DISTRIBUTION SOLUTIONS

UniGear Family
UniGear Digital
Engineering Guide

DISTRIBUTION SOLUTIONS

UniGear Family
UniGear Digital
Engineering Guide

NOTICE

TRADEMARKS

Release: December 2020

Document Number: 1VLG500007

Revision: G

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 This manual

The engineering guide provides information for the UniGear Digital solution by providing details about its main components. This guide focuses especially on the IEC 61850 digital communication and it can be used as a technical reference during the engineering phase.

1.2 Intended users

This manual is intended for to be used by design, protection and control relay, test and service engineers. The protection relay engineer needs to have a thorough knowledge of protection systems, protection equipment, protection functions, configured functional logic in the Protection and control relays and their IEC 61850 engineering. The test and service engineers are expected to be familiar with handling of the electronic equipment.

2 UniGear Digital

UniGear Digital is a new solution implemented to the traditional UniGear switchgear. It is accomplished by using state-of-the-art, well-proven components: current and voltage sensors, Relion® protection and control relays and IEC 61850 digital communication.
The design of the current sensors is very compact, and it is optimized for the use in UniGear. Each panel can accommodate two sets of current sensors. The voltage sensors are very compact as well. They are integrated as part of support insulators housed in the cable compartment or directly in the busbar compartment.
The current and voltage sensors are very accurate (accuracy class 0.5), however revenue metering might require higher accuracy classes or separate instrument current and voltage transformer. Such transformers can optionally be added to sensor-equipped panels.
Capacitive voltage detection is enabled by capacitive dividers that are either integrated into the support insulators or into the conventional current transformers, which is used case by case.
Fast horizontal GOOSE communication for inter-panel (bay-to-bay) signals exchange is a mandatory part of this solution, while the Process bus is optional.

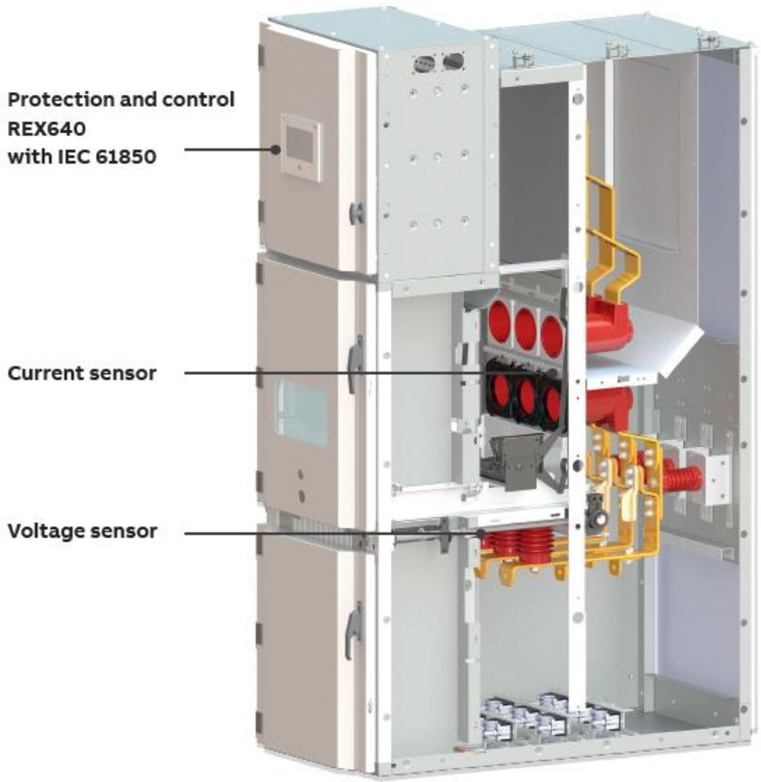


Figure 1: UniGear Digital and its key components

2.1 Sensors

Sensors, for current and voltage measurement, are important part of UniGear Digital. Each switchgear type offering UniGear Digital solution uses sensors as shown in the table below.

Table 1: Sensor product portfolio for UniGear Digital

Meas-urement type	Sensor type	Maxi-mum app. parame-ter	Panel width [mm]	UniGear ZS1 Digital up to 17.5 kV	UniGear ZS1 Digital up to 24 kV	UniGear 550 Digital	UniGear 500R Digital	UniGear MCC Digital	UniGear ZS2 Digital
Current	KECA 80 C104	Up to 1 250 A	650	Yes	No	No	No	No	No
	KECA 80 C165	Up to 4 000 A	800 / 1000	Yes	No	No	No	No	No
	KECA 80 C184	Up to 1 250 A	800	No	Yes	No	No	No	No
	KECA 80 C216	Up to 3 150 A	1000	No	Yes	No	No	No	No
	KECA 250 B1	Up to 2 000 A		No	No	Yes	Yes	Yes	No
	KECA 80 C260 ZS2	Up to 2 500 A		No	No	No	No	No	Yes
Voltage	KEVA 17.5 B20	Up to 17.5 kV		Yes	No	Yes	Yes	Yes	No
	KEVA 24 B20	Up to 24 kV		No	Yes	No	No	No	No
	KEVA 36 B20	Up to 36 kV		No	No	No	No	No	Yes

2.1.1 Current sensors

Current measurement in KECA sensors is based on the Rogowski coil principle.

KECA 80 C104 / KECA 80 C165

For dynamic current measurement (protection purposes) the ABB sensors KECA 80 C104, and KECA 80 C165, fulfil requirements of protection class 5P up to an impressive value reaching the rated short-time thermal current I_{th} (31.5 kA or 50 kA). With KECA 80 C104 and KECA 80 C165 sensors, measuring class 0.5 is reached for continuous current measurement in the extended accuracy ranges from 5 % of the rated primary current I_{pr} not only up to 120 % of I_{pr} (as being common for conventional current transformers), but even up to the rated continuous thermal current I_{cth} (1 250 A or 4 000 A). That provides the possibility to designate the corresponding accuracy class as 5P400 and 5P630, proving excellent linearity and accuracy measurements.

Figure 2: Current sensor KECA 80 C104 / KECA 80 C165

Technical parameters

– Continuous thermal current	1 250 / 4 000 A
– Rated primary current	80 A / 150 mV at 50 Hz or 80 A / 180 mV at 60 Hz
– Accuracy class	0.5 / 5P400; 5P630

KECA 80 C184 / KECA 80 C216

For dynamic current measurement (protection purposes) the ABB sensors KECA 80 C184, and KECA 80 C216, fulfil requirements of protection class 5P up to an impressive value reaching the rated short-time thermal current I_{th} (31.5 kA). With KECA 80 C184 and KECA 80 C216 sensors, measuring class 0.5 is reached for continuous current measurement in the extended accuracy range from 5 % of the rated primary current I_{pr} not only up to 120 % of I_{pr} (as being common for conventional current transformers), but even up to the rated continuous thermal current I_{cth} (1 250 A or 3 150 A). That provides the possibility to designate the corresponding accuracy class as 5P400, proving excellent linearity and accuracy measurements.

Figure 3: Current sensor KECA 80 C184 / KECA 80 C216

Technical parameters

– Continuous thermal current	1 250 / 3 150 A
– Rated primary current	80 A / 150 mV at 50 Hz or 80 A / 180 mV at 60 Hz
– Accuracy class	0.5 / 5P400

KECA 250 B1

For dynamic current measurement (protection purposes) the ABB sensors KECA 250 B1, fulfil requirements of protection class 5P up to an impressive value reaching the rated short-time thermal current I_{th} (31.5 kA). With KECA 250 B1 sensors, measuring class 0.5 is reached for continuous current measurement in the extended accuracy range from 5 % of the rated primary current I_{pr} not only up to 120 % of I_{pr} (as being common for conventional current transformers), but even up to the rated continuous thermal current I_{cth} (2 000 A). That provides the possibility to designate the corresponding accuracy class as 5P125, proving excellent linearity and accuracy measurements.

Figure 4: Current sensor KECA 250 B1

Technical parameters

- Continuous thermal current 2 000 A
- Rated primary current 250 A / 150 mV at 50 Hz or 250 A / 180 mV at 60 Hz
- Accuracy class 0.5 / 5P125

KECA 80 C260 ZS2

For dynamic current measurement (protection purposes) the ABB sensors KECA 80 C260 ZS2, fulfil requirements of protection class 5P up to an impressive value reaching the rated short-time thermal current I_{th} (31.5 kA). With KECA 80 C260 ZS2 sensors, measuring class 0.5 is reached for continuous current measurement in the extended accuracy range from 5 % of the rated primary current I_{pr} not only up to 120 % of I_{pr} (as being common for conventional current transformers), but even up to the rated continuous thermal current I_{cth} (2 500 A). That provides the possibility to designate the corresponding accuracy class as 5P400, proving excellent linearity and accuracy measurements.

Figure 5: Current sensor KECA 80 C260 ZS2

Technical parameters

– Continuous thermal current	2 500 A
– Rated primary current	80 A / 150 mV at 50 Hz or 80 A / 180 mV at 60 Hz
– Accuracy class	0.5 / 5P400

2.1.2 Voltage sensors

Voltage measurement in the KEVA sensor is based on the resistive divider principle. Voltage sensors are designed to be compact and shaped as support insulators. They can be installed in the switchgear´s cable compartment or directly in the busbar compartment.

KEVA 17.5 B20

KEVA B sensor can be used in all applications up to the voltage level 17.5 kV. The sensor fulfils requirements of accuracy class 0.5 for measurement purposes and accuracy class 3P for protection purposes.

Figure 6: Voltage sensor KEVA 17.5 B20

Technical parameters

– Rated primary voltage	15 / √3 kV
– Rated power frequency withstand voltage	38 (42) kV
– Rated lightning impulse withstand voltage	95 kV
– Transformation ratio	10 000: 1
– Accuracy class	0.5 / 3P

KEVA 24 B20

KEVA B sensor can be used in all applications up to the voltage level 24 kV. The sensor fulfils requirements of accuracy class 0.5 for measurement purposes and accuracy class 3P for protection purposes.

Figure 7: Voltage sensor KEVA 24 B20

Technical parameters

– Rated primary voltage	22 / √3 kV
– Rated power frequency withstand voltage	50 kV
– Rated lightning impulse withstand voltage	125 kV
– Transformation ratio	10 000: 1
– Accuracy class	0.5 / 3P

KEVA 36 B20

KEVA B sensor can be used in all applications up to the voltage level 36 kV. The sensor fulfils requirements of accuracy class 0.5 for measurement purposes and accuracy class 3P for protection purposes.

Figure 8: Voltage sensor KEVA 36 B20

Technical parameters

– Rated primary voltage	33 / √3 kV
– Rated power frequency withstand voltage	70 kV
– Rated lightning impulse withstand voltage	170 kV
– Transformation ratio	10 000: 1
– Accuracy class	0.5 / 3P

Sensor accessories

Sensors are connected to protection and control relay via cable with RJ-45 connector. In case both current and voltage sensors are connected to a protection and control relay, a coupler adapter AR5 is used. The coupler adapter AR5 is three phases adapter. Protection and control relays used in UniGear Digital have combined sensor inputs. Each current and voltage sensor has separate cable with one RJ-45 connector. The cable is a separable part of each sensor and it can be replaced by cable of the same length because of the guaranteed accuracy and performance of the sensor. The cable is to be connected directly (or via the coupler adapter AR5 if needed) to the protection and control relay. The coupler adapter AR5 is used to combine two RJ-45 connectors from current and voltage sensors into a combined sensor input for each phase on a protection and control relay.

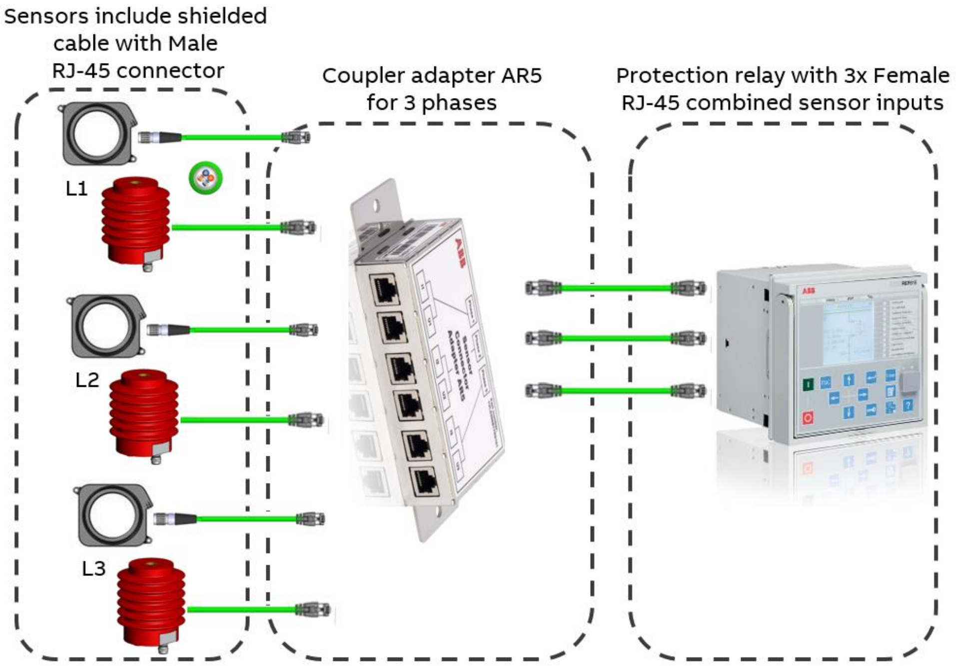


Figure 9: Coupler adapter AR5 utilized with Relion® 615, 620 and 640 series protection relays

Current sensor wires are connected according to the following assignment:
PIN 4 – S1, PIN 5 – S2, other PINs remain unused.

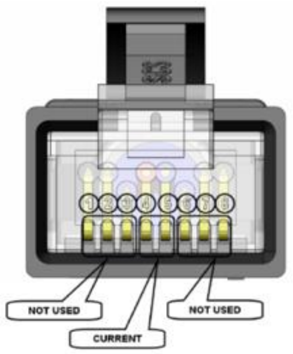


Figure 10: Connector pins assignment of a current sensor plug

Voltage sensor wires are connected according to the following assignment: PIN 7 – a,
PIN 8 - ⏚, other PINs remain unused.

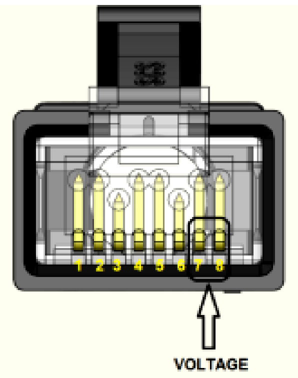


Figure 11: Connector pins assignment of a voltage sensor plug

2.2 Protection and control relays

UniGear Digital is supported by the following types of protection and control relays, shown in table below.

Table 2: Protection and control relay key functionality overview for UniGear Digital

Relion®	Product type	Standard configuration	I/U sensor input	Arc protection	IEC 61850-9-2LE	Synchro-check / Synchronizer
615 series	REF615	G	Yes	Yes	Yes	Yes* / No
		L	Yes	Yes	Yes	Yes* / No
	REM615	D	Yes	Yes	Yes	No / No
	RED615	E	Yes	No	Yes	Yes* / No
620 series	REF620	B	Yes	Yes	Yes	Yes* / No
	REM620	B	Yes	Yes	Yes	Yes* / No
640 series	REX640		Yes	Yes	Yes	Yes / Yes

* Only available with IEC 61850-9-2LE

The above-mentioned protection and control relays support IEC 61850 Ed.2 and Ed.1 communication with GOOSE messaging (performance class P1 / 1A) and 9-2LE stream (sample rate 4 kHz in case of 50 Hz, 80 samples per cycle, 1 ASDU per frame). The IEC 61850-9-2LE interface is supported by the Relion® 615, 620 and 640 series, including the PRP1 / HSR redundancy (RED615 only via fiber optic interfaces). The 615, 620 and 640 series work as a redundancy box (Redbox) between the HSR / PRP1 networks and single attached devices or networks not aware of PRP1 / HSR.

The 615, 620 and 640 series support the IEEE 1588 (PTPv2) and Power profile as defined in IEEE C37.238 standard to reach the required timing accuracy over an Ethernet network. The 615, 620 and 640 series work as an ordinary clock (capable of acting as either a Master or a Slave clock). There is no need to design a substation with two Grandmaster clocks to reach redundancy because the 615, 620 and 640 series can work as Master clock. For more details see 615, 620 and 640 series manuals.

Feeder protection and control REF615

The REF615 is a dedicated feeder protection and control relay perfectly aligned for protection, control, measurement and supervision of utilities and industrial power distribution systems including radial, looped and meshed networks, and involving a potential distributed power generation. The REF615 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE and to synchrocheck with IEC 61850-9-2 LE.

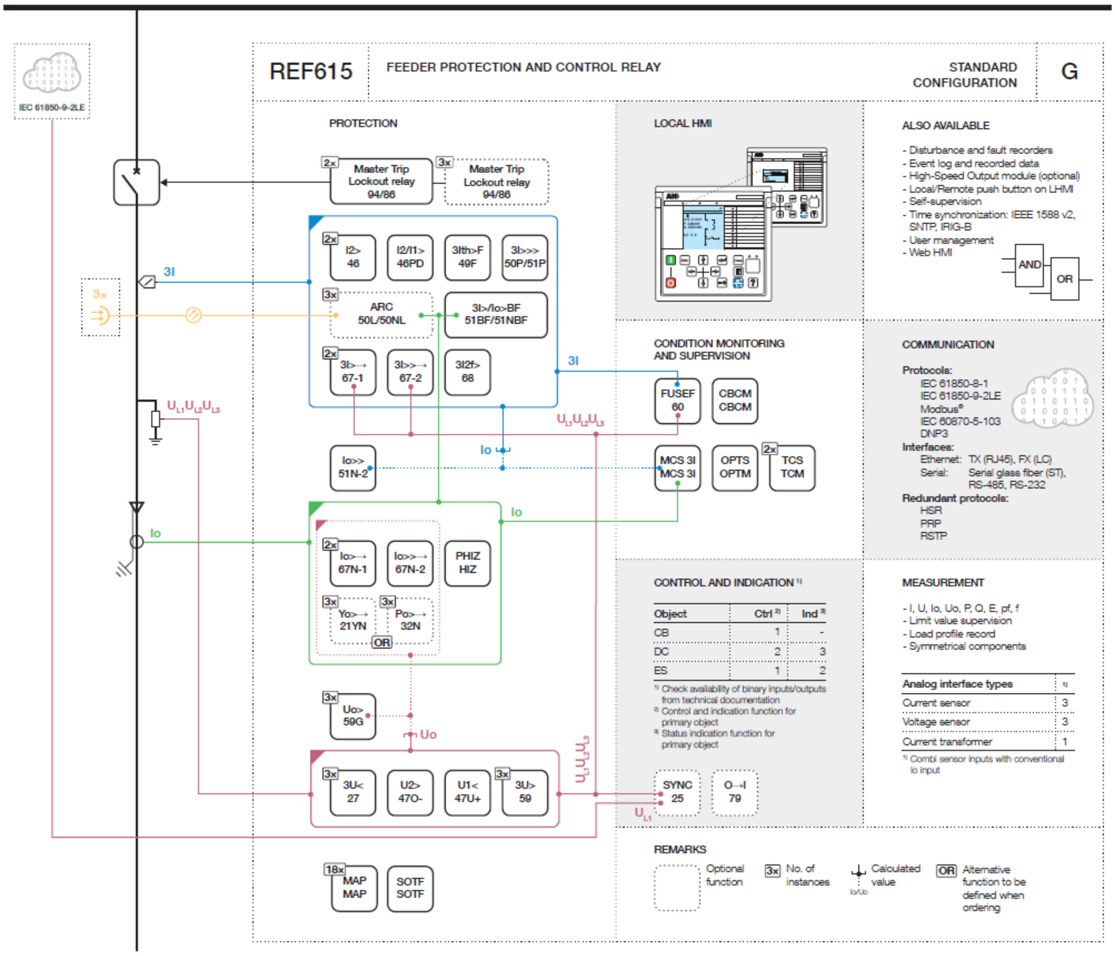


Figure 12: Functionality overview of REF615 standard configuration G

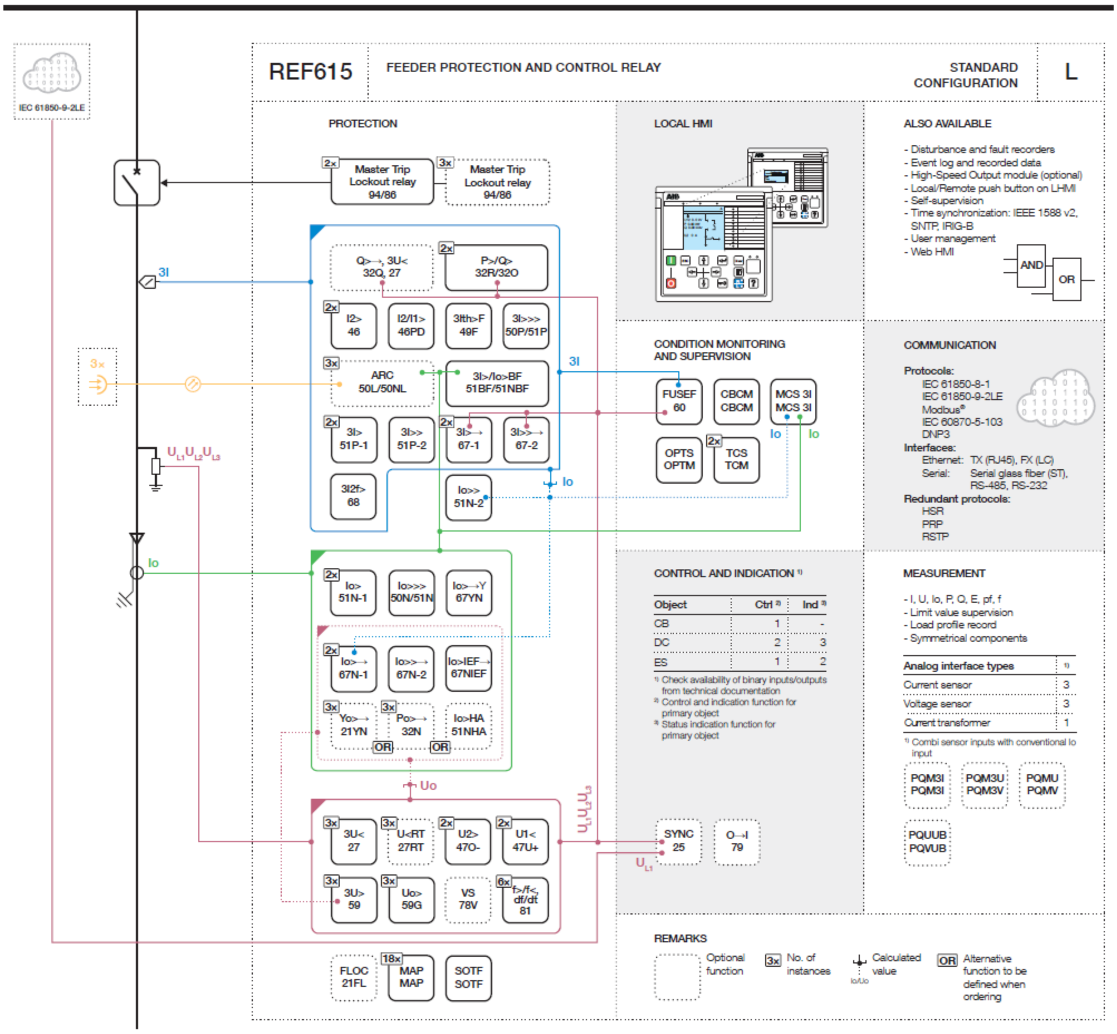


Figure 13: Functionality overview of REF615 standard configuration L

Motor protection and control REM615

The REM615 is a dedicated motor protection and control relay perfectly aligned for protection, control, measurement and supervision of asynchronous motors in manufacturing and process industry. The REM615 offers all the functionality needed to manage motor starts and normal operation, including also protection and fault clearance in drive and network disturbance situations. The REM615 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE.

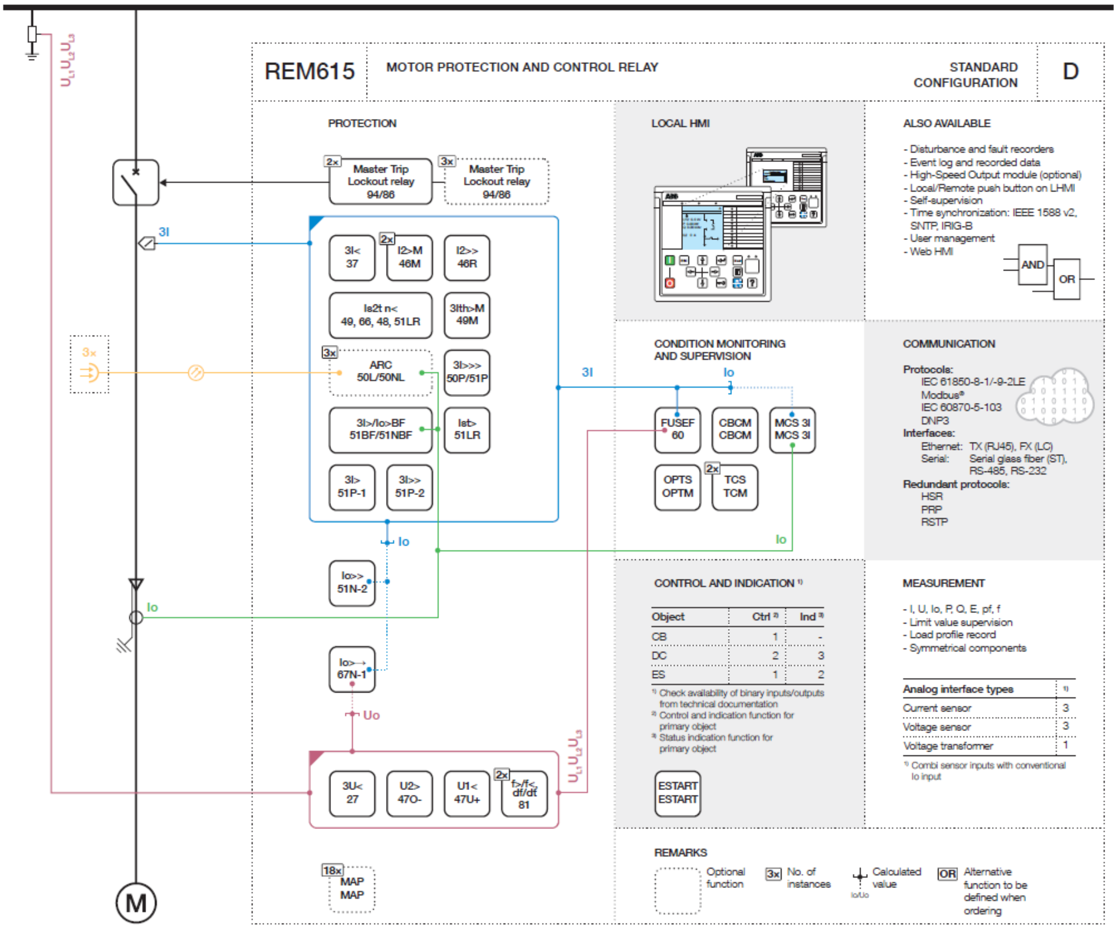


Figure 14: Functionality overview of REM615 standard configuration D

Line differential protection and control RED615

RED615 is a phase-segregated, two-end, line differential protection and control relay. With in-zone transformer support, perfectly harmonized for utility and industrial power distribution networks. The RED615 relays communicate between substations over a fiber optic link or a galvanic pilot wire connection. Protection of ring-type and meshed distribution networks generally requires unit protection solutions, also applied in radial networks containing distributed power generation. With relation to UniGear Digital this protection and control relay is used for more dedicated applications only. The RED615 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE and to synchrocheck with IEC 61850-9-2 LE.

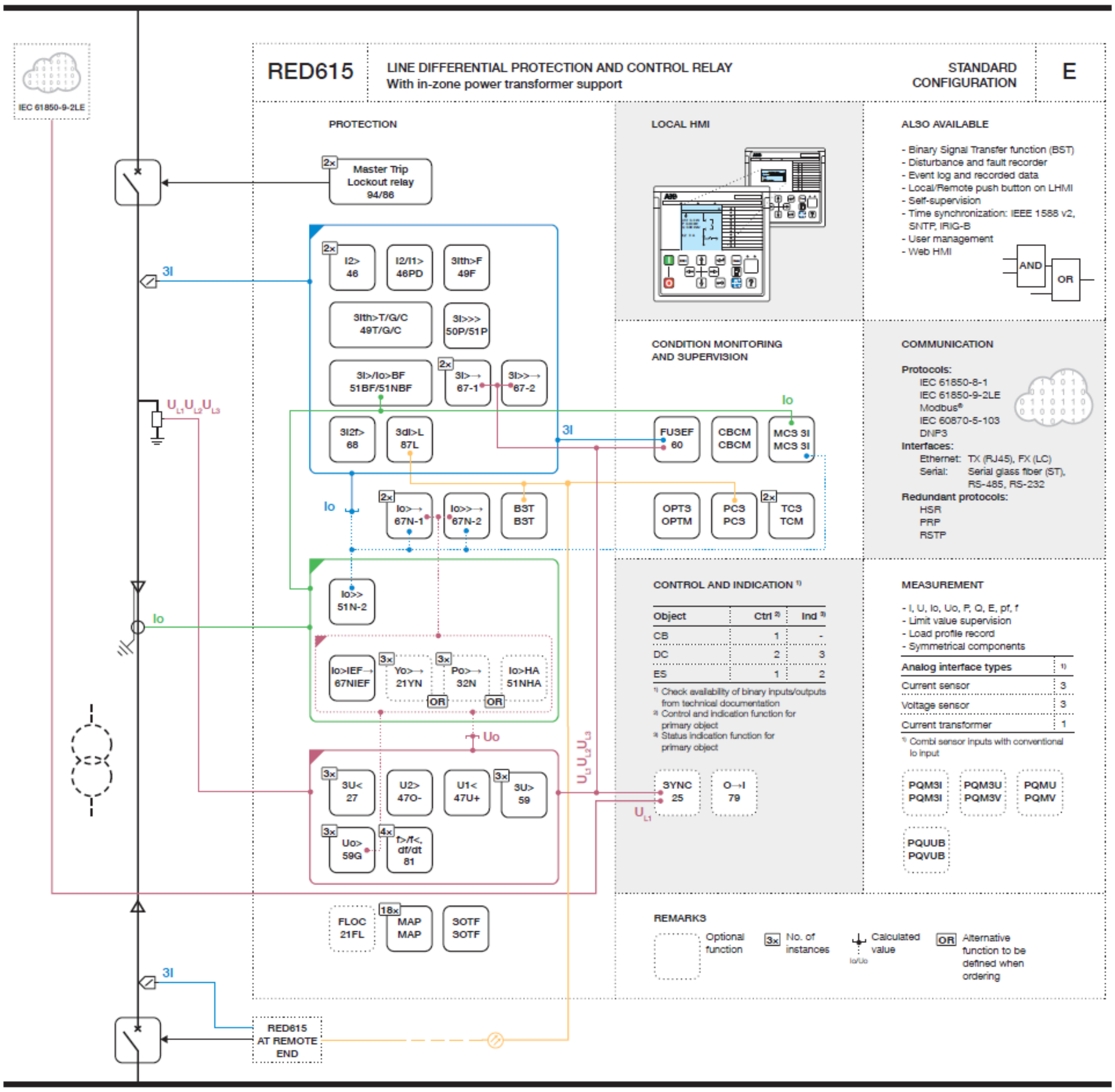


Figure 15: Functionality overview of RED615 standard configuration E

Feeder protection and control REF620

The REF620 is a dedicated feeder management relay perfectly aligned for the protection, control, measurement and supervision of utility and industrial power distribution systems, including radial, looped and meshed networks, with or without distributed power generation. REF620 can also be used to protect feeders including motors or capacitor banks. Additionally, REF620 offers functionality for interconnection protection used with distributed generation like wind or solar power connection to utility grid. The REF620 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE and to synchrocheck with IEC 61850-9-2 LE.

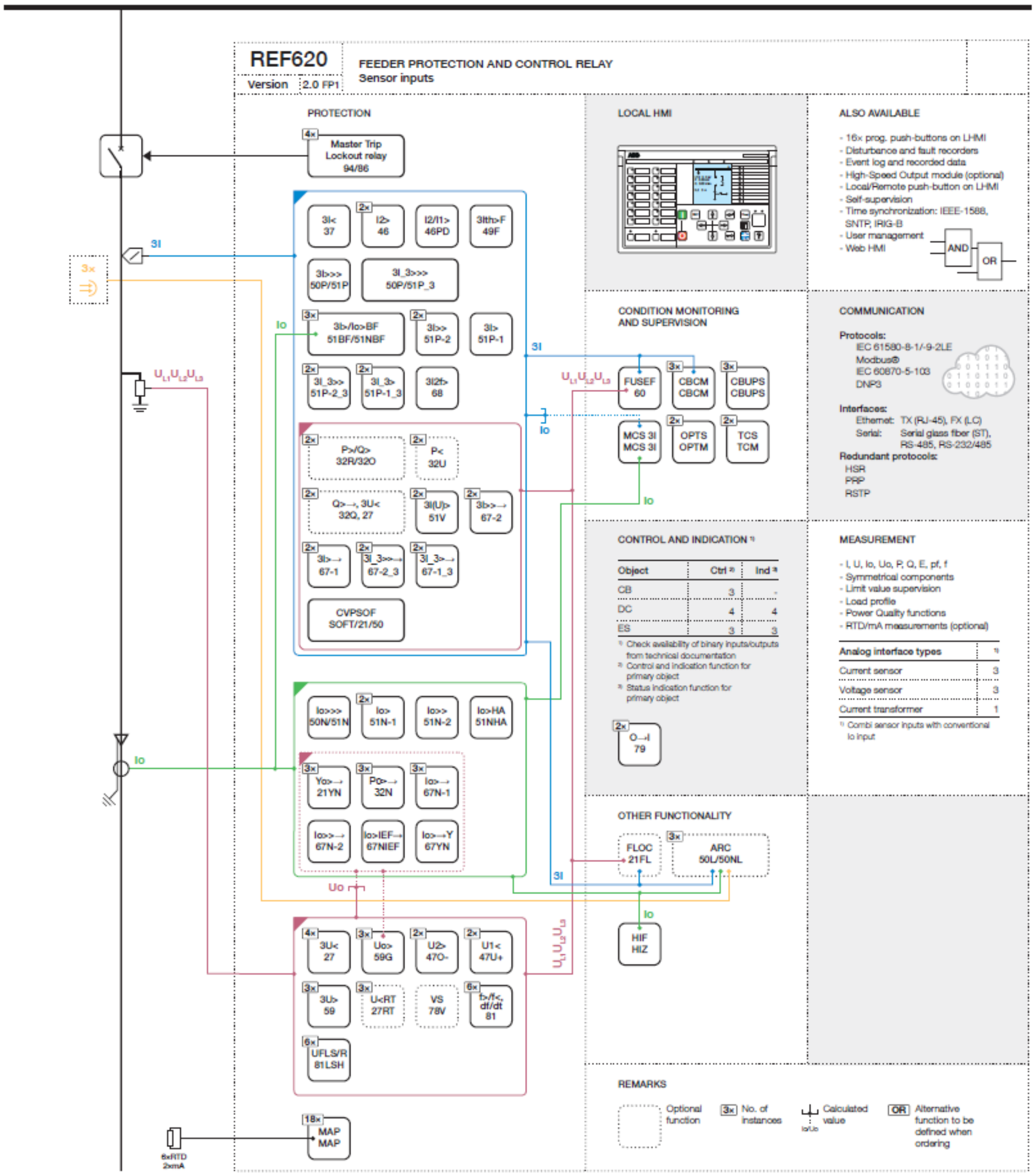


Figure 16: Functionality overview of REF620 standard configuration B

Motor protection and control REM620

The REM620 is a dedicated motor management relay perfectly aligned for the protection, control, measurement and supervision of medium-sized and large asynchronous and synchronous motors requiring also differential protection in the manufacturing and process industry. The REF620 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE and to synchrocheck with IEC 61850-9-2 LE.

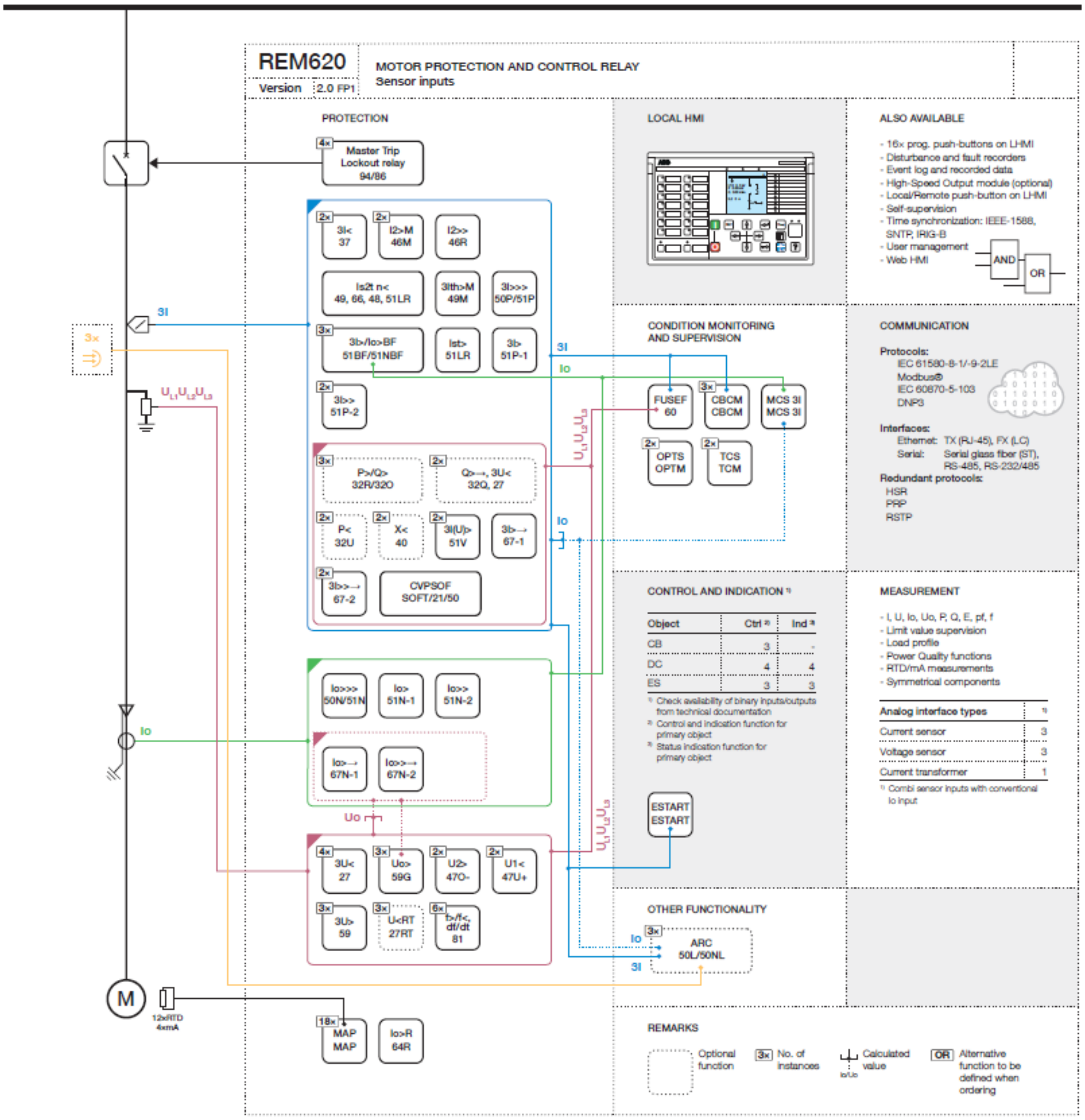


Figure 17: Functionality overview of REM620 standard configuration B

Protection and control REX640

REX640 is a powerful all-in-one protection and control relay for use in advanced power distributions and generation applications with unmatched flexibility available during the complete life cycle of the device. The modular design of both hardware and software elements facilitates the coverage of any comprehensive protection application requirement that may arise during the complete life cycle of the relay and substation.
One full IEC 61850-9-2 LE stream containing both voltages and currents can be sent. Receiving of up to four Sampled Measured Value (SMV) streams is supported with a total of maximum 16 channels. The channels are freely configurable with the possibility to engineer SMV stream redundancy using the voltage and current switch functions with either another SMV stream or local measurements.

Figure 18: Protection and control REX640

Remote IO unit RIO600

The remote inputs / outputs unit RIO600 is designed to expand the digital and analog inputs / outputs of ABB's Relion® protection and control relays and to provide inputs / outputs for the ABB ZEE600 using the IEC 61850 Ed.2 communication. The RIO600 communicates with the protection and control relays over the Ethernet cable via fast horizontal GOOSE communication.

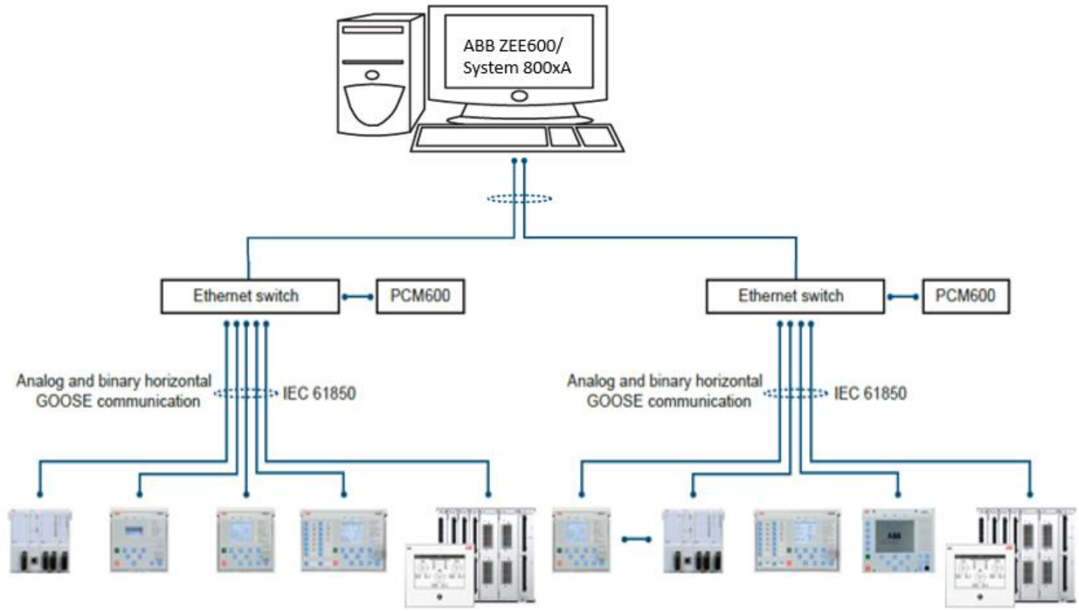


Figure 19: Overview of RIO600 connection

The RIO600 AOM4 analog output module has four mA outputs providing mA output signal in range 0–20 mA. These outputs can be used for connection to the analog / digital panel meters. Operation accuracy of mA output is 0.1 % or 0.2 mA. There is an option to use a selector switch to display more than one phase on one panel meter.

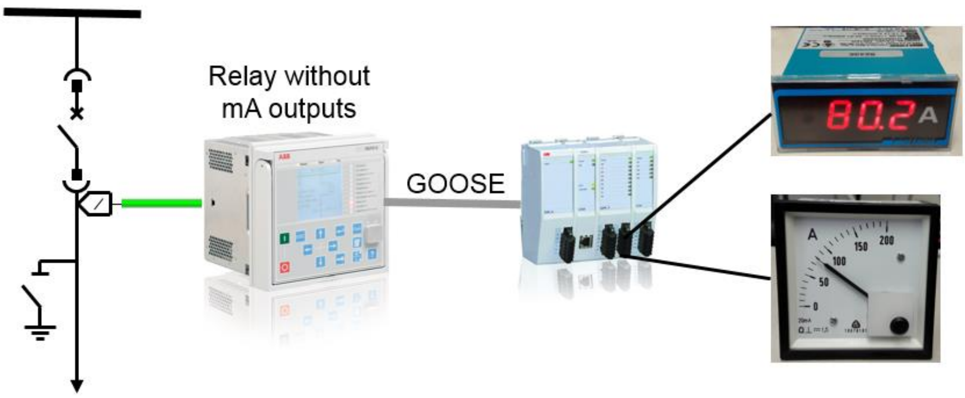


Figure 20: RIO600 communicating analog signals for the panel meters

TE Connectivity's ESSAILEC RJ45 test block

The test block is used for efficient testing of protection and control relay with sensor inputs during regular maintenance. The test block is flush mounting type on the low voltage compartment door and its vertical layout is recommended. The testing of protection and control relay's sensor inputs is possible without opening the low voltage compartment door. One test block is intended for one phase and it consists of a socket, a lid and a plug.

Figure 21: ESSAILEC RJ45 test block

Figure 22: Low Voltage Compartment door with ESSAILEC RJ45 test blocks

The socket is covered during Normal operation by the lid. For testing, the lid is removed and replaced by the test plug.

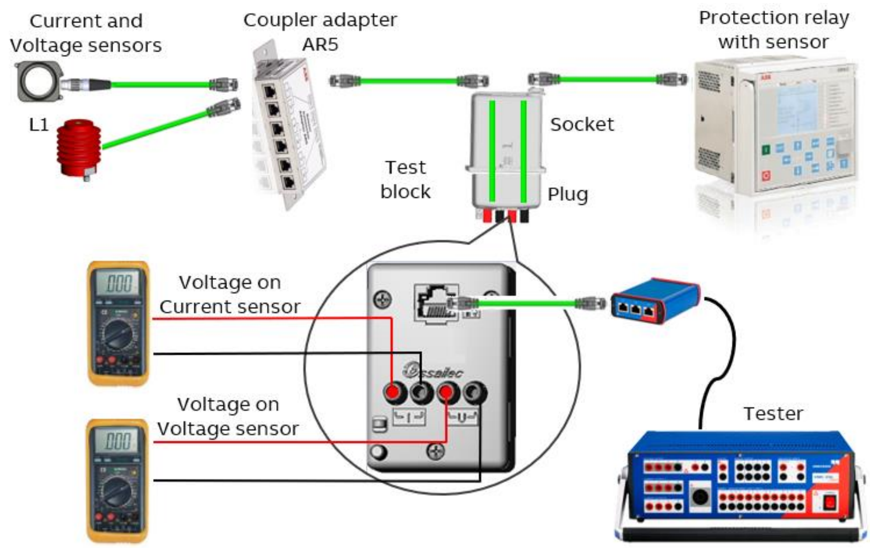


Figure 23: The testing (only one phase is shown)

ESSAILEC Trip or Polarity range test block

A test block allows the testing without circuit breaker tripping.

2.3 Smart substation control and protection SSC600

Centralized protection and control for distribution substations

ABB Ability™ smart substation control and protection for electrical systems SSC600 centralizes all protection and control functionality in one single device on distribution substation level for minimal engineering, station-wide visibility and optimal process management. Combining SSC600 with protection and control relays with merging unit functionality / merging units creates an IEC 61850-compliant centralized protection and control solution. The modular software can be flexibly modified for the entire lifetime of the digital substation and allows SSC600 to change with the evolving grid. SSC600 builds on ABB's solid and proven technological foundation manifested in the renowned Relion® protection and control family of relays.

The SSC600 Smart Substation devices offer native support for IEC 61850 Edition 2 also including binary and analog horizontal GOOSE messaging. SSC600 also supports IEC 61850 process bus by receiving sampled values of voltages and currents from up to 20 protection and control relays with merging unit functionality / merging units.

Figure 24: Smart substation control and protection SSC600

Substation merging unit SMU615

SMU615 is a dedicated substation merging unit intended for measuring current and voltage signals from sensors and merging them into the standard digital output format that other devices can further use for various power system protection application purposes. SMU615 itself includes no protection functionality but it offers the physical interface into the switchgear primary equipment, that is, circuit breaker, disconnector and earthing switch. SMU615 is a member of ABB's Relion® product family and is characterized by the compactness, simplicity and withdrawable-unit design. SMU615 has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability in the digital substations. SMU615 supports process bus according to IEC 61850-9-2 LE with IEEE 1588 v2 time synchronization and sensor inputs, it can send (1 instance) over the IEC 61850-9-2LE.

Figure 25: Substation merging unit SMU615

2.4 Statistical energy meters

ESM-ET statistical energy meter (Order code: ESM-ET97-220-A2E2-05S) is manufactured by EnergoService (https://enip2.ru/en/). The meter is compatible and has been tested with ABB's current and voltage sensors. New sets of dedicated I/U sensors are required. The energy meter can be used for current measurement up to 4 200 A and voltage measurement up to 40 kV. The amplitude correction and the phase error correction factors of the current and voltage sensors must be entered in the energy meter. ESM-ET counts four-quadrant active and reactive energy, it uses its built-in memory to store power demands and energy readings by time of use tariffs. ENMI-5 and 7 display panels connected with single patch cord serves as a Human Machine Interface (HMI) for the energy meter. The display panel can be mounted separately or attached to the back of the meter.

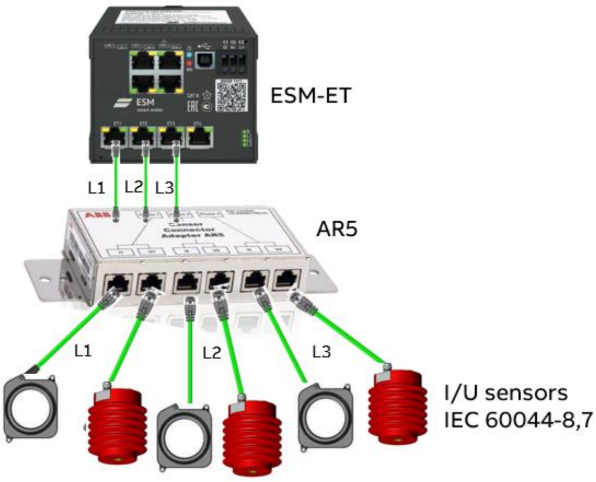


Figure 26: ESM-ET connectivity to I/U sensors

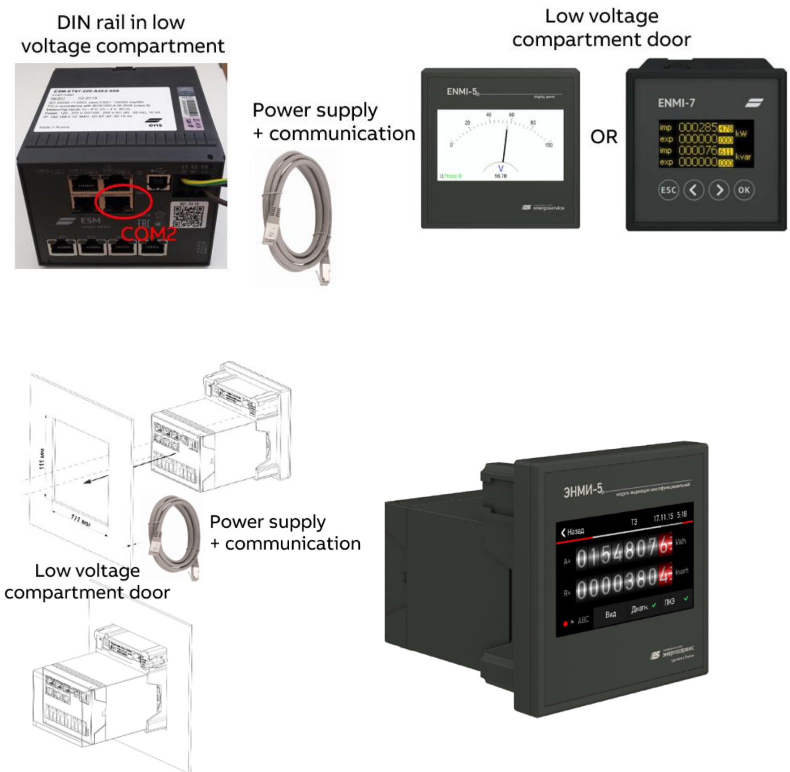


Figure 27: Examples of ESM and ENMI assembly

2.5 IEC 61850

The IEC 61850 standard was released in 2004 as a global international standard representing the architecture for communication networks and systems for power utility automation. It is updated with new version, Edition 2, which extends to new application areas in transmission and distribution power systems and defines a new functionality to Edition 1 functionality. IEC 61850 Edition 2 adds new functionality which is not supported by the Edition 1. Therefore, it is recommended to always use the same standard version in all devices and not to mix different versions in the same project.

The IEC 61850 standard defines the Ethernet technology for substation automation communication. It also includes the related system requirements and the data model of the protection and control functions. The standardized data modelling of substation functions including the communication interfaces pave the way to openness and interoperability of devices.

The IEC 61850 standard distinguishes Station bus IEC 61850-8-1 with vertical and horizontal GOOSE communication (real time communication between protection and control relays) and Process bus IEC 61850-9-2 for transmission of Sampled Measured Values (SMV) gathered by measurements. The UCA International Users Group created a guideline (commonly referred to as IEC 61850-9-2LE where “LE” stays for “Lite Edition”) that defines an application profile of IEC 61850-9-2 to facilitate implementation and enable interoperability.

The Station and Process busses can be physically separated, or they can coexist on the same Ethernet network. The GOOSE and SMV profiles enable designing substation communication for MV switchgear in a novel and flexible way to make the protection and control relay process data available to all other protection and control relays in the local network in a real-time manner.

Protection and control relays publish signals for interlocking, blocking, tripping between panels via horizontal GOOSE communication in UniGear Digital. Nowadays, GOOSE communication is used increasingly in substations and it offers new additional values like simplicity, functional flexibility, easy scalability and improved diagnostic, faster performance compared to conventional hard wired interpanel wires.

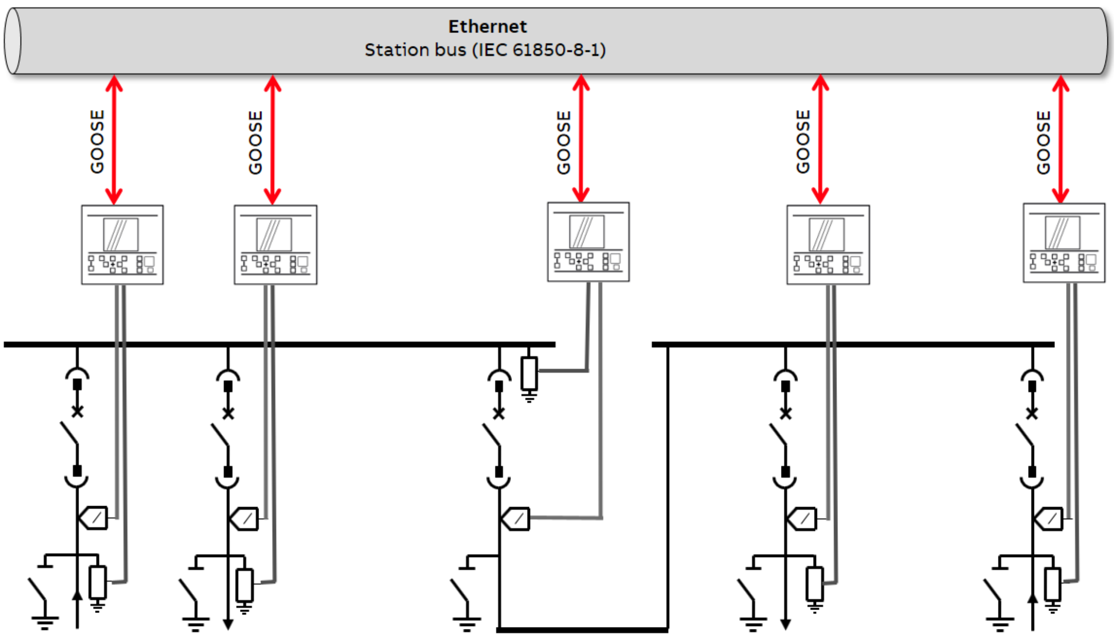


Figure 28: Switchgear with sensor measurement

Process interfaces to MV apparatus (for example voltage sensors) are on the process level. Besides the conventional signal wiring between the process interface and protection and control relays, IEC 61850 introduces a concept where process signals can be exchanged in process bus, under IEC 61850-9-2. In MV switchgear application the station and the process bus can be combined to one common bus. When using conventional voltage instrument transformers (VTs) in MV switchgear they are usually located in the incoming feeders on the cable side and the busbar voltage is measured in any of the outgoing feeders or in dedicated metering panel. The sharing of the busbar voltage is done by interconnection wires between busbar VTs and protection and control relays in all outgoing feeders. Usage of sensors and IEC 61850-9-2 has significant effect on the design of the switchgear. The signal from the voltage sensor measuring the busbar voltage in one of the protection and control relays is digitized into sampled values stream shared over Ethernet network. The interconnection wiring in switchgear becomes simplified as less regular galvanic signal wires are needed. Transmitting voltage signal over process bus enable also higher error detection because the signal transmission is supervised.

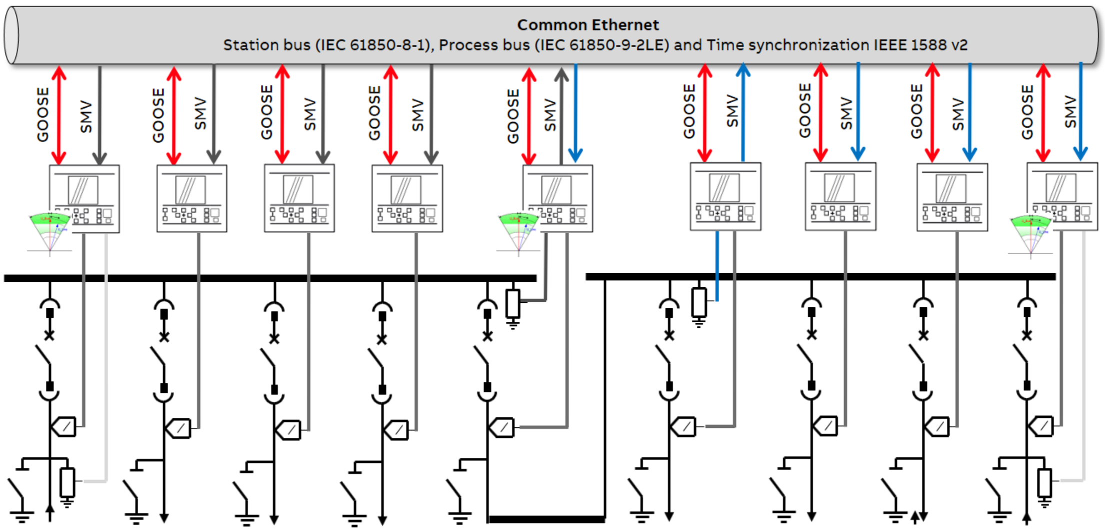


Figure 29: Switchgear with sensor measurement and process bus application of voltage sharing and synchrocheck

2.6 Switchgear type overview

UniGear Digital is available for the following switchgear types:

- UniGear ZS1
- UniGear 550
- UniGear 500R
- UniGear MCC
- UniGear ZS2

Table 3: Overview of UniGear Digital in UniGear switchgear family

Switch-gear type	Busbar arrangement	UniGear Digital	Voltage level	Rated feeder current	Rated short-circuit current
UniGear ZS1	Single busbar	Yes	Up to 24 kV	Up to 4 000 A	Up to 63 kA / 1 s (50 kA / 3 s)
	Double busbar	Yes (Up to 17.5 kV)	Up to 24 kV	Up to 4 000 A	Up to 31.5 kA / 3 s
	Back to back	No	Up to 24 kV	Up to 4 000 A	Up to 50 kA / 3 s
UniGear 550	Single busbar	Yes	Up to 12 kV	Up to 1 250 A	Up to 31.5 kA / 3 s
UniGear 500R (IEC)	Single busbar	Yes	Up to 17.5 kV	Up to 2 000 A	Up to 31.5 kA / 3 s
UniGear MCC	Single busbar	Yes	Up to 12 kV	Up to 400 A	Up to 50 kA / 3 s
UniGear ZS2	Single busbar	Yes	Up to 36 kV	Up to 2 500 A	Up to 31.5 kA / 3 s

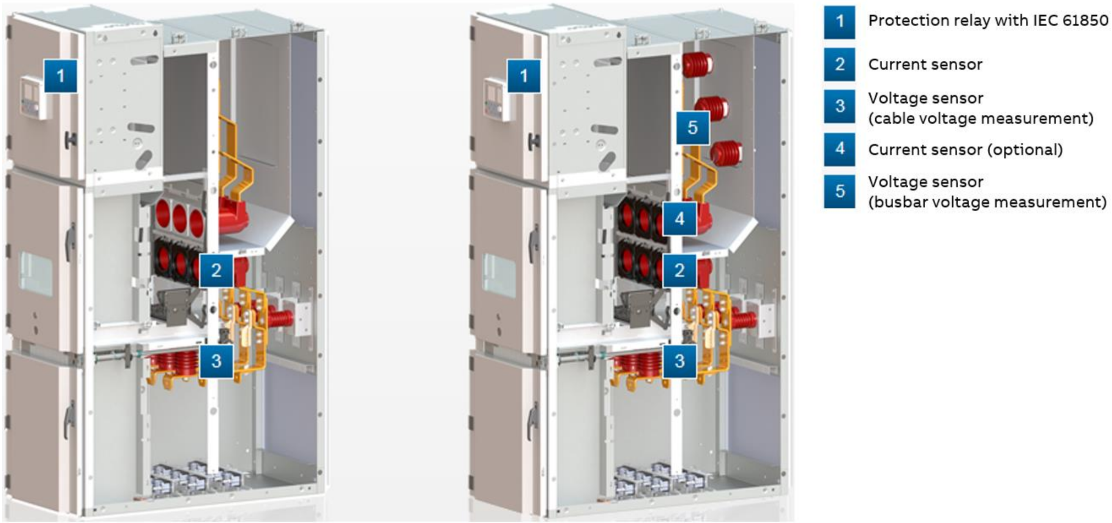
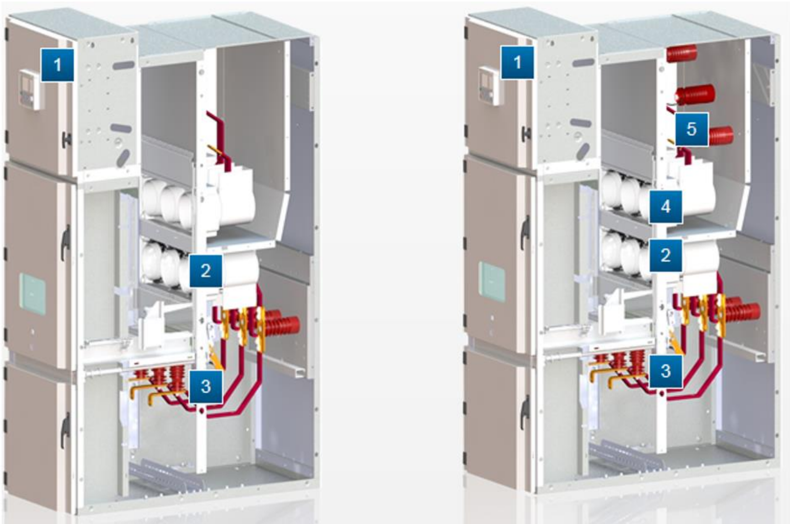
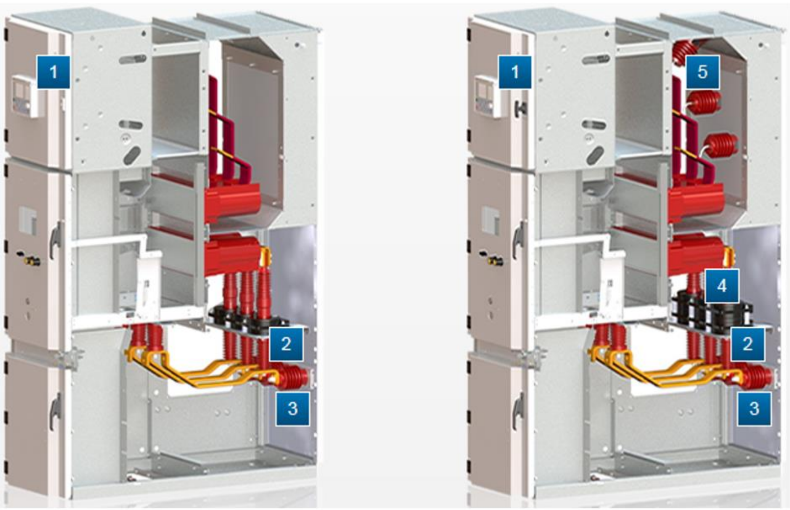


Figure 30: UniGear ZS1 Digital (17.5 kV, 4 000 A, 50 kA)



1 Protection relay with IEC 61850
2 Current sensor
3 Voltage sensor (cable voltage measurement)
4 Current sensor (optional)
5 Voltage sensor (busbar voltage measurement)

Figure 31: UniGear ZS1 Digital (24 kV, 3 150 A, 31.5 kA)

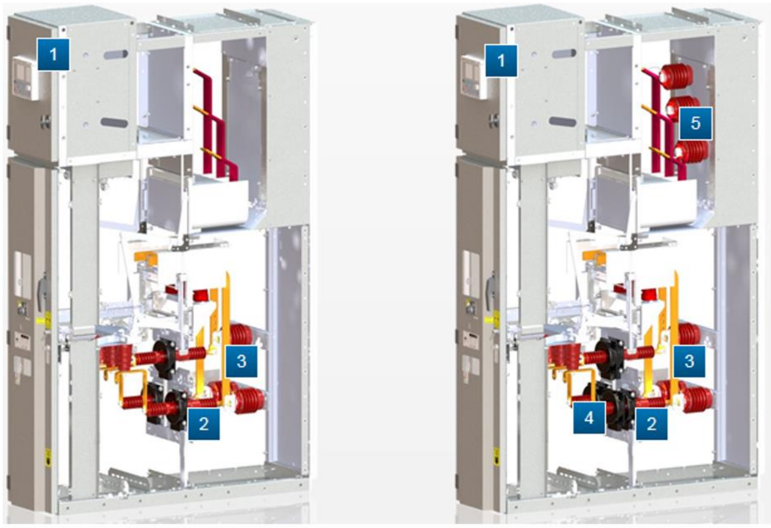


1 Protection relay with IEC 61850
2 Current sensor
3 Voltage sensor (cable voltage measurement)
4 Current sensor (optional)
5 Voltage sensor (busbar voltage measurement)

Figure 32: UniGear 550 Digital (12 kV, 1 250 A, 31.5 kA)

1 Protection relay with IEC 61850
2 Current sensor
3 Voltage sensor (cable voltage measurement)
4 Current sensor (optional)
5 Voltage sensor (busbar voltage measurement)

Figure 33: UniGear 500R Digital (17.5 kV, 2 000 A, 31.5 kA)



1 Protection relay with IEC 61850
2 Current sensor
3 Voltage sensor (cable voltage measurement)
4 Current sensor (optional)
5 Voltage sensor (busbar voltage measurement)

Figure 34: UniGear MCC Digital (12 kV, 400 A, 50 kA)

1 Protection relay with IEC 61850
2 Current sensor
3 Voltage sensor (cable voltage measurement)
4 Current sensor (optional)
5 Voltage sensor (busbar voltage measurement)

Figure 35: UniGear ZS2 Digital (36 kV, 2 500 A, 31.5 kA)

3 Engineering

3.1 Sensors

3.1.1 Current sensors

Correction factors

The amplitude and phase error of a current sensor is, in practice, constant and independent on the primary current. This means it is an inherent and constant property of each sensor and it is not considered to be unpredictable and bound to influences. Hence, it can be easily rectified in the protection and control relay by using appropriate correction factors, specified separately for every sensor. Values of correction factors for the amplitude and phase error of a current sensor are entered on the sensor label and as well as in the sensor´s routine test report. To achieve the required accuracy classes, it is recommended to use both correction factors (Cfs), that is, the amplitude correction factor (aI) and the phase error correction factor (pI) of the current sensor.

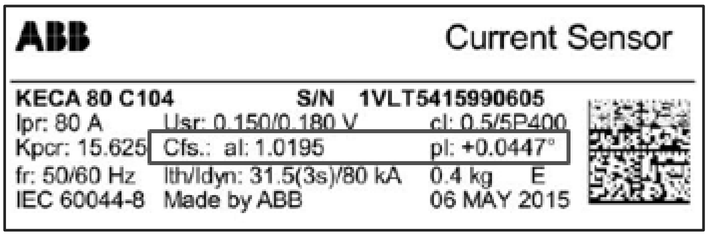
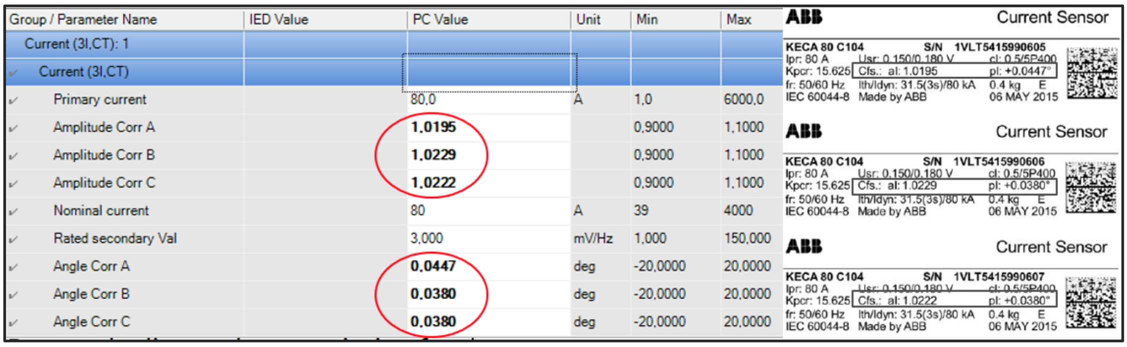


Figure 36: Example of a current sensor label

Due to linear characteristics of the sensor measurement error caused by manufacturing tolerances can be compensated for by using correction factors entered in the protection relay. The correction factors are entered via parameter setting in PCM600 *(IED Configuration / Configuration / Analog inputs / Current (3I, CT))*



Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
Current (3I,CT): 1					
Current (3I,CT)					
Primary current		80,0	A	1,0	6000,0
Amplitude Corr A		1,0195		0,9000	1,1000
Amplitude Corr B		1,0229		0,9000	1,1000
Amplitude Corr C		1,0222		0,9000	1,1000
Nominal current		80	A	39	4000
Rated secondary Val		3,000	mV/Hz	1,000	150,000
Angle Corr A		0,0447	deg	-20,0000	20,0000
Angle Corr B		0,0380	deg	-20,0000	20,0000
Angle Corr C		0,0380	deg	-20,0000	20,0000

Figure 37: Example of setting the correction factors for the current sensors in PCM600

Primary current

Setting example

In this example, an 80 A / 0.150 V at 50 Hz sensor is used and the application has a 1 000 A nominal current (I_n).

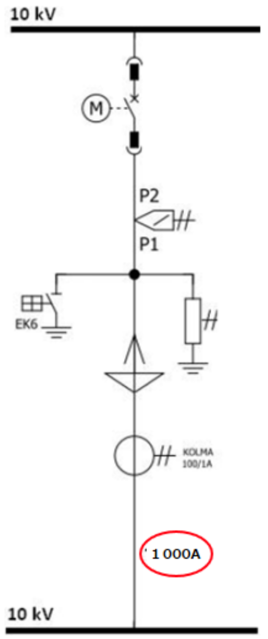


Figure 38: Single line diagram

When defining another primary value for the sensor, also the nominal voltage should be redefined to maintain the same transformation ratio. However, the setting in the protection and control relay (*Rated Secondary Value*) is not in V but in mV / Hz, which makes the same setting value valid for both 50 Hz and 60 Hz nominal frequency.

$$RSV = \frac{In \,/\, Ipr \times Kr}{fn}$$

RSV	Rated secondary value in mV / Hz
I_n	Application nominal current
I_{pr}	Sensor-rated nominal current
K_r	Sensor-rated voltage at the rated current in mV
f_n	Network nominal frequency

In this example, the value is as calculated using the equation.

$$RSV = \frac{1000\,A \,/\, 80\,A \times 150\,mV}{50\,Hz} = 37.5\,\frac{mV}{Hz}$$

Primary, Nominal current and Rated secondary values are entered via parameter setting in PCM600 (IED Configuration / Configuration / Analog inputs / Current (3I, CT))

Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
Current (3I,CT): 1					
Current (3I,CT)					
Primary current		1000,0	A	1,0	6000,0
Amplitude Corr A		1,0195		0,9000	1,1000
Amplitude Corr B		1,0229		0,9000	1,1000
Amplitude Corr C		1,0222		0,9000	1,1000
Nominal current		1000	A	39	4000
Rated secondary Val		37,500			
Angle Corr A		0,0447			
Angle Corr B		0,0380			
Angle Corr C		0,0380			

ABB Current Sensor
KECA 80 C104 S/N 1VLT5415990605
Ipr: 80 A Usr: 0.150/0.180 V cl: 0.5/5P400
Kpcr: 15.625 Cfs.: al: 1.0195 pl: +0.0447°
fr: 50/60 Hz Ith/Idyn: 31.5(3s)/80 kA 0.4 kg E
IEC 60044-8 Made by ABB 06 MAY 2015

Figure 39: Example of setting values for current sensor in PCM600

Unless otherwise specified, the *Nominal Current* setting should always be the same as the *Primary Current* setting which is a reference value for protection functions.

Each setting parameter of current protection functions is divided by application nominal current I_n.

Threshold for *PHIPTOC1* Start value tripping at 2 000 A is:

$$\frac{I_{nTRIP}}{I_n} = \frac{2\,000\text{ A}}{1\,000\text{ A}} = 2$$

REF615 - Parameter Setting

Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
PHIPTOC1: 1					
3I>>>(1)					
Operation		on			
Num of start phases		1 out of 3			
Reset delay time		20	ms	0	60000
Setting Group 1					
Start value		2.00	xIn	1.00	40.00
Start value Mult		1.0		0.8	10.0
Operate delay time		20	ms	20	200000

Figure 40: Example of parameter setting for PHIPTOC1 Start value in PCM600

Maximum current Start and protection setting values

If the ratio of the application nominal current I_n and sensor-rated primary current I_{pr} becomes higher, and the rated secondary value needs to be set higher than 46.875 mV / Hz, the highest value that the relay can measure before the current sensor input is saturated is smaller than the maximum setting value of the current protection.

Table 4: Maximum current Start and protection setting values

Application Nominal current (I_n)	Rated Secondary Value with 80 A / 0.150 V at 50 Hz	Maximum current Start and protection setting values
... 1 250 A	1.000 … 46.875 mV / Hz	40 x I_n
1 250 … 2 500 A	46.875 … 93.750 mV / Hz	20 x I_n
2 500 … 4 000 A	93.750 … 150.000 mV / Hz	12.5 x I_n

Priority

Each current sensor has unique physical polarity defined by sensor hardware.

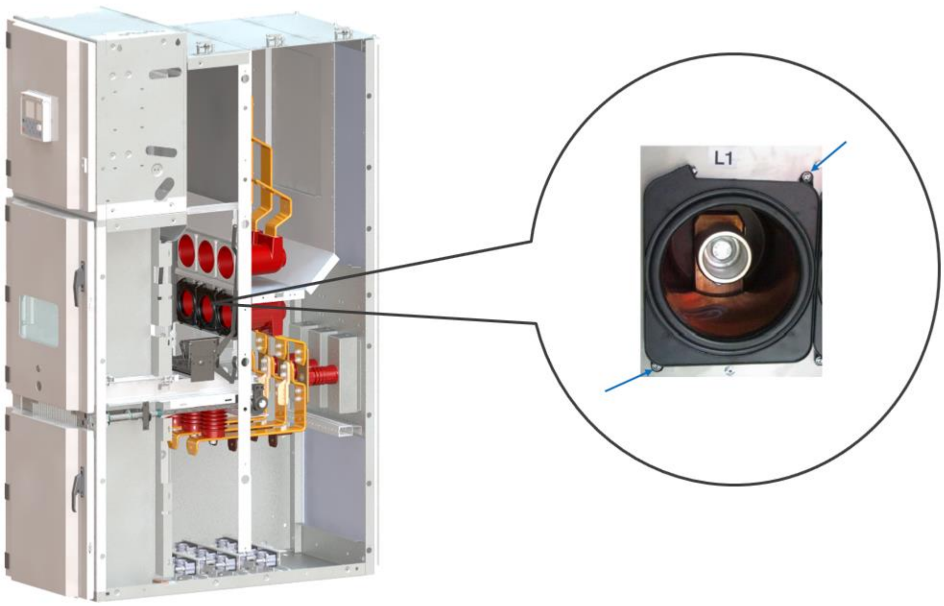


Figure 41: Current sensor with unique physical polarity

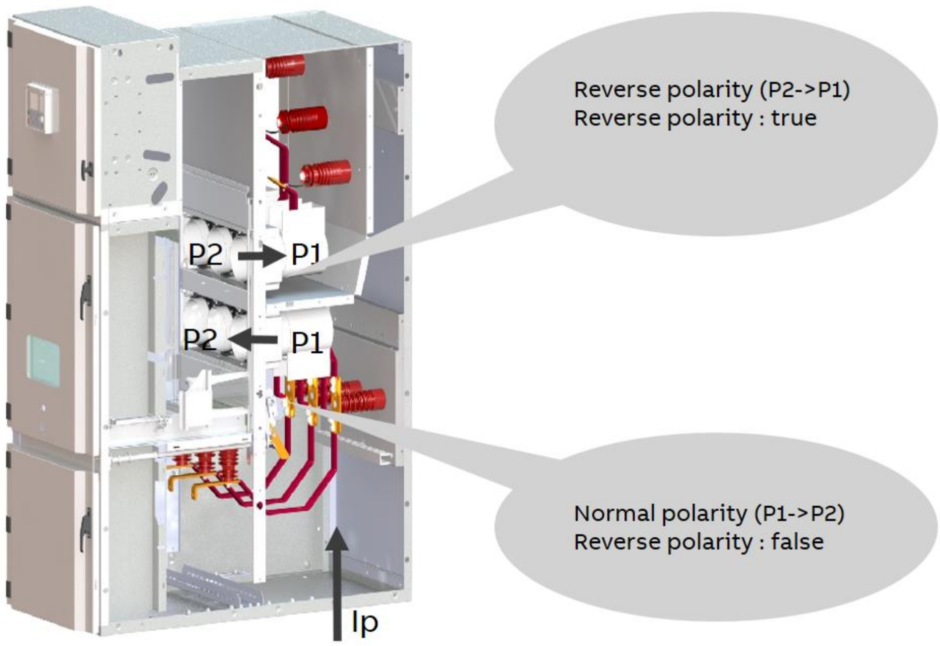


Figure 42: Polarity setting for current sensors in incoming feeder

Sensor polarity is changed via parameter setting in PCM600 (IED Configuration / Configuration / Analog inputs / Current (3I, CT))

Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
Current (3I,CT): 1					
Current (3I,CT)					
Primary current		1000,0	A	1,0	6000,0
Amplitude Corr A		1,0195		0,9000	1,1000
Amplitude Corr B		1,0229		0,9000	1,1000
Amplitude Corr C		1,0222		0,9000	1,1000
Nominal current		1000	A	39	4000
Rated secondary Val		37,500	mV/Hz	1,000	150,000
Reverse polarity		**True**			
Angle Corr A		0,0447	deg	-20,0000	20,0000
Angle Corr B		0,0380	deg	-20,0000	20,0000
Angle Corr C		0,0380	deg	-20,0000	20,0000

Figure 43: Example of polarity setting for current sensor in PCM600

3.1.2 Voltage sensors

Correction factors

The amplitude and phase error of a voltage sensor is, in practice, constant and independent on the primary voltage. This means it is an inherent and constant property of each sensor and it is not considered to be unpredictable and bound to influences. Hence, it can be easily rectified in the protection and control relay by using appropriate correction factors, specified separately for every sensor. Values of correction factors for the amplitude and phase error of a voltage sensor are entered on the sensor label and as well as in the sensor´s routine test report. To achieve the required accuracy classes, it is recommended to use both correction factors (Cfs), that is, the amplitude correction factor (aU) and the phase error correction factor (pU) of the voltage sensor.

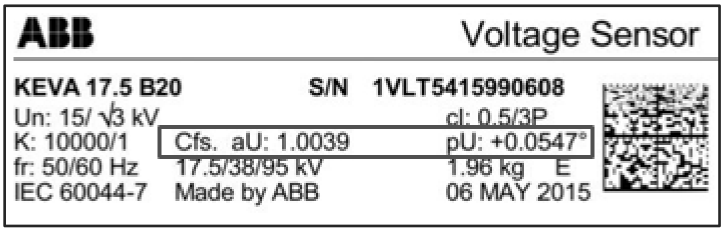


Figure 44: Example of a voltage sensor label

Due to linear characteristics of the sensor measurement error caused by manufacturing tolerances can be compensated for by using correction factors entered in the protection and control relay. The correction factors are entered via parameter setting in PCM600 *(IED Configuration / Configuration / Analog inputs / Voltage (3U, VT))*

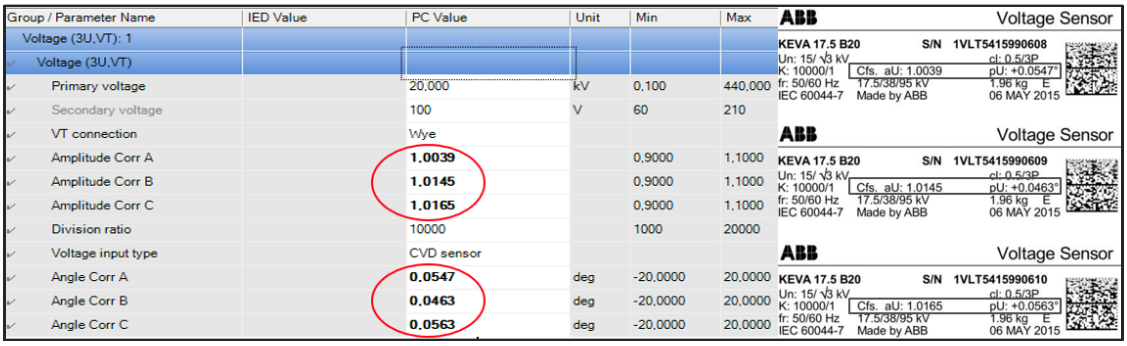


Figure 45: Example of setting the correction factors for the voltage sensors in PCM600

Amplitude correction factors of sensors also affect the scaling of SMV frames. Thus, it is enough to configure these correction factors in the sender only. On the other hand, phase error correction factors affect only the phasor of fundamental frequency and need to be set both in the SMV senders and the receivers.

Other parameters

The voltage sensor is based on the resistive divider principle. Therefore, the voltage is linear throughout the whole measuring range. The output signal is a voltage, directly proportional to the primary voltage. For the voltage sensor all parameters are readable directly from its rating plate and conversions are not needed.

In this example the system phase-to-phase voltage rating is 10 kV.

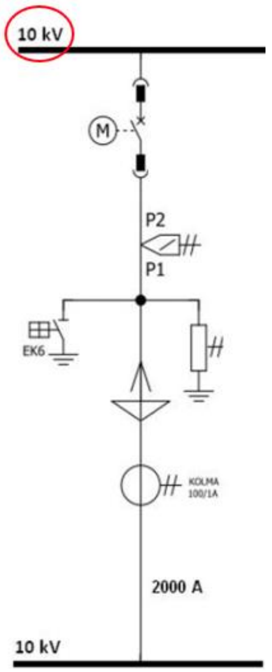
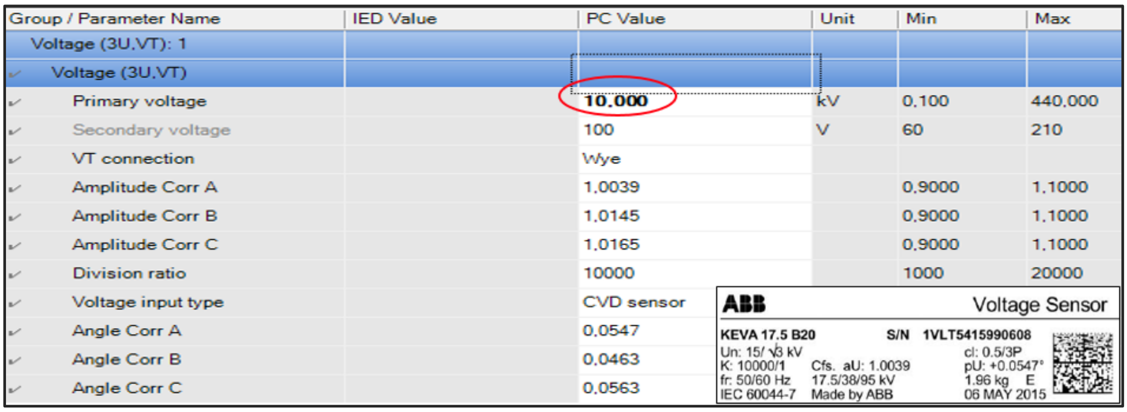


Figure 46: Single line diagram

Primary voltage parameter is set to 10 kV. For protection and control relays with sensor measurement support the *Voltage input type* is always set to “CVD sensor” and it cannot be changed. The same applies for the *VT connection* parameter which is always set to “WYE” type. The division ratio is 10 000: 1. Thus, the *Division ratio* parameter is set to “10 000”. The primary voltage is proportionally divided by this division ratio.



Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
Voltage (3U,VT): 1					
Voltage (3U,VT)					
Primary voltage		10,000	kV	0,100	440,000
Secondary voltage		100	V	60	210
VT connection		Wye			
Amplitude Corr A		1,0039		0,9000	1,1000
Amplitude Corr B		1,0145		0,9000	1,1000
Amplitude Corr C		1,0165		0,9000	1,1000
Division ratio		10000		1000	20000
Voltage input type		CVD sensor			
Angle Corr A		0,0547			
Angle Corr B		0,0463			
Angle Corr C		0,0563			

Figure 47: Example of setting values for Voltage sensor in PCM600

3.2 Documentation

Network overview diagram

The diagram provides an overview of the substation network (interconnections between the protection and control relay and Ethernet switch, network architectures, and device location – Panel No. …)

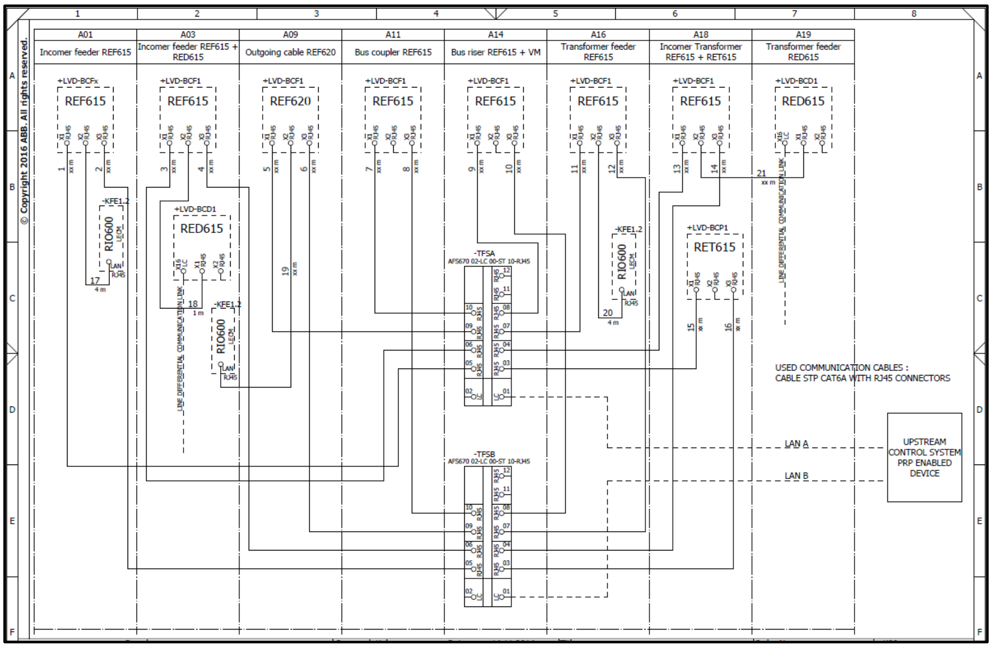


Figure 48: Example of a Network Overview Diagram

Logic diagrams for interconnection between panels

The GOOSE Logic diagrams show the principle of the application used and are project oriented.

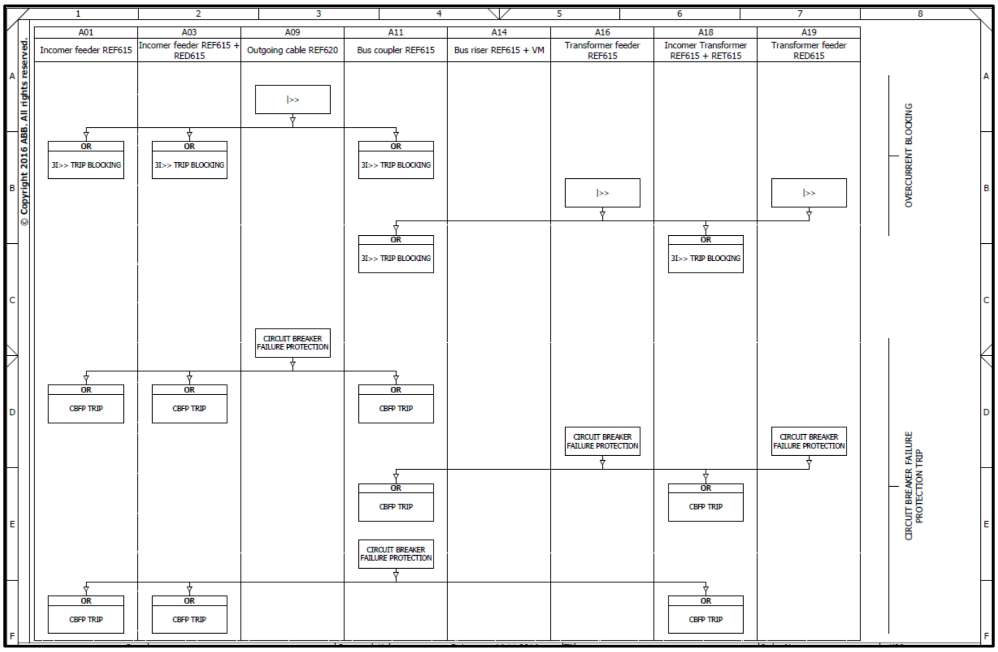


Figure 49: Example of a logic diagram for interconnection between panels

Sampled measured value diagram

The diagram gives overview about measurement sharing when using the IEC 61850-9-2LE (Process Bus).

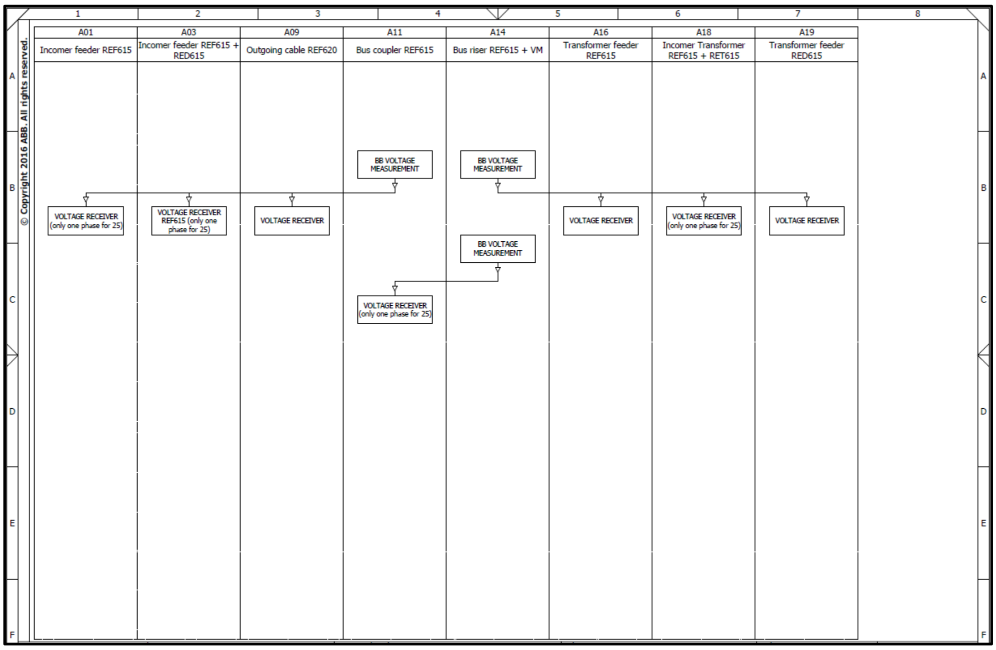


Figure 50: Example of a Sampled measured value diagram

3.3 Station bus (GOOSE)

Protection and control relay manager (PCM600)

The protection and control relay configuration process is carried out via a protection and control relay configuration tool. The PCM600 provides versatile functionalities for the entire lifecycle of all Relion® protection and control relay applications, on all voltage levels. The IEC 61850 configuration tool of PCM600 makes it possible to view or engineer a data set and dataflow configuration for a vertical, GOOSE and SMV IEC 61850 communication. The IEC 61850 configuration tool is recommended to be used for simple applications.

– PCM600 v.2.5 or later / IEC 61850 Configuration / GOOSE Communication

Always use the latest version of PCM600 and the latest relevant connectivity package for protection and control relays.

Integrated Engineering Tool (IET600)

The IET600 is a System Configuration Tool which contains various modules to complete the system engineering of an IEC 61850 based substation, including:

– Configuration of the substation topology

– Configuration of the communication network

– Configuration of the IEC 61850 dataflow (Data sets, Control blocks)

– Engineering of typical bays for efficient engineering

– Import and export of IEC-61850-SCL data for exchange with other tools

– Export of project data for documentation

The IET600 tool is recommended for use in advanced applications. Always use the latest version of IET600 and the latest relevant connectivity package for protection and control relays.

Detailed information on the specific protection and control relay and its network configuration can be found in the Technical Manual or in the IEC 61850 Engineering Guide of dedicated protection and control relay.

Configuration procedure in PCM600

A maximum of allowed GOOSE control blocks, data sets and data attributes of the protection and control relay must not be exceeded. To minimize the message-handling load in receiving and sending protection and control relays, it is recommended to limit data attributes amount to 20 per data set.

Only three simple steps are needed to get GOOSE engineered in PCM600.

Step 1 / 3

Creating a GOOSE data set and its entries with the IEC 61850 Configuration tool

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

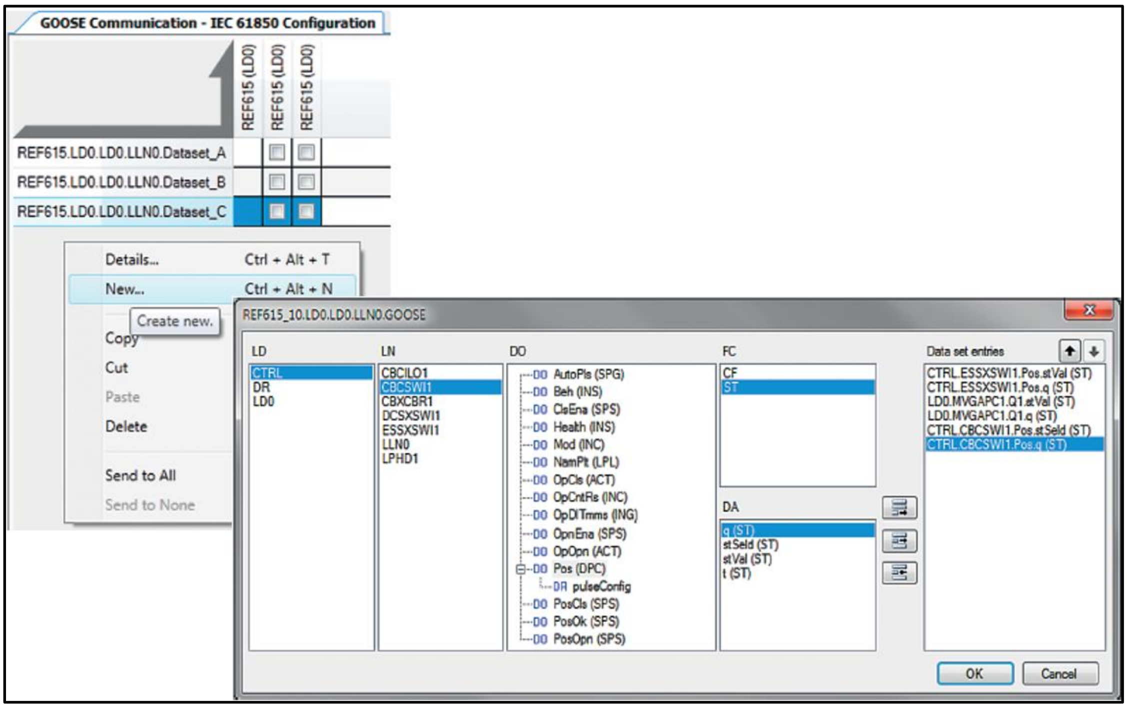


Figure 51: Creating a new GOOSE data set and its entries

A maximum of 20 data attributes can be added to a single GOOSE data set. If a data set has quality attributes, the attributes must be located after the status value of the same data object.

Step 2 / 3

Configuring a GOOSE control block with the IEC 61850 Configuration tool

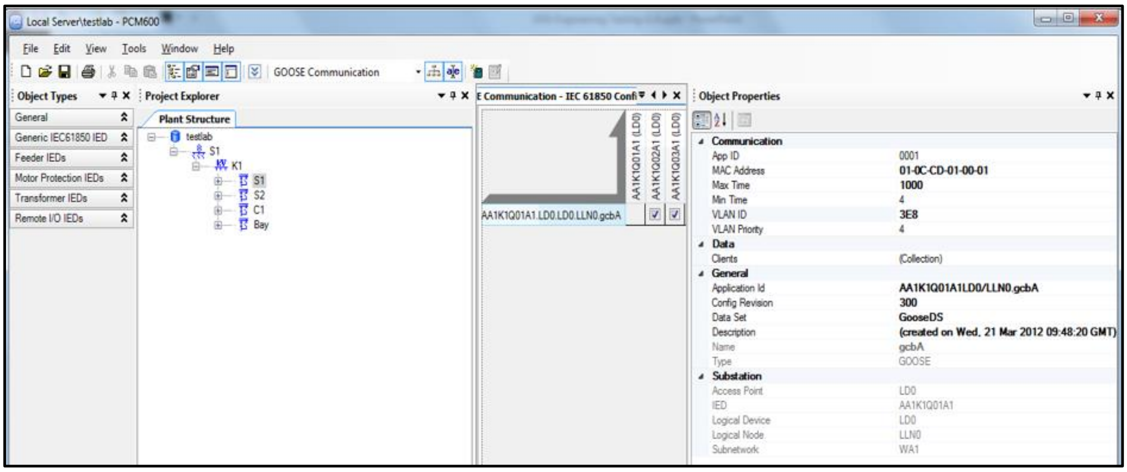


Figure 52: GOOSE control block properties

The data set defines what protection and control relay 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.

GOOSE Control Block Attributes

– APPID – unique GoID in network
  - Reserved value is ranging from ***0x0000*** to ***0x3FFF*** (Ed.1)
– MAC address
  - Unique Multicast address per GoCB is recommended
  - The allowed multicast address ranges from ***01-0C-CD-01-00-00*** to ***01-0C-CD-01-01-FF***
– GOOSE Control block name
– Data set definition
– VLAN ID
  - The default value is 0x000; it should be configured to > 0
  - Recommended values (as per IEC 61850-90-4) are ranging from ***0x3E8 (1 000)*** to ***0x5E7 (1 511)***
– VLAN priority
  - The default value is **4** as per IEC 61850-8-1 (value range 0 …7)
– T_{min} [ms]
  - Maximum response time to data change
– T_{max} [ms]
  - Heartbeat cycle time in (the default value is 10 000 ms)
– ConfRev
  - Its value increases when referenced data set becomes modified

Step 3 / 3

Configuring GOOSE receivers with the IEC 61850 Configuration tool

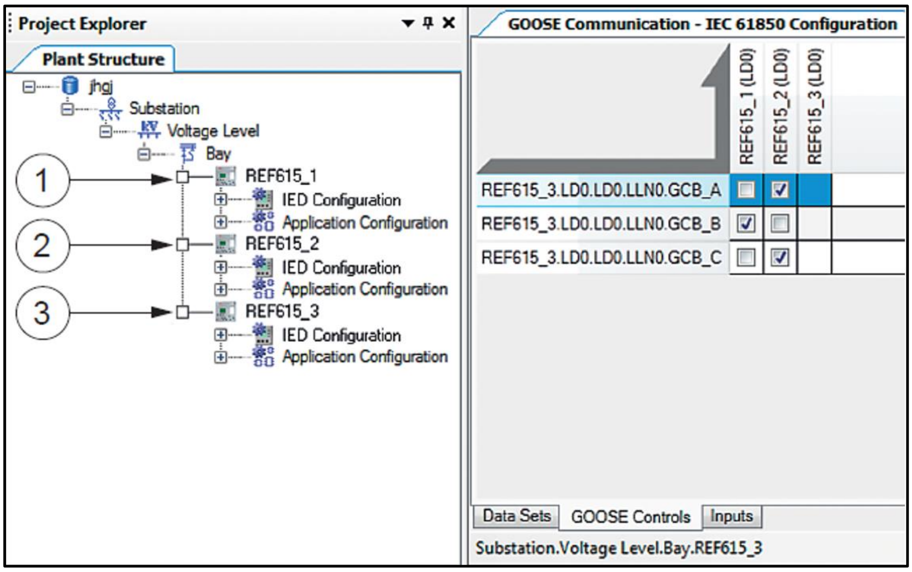


Figure 53: GOOSE control block editor (1- receiver #1, 2- receiver #2, 3 – sender)

Configuration procedure in IET600

Step 1 / 6

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.

Step 2 / 6

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

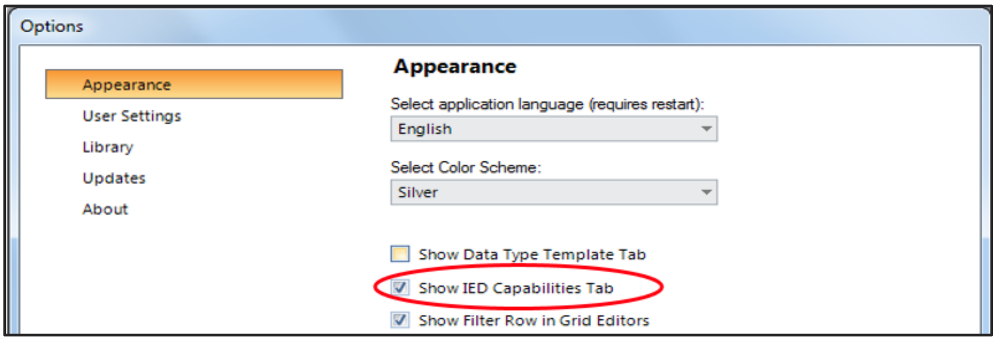


Figure 54: Selecting Show IED Capabilities Tab

In the IED Capabilities tab, check the *Override for Client Service for Client Service Conf Dataset Modify* box to adjust the IED615 / IED620 option to support GOOSE dataset modification.

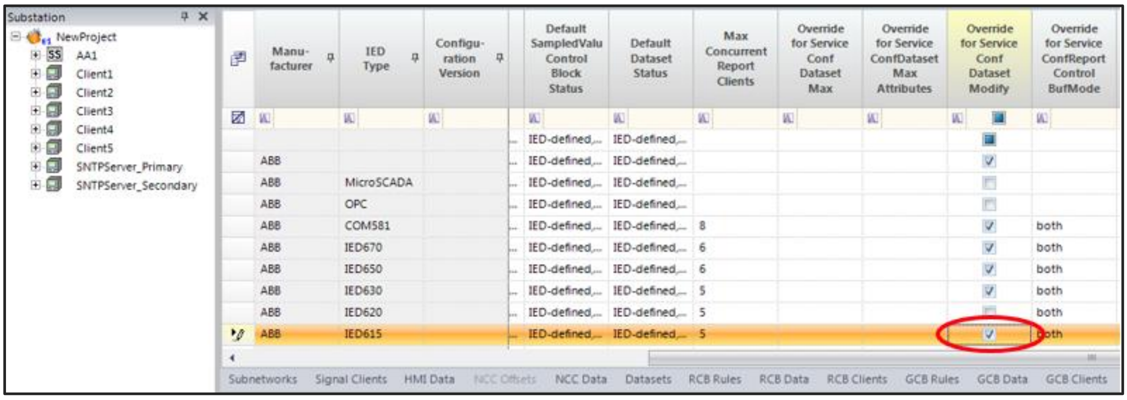


Figure 55: Editing 615 series capabilities

Step 3 / 6

Creating a GOOSE data set and its entries with the IET600

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

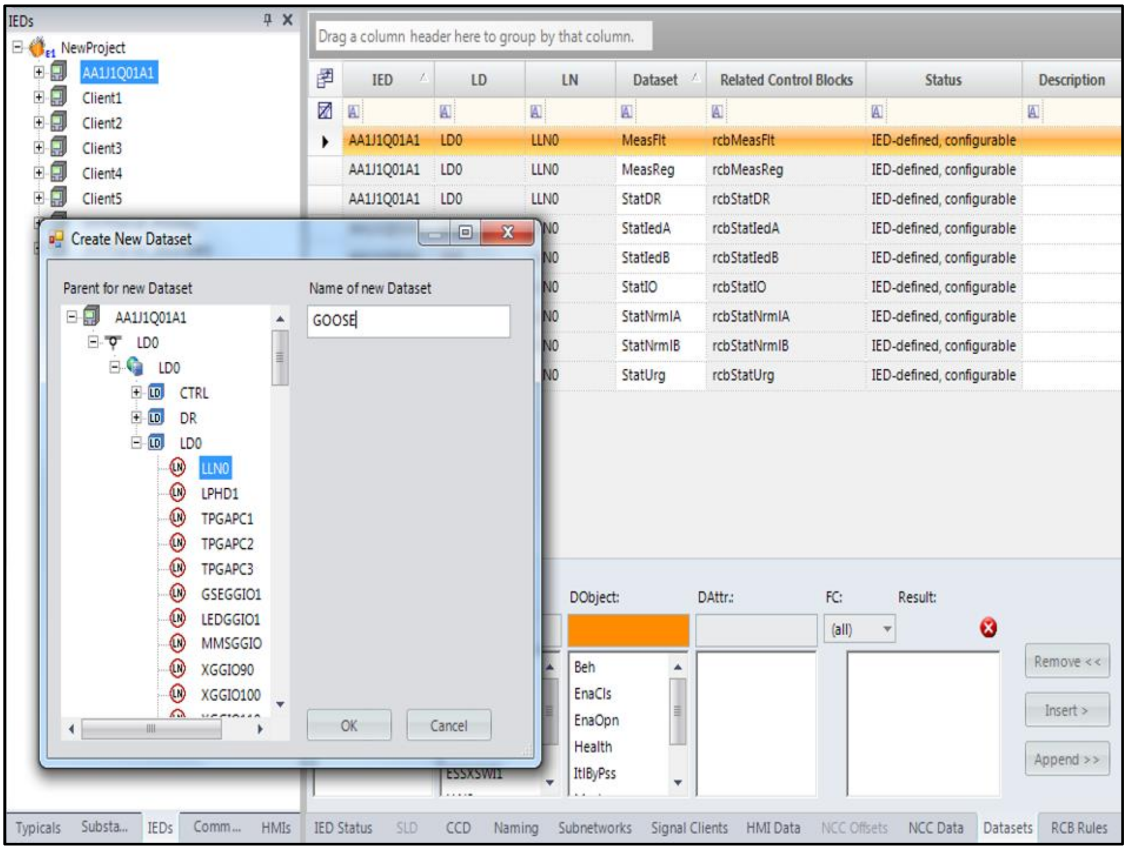


Figure 56: Creating a new GOOSE data set and its entries

Step 4 / 6

Configuring a GOOSE control block with the IET600

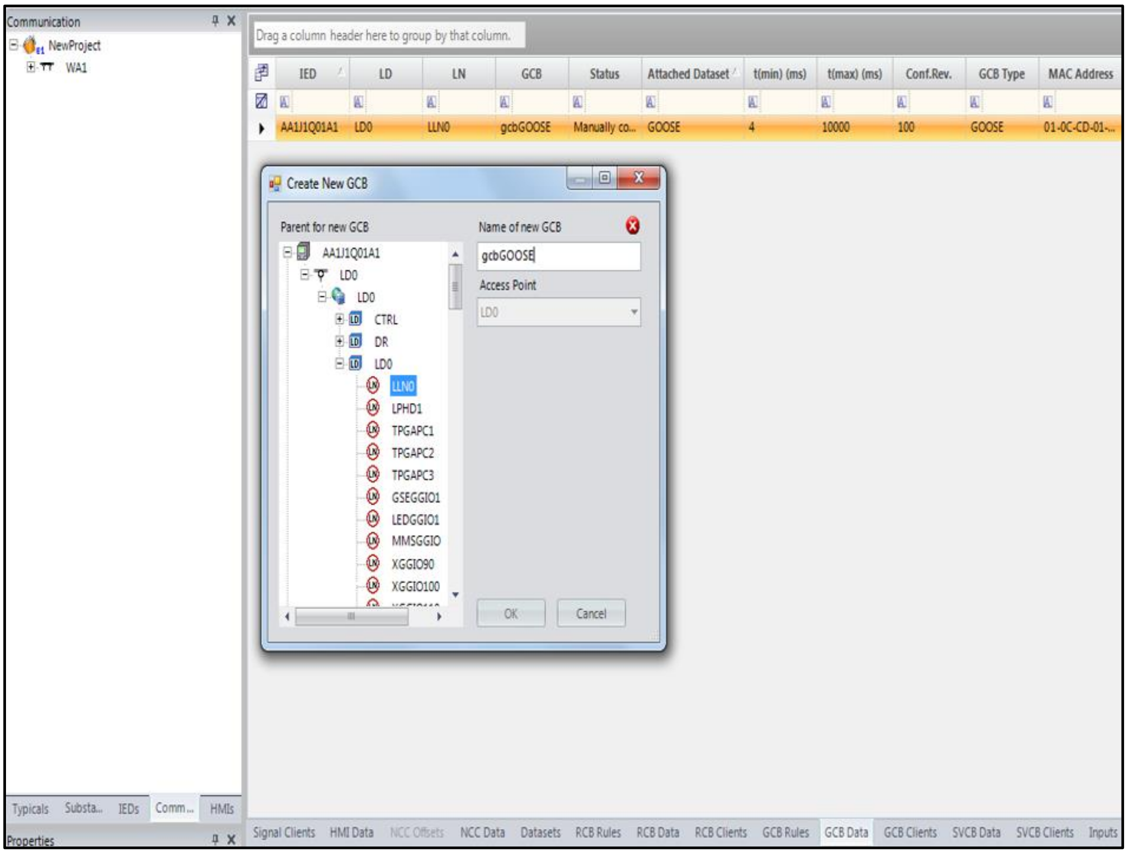


Figure 57: Naming a GOOSE control block

Step 5 / 6

Configuring GOOSE receivers with the IET600

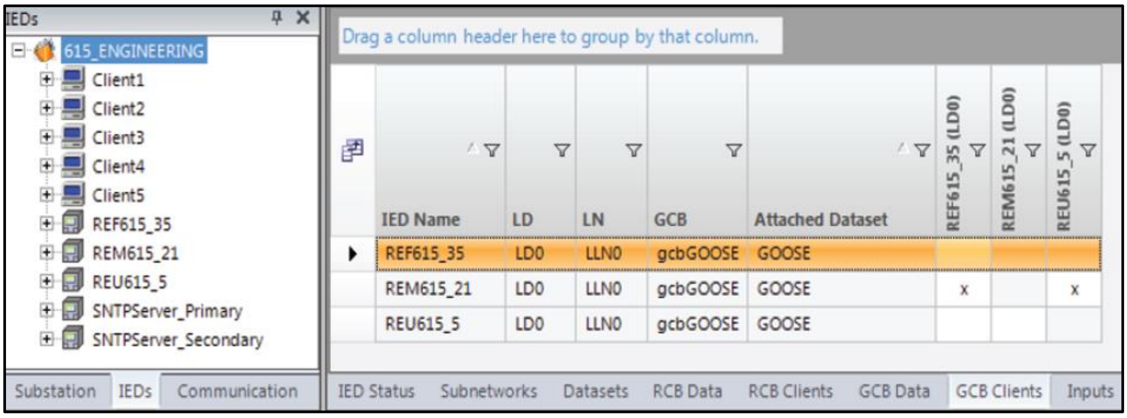


Figure 58: GCB client

Step 6 / 6

Save and export the SCD file and import it to PCM600

Connecting GOOSE sender data to a protection and control relay application in PCM600

Step 1 / 3

Adding GOOSERCV function block with 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.

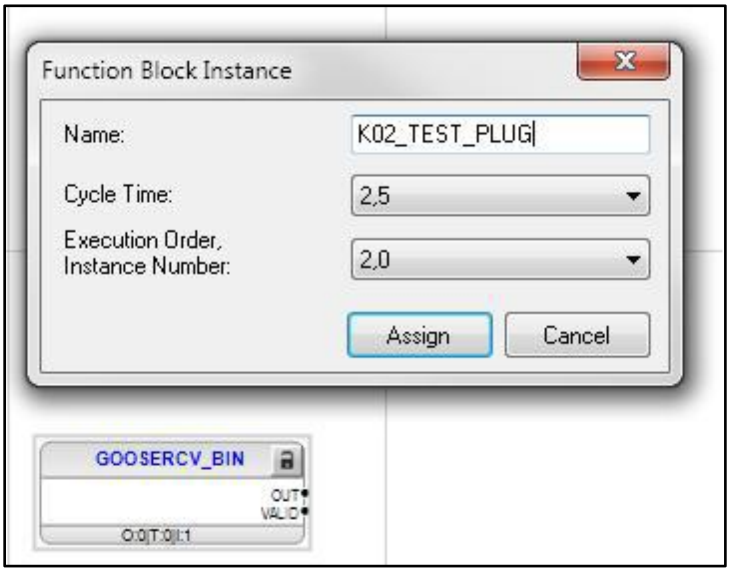


Figure 59: Adding a GOOSERCV function block in the Application Configuration Tool

Step 2 / 3

Creating GOOSERCV block connection into the application

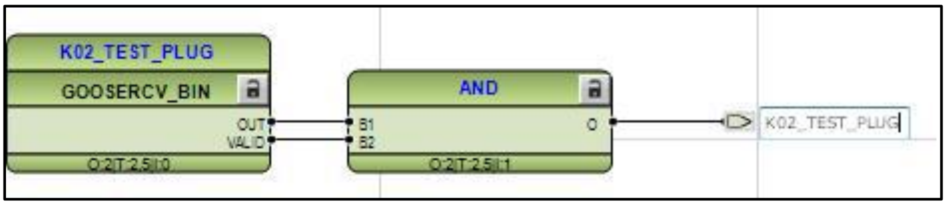


Figure 60: Creating GOOSERCV block connection to a new variable

Step 3 / 3

Mapping of GOOSE sender data into the corresponding GOOSERCV function block in Signal Matrix

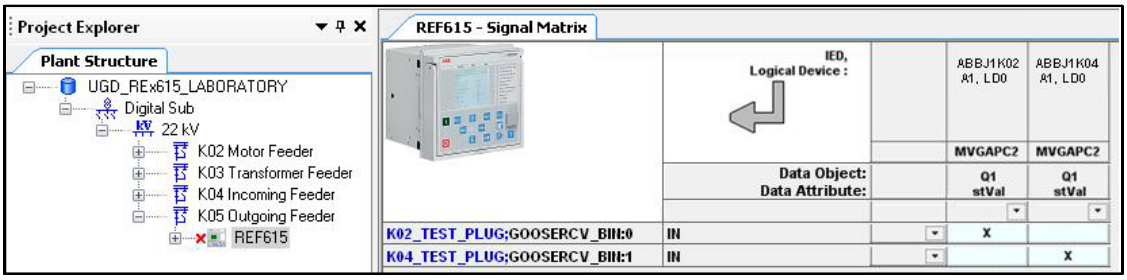


Figure 61: Signal Matrix

3.4 Process bus (SMV)

Supported applications

Power measurement, directional protections, voltage-based protections and synchro-check work when voltage is shared over the Process bus.
640 series support redundant SMV streams by using the voltage (VMSWI) and current (CMSWI) function blocks. Automatic switching to the backup SMV stream can be configured in Application Configuration using SMV quality and / or other logic.

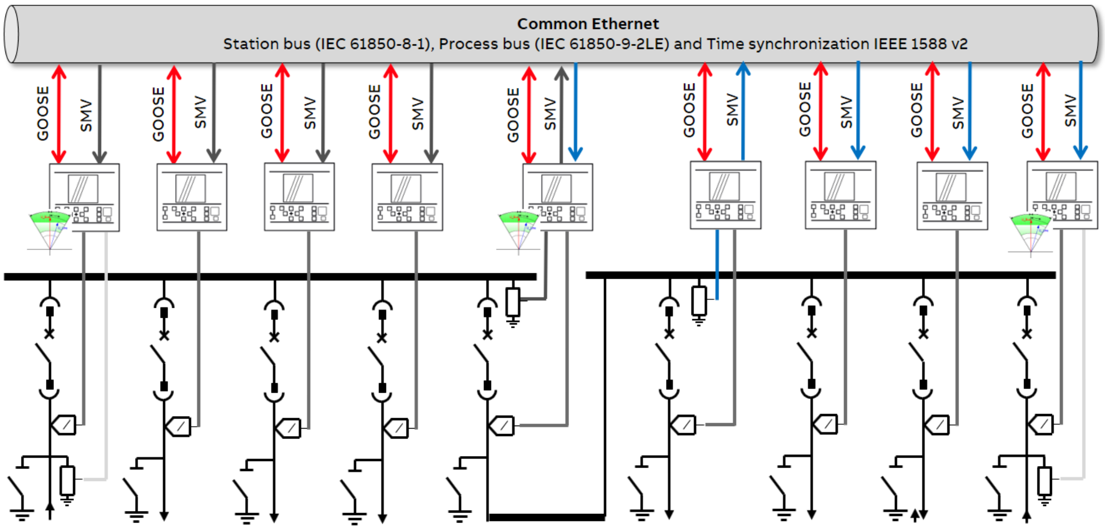


Figure 62: Example of Process bus application of voltage sharing and synchro-check

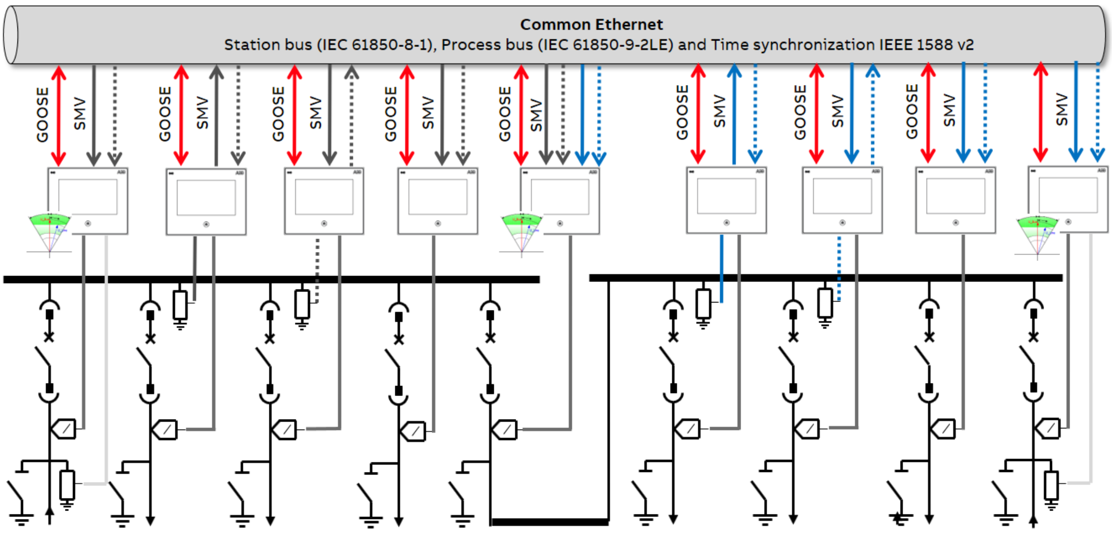


Figure 63: Example of Process bus application of voltage sharing redundancy and synchro check

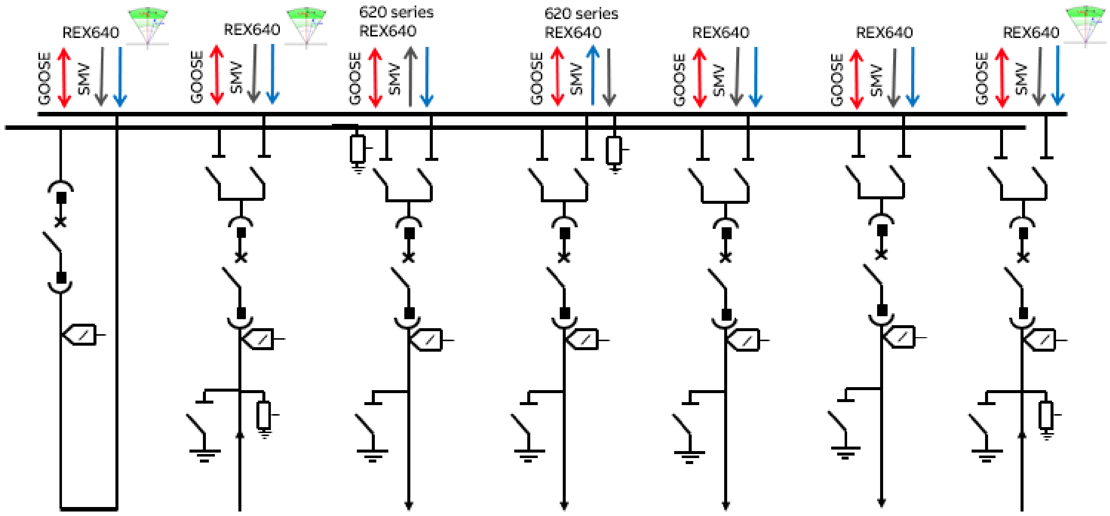


Figure 64: Example of Process bus application of voltage sharing (Double busbar system) and synchro check

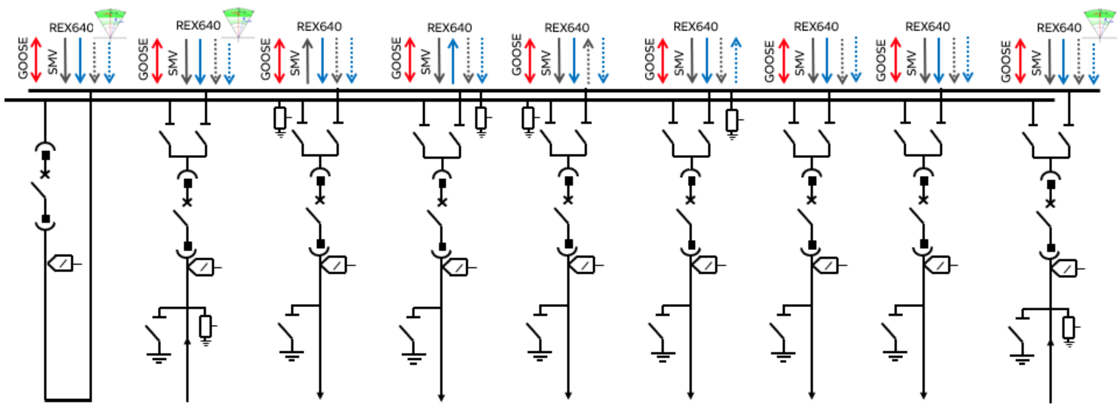


Figure 65: Example of Process bus application of voltage sharing redundancy (Double busbar system) and synchro check

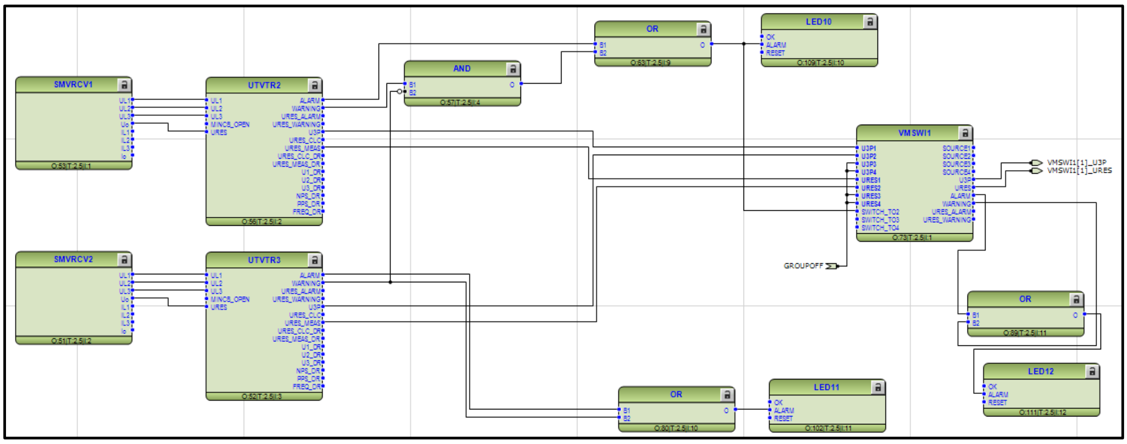


Figure 66: Example of VMSWI voltage switch function block implementation in the Application Configuration Tool

SMV Engineering tools

– PCM600 v.2.6 or later / IEC 61850 Configuration / Process bus Communication

– IET600 v.5.2 or later

Always use the latest version of tools and the latest relevant connectivity package for protection and control relays.

Detailed information on the specific protection and control relay and its network configuration can be found in Technical Manual of dedicated protection and control relay or in the IEC 61850 Engineering Guide, ABB Oy, Distribution Automation.

Configuration procedure in PCM600

Only four simple steps are needed to get Process Bus engineered in PCM600.

Step 1 / 4

Activation of transmission of Sampled Measured Value needs to have the SMVSENDER function block added to the Application Configuration Tool (ACT) in a voltage sender protection and control relay. By adding the SMVSENDER function block new data set is automatically added to the protection and control relay configuration and a control block for SMV is created.

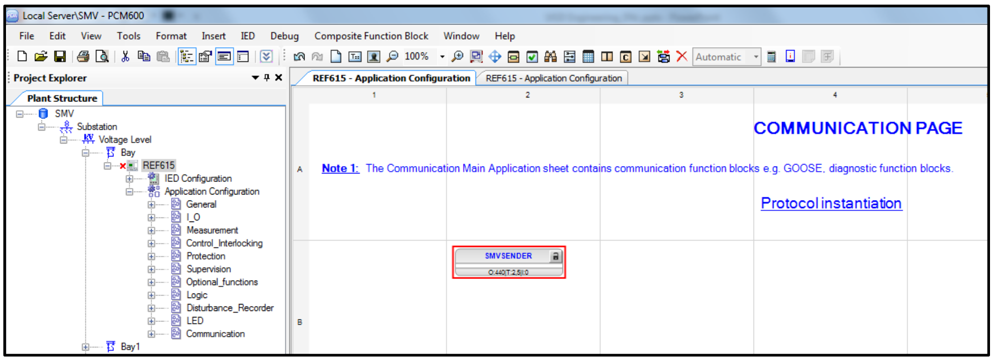


Figure 67: Adding a SMSENDER block in the Application Configuration Tool

Supervision of Sampled Measured Value receiving status needs to have the ULTVTR1 function block added to the ACT in all voltage receiver protection and control relays.

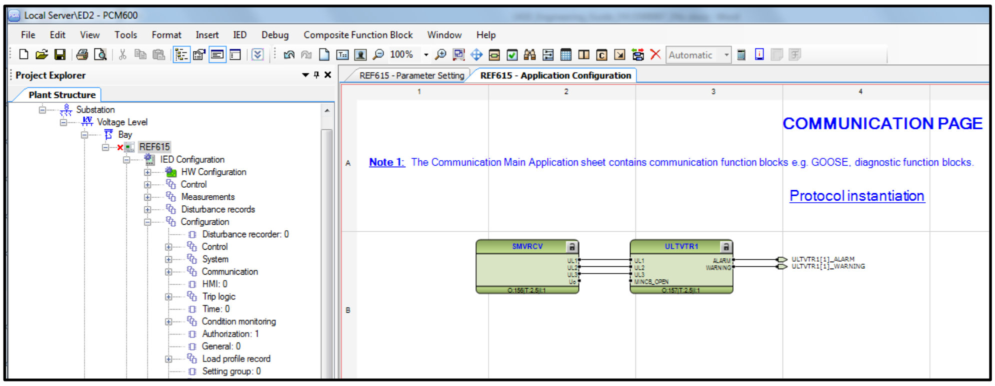


Figure 68: Adding a ULTVTR1 block in the Application Configuration Tool

Step 2 / 4

Since the SMV needs to obtain accurate time synchronization the synchronization method is to correspond to IEEE 1588, with the PTP priority to be set to correct values. Lower value means highest priority. Identical time synchronization method is to be used in all SMV sending and receiving protection and control relays.

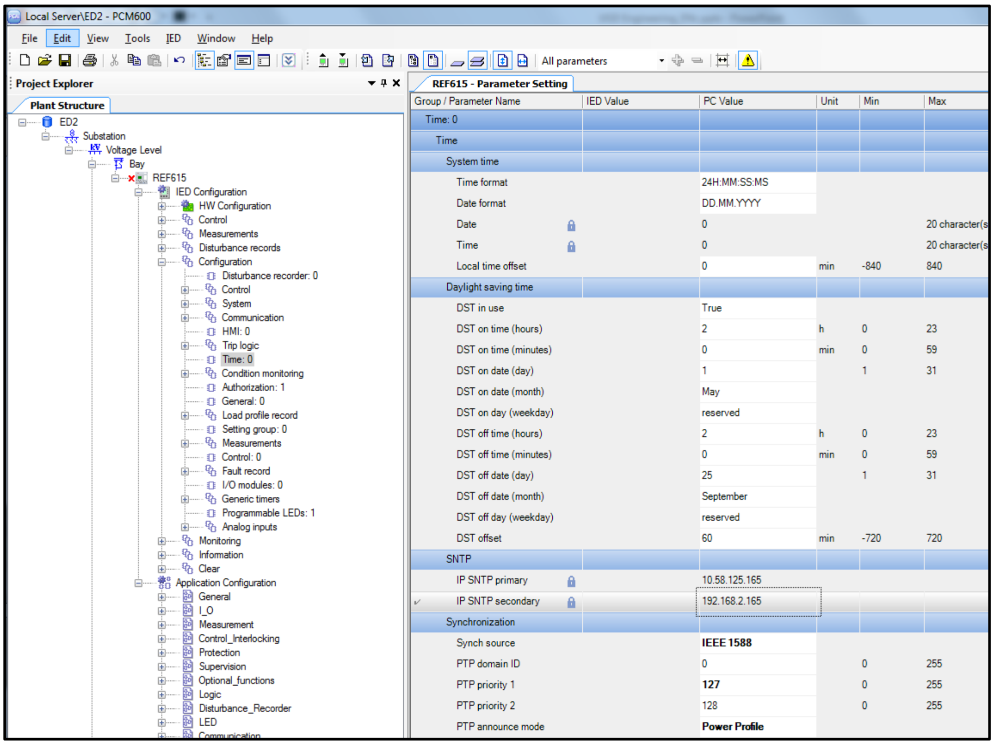


Figure 69: Time parameter setting dialog in PCM600

IED Configuration / Configuration / Time / Parameter Setting / Synchronization

- Synch source = IEEE 1588
- PTP domain ID = 0, only clocks with the same domain are synchronized
- PTP priority 1 = 127...128, the clock with the lowest priority 1 becomes reference clock (Grandmaster)
- PTP priority 2 = 128...255, if all the relevant values for selecting the reference clock for multiple devices are the same, the clock with the lowest priority 2 is selected as the reference clock
- PTP announce mode: Power Profile

It is recommended to set Priority 1 and Priority 2 to be equal to 128 for all protection and control relays, except the voltage sender protection and control relays (Priority 1 = 127, Priority 2 = 128...255 to be different for each protection relay). Voltage sender protection and control relay provides the synchronization of network time in case Grandmaster clock is not available.

Step 3 / 4

The connection between SMV sender and receiver is handled using the IEC 61850 Configuration tool. Protection and control relay can receive voltage only from one another relay via IEC 61850-9-2LE.

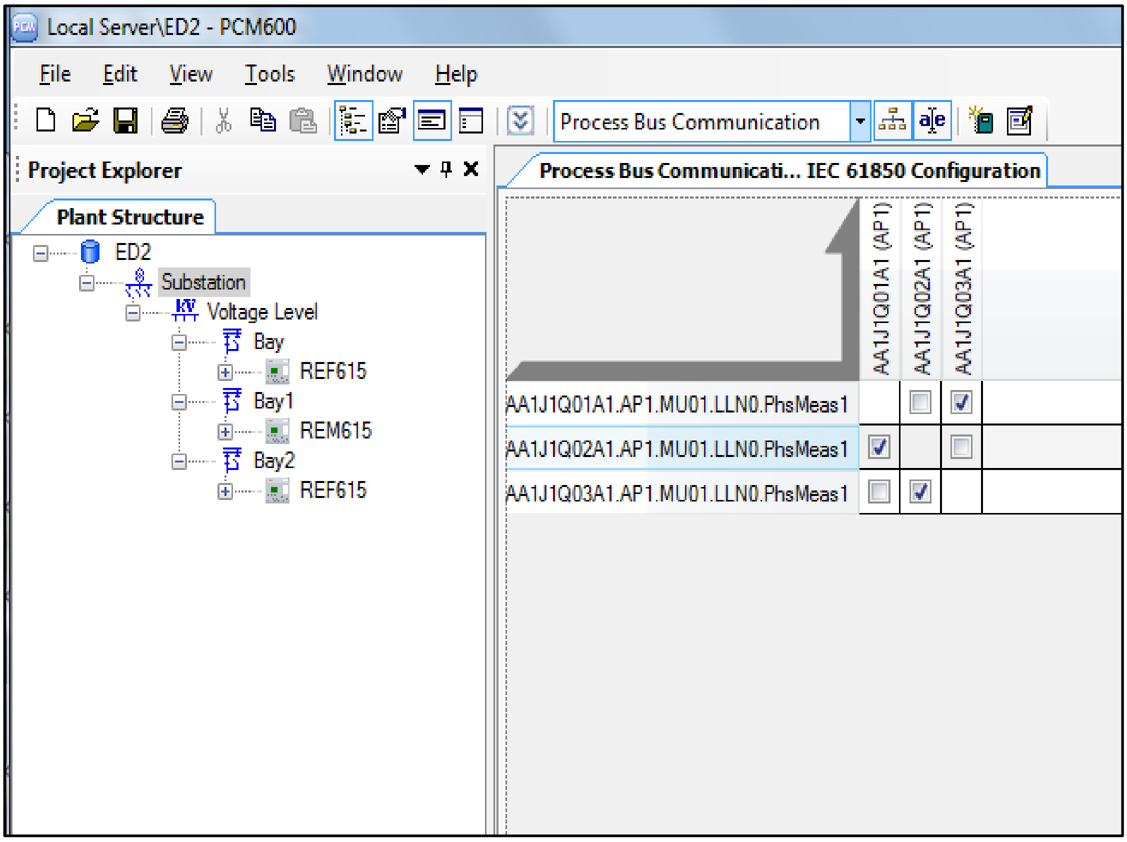


Figure 70: Configuring the SMV senders and receivers

Step 4 / 4

Setting the Sampled Measured Value Control Block attributes

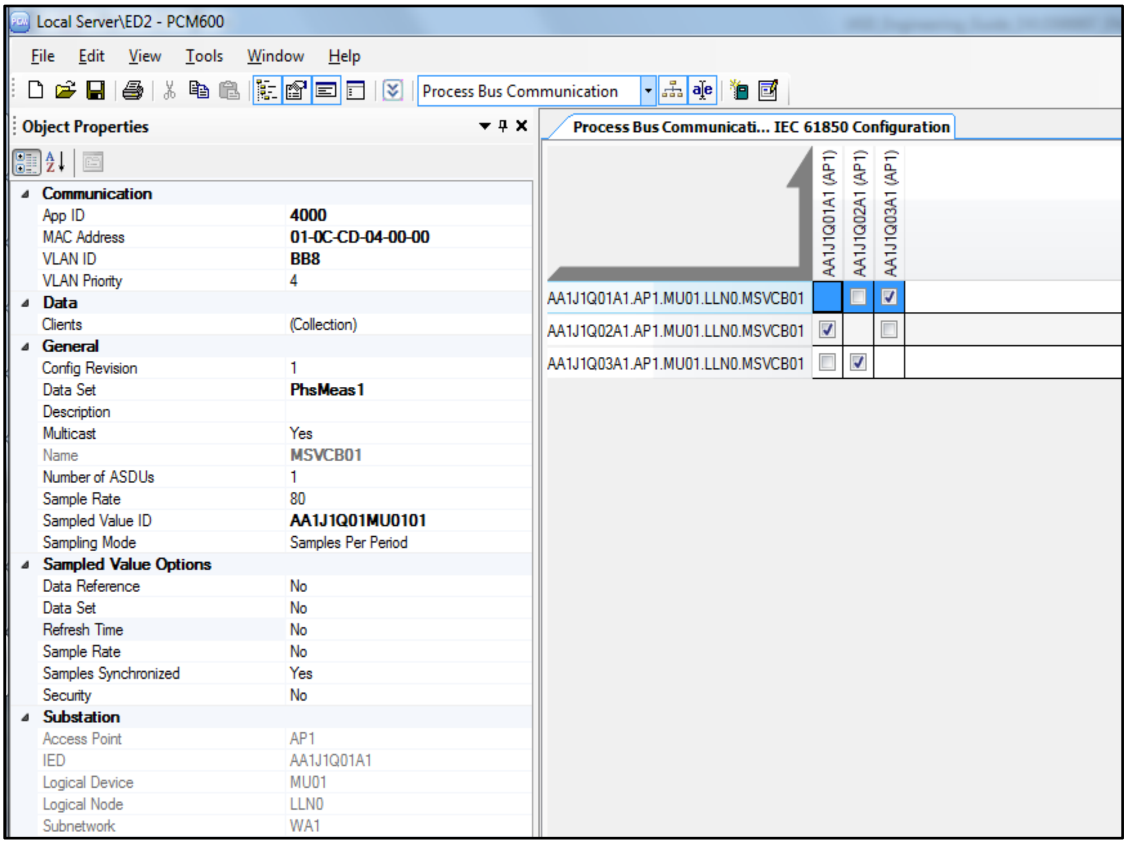


Figure 71: Changing the Sampled Measured Value Control Block attributes

Sampled Measured Value Control Block Attributes

– App ID – unique SvID in network
  - Reserved value range is from ***0x4000*** to ***0x7FFF*** (if no APPID is configured, the default value shall be 0x4000 based on IEC 61850-9-2)
– MAC address
  - Unique Multicast address per Control Block is recommended
  - The allowed multicast address range is from ***01-0C-CD-04-00-00*** to ***01-0C-CD-04-01-FF***
– VLAN ID
  - The default value is 0x000, should be configured > 0
  - Recommended value range (as per IEC 61850-90-4) is from ***0xBB8 (3 000)*** to ***0xDB7 (3 511)***
– VLAN priority
  - The default value is **4** as per IEC 61850-9-2 (value range 0 …7)
– Config Revision
  - It increases in case of modification of attributes
  - Recommended value is **1**
– Data Set Definition
– Control block name (Sampled value ID)

If configuration is updated in a manner that affects the *Config Revision* value of Sampled Measured Value Control Block, update all SMV sender and receiver protection and control relays using the PCM600 tool.

Configuration procedure in IET600

Step 1 / 5

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.

Step 2 / 5

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

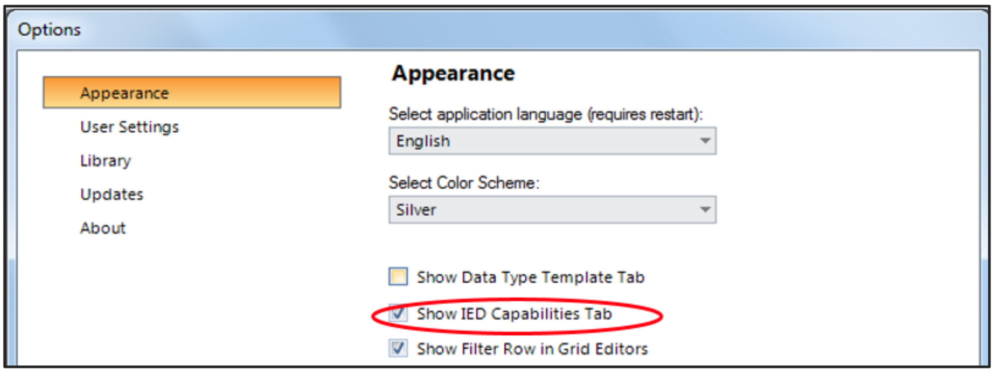


Figure 72: Selecting Show IED Capabilities Tab

In the IED Capabilities tab, check the *Override for Client Service SampledValues* box to adjust the IED615 / IED620 option to support sampled values services.

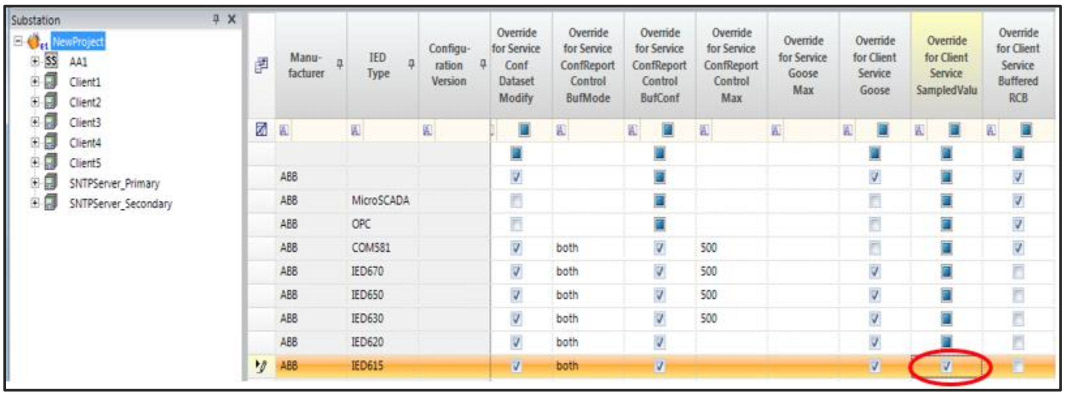


Figure 73: Editing 615 series capabilities

Step 3 / 5

Configuring sampled value control block in the IET600

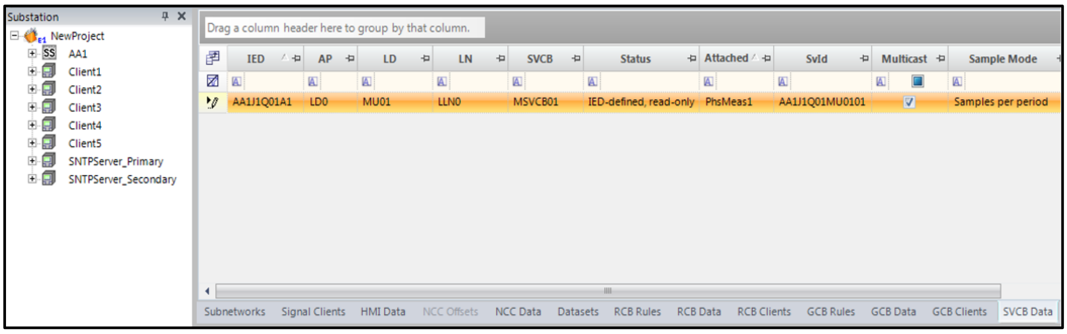


Figure 74: Sampled value control block

Step 4 / 5

Connecting the SMV senders and receivers in the IET600

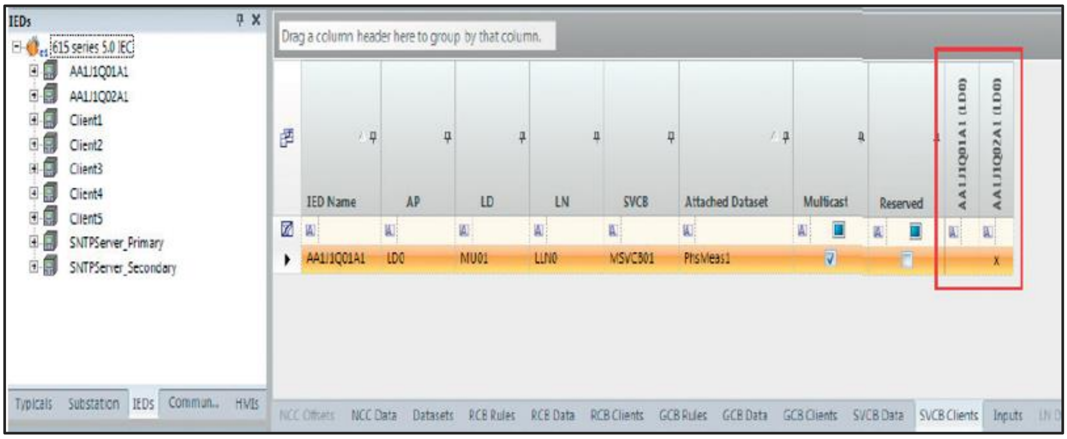


Figure 75: Connecting the SMV senders and receivers

Step 5 / 5

Save and export the SCD file and import it to PCM600

Application configuration of the SMV receiver

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 protection and control relay. 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 input. RESTVTR1 input is typically connected only in case there is measured neutral voltage needed and then available from the sender.

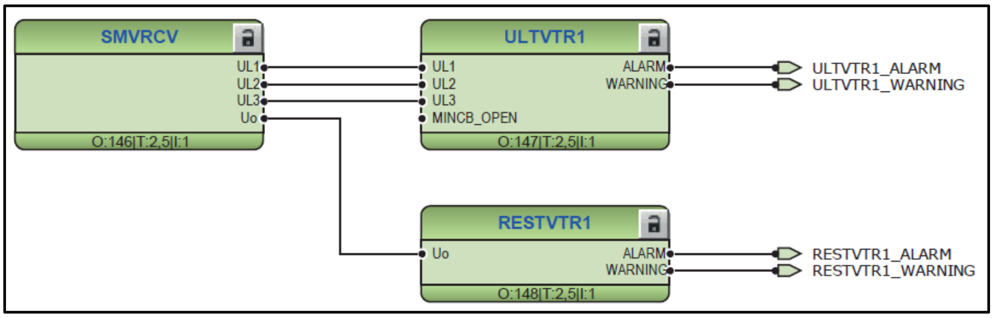


Figure 76: Receiving all phase voltages and residual voltage using SMV

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

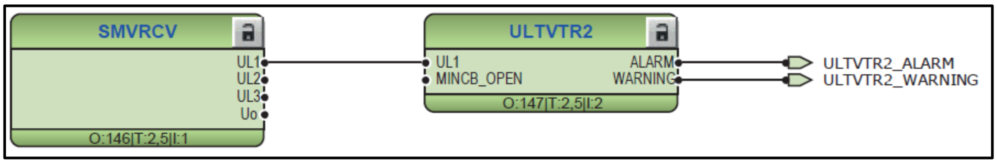


Figure 77: Receiving line voltage for synchrocheck functionality using SMV

The ALARM output of UL1TVTR1 function block should be connected to ensure failsafe operation in all circumstances. The WARNING output is always internally active whenever the ALARM output is active. The WARNING in the receiver is activated if the synchronization accuracy of the sender or the receiver is less than 4 µs. The output is held on for 10 s after the synchronization accuracy returns within limits. The ALARM in the receiver is activated if the synchronization accuracy of the sender or the receiver is unknown, less than 100 ms or more than one consecutive frame is lost. The output is held on for 10 s after the synchronization accuracy returns within limits.

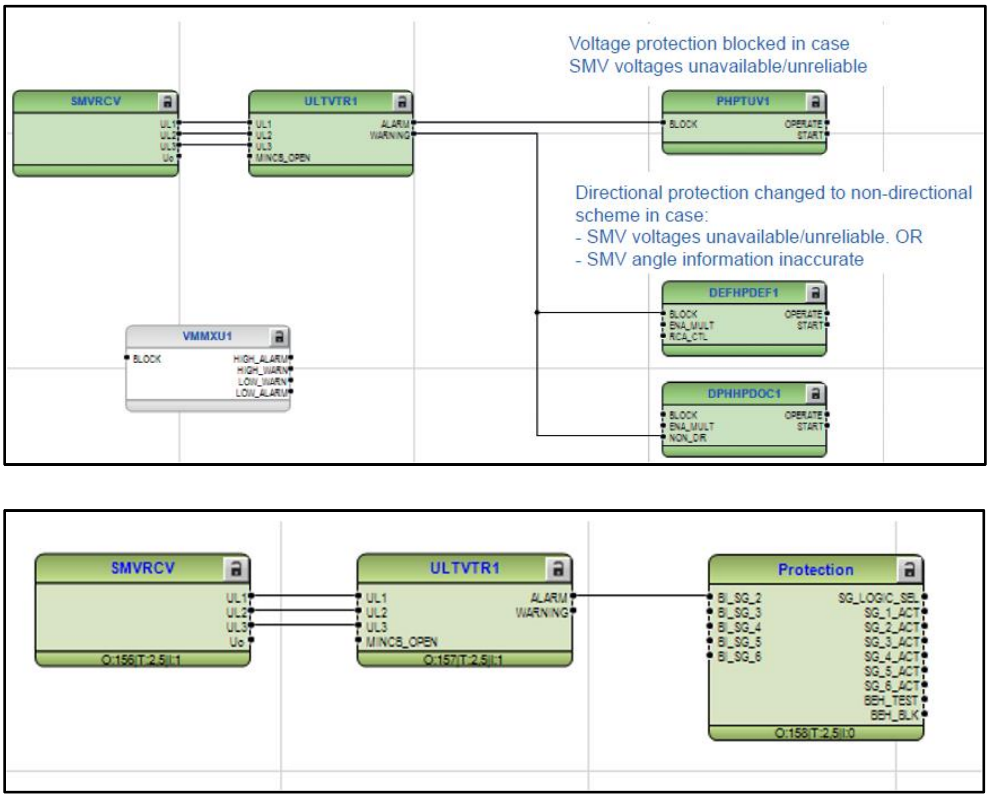


Figure 78: Application Configuration tool logic examples for the SMV fail save operation

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 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.

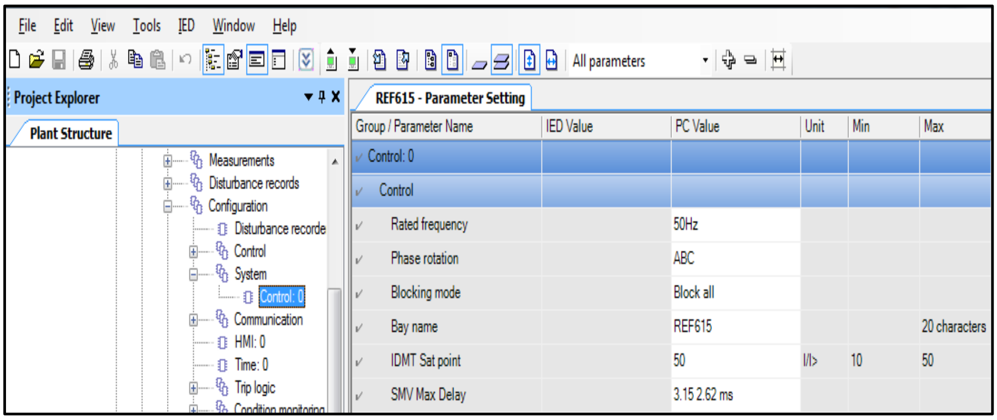


Figure 79: SMV Max delay setting in PCM600

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 WARNING or ALARM outputs.

Table 5: Topology-dependent SMV max delay setting

Number of hops in network	Internal App.delay [µs] [50Hz]	Internal switch delay [µs]	Store and forward latency [µs]	Queue latency [µs] 1)	Additional tolerance [µs] 2)	Theoretical max delay [µs]	Recommended max delay setting [µs]
2	1 746	20	24	240	80	2 112	3 150
5	1 746	50	60	600	200	2 656	3 150
10	1 746	100	120	1 200	250	3 416	3 150
15	1 746	150	180	1 800	300	4 176	3 150
20	1 746	200	240	2 400	350	4 936	4 400
25	1 746	250	300	3 000	400	5 696	5 650
30	1 746	300	360	3 600	450	6 456	5 650

1) 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

2) Additional tolerance in case of long wires or disturbance in network

Default max delay setting (3 150 µs) can be set for most of the communication topologies. Special attention must be focused on HSR topology when number of hops in network should be calculated for the worst situation (HSR ring is open).

3.5 Ethernet

3.5.1 Requirements

Electro Magnetic Immunity (EMI)

The IEC 61850-3 standard outlines the EMI immunity requirements for communication equipment installed in substations. EMI phenomena include inductive load switching, lightning strikes, electrostatic discharges from human contact, radio frequency interference due to personnel using portable radio handsets, ground potential rise resulting from high current fault conditions within the substation and a variety of other events commonly encountered in the substation.

Environmental Robustness

Both the IEC 61850-3 standard and the IEEE P1613 standard define the atmospheric environmental requirements for network communication devices such as the Ethernet switches in substations. Devices connected to the substation network must be specifically toughened for the substation environment.

Real-Time Operation

Modern managed Ethernet switches offer advanced Layer 2 and Layer 3 features that are critical for real-time control and substation automation. These include:

– IEEE 802.3x **Full-Duplex** operation on all ports, which ensures that no collisions occur and thereby makes Ethernet much more deterministic. There are absolutely zero collisions in connections that both support IEEE 802.3x Full-Duplex operation.

– IEEE 802.1p **Priority Queuing**, which allows frames to be tagged with different priority levels to ensure that real-time critical traffic always makes it through the network even during periods of high congestion.

– IEEE 802.1Q **VLAN** which allows the segregation and grouping of protection and control relays into virtual LANs to isolate real-time protection and control relays from data collection or less critical protection and control relays.

– IEEE 802.1w **Rapid Spanning Tree Protocol**, which allows the creation of fault tolerant ring network architectures that will reconfigure in milliseconds as opposed to tens of seconds, as was the case for the original Spanning Tree Protocol 802.1D.

It is important to note that the above features are based on standards, thereby ensuring interoperability amongst different vendors.

3.5.2 Technology

Metal cabling

Metal cabling consists of four twisted pairs terminated with RJ-45 (not ruggedized) connectors. The cabling should be shielded CAT6 S / FTP or better. In general, metal cabling is susceptible to electromagnetic interference, therefore should be only used inside the panels / switchgear.

Figure 80: FTP patch cable terminated with RJ-45 connectors

Fiber Optic

The ABB standard for fiber optic in substations is the multi-mode fiber cable 50 / 125 µm, 1 300 nm. Multi-mode communication links are generally the most common due to the low cost of fiber cabling and transceivers. When forming a multi-mode link, multi-mode transceivers must be used as well as multi-mode cabling. Multi-mode fiber cable 50 / 125 µm embodies a core size of 50 µm in diameter and a cladding size of 125 µm. 62.5 / 125 µm cabling is generally the most popular one. The name “Multi-mode” comes from the fact that the light used to transmit the data travels multiple paths within the core.

Patch cords

A patch cord or patch cable is an electrical or optical cable used to connect (“patch-in”) one device to another one for signal routing. The patch cord is terminated by connectors on both ends. Interconnections between protection and control relays and the Ethernet switch and between Ethernet switches inside the substation are made with the help of patch cables. Patch cables should be duplex; they have two fiber optics, one used for data transmission and the other for data reception.

Figure 81: Fiber optic patch cable terminated with LC connectors

Fiber Optics Connector

Relion® protection and control relays are equipped with Small Form Factor connectors, type LC. The innovative LC design offers a form factor one-half the size of current industry standards.

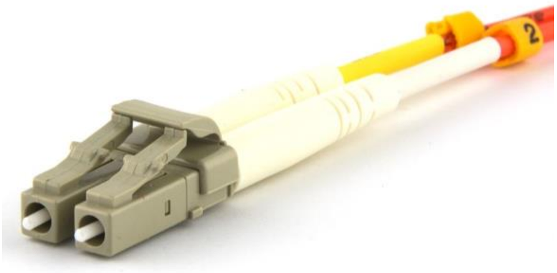


Figure 82: LC connectors

Ethernet rear connections of protection and control relays

The Ethernet communication module is provided with either galvanic RJ-45 connection or optical multimode LC type connection, depending on the product variant and the selected communication interface option.

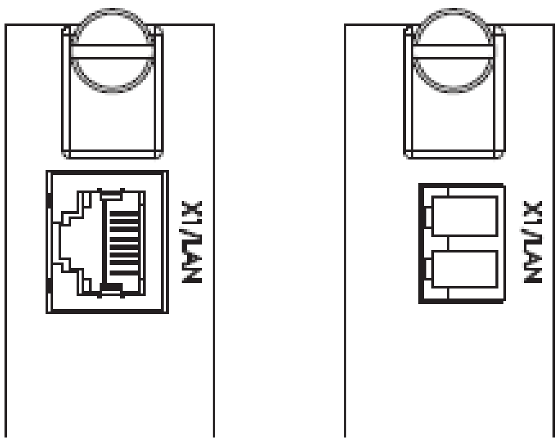


Figure 83: Communication module with single Ethernet connector (615 and 620 series)

Communication modules with multiple Ethernet connectors enable the forwarding of Ethernet traffic. These variants include an internal Ethernet switch that handles the Ethernet traffic. All Ethernet ports share this one common MAC table Ethernet ports marked with LAN A and LAN B are used with redundant Ethernet protocols HSR and PRP. The third port without the LAN A or LAN B label is an interlink port which is used as a redundancy box connector with redundant Ethernet protocols.

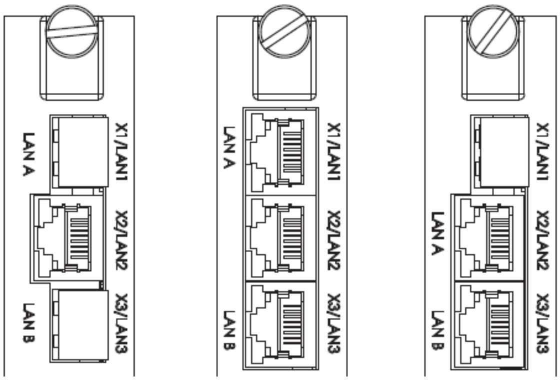
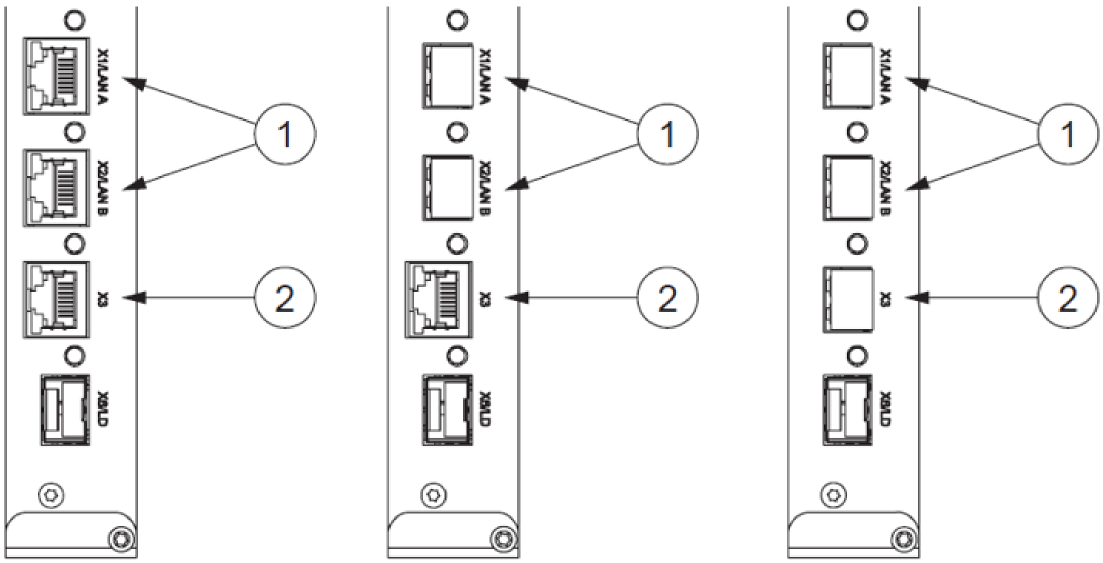


Figure 84: Communication modules with multiple Ethernet connectors (615 and 620 series)



1: Network 1
2: Network 2

Figure 85: Communication modules with multiple Ethernet connectors (640 series)

640 series allow the use of a secondary IP address. This secondary IP network is assigned to a single Ethernet port and can be used to make separate networks for different communication protocols or, for example, a service network for configuration purposes. Multicast communication, such as IEC 61850-9-2LE and GOOSE, is only supported on the Network 1 interface. The IP address for Network 2 is disabled by default settings, and all Ethernet ports are assigned to the same IP address used in Network 1. If Network 2 is taken into use, the interlink port X3 of the module is assigned to this second network and PTP time synchronization and SMV / GOOSE multicast are disabled for that port.

Managed Ethernet switches

A switch is an Ethernet device that filters and forwards data packets between the LAN segments. The switches operate on the data link layer and occasionally the network layer. Packets that arrive on a port are analysed for errors and only forwarded onto the port that has a connection to the destination device.

The AFS family offers many features which are required in the utility environments, including fast protection schemes, redundant power supply and alarm contacts, and enables the stepwise introduction of Smart grid applications. Recommended types of managed Ethernet switches are shown in table below.

Table 6: Recommended Managed Ethernet switches overview for UniGear Digital

Type	Manufacturer	Assembly	Number of ports	HSR Redbox	PRP Redbox	RSTP	SNTP	PTPv2	Station bus	Process bus
AFS670	ABB	19'	up to 24	No	No	Yes	Yes	No	Yes	No
AFS675	ABB	19'	up to 28	No	No	Yes	Yes	No	Yes	No
AFS677	ABB	19'	16	No	No	Yes	Yes	Yes	Yes	Yes
AFS660B	ABB	DIN Rail	8	No	No	Yes	Yes	No	Yes	No
AFS665B	ABB	DIN Rail	10	No	No	Yes	Yes	No	Yes	No
AFS660C	ABB	DIN Rail	6	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AFS660S	ABB	DIN Rail	6	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AFS665S	ABB	DIN Rail	11	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RSG2100	Siemens	19'	up to 19	No	No	Yes	Yes	No	Yes	No
RST2228	Siemens	19'	Up to 28	No	No	Yes	Yes	Yes	Yes	Yes
RSG2300	Siemens	19'	up to 32	No	No	Yes	Yes	No	Yes	No
RS900	Siemens	DIN Rail	up to 9	No	No	Yes	Yes	No	Yes	No
RS900G	Siemens	DIN Rail	10	No	No	Yes	Yes	No	Yes	No
RS950G	Siemens	DIN Rail	3	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Figure 86: Example of Managed Ethernet Switches from AFS family

Small form-factor pluggable (SFP) module / port

SFP modules allow users to select appropriate transceiver for each SFP port embedded in Ethernet switch to provide the required connection over the available optical fiber type (for example multi-mode fiber or single-mode fiber) or over metal twisted pair type. SFP modules are commonly available in several different categories: multi-mode fiber, single-mode fiber and twisted pair cabling. Fast Ethernet SFP modules are not applicable for the slots (ports) that support only Gigabit Ethernet and Gigabit Ethernet SFP modules are not applicable for the slots (ports) that support Fast Ethernet. Only use ABB SFP modules for AFS family.

Figure 87: 1 - Fast Ethernet fiber optic SFP module, 2 - Gigabit Ethernet fiber optic SFP module

Figure 88: Installed SFP module in managed Ethernet switch AFS677

Satellite reference clock

It synchronizes all connected devices using its reference time source. Optional accessories usually are antenna, antenna cable, antenna mount and lightning protection kit.

Recommended type of a compact substation clock, TTM 01-G manufactured by TEKRON, supports accurate GPS (USA) / GLONASS (Russian) clock with sub-microsecond timing that is used to synchronize protection and control relays. Key features are:

– Synchronization of IEEE 1588-2008 (PTPv2) compatible clients via IEEE C37.238-2011 Power Profile
– Synchronization of NTP and SNTP compatible clients
– 1x RJ-45 or 1x multi-mode fiber optic interface

Parallel Redundancy Protocol support for ultimate reliability is available in a fully customizable satellite reference clock NTS 03-G+ manufactured by TEKRON too.

Refer to www.tekron.com for additional information.

Figure 89: Example of satellite-controlled clock from Tekron with optional accessories

Other recommended type of substation clock is LANTIME M400 manufactured by Meinberg. It supports GPS / GLONASS clock and synchronization of IEEE 1588-2008 (PTPv2) compatible clients via IEEE C37.238-2011 Power Profile, two-step clock. Refer to www.meinberg.de for additional information.

Figure 90: Example of satellite-controlled clock from Meinberg

Layout

The communication devices are usually mounted inside the low voltage compartment of the panel. Therefore, the panels are ready for connection. The main benefits of this solution are:

- Cubicles are ready for connection
- Saving space in substation building
- Shorter communication links
- Cheaper solution

Protection and control relays are connected to the Ethernet network in compliance with the Network Overview Diagrams. It is recommended to wire communication link from Ethernet switch to protection and control relays and keep minimal allowed bend radius especially for fiber optic patch cords.

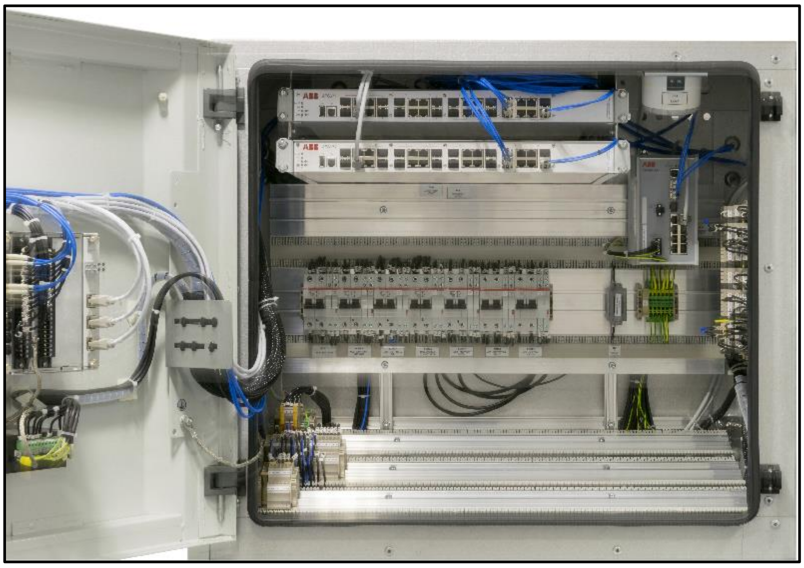


Figure 91: Low Voltage Compartment of UniGear panel

3.5.3 Topologies

SINGLE network using Rapid Spanning Tree Protocol (RSTP) / Fast Media Redundancy Protocol (E-MRP)

The single network topology is the most common one, protection and control relays are connected to managed Ethernet switch via single connection. The managed Ethernet switches form a physical loop (ring).

RSTP ring offer redundancy mechanism against link between switches failures, but not against protection and control relay link or switch failure. Rapid Spanning Tree protocol always blocks one path to avoid duplicates. Moreover, the RSTP ring cannot guarantee a zero or near-zero frame loss upon network failure occurrence. It is supported by AFS and RUGGEDCOM family.

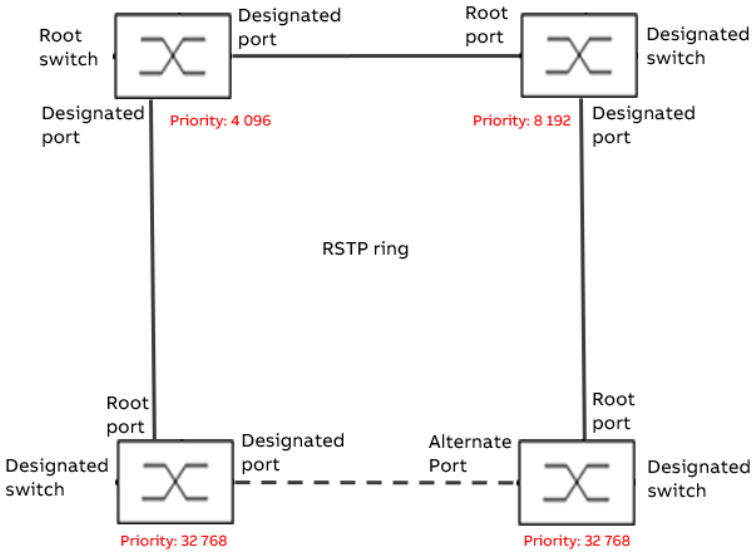


Figure 92: RSTP ring redundant structure

Media Redundancy Protocol (MRP) is a ring redundancy protocol defined in IEC 62439-2 standard. One of the Ethernet switches in the ring acts as a Ring Manager. There is exactly one ring manger in the ring. With the help of the ring manager function, the two ends of a backbone in a line structure can be closed to a redundant ring. The Ring Manager keeps the redundant line open if the line structure is intact. If a segment fails, the ring manager immediately closes the redundant line, and line structure is intact again. E-MRP is fast MRP with decreased recovery time (Ring < 10 switches: < 10 ms recovery time, Ring < 100 switches: < 40 ms). It is supported by AFS family.

MRP provides shorter switching times than RSTP, it is limited to ring topology and it covers much bigger networks in comparison to RSTP. Coupling RSTP, MRP and E-MRP networks is possible.

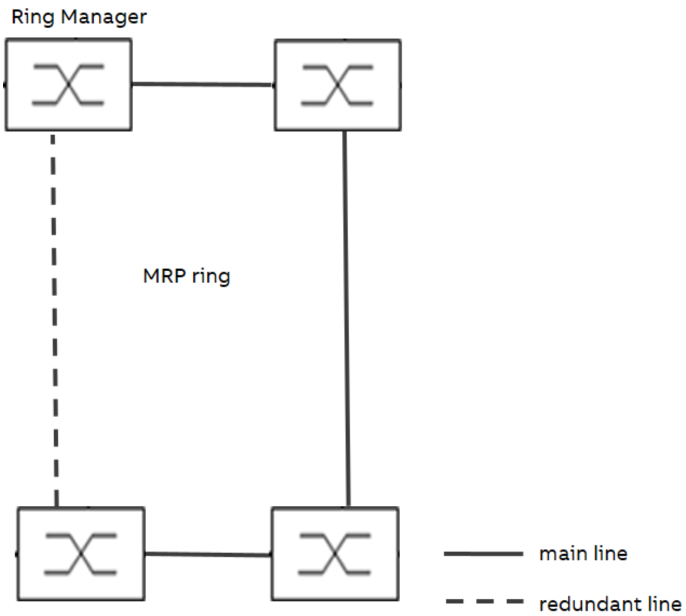


Figure 93: MRP / E-MRP ring redundant structure

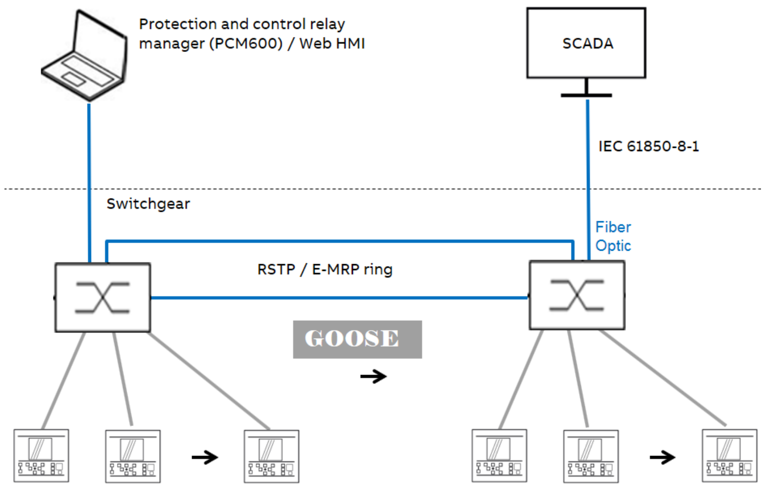


Figure 94: Single network using RSTP / E-MRP

Network Redundancy

IEC 61850 standard specifies network redundancy that improves the system availability for substation communication. It is based on two complementary protocols defined in the IEC 62439-3 standard: **Parallel Redundancy Protocol** and **High Availability Seamless Redundancy protocol**. Both protocols can overcome failure of a link or switch with zero-switchover time. In both protocols, each node has two identical Ethernet ports for one network connection. They rely on the duplication of all transmitted information and provide zero-switchover time if links or switches fail, thus fulfilling all the stringent real-time requirements of substation automation. The choice between these two protocols depends on the application and the required functionality.

Parallel Redundancy Protocol (PRP) networks using Rapid Spanning Tree Protocol (RSTP) / Fast Media Redundancy Protocol (E-MRP)

In PRP, each node is attached to two independent networks operated in parallel. The networks are completely separated to ensure failure independence and can have different topologies. Both networks operate in parallel, thus providing zero-time recovery and continuous checking of redundancy to avoid failures. The PRP1 redundancy is supported by Relion® 615 (RED615 only via fiber optic interfaces), 620 and 640 series. SCADA system can be connected to PRP networks via Redbox or directly if PRP redundancy is supported by SCADA.

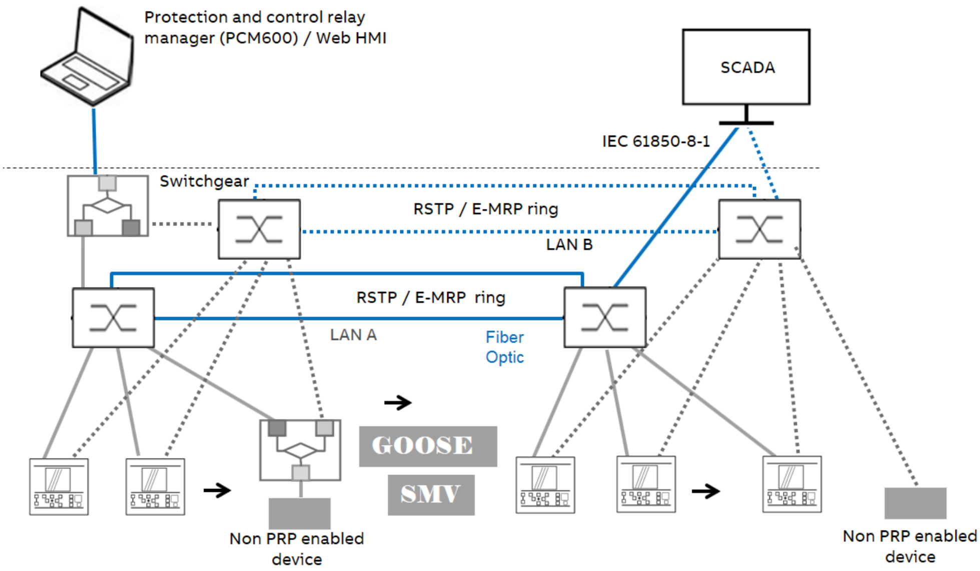


Figure 95: PRP networks using RSTP / E-MRP

Smart substation control and protection SSC600 can be deployed in several different architectures depending on other solution components used and overall solution requirements. Fully centralized architecture with duplicated SSC600 ensures fully functional protection in case of unit failure. Since SSC600 units can have identical configurations, the engineering and maintenance remains efficient.

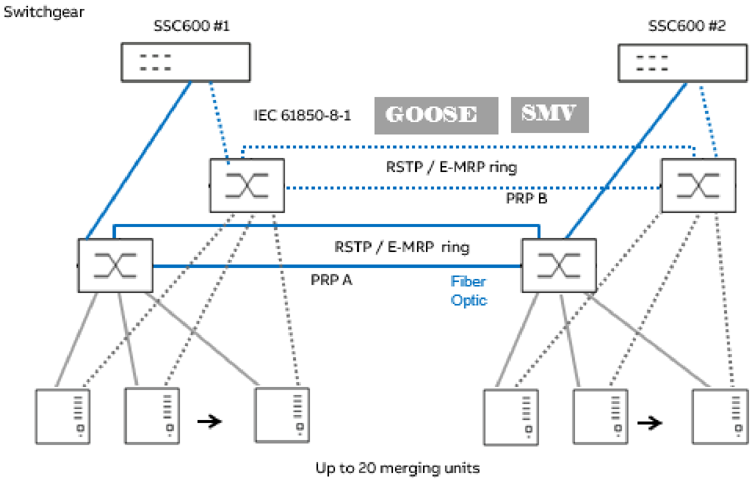


Figure 96: Fully centralized architecture

Hybrid architecture combines centralized and decentralized approaches by using bay level backup protection with SSC600. The idea of the combined solution is to use simplified protection at the bay level and all the substation-wide and advanced protection in the central device.

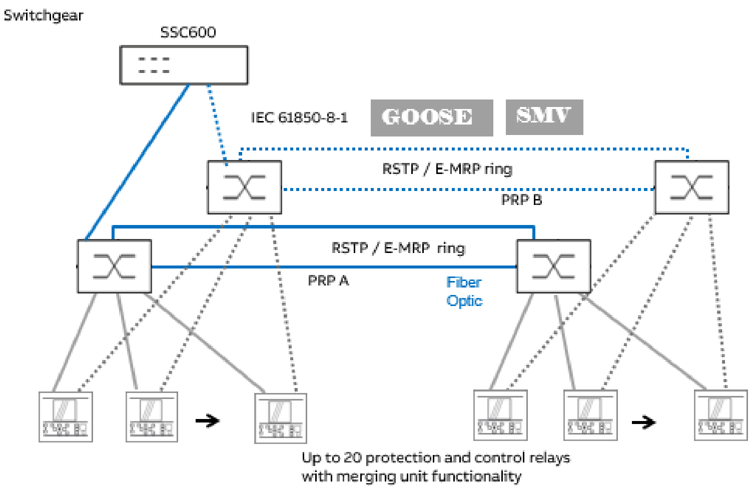


Figure 97: Hybrid architecture with protection and control relays

High Availability Seamless Redundancy (HSR) network

The HSR ring applies the PRP principle of parallel operation to a single ring. For each message sent, a node sends two frames, one over each port. Both frames circulate in opposite directions over the ring and every node forwards the frames it receives from one port to the other. When the originating node receives a frame it sent, it discards the frame to avoid loops.

HSR redundancy is supported by Relion® 615 (RED615 only via fiber optic interfaces), 620 and 640 series.

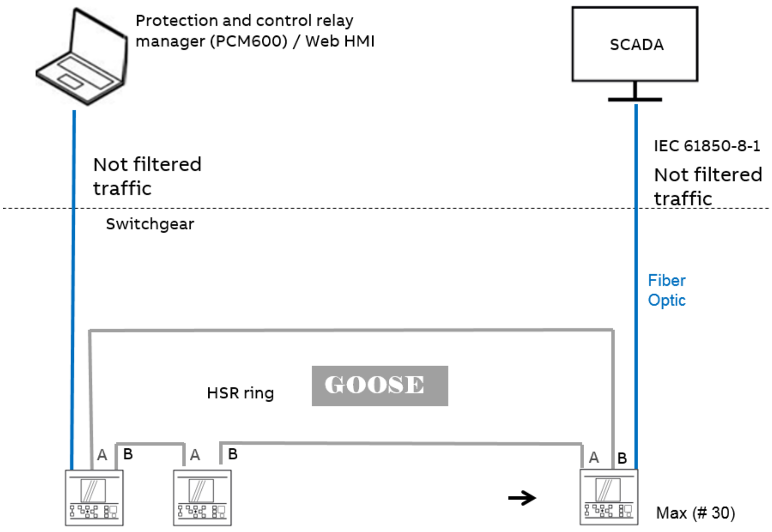


Figure 98: HSR network

HSR network with redboxes

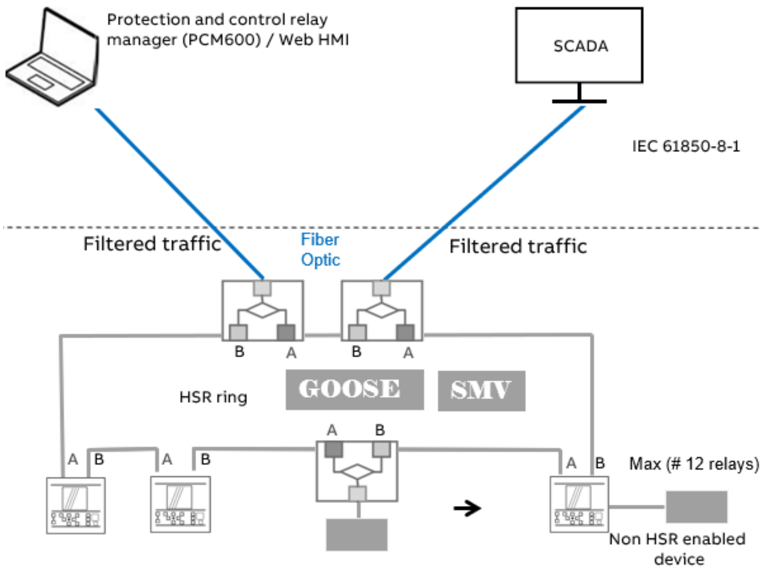


Figure 99: HSR network with redboxes

The maximum number of IEDs supported in the HSR ring is 30. When using IEEE 1588 time synchronization and IEC 61850-9-2 LE, 15 hops from the clock master to the protection and control relay is the maximum to reach 1 µs accuracy in measurements according to the IEEE 1588 v2 standard, therefore it is recommended to have maximum 12 protection and control relays in the HSR ring. It is not recommended to configure more than four SMV senders due to all information is sent into both directions in parallel.

Combined Parallel Redundancy Protocol (PRP) and High Availability Seamless Redundancy (HSR) networks

Combining PRP and HSR networks can be overcome some drawback of pure PRP or HSR network. PRP and HSR protocols have been developed to work interoperable, because HSR ring applies the PRP principle of parallel operation to a single ring. PRP networks and HSR rings are coupled through PRP / HSR redboxes. Two redboxes should be used per one ring to be redundant and have access to both PRP networks. If one Redbox fails, the seamless redundancy is still available through the other. The redboxes divide HSR ring in two parts of equal size minimizing the maximum number of hops.

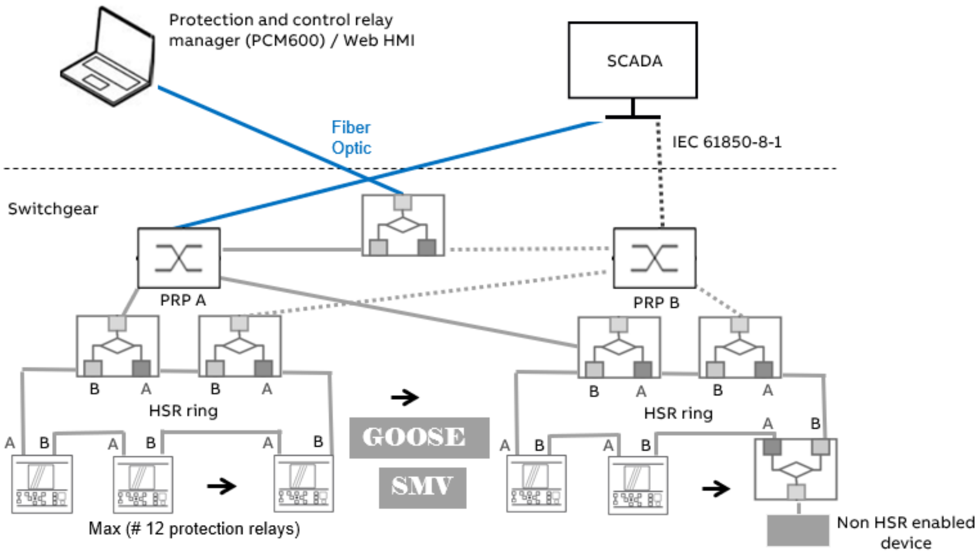


Figure 100: Combined PRP and HSR networks

Comparison of network topologies

Comparison of network topologies is shown in table below.

Table 7: Comparison of network topologies

	SINGLE network + RSTP	PRP networks	HSR network
ARCHITECTURE			
Supported topologies	Any topology: tree, star, ring, mashed	Any topology: tree, star, ring, mashed	Limited: rings, rings of rings
Connecting single port protection relays	Yes	Yes, directly to one network	No, only via Redbox
Number of devices	No limitations, due to flexible topology	No limitations, due to flexible topology	Max 30 per ring
Network independent of protection relays	Yes	Yes	No
INTEROPERABILITY			
Interoperability with non-redundant protection relays	Yes	Yes	No, only via Redbox
Compatible with standard Ethernet Components	Yes	Yes	No, HSR support is needed
PERFORMANCE			
Recovery time	10…500 ms	0 ms	0 ms
Network bandwidth	Full bandwidth	Full bandwidth	Half bandwidth
Latency	No latency in protection relay	No latency in protection relay	Latency in each protection relay
AVAILABILITY			
Failure of a switch / active network component	Connected protection relays are lost	No impact	One protection relay is lost
Failure of 2 or more protection relays	No impact to communication	No impact to communication	Communication between relays interruption

	SINGLE network + RSTP	PRP networks	HSR network
Data loss	Yes	No	No
ECONOMICS			
Equipment costs	Medium, Ethernet switches	High, double amount of Ethernet switches, protection relay with more interfaces	Medium, Redbox, protection relay with more interfaces
Communication Links	Medium, links between protection relays and Ethernet switches	High, double links between protection relays and Ethernet switches	Low, only links between protection relays
Space requirements	Medium, Ethernet switches	High, Ethernet switches	Low, less devices
ENGINEERING			
Effort	Less	More	Less

3.5.4 Ethernet traffic estimation

MMS	0.01 Mb/s	per a single protection and control relay
GOOSE	0.1 Mb/s	in burst conditions per a single protection and control relay (2 data sets)
SMV	5 Mb/s	per a source protection and control relay

Fast Ethernet = 100 Mb/s

The bandwidth of the HSR ring is half of the Fast Ethernet, because each message is sent in parallel into either direction.

For instance, estimated Ethernet traffic volume for a substation consisting of two sections (20x GOOSE sender, 2x SMV sender) is: 20 x 0.01 + 20 x 0.1 + 2 x 5 = 12.2 Mb/s

Knowledge of data flows and traffic patterns allows for detecting bottlenecks and planning the network segmentation and segregation of traffic.

3.5.5 Naming convention to identify protection and control relays

The protection and control relay name must be unique within the planned network. A default name is applied if it is not specified by the client and it is based on the reference designation system of IEC 61346

– **Substation** 3 characters

– **Voltage Level** 1 character

- **B** > 420kV
- **C** < 380, 420> kV
- **D** < 220, 380) kV
- **E** < 110, 220) kV
- **F** < 60, 110) kV
- **G** < 45, 60) kV
- **H** < 30, 45) kV
- **J** < 20, 30) kV
- **K** < 10, 20) kV
- **L** < 6, 10) kV
- **M** < 1, 6) kV
- **N** < 1 kV

– **Voltage Level Index** 1 character

– **Bay** 3 characters, 1^{st} char. = letter, 2^{nd}-3^{rd} char. = digits

– **Protection Relay** 2 characters

For example, **S**ubstation**V**oltagelevel**V**oltagelevelindex**B**ay**P**rotectionRelay **SUBJ1J01A1**

3.5.6 IP address allocation

The IP address is a number that identifies a network device. Each device connected to a network must have a unique address. The default IP address range for a substation is: 172.16.X.X - 172.30.X.X. The IP addresses and IP masks are a specific feature of each device. In case of device failure, the replacement device receives the same IP address. The IP address should be structured in a way to reflect the physical plant layout according to IEC 61850-90-4.

– 172.**NET.BAY.DEVICE**

Subnet mask 255.255.0.0 (Class B)

– **NET**

- 16 - 30 16 = the highest voltage level,
  17 = the second highest voltage level …
  30 = Station LAN (non IEC 61850 communication)

– **BAY**

- 0 Station level (PC, ZEE600, Satellites reference clock ...)
- 1-169 Bays
- 170 - 179 Virtual bays (substitution of actual devices by simulation or calculation)
- 201 - 250 Station Level Ethernet Switches

– **DEVICE**

- 1- … Protection and control relays
- 100 Bay or Station level Ethernet switch

Note: PRP redundancy +100

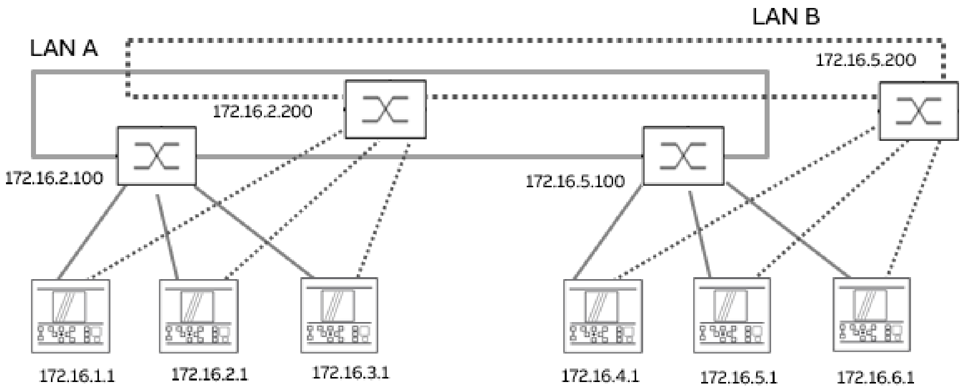


Figure 101: Example of an allocation of device IP addresses

3.5.7 Time synchronization

Accurate time synchronization with precision requirements of sub one microsecond is essential for a proper functionality of process bus. Sampled measured values need to be synchronized between the sending and the receiving protection and control relays that perform protection or control functions. The 615, 620 and 640 series support the IEEE 1588 (PTPv2) protocol and Power Profile as defined in IEEE C37.238 to reach required timing accuracy over an Ethernet network. Using the Ethernet network to propagate the timing signals eliminates extra cabling requirements.

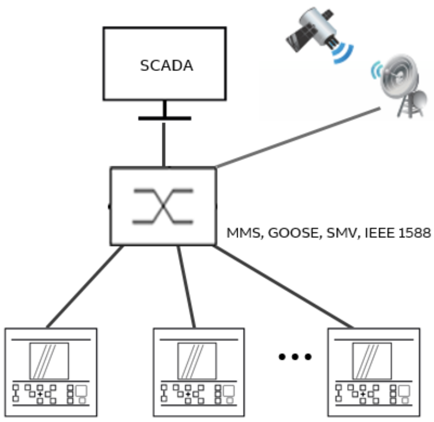


Figure 102: Example of IEEE 1588-time synchronization via the Ethernet network

Using the Best Master Clock (BMC) algorithm devices in the network with the most accurate time are determined, which are to be used as a reference time source (Grandmaster). Subsequently the participating devices synchronize themselves with this reference time source. The BMC algorithm run continuously to quickly adjust for changes in network configuration. IEEE 1588 networked protocol supports multiple master clock, which improves redundancy and reliability of substation time synchronization system.

PTP clock types

- Grandmaster clock is synchronized with an external source as satellites (satellites reference clocks)
- Ordinary clock can act as either a Master or a Slave clock (protection and control relay). In most network implementations the clocks remain in the Slave state and only become Master when the Grandmaster fails.
- Transparent clock corrects the time information before forwarding it without synchronizing itself (Managed Ethernet switch)

The PTP Clocks can be either one-step or two-step ones; their mixing should be avoided. Two-step clock sends Sync message (contains the approximate time) and follow-up message (contains more precise value of when Sync message left the clock). One-step clock does not send Follow-up message, instead the Sync message carries a precise time stamp. The One-step mode reduces network traffic and is preferable.

System settings for the 3rd party devices

To be capable of supporting the IEEE 1588-2008 (PTPv2) version of the standard

Preferably of 1588 type according to the Power profile, either via power profile parameters or by individually setting the parameters according to the Power Profile, with implementation in line with the one-step mode.

Table 8: C37.238 Power Profile key parameters

Parameter	Value
Path delay	Peer to peer
VLAN	1 recommended
Ethertype	0x88f7
Announce period	1 s
Sync period	1 s
Pdelay period	1 s

Time synchronization schemes

Preferred schemes for HSR-PRP and PRP networks

The PRP redundancy protocol foresees that the grandmaster clock is doubly attached to both LANs. An ordinary clock therefore receives the Sync (Follow-Up) and Announce messages from each LAN independently. The ordinary clock treats each side as a different clock, but it does not apply the Best Master Clock algorithm since both have the same identity. Locating two grandmaster clocks, one in each LAN also possible, in that case the doubly attached ordinary clocks execute the Best Master Clock algorithm to select the clock they are synchronized to. However, singly attached nodes do not benefit from redundancy.

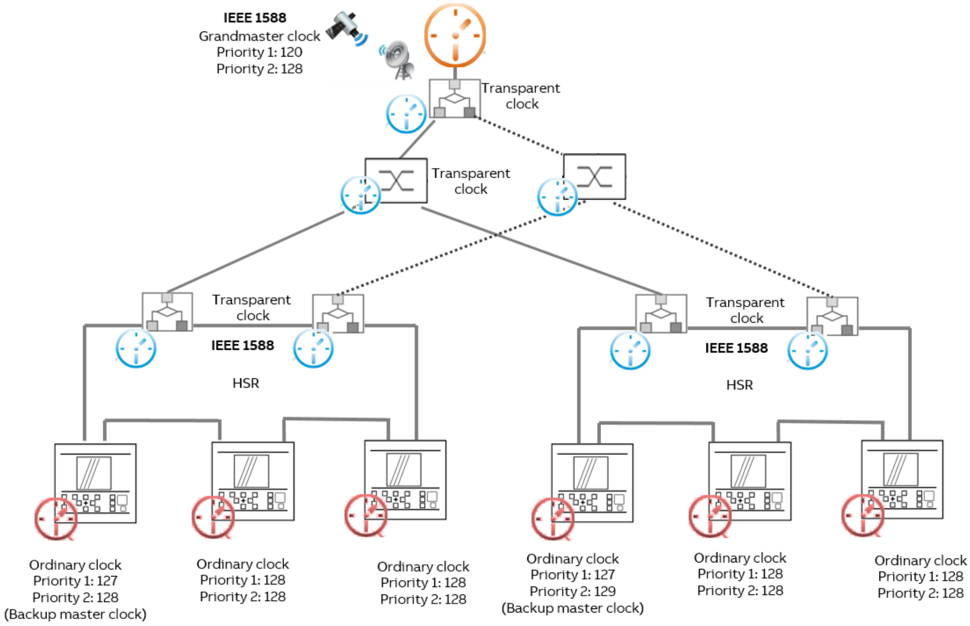


Figure 103: IEEE 1588 Time synchronization scheme for HSR-PRP networks

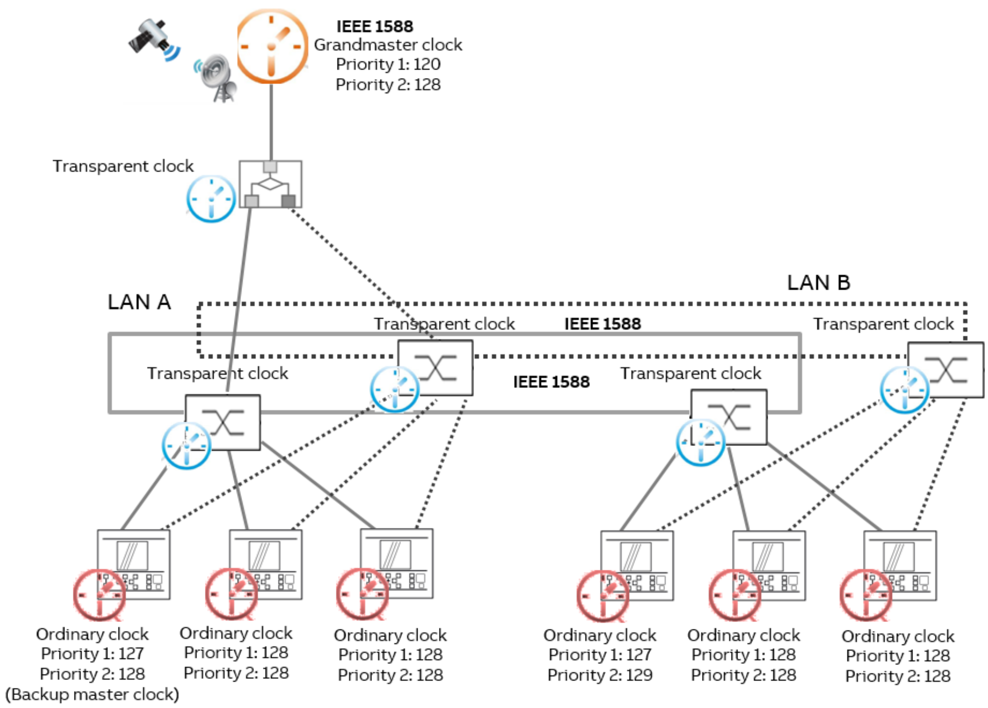


Figure 104: IEEE 1588 Time synchronization scheme for PRP networks

3.5.8 Traffic segregation

SMV messages causing high traffic should be filtered out so that they do not reach network devices which do not subscribe to SMV messages. This is done in managed Ethernet switch configuration which must be configured to perform the filtering operation. Traffic over Ethernet network is grouped into several virtual LANs.

- VLAN ID = 1 — (MMS, IEEE 1588, SNMP, …). It exists as default and its usage throughout LAN yields the same behaviour as if there were no VLANs (VLAN ID = 0)
- VLAN ID = 1 000 – 1 511 — (GOOSE messages). It is grouped based on substation, application, …
- VLAN ID = 3 000 – 3 511 — (SMV stream). It is grouped based on sender and associated receivers.

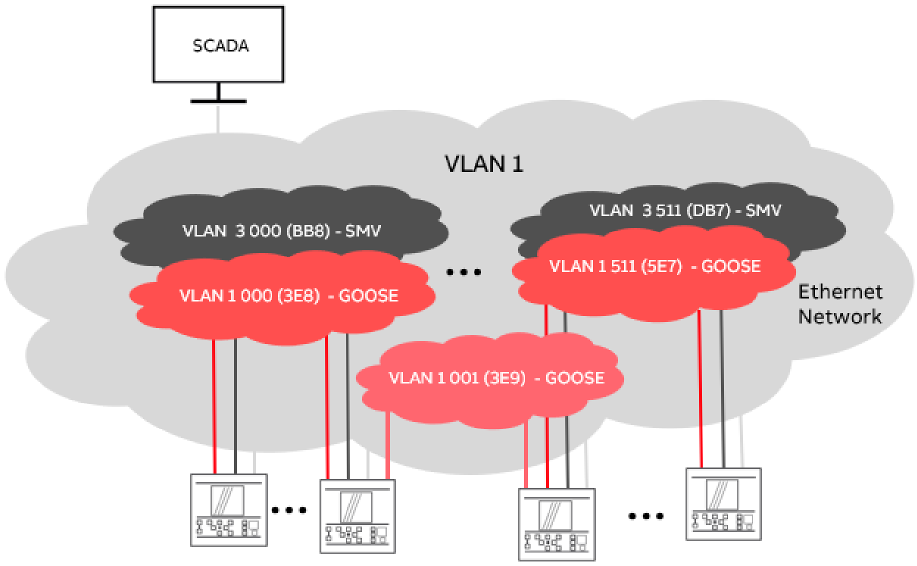


Figure 105: Example of traffic segregation via building virtual LANs

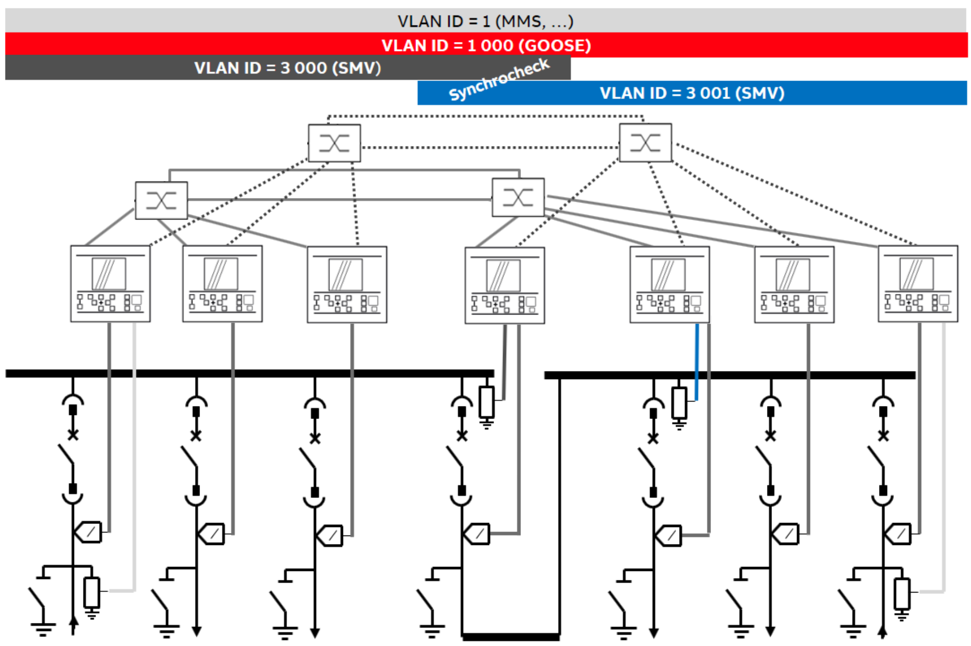


Figure 106: Virtual LANs allocation in PRP-RSTP networks

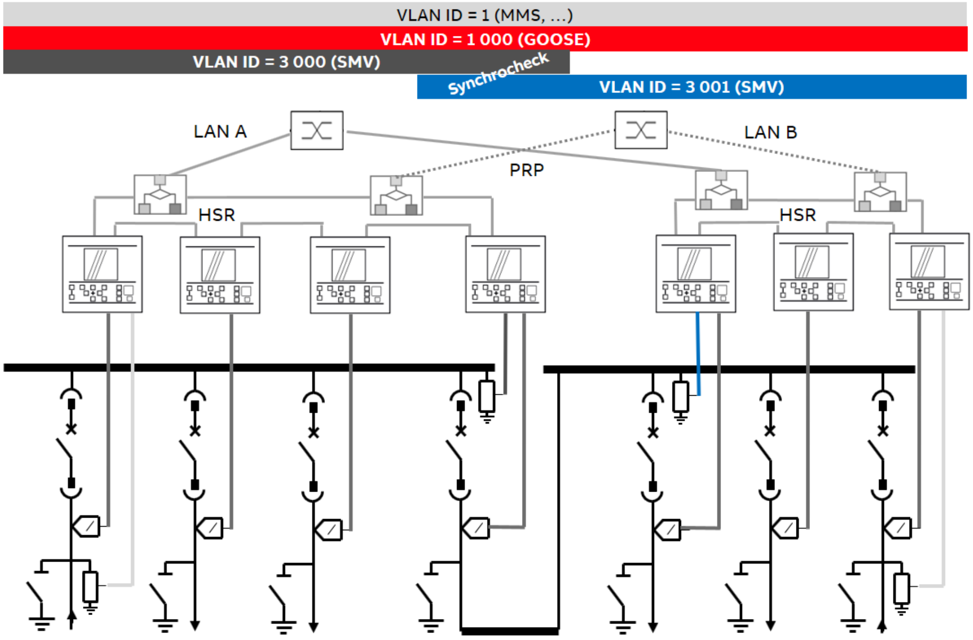


Figure 107: Virtual LANs allocation in HSR-PRP networks

3.5.9 Protection and control relays

Ethernet rear ports and redundancy settings

IED configuration / Configuration / Communication / Ethernet / Communication: 0

– IP address = IP number

– Subnet mask = Subnet mask

– Switch mode = HSR / PRP / Normal

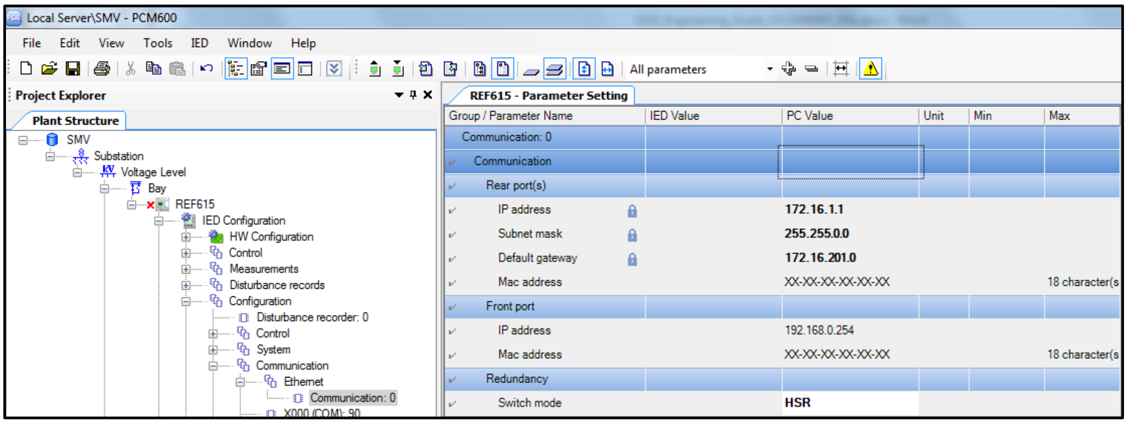


Figure 108: Communication parameter setting dialog

Ethernet rear ports supervision

RCHLCCH or / and SCHLCCH are used for supervision. RCHLCCH block supervises redundant channels and SCHLCCH block supervises status of Ethernet ports.

RCHLCCH outputs signals

– CHLIV Status of redundant Ethernet channel LAN A. When redundant mode is set to HSR or PRP mode, value is **True** if the protection and control relay is receiving redundancy supervision frames. Otherwise value is **False**.

– REDCHLIV Status of redundant Ethernet channel LAN B. When redundant mode is set to HSR or PRP mode, value is **True** if the protection and control relay is receiving redundancy supervision frames. Otherwise value is **False**.

– LNKLIV Link status of redundant port LAN A

– REDLNKLIV Link status of redundant port LAN B

SCHLCCH outputs signals

- CH1LIV Status of Ethernet channel X1 / LAN1. Value is **True** if the port is receiving Ethernet frames. Valid only when redundant mode is set to None or port is not one of the redundant ports (LAN A or LAN B)
- LNK1LIV Link status of Ethernet port X1 / LAN1
- CH2LIV Status of Ethernet channel X2 / LAN2. Value is **True** if the port is receiving Ethernet frames. Valid only when redundant mode is set to None or port is not one of the redundant ports (LAN A or LAN B)
- LNK2LIV Link status of Ethernet port X2 / LAN2
- CH3LIV Status of Ethernet channel X3 / LAN3. Value is **True** if the port is receiving Ethernet frames. Valid only when redundant mode is set to None or port is not one of the redundant ports (LAN A or LAN B)
- LNK3LIV Link status of Ethernet port X3 / LAN3

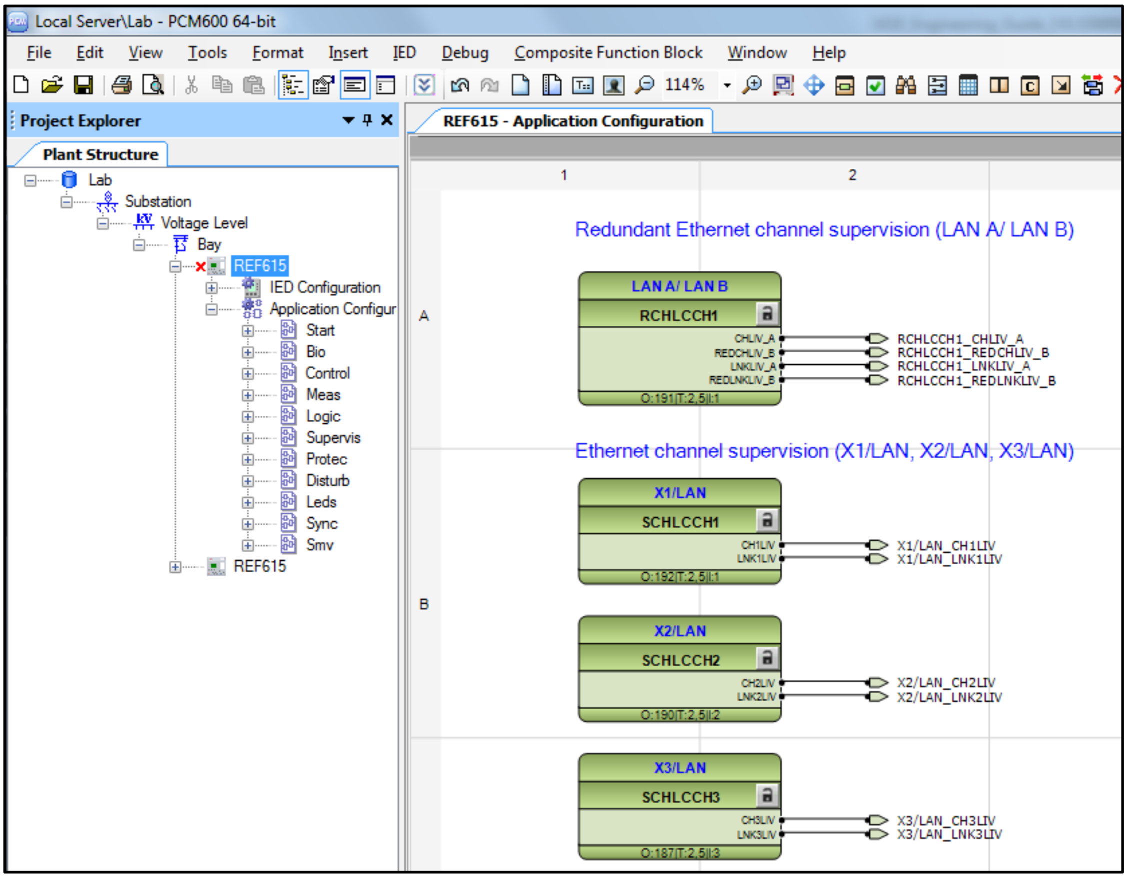
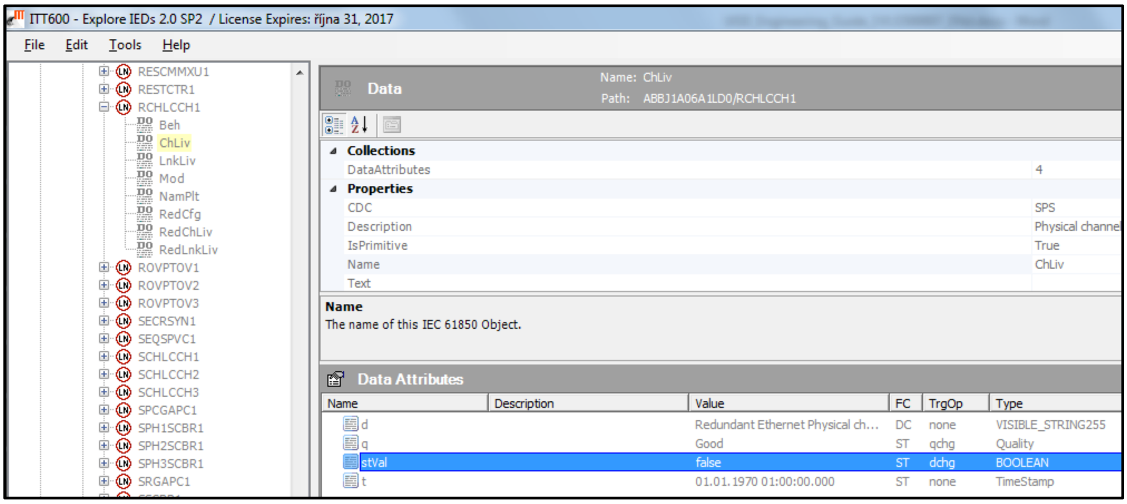


Figure 109: Adding RCHLCCH and SCHLCCH blocks in the Application Configuration Tool



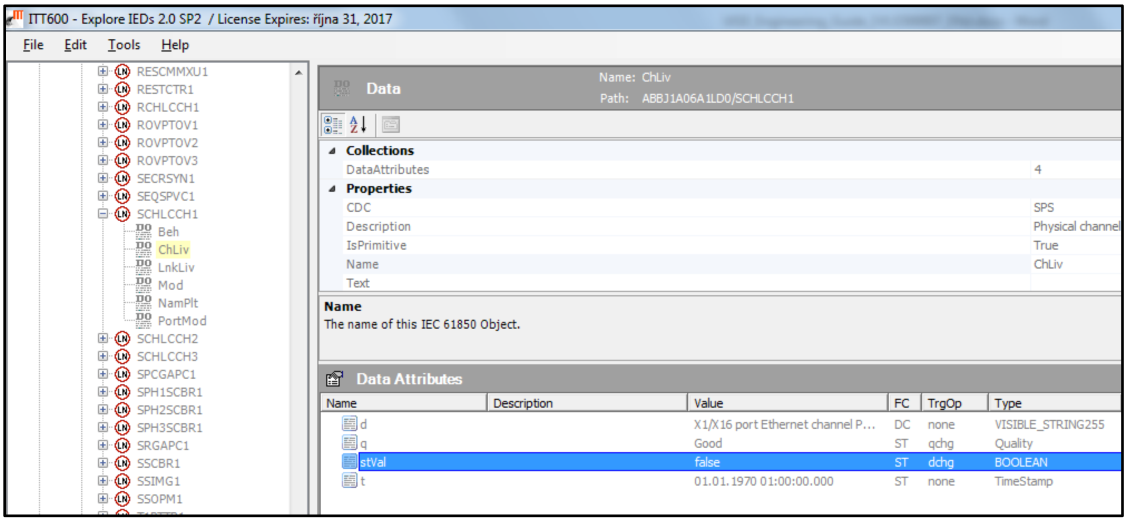


Figure 110: Status of Ethernet rear port displayed via ITT SA Explorer (on top and on bottom)

3.5.10 Managed Ethernet switches

AFS Family

After connecting a notebook with the AFS Finder SW tool to any Switch Port except HSR dedicated ports, the following dialogue screen appears. AFS Finder automatically searches the network for those devices, which support the AFS finder protocol. The next dialogue, opened by double clicking on the respective switch in AFS finder, defines the IP address and netmask.

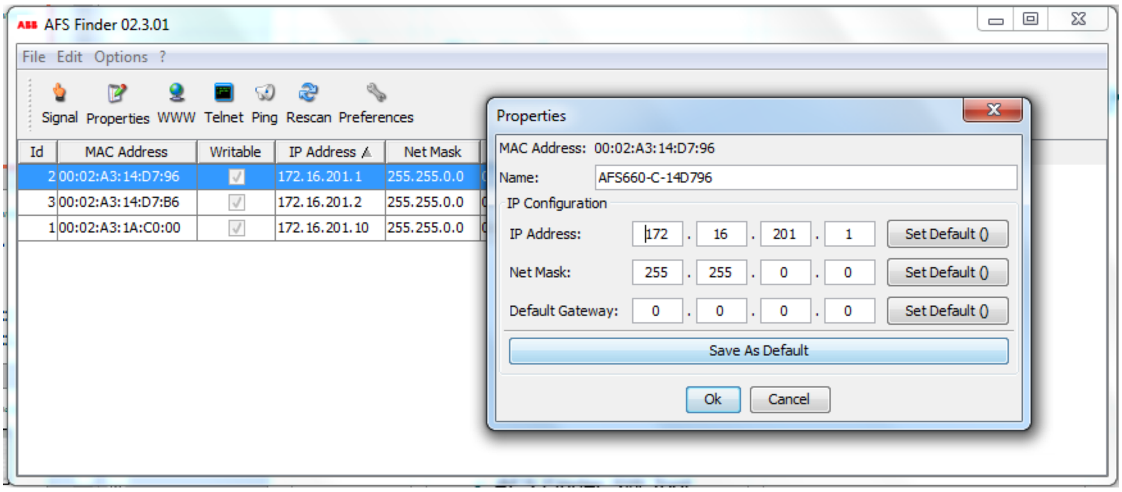


Figure 111: AFS switch screen

The user-friendly Web-based interface offers the possibility of operating the device from any location in the network via a standard browser such as Microsoft Edge, Chrome or Firefox. Being a universal access tool, the Web browser uses an applet which communicates with the device via the Simple Network Management Protocol (SNMP). The Web-based interface allows the device to be graphically configured and it uses Java. Java must be enabled in the security settings of the Web browser.

Login

Default User name to configure the AFS67x family is **admin** and the password is **admin**.

Default User name to configure the AFS66x family is **admin** and password is **abbadmin**.

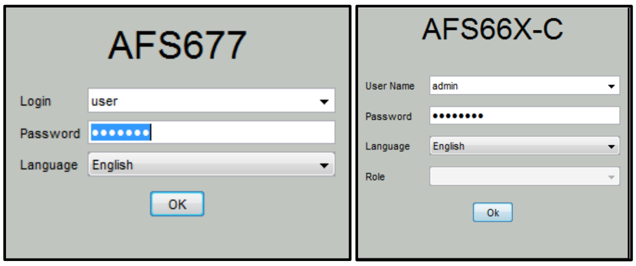


Figure 112: Login window

Notes on saving the Configuration profile

- To copy changed settings to the volatile memory (RAM), click the Set button
- To refresh the display in the dialogs, click the Reload button
- To keep the changed settings even after restarting the device, click the Save button in **Basic Settings / Load / Save** dialog

3.5.10.1 Basic Settings <Mandatory>

Basic Setting / Network

Mode / Local = enabled

VLAN / ID = 1

Local

- IP address = IP number
- Netmask = Netmask

AFS Finder Protocol / Operation = ON

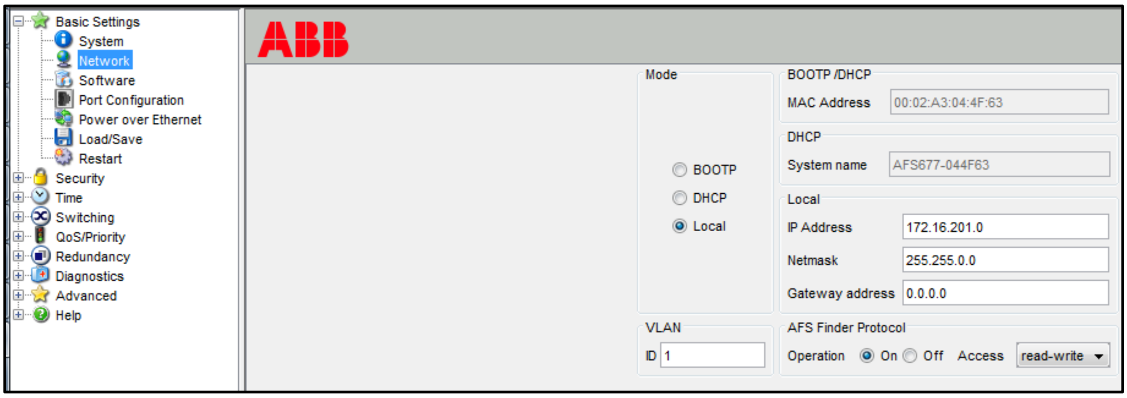


Figure 113: Network parameters dialog

Basic Setting / Port configuration

Port on = enabled

Automatic Configuration

- Enabled, Gigabits ports and TX (RJ-45) ports to protection and control relay supporting auto negotiation function
- Disabled, fiber optic ports

Manual Configuration = Fixed speed to protection and control relay should be set

Manual cable crossing = enabled on one ring port, when automatic configuration is disabled

Flow control = disabled

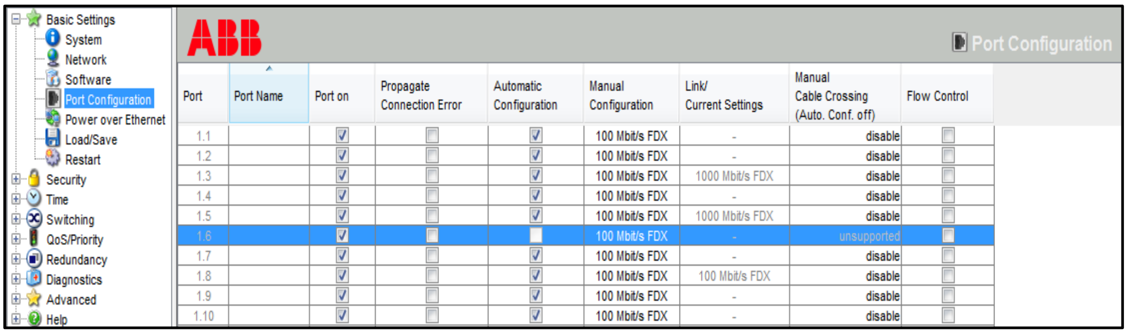


Figure 114: Port Configuration dialog

Basic Settings / Load / Save

The changes must be stored to Device in a permanent way. If a yellow triangle with the exclamation mark is seen, the configuration does not contain data entered permanently. After saving the configuration to the switch (Device) the yellow triangle symbol disappears.

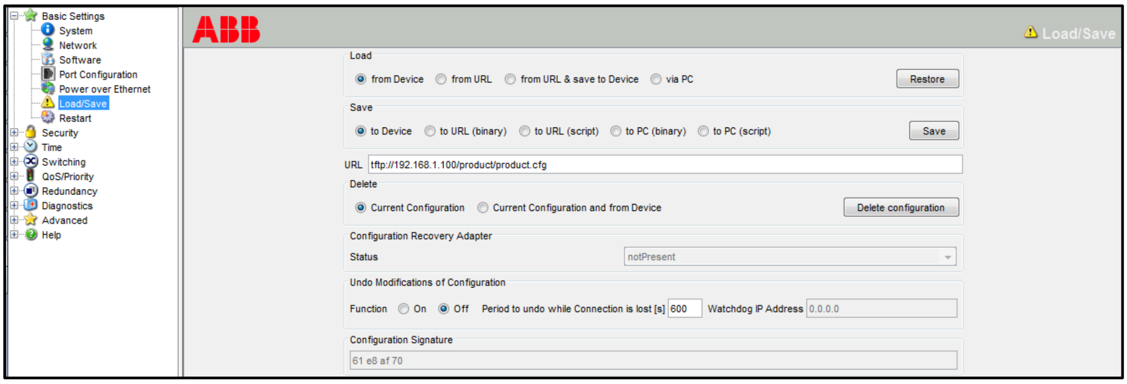


Figure 115: Load / Save dialog

3.5.10.2 Time Settings <Mandatory>

Time / PTP / Global

PTPv2 must be configured in case SMV (IEC 61850-9-2LE) is used.

Operation IEEE 1588 / PTP = ON

Configuration IEEE 1588 / PTP / PTP Version-Mode

- V2-transparent-clock; used only to correct and forward PTP messages. The device cannot become a PTPv2 master.

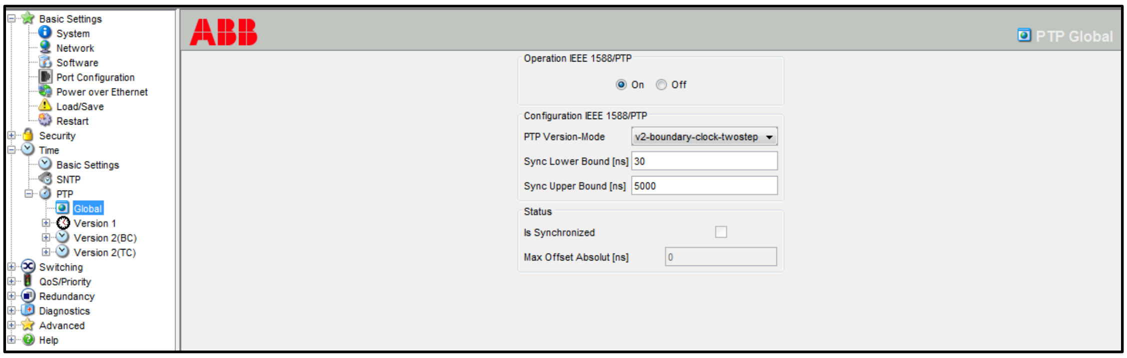


Figure 116: PTP Global dialog

Time / PTP / Version 2(TC) / Global

Profile Presets / Profile = Power - Defaults

Operation IEEE 1588 / PTPv2 TC

- Delay mechanism = P2P (Peer to Peer)
- Primary Domain = 0
- Network protocol = IEEE 802.3
- Syntonize = enabled to synchronize also local time
- Power TLV Check = enabled
- VLAN = 1

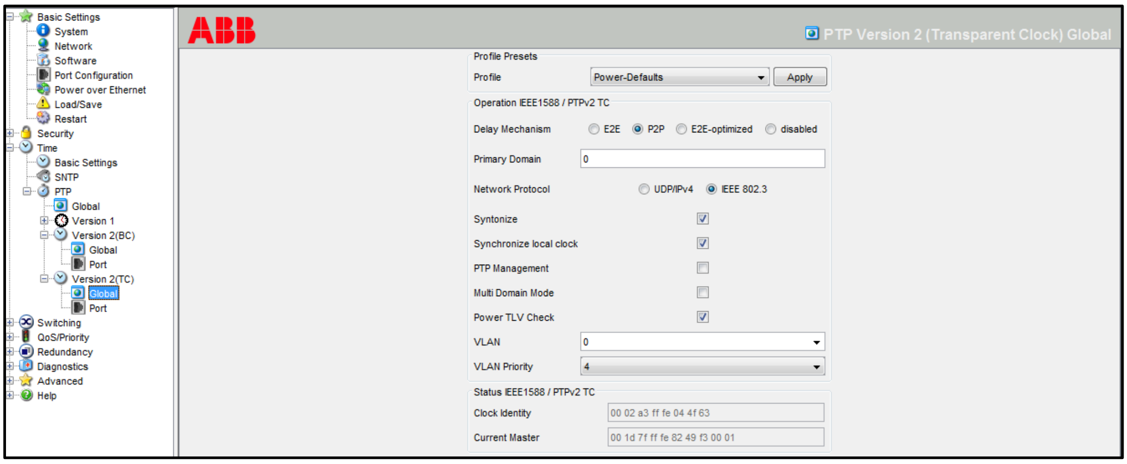


Figure 117: PTP Version 2 (Transparent Clock) Global dialog

Time / PTP / Version 2(TC) / Port

PTP Enable = enabled on all ports

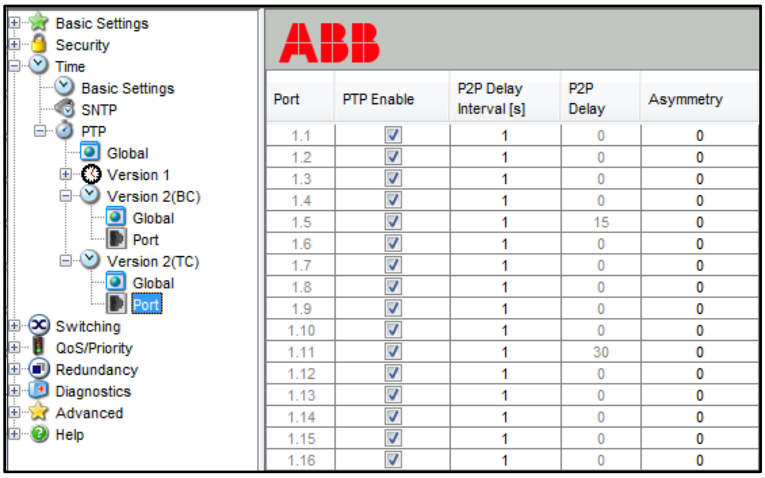


Figure 118: PTP Version 2 (Transparent Clock) Port dialog

3.5.10.3 Switching Settings <Mandatory>

The traffic segregation is essential especially for process bus to reduce data traffic and to let it go only where needed (for example GOOSE, SMV shared between protection and control relays should be not sent to the control system; GOOSE, SMV should be sent only where required). Traffic filtering in managed Ethernet switches can be done via logical separation of the data traffic to several VLANs or via multicast MAC address filtering for ports.

Switching / Global

Global setting should be kept as default.

Configuration

- Activate Flow Control = disabled
- Address Learning = enabled; it is disabled only to observe data at all ports (disable direct packet distribution)
- Frame size = 1 522, 1 552 is intended for double VLAN tagging

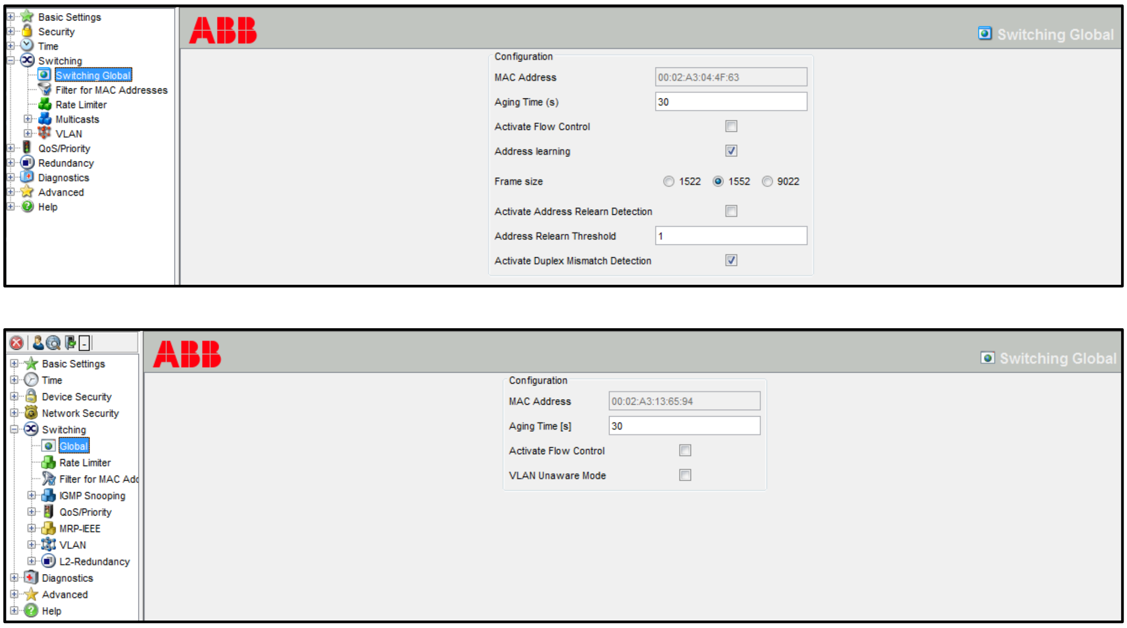


Figure 119: Switching Global dialog in AFS67x (on top) and AFS66x (on bottom)

Switching / VLAN / Global

Configuration

– VLAN 0 Transparent Mode / VLAN Unaware Mode = disabled

– GVRP active = disabled (enabled to synchronize VLAN information between Ethernet switches)

Learning / Mode / Independent VLAN = enabled

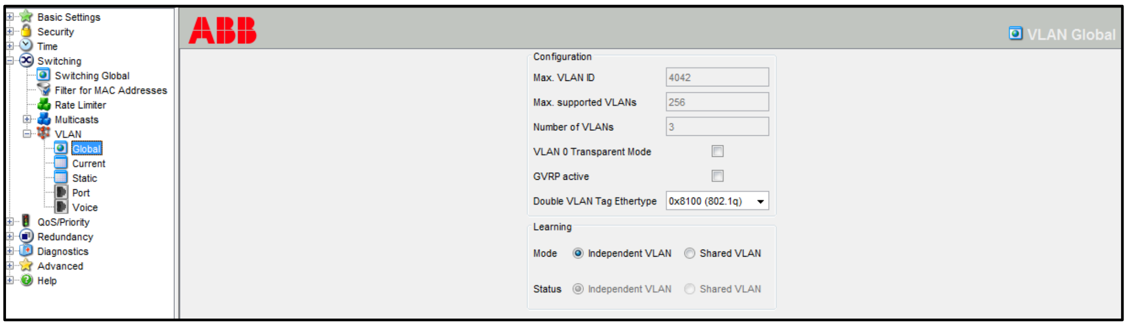


Figure 120: VLAN Global dialog in AFS67x

Switching / VLAN / Static

This item is used to configure outgoing packets (Egress filtering) from the switch. New VLAN ID Entries as per the protection and control relays engineering must be created.

VLAN ID

– GOOSE ranging from 1 000 to 1 511

– SMV ranging from 3 000 to 3 511

Name = for information purpose on the switch only

Untagged ports = **U** (The port transmits data without the VLAN tag), all ports in VLAN ID 1 except ring, PRP, HSR ports. It is possible to connect engineering tools, Internet Explorer or other features via this untagged VLAN

Tagged ports = **T** (The port transmits data with the VLAN tag)**,** all ports in the VLAN IDs > 1 (ring, PRP, HSR, GOOSE and SMV receiver)

Default setting = **-** (The port is not member of the VLAN and does not transmit data packets of the VLAN)

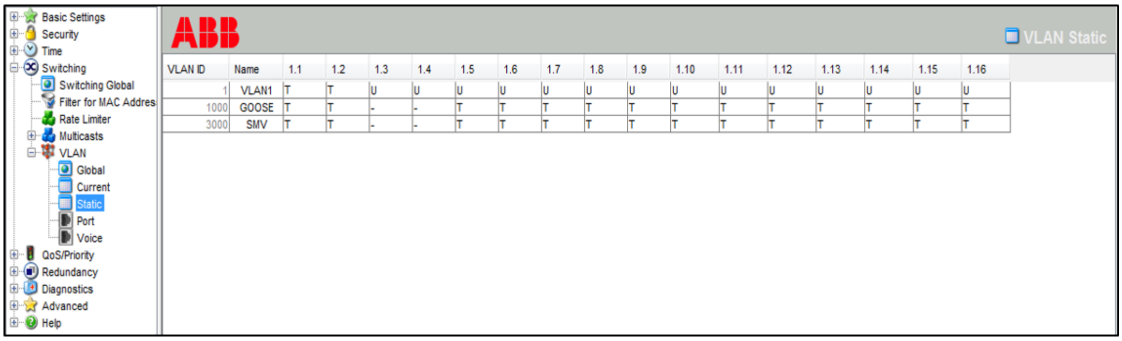


Figure 121: VLAN Static dialog

Switching / VLAN / Port

Ingress Filtering = enabled on all ports. The port evaluates the received VLAN tags and transmits messages relevant to VLANs configured for this port; other messages are discarded.

GVRP = disabled on all ports, (VLANs are manually created and administered)

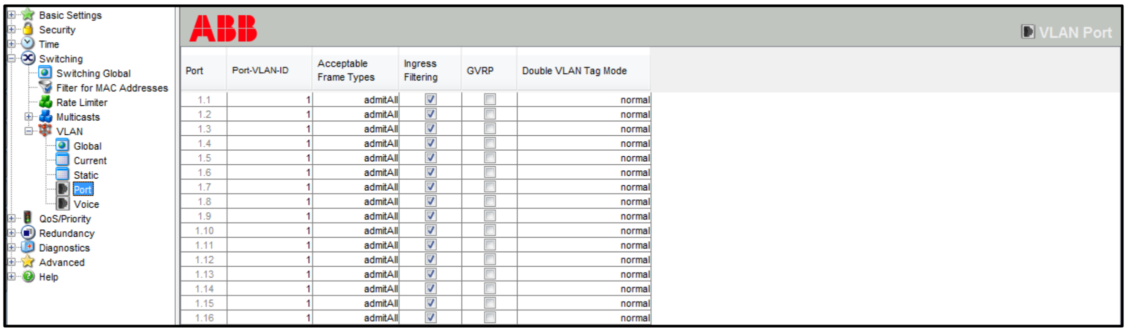


Figure 122: VLAN Port dialog

3.5.10.4 Redundancy Settings RSTP <Conditional>

Redundancy / Spanning Tree / Global

Operation = ON

Protocol version = RSTP

Protocol Configuration / Information

- Priority
  - 4 096 for Root (Master) Switch
  - 8 192 for Backup Root Switch
  - 32 768 for all Bay (Slave) Switches
- Hello Time = 2 s
- Forward Delay = 15 s
- Max Age = 20 s
- MRP Compatibility = disabled; enabled if MRP ring ID is used together with RSTP

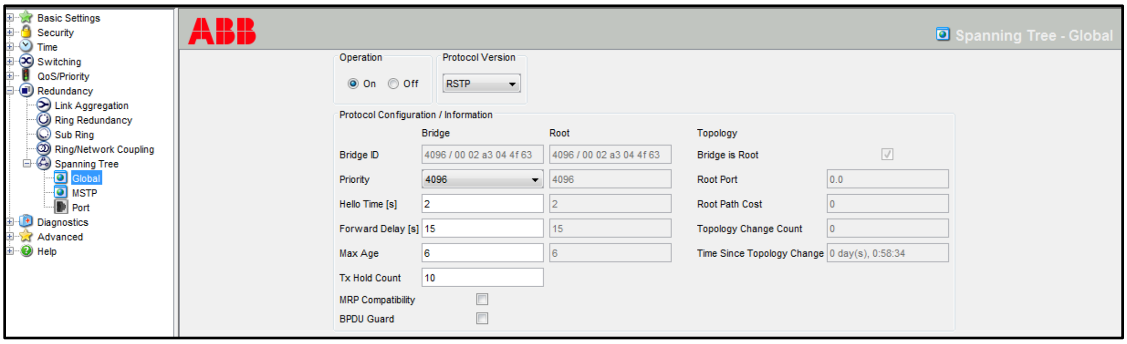


Figure 123: Spanning Tree Global dialog

Redundancy / Spanning Tree / Port

STP active = enabled for all ports

AdminEdge Port = enabled for all ports except the ring ones

AutoEdge Port = enabled for all ports

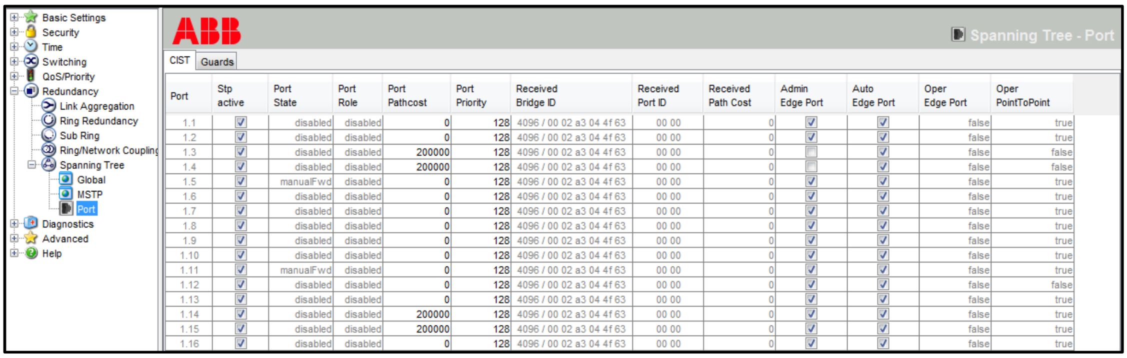


Figure 124: Spanning Tree Ports dialog

3.5.10.5 Redundancy Settings E-MRP <Conditional>

E-MRP ring is supported only by AFS family. Spanning Tree Operation is off (Redundancy / Spanning Tree / Global / Operation) or STP protocol is disabled on all ports used for E-MRP (Redundancy / Spanning Tree / Port) before configuring the E-MRP.

Redundancy / Ring Redundancy

Version = E-MRP (not all switches support E-MRP; use same version for all switches)

Ring Port 1 & 2 = Ring Ports used for E-MRP

Ring Manager / Mode = enabled in one switch (Ring Manager)

Ring Manager / Mode = disabled in in all ring switches except of switch (Ring Manager)

Operation = ON

VLAN / VLAN ID = 1

Switches / Number = the number of switches in the ring

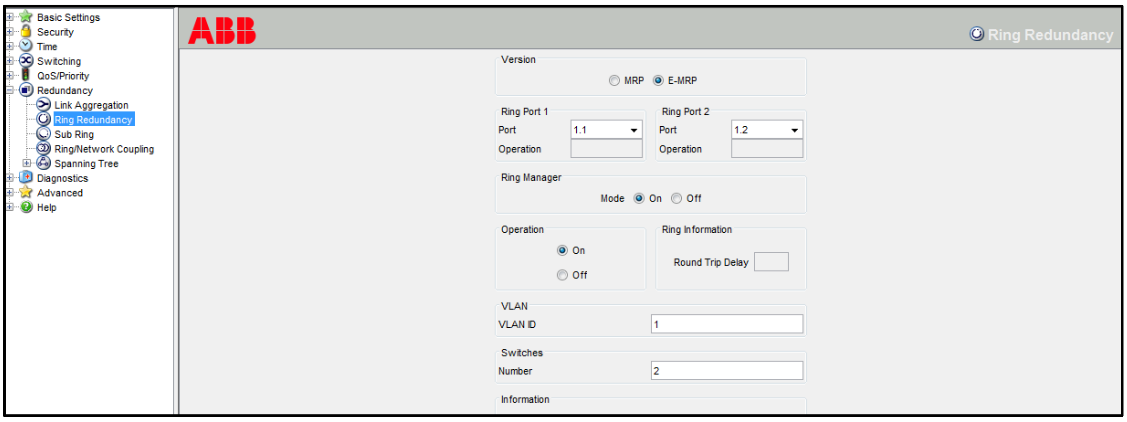


Figure 125: E-MRP Ring Redundancy dialog

3.5.10.6 Redundancy Settings PRP and HSR < Conditional>

Supported by AFS66x. The PRP and HSR networks are always connected to AFS66x via ports 1/1 and 1/2, marked as port 1A and port 2B. Both ports support fiber optic connection (SFP slot) or twisted-pair connection (RJ-45 socket). PRP function replaces interfaces 1/1 and 1/2 with interface prp/1 and HSR function replaces interfaces 1/1 and 1/2 with interface hsr/1, that is why it is recommended to initialize configuration process of the Ethernet switch with redundancy settings if it is applicable.

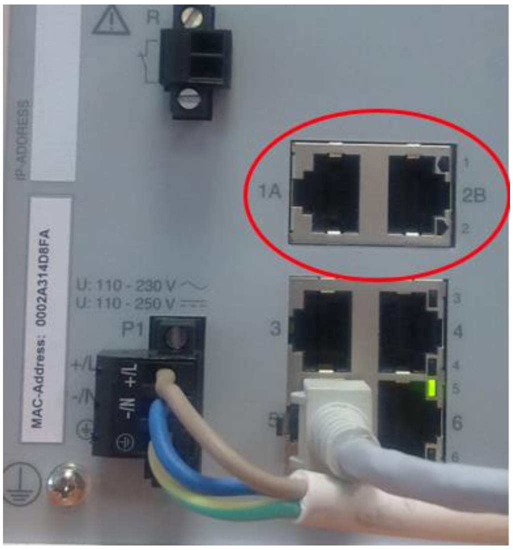


Figure 126: Example of AFS660 Front view

Switching / Global

Configuration / VLAN Unaware mode = disabled (another name for the VLAN 0 transparent mode). When VLAN Unaware mode is enabled, the device transmits data packets to all learned ports without evaluating or changing the VLAN tagging in the data packet. The priority information remains unchanged.

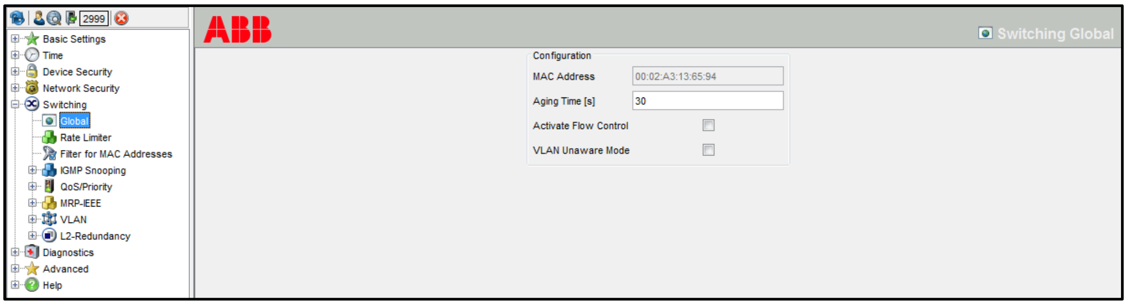


Figure 127: Switching Global dialog

L2-Redundancy / PRP / Configuration

MRP and STP protocol cannot operate on the same ports as PRP

- STP protocol is disabled on ports used for PRP (Redundancy / Spanning Tree / Port (both tabs))
- PRP ports are different from MRP or MRP operation is completely disabled

Operation = ON

Ports A, B = ON, other devices not providing support to PRP are connected to other ports.

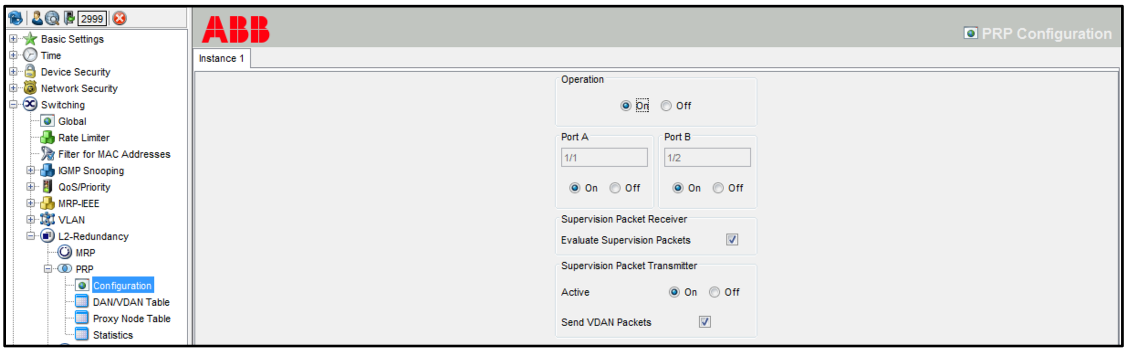


Figure 128: PRP Configuration dialog

L2-Redundancy / HSR / Configuration

MRP and STP protocol cannot operate on the same ports as HSR

- STP protocol is disabled on ports used for HSR (Redundancy / Spanning Tree / Port (both tabs))
- HSR ports are different from MRP or E-MRP operation is completely disabled

Operation = ON

Ports A, B = ON, other devices not providing support to HSR are connected to other ports.

HSR parameter

- HSR mode = modeu (host operates as a proxy for destination device, it forwards unicast traffic around the ring and forwards it to destination address, when the frames return to the source node it discards the unicast message) / modeh (host operates as a proxy for destination device, it removes unicast traffic from the ring and forwards it to destination address)
- Switching node Type = hsrredboxsan (to connect non HSR device to HSR ring) / hsrredboxprpa (to connect HSR ring to PRP LAN A) / hsredboxprpb (to connect HSR ring to PRP LAN B)
- Redbox Identity = Id1a / Id1b, specifies the tags for PRP LAN traffic

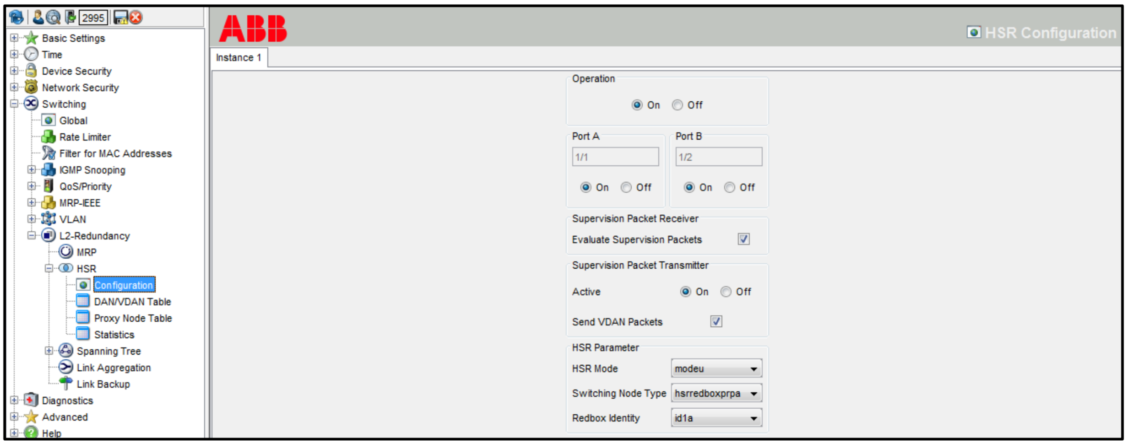


Figure 129: HSR Configuration dialog

3.5.10.7 Advanced Settings <Optional>

Advanced / Industrial Protocols / IEC61850-MMS

Operation = ON to make information related to the Ethernet switch available on the IEC 61850 network.

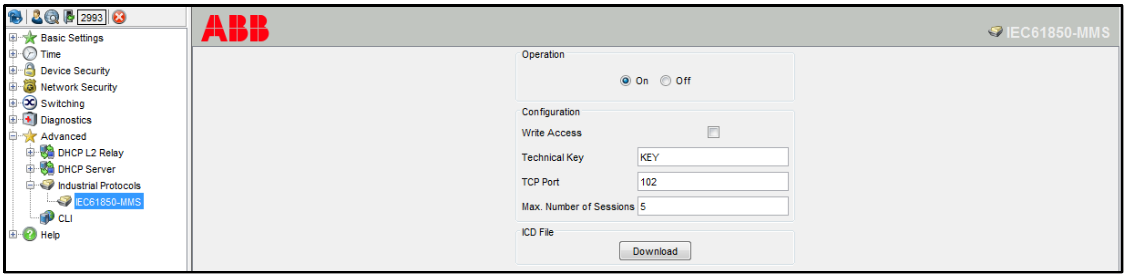


Figure 130: IEC61850-MMS Configuration dialog

3.5.11 Satellite controlled clock

3.5.11.1 Tekron

After connecting a notebook with the Tekron clock configuration tool software (available from www.tekron.com) to Ethernet port of Tekron device, the following dialogue screen appears. Tekron clock configuration tool automatically discover connected unit supposing (Discover button).

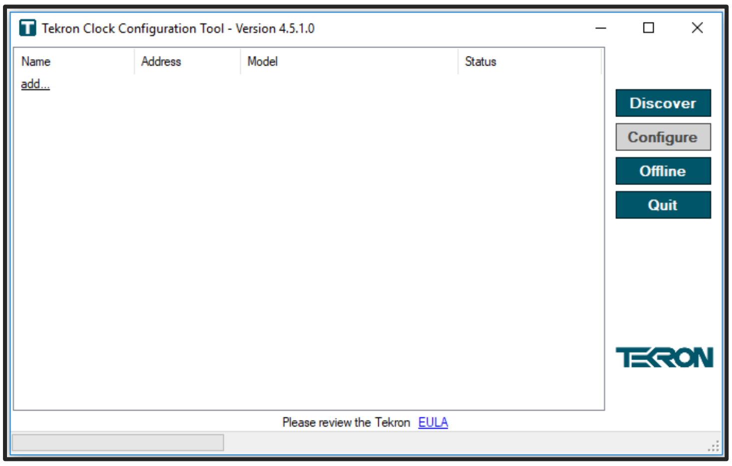


Figure 131: Tekron clock configuration Tool

Configuration procedure is initiated by Configure button after selecting of unit from the list. Default login is: User Name - **admin**, Password - **Password.** The procedure can be blocked by Windows firewall settings.

Network / Basic Settings

Advanced Options = enabled

IPv4

- Method / Static = enabled
- IP address = IP number
- Netmask = Netmask
- Gateway = IP number

VLAN

- Enable = enabled
- ID = 1
- Priority = 4
- Tagged traffic / PTP = enabled

Ethernet

- Link Settings = 100 Mb/s + Full duplex

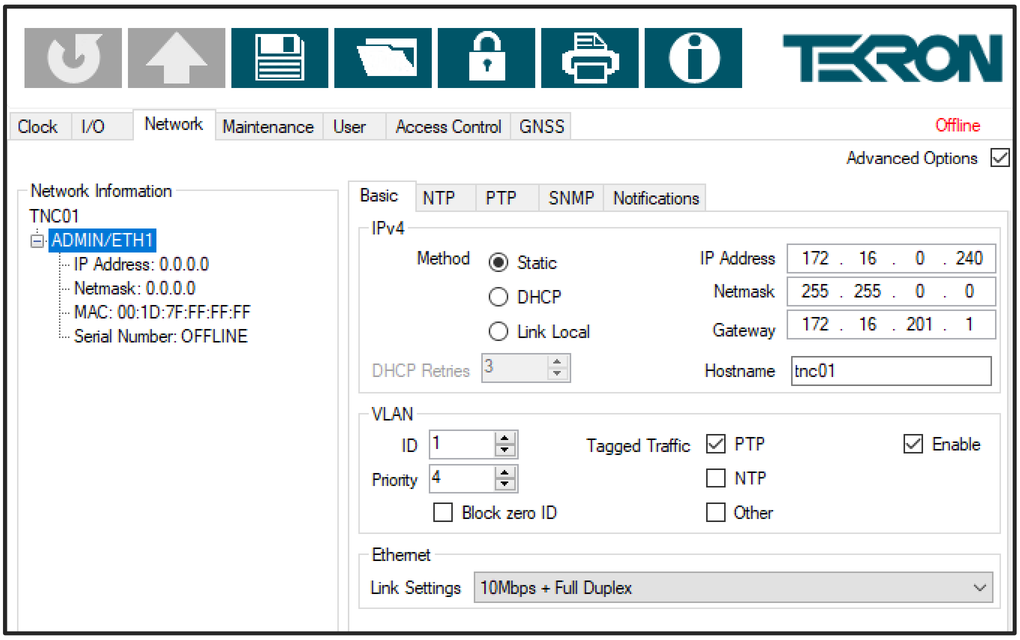


Figure 132: Basic setting dialog

Network / PTP Settings

Enable = enabled

Operating mode = Two-Step

Profiles = C37.238

Grandmaster Priority #1 = 120 (128 default setting)

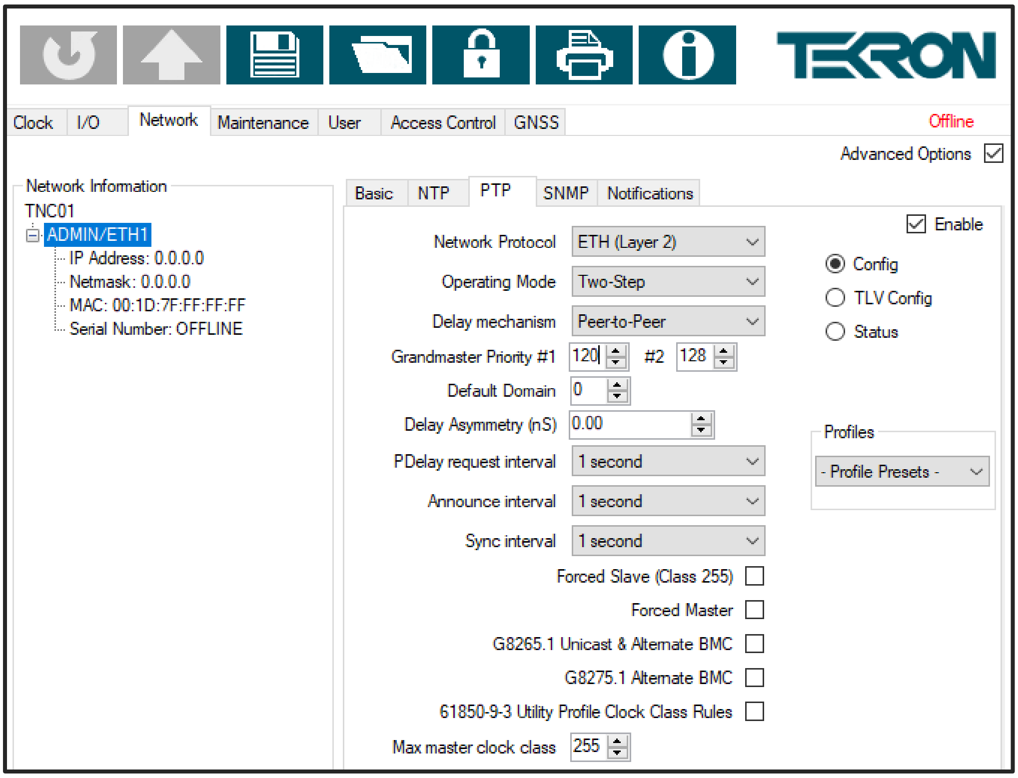


Figure 133: PTP setting dialog

Ethernet switch - Basic settings / Port configuration

Ethernet switch port, where TEKRON clock is connected, must have Automatic Configuration disabled and 100 Mbit/s FDX mode.

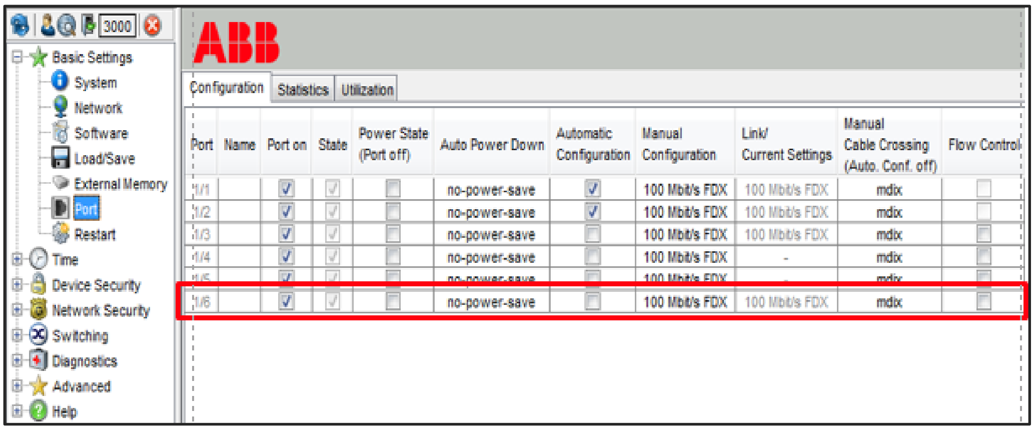


Figure 134: Port Configuration dialog

3.5.11.2 Meinberg

The LANTIME M400 timeserver can be configured via several user interfaces (for example local display, web interface).

Web interface

For first time installation enter IP address, netmask for Ethernet connection LAN0 of LANTIME via local HMI and then connect to the web interface by entering IP address of the LANTIME into the address field of a web browser. Default User name to configure device is ***root*** and password is ***timeserver***.

PTP Settings

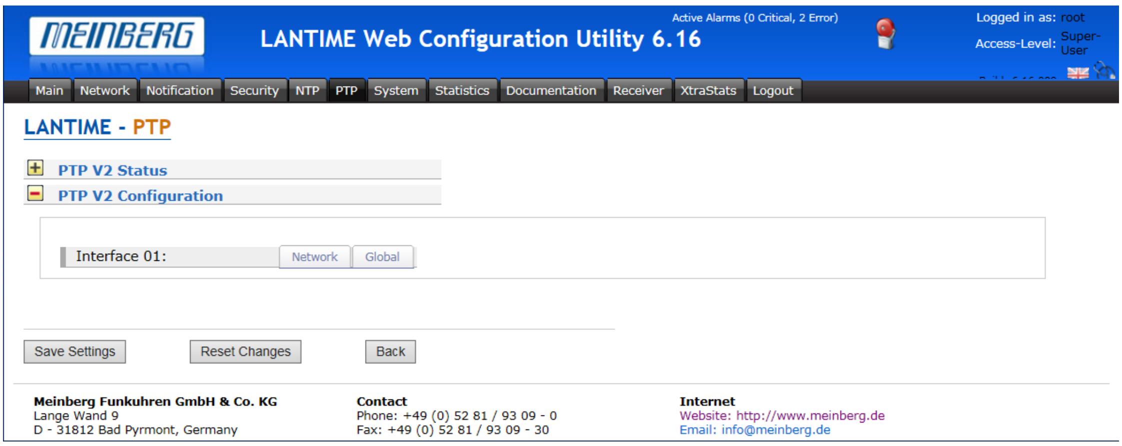


Figure 135: PTP setting dialog

PTP Setting / Interface 01 / Global

Select Profile = Power

Priority1 = 120 (128 default setting)

Other setting is default

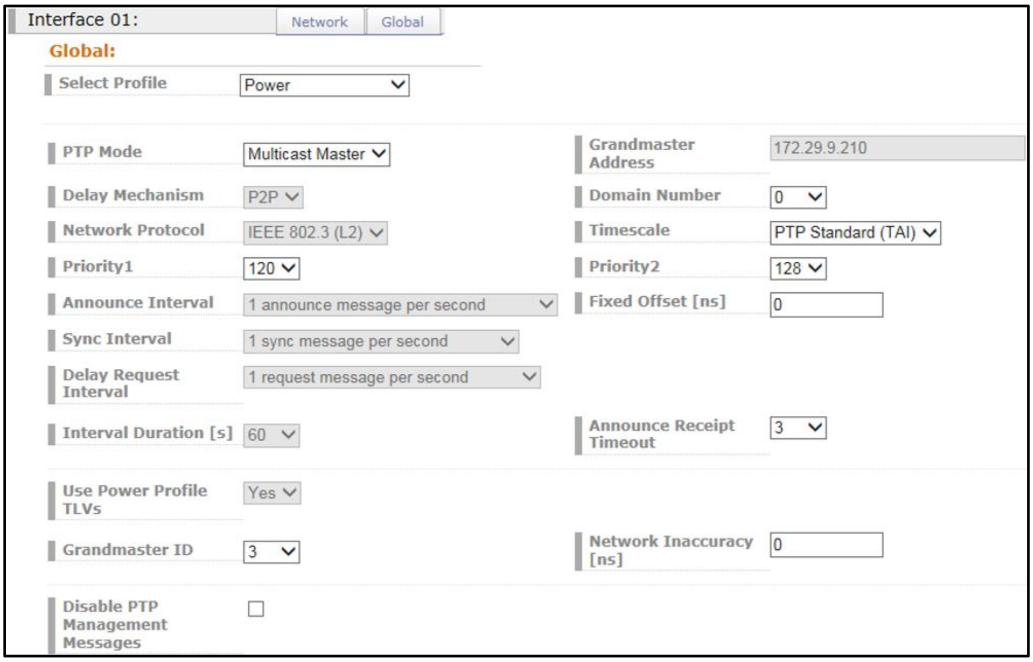


Figure 136: PTP Global settings dialog

PTP Setting / Interface 01 / Network

Enable DHCP-Client = Static

TCP/IP Address = IP number

Netmask = Netmask

Gateway = IP number

Other setting is default

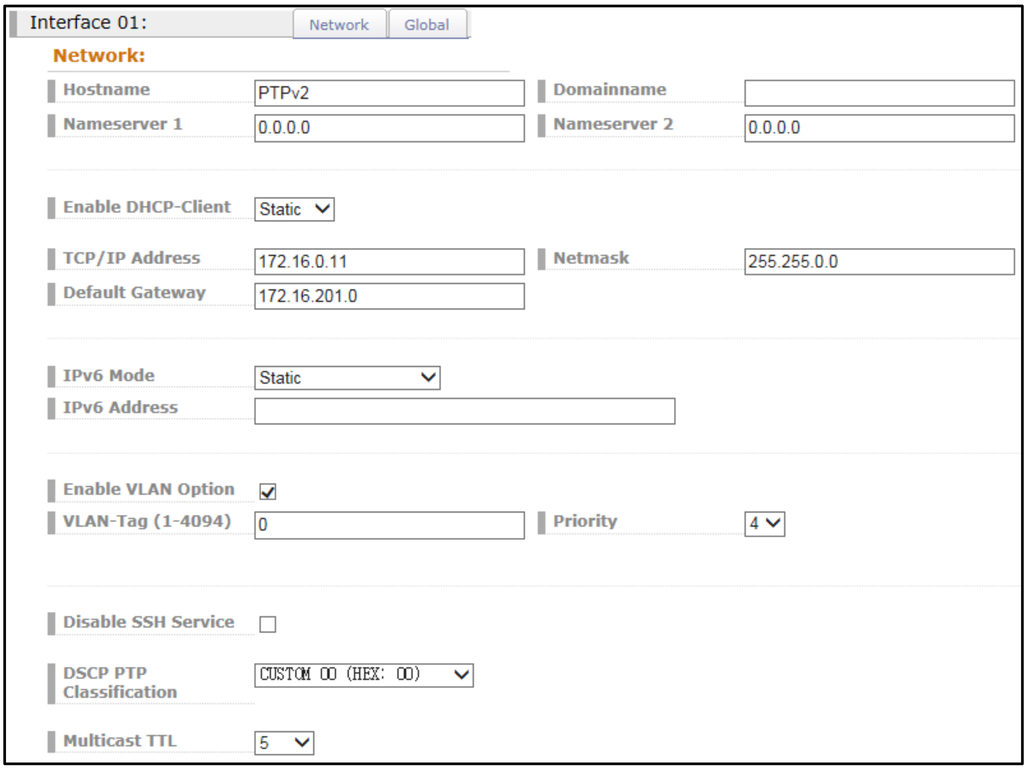


Figure 137: PTP Network settings dialog

3.6 Statistical energy meters

3.6.1 ESM-ET statistical energy meter

The statistical energy meter configuration process is carried out via EsConfigurator and ESM Test tools.

3.6.1.1 EsConfigurator tool

Network

IP address = IP number

Subnet mask = Netmask

Default gateway = IP address

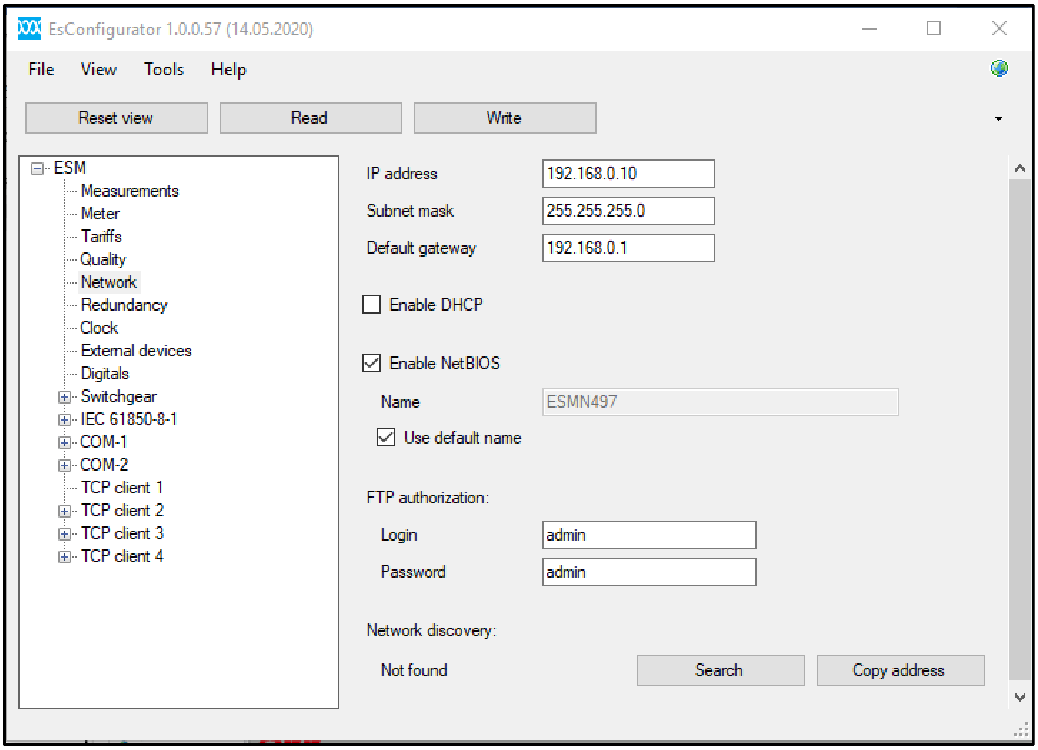


Figure 138: Network configuration dialog

Measurements / Transformation ratios and measurement units

current = 426.667

voltage = 346.620

Calculate automatically = enabled

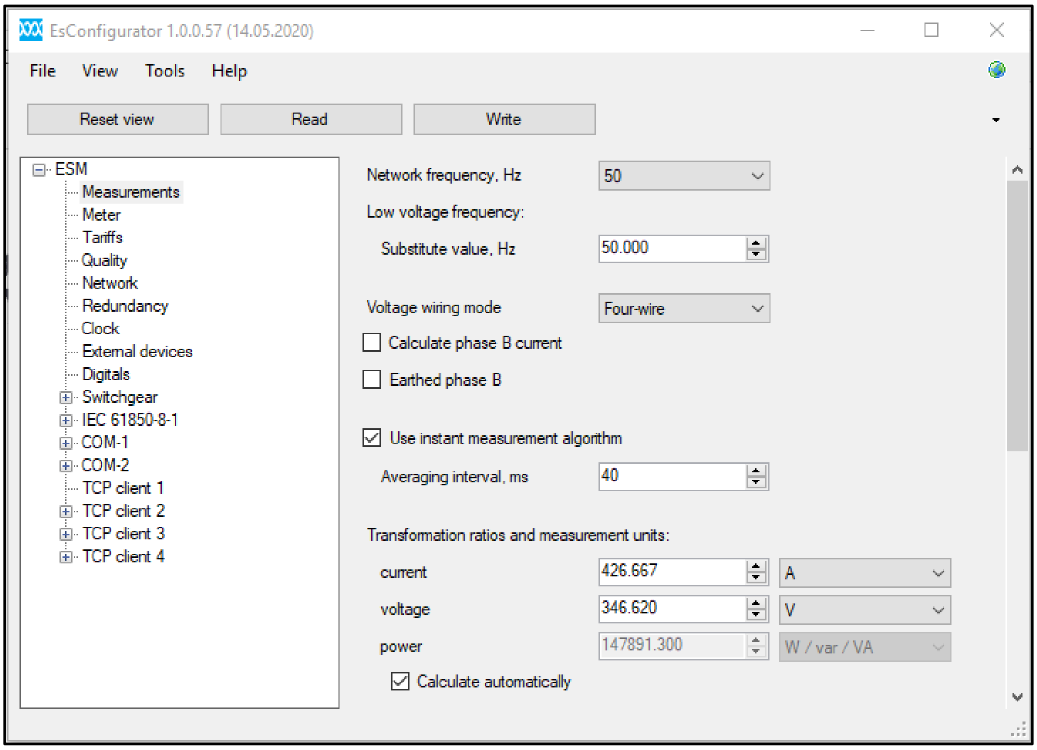


Figure 139: Measurements configuration dialog

Clock

Synchronization

– Source = NTP

SNTP synchronization

– Server 1 = IP address

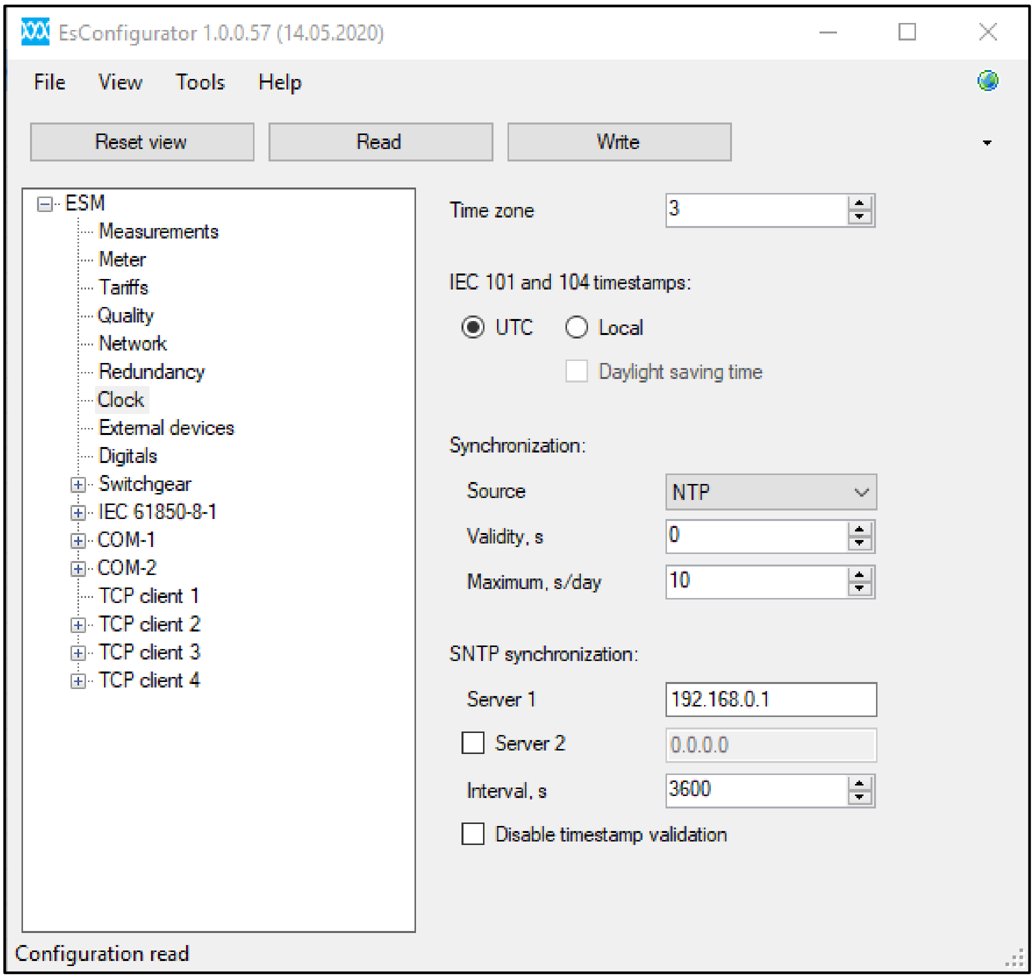


Figure 140: Clock configuration dialog

3.6.1.2 EST Test tool

Due to linear characteristics of the sensor measurement error caused by manufacturing tolerances can be compensated for by using correction factors entered in the statistical energy meter. The correction factors are entered via parameter setting in ESM Test tool.

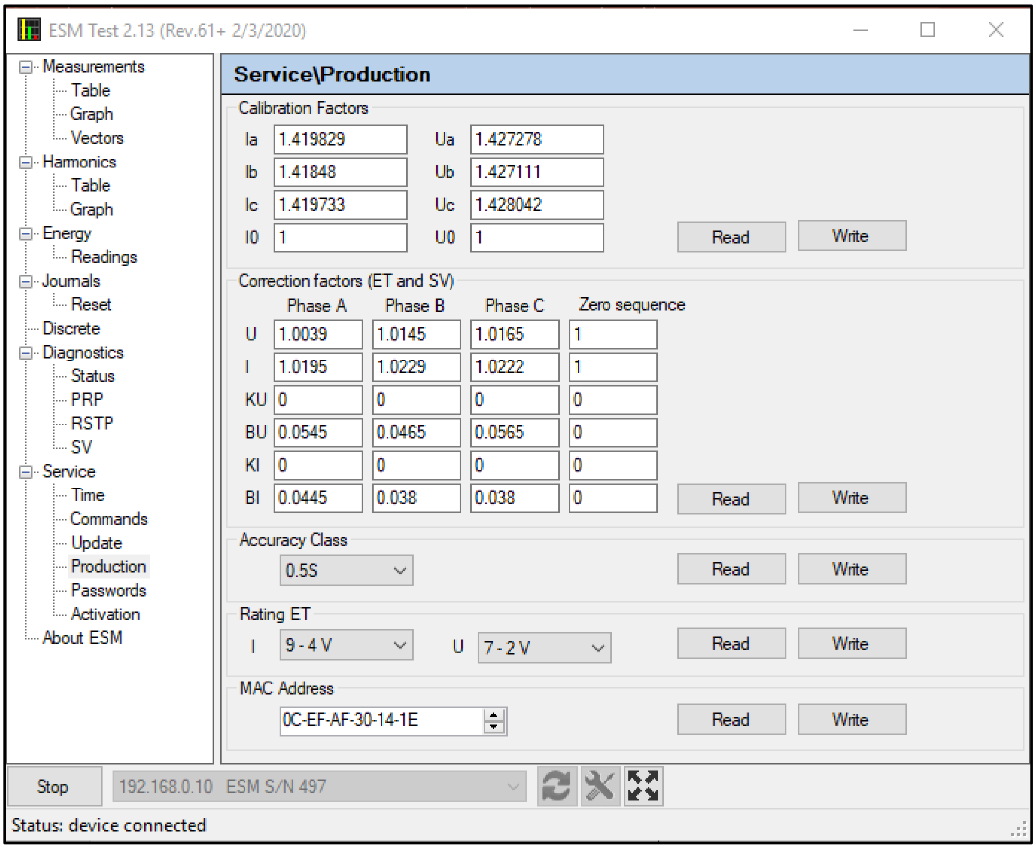
Service/ Production / Correction factor (ET and SV)

U =the correction factor for the amplitude of the voltage sensor (aU)

I = the correction factor for the amplitude of the current sensor (aI)

BU = the correction factor for the phase error of the voltage sensor (pU)

BI = the correction factor for the phase error of the current sensor (pI)



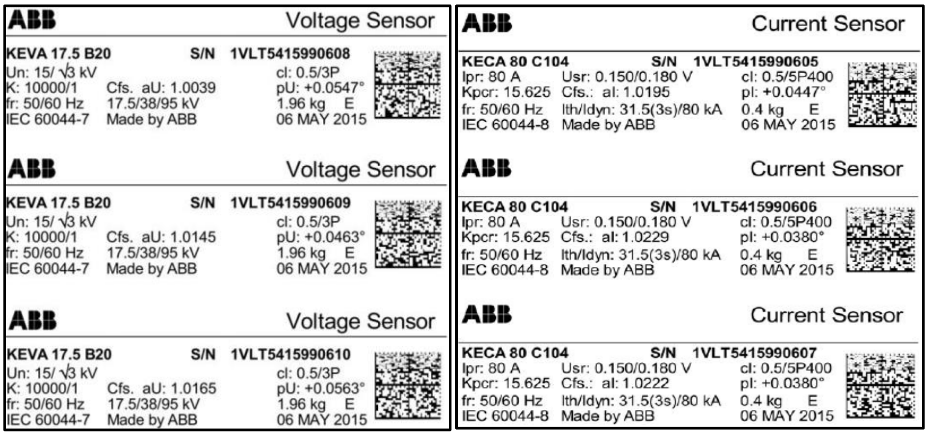


Figure 141: Example of setting the correction factors for the current and the voltage sensors in ESM Test tool

Glossary

615 series	Relion® 615 series protection and control relays
620 series	Relion® 620 series protection and control relays
640 series	Relion® 640 series protection and control relays
ACT	Application Configuration Tool
AFS Family	ABB FOX Switch family for utility applications
APPID	Application Identifier in GOOSE and SMV messages
ASDU	Application Service Data Unit
BC	Boundary clock
BMC	Best Master Clock algorithm
Control Block	It defines HOW and WHEN data is sent to WHOM
CT	Current Transformer
Data set	It defines WHAT data is sent
EMI	Electro Magnetic Immunity
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
E-MRP	Fast Media Redundancy Protocol with decreased recovery time
FDX	Full Duplex
FTP	Foiled Twisted pairs
GOOSE	Generic Object-Oriented Substation Event
GLONASS	Global Navigation Satellite System
GoID	GOOSE message identifier
GPS	Global Positioning System
GVRP	Generic VLAN Registration Protocol
HMI	Human Machine Interface
HSR	High Availability Seamless Redundancy
HW	Hardware
ID	Identifier
IGMP	Internet Group Management Protocol
IEC	International Electrotechnical Commission
IEC 61850	International standard for communication networks and systems for power utility automation
IEC 61850-8-1	Station bus (MMS + GOOSE)
IEC 61850-9-2	Process bus
IEC 61439	International standard for High availability automation networks
IED	Intelligent Electronic Device

IEEE	Institute of Electrical and Electronics Engineers. The IEEE standard groups defined the PTP and Power profile
IEEE 1588	Standard for Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
IET600	Integrated Engineering Toolbox
IP	Internet Protocol
ITT	Integrated Testing Toolbox for efficient testing and commissioning of IEC 61850 based Substation Automation Systems
I/O	Input / Output
I/U	Current / Voltage
KECA	Indoor Current Sensor
KEVA	Indoor Voltage Sensor
LAN	Local Area Network
LC	Type of connector for glass fiber cable
LE	Light Edition (Lite Edition)
MAC	Media Access Control
Mbps	Megabit per second
MMS	Manufacturing Message Specification
MRP	Media Redundancy Protocol (according IEC 62439)
MV	Medium voltage
NTP	Network Time Protocol
PC	Personal computer
PCM600	Protection and control relay Manager
PPS	Pulses per second
PRP	Parallel Redundancy Protocol
PTPv2	Precision Time Protocol Version 2
REF615	Feeder protection and control relay
REF620	Feeder protection and control relay
Redbox	Redundancy box connects non-PRP / non-HSR devices to high availability IEC 62439 networks
RED615	Line differential protection and control relay
REM615	Motor protection and control relay
REM620	Motor protection and control relay
REX640	Protection and control REX640
RJ-45	Galvanic connector type
RSTP	Rapid spanning tree protocol
SA	Substation Automation

SCADA	Supervisory Control and Data Acquisition
SCD	SCL file type (Substation Configuration Description)
SCL	XML-based substation description configuration language defined by IEC 61850
SFP	Small form-factor pluggable
SMV	Sampled Measured Value
SNMP	Simple Network Management
SNTP	Simple Network Time Protocol
SvID	Sampled value message identifier
TC	Transparent clock
TLV	Type Length Value
VLAN	Virtual LAN
VT	Voltage Transformer
ZEE600	ABB Ability Operations Data Management system Zenon

Revision History

Rev.	Page	Change Description	Date / Initial
A	All	Initial release	2014
B	All	New switchgear types for UniGear Digital (UniGear ZS1 24kV, UniGear 550, UniGear 500R, UniGear MCC) 3D models of switchgear panels Extended sensor product portfolio for UniGear Digital Engineering of sensors including setting examples Updated recommended network topologies (HSR networks with redboxes, HSR-PRP networks) Updated recommended time synchronization schemes (HSR-PRP networks) HSR and IEEE1588 v2 support in AFS 66x	2015-01-16
C	All	615 series 5.0 FP1 (new functionality: for example, IEC 61850 Edition 2 support, synchro check function with IEC 61850-9-2LE, RED615 supports HSR, PRP and IEC61850-9-2LE) Connecting GOOSE sender data to a protection and control relay application in PCM600 Application configuration of the SMV receiver Protection and control relay Ethernet rear ports setting and supervision Updated engineering of current sensors (RSV up to 150 mV / Hz) Small form-factor pluggable module / port Recommended Satellite controlled clocks and their engineering Updated recommended network topologies (Fast Media redundancy protocol)	2015-12-01
D	All	Ethernet technology extended about Ethernet rear connections of protection and control relays 620 series 2.0 FP1 (new functionality: for example, IEC 61850 Edition 2 support, synchro check function with IEC 61850-9-2LE, REM620 supports sensor inputs) Testing section has moved to UniGear Digital Commissioning and testing Guide Updated figures with UniGear ZS1 Digital (17.5 kV, 4 000 A, 50 kA) – a new post insulator support Automatic port configuration in Ethernet switch for connected protection and control relays via metal cabling Ethernet channel supervision function blocks (RCHLCCH and SCHLCCH) Coupler adapter AR5 – three phases adapter ESSAILEC® test block Removal of SNTP-> IEEE1588 Time synchronization scheme (It is not optimal solution for UniGear Digital)	2017-01-02

E	All	Satellite reference clock with PRP support Removal of Coupler adapter AR4 SMV Max delay parameter UniGear 500R – tested voltage level up to 17.5kV Protection and control REX640 Updated recommended Managed Ethernet switches Supported Process bus application extended about voltage sharing redundancy	2019-02-26
F	All	Statistical Energy meter ESM-ET UniGear Digital (UniGear ZS1 Double busbar system up to 17.5 kV, UniGear ZS1 63 kA)	2020-06-17
G	All	New switchgear type for UniGear Digital (UniGear ZS2) Extended sensor product portfolio for UniGear ZS2 Digital IP address allocation update according to IEC 61850-90-4 (ed2) Recommended maximum number of protection and control relays in HSR ring is limited to 12 when IEEE 1588 time synchronization and IEC 61850-9-2LE are implemented Smart substation control and protection SSC600 (recommended architectures)	2020-12-01

Visit us

www.abb.com/mediumvoltage

Document Number: 1VLG500007 Rev. G