to be run on the interfaces that ptp4l is configured to run on.

The time synchronization is handled by the timemaster service. It sets up and starts the ptp4l and phc2sys daemons for handling the PTP traffic, and runs the chrony daemon which handles the actual clock sync. Configuration is done through /etc/linuxptp/timemaster.conf on Ubuntu, and /etc/timemaster.conf on Fedora.

The configuration file is divided into sections, one for each functionality. The PTP functionality is setup using the `ptp_domain` and `ptp4l.conf` sections, while `chrony` is setup with the `chrony.conf` section. Below is an example that can be used with PRP networks.

```
# Configuration file for timemaster


[ptp_domain 0]
interfaces enp4s0 enp5s0


[timemaster]
ntp_program chronyd


[chrony.conf]
makestep 0.1 -1
logchange 0.1
lock_all
sched_priority 60
combinelimit 0


[ptp4l.conf]
step_threshold  0.1
network_transport  L2
delay_mechanism  P2P


[chronyd]
path /usr/sbin/chronyd


[phc2sys]
path /usr/sbin/phc2sys


[ptp4l]
path /usr/sbin/ptp4l
```

For the `ptp_domain` section, the domain number for the PTP traffic is indicated in the section name. Multiple domains can be configured if needed. The `ptp4l.conf` section can be used to configure PTP settings common for all PTP instances. `network_transport` should be either `L2` or `UDP`, `delay_mechanism` should be

either P2P or E2E. L2 and P2P are the most commonly used settings. If multiple PTP domains with different settings need to be supported. The domain specific settings should be specified under the domain section, prepended with ntp_options. Possible ntp.conf section should be removed from the timemaster configuration to avoid a situation where NTP is used to syncronize the clocks.

Below is an example with two separate PTP configurations, where the PTP master connected to interface enp4s0 should be preferred.

```
[ptp_domain 0]
interfaces enp4s0
ntp_options trust


[ptp_domain 0]
interfaces enp5s0
```

Below is an example of the chronyd configuration section.

```
[chrony.conf]
makestep 0.1 -1
logchange 0.1
lock_all
sched_priority 60
combinelimit 0
```

If VLAN is used on the network, a VLAN interface needs to be used for the PTP synchronization. To setup a VLAN interface on, for example, interface enp4s0, run sudo ip link add link enp4s0 name enp4s0.vlan1 type vlan id 1 and use the enp4s0.vlan1 interface in the ptp_domain section of the configration.

```
[ptp_domain 0]
interfaces enp4s0.vlan1
```

Set priority of linuxptp sudo systemctl edit timemaster

```
[Service]
CPUSchedulingPriority=40
CPUSchedulingPolicy=rr
```

Finally enable and run the timemaster service

```
sudo systemctl enable timemaster
sudo systemctl start timemaster
```

The SSC600 SW requires one additional service *ptp_status.sh* (../template/kvm/ptp_status.sh) to run on the host that outputs the ptp4l synchronization status to file. This is required to make sure that the virtual protection relay application is aware of the synchronization quality. The service is distributed with SSC600 SW product. By default the service writes the current PTP status to a file under /var/lib/libvirt/images/ptp/. If this location is unsuitable override the PTP_STATUS_FOLDER variable in the service file. Execute sudo systemctl edit ptp_status, and add the below:

```
[Section]
```

```
Environment=PTP_STATUS_FOLDER=<absolute path to ptp status folder>
```

Run the below to enable the PTP monitoring

```
sudo systemctl enable ptp_status.service
sudo systemctl start ptp_status.service
```

If PRP is used, 3.x and older versions of linuxptp require patching. See *Strip PRP trailer*.

9.4.2.3 SSC600 SW virtual machine

VM configuration

Before taking the template into use, some minor changes are required.

Open `ssc600-kvm.xml` in a text editor. For example `vi <path to SSC600 SW package>/virtual_products/ssc600-kvm.xml`.

The CPU configuration must be updated to match the available CPU cores on the host. The SSC600 SW requires 4 cores, also the emulator requires one additional core. Update the cpuset attributes to match available cores.

```
<vcpu placement='static'>4</vcpu>
<cputune>
 <vcpupin vcpu='0' cpuset='15'/>
 <vcpupin vcpu='1' cpuset='14'/>
 <vcpupin vcpu='2' cpuset='13'/>
 <vcpupin vcpu='3' cpuset='12'/>
 <emulatorpin cpuset='11'/>
 <vcpusched vcpus='0' scheduler='fifo' priority='50'/>
 <vcpusched vcpus='1' scheduler='fifo' priority='50'/>
 <vcpusched vcpus='2' scheduler='fifo' priority='50'/>
 <vcpusched vcpus='3' scheduler='fifo' priority='50'/>
</cputune>
```

The path to the virtual disk must also be updated:

```
<disk type='file' device='disk'>
 <driver name='qemu' type='raw' cache='none' io='threads'/>
 <source file='/var/lib/libvirt/images/ssc600_disk.img'/>
 <target dev='vda' bus='virtio'/>
 <address type='pci' domain='0x0000' bus='0x00' slot='0x05'
function='0x0'/>
</disk>
```

Update the path to the PTP status file if needed.

```
<filesystem type="mount" accessmode="mapped">
```

```
 <driver type="path" wrpolicy="immediate"/>
 <source dir="/var/lib/libvirt/images/ptp"/>
 <target dir="ptp"/>
 <readonly/>
 <address type="pci" domain="0x0000" bus="0x00" slot="0x04"
function="0x0"/>
</filesystem>
```

Also, the networking must be updated to use the correct interfaces. For the process bus(ses), `trustGuestRxFilters` attribute must be set to `yes` for the network traffic to be passed through to the virtual machine.

By default the network device with the lowest PCI ID will be used for management purposes, and the ones with a higher ID will be used for the process busses. The mapping can be changed through the SSC600SW web interface once it has been started.

```
<interface type='bridge'>
 <mac/>
 <source bridge='mgmt-bridge'/>
 <model type='virtio'/>
 <address type='pci' domain='0x0000' bus='0x00' slot='0x02'
function='0x0'/>
</interface>
<interface type='direct' trustGuestRxFilters='yes'>
 <mac/>
 <source dev='enp5s0' mode='bridge'/>
 <model type='virtio'/>
 <address type='pci' domain='0x0000' bus='0x00' slot='0x03'
function='0x0'/>
</interface>
```

If a protection communication port is required, use PCI passthrough to attach the desired network interface to the virtual machine. Add the following configuration under the `<devices>` tree in the template.

```
<hostdev mode='subsystem' type='pci' managed='yes'>
 <source>
  <address domain='0x...' bus='0x...' slot='0x...' function='0x...'/>
 </source>
</hostdev>
```

To obtain the domain, bus, slot, and function parameters of a PCI device, use the `virsh nodedev-dumpxml [dev id]` command.

The parameters are reported in decimal format but must be defined in hexadecimal format in the template.

To identify available PCI devices on the host system, use the `virsh nodedev-list --tree` command.

For example, if `eno5` is the desired interface for the protection communication port and `virsh nodedev-list --tree` prints:

```
+- pci_0000_b0_02_0
|   |
|   +- pci_0000_b2_00_0
|   |   |
|   |   +- net_eno5_d4_f5_ef_78_a6_2c
|   |
```

Then, the device parameters can be obtained from the output of the `virsh nodedev-dumpxml pci_0000_b2_00_0` command:

```
<device>
 <name>pci_0000_b2_00_0</name>
 <path>/sys/devices/pci0000:b0/0000:b0:02.0/0000:b2:00.0</path>
 <parent>pci_0000_b0_02_0</parent>
 <driver>
  <name>igb</name>
 </driver>
 <capability type='pci'>
  <domain>0</domain>
  <bus>178</bus>
  <slot>0</slot>
  <function>0</function>
  <product id='0x1521'>I350 Gigabit Network Connection</product>
  <vendor id='0x8086'>Intel Corporation</vendor>
  .
  .
  .
```

In this example, the `eno5` interface can be attached to the virtual machine using the following configuration:

```
<hostdev mode='subsystem' type='pci' managed='yes'>
 <source>
  <address domain='0x0’ bus='0xb2’ slot='0x0' function='0x0’ />
 </source>
</hostdev>
```

Once SSC600 SW has been started, the PCI device can be mapped as a protection communication port through the web interface.

See the libvirt template *ssc600-kvm.xml* (../template/kvm/ssc600-kvm.xml).

Once the template has been updated, import the SSC600 SW virtual machine using the `virsh` command:

```
virsh define ssc600-kvm.xml
```

If the `virsh define` command fails with `unsupported machine type`, update the machine type in the template.

```
<os>
 <type arch="x86_64" machine="q35">hvm</type>
 <boot dev="hd"/>
</os>
```

Supported machine types can be listed using `qemu-system-x86_64 --machine help`. `q35*` machine types are known to work.

If the command fails with `chardev 'spicevmc' not supported without spice graphics` add the below inside the `devices` XML block.

```
<graphics type="spice">
 <listen type="none"/>
 <image compression="off"/>
 <gl enable="no"/>
</graphics>
```

Running the VM

The VM can be started with `virsh start ssc600-1`.

On first bootup, the SSC600 SW will start up with the default IP address of 192.168.2.10/24.

Autostart can be enabled with `virsh autostart ssc600-1`.

9.4.2.4 Reference

The following instructions are for reference/troubleshooting in case of issues with the SSC600 SW services and scripts.

Process bus networking

If the NIC uses MSI interrupts, the interrupt numbers can be found under the sysfs mount-point, for example */sys/class/net/\<nic\>/device/msi_irqs/*. Also *proc/interrupts* can be used to determine the interrupt numbers.

For possible kernel threads handling the interrupts, they can be listed with `ps axo pid,command | grep [i]rq/<irq number>-`.

Example showing the irqs used by `enp7s0` interface, and the process handling the 1st irq:

```
ls /sys/class/net/enp7s0/device/msi_irqs/
40 41 42 43 44
```

```
cat /proc/interrupts | grep enp7s0
```

```
  40:          0          0         10          0          0          0          0
0          0          0     313415          0          0          0          0
0  IR-PCI-MSI 3670016-edge      enp7s0

  41:          0          0          0        675          0          0          0
0          0          0 3215212303          0          0          0          0
0  IR-PCI-MSI 3670017-edge      enp7s0-TxRx-0

  42:         17          0          0          0          0          0          0
0          0          0     268572          0          0          0          0
0  IR-PCI-MSI 3670018-edge      enp7s0-TxRx-1

  43:          0         28          0          0          0          0          0
0          0          0     505142          0          0          0          0
0  IR-PCI-MSI 3670019-edge      enp7s0-TxRx-2

  44:          0          0         35          0          0          0          0
0          0          0     804476          0          0          0          0
0  IR-PCI-MSI 3670020-edge      enp7s0-TxRx-3
```

```
ps axo pid,command | grep [i]rq/40-
```

```
  905 [irq/40-enp7s0]
```

The `taskset` utility can be used to pin the threads to specific CPU core(s): `sudo taskset -p <cpu core mask> <pid>`

The interrupts can be pinned by writing the CPU core mask to */proc/irq/<irq number>/smp_affinity*: `echo <cpu core mask> | sudo tee /proc/irq/<irq>/smp_affinity`

For pinning the task and the interrupt to the 11th CPU core:

```
sudo taskset -p 0x400 905
```

```
echo 400 | sudo tee /proc/irq/40/smp_affinity
```

The above must be repeated for any possible redundant process bus.

Miscellaneous settings

The below settings need to be applied whenever the system is booted.

```
NON_RT_CORES=f
```

```
# Try to move ALL kernel threads to the first 4 cores
```

```
pgrep -P 2 | xargs -i sudo taskset -p $NON_RT_CORES {}
```

```
# Assign CPU mask for all workqueues.
```

```
find /sys/devices/virtual/workqueue -name cpumask -exec sh -c
"echo $NON_RT_CORES > {}" ';'
```

```
# Disable transparent hugepages, can cause page faults
```

```
echo never > /sys/kernel/mm/transparent_hugepage/enabled
```

```
# kernel memory merging, can cause page faults
```

```
echo 0 > /sys/kernel/mm/ksm/run
```

```
# and timer migrations
```

```
echo 0 > /proc/sys/kernel/timer_migration
```

```
# Lengthen the virtual memory update interval, only relevant for
older kernels

echo 60 > /proc/sys/vm/stat_interval

# Set the scaling governor to *performance*

echo "performance" | sudo tee -a /sys/devices/system/cpu/cpu*/
cpufreq/scaling_governor

# Make sure turbo boost is disabled

echo 1 | sudo tee -a /sys/devices/system/cpu/intel_pstate/no_turbo
```

9.4.3 VMware ESXi setup

This chapter describes how to setup VMware ESXi hypervisor for SSC600 SW system.

This guide is applicable for the following setup:

- VMware ESXi 7.0 Update 3
- PCI passthrough configuration for the networking
- SSC600 SW VMDK files

9.4.3.1 Installing SSC600 SW

Uncompress the CAB archive received from ABB locally on the computer. Open the ESXi web interface and follow the steps below.

1. Create a new virtual machine and select the option to deploy it from an OVF file.

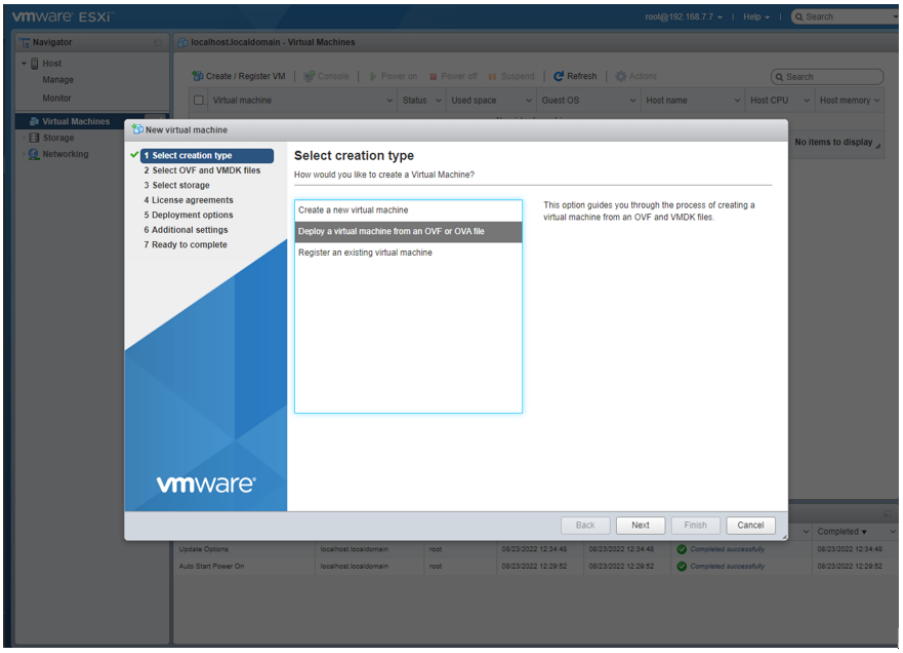


Figure 114: Creating a new virtual machine

2. Select the SSC600 SW VMDK files extracted previously.

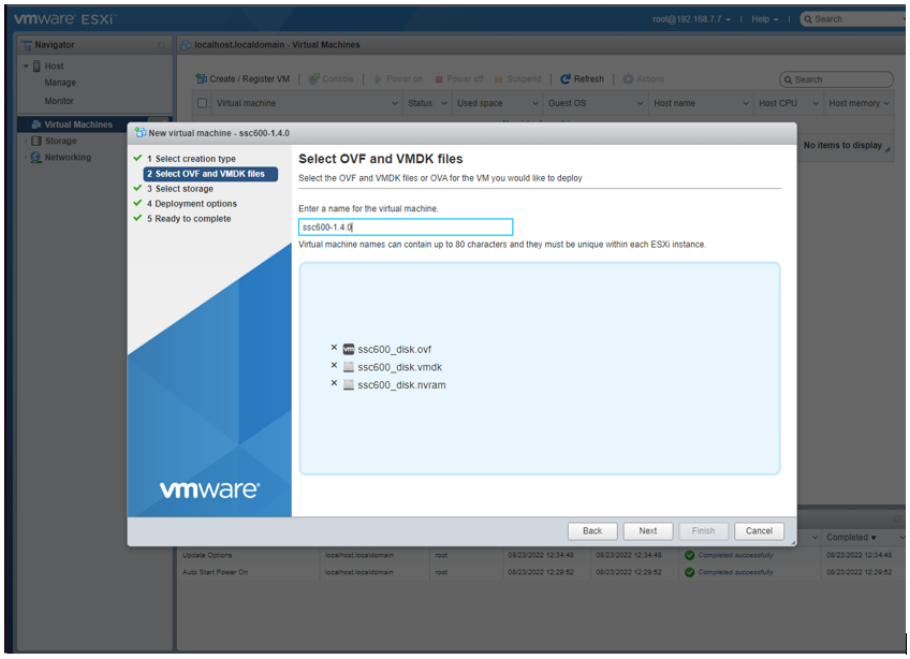


Figure 115: Selecting the SSC600 SW VMDK files

3. For the Deployment options, select the **Disk provisioning: Thick** option.

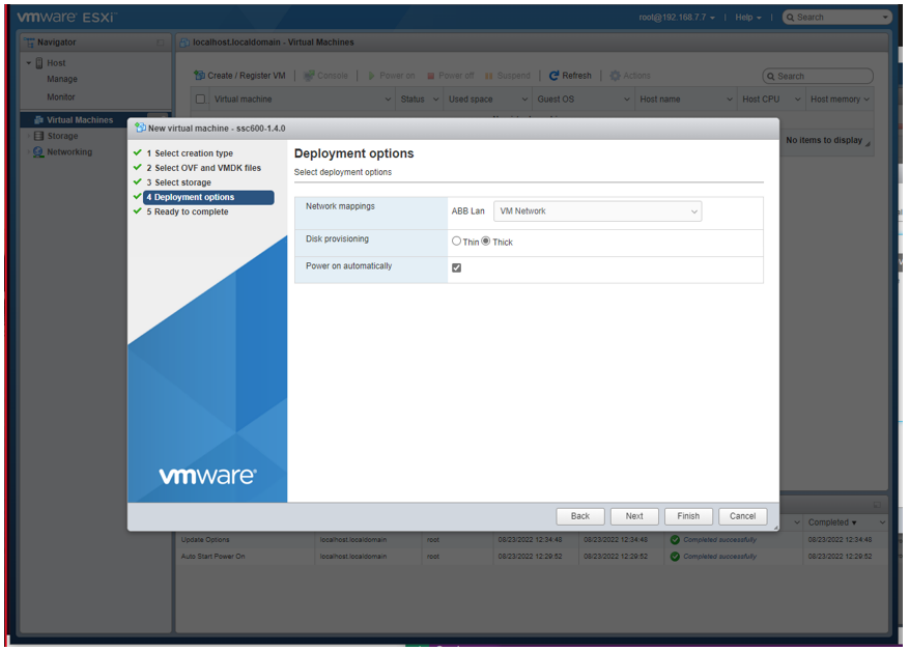


Figure 116: Deployment options

9.4.3.2 Configuring SSC600 SW virtual machine

This chapter discusses the virtual machine options that are hardware dependent.

Network configuration

Network configuration consists of three different networks:

- Virtual network for the station bus communication
- PCI passthrough for the process bus communication
- PCI passthrough for the optional protection communication port

By default there is one virtual adapter assigned to the SSC600 SW virtual machine. Ensure that the VMXNET 3 adapter is selected as the adapter type. This adapter must be connected to the virtual network from which a connection will be made to the SSC600 SW.

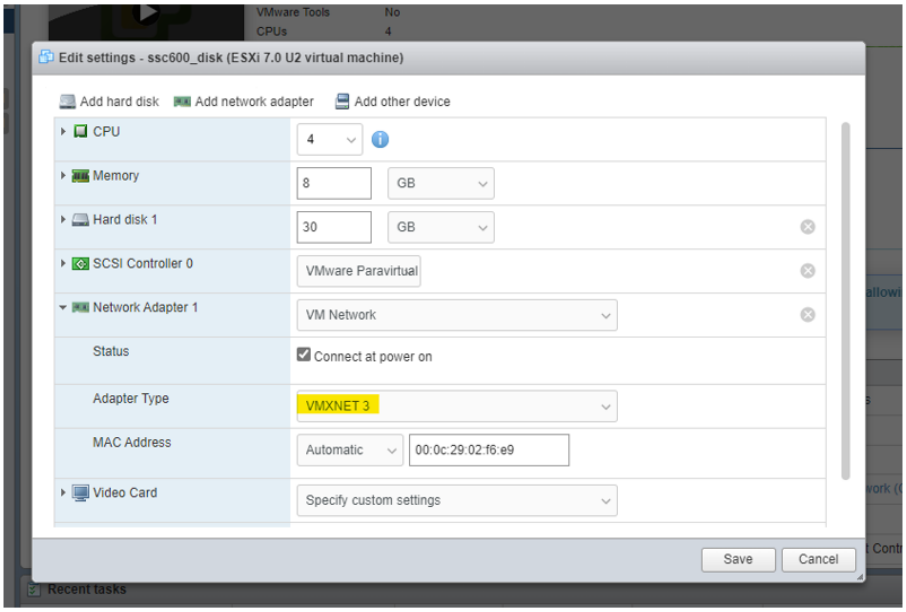


Figure 117: Configuring the network

PCI Passthrough

PCI passthrough grants the SSC600 SW an exclusive access to the network interface card, thus guaranteeing real-time performance of the network.

1. Navigate to the **Hardware** configuration of the host and find the PCI device you want to use for the passthrough.
2. Click the **Toggle passthrough** option to enable or disable PCI passthrough.

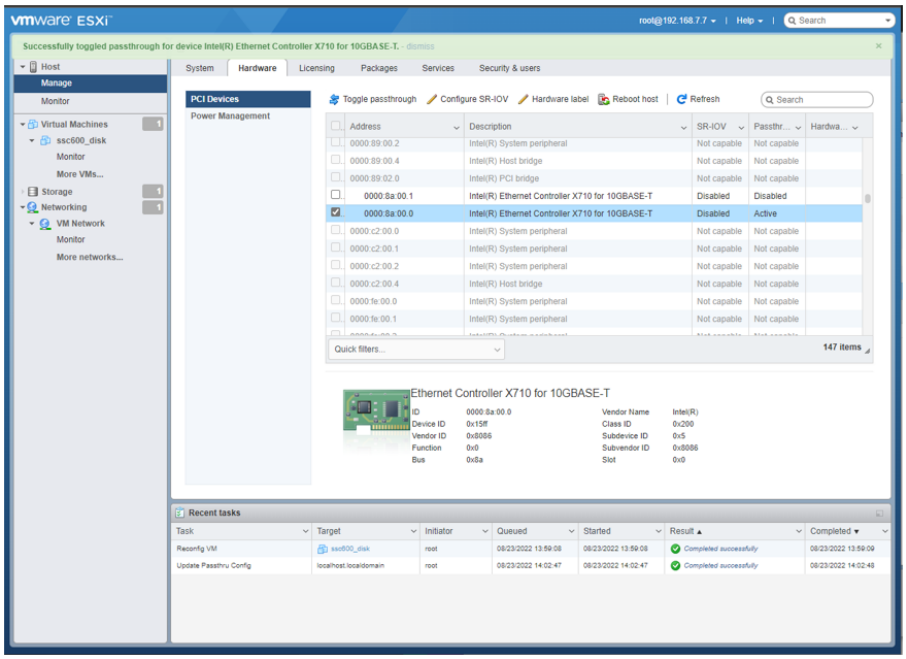


Figure 118: Hardware configuration

3. Assign the PCI device to the SSC600 SW virtual machine.
4. Navigate to the SSC600 settings.
5. Click **Add other device** and select the PCI device that matches the one that passthrough was configured for.

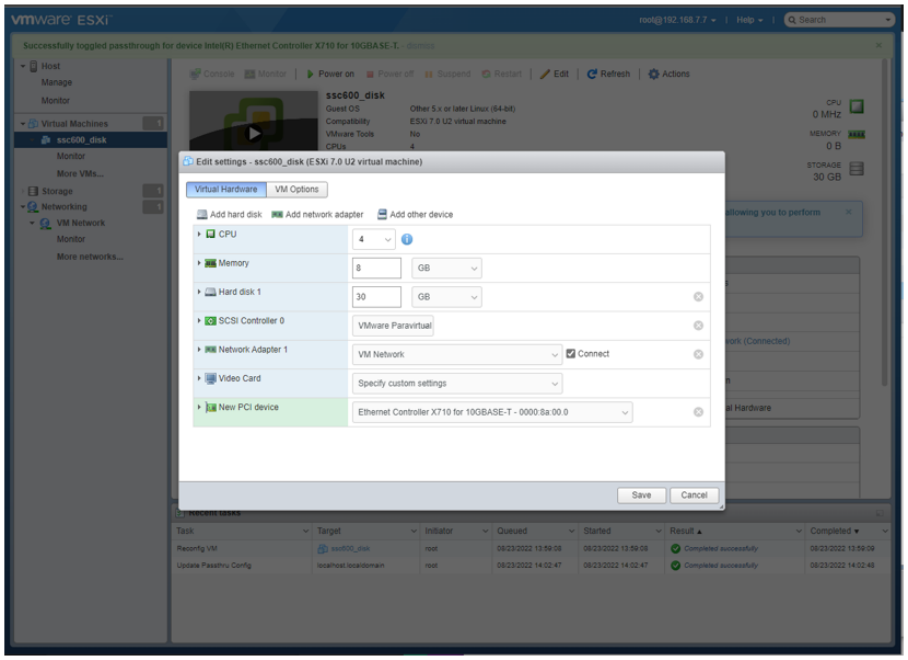


Figure 119: Assigning the PCI device to the SSC600 SW virtual machine

CPU Configuration

SSC600 SW requires 4 CPU cores. To ensure the real-time performance of the SSC600 SW, exclusive access needs to be reserved also for the CPU.

1. Open virtual machine settings and expand the CPU settings.
2. Configure the **Reservation** value so that it matches the number of CPU cores, and the base CPU frequency: number CPU cores × CPU frequency.

   For example, if the base CPU frequency is 2400 MHz, the values must be 4 × 2400 MHz = 9600 MHz.

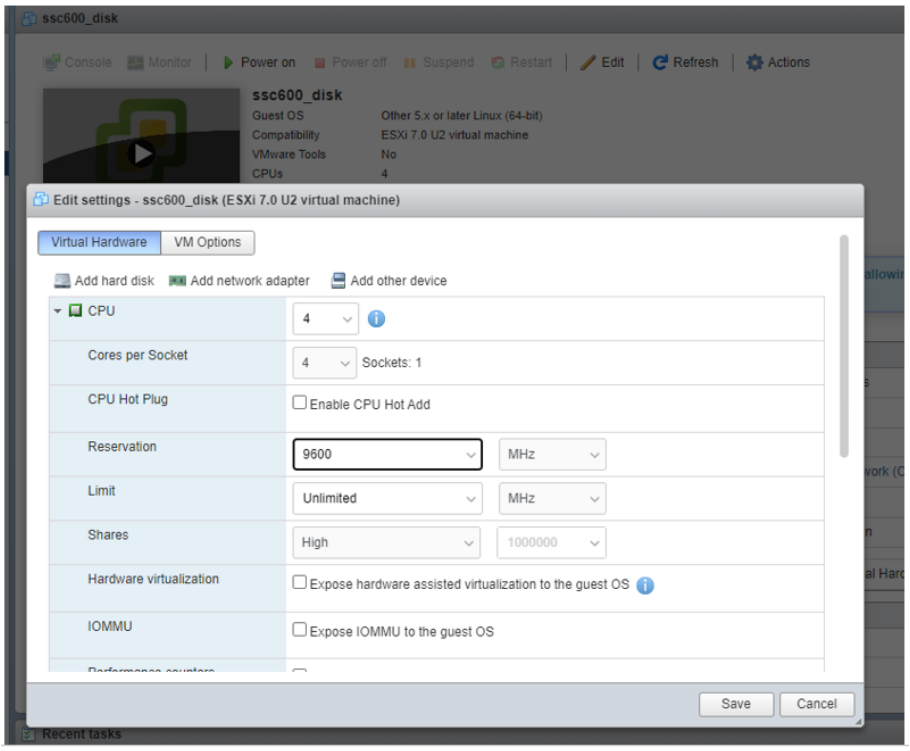


Figure 120: CPU settings

   The CPU base frequency can be checked from ESXi's Hostpage.
3. **Scheduling affinity** should not be used for CPU core allocation in ESXi. Leave Scheduling affinity unconfigured.

The L3 CPU cache reservation settings should be already imported from the OVF file. However, if the hardware has more cache available, the cache size can be increased.

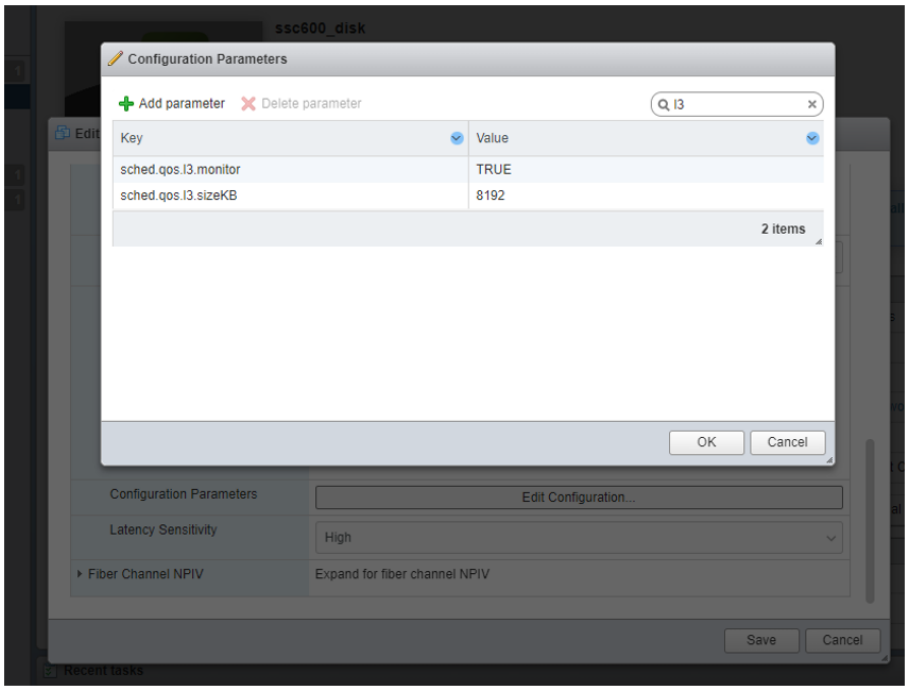


Figure 121: Increasing cache size

Memory Configuration

Ensure that the **Reserve all guest memory** option is enabled.

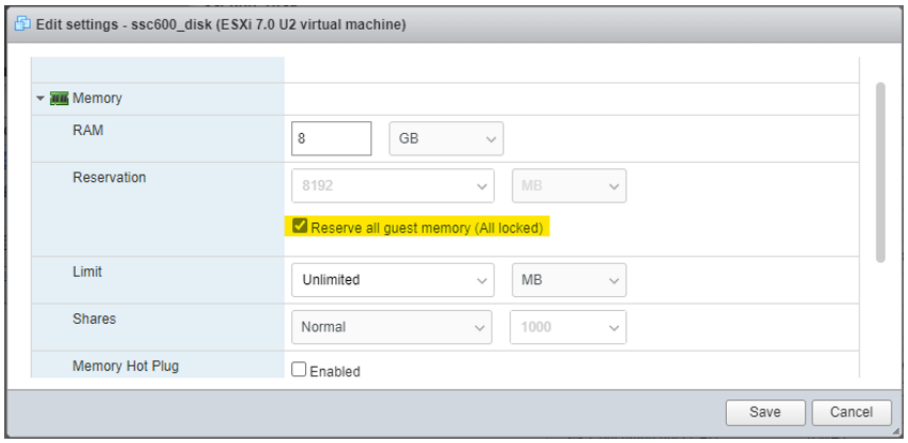


Figure 122: Memory configuration

Advanced VM settings

There are few advanced settings that need to be configured for the SSC600 virtual machine. Navigate to **VM Options** tab and disable logging by unselecting the **Enable logging** checkbox.

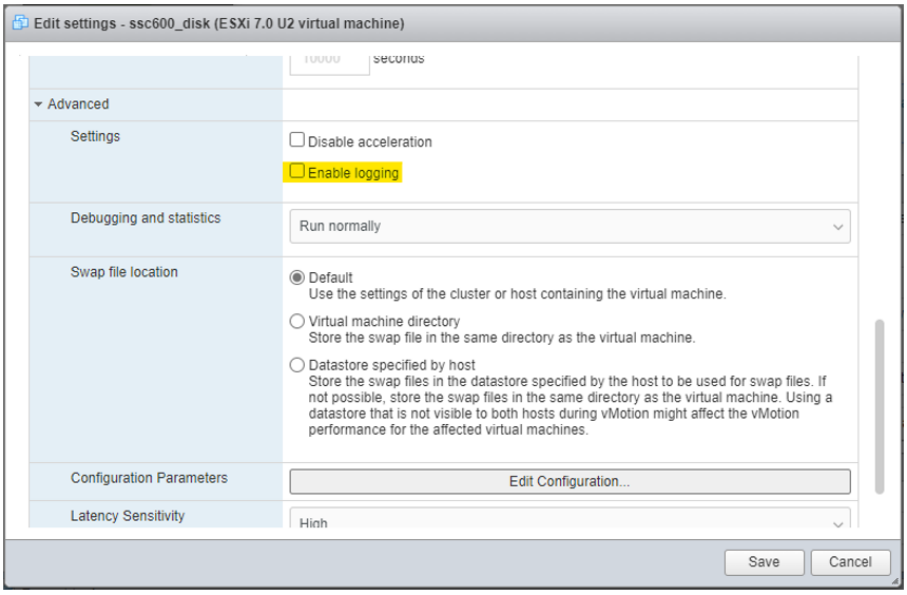


Figure 123: Disabling logging

9.4.4 SSC600 SW installations in general

Before communication is enabled in SSC600 SW, it's important to note that some communication ports - like process bus - needs to be enabled separately from parameter settings. Port enabling parameters can be found in **IED Configuration** > **Configuration** > **Communication** > **Ethernet**

In addition the SSC600 SW ports needs to be attached to the physical Network Interfaces in the hardware. This can be achieved with the Network configuration -view in SSC600 SW WHMI.

If the HW used in SSC600 SW has a dedicated PRP card, it's important to note that on SSC600 side configuration should be for non-redundant communication. So PRP card does the PRP itself, without SSC600 SW not knowing about it.

10 Removing, repairing and exchanging

10.1 Product lifecycle

At some point of the product lifecycle, the device is upgraded to a next generation unit. When selecting the original product, already consider the upgrading and extension possibilities that the specific product offers for its whole lifecycle.

Device-specific options can be found from Retrofit Solutions Database on the Internet *www.abb.com* by following the links within ABB Service Guide or via ABB Product Guide from the product specific Service & Support sheet.

10.2 Checking IED information

The IED information includes detailed information about the device, such as version and serial number. The IED information can be found in the WHMI Parameters view, under **IED Configuration** > **Information**.

The **Information** > **Product identifiers** node contains product related information like product type, serial number, order number, production date, configuration name, SW version, SW date and HW revision.

The **Information** > **Site identifiers** node contains information about the site where the device has been installed.

The **Information** > **System identifiers** node contains the Technical key and IEC 61850 version. The Technical key is unique and cannot be changed.

10.3 Removing the IED

1. Turn off the power.
2. Disconnect the wiring.
3. Remove the device from the rack.

10.4 Sending the device for repair

- In case of product problems, contact the nearest ABB office or representative for consultation and instructions.

10.5 Exchanging the device

To exchange the device with another identical unit, remove the device and install the new one. The exchangeable units can be found from the PartsOnLine system, see *www.abb.com/partsonline*. Use of PartsOnLine requires user registration.

11 Environmental aspects

11.1 Sustainable development

Sustainability has been taken into account from the beginning of the product design including the pro-environmental manufacturing process, long life time, operation reliability and disposing of the device.

The choice of materials and the suppliers have been made according to the EU RoHS directive (2011/65/EU). This directive limits the use of hazardous substances which are the following:

Table 37: Maximum concentration values by weight per homogeneous material

Substance	Proposed maximum concentration
Lead - Pb	0.1%
Mercury - Hg	0.1%
Cadmium - Cd	0.01%
Hexavalent Chromium Cr (VI)	0.1%
Polybrominated biphenyls - PBB	0.1%
Polybrominated diphenyl ethers - PBDE	0.1%

Operational reliability and long life time have been assured with extensive testing during the design and manufacturing processes. Moreover, long life time is supported by maintenance and repair services as well as by the availability of spare parts.

Design and manufacturing have been done under a certified environmental system. The effectiveness of the environmental system is constantly evaluated by an external auditing body. We follow environmental rules and regulations systematically to evaluate their effect on our products and processes.

11.2 Disposal of an IED

Definitions and regulations of hazardous materials are country-specific and change when the knowledge of materials increases. The materials used in this product are typical for electric and electronic devices.

All parts used in this product are recyclable. When disposing of an IED or its parts contact a local waste handler who is authorized and specialized in disposing of electronic waste. These handlers can sort the material by using dedicated sorting processes and dispose of the product according to the local requirements.

12 Glossary

ACT	1. Application Configuration tool in PCM600 2. Trip status in IEC 61850
ANSI	American National Standards Institute
ARP	Address Resolution Protocol
CA	Certification Authority
CB	Circuit breaker
CBFP	Circuit breaker failure protection
CID	Configured IED description
CMT	Communication Management tool in PCM600
COMTRADE	Common format for transient data exchange for power systems. Defined by the IEEE Standard.
Connectivity package	A collection of software and information related to a specific protection and control IED, providing system products and tools to connect and interact with the IED
CT	Current transformer
DA	Data attribute
Data attribute	Defines the name, format, range of possible values and representation of values while being communicated
DC	1. Direct current 2. Disconnector 3. Double command
DHCP	Dynamic Host Configuration Protocol
DO	Data object
DT	Definite time
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FTP	File transfer protocol
FTPS	FTP Secure
GCB	1. GOOSE control block 2. Generator circuit breaker
GDE	Graphical Display Editor in PCM600
GoCB	GOOSE control block
GOOSE	Generic Object-Oriented Substation Event
GPS	Global Positioning System
HMI	Human-machine interface
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure

HW	Hardware
I/O	Input/output
ICD	IED capability description
IEC	International Electrotechnical Commission
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IED	Intelligent electronic device
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IEEE 1588 v2	Standard for a Precision Clock Synchronization Protocol for networked measurement and control systems
IET600	Integrated Engineering Toolbox
IGMPv3	Internet Group Management Protocol Version 3
IID	Instantiated IED description
Instance	Identical protection function blocks available in a standard configuration. By setting the applicationspecific parameters of an instance, a protection function stage can be established.
IP	Internet Protocol
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/ IP protocol.
LAN	Local area network
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
LN	Logical node
MAC	Media access control
NCC	Network control center
MM	1. Multimode 2. Multimode optical fiber
MMS	1. Manufacturing message specification 2. Metering management system
MSB	Most significant bit
MV	Medium voltage
P2P	peer-to-peer
PC	1. Personal computer 2. Polycarbonate
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol

PST	1. Parameter Setting tool in PCM600 2. Product Selection Tool
PTP	Precision Time Protocol
R-GOOSE	Routable GOOSE
R-SMV	Routable Sampled measured values
SAB600	Substation automation builder tool
SCADA	Supervision, control and data acquisition
SCD	Substation configuration description
SCL	XML-based substation description configuration language defined by IEC 61850
SLD	Single-line diagram
SMT	Signal Matrix tool in PCM600
SMV	Sampled measured values
Subnet mask	A set of four numbers used to create IP address numbers that are used only within a particular network, subnet
SOTF	Switch onto fault
ST	Connector type for glass fiber cable
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TP	Disturbance data recorded with or without trip bit
UDP	User Datagram Protocol
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface
XRIO	eXtended Relay Interface by OMICRON
ZEE600	Electrification Monitoring and Control

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