

RELION® PROTECTION AND CONTROL

620 series

IEC 61850 Engineering Guide





Document ID: 1MRS757650

Issued: 2021-12-16

Revision: D

Product version: 2.0 FP1

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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.

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 protection relay has to be carefully earthed.



When the plug-in unit has been detached from the case, do not touch the inside of the case. The relay case internals may contain high voltage potential and touching these may cause personal injury.



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



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

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1 Introduction

1.1 This manual

The engineering guide provides information for IEC 61850 engineering of the protection relays with PCM600 and IET600. The guide can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service. For more details on tool usage, see the PCM600 documentation.

1.2 Intended audience

This manual addresses the system engineers and installation and commissioning personnel.

The system engineer must have a thorough knowledge of protection systems, protection equipment, protection functions and the configured functional logic in the protection relays. The installation and commissioning personnel must have basic knowledge of how to handle the electronic equipment.

1.3 Product documentation

1.3.1 Product documentation set

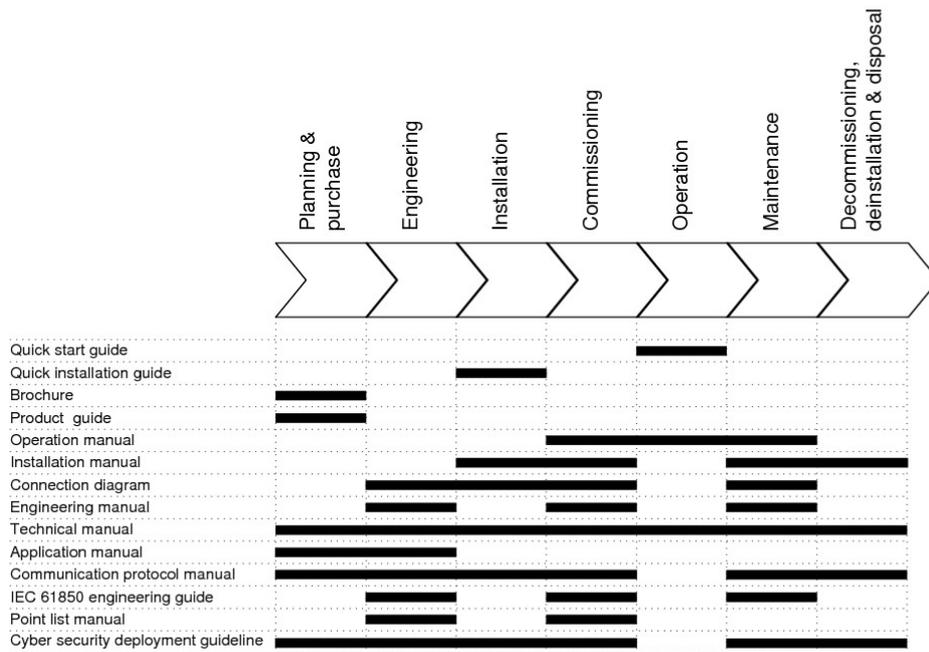


Figure 1: The intended use of documents during the product life cycle



Product series- and product-specific manuals can be downloaded from the ABB Web site www.abb.com/reion.

1.3.2 Document revision history

Document revision/date	Product series version	History
A/2013-05-07	2.0	First release
B/2015-12-11	2.0 FP1	Content updated to correspond to the product series version
C/2019-06-19	2.0 FP1	Content updated
D/2021-12-16	2.0 FP1	Content updated



Download the latest documents from the ABB Web site

<http://www.abb.com/substationautomation>.

1.3.3 Related documentation

Name of the document	Document ID
IEC 61850 Tissues Conformance Statement (TICS)	1MRS757834
IEC 61850 Protocol Implementation eXtra Information (PIXIT)	1MRS757833
IEC 61850 Protocol Implementation Conformance Statement (PICS)	1MRS757832
IEC 61850 Model Implementation Conformance Statement (MICS)	1MRS757831

Product series- and product-specific manuals can be downloaded from the ABB Web site www.abb.com/substationautomation.

1.4 Symbols and conventions

1.4.1 Symbols



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 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.

1.4.2 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.
- Push-button navigation in the LHMI menu structure is presented by using the push-button icons.

To navigate between the options, use  and .

- Menu paths are presented in bold.

Select **Main menu > Settings**.

- LHMI messages are shown in Courier font.

To save the changes in nonvolatile memory, select *Yes* and press .

- 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 IEC 61850 overview

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.

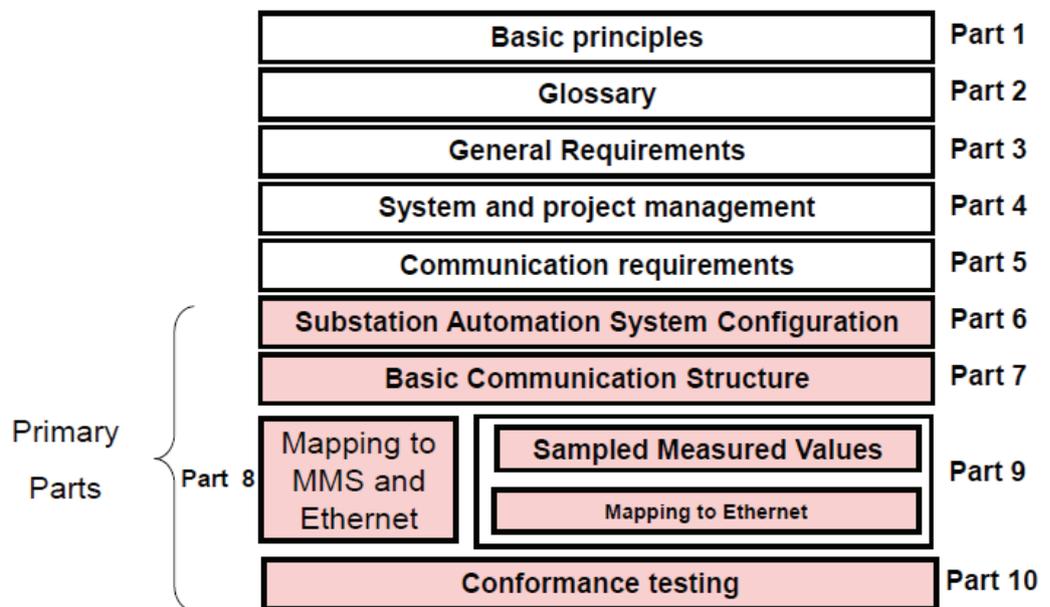


Figure 2: Structure and parts of the IEC 61850 standard

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.

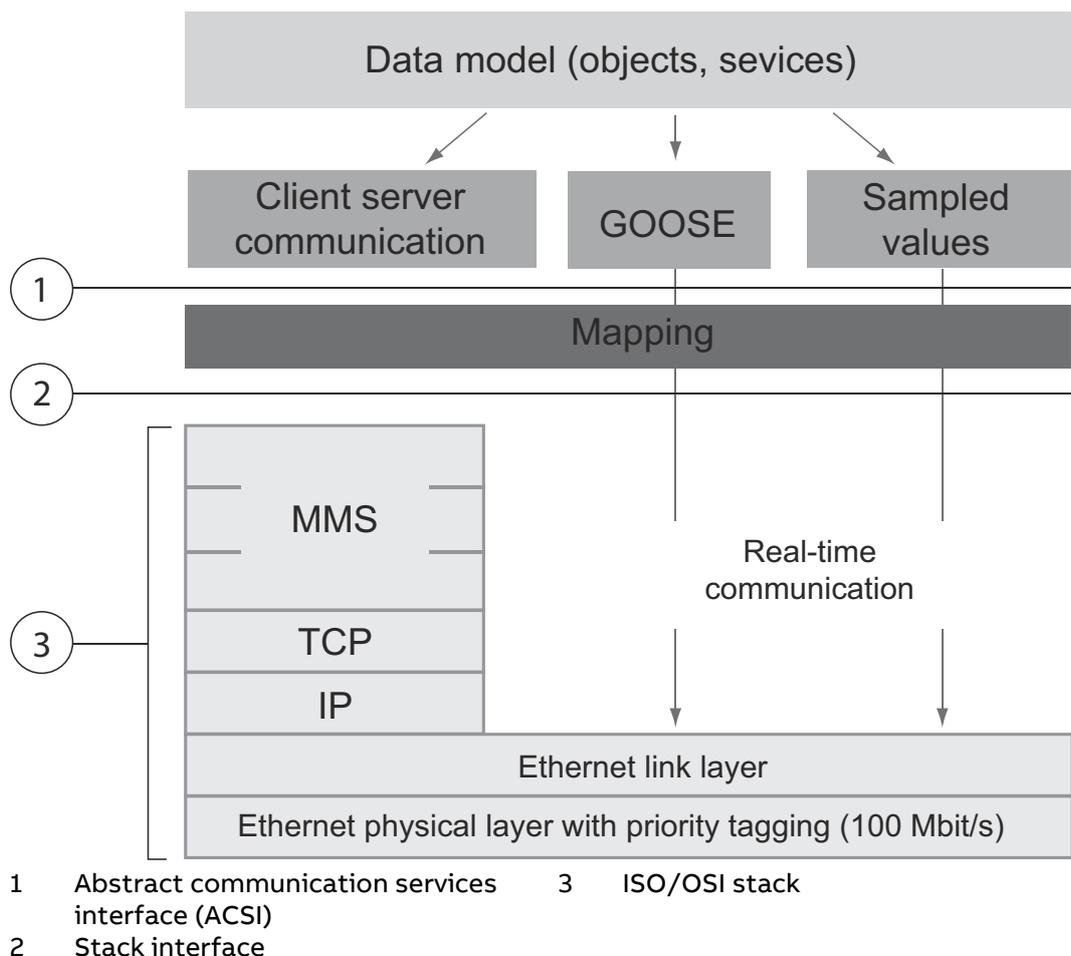


Figure 3: Communication stacks and mapping used in IEC 61850

3 PCM600 tool

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

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

The whole substation configuration 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 protection relays.

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 620 series protection relay 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 protection relays.

The modern-day protection relays are designed using the concept of the IEC 61850 standard. This is primarily in regards to how functions within the protection relay are modelled and how the protection relay is represented in the substation. See the IEC 61850 parameter list for the list of logical nodes available in the protection relay 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 protection relay life cycle. A set of special tools is available for different applications.

The applications can be organized into groups.

- Relay engineering
- Communication engineering
- Record management
- Device monitoring and diagnostic



For more information, see the PCM600 documentation.

3.1 Connectivity packages

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

A connectivity package includes all the data which is used to describe the protection relay. For example, it contains a list of the existing parameters, data format used, units, setting range, access rights and visibility of the parameters. In addition, it contains code which allows software packages that use the connectivity package to properly communicate with the protection relay. It also supports localization of text even when it is read from the protection relay 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 the products that use connectivity packages.

3.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 2.6 (Rollup 20150626) or later
- REF620 Connectivity Package Ver.2.1 or later
- REM620 Connectivity Package Ver.2.1 or later
- RET620 Connectivity Package Ver.2.1 or later



Download connectivity packages from the ABB Web site www.abb.com/substationautomation or directly with Update Manager in PCM600.

4 620 series data model

4.1 Product series implementation

The protection relays have been fully designed according to IEC 61850. This means that the functionality of the protection relay is represented in a data model in accordance with the standard and the protection relays 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 relays 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 relay's protection and control functionality is independent of the IEC 61850 version used. Any differences between data model versions are documented.

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

4.2 Information model

The protection relay 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 on the selected functionality in the protection relay, 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, LDO

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 relay'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.

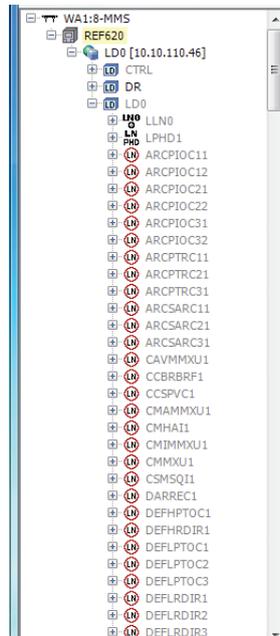


Figure 4: Example of an IEC 61850 data model of a protection relay

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 LLNO, 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 LLNO.

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.

4.3 Vertical and horizontal communication

The protection relays are capable of vertical communication between the protection relay and monitoring and control systems (clients) such as PCM600 or MicroSCADA. 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) information to and subscribe (receive) information from other devices according to IEC 61850-8-1 and IEC 61850-9-2 LE.

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 1: 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 2: Number of control block data sets and size of data sets

Control Block	Maximum data sets	Maximum length	Description
GoCB	4	80 data attributes	The protection relays allow a maximum of four GOOSE control blocks, which effectively limits the protection relay to four data sets for GOOSE. The sending GOOSE data sets can have a maximum total of 80 data attributes. To minimize the message-handling load in the receiving and sending protection relays, it is recommended to limit data attribute amount to 20 per data set.
RCB	16	Edition 1: 256 data attributes Edition 2: 80 data objects	The IEC 61850 configuration tool (IET600 or PCM600) allows a maximum of 16 data sets for the report control blocks.
SVCB	1	16 data attributes	Some protection relay variants allow one sampled value control block. The sending sampled value data set has a fixed set of 16 data attributes as defined in IEC 61850-9-2 LE.

4.3.1 Predefined vertical communication data sets

In vertical communications, the protection relay 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 relay 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 relay type and options.

The data sets and report control blocks can be modified using the IEC 61850 Configuration tool or IET600, however, this should only be done by individuals that are extremely familiar with both the protection relays and IEC 61850. Inappropriate modifications can result in misoperation of the protection relay.

- Statled – generic status information of IEDs
- Statlo – 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 relay 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 relays 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 relay allows free renaming and editing of report control blocks and data sets. Only users who have an in-depth understanding of the protection relay and IEC 61850 should modify the default configuration. Description of data in default data sets is available in the parameter list.



Vertical communication protocols, such as Modbus, 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.



A 620 series protection relay can have at maximum 20 configured data sets and 16 report control blocks for event handling. The maximum length for a data set is 256 data attributes. The amount of data attributes within a data object varies, however, a 620 series protection relay can have 1500 data attributes in data sets in total.



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

4.3.2 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.

4.3.3 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 3: 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.ct/Val` attribute under MMSLPRT1.

GOOSE communication has its own diagnostic counters. See [Chapter 5.7.4 Diagnostic counters](#) for information on diagnostic counters used in GOOSE communication.

4.4 Parameter setting and disturbance recorder

The relay's protection function settings and parameters can be set and the active setting groups changed by a IEC 61850 client using the standard IEC 61850 services. The disturbance recorder and load profile 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.

5 GOOSE

5.1 Horizontal 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 tightest 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, zero-point clamping and limit supervision.

The horizontal 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.

5.1.1 Configuring horizontal communication

Configure GOOSE by using the IEC 61850 Configuration tool in PCM600 or by using the separate IET600 tool. PCM600 interacts with IET600 by importing and exporting SCL files.

5.2 GOOSE publishing properties

GOOSE data is transmitted event based and at regular intervals in 802.1Q multicast frames over the LAN. 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.

Table 4: GOOSE control block attributes

GoCB attribute	Description
Multicast address	A multicast addressing scheme is used when sending GOOSE messages. A multicast address can be shared by several sending devices, or it can be device specific. To keep the multicast message filtering of the devices working it is recommended to use unique multicast addresses.
Ethernet frame-specific information (802.1 Q tagging info: APPID, priority and VLAN id)	APPID is a GoCB-specific integer value identifying the sender GoCB and its data. The APPID must be unique for the GoCB in the system. The priority can be used according to the local network priority scheme, but normally the default value is sufficient. The VLAN group can be used when configuring the Ethernet network topology Virtual LANs for routing and filtering multicast messages. Configuration is done in managed Ethernet switches.
GoCB name	The name of the GoCB structure seen from the IEC 61850/MMS client. Some devices use this as a unique data reference.
GoID	A GOOSE control block specific string. The default value is the GoCB path in the 61850 namespace if nothing is set. It is recommended to always set a unique value in tool. Check the GOOSE Control block GoID name according to the system requirements of the receiving device. Although the protection relays use MAC address and APPID for receiving packet detection, some devices require additionally that the GOOSE control block GoID is named explicitly.
Data set definition	Data sent in GOOSE messages to the network.
ConfRev	ConfRev increases when the referenced data set is modified. Both the GOOSE sender and the receiver must have the same ConfRev value. This ensures that the both devices have the same configuration level in the substation configuration. ConfRev usage is done automatically by tools. If the latest system configuration is not downloaded to all required devices, the configuration revision may differ between the receiver and sender and data exchange does not work.

5.3 Configuring GOOSE with 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.

5.3.1 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.

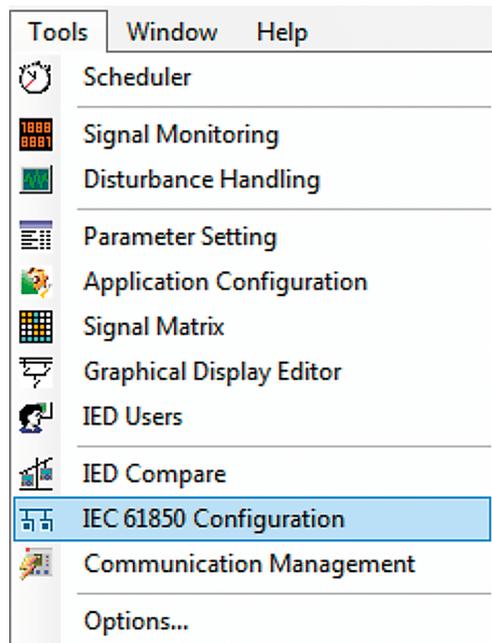


Figure 5: Starting IEC 61850 Configuration

5.3.2 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.

5.3.2.1 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.

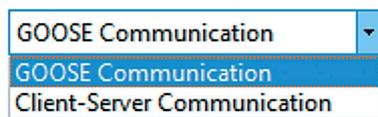


Figure 6: Selecting GOOSE communication

3. Select the **Data Sets** tab.

- To add a new data set, right-click the area containing the data set names and select **New**.

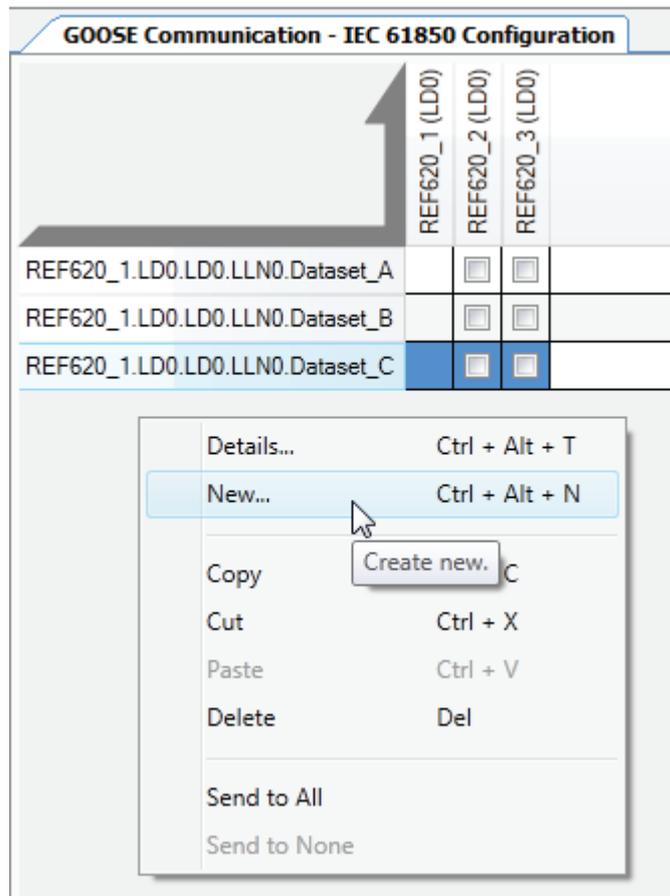


Figure 7: Creating a new data set

- Define the LN where the data set is to be placed (accept preselected "LD0/LLN0") and give the data set a unique name.

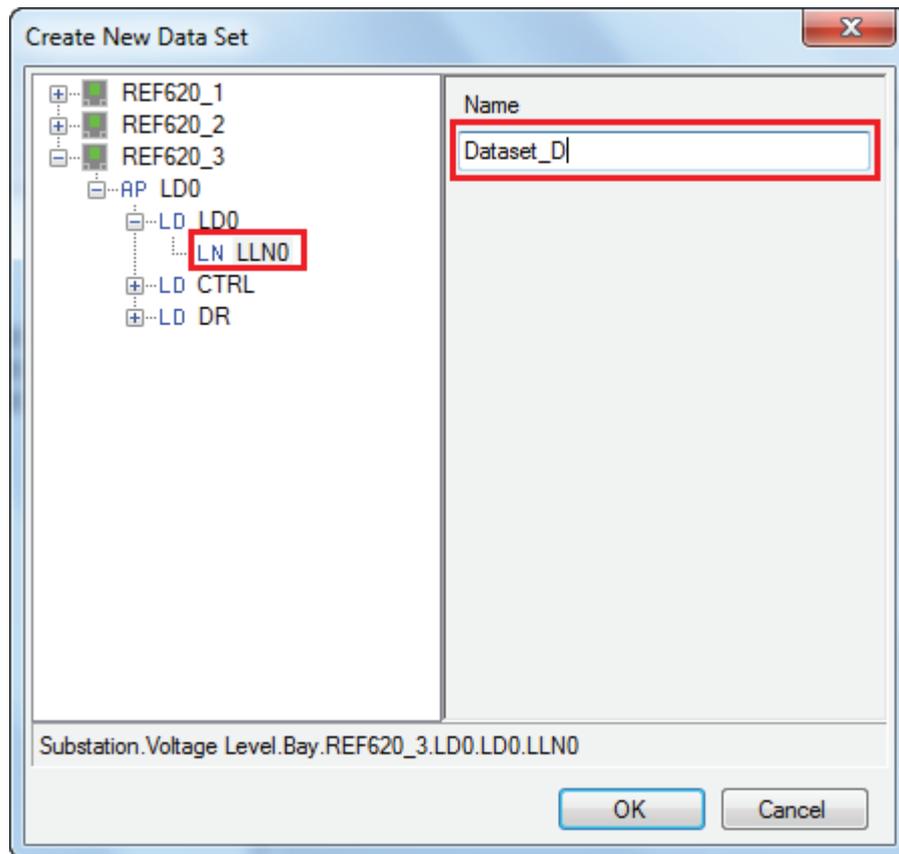


Figure 8: Naming the data set

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.

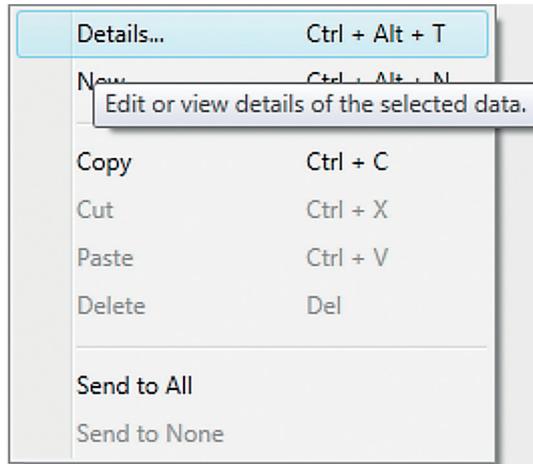


Figure 9: Opening Details

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.

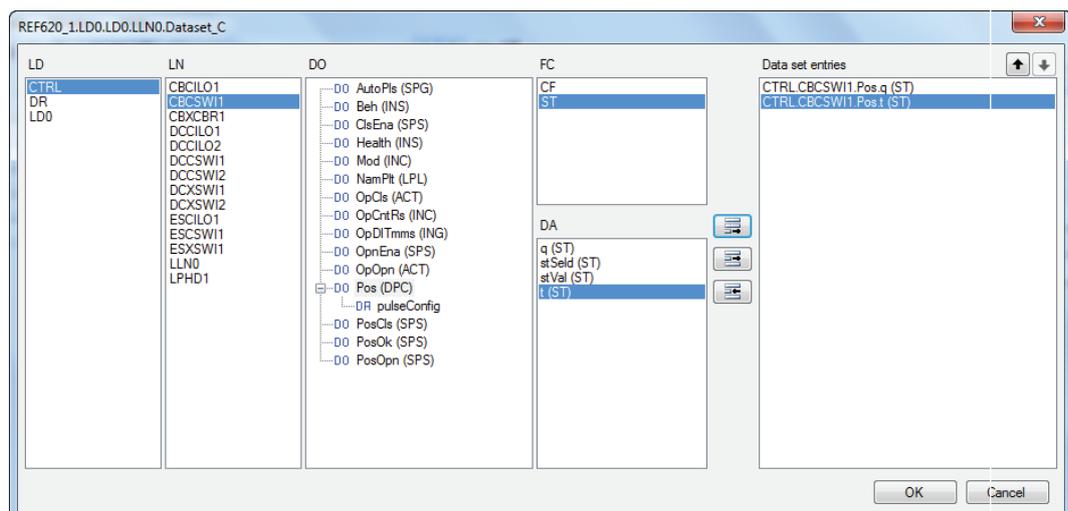


Figure 10: Adding data set entries



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.

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

5.3.2.2 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 GOOSE control block, right-click the area containing the existing GOOSE control blocks and select **New**.

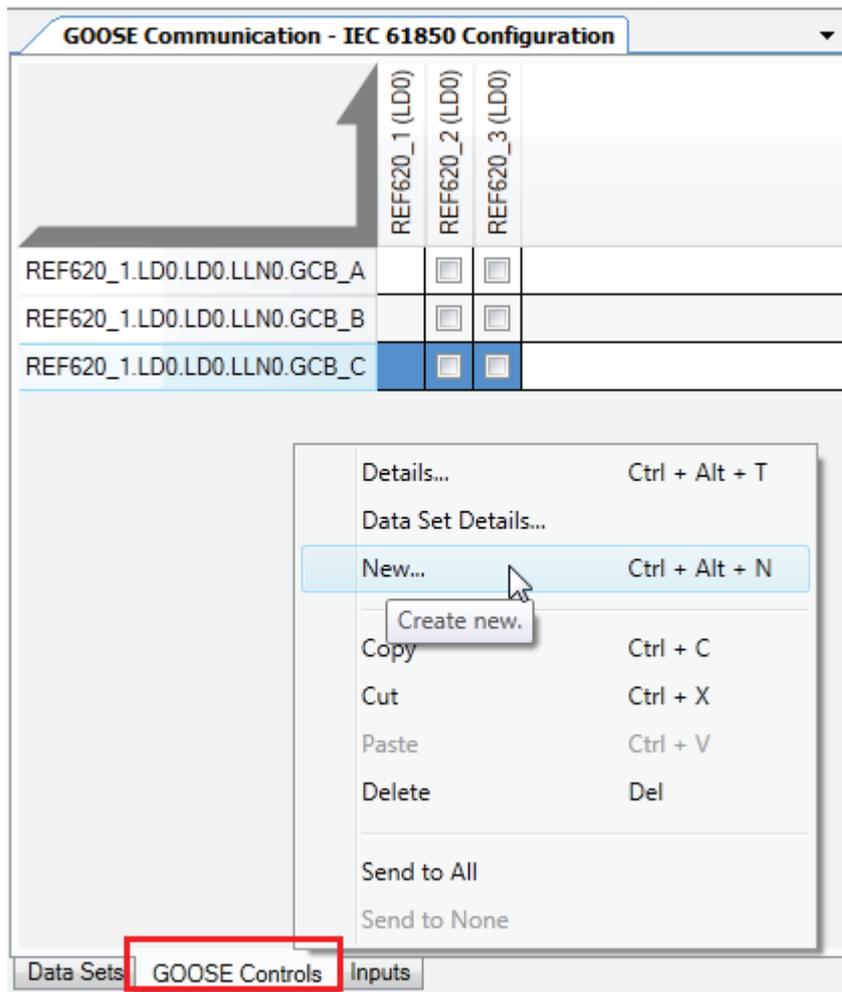


Figure 11: Creating a new GOOSE control block

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.

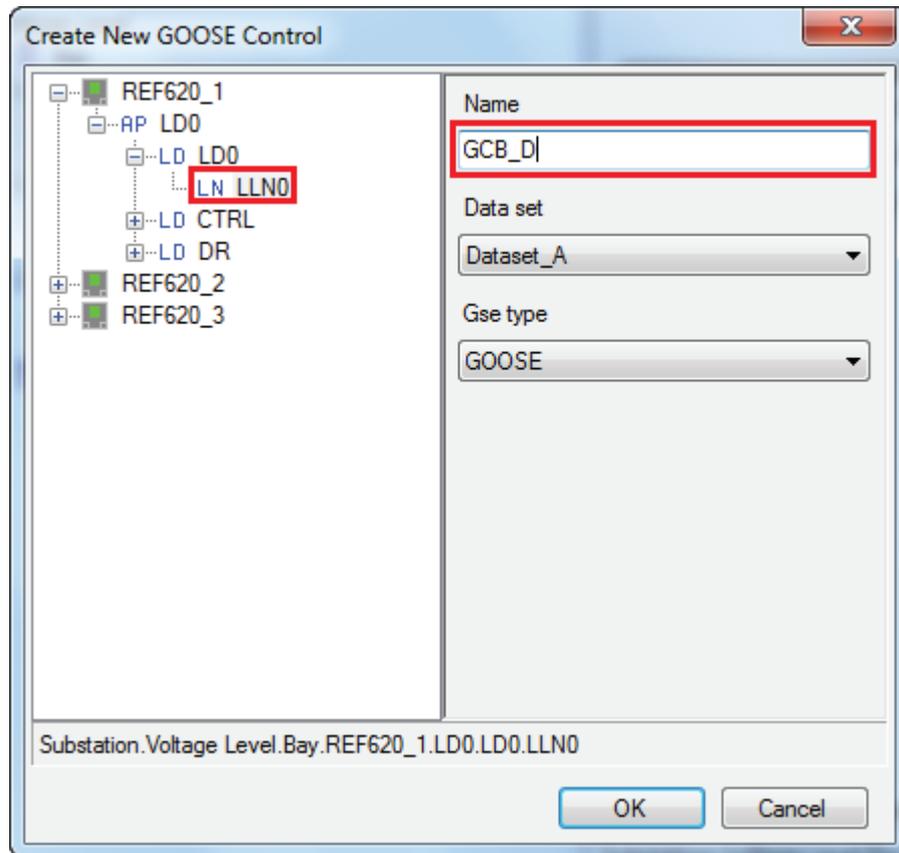


Figure 12: Naming a GOOSE control block

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

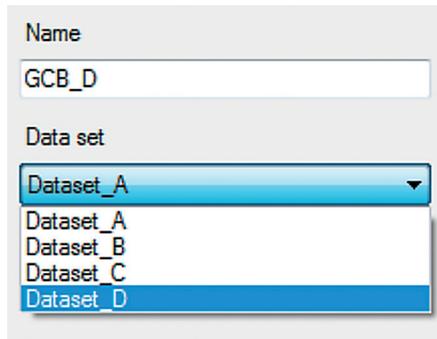


Figure 13: Data set drop-down list



Data set entries in a data set linked to the GCB can be modified from the GOOSE control block tab by selecting **Data Set details** in the shortcut menu.

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

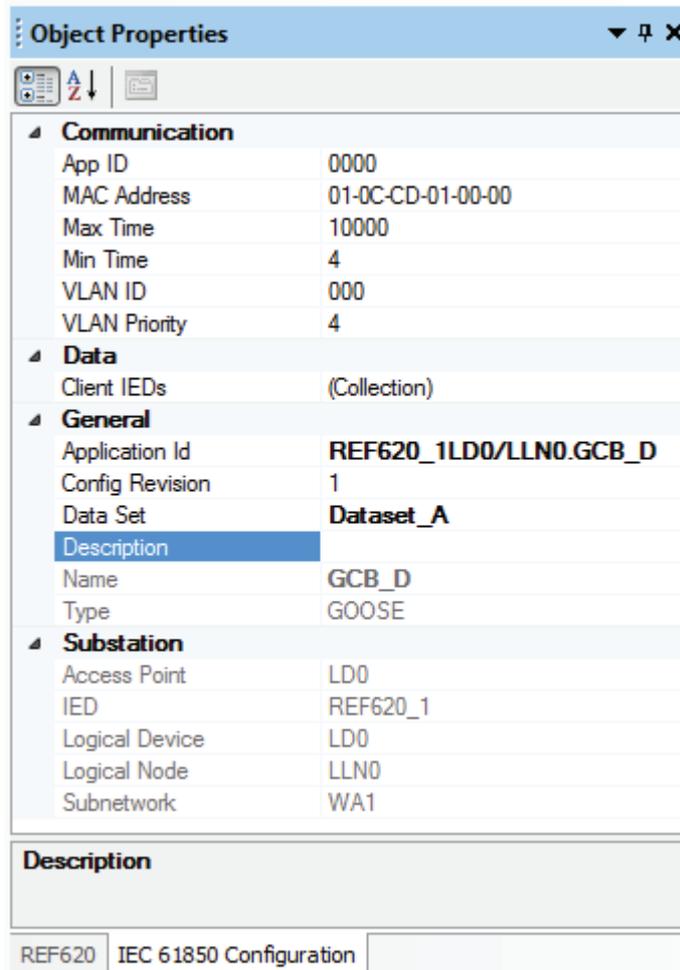


Figure 14: GOOSE control block properties

Table 5: GOOSE control block properties

GoCB property	Description
GoCB name	GOOSE control block name. The maximum length is 28 characters.
Application (AppID)	A unique GOOSE Identification string for each GoCB in the system. Recommendation is to define a device-specific value and not to use the default empty value. The maximum length is 64 characters.
t(min) (ms)	Indicates the maximum response time in milliseconds to data change. This time can be used by the receiver to discard messages that are too old. In principle, t(min) can vary depending on the data type, but for the IEDs, the value is always “10 ms” for sent data.

Table continues on the next page

GoCB property	Description
t(max) (ms)	Indicates the background "heartbeat" cycle time in milliseconds; the default value is "10 000 ms". If there are no data changes, the IED still resends the message with the heartbeat cycle to enable the receiver to detect communication losses, that is, the communication is supervised.
Configuration Revision	Contains an integer value that is sent in every GOOSE message. The integer indicates the amount of changes in the data set. The receiver checks the message for configuration mismatches. "Configuration Revision" cannot be manually edited in IET600.
MAC Address	Multicast MAC address to which the specific GOOSE data is sent. The receiving IED filters the frames and starts to process them if a specific multicast address is defined in the configuration. It is recommended to have one unique multicast address per GoCB. The address range for GOOSE Multicast addresses is 01-0C-CD-01-00-00...01-0C-CD-01-01-FF
App ID	Unique HEX value application identifier for sending the GoCB within the system. It identifies the purpose of this particular data set. The value range is 0000...3FFF.
VLAN-ID	Used if the Ethernet switches in a station bus support VLAN. If static VLAN identifiers are defined, it also affects the switch port configuration. Value "000" indicates a non-configured VLAN and switches do not filter these messages on a port basis. This is recommended if there is no need to split the logical network. The VLAN identifier is a 3-character HEX value with range 000...FFF. Recommended values are 2...1001.
VLAN Priority	Used in networks supporting VLANs. The priority is used with network switches. The default value for GOOSE is "4" and the value range is 0...7.



With the IEDs of this product series, only $t(max)$ is configurable, not $t(min)$.



The multicast *MAC address* is usually unique, and *APP-ID* must be unique.

5.3.3 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.

1. Add devices to a PCM600 project.
2. Export the SCD file.
3. Import the SCD file to IET600.
4. 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.
5. Export the SCD file back to PCM600.
6. In PCM600, engineer the IED applications with GOOSE inputs.



Before any configuration, create backups of the PCM600 and IET600 projects. For example, once an SCD file is imported into PCM600, the changes cannot be undone except by restoring the backup.

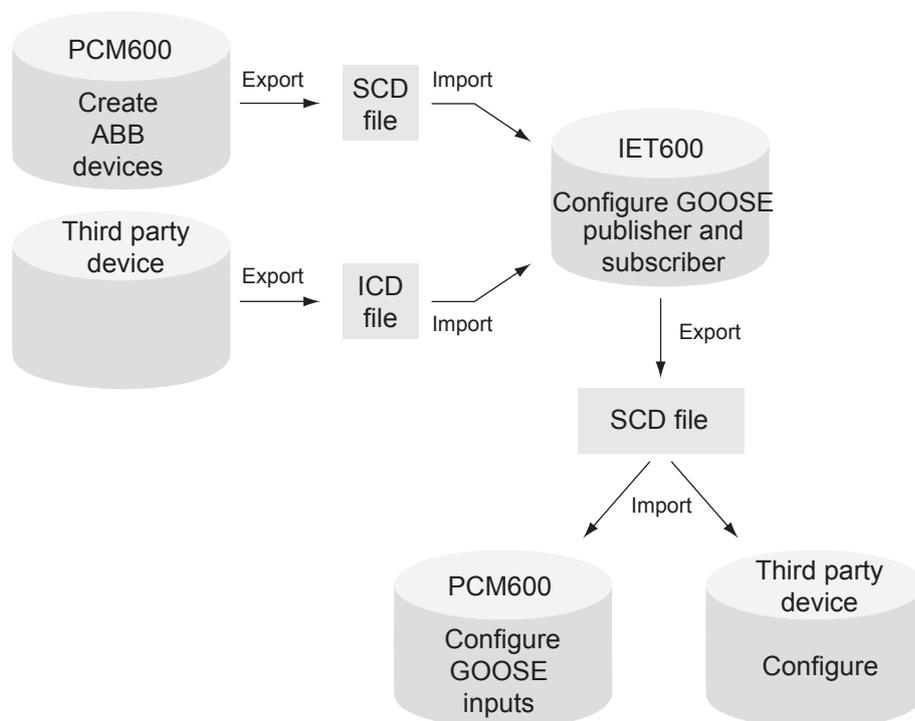


Figure 16: Horizontal communication configuration process

5.4.1 Defining devices and exporting the SCD file for IET600

Use PCM600 to define the substation and the devices. Before starting the system engineering, configure the device in PCM600.



For more information, see PCM600 documentation.

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

- To export the SCD file, click the **Plant Structure** tab, right-click the substation node in the submenu and select **Export**.

The file includes the whole substation configuration in SCL format for other tools.

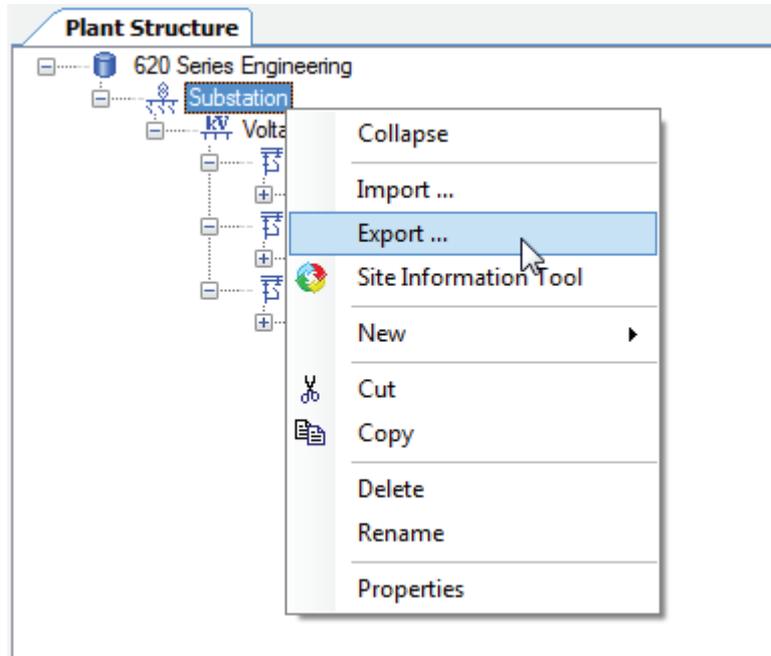


Figure 17: Exporting an SCD file from PCM600

- Define the export options.

A dialog box with several options opens. Unlike other ABB tools such as COM600S or MicroSCADA product configuration tools, IET600 does not use the private sections. Select all the check boxes but clear **Export As SCL Template**.

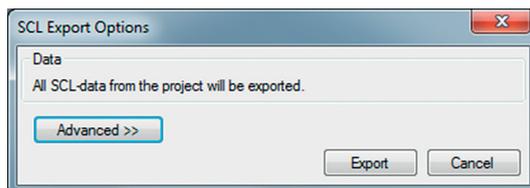


Figure 18: Export options for an SCL file

- Click **Export**.

5.4.2 Creating an empty project with IET600

- Open IET600.
- To create an empty project, click the round button on the upper-left corner of the IET600 tool.
- Click **Manage Projects**.
- In the **Projects** dialog, click **New**.

5. Name the project.

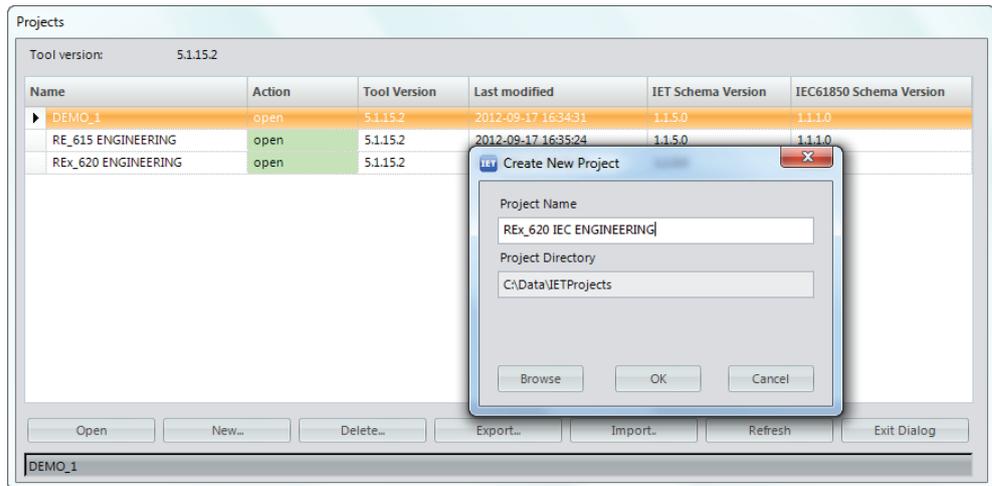


Figure 19: Naming a project

6. To select the destination folder for the project, click **Browse**.7. Click **OK**.

After creating an empty project, import the SCD file from PCM600 to the project.

5.4.3 Importing the SCD file into IET600

1. Import the SCD file from PCM600 to the empty project.

- Click **Import SCL File** on the shortcut menu of the project object.
- Click **Import** button.

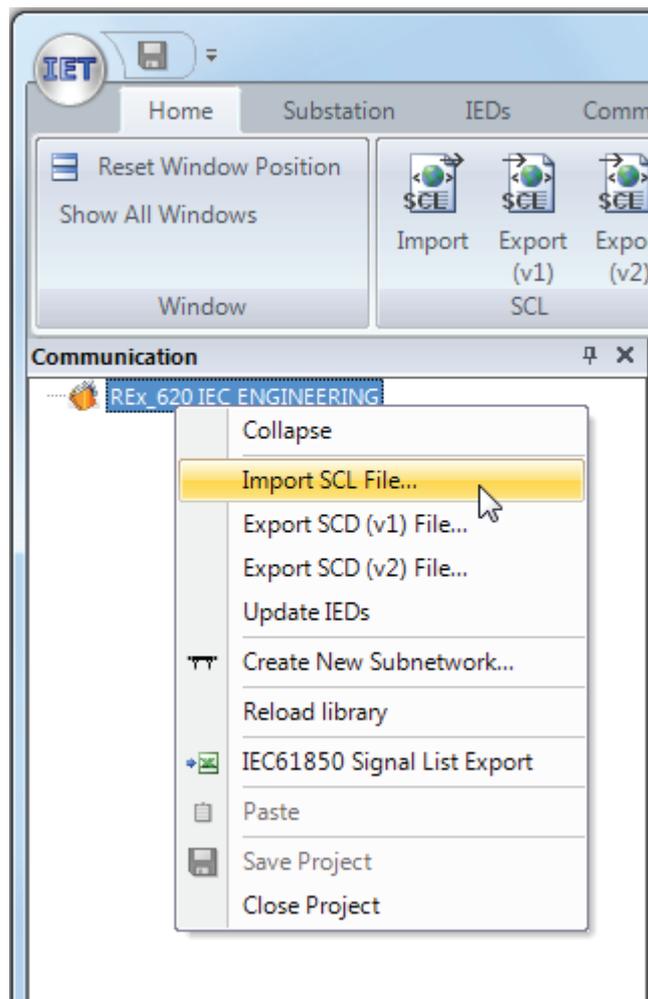


Figure 20: Importing an SCL file

2. Locate the SCL file and click **Open**.



If the substation includes third-party devices which need to be configured for horizontal GOOSE communication, the SCL files holding the information from those devices must be imported as well. The third-party devices have separate tools for creating the ICD/CID/SCD file.



SCD files can be imported to a project only once. If a new device needs to be later added to the configuration, it must be first created using the **Create New IED** function after which the **Update IED** function can be used to import the related CID or ICD file. Another alternative is to create a new project in IET600 and import the whole SCD file from PCM600. The existing IEC 61850 configuration including GOOSE remains if the changes made in IET600 have been already imported to PCM600.

5.4.4 Configuring a GOOSE publisher with IET600

To control the GOOSE data publishing, such as addressing, every publisher device 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 protection relay 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.

5.4.4.1 Creating a GOOSE data set with IET600

The sending data set used by the GOOSE control block must be defined. With the protection relays of this product series, the sending device can have a maximum of 80 data attributes in GOOSE data sets. To minimize the message-handling load in receiving and sending protection relays, the recommendation is to divide data attributes to a maximum of 20 per data set.

All data sets must be configured under the logical node LLN0 and must be provided with names unique within the device. The protection relays allow a maximum of four GOOSE control blocks, which effectively limits the protection relay 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 **IEDs** tab in the navigation pane.
2. Click the IED node.
3. Click the **Datasets** tab in the editor pane.

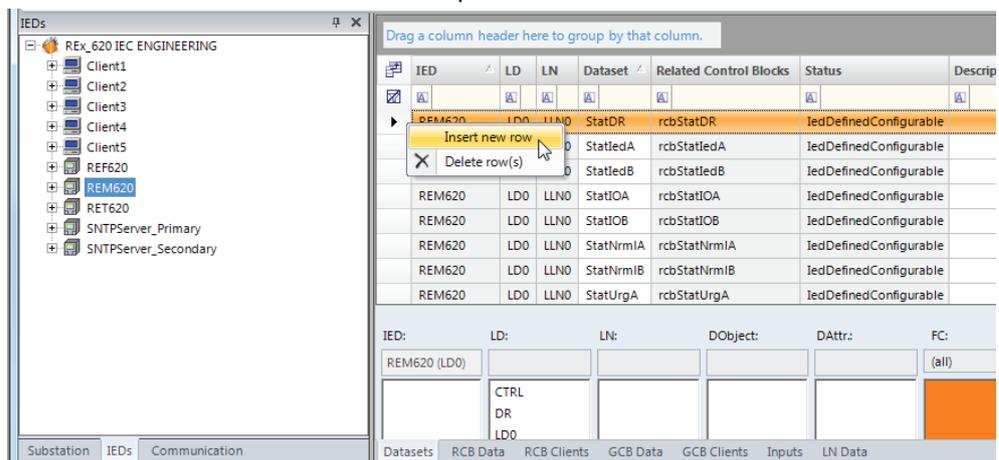


Figure 21: Creating a data set in IET600

4. To add a new data set, right-click the area containing the data set names and select **Insert new row** the shortcut menu.
5. Define the LN where the data set is to be placed (accept preselected “LD0/LLN0”) and give the data set a unique name.

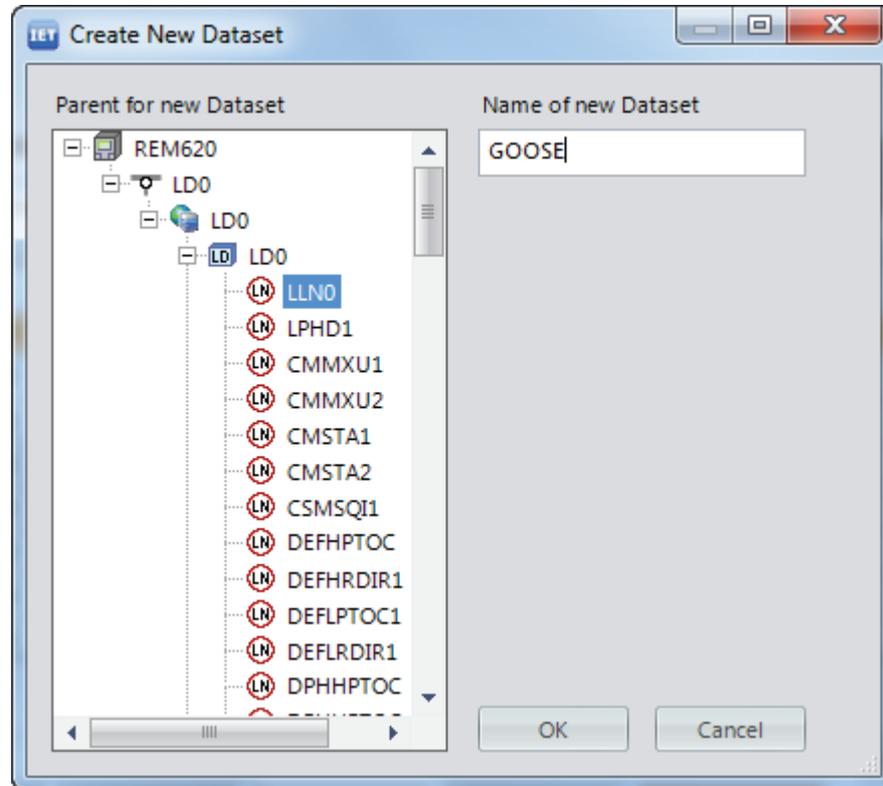


Figure 22: Naming a data set in IET600

After creating the GOOSE data sets, define the data attributes 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 data entries with IET600

1. Select the **Datasets** tab on the editor pane.
2. Select a GOOSE data set.
3. Using the selection lists below the data set grid, select a data attribute or data object to be used.
 - Click **Append >>** to add the data attribute to the end of the data set.
 - Click **Insert >** to add the data attribute above the selected row in the data set entries list.

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

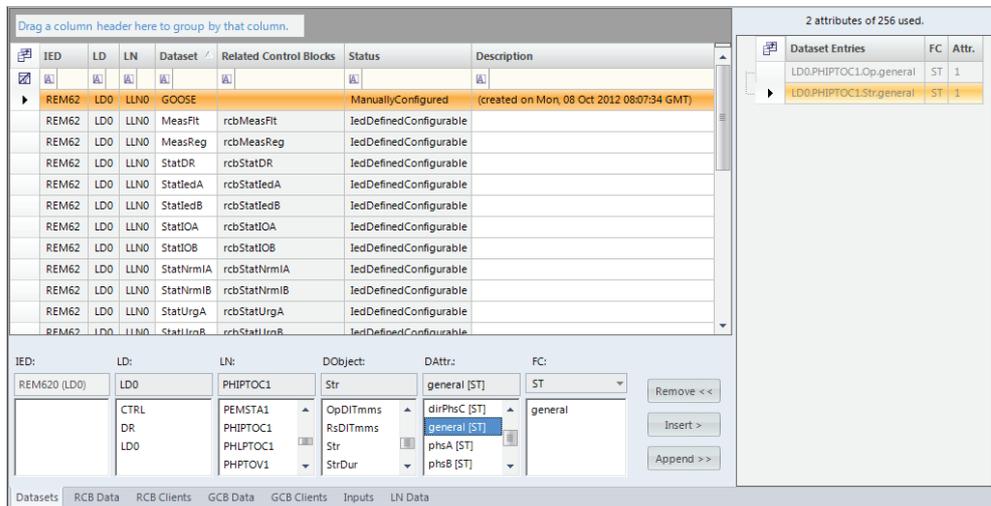


Figure 23: Adding data set entries



The possible amount of attributes that can be added to a data set and the amount of already added attributes are shown above the data set entries list. However, since IET600 cannot make a difference between the maximum data attribute count of a data set for vertical reporting and a GOOSE data set, too high a maximum value is shown for a GOOSE data set.



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



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.



After installation of the connectivity package documentation add-on, a full list of the available signals with descriptions and IEC 61850 names is available in PCM600 under the Documentation menu of the IED node. The document name in PCM600 is Parameter List.

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

5.4.4.2

Configuring a GOOSE control block with IET600

1. Select the IED node on the **IEDs** tab in the navigation pane.

2. Select the **GCB Data** tab in the editor pane.

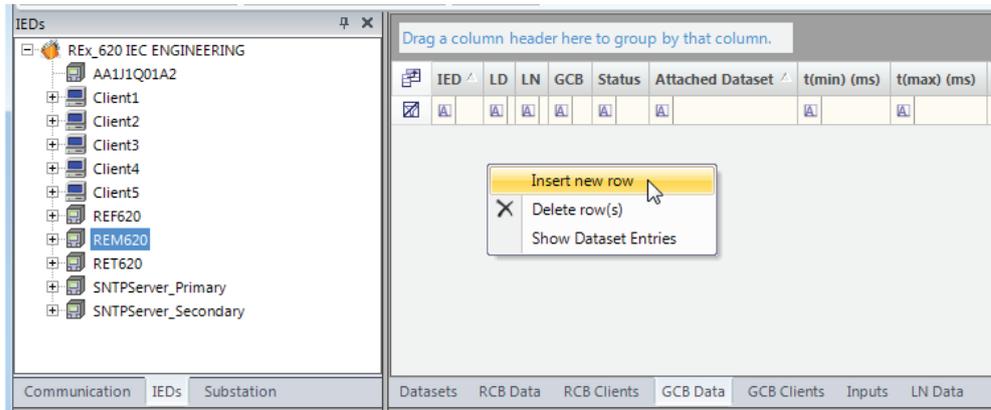


Figure 24: Creating a GOOSE control block

3. To add a new GOOSE control block, right-click the area containing the existing GOOSE control blocks and select **Insert new row**.

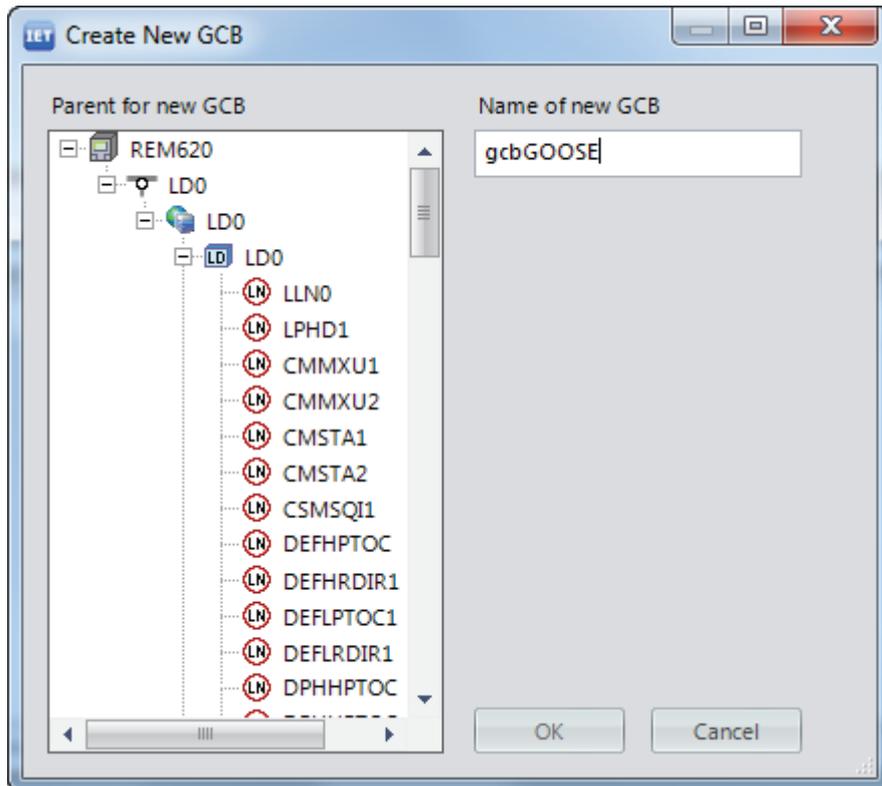


Figure 25: Naming a GOOSE control block

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.
6. In the **Attached Dataset** drop-down list, select the previously created data set. After creating the GOOSE control block, edit its properties and addresses. Edit at least **MAC Address** and **APP-ID**.

IED	LD	LN	GCB	Status	Attached Dataset	t(min) (ms)	t(max) (ms)	Conf.Rev.	MAC Address	APP-ID	VLAN-ID
REM620	LD	LL	gcbGOOSE	ManuallyConfigured	GOOSE	4	10000	100	01-0C-CD-01-00-00	3001	000

Figure 26: GOOSE control block properties



To set the visibility of the GoCB columns, click the upper-left icon of the table and select or clear the check boxes in the **Field Chooser** dialog.

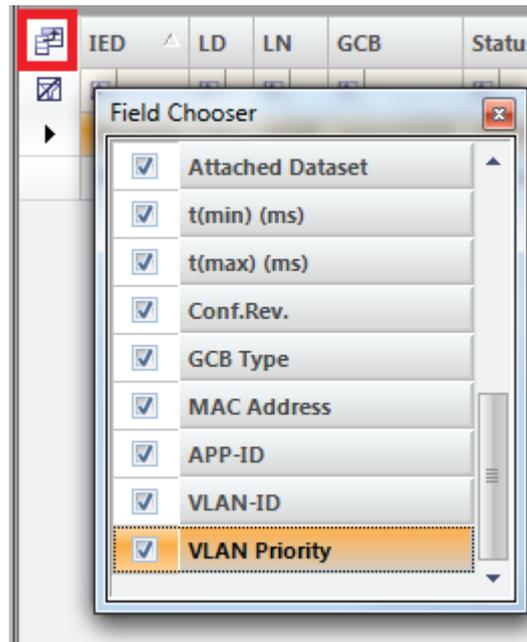


Figure 27: Field Chooser dialog

Table 6: Selected GOOSE control block properties

GoCB property	Description
GCB	GOOSE control block name
Application (appID)	A unique GoID for each GoCB in the system. Recommendation is to define a device-specific value and not to use the default empty value.
t(min) (ms)	Indicates the maximum response time in milliseconds to data change. This time can be used by the receiver to discard messages that are too old. In principle, t(min) can vary depending on the data type, but for the protection relays, the value is always “10 ms” for sent data.

Table continues on the next page

GoCB property	Description
t(max) (ms)	Indicates the background "heartbeat" cycle time in milliseconds; the default value is "10 000 ms". If there are no data changes, the protection relay still resends the message with the heartbeat cycle to enable the receiver to detect communication losses, that is, the communication is supervised.
Conf.Rev.	Contains an integer value that is sent in every GOOSE message. The integer indicates the amount of changes in the data set. The receiver checks the message for configuration mismatches. "Configuration Revision" cannot be edited manually in IET600.
MAC Address	Multicast MAC address to which the specific GOOSE data is sent. The receiving device filters the frames and starts to process them if a specific multicast address is defined in the configuration. It is recommended to have one unique multicast address per GoCB. The address range for GOOSE Multicast addresses is 01-0C-CD-01-00-00...01-0C-CD-01-01-FF.
APP-ID	Unique HEX value application identifier for sending the GoCB within the system. It identifies the purpose of this particular data set. The value range is 0000...3FFF.
VLAN-ID	Used if the Ethernet switches in a station bus support VLAN. If static VLAN identifiers are defined, it also affects the switch port configuration. Value "000" indicates a non-configured VLAN and switches do not filter these messages on a port basis. This is the recommended if there is no need to split the logical network. The VLAN identifier is a 3-character HEX value with range 000...FFF. Recommended values are 2...1001.
VLAN Priority	Used in networks supporting VLANs. The priority is used with network switches. The default value for GOOSE is "4" and the value range is 0...7.



With the protection relays of this product series, only $t(max)$ is configurable, not $t(min)$.



Conf.Rev. cannot be manually edited. IET600 updates it automatically to the next multiple of 100 when the configuration changes.



The multicast *MAC address* is usually unique, and *APP-ID* must be unique.

5.4.5 Configuring a GOOSE subscriber with IET600

The relay 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.

5.4.5.1 Configuring GOOSE inputs with IET600

1. Select the root node on the **IEDs** tab in the navigation pane.
2. Click the **GCB Clients** tab in the editor pane.

The rows of the GCB client editor show GoCBs, that is, “senders”, and the columns show the devices available as GOOSE clients, that is, “receivers”. If the client device is not on the same subnetwork as the GoCB sender, it cannot be configured as a client.

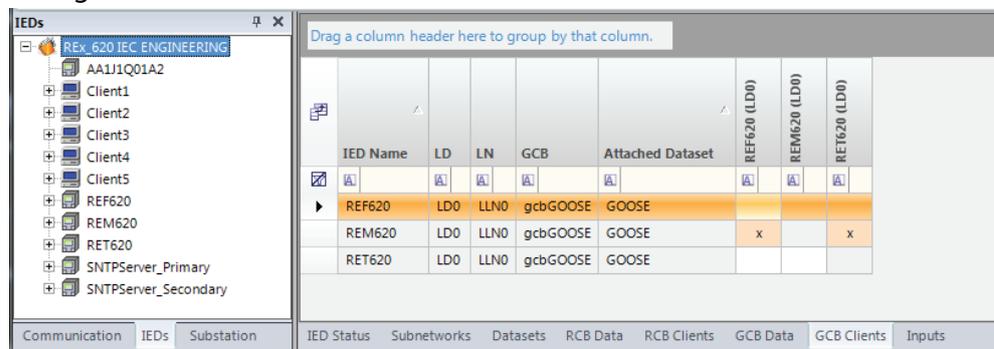


Figure 28: GCB client editor

3. To add or to delete clients, double-click the cell. Upon adding or removing clients, the corresponding input sections are updated.

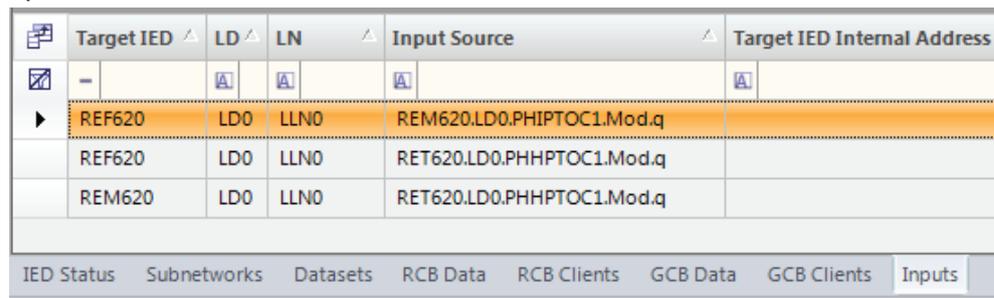


Figure 29: GOOSE inputs

5.4.6 Finalizing GOOSE configuration with IET

5.4.6.1 Exporting the SCL file

1. Export the SCL file in one of the alternative ways.
 - Click **Export SCD File** on the shortcut menu of the project object

- Click **Export** button.

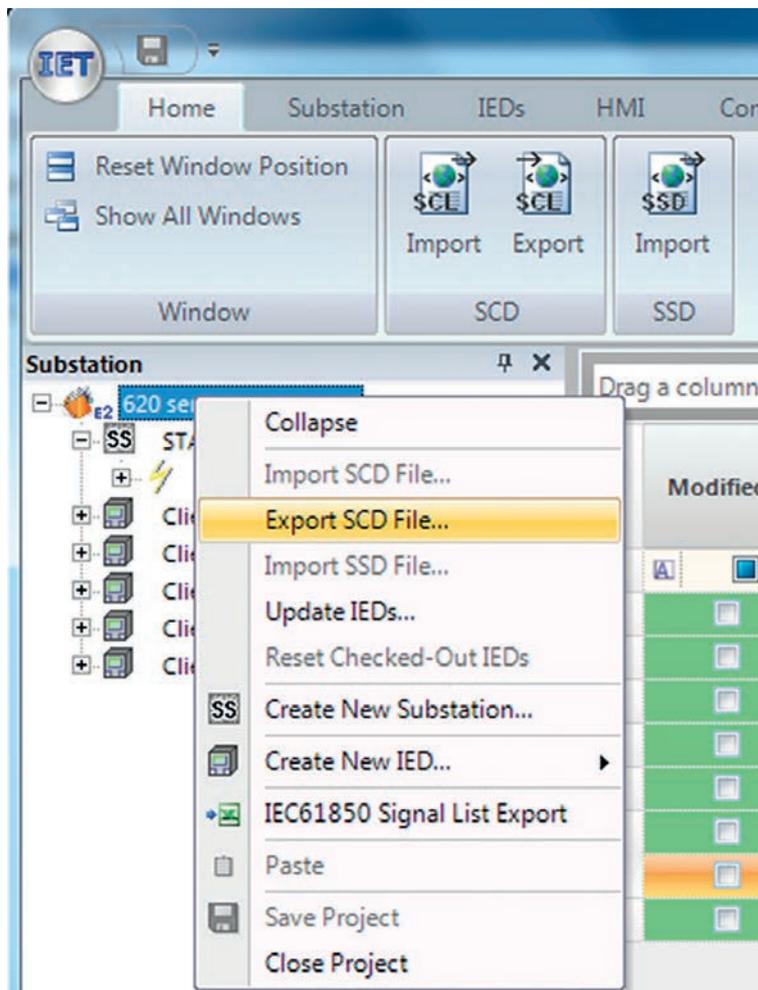


Figure 30: Exporting an SCD file

2. Select the file destination and click **Save**.
It is recommended to leave the SCD file exported from PCM600 as a backup.

5.4.6.2 Importing the SCL file

1. Open PCM600 and ensure the original project is open.

2. Switch off the engineering mode.

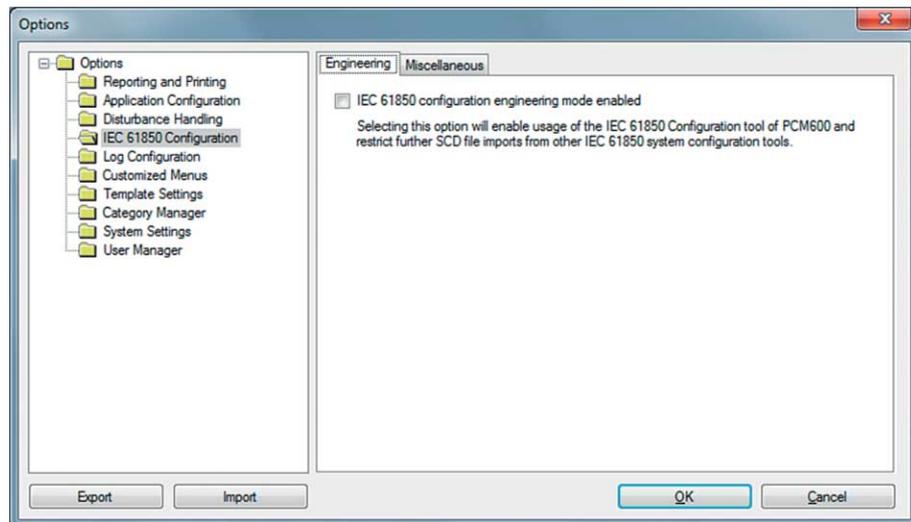


Figure 31: Switching off the engineering mode

3. Go to the **Project Explorer** view and select the **Plant Structure** tab.
4. Right-click the project and select **Import**.

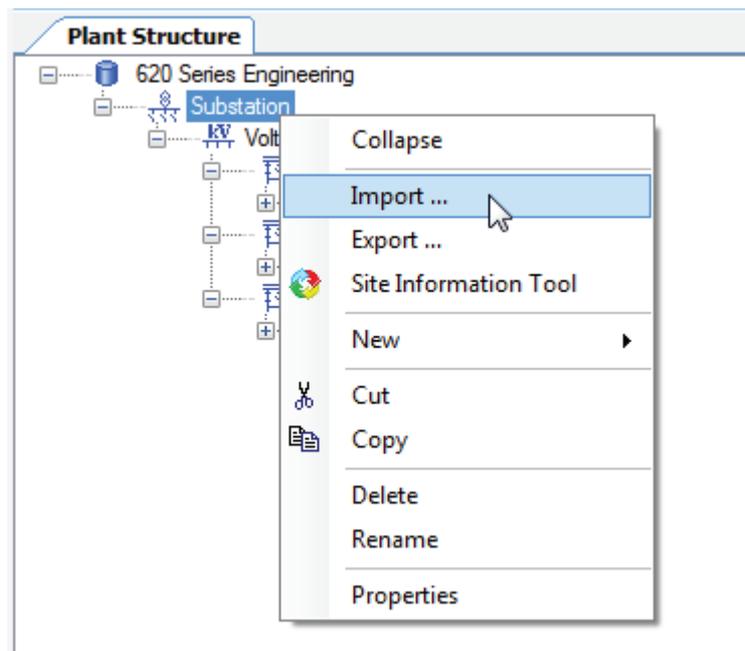


Figure 32: Importing an SCD file to PCM600

5. Open the SCL file exported from IET600.

6. In the **SCL Import Options** dialog box under IED Types, select **Don't import IEDs of unknown type** if the GOOSE configuration does not include third-party devices.

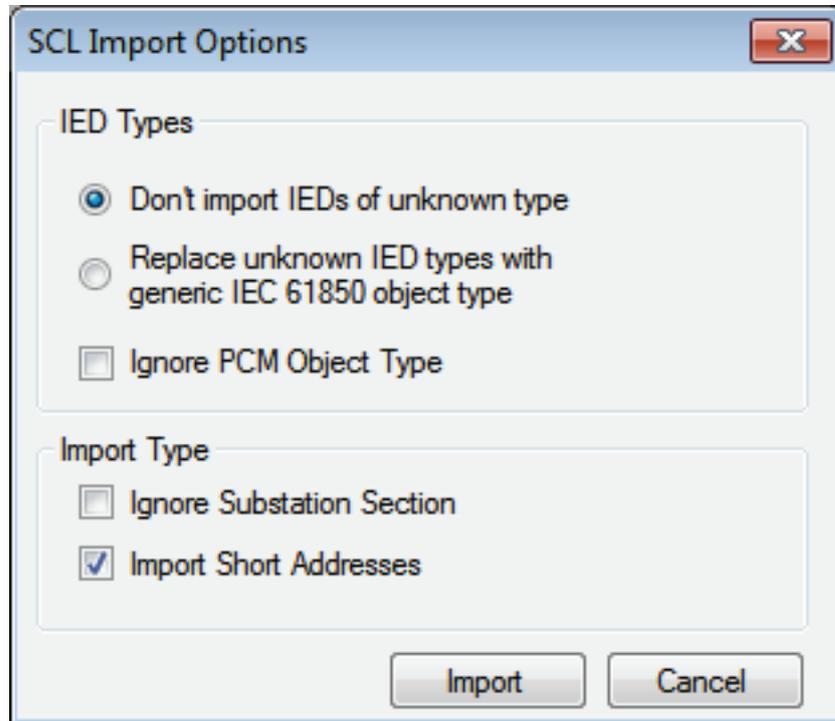


Figure 33: SCL import options in PCM600

7. Click **Import**.



For more information, see the PCM600 documentation.

5.5 Connecting GOOSE inputs to a relay application

1. In PCM600, open **Project Explorer** and select the **Plant Structure** tab.

2. Add the GOOSERCV function block with the Application Configuration tool.



The GOOSERCV function block can only be added with the Application Configuration tool.



Give the GOOSERCV block application-specific user-defined names to distinguish between different blocks when making GOOSE connections in the Signal Matrix tool.

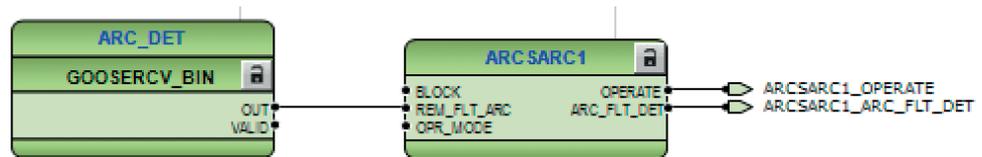


Figure 34: Adding the GOOSERCV function block

3. Create the connection into the application.
 - a) Create the connection.
 - b) Click **Calculate execution order**.
 - c) Click **Validate configuration**.
 - d) Save the connection to the application.
4. To open the Signal Matrix tool, right-click the protection relay, and select **Signal Matrix**.
5. To map the input points to the receiving input data, click the cell.
To expand the source field, drag the edge of the field to expand it until the whole GOOSE source address is visible.

- In Signal Matrix in the GOOSE sheet, map the GOOSE publisher data into the corresponding GOOSERCV function block.

The columns in the GOOSE sheet represent publisher data and the rows represent the possible subscriber input point.

The screenshot shows the 'REF620 - Signal Matrix' interface. It features a grid where publisher data is mapped to subscriber input points. The publisher data is organized into columns: 'IED, Logical Device', 'Feeder2, LD0', and 'Data Object: Data Attribute'. The subscriber input points are listed in rows: '- ARC_DEC;GOOSERCV_BIN:0' and 'ARC_DEC;GOOSERCV_BIN:0'. The 'ARC_DEC;GOOSERCV_BIN:0' row is highlighted in blue, and its 'IN' input point is connected to the 'ARC_SARC11' and 'FADet stVal' data objects. A navigation bar at the bottom includes 'Binary Inputs', 'Binary Outputs', 'Analog Inputs', 'Functions', and 'GOOSE'.

Subscriber Input Point	IED, Logical Device	Feeder2, LD0	Data Object: Data Attribute
- ARC_DEC;GOOSERCV_BIN:0			
ARC_DEC;GOOSERCV_BIN:0			ARC_SARC11 FADet stVal

Figure 35: GOOSE sheet in Signal Matrix



The GOOSE receiver block output `VALID` defines the validity for the received data. The value is based on the received quality attribute value or communication status. This validity information can be used in the application to build the validity logic in addition to the GOOSE default supervision information.



During the protection relay start-up phase, the protection relay keeps the value of the output `VALID` as “1” until the communication is activated. After the communication is activated, the value of the output `VALID` is updated by the value received via the communication.



If the data type does not match with the GOOSERCV function block, the attribute cell is red.

In Signal Matrix, the received GOOSE data can be directly connected to the relay application. The GOOSE inputs are shown on the Binary or Analog Inputs sheets and they can be connected to the application receiver function blocks. The columns represent publisher data and the rows represent the possible subscriber input points.

If the data type, for example timestamp, is not supported by the relay application, the attribute column is red. The quality attribute is automatically incorporated in the application with the status value, and it is not seen in Signal Matrix.

- Save the changes made in Signal Matrix.
- Write to the IED.

5.6 Received GOOSE message handling

A GOOSE frame is not accepted if the Needs Commission bit is set. When the protection relay uses IEC 61850 Edition 2, data with the Test quality bit set is accepted only if the receiving device is also in the test mode. When the relay uses IEC 61850 Edition 1, the Test field in GOOSE message is also used. For more information about GOOSE quality handling, see the corresponding flowcharts.



When the protection relay uses IEC 61850 Edition 2, a GOOSE frame is not accepted if the Simulation bit is set.

When the protection relay uses IEC 61850 Edition 2, the Test quality bit is active in the sender if the relay is set to test mode. When the relay uses IEC 61850 Edition 1, the Test field in GOOSE message is also set when in test mode.

When the GOOSE sender is in test mode and the GOOSE receiver is not, in Edition 1 mode the GOOSE receiver freezes to its previous valid state, and in Edition 2 mode the data value is defaulted and the quality set to invalid.

The Test bit is active in the sender if the protection relay is set to test mode.



See the technical manual for more information on the test mode.

The GOOSE frame is also not accepted if ConfRev deviates from the one in the configuration. These error situations can be observed in the GSELPR1 diagnostic counters.

The default GOOSE input value is “0” for all the data types. The functionality is analogous to physically wired galvanic Normally Open (NO) contacts where the disconnected signal gives value “0” of FALSE to relay application. The application must be designed to withstand the default value. This value is used when the subscribed GOOSE data is not valid, or it is not received from the network and the peer device is considered to be in a time-out state.

If a peer device sends the data including the quality attribute, the receiver device input object is not updated according to the received status value if the data quality is bad, questionable or blocked. The default value is also used in this case.

5.7 GOOSE supervision

5.7.1 Background sending

To ensure reliability and availability of the application, the GOOSE communication must be supervised. Design the application so that it can handle communication losses, for example, when a peer device is not available or there are communication time-outs.

If there are no GOOSE-related data changes, the protection relay resends the last GOOSE message with a heartbeat cycle to enable the receiver to detect communication losses. The heartbeat cycle is defined by modifying the *MaxTime* property on GOOSE control block.

Every GOOSE frame has a TAL field which shows how long the frame is valid until the next heartbeat frame. Other devices may have their own TAL values. Nevertheless, all the TAL values under 1000 ms are rounded up to 1000 ms on the receiving side.

If no frames are received during 2xTAL, that is, if at least two consecutive frames are lost, then the receiver considers the whole data set as invalid. The quality attribute for the entire data set is set to "bad" and the values are set to their default values. This is an important consideration when designing the application as the default values need to be "fail-safe" values. For example, the protection relay should use an enabled signal for interlocking and a blocking-type signal for protection.

5.7.2 Default value handling

The information is of point-to-point type which means that there is only one signal connected to the function block input.

The default value of the GOOSE receiver blocks output (OUT) is FALSE (0) in case there is a communication error. This handling is applicable for all signal types (binary, integer, enum and floating point). In addition to the default value handling, value output signal automatically carries validity information to the application function blocks. Validity information can be used in application by adding the quality function blocks.

In communication disturbance cases, GOOSE receiver blocks use default values. Application function blocks using these signals have their own handling for propagated quality information and fail-safe functionality, especially when receiving analog type of data. Exact fail-safe functionality must be checked from the function block description in the technical manual.

If one relay application function block input receives several signals from several protection relays, the input value is calculated in OR or AND operation (configured in the Application Configuration tool) from several inputs. In this case, one default signal is treated as logical FALSE (0), but the other signals can keep the function block input value active. It works similarly as the traditional galvanic signal wires connected between protection relays. The advantage in the GOOSE-based signalling is that the application always detects faulty connections, which is not the case with the Normally Open (NO) type of physically wired galvanic contacts.

In all cases, however, a separate alarm event is always generated by the GSELPRT1.Alm data object for IEC 61850 event clients.

GSELPRT1.Alm can also be used on the application side as an input in the Signal Matrix Tool's Binary Outputs sheet (signal GSELPRT ALARM). For example, it is possible to change the setting group in case one or several protection relays are disconnected from the network.

5.7.3 Alarm supervision in application

In a communication time-out situation, all the peer devices receive information about the problem. The system does not tolerate single failures or non-existing

devices, for example, in service situations. Take this into account when designing an application.



Disable GOOSE sending by writing “false” from IEC 61850 clients to the GoEna attribute under the GOOSE control block. Use this feature carefully, and for test purposes only.

5.7.4 Diagnostic counters

The IEC 61850 data model of the protection relays includes a logical node LD0.GSELPR1 for the GOOSE communication diagnostic. The counters are also available via the HMI or PCM600 path **Monitoring > I/O Status > Communication > GSELPR1 > Monitoring**.

It is possible to reset the GOOSE communication diagnostics counters via **Monitoring > I/O Status > Communication > GSELPR1 > Monitoring > Reset counters** and via the IEC 61850 communication by writing `TRUE` to the `RsCnt.OperctlVal` attribute under GSELPR1.

Table 7: Diagnostics data objects

Data object	Description	Diagnostics information
FrRxCnt	Received messages	When increasing, the protection relay is receiving GOOSE messages.
FrTxCnt	Transmitted messages	When increasing, the protection relay is sending GOOSE messages.
RxStCnt	Received state changes	Received GOOSE messages with a new stNum value
RxSeqCnt	Received sequence number	Received GOOSE retransmissions or heartbeat cycle messages with a new sequence number
RxTestCnt	Received frames with test bit	Received GOOSE frames with the test flag on
StWrnCnt	State errors	Number of notified state number jumps
SeqWrnCnt	Sequence errors	Number of notified sequence number jumps
RxTmOutCnt	Receiver time-outs	Number of notified peer device time-outs
ConfErrCnt	Received ConfRev mismatches	When increasing, there is a mismatch between the received GOOSE frame information and the used GOOSE configuration.
NdsComCnt	Received frames with Needs Commissioning	One peer device Indicates that its configuration is not valid or up-to-date.
DSErrCnt	Errors in received data set	Received data are syntactically wrong, or there are less data in received data set than expected.
Alm	Receiver alarm	Alarm signal value connected to the event and application logic. It is active when one peer device is in time-out.

GOOSE Alarm is activated in the receiver device in certain situations.

- Time-out
- Configuration revision mismatch
- Error in the received data set
- The Needs Commissioning bit is active in the received message

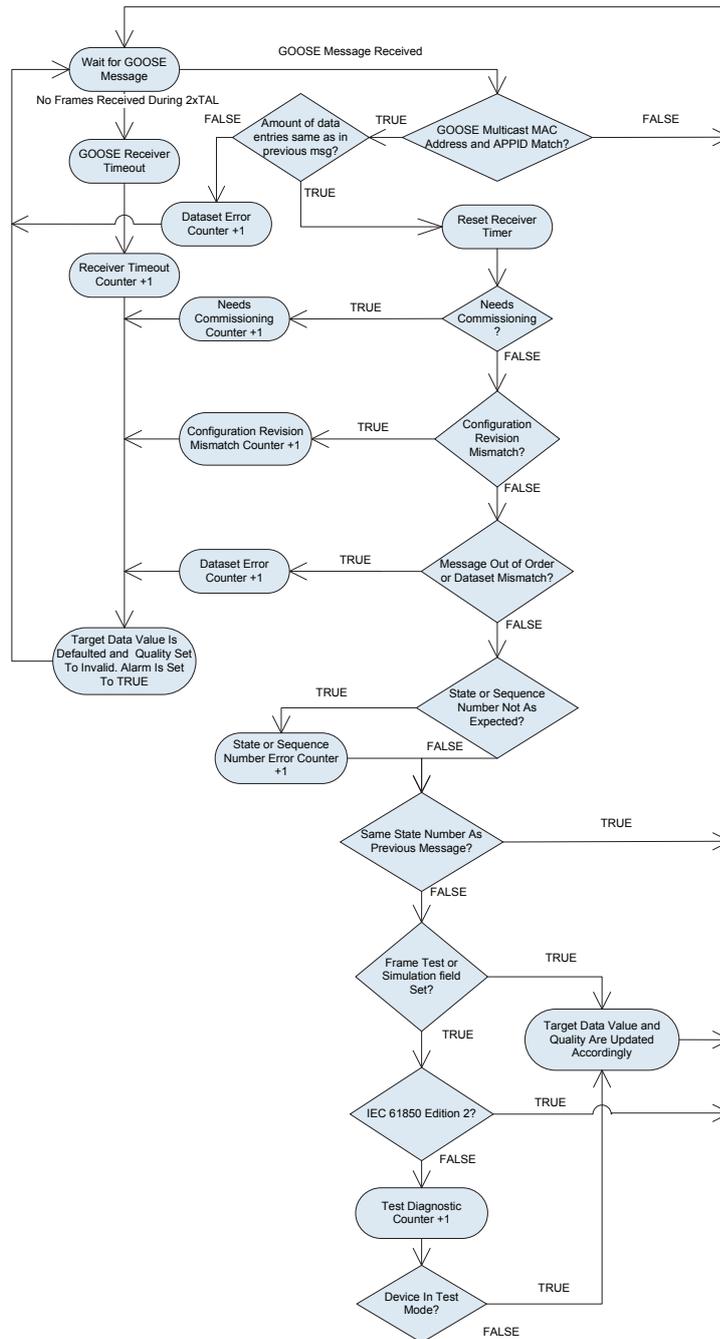


Figure 36: Receiving GOOSE data in the protection relays

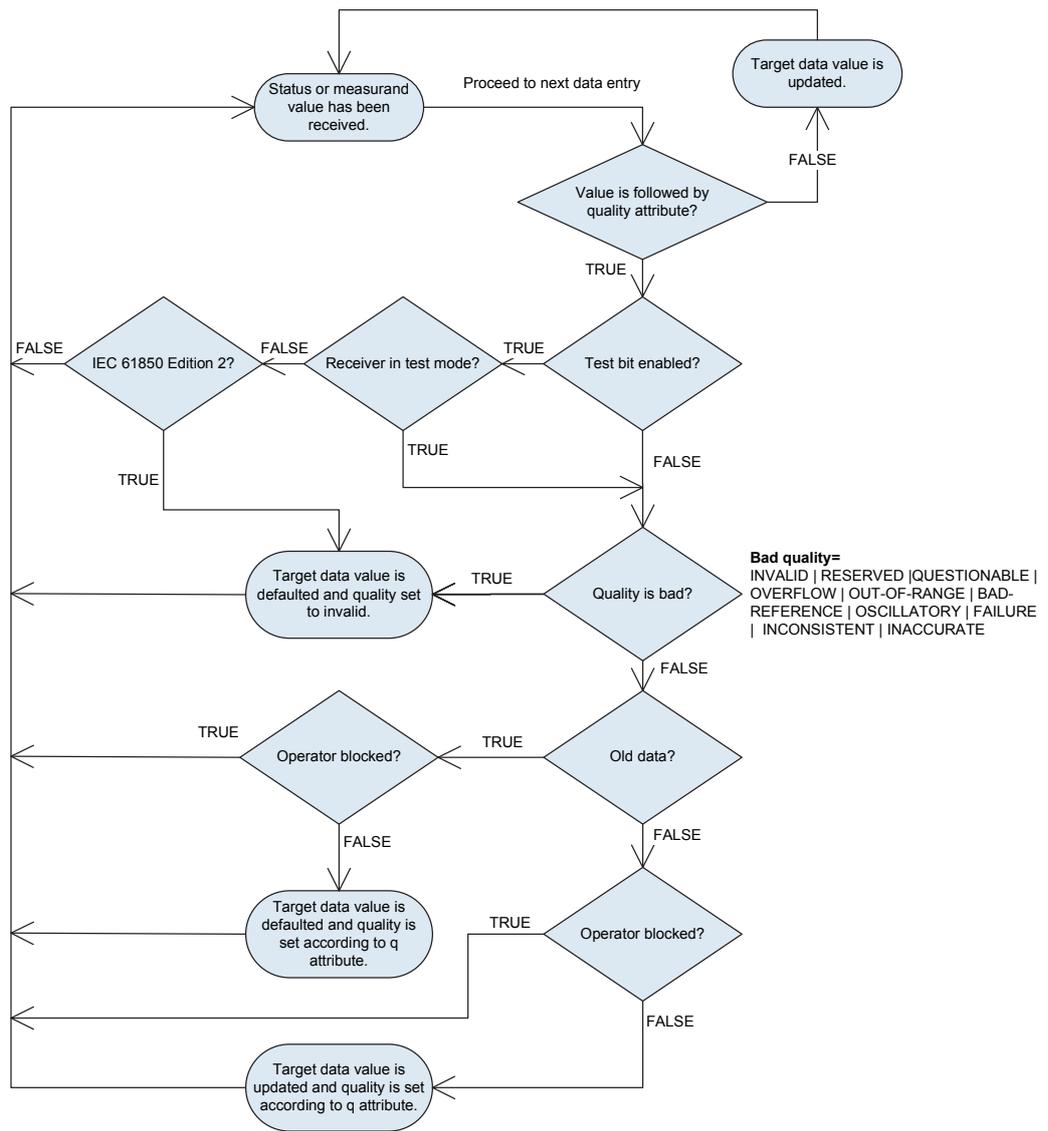


Figure 37: Receiving GOOSE data with quality in the protection relays

5.8 Forcing of GOOSE signals

Application Configuration tool in PCM600 is used for configuring the IED.

5.8.1 Testing of one device

Configuration logic testing is done for individual configurations. GOOSE signals can be forced using the Signal Monitoring tool.

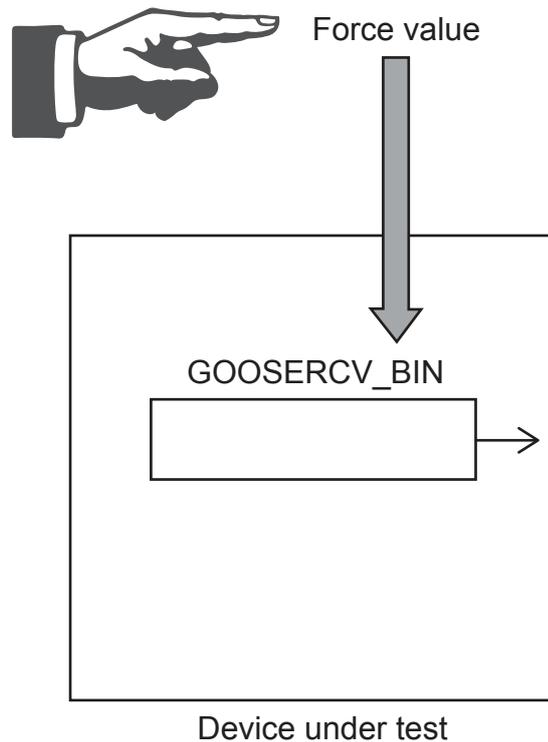


Figure 38: Testing of one device



The device must be in test mode.

5.8.2 Testing of many devices in a system

Any status data can be sent through GOOSE communication. Horizontal communication can be tested by forcing the outputs of the sender device and observing the results in the receiving device.

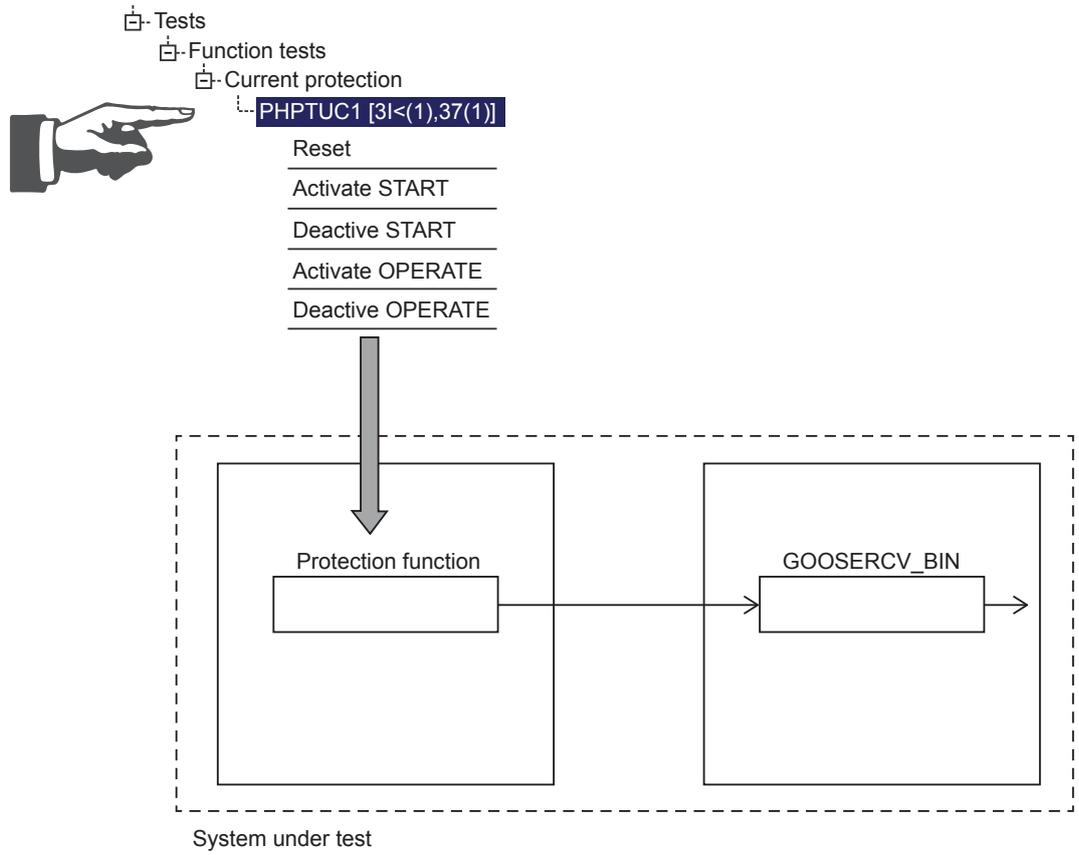


Figure 39: Testing of many devices



Both devices must be in test mode.

6 Process bus and IEEE 1588 time synchronization

6.1 Sampled measured values and IEEE 1588 v2 time synchronization

The IED supports IEC 61850 process bus with sampled values of analog neutral and phase voltages. Thus, the galvanic interpanel wiring used for sharing the busbar voltage value can be replaced with Ethernet communication. Sending 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 measured values are transferred as sampled values using the IEC 61850-9-2 LE protocol. Sampled values are intended for sharing neutral and phase voltages to other IEDs with phase voltage based functions and 9-2 support. IEDs with process bus based applications use IEEE 1588 v2 Precision Time Protocol (PTP) according to IEEE C37.238-2011 Power Profile for high accuracy time synchronization.



Configure IEC 61850-9-2 LE with the IEC 61850 Configuration tool in PCM600 or with the separate IET600 tool. PCM600 interacts with IET600 by importing and exporting SCL files.

6.2 System building

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

6.2.1 High-availability seamless redundancy HSR

HSR topology presented here is a reference system for process bus usage with switches supporting HSR and IEEE 1588 v2. This topology includes an HSR ring with the protection relays of this product series where IEEE 1588 v2 clock masters are connected to the ring utilizing Ethernet switches. Ethernet switches filter out IEC 61850-9-2 LE traffic from the IEEE 1588 v2 clock masters. HSR ring is presented with light blue lines and normal Ethernet connections with dark blue.

Each connected node in the HSR ring must support HSR protocol to ensure smooth redundancy. Otherwise Ethernet communication is disturbed and might not work. Single attached nodes can be connected to a HSR ring with a separate redundancy box (RedBox).



Use correct Ethernet connectors in the IED with HSR. IEDs with HSR support have three Ethernet connectors and redundant Ethernet ports are marked as LAN A and LAN B. The third Ethernet port without any LAN A or LAN B marking is an interlink port which is used as a redundancy box connector.

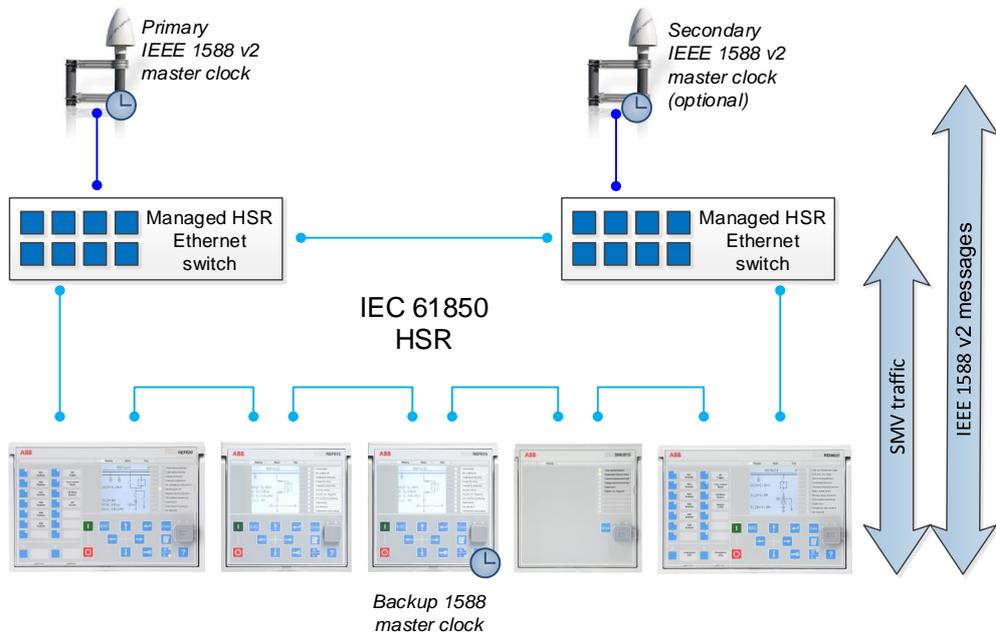


Figure 40: Recommended HSR reference topology with SMV and IEEE 1588 v2



The maximum number of IEDs supported in the HSR ring is 30. This is to keep the ring delay as small as possible for horizontal applications.



The IED interlink port does not support IEEE 1588 v2 slave devices.



HSR bandwidth is 50 Mbit/s as all messages are doubled for both directions of the ring.

6.2.2 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

- One SMV publisher generates around 5 Mbit/s traffic to the network. This is about 5 % of bandwidth in PRP and 10 % in HSR when the bandwidth of the used network is 100 Mb/s.

6.2.4 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

IEEE 1588 v2 master clock requirements

- Support for IEEE 1588 v2 Grand Master operation mode
- Clock accuracy of $\pm 1 \mu\text{s}$ or better to enable accurate enough sampled measured values

6.3 SMV system configuration

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. 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.

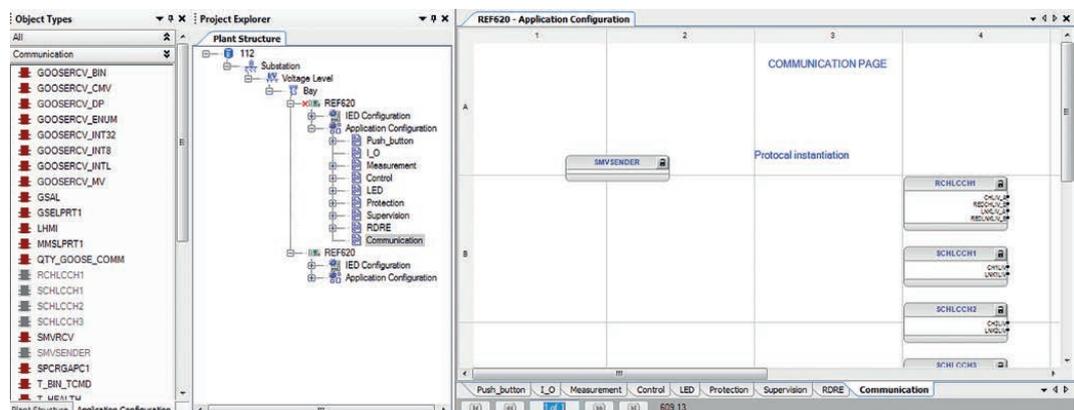


Figure 42: Adding an SMVSENDER block in the Application Configuration tool



The SMV receiver cannot be configured to transfer received sample values from 9-2 LE to a second receiver.



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

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.

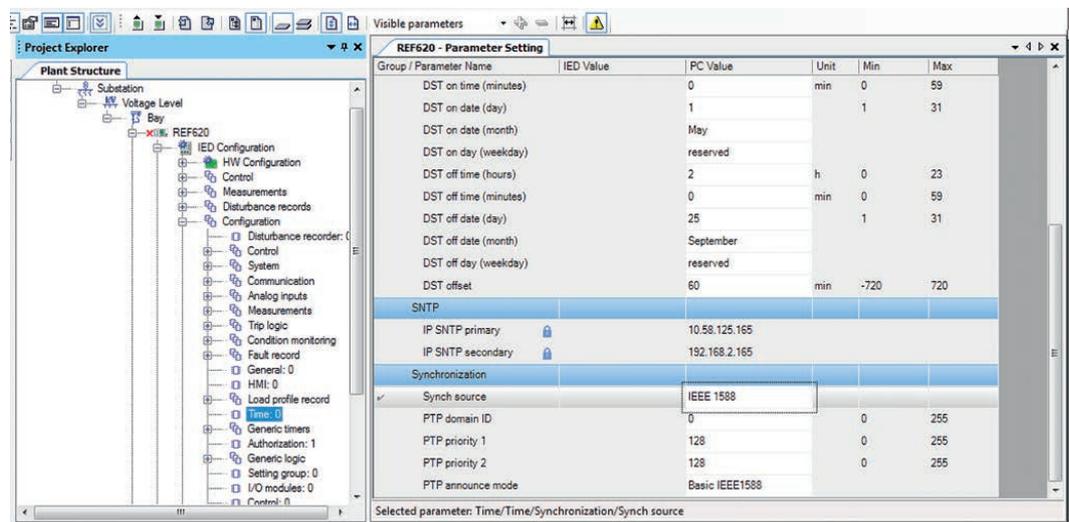


Figure 43: Time synchronization source

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

6.3.1 Configuring SMV with the IEC 61850 Configuration tool

The connection between SMV sender and receiver is handled using the IEC 61850 Configuration tool.

1. Start the IEC 61850 Configuration tool.

2. Select **Process Bus Communication** in the drop-down box on the toolbar.



Figure 44: Selecting Process Bus Communication

The SMV sender and the possible SMV receiver IEDs become visible.

3. Edit the properties and addresses of the sampled value control block.

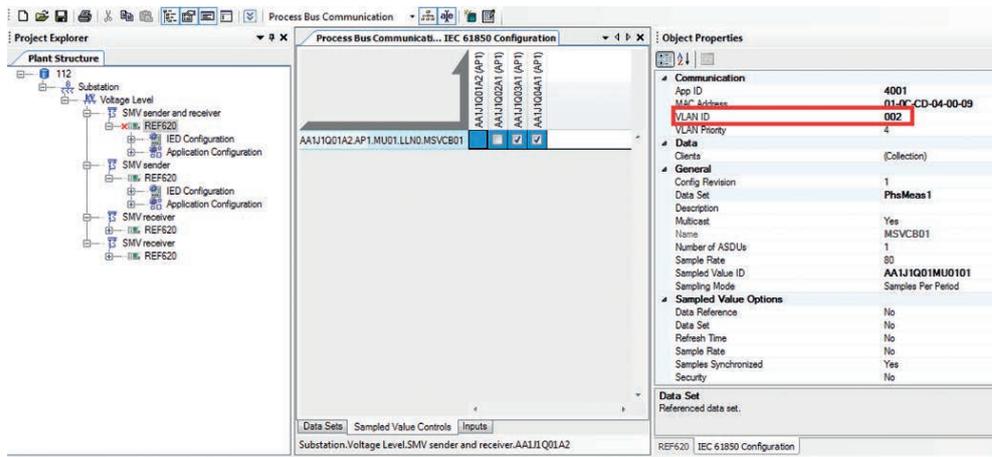


Figure 45: Changing the VLAN ID



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.

A 620 series IED as SMV receiver should never be configured to receive sampled values from more than one sender, although the configuration tools do not prevent this. Extra senders or SMV inputs can be checked from the SMV inputs view of the receiver with the ICE tool. If SMV inputs from extra senders are seen, and the extra sender IEDs are available in the same project, the extra inputs can be removed by clearing the receiver from the sender's side, or by deleting it manually in the SMV inputs view. If SMV inputs from extra senders are seen, but the extra senders are not available in the same project (for example, extra senders are introduced by reading configuration from a configured receiver), the extra inputs can be removed by deleting them manually in the SMV inputs view.

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

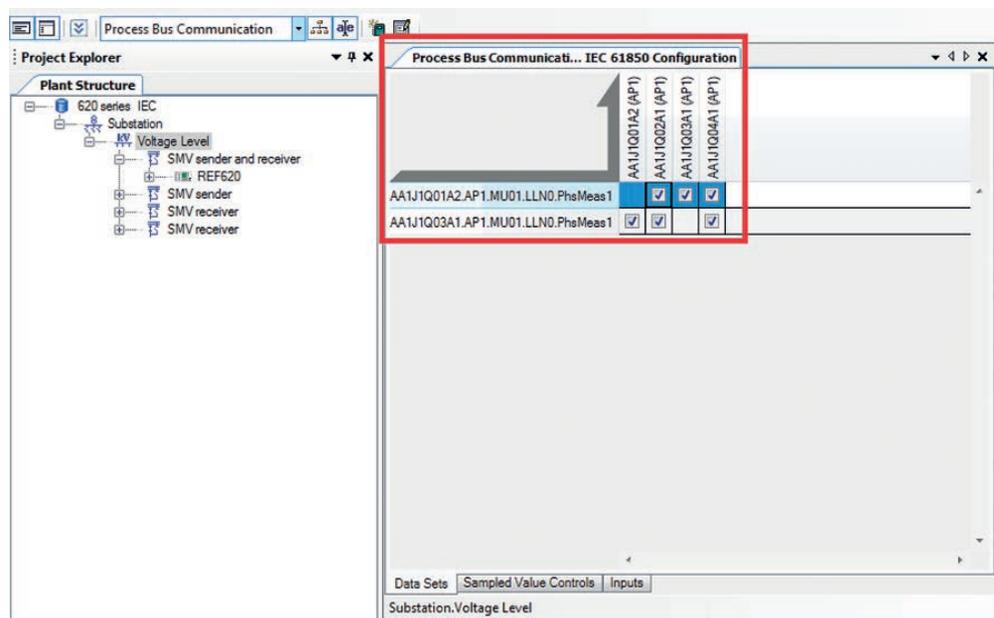


Figure 46: Configuring the SMV sender and receivers



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.

6.3.2 Configuring SMV with IET600

After the common configuration items have been completed, the SCD file has been exported from PCM600 and the SCD file has been imported to IET600, the SMV sender and receiver connections can be handled using the IET600 tool Ver.5.3.21 or later.

1. In the **Options** dialog box in IET600, click **Show IED Capabilities Tab**.

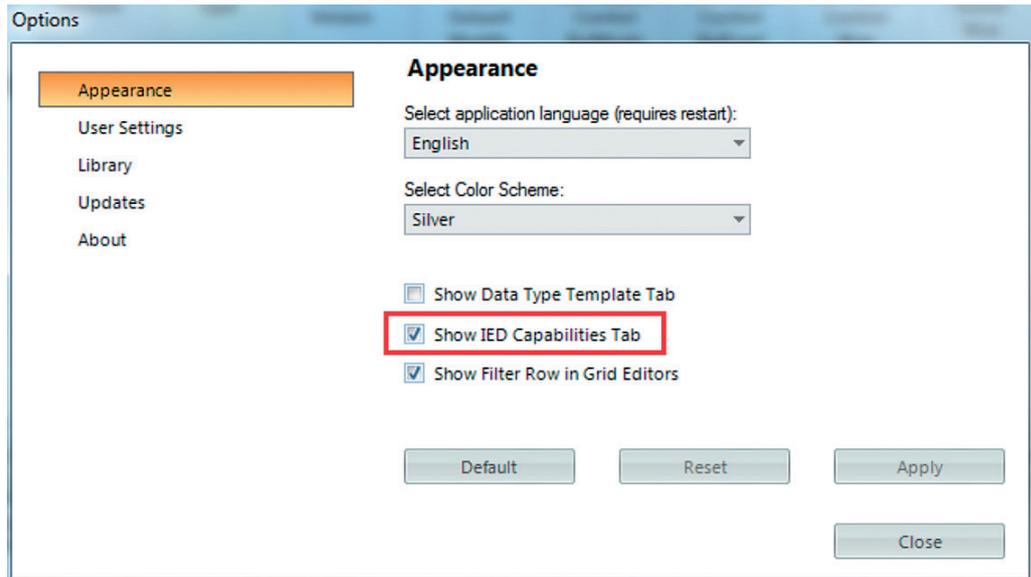


Figure 47: Selecting Show IED Capabilities Tab

2. In the **IED Capabilities** tab, check the **Override for Client Service SampledValues** box to adjust the IED620 option to support sampled values services.

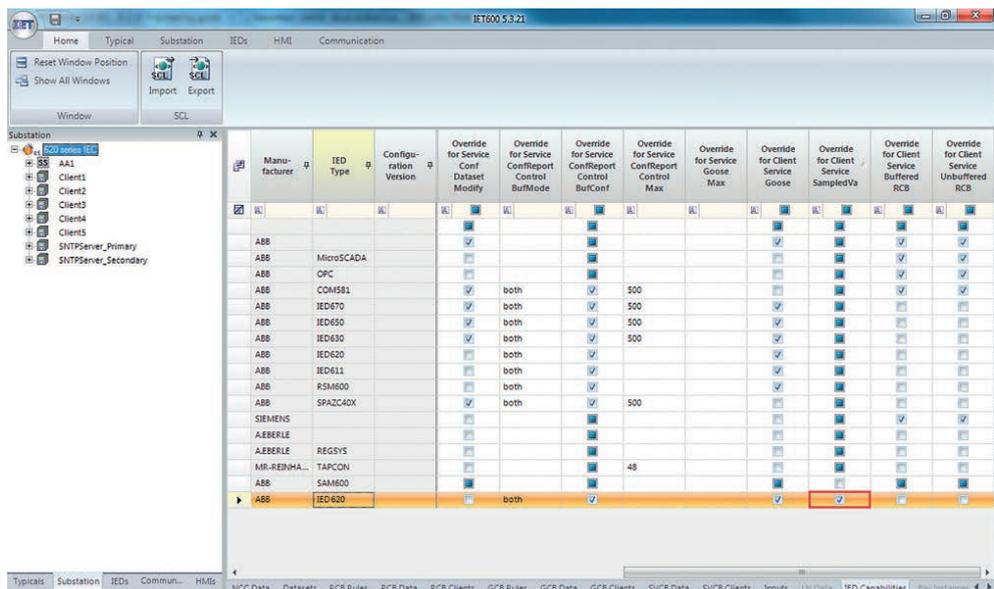


Figure 48: Editing the IED capabilities

3. Edit the properties and addresses of the sampled value control block.

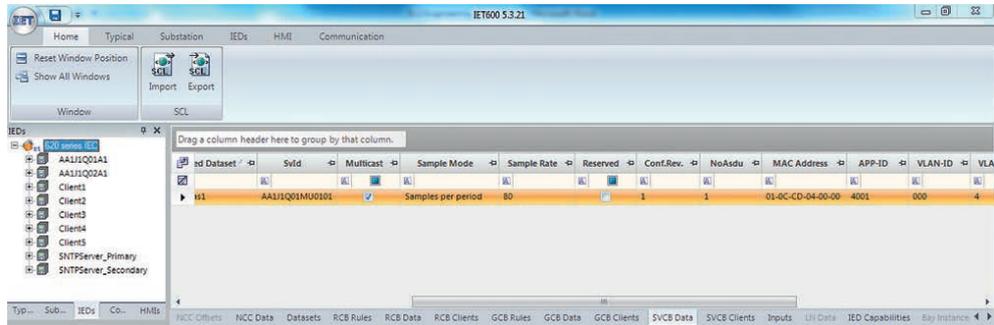


Figure 49: Sampled value control block



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 01-0CCD- 04-00-00...01-0C-CD-04-FF-FF.

4. Connect the SMV sender and receivers.

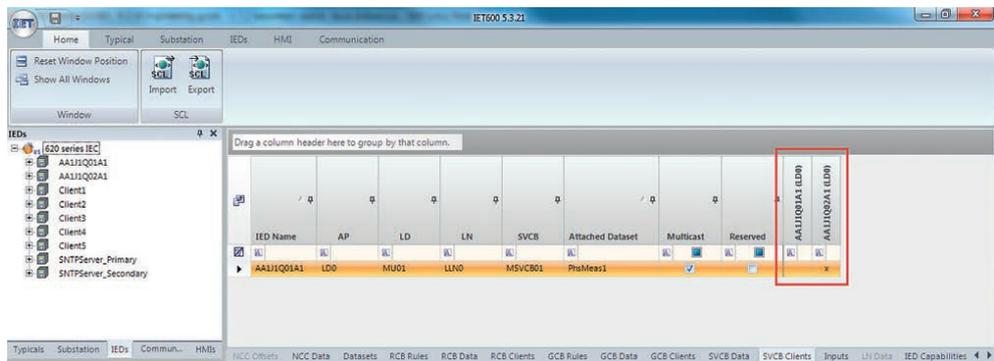


Figure 50: Connecting the SMV sender and receivers in IET600

5. Save and export the SCD file and import it to PCM600.

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



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.

6.4 Bay level configuration

6.4.1 Application configuration of the SMV receiver

The SMV receiver application configuration is done with the Application Configuration tool in PCM600. TVTR function blocks are used in receiver application to perform the supervision for the sampled values and to connect the received analog voltage inputs to the application. When SMVRCV is connected to the TVTR inputs, the connected TVTR does not physically measure its analog inputs if they are available in the IED. SMVRCV function block outputs need to be connected according to the SMV application requirements, typically all three analog phase voltages connected either to ULTVTR1 or alternatively only a single analog phase voltage UL1 connected to the ULTVTR2 or ULTVTR3 input. It depends on the configuration variant whether ULTVTR2 or ULTVTR3 can be used for SVM receiving, for detailed information see the corresponding application manuals. The *VT connection* analog input setting parameter for phase voltages must be selected accordingly and depending of the inputs connected either as "Wye" or "UL1". RESTVTR1 input is typically connected only in case there is measured neutral voltage needed and then available from the sender.

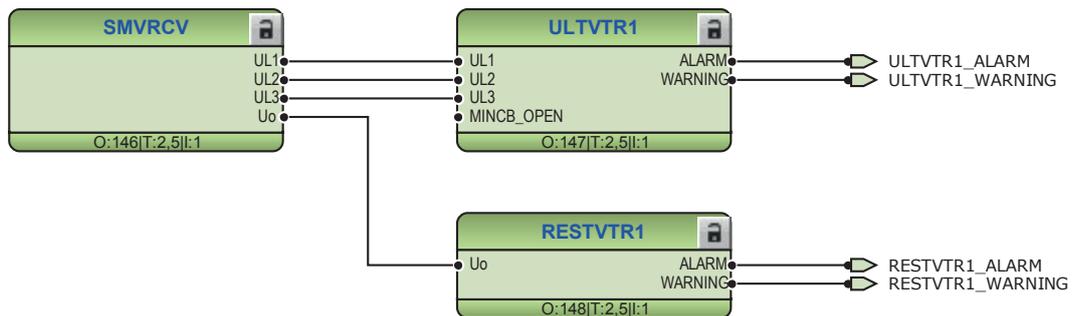


Figure 51: Receiving all phase voltages and residual voltage using SMV

Synchrocheck function requires and uses only single analog phase voltage (UL1) connected to ULTVTR2.



Figure 52: Receiving line voltage for synchrocheck functionality using SMV



If only one phase (UL1) is connected between SMVRCV and ULTVTR2 or ULTVTR3, then *VT connection* parameter of the ULTVTR2 or ULTVTR3 function block needs to be set to "UL1" in the Parameter Setting tool in PCM600 before writing the configuration to the IED.



ALARM and WARNING outputs are active during the configuration writing. If *VT connection* type is set incorrectly, ULTVTR ALARM and WARNING outputs are always active. In case of unsupported configuration, SMV error is indicated.

The `WARNING` output of TxTR 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 TxTR 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.

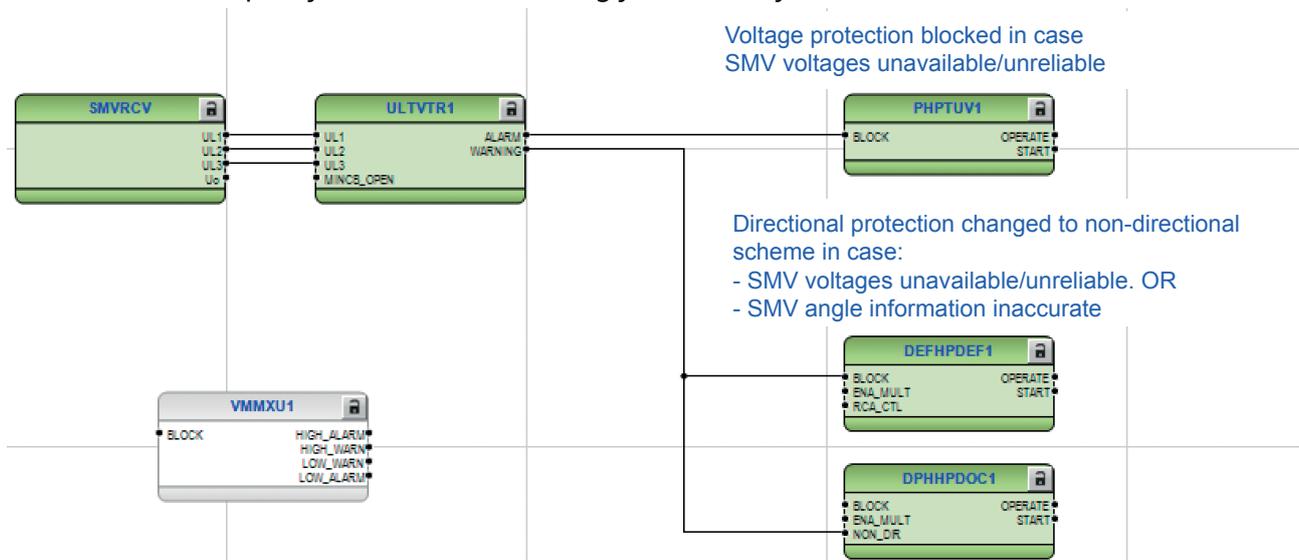


Figure 53: Application Configuration tool logic example for the SMV applications

The receiver activates the TxTR `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 TxTR `WARNING` and `ALARM` outputs.

The TxTR `WARNING` in the receiver is activated if the synchronization accuracy of the sender or the receiver is worse than 4 μ s. The output is held on for 10 seconds after the synchronization accuracy returns within limits.

The TxTR `ALARM` in the receiver is activated if the synchronization accuracy of the sender or the receiver is unknown, worse than 8 ms in 50 Hz mode and 6,7 ms in 60 Hz mode or two or more consecutive frames are lost. The output is held on for 10 seconds after the synchronization accuracy returns within limits.

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` and `ALARM` outputs of SMV measurement function blocks must be connected to application, for example to block directional protection.

6.4.2 SMV control block

Table 8: Sampled value control block attributes

SVCB attribute	Description
SvID	A sampled value control block specific string. The default value is <Ied-Name>MU01.
Multicast address	A multicast addressing scheme is used when sending sampled values messages. A multicast address can be shared by several sending devices or it can be IED specific. To keep the multicast message filtering of the devices working, it is recommended to use a unique multicast addresses.
SVCB name	The name of the SVCB structure seen by the IEC 61850/MMS client.
Data set	Data sent in sampled values messages to the network.
ConfRev	ConfRev increases when the referenced data set is modified. Both the sampled values sender and the receiver must have the same ConfRev value. This ensures that both IEDs have the same configuration level in the substation configuration. ConfRev usage is done automatically by the tools. If the latest system configuration is not downloaded into all required IEDs, the configuration revision may differ between the receiver and sender.
MAC Address	Multicast MAC address to which the specific sampled values data is sent. The receiving IED filters the frames and starts to process them if a specific multicast address is defined in the configuration. It is recommended to have one unique multicast address per SVCB. The address range for sampled values Multicast addresses is 01-0C-CD-04-00-00...01-0C-CD-04-01-FF.
App ID	Unique HEX value application identifier for sending the SVCB within the system. It identifies the purpose of this particular data set. Value range for sampled values is 0x4000 to 0x7FFF.
VLAN-ID	Used if the Ethernet switches in a station bus support VLAN. If static VLAN identifiers are defined, it also affects the switch port configuration. Value "000" indicates a non-configured VLAN and switches do not filter these messages on a port basis. This is recommended if there is no need to split the logical network. The VLAN identifier is a 3-character HEX value with range 000...FFF. Recommended values are 2...1001.
VLAN Priority	Used in networks supporting VLANs. The priority is used with network switches. The default value for sampled values is "4" and the value range is 0...7.
Sample Rate	Amount of samples per period.
NoAsdu	Number of ASDUs, which are concatenated into one APDU.
IncludeRefreshTime	If selected SV buffer contains the attribute "RefrTm".
IncludeSampleRate	If selected SV buffer contains the attribute "SmpRate".



Modify only MAC address, VLAN ID and sampled value ID to keep the 9-2 LE compliancy. Leave the others as default.

6.4.3 Angle and amplitude corrections

The TxTR instrument transformer amplitude and angle correction factors also affect the scaling in SMV frames. Thus, it is sufficient to configure these correction factors in the sender only.

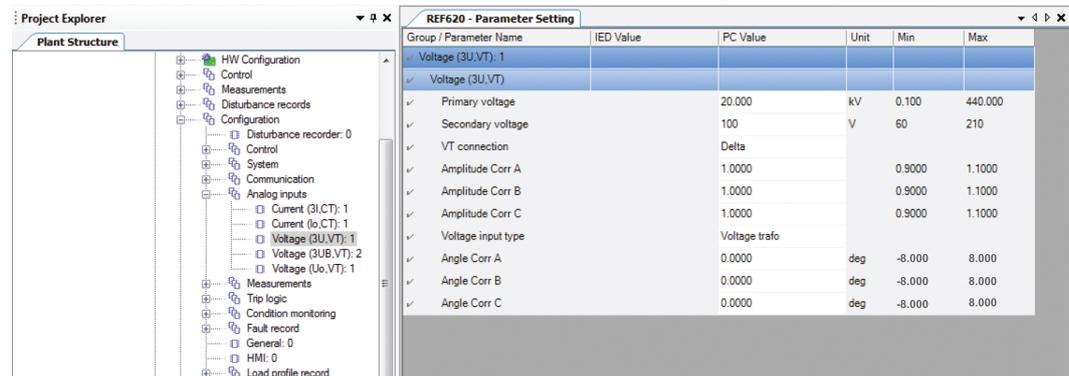


Figure 54: Amplitude and angle correction

6.4.4 SMV delay

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

For best performance, the *SMV Max Delay* value should not be set needlessly high since this delays the protection by an equal amount of time ([Table 10](#)). Setting it too low can cause SMV samples to arrive after the set deadline and thus make SMV-based protection inoperable. To determine suitable *SMV Max Delay* values, see [Table 9](#).

TxTR ALARM activates when two or more consecutive SMV frames are lost or late. A single loss of frame is corrected with a zero-order hold scheme. The effect on protection is considered negligible in this case and it does not activate the TxTR WARNING or ALARM outputs.

Table 9: Topology-dependent SMV max delay setting

Number of hops in network	Maximum signal processing delay (μs) ¹		Internal switch latency (μs) ²	Store and forward latency (μs) ²	Queue latency (μs) ^{2, 3}	Additional tolerance (μs) ⁴	Theoretical max sum of delays (μs)		Recommended max delay setting (ms)	
	50Hz	60Hz					50Hz	60Hz	50Hz	60Hz
2	1980	1700	20	24	240	80	2344	2064	3	3
5	1980	1700	50	60	600	200	2890	2610	3	3
10	1980	1700	100	120	1200	250	3650	3370	5	4
15	1980	1700	150	180	1800	300	4410	4130	5	4
20	1980	1700	200	240	2400	350	5170	4890	5	5
25	1980	1700	250	300	3000	400	5930	5650	6	6
30	1980	1700	300	360	3600	450	6690	6410	7	6

Table 10: Protection delays and network margins

System frequency (Hz)	SMV max delay setting (ms)	Ethernet network margin (ms) ⁵	Protection delay (ms)
50	2	0.23	0.94
	3	1.48	2.19
	5	2.73	3.44
	6	3.98	4.69
	7	5.23	5.94
60	2	0.18	0.78
	3	1.22	1.82
	4	2.26	2.86
	5	3.3	3.91
	6	4.35	4.95



For best performance, the *SMV Max Delay* value should not be set needlessly high since this delays the protection by an equal amount of time ([Table 10](#)). Setting it too low can cause SMV samples to arrive after the set deadline and thus make SMV-based protection inoperable. To determine suitable *SMV Max Delay* values, see [Table 9](#).

¹ Signal processing delay of SMV sender, REF620 2.0 FP1 2.1.15 used as example. Depends on merging unit used.

² Latencies are totals over the number of hops and they are calculated for 100 Mbit full-duplex Ethernet network.

³ Queue latency calculated when the port has started to send a full-sized frame (1500 bytes) before the SMV frame and the switch has been configured to prioritize SMV.

⁴ Additional tolerance in case of long wires or disturbance in network.

⁵ Average values, variation is ±0.1 ms.

6.4.5 IEEE 1588 v2 parameters and status information

Time

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

Table 11: Time parameters

Parameter	Value	Range
Synch source	IEEE 1588	
PTP Domain ID	0	0...255
PTP priority 1 ⁴	128	0...255
PTP priority 2 ⁴	128	0...255

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.

PTP priority 1 and *PTP priority 2* are used in the execution of the best master clock algorithm in which lower values take precedence. Priority 1 is the first one used to decide the clock master.

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. It is also used to determine whether a newly discovered clock is better than the local clock.

The comparison algorithm is based on pair-wise comparisons of attributes with the following precedence.

- Priority 1
- Clock class
- Clock accuracy
- Clock stability
- Priority 2
- Clock identity: A tie-breaker based on unique identifiers

Transition between the "IEEE 1588 master" and the "IEEE 1588 slave" modes causes a short period of 1...3 s during which the SMV sender sets *smpSynch* in the SMV frame to "0: less than 4 μs synch accuracy" mode. This activates the TxTR WARNING output in the SMV receiver for a period of 11...33 s. The duration depends on the time offset between the previous and the new IEEE 1588 v2 master. The TxTR ALARM output activates in the SMV receiver if transfer is made to a IEEE 1588 v2 master that has 100 ms or more offset compared to the previous master. The ALARM output stays on for a period of 11...33 s.

⁴ Smaller value has higher priority

Time synchronization monitoring values

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

Table 12: Time synchronization monitoring values

Description	Value
Sync source	IEEE 1588 master
	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.

$$\text{Synch_accuracy} = 2^{-\text{bits}} \text{ seconds}$$

Table 13: 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 14: IEEE 1588 v2 monitoring values

Description	Value
Grandmaster Identity	
Grandmaster time src	Atomic clock
	GPS
	Terrestrial radio
	PTP
	NTP
	Hand set
	Other
	Internal oscil.
Grandmaster accuracy	

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.

Grandmaster time src indicates the source of time used by the grandmaster clock.

Grandmaster accuracy indicates the accuracy of the grandmaster clock.

SMV accuracy monitoring values

The SMV accuracy monitoring values are found via menu path **Monitoring > IED status > SMV accuracy**.

Table 15: SMV accuracy monitoring values

Description	Value
SMV synch accuracy	No sync
	Local clock
	Global clock
Local synch accuracy	
Max Dev Sync Acc	

SMV synch accuracy value "No sync" indicates that the SMV is either not in use or it does not use IEEE 1588 v2. The clock synchronization is locally synchronized to the grandmaster clock with parameter value "Local clock" and to the GPS clock with parameter value "Global clock".

Local synch accuracy indicates the time synchronization accuracy in microseconds.

Max Dev Sync Acc indicates the maximum clock deviation in situation where clock accuracy was over 4 μ s.

6.4.6 Power profile parameters

The IEDs' IEEE 1588 v2 time synchronization complies with the IEEE C37.238-2011 Power 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 16: IEEE C37.238-2011 Power Profile key parameters

Parameter	Value ⁵
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

6.4.7 Quality bits in SMV frames

Table 17: 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.

6.5 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.

⁵ 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 receiver, the voltage values in brackets indicate an invalid or a questionable measurement.

Table 18: SMV sender

Item	Description	Checked
Missing sender	Disable the SMV sender via Configuration > Communication > Ethernet > SMVSENDER and verify the expected handling in receivers. In the SMV receivers'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 receiver monitored data is available in three locations.

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

Table 19: SMV receiver

Item	Description	Checked
WARNING	<i>WARNING</i> (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. <i>WARNING</i> is active when the IED starts.	
ALARM	<i>ALARM</i> (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. <i>ALARM</i> is active when the IED starts.	
Max delay	The maximum delay (Monitoring > IED status > SMV traffic) must be in all conditions smaller than the <i>SMV Max Delay</i> parameter (Configuration > System). Larger values indicate configuration problems in the network or the need to change the <i>SMV Max Delay</i> .	
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 receivers' Measurement view, the voltage values should be without brackets indicating good status. Brackets indicate questionable or invalid values. The <i>SMV traffic delay</i> (Monitoring > IED status > SMV traffic) value should be lower than the value of <i>SMV Max delay</i> (Max 6.48ms).	

Table 20: 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 <code>GNRLLTMS1 WARNING</code> 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 priorities 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 μ s which is the defined supervision limit.	
Max Dev synch Accuracy	According to 9-2 LE the synchronization accuracy needs to be better than 4 μ s which is the defined supervision limit. ⁶	
Grandmaster	Check the grandmaster monitoring from the master configuration via the LHMI path Monitoring > IED status > Time synchronization > IEEE 1588 . Check that all IEDs are synchronized to same PTP master.	

Table 21: 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.	

⁶ 4 μ s corresponds to approximately 0.07 degrees in 50 Hz systems

7 Engineering of event reporting with PCM600

7.1 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.

MicroSCADA and COM600S 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.

7.1.1 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**.

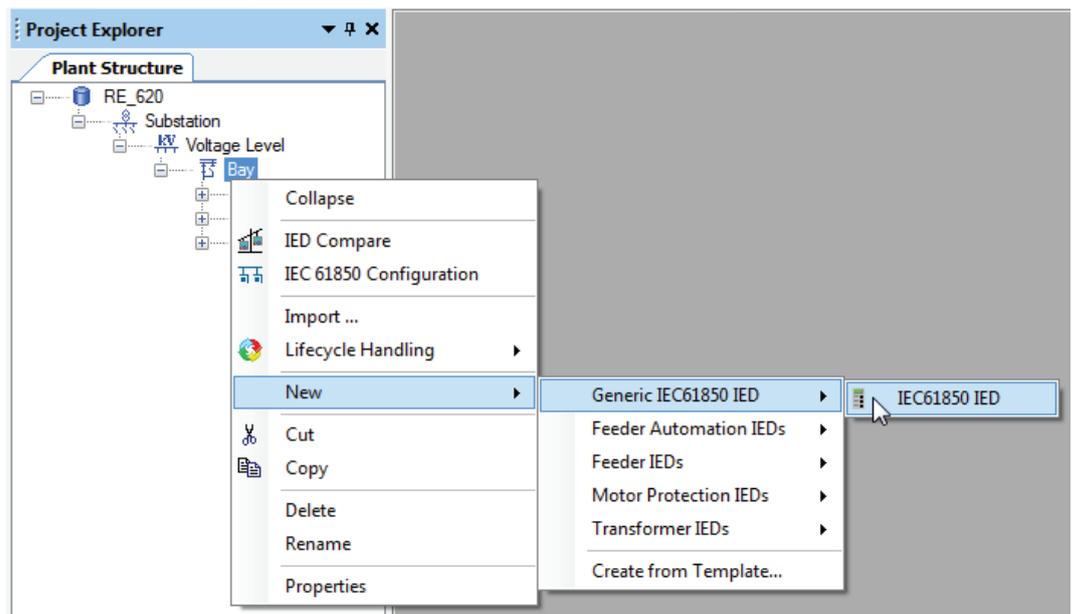


Figure 55: Creating a generic IEC 61850 IED

2. Rename the IED object as “Client_G”.
3. Right-click the **IED** and then select **Import**.

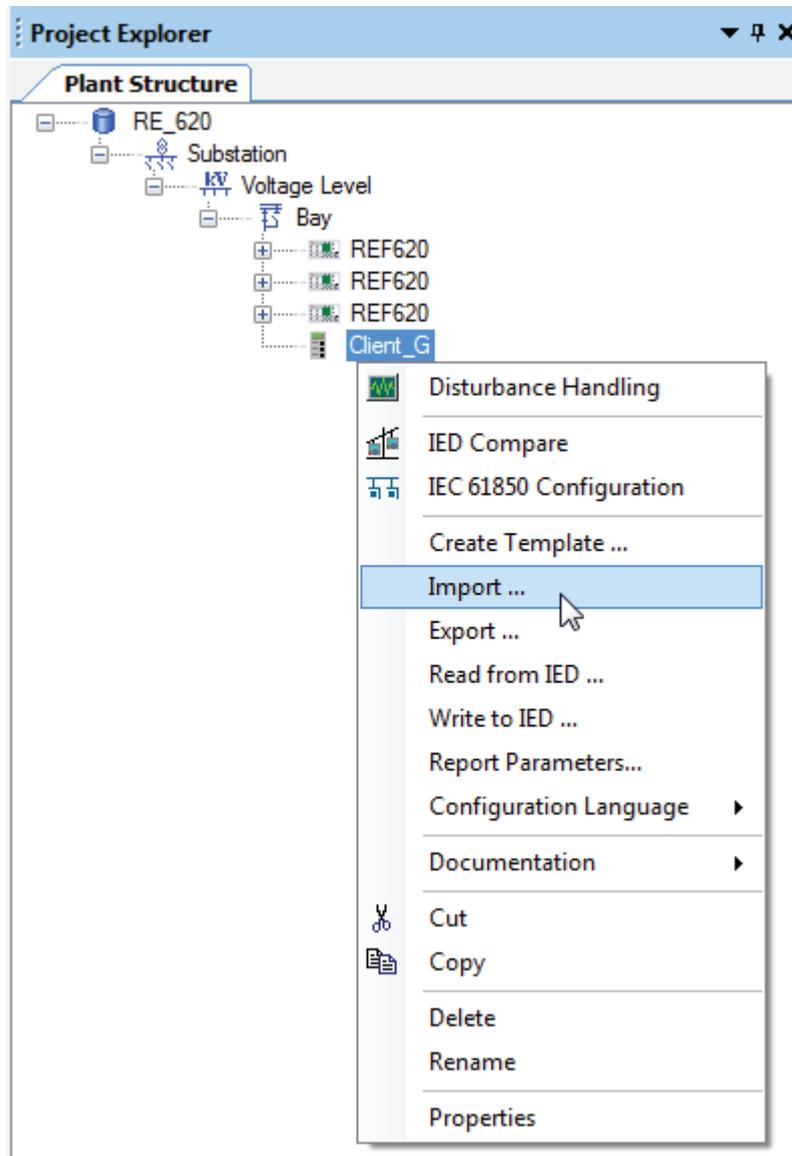


Figure 56: Selecting Import on the shortcut menu

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.

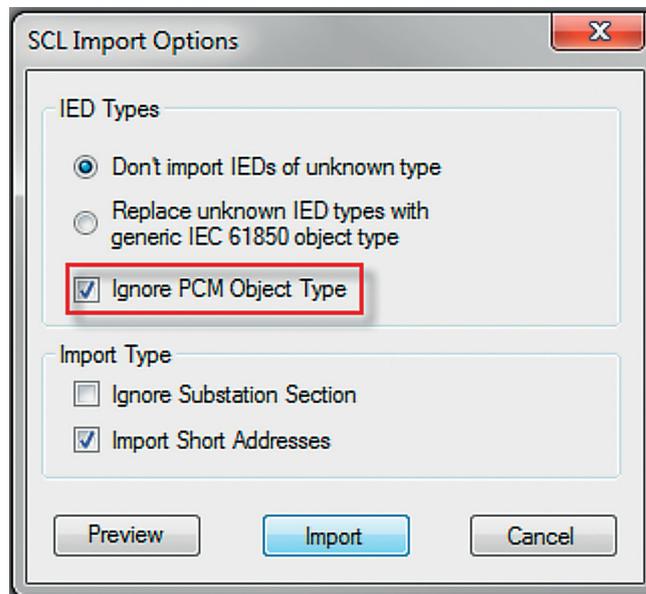
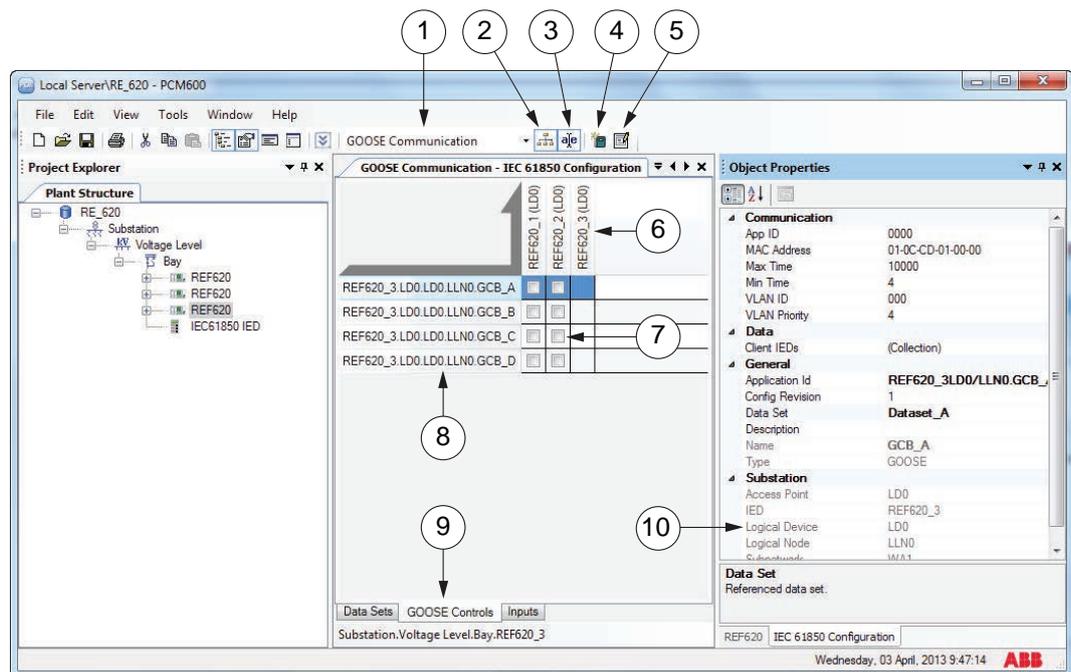


Figure 57: Defining SCL import options

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.

7.2 IEC 61850 Configuration tool user interface



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

Figure 58: IEC 61850 Configuration tool user interface

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.

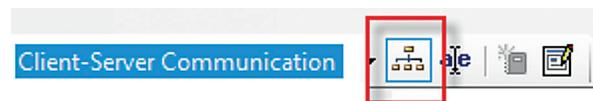


Figure 59: Engineering mode selection button



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.

7.3 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 60: 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.

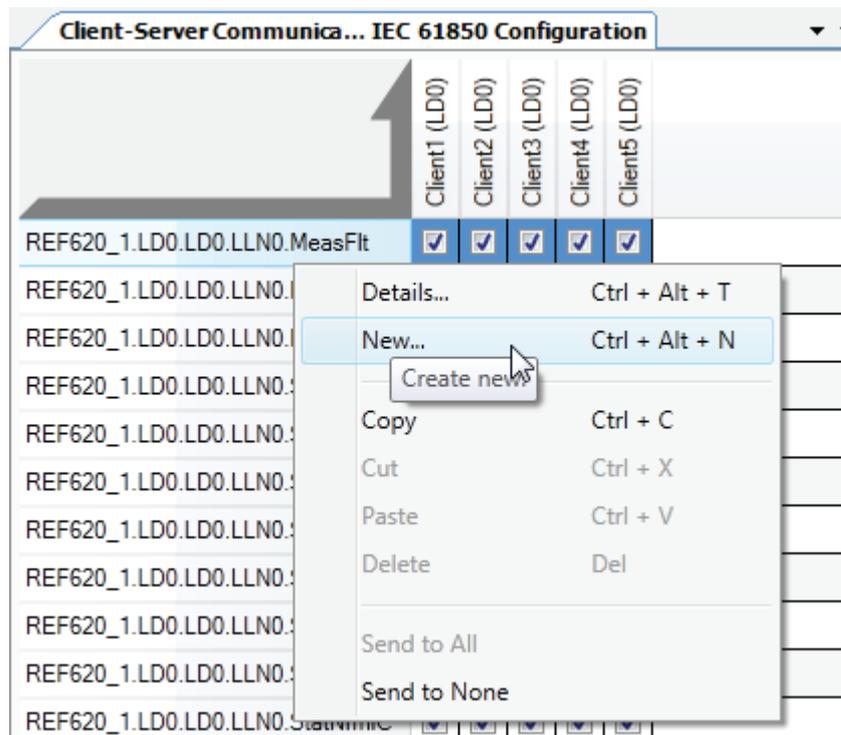


Figure 61: Creating a new data set

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

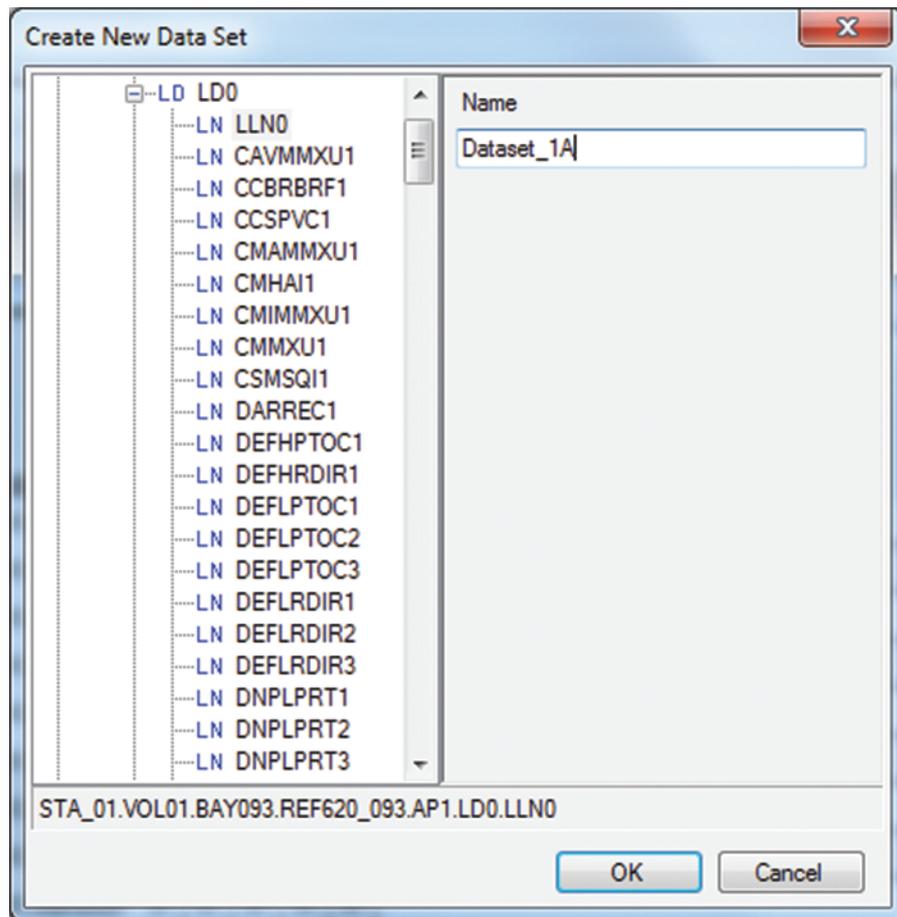


Figure 62: Naming the data set

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

7.3.1 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.

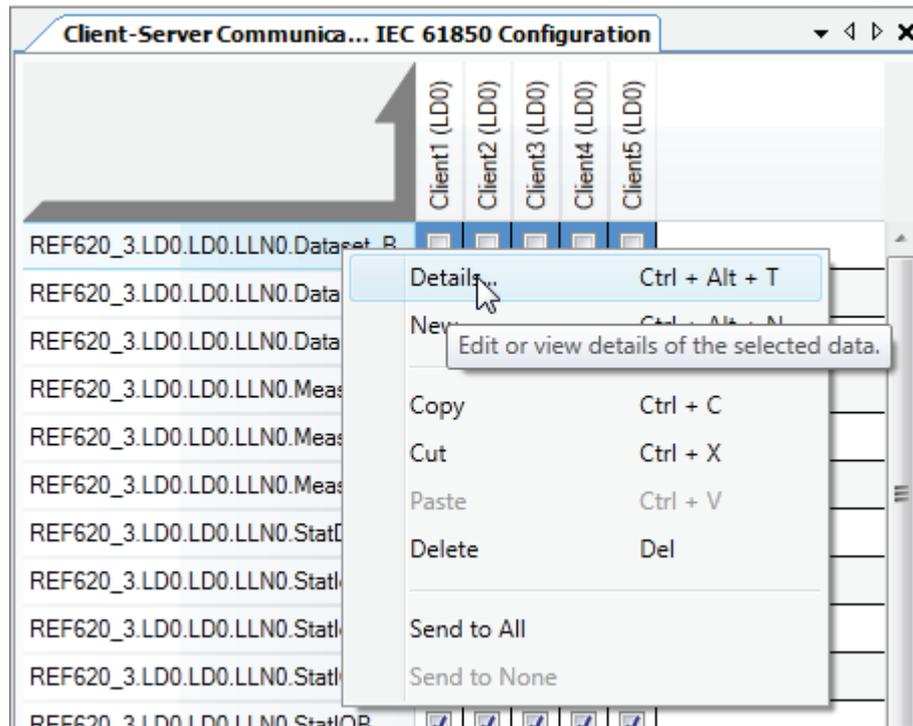


Figure 63: Adding data attributes

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.

7.4 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.

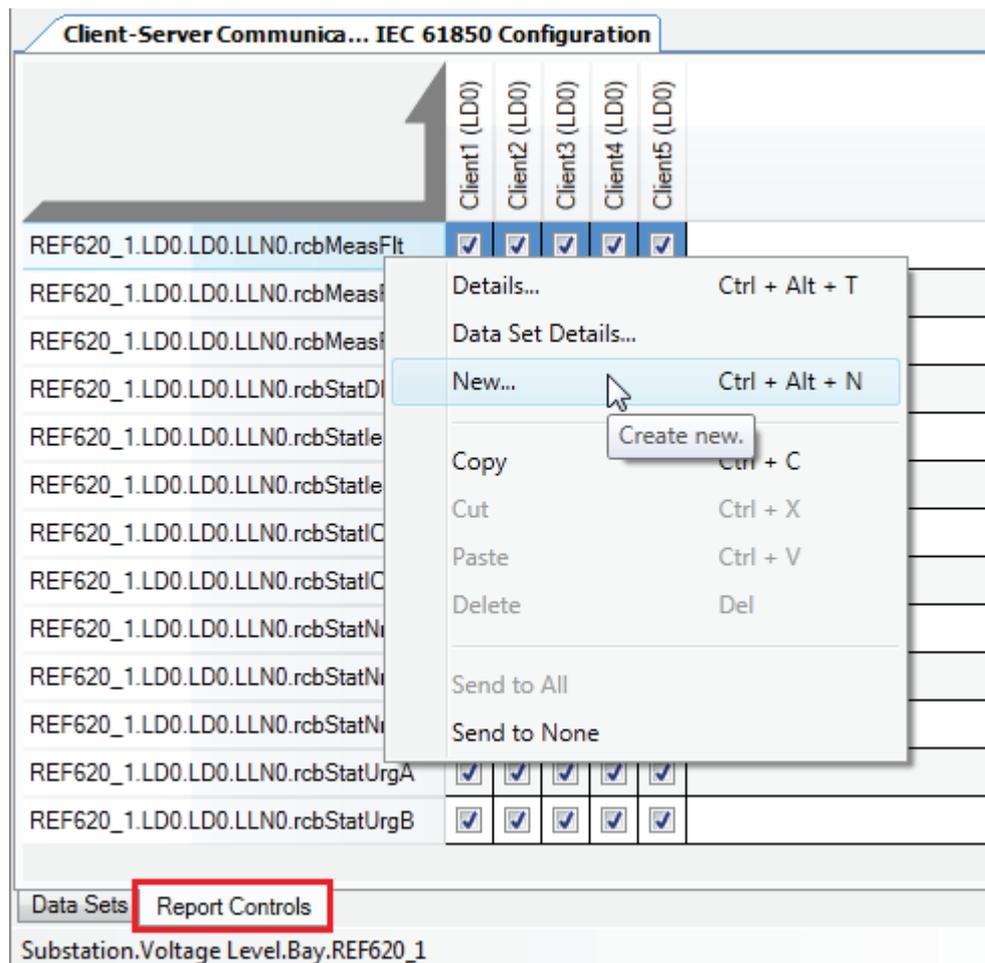


Figure 64: Adding a new report control block

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.

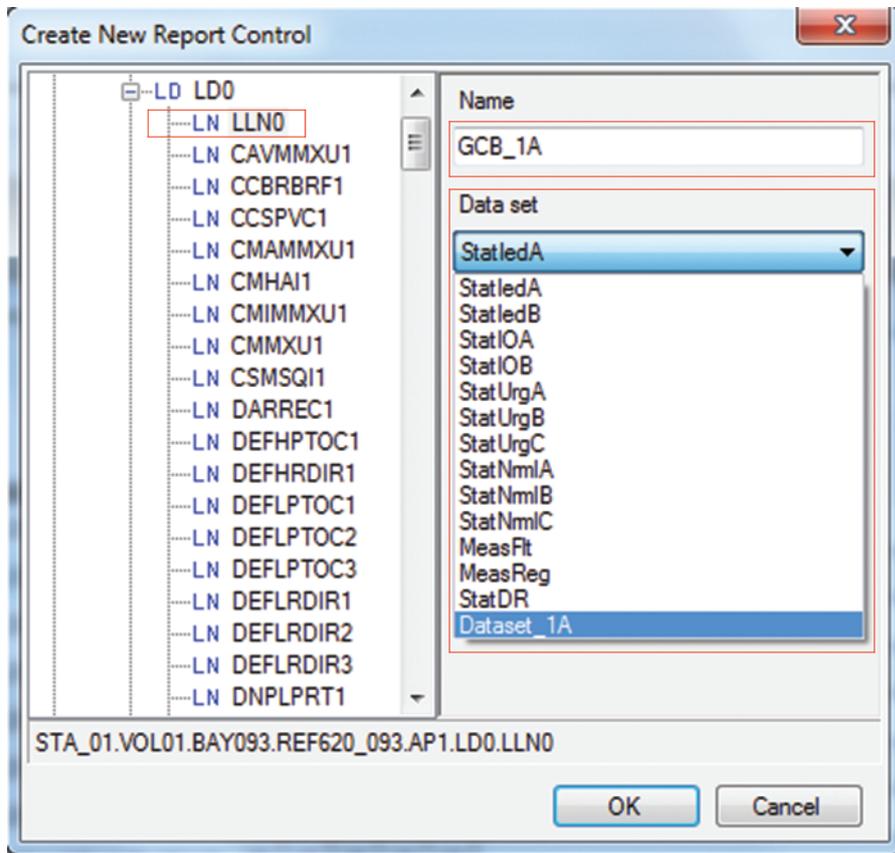


Figure 65: Data set drop-down list

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

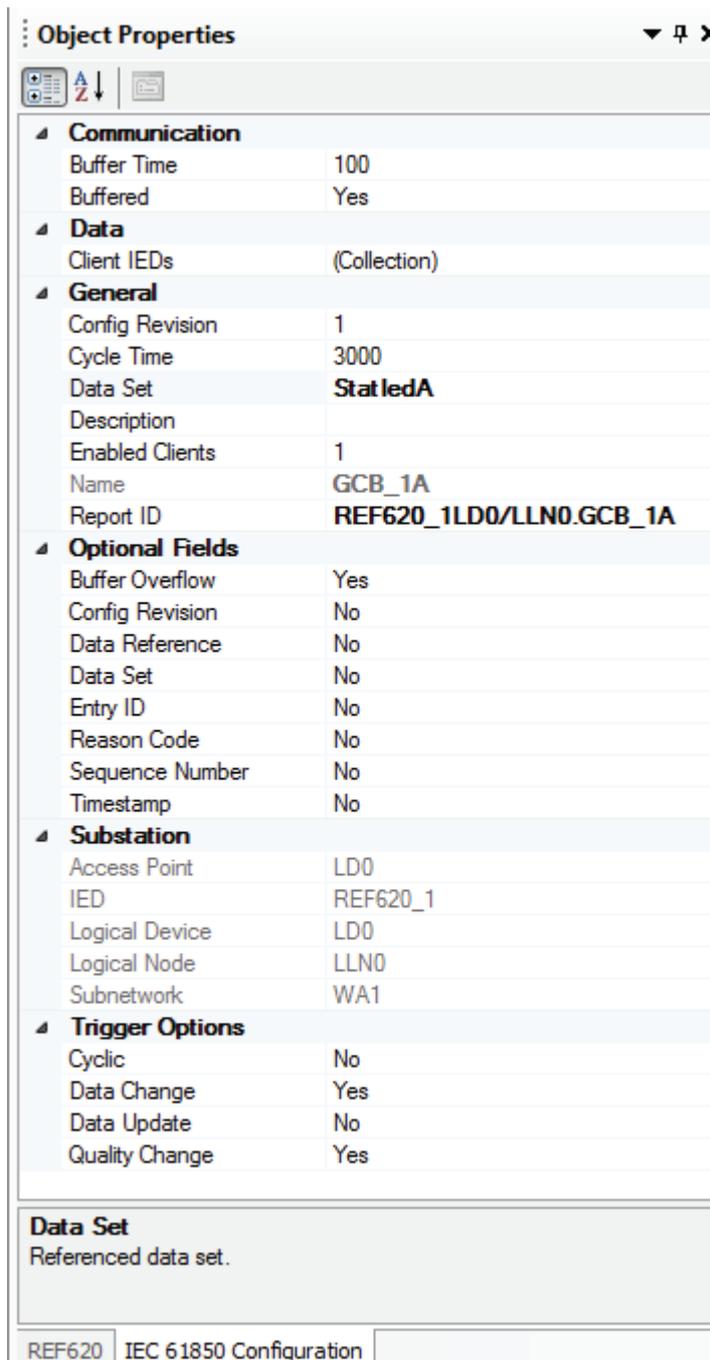


Figure 66: Report control block properties



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.

7.5 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.

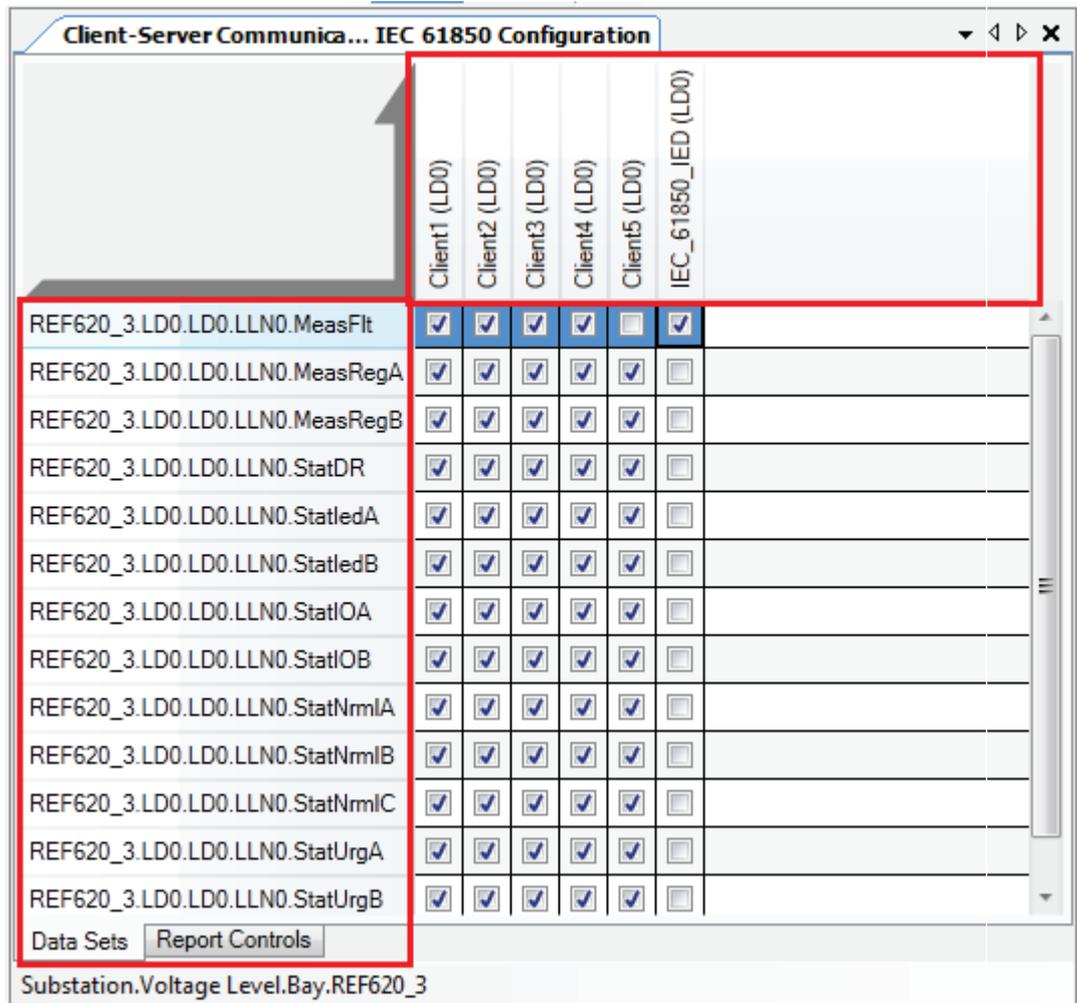


Figure 67: RCB clients

- 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.

7.6 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.

8 Engineering of event reporting with IET600

8.1 Managing IEC 61850 clients with IET600

When the relay configurations are changed using IET600, some preparations are required when a project is started and the protection relay's data model is imported to the tool for the first time.

- The default IED SCL export from PCM600 contains five default client definitions, "Client1"... "Client5", which are used by all the RCBs. MicroSCADA and COM600S clients can use the client definitions directly. If other clients need to be added to the IET600 project, import the ICD file describing the client data model to the project and attach the file to the same IEC 61850 subnetwork in the **Communication** tab.
- Create the bus connections for the IEC 61850 clients.

8.1.1 Adding new IEC 61850 clients for IET600

Adding a new IEC 61850 client to an IET600 project is a two-step operation. The client must be first created using the **Create New IED** function, after which the **Update IED** function can be used to import the related ICD or CID file.

1. To create an IED, click the **IEDs** tab in the navigation pane.
2. Click the root node in the IED tree.

3. Right-click the node and click **Create New IED**.

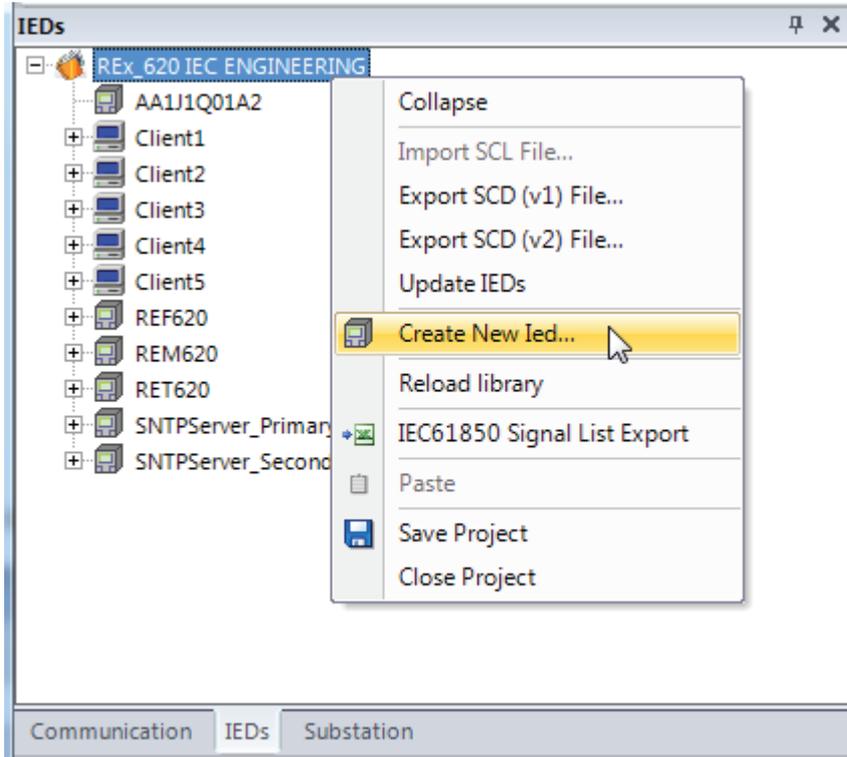


Figure 68: Creating a new IED

4. Type the name of the client IED as it is in the file to be imported. Click **OK**.

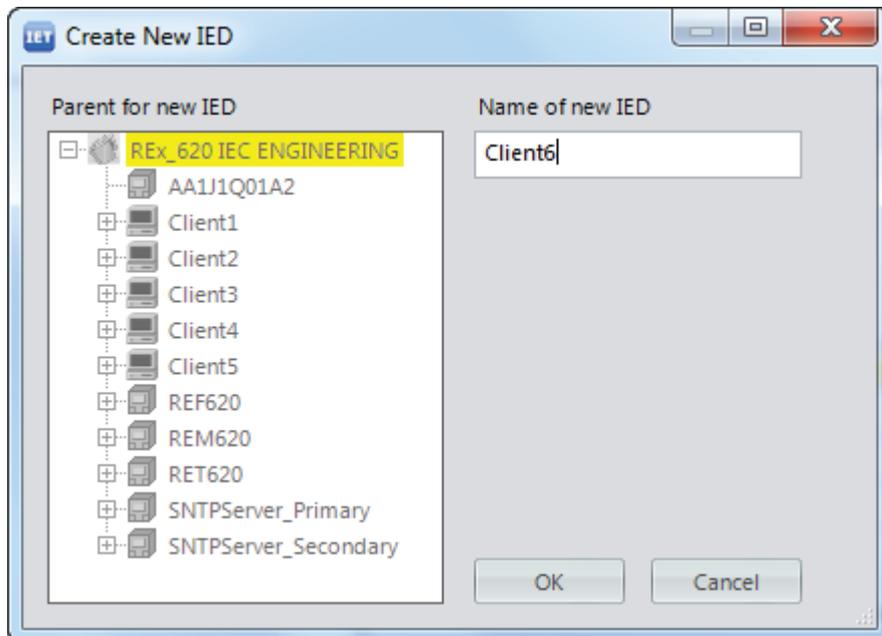


Figure 69: Naming the new IED

- 5. Right-click the created IED and click **Update IED**.

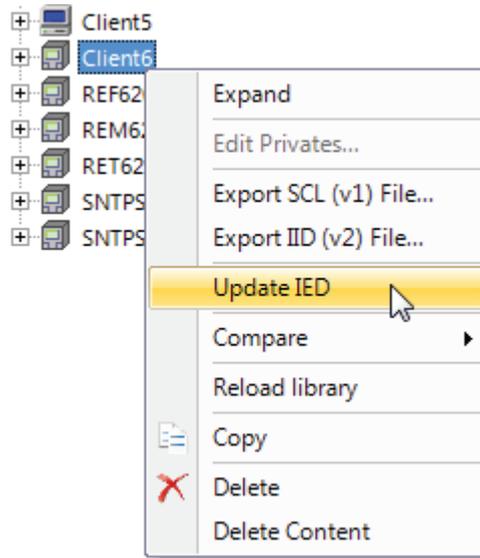


Figure 70: Choosing an SCD file for updating the IED

- 6. Select any valid SCL file that is SCD, ICD, CID or IID, and click **Open** from the selection dialog box.
IET600 automatically matches IEDs with the same name in IET600 and in the file.
- 7. To import the IED from the file, click **OK**.

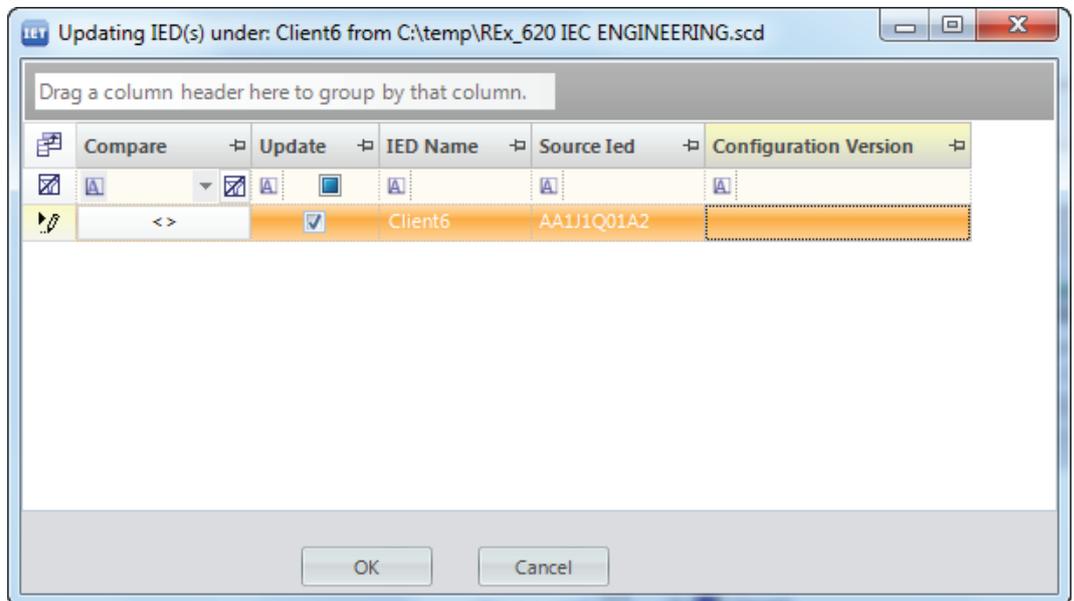


Figure 71: Updating the IED



The procedure used in configuring IEC 61850 clients can be used to create or update any IED, also several IEDs at the same time.

8.1.2 Attaching IEC 61850 clients to a bus with IET600

1. Click the **Communication** tab in the navigation pane.
2. Click the **Subnetworks** tab in the editor pane.
3. In the Subnetworks grid, select the bus from the Subnetwork list to attach the IEC 61850 client to the bus.

An alternative way is to drag the client in the **Communication** tab to the correct subnetwork.

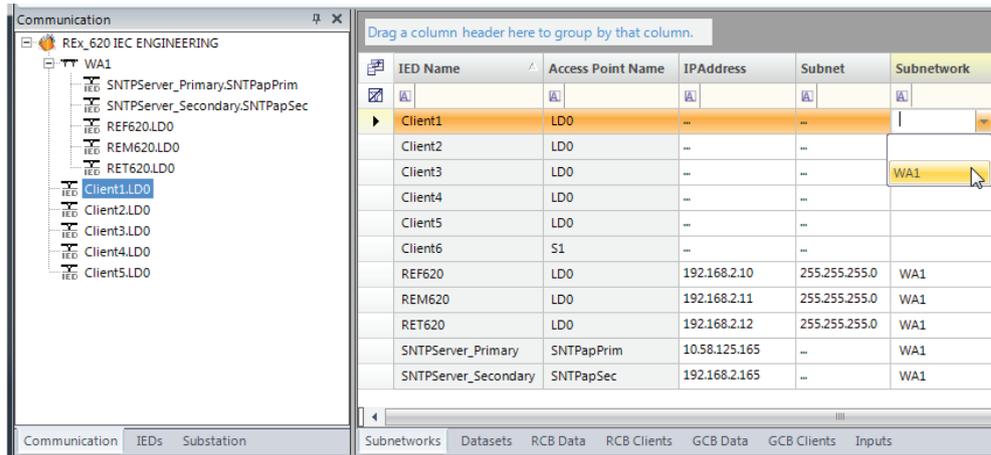


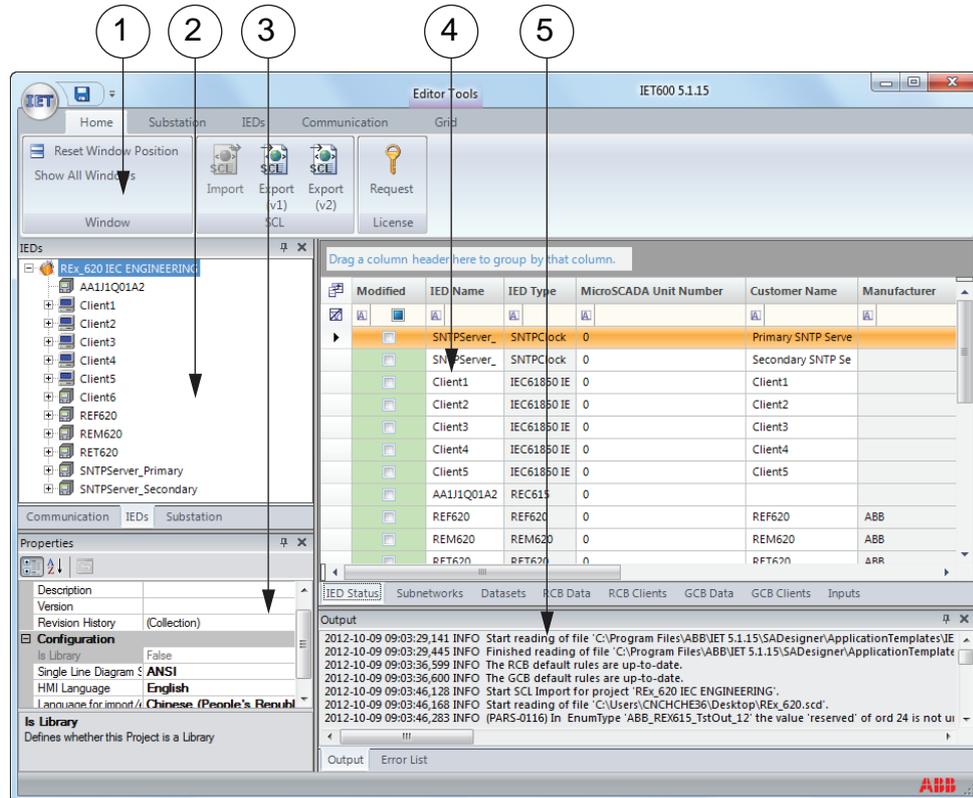
Figure 72: Defining bus connection properties for IEC 61850 clients

4. Repeat the steps to attach all five default clients in the project to the bus.

By default, the IEDs' bus connections are ready-made when the configuration work is started and need not to be set separately. After the client bus connections are created, the event clients appear in the **RCB Clients** tab.

8.2 IET600 user interface

IET600 user interface is divided into sections, that is, panes for navigating and displaying the project data.



- 1 Menu on the top of the user interface
- 2 Navigation pane for context-oriented navigation and filtering the various editors
- 3 Properties pane for detailed properties of the selected element in the navigation pane
- 4 Editors for detailed design and engineering of the substation, IEDs and IEC 61850 communication
- 5 Logging and messaging (output) pane

Figure 73: IET600 user interface

The navigation pane provides context-oriented navigation of the editors. It has three tabs, which correspond to three different context views.

- **Substation** – Full substation topology and primary equipment nodes
- **IEDs** – IED nodes and corresponding functionality
- **Communication** – Subnetworks and connected IED access points

The editor pane is the main working area of the IET600 user interface. It is organized to various tabs for detailed substation design and engineering. The visible tabs depend on the node type selected in the navigation pane.



Available editor tabs depend on the selected node type, not on the selected navigation tab. Choose any available context view to do the needed engineering tasks.



Choose upper or lower level in the structure to see the data of single, many or all IEDs at the same time in the editor pane.

8.2.1 Setting visibility of columns in grid editors

Most editors are implemented as tables. These grid editors provide features like setting column visibility, filtering, sorting, automatic data filling, copying and pasting, finding and replacing and exporting to Excel.

Most tables include columns which are hidden by default.

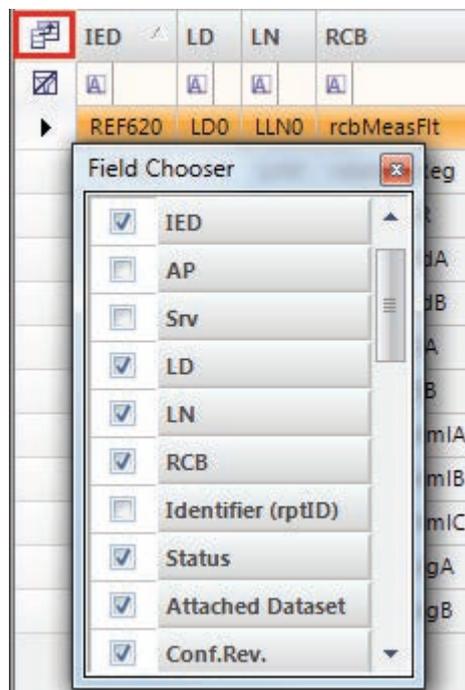


Figure 74: Setting column visibility in a grid editor

1. To set the visibility of the columns, click the upper-left icon of the table.
2. Select or clear the check boxes from the **Field Chooser** dialog box.

8.3 Substation section configuration in IET600

Substation topology consists of the substation, voltage level and bay nodes. Bay nodes include also the conducting (primary) equipment, which corresponds to the switches, that is, the circuit breakers, disconnectors, earth switch, of the configured protection relay. Substation topology is initially built by importing the SCD file from PCM600.

The SLD editor is a graphical editor for the configuration of the substation section in IET600. It provides tools to draw the primary equipment and the interconnection between the equipment in the bay.

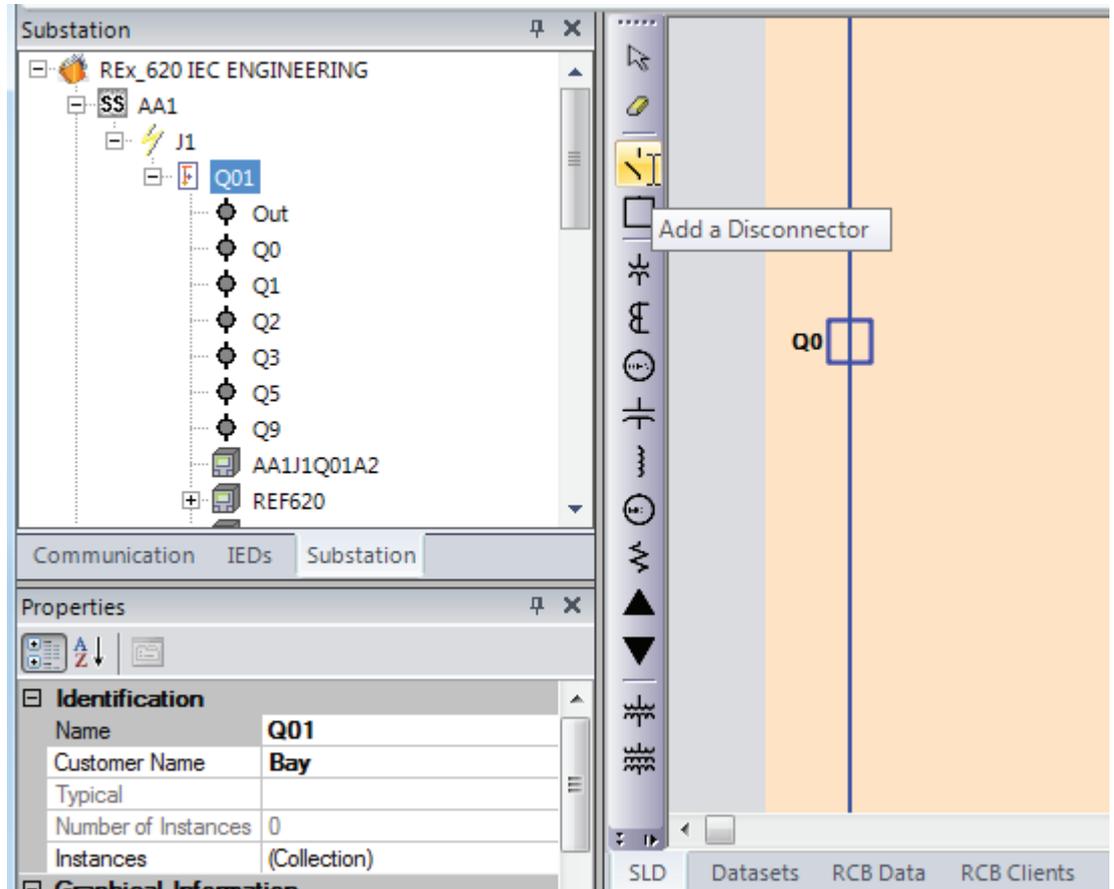


Figure 75: SLD Editor



SLD in the protection relay is configured using the Graphical Display Editor of PCM600, not in IET600

In addition to the substation topology configuration, logical nodes of IEDs need to be mapped to proper objects, for example, to support the automatic bay configuration via SCL files in the SCADA system. Logical nodes are mapped with the LN Mapping Editor.

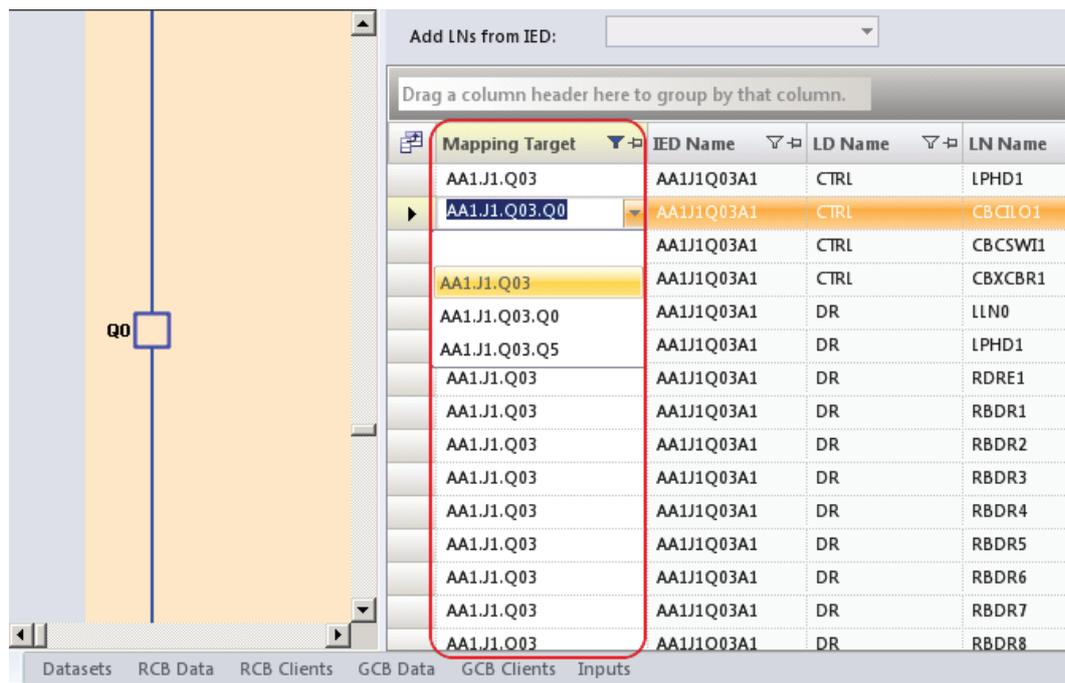


Figure 76: LN Mapping Editor

8.5 Creating report control blocks with IET600

Configuration properties, such as the attached data set and the buffering and triggering options of the RCBs are defined in the RCB editor. A predefined RCB configuration of a preconfigured IED is a proposed default configuration which can be adapted according to the requirements.

1. Click an IED node in the IEDs navigation pane.
2. Click the **RCB Data** tab in the editor pane.
3. Right-click the area containing RCB names and select **Insert new row**.
4. Define the LN where the RCB is to be placed (preselected **LDO/LLNO** is recommended) and the name for the new RCB.

Use the field chooser to show or hide the properties. For example, the **SeqNum**, **Entry ID** and **Reason Code** options (set by default in the IED) are hidden by default.

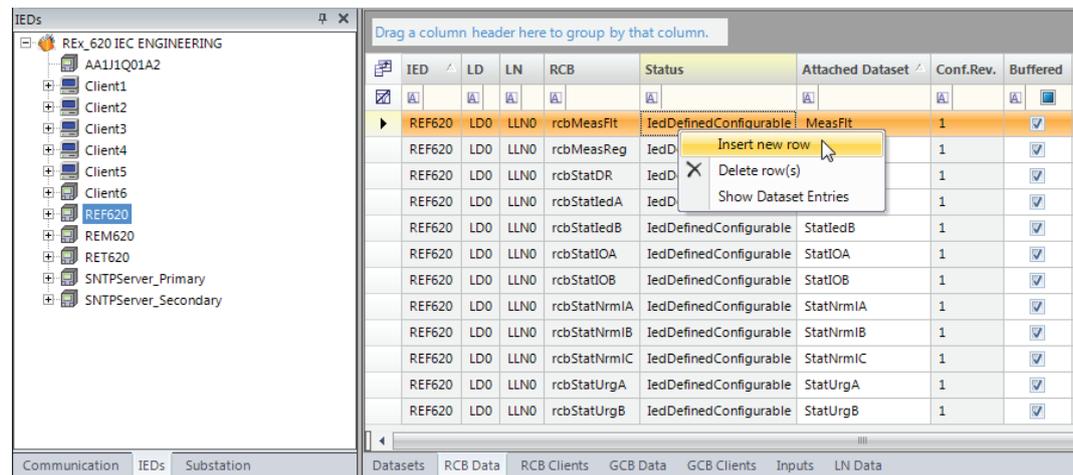


Figure 78: RCB editor



Conf.Rev cannot be manually edited. IET600 updates it automatically to the next multiple of 100 when the configuration changes.



Deleting an RCB does not totally remove it from IET600. Instead, its status is set to “Deleted” and it is not exported to SCL files. Removing a data set automatically puts the related RCB to the “Deleted” state.



An RCB cannot be renamed. To rename an RCB, delete it and create a new RCB with a new name.



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.

8.6 RCB client configuration with IET600

To succeed with an RCB client configuration, the potential clients and their communication configuration should be known. Therefore, the IEDs must be added and configured to the subnetwork before configuring the RCB client.

The rows of the RCB client editor show IEDs and RCBs and the columns show the available client IEDs.



If a client IED is not on the same subnetwork as a server IED or RCB, it cannot be configured as a client.

	IED Name	LD	LN	RCB	Attached Dataset	Client1 (LD0)	Client2 (LD0)	Client3 (LD0)	Client4 (LD0)	Client5 (LD0)
	REF620	LD0	LLNO	rcbStatDR	StatDR	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatIedA	StatIedA	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatIedB	StatIedB	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatIOA	StatIOA	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatIOB	StatIOB	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatNrmIA	StatNrmIA	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatNrmIB	StatNrmIB	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatNrmIC	StatNrmIC	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatUrgA	StatUrgA	1	2	3	4	5
	REF620	LD0	LLNO	rcbStatUrgB	StatUrgB	1	2	3	4	5
	REM620									

Figure 79: RCB client editor

Different keys can be used when editing the cells.

- PLUS SIGN (+), asterisk (*) or X to add an additional client to the existing ones
- Numbers to change the client sequence or add clients
- MINUS SIGN (-), SPACEBAR or DELETE to delete existing clients
- Double-clicking with the mouse to add or delete clients

RCB client editor supports both manual and semi-automatic client configuration.

8.6.1 Configuring RCB clients semi-automatically

On the right in the RCB client editor there are option buttons to choose whether to show IEDs (for defining default clients) or RCBs or both together.

There are also buttons to allow semi-automatic configuration of default clients and RCB clients.

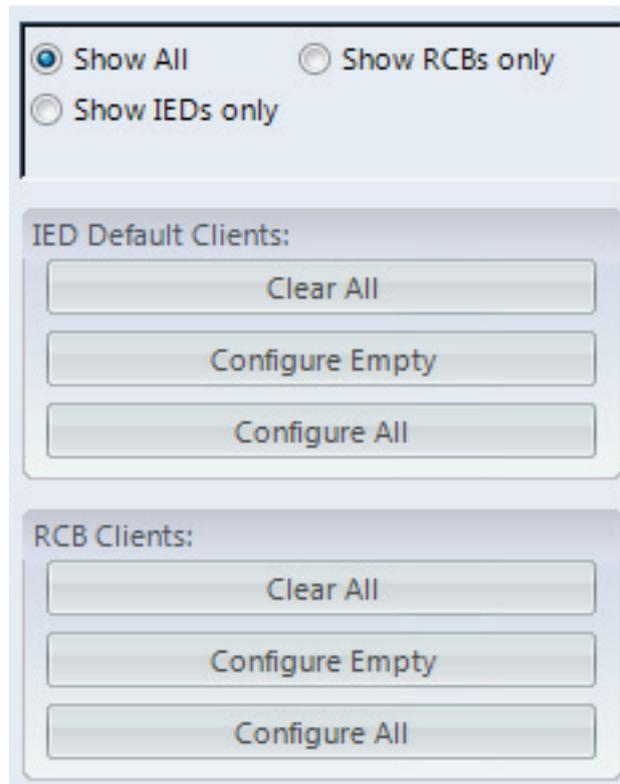


Figure 80: Semi-automatic configuring of RCB clients

1. Configure the default clients which are used by the rule-based RCB generation to automatically configure RCB clients.
Use buttons on the RCB client editor.
 - **Clear All** removes all default clients
 - **Configure Empty** fills out only default clients for those IEDs that have no clients configured yet
 - **Configure All** deletes all existing default clients and fills them out afterwards
2. Configure the RCBs clients.
The default clients must be configured before configuring RCB clients otherwise the automatic RCB client configuration does not work. Use buttons on the RCB client editor.
 - **Clear All** removes all RCB clients
 - **Configure Empty** copies the default client configuration of this IED to its RCBs (only for those RCBs that have no clients configured yet)
 - **Configure All** deletes the existing RCB clients and copies the default client configuration of this IED to its RCBs



IET600 updates the *Enabled Clients* configuration value of the RCBs automatically based on the configuration made in the RCB client editor. In addition, IET600 always reserves one extra engineering client. For example, when configuring three RCB clients, the *Enabled Clients* value of that RCB is “4”.

9 Glossary

620 series	Series of numerical protection and control relays for high-end protection and supervision applications of utility substations, and industrial switch-gear and equipment
ACSI	Abstract communication service interface
APDU	Application protocol data unit
APPID	Application identifier
CID	Configured IED description
COM600S	Substation Management Unit. An all-in-one communication gateway, automation platform and user interface solution for utility and industrial distribution substations.
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
CTRL	Control logical device
Data attribute	Defines the name, format, range of possible values and representation of values while being communicated
Data set	The content basis for reporting and logging containing references to the data and data attribute values
DR	Disturbance recorder
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FC	Functional constraint
FTP	File transfer protocol
GCB	1. GOOSE control block 2. Generator circuit breaker
GoCB	GOOSE control block
GoID	GOOSE control block-specific identifier
GOOSE	Generic Object-Oriented Substation Event
GPS	Global Positioning System
HMI	Human-machine interface
HSR	High-availability seamless redundancy
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

Table continues on the next page

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
IET600	Integrated Engineering Toolbox
IID	Instantiated IED description
LDO	Logical device zero (0)
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
LLNO	Logical node zero (0)
LN	Logical node
MAC	Media access control
MicroSCADA	Substation automation system
MMS	1. Manufacturing message specification 2. Metering management system
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
Multicast address	An identifier for a group of hosts that have joined a multicast group
NTP	Network time protocol
P2P	peer-to-peer
PCM600	Protection and Control IED Manager
PRP	Parallel redundancy protocol
PTP	Precision Time Protocol
RCB	Report control block
SCADA	Supervision, control and data acquisition
SCD	Substation configuration description
SCL	XML-based substation description configuration language defined by IEC 61850
SMV	Sampled measured values
ST	Connector type for glass fiber cable
SVCB	Sampled value control block
TAL	Time allowed to live
TCP/IP	Transmission Control Protocol/Internet Protocol
VLAN	Virtual LAN
VT	Voltage transformer
XML	Extensible markup language



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