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## **UniGear Smart solutions**

Current and voltage sensors and IEC  
61850

Commissioning and testing Guide







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Release: September 2024

Document Number: 1VLG500017

Revision: D

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# **1 Introduction**

## **1.1 This manual**

The maintenance and commissioning guide provides information about maintenance and commissioning activities on the UniGear with current and voltage sensors and IEC 61850 by providing details about its main components and proven testing methods.

## **1.2 Intended users**

This manual is intended to be used by protection 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 relays and IEC 61850 engineering. The test and service engineers are expected to be familiar with the handling of electronic equipment and medium voltage switchgear.

## 2 UniGear with current and voltage sensors and IEC 61850

UniGear with current and voltage sensors and IEC 61850 is a new solution implemented to a traditional UniGear switchgear. It is accomplished by using well-proven components such as current and voltage sensors, Relion<sup>®</sup> protection relays and IEC 61850 digital communication. Commissioning is very similar to commissioning activities run on traditional UniGear switchgear. Differences in procedures are corresponding to implementation of Process bus and GOOSE functionalities and usage of sensors. The traditional method of commissioning activity starts with primary injections, then continues with protection relays testing, apparatus functionality verification, etc., and ends with testing of the communication if applicable. In UniGear with current and voltage sensors and IEC 61850, commissioning must start with verification of IEC 61850 digital communication, particularly with the Ethernet network check. After commissioning of the Ethernet network, there is no restriction regarding the order of other commissioning activities.

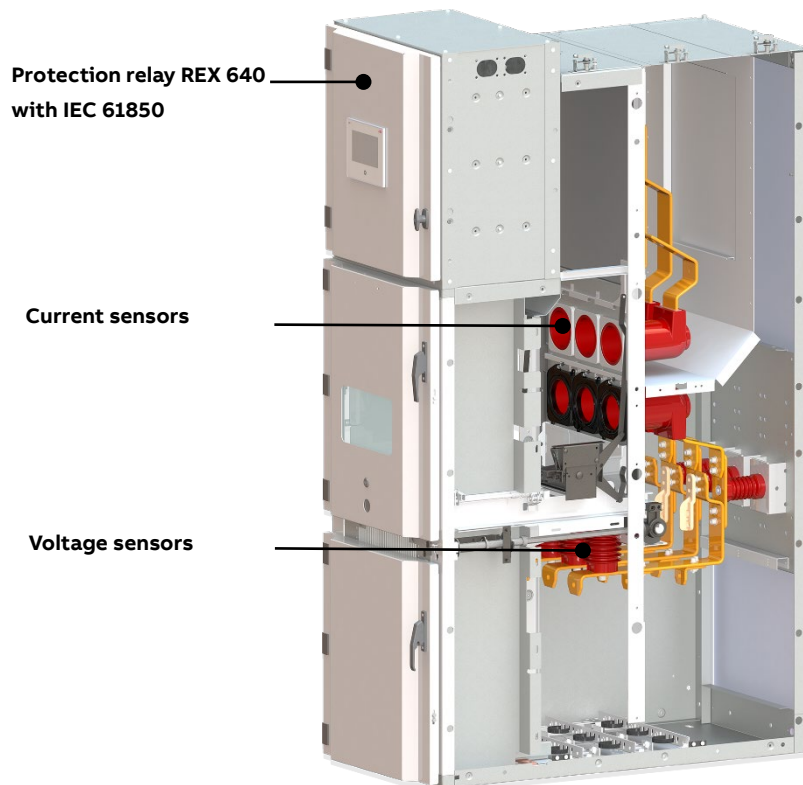


Figure 1: UniGear with current and voltage sensors and IEC 61850 and its key components

## 3 Ethernet network verification

The Ethernet network interconnects protection relays in a substation. As the GOOSE and Process bus are used, to make the network functional is essential for most of the tests. The network is set up and tested in the factory. Therefore, after switchgear assembly onsite, it is only necessary to verify its functionality. Before starting any testing of the communication, properly set the Ethernet settings in the protection relays, set the Ethernet switches and, only then, interconnect the Ethernet network according to the project documentation.

It is supposed that the protection and control circuits are powered from the power supply.

### 3.1 Protection relays

Before starting any secondary testing of the protection relay functions, verify if the IP addresses, the network topology and time synchronization settings are in accordance with the project documentation.

#### IP address setting

Check communication board setting according to documentation (for example Network Overview diagram ...).

On the protection relay LHMI go to -> **Main Menu/Configuration/Communication/Ethernet/Rear port(s)**

- IP address = for example, 172.16.2.1
- Subnet mask = for example, 255.255.0.0

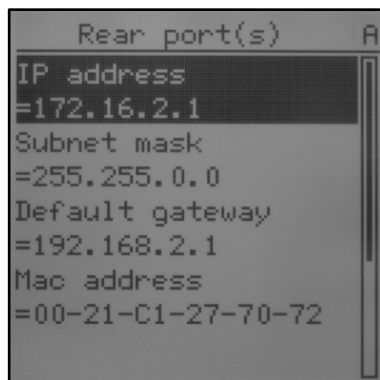


Figure 2: IP address setting for rear port(s)

#### Network topology setting

Check the network topology setting according to the documentation.

On the protection relay LHMI go to -> **Main Menu/Configuration/Communication/Ethernet/Redundancy/Redundant mode**

- Redundancy mode = None
- Redundancy mode = HSR (High-availability Seamless Ring)
- Redundancy mode = PRP (Parallel Redundancy Protocol)

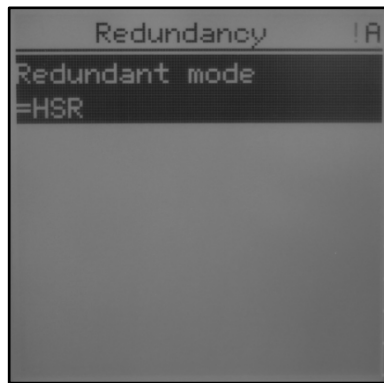


Figure 3: Network topology setting and its Redundancy mode

### Time synchronization setting

Check the setting of time synchronization. For Process bus functionality, the IEEE 1588 protocol must be set up.

On the protection relay LHMI go to -> **Main Menu/Configuration/Time/Synchronization/Synch source**

- Synch source = IEEE 1588

Protection relays, Ethernet switches and Time Synchronization Clocks must be in the same PTP domain ID (PTP = precision time protocol).

On the protection relay LHMI go to -> **Main Menu/Configuration/Time/Synchronization/PTP domain ID**

- PTP domain ID = 0

In case of Grandmaster clock (Satellite controlled clock) failure, it is necessary to have one protection relay defined as the Master clock and one protection relay as the Backup master clock. It is a matter of PTP priority setting. Devices with a lower PTP priority 2 value become the first master clock.

### Voltage sender protection relays

On the protection relay LHMI go to -> **Main Menu/Configuration/Time/Synchronization**

- PTP priority 1 = 127
- PTP priority 2 = 128-255 to be different in each protection relay

```

Synchronization  R
Synch source
=IEEE 1588
PTP domain ID
=0
PTP priority 1
=127
PTP priority 2
=128

```

Figure 4: PTP priority setting for Master clock

#### Other protection relays

On the protection relay LHMI go to -> **Main Menu/Configuration/Time/Synchronization**

- PTP priority 1 = 128
- PTP priority 2 = 128

```

Synchronization  R
Synch source
=IEEE 1588
PTP domain ID
=0
PTP priority 1
=128
PTP priority 2
=128

```

Figure 5: PTP priority setting for Slave clock



If both, Master and Backup master clocks fails, the protection relays establish a new primary source for time synchronization information automatically.

Check time synchronization status at the voltage sender protection relay.

On the protection relay LHMI go to -> **Main Menu/Monitoring/IED status/Time synchronization**

- Synch source = IEEE 1588 master

```
Time synchronizati... A
Synch source
=IEEE 1588 master
Synch status
=Up
Synch accuracy
=25
IEEE 1588
```

Figure 6: IEEE 1588 master clock status

Check the time synchronization status at other protection relays.

On the protection relay LHMI go to -> **Main Menu/Monitoring/IED status/Time synchronization**

- Synch source = IEEE 1588 slave

```
Time synchronizati... A
Synch source
=IEEE 1588 slave
Synch status
=Up
Synch accuracy
=21
IEEE 1588
```

Figure 7: IEEE 1588 slave clock status

### 3.2 Managed Ethernet switches

To create a reliable Ethernet network for IEC 61850 communication, a managed Ethernet switch is recommended to be used. The most important settings of Hirschmann’s family Ethernet switches to be observed are highlighted in this section.

If the IP address is unknown, disconnect all Ethernet cables from the switch or turn other Ethernet switches off. After connecting a notebook with the HiDiscovery tool to any port on the Ethernet switch, the following dialogue screen appears (shown in Figure 8). HiDiscovery automatically searches the network for those devices, which support the HiDiscovery protocol. The next dialogue, open by double clicking on the respective switch in HiDiscovery defines the IP address and net mask.

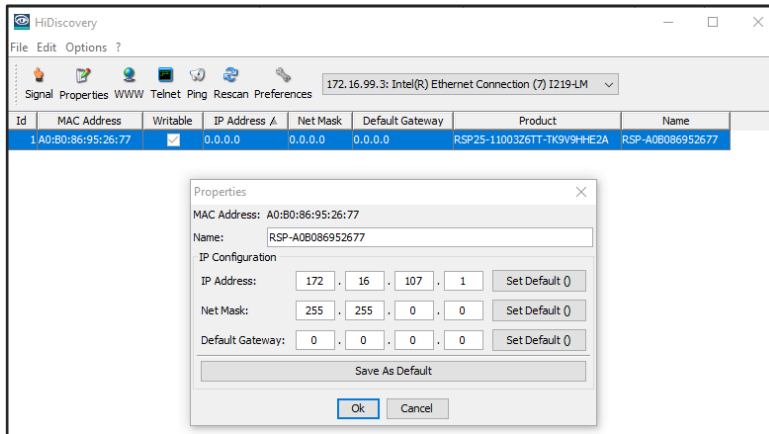


Figure 8: Properties dialogue of discovered Ethernet switch by HiDiscovery

The user-friendly web-based interface of the Hirschmann RSP switches offers the possibility of operating the device from any location in the network via a standard browser such as Mozilla Firefox or Microsoft Internet Explorer. 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.

For MACH family can be used HiView tool.

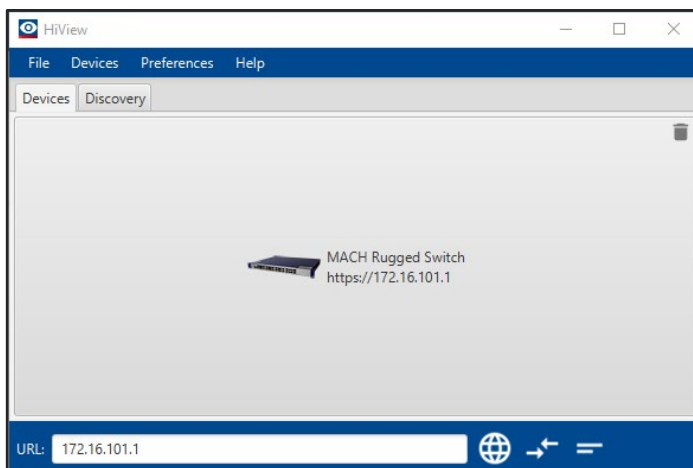


Figure 9: HiView screen

### Login

Default Username to configure Hirschmann RSP or MACH family is **admin**, and the password is **private**.

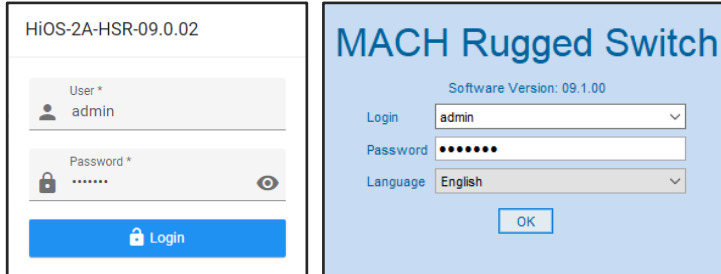


Figure 10: Login window

### 3.2.1 Basic Settings

#### Basic Settings / Port configuration

Check Port setting according to the UniGear Smart solutions – Current and voltage sensors and IEC 61850 Engineering Guide. It is recommended to assign a bay to port name according to the project documentation (for example Network Overview diagram). Interconnect the Ethernet cable from the bay (protection relay) to the Ethernet switch port.

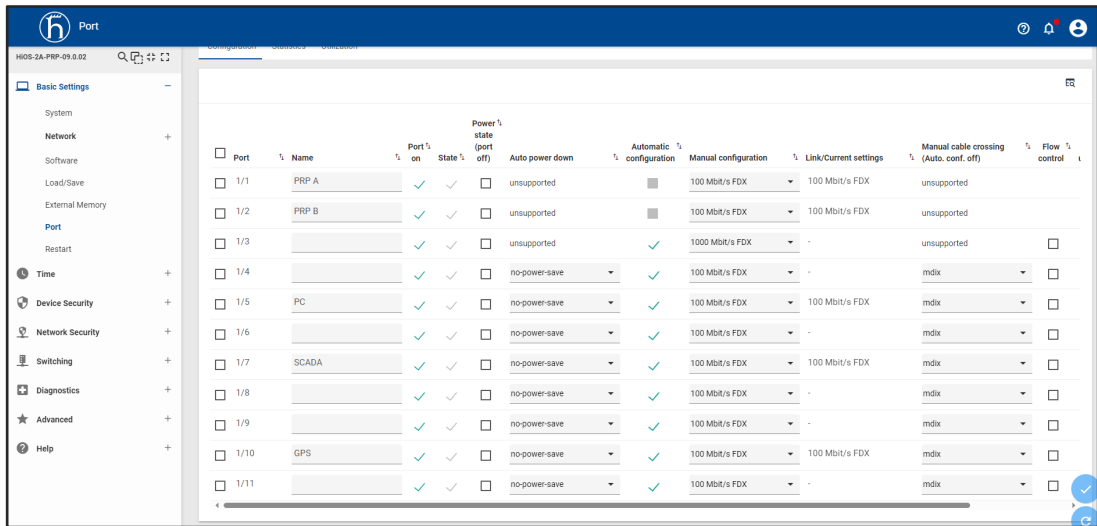


Figure 11: RSP family Port configuration dialogue

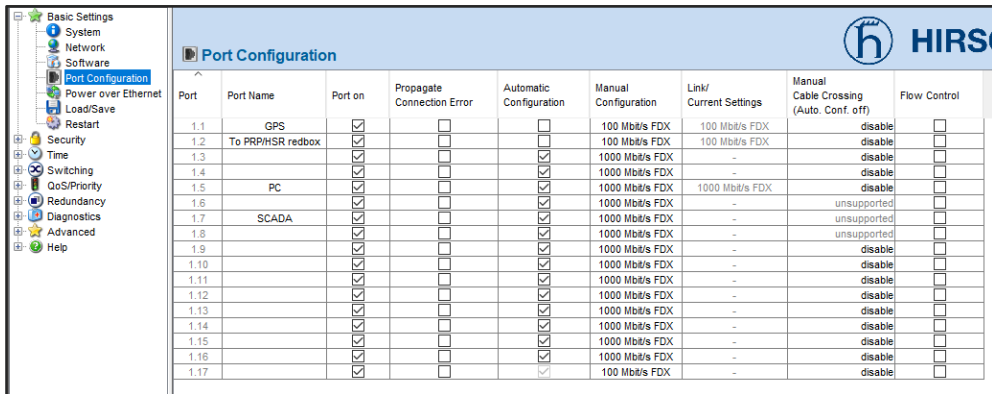


Figure 12: MACH family Port configuration dialogue

### 3.2.2 Time Settings

Check Time setting. It is recommended to set a transparent time with Power profile. The Ethernet switch then only corrects and forwards the PTP messages and cannot become the PTP master. The PTP profile must be enabled on all ports. The Peer-to-peer delay interval is definite for power profile 1s.

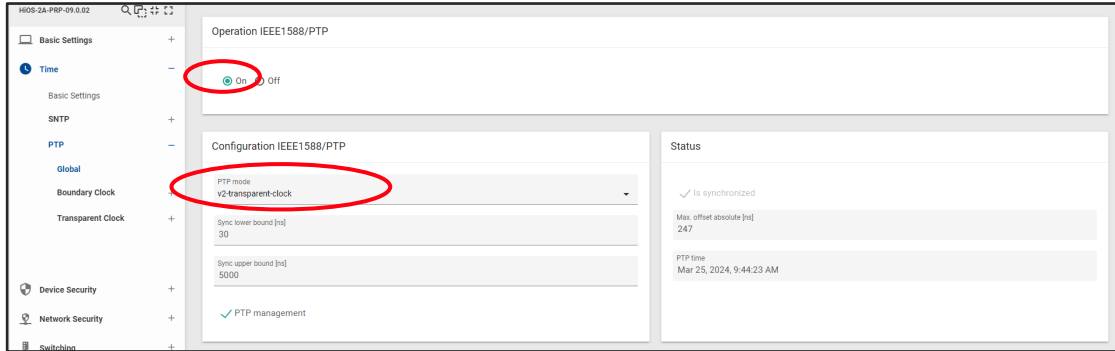


Figure 13: RSP family PTP Global dialogue

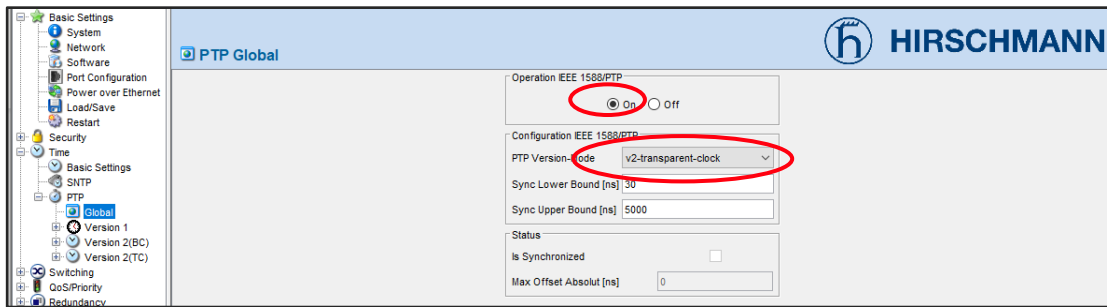


Figure 14: MACH family PTP Global dialogue

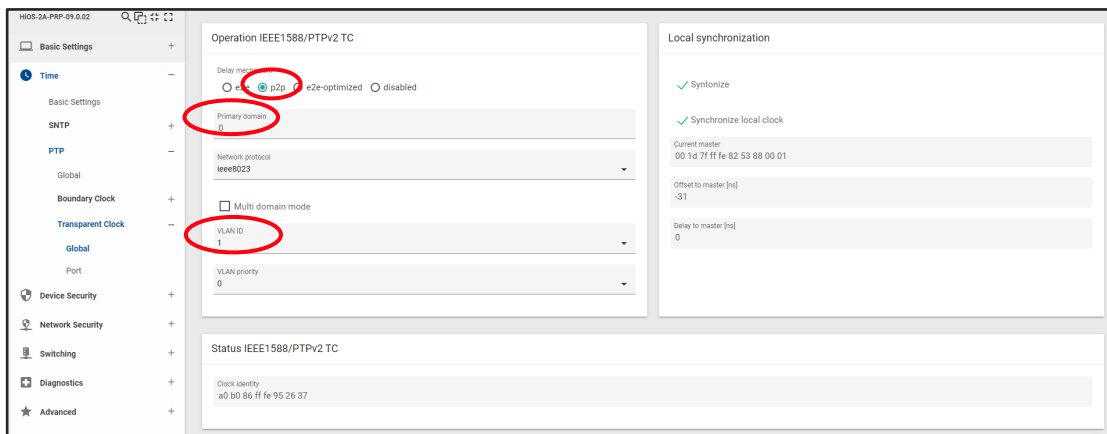


Figure 15: PTP Transparent Clock Global dialogue

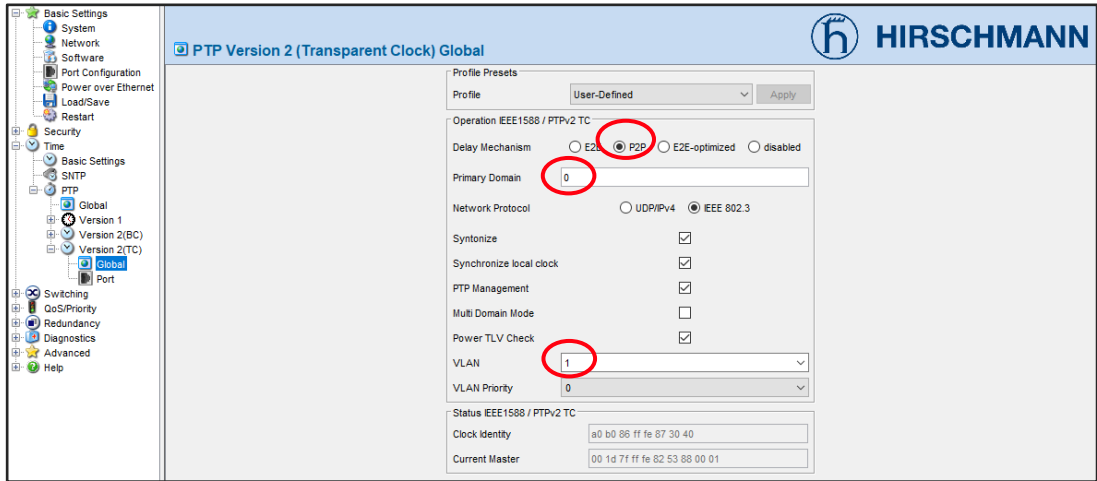


Figure 16: MACH 1040 PTP Transparent Clock global dialogue

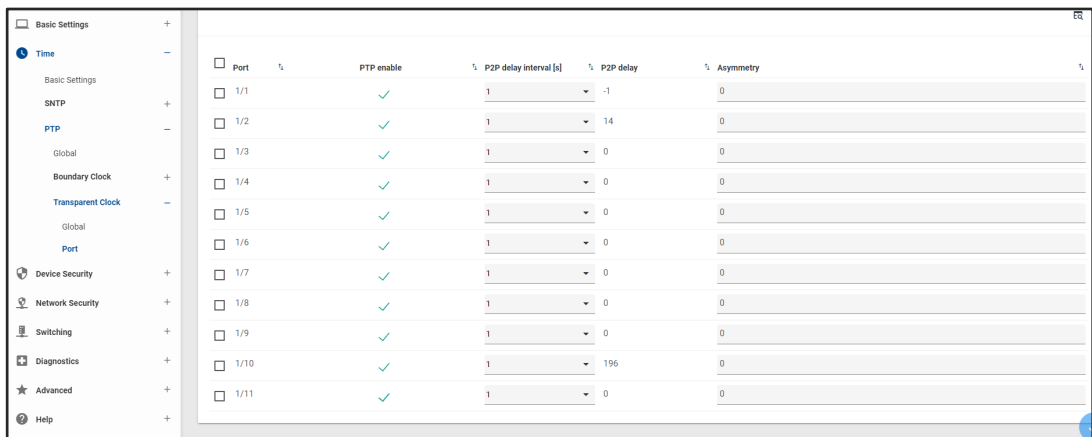


Figure 17: RSP family Transparent clock Port dialogue

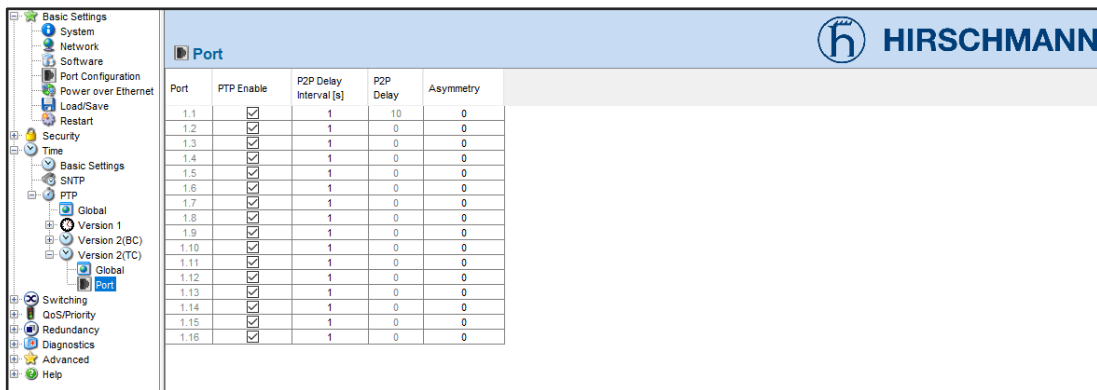


Figure 18: MACH 1040 Transparent clock Port dialogue

### 3.2.3 Switching Settings (VLAN)

The traffic segregation is especially essential for the process bus to reduce data traffic and to let it go only where needed (for example GOOSE, SMV shared between protection relays should not be sent to the control system, SMV should only be sent 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

Check VLAN mode. To segregate the Process bus and GOOSE per sections, for unaware mode the checkbox must be ticked off.

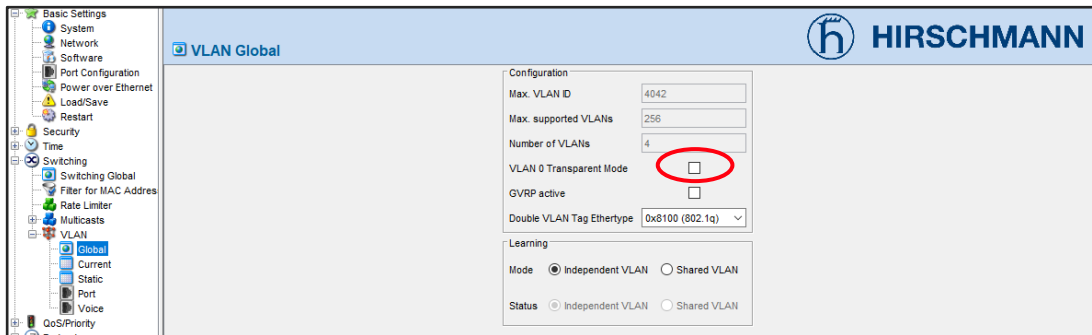


Figure 19: Switching VLAN Global dialogue in MACH family

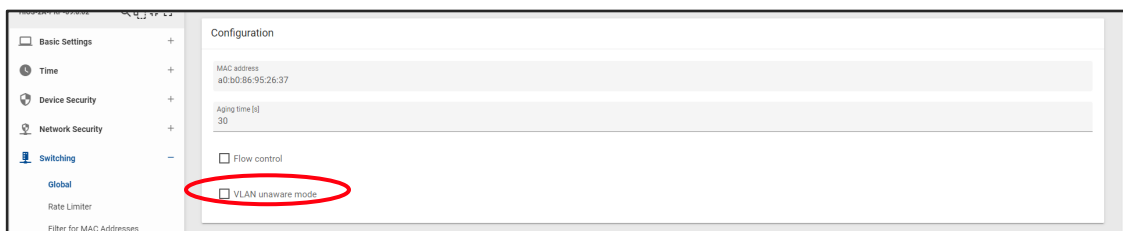


Figure 20: Switching Global dialogue in RSP family

**Switching/VLAN**

Check ports assignment to VLANs in VLAN Configuration dialogue. Setting must match the VLAN ID of GOOSE and SMV messages in PCM600.



A port assigned for SCADA is not a member of any VLAN except the native one.

VLAN ID	Name	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17
1	Default	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2	Vlan2	-	-	-	-	-	-	T	-	-	-	-	-	-	-	-	-	-
1000	GOOSE	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
3000	SMV	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

Figure 21: VLAN Configuration dialogue MACH family

VLAN ID	Status	Creation time	Name	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17
1	other	0d 0h 0m 0s	default	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2	permanent	0d 0h 0m 10s	Vlan2	-	-	-	-	T	-	-	-	-	-	-	-	-	-	-
1,000	permanent	0d 0h 0m 10s	GOOSE	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
3,000	permanent	0d 0h 0m 10s	SMV	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

Figure 22: VLAN Configuration dialogue RSP family

Check setting of Ingress filtering. Ingress filtering must be marked for each port. The device compares the VLAN ID in the data packet with VLANs of which the device is a member. If the VLAN ID in the data packets matches one of these VLANs, the port transmits the data packet. Otherwise, the device discards the data packet.

Port	Port-VLAN-ID	Acceptable Frame Types	Ingress Filtering	GVRP	Double VLAN Tag Mode
1.1	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.2	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.3	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.4	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.5	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.6	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.7	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.8	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.9	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.10	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.11	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.12	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.13	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.14	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.15	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.16	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal
1.17	1	admitAll	<input checked="" type="checkbox"/>	<input type="checkbox"/>	normal

Figure 23: VLAN Port dialogue MACH family

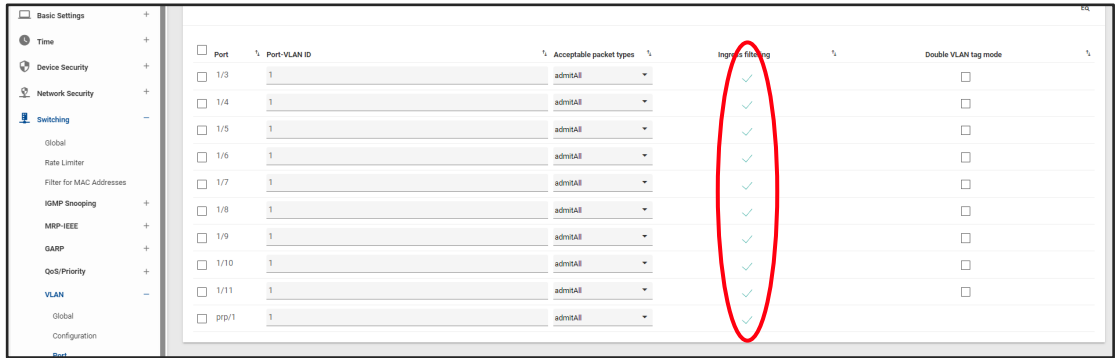


Figure 24: VLAN Port dialogue RSP family

**SCADA connection**

There could be GOOSE messages from foreign substations in the SCADA, which may affect interlocks/trips between your panels and therefore must be filtered out. This is ensured by setting Ingress filtering on via the VLAN port dialogue.

The port on the Ethernet switch connected to SCADA is not a member of any VLAN except the native one, to filter out GOOSE messages coming from SCADA.

The port on the switch connected to SCADA is a member of a VLAN to communicate with other protection relay(s) (in another substation) on the same VLAN.

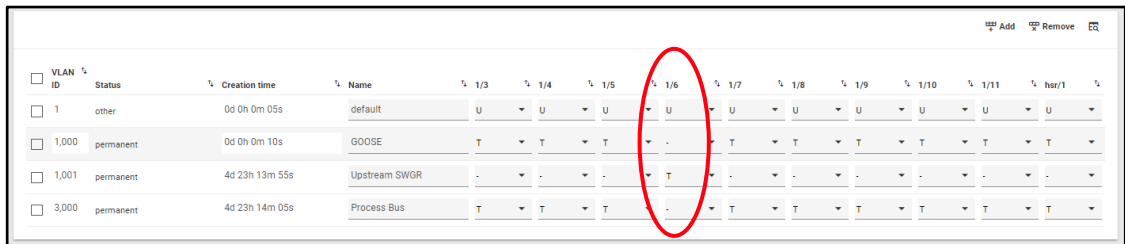


Figure 25: VLAN Configuration dialogue (Port 6 is connected to SCADA)

### 3.2.4 PRP and HSR Redundancy Settings

#### PRP

There is no special setting in the Ethernet switch for PRP networks. For more details and a network topology overview, refer to the UniGear Smart solutions – Current and voltage sensors and IEC 61850 Engineering Guide.

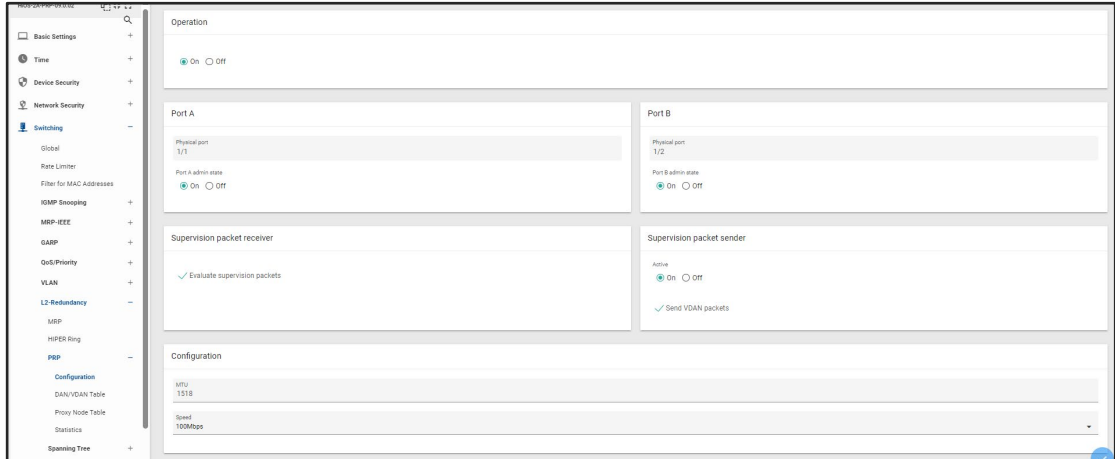


Figure 26: RSP family PRP redundancy dialogue

#### HSR

Check the HSR parameters setting according to the UniGear Smart solutions – Current and voltage sensors and IEC 61850 Engineering Guide. It varies based on the used network topology.

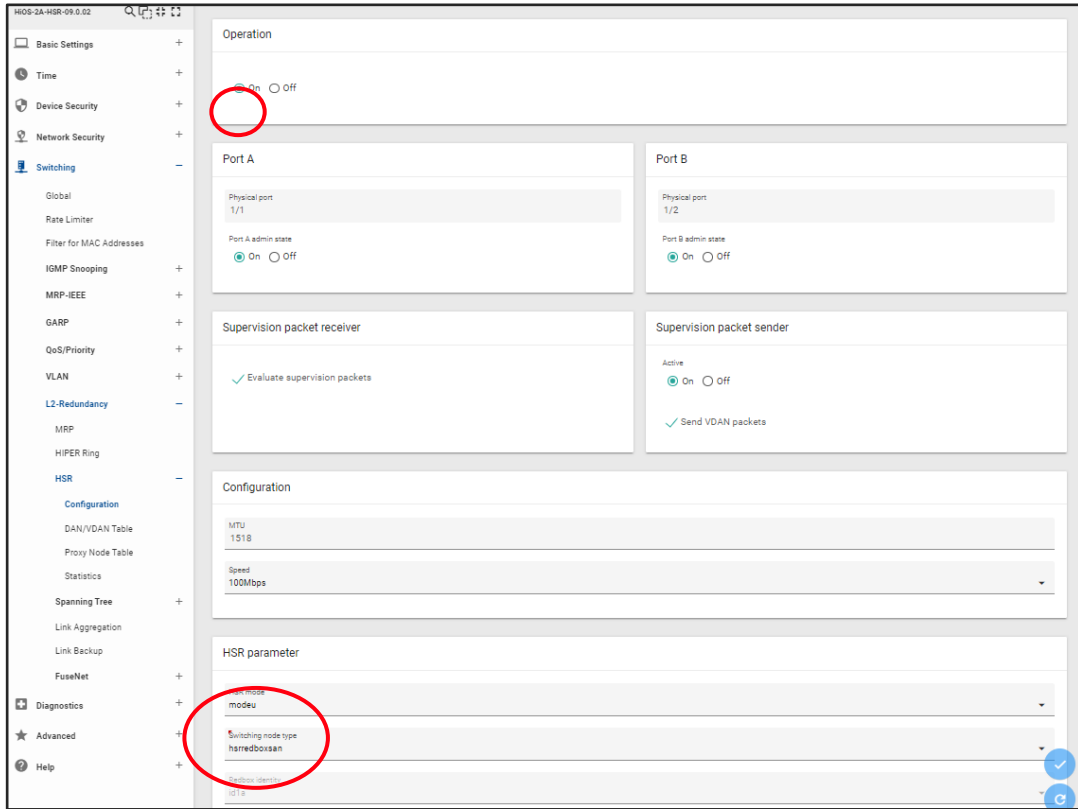


Figure 27: RSP family HSR configuration

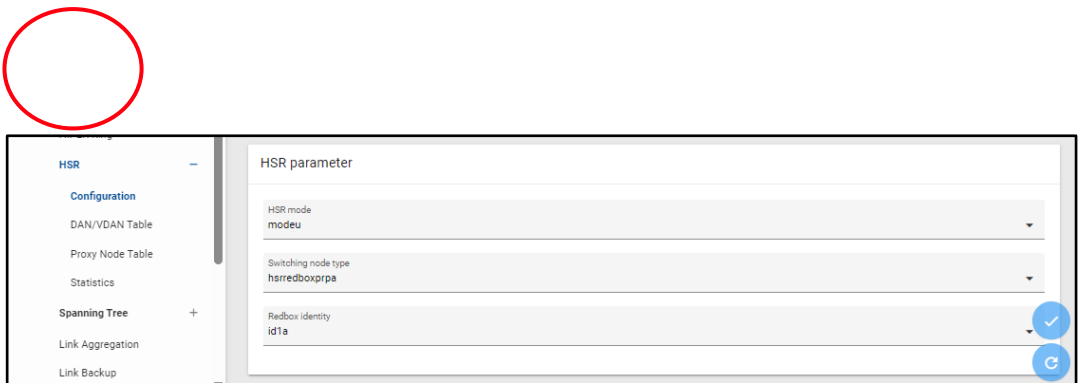


Figure 28: RSP family HSR to PRP configuration

### 3.3 Interconnections

Check the interconnection of network components (protection relays, managed Ethernet switches ...) according to documentation (for example, the Network Overview Diagram).

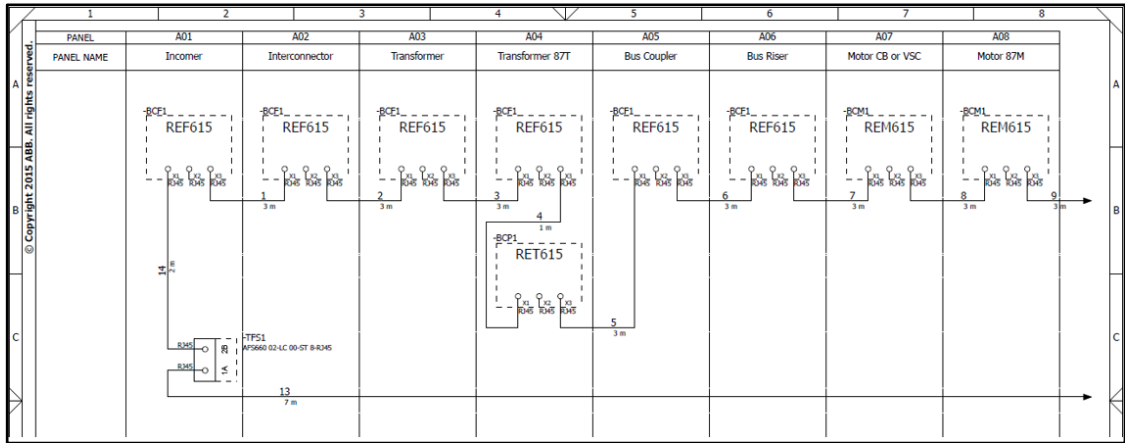


Figure 29: Example of HSR Network overview diagram

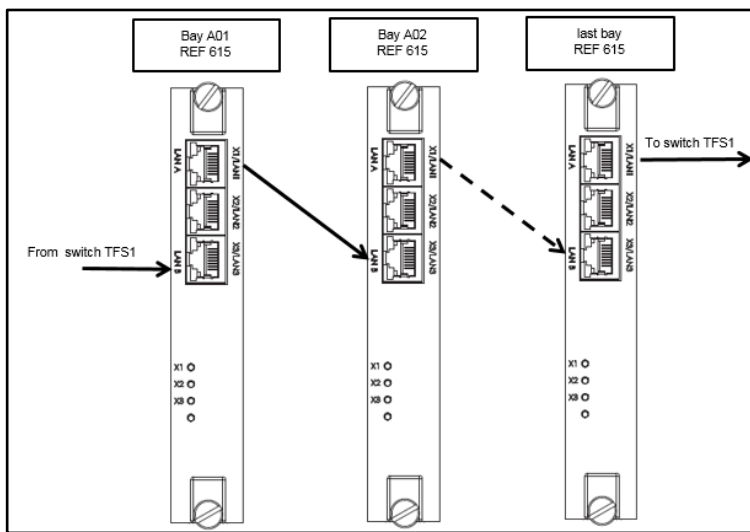


Figure 30: Interconnection of protection relays into HSR ring

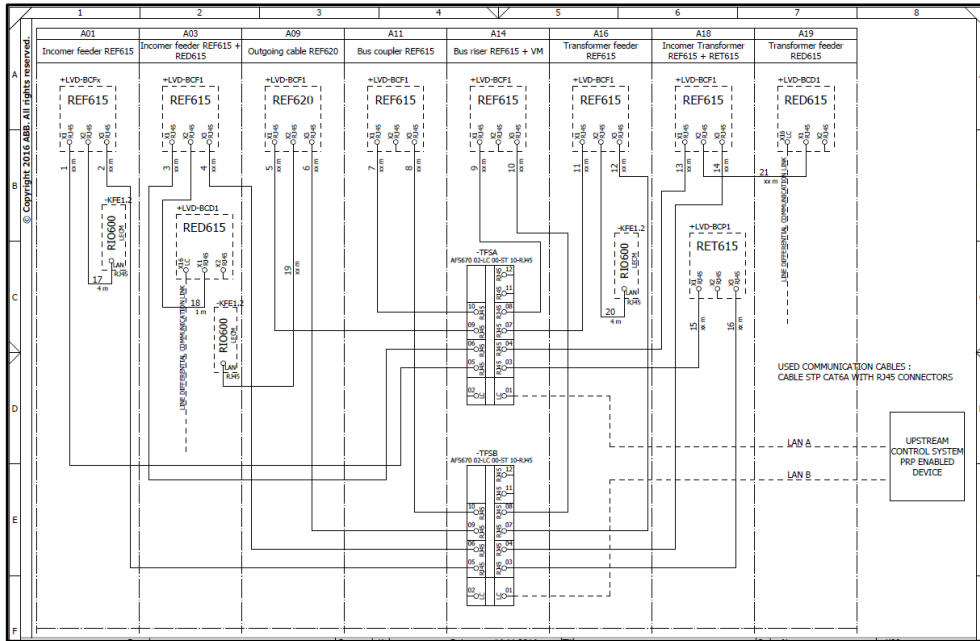


Figure 31: Example of PRP network overview diagram

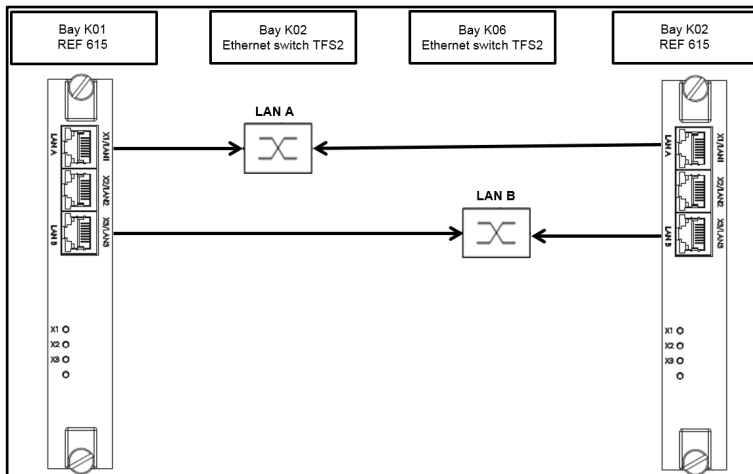


Figure 32: Interconnection of protection relays into PRP networks

### Protection relay

Check the connection status of protection relays via PCM600. Open the factory delivered project and select the protection relay for which you want to check the connection. If the connection between the PCM600 and protection relay is established, a green tick mark is shown next to the protection relay icon.

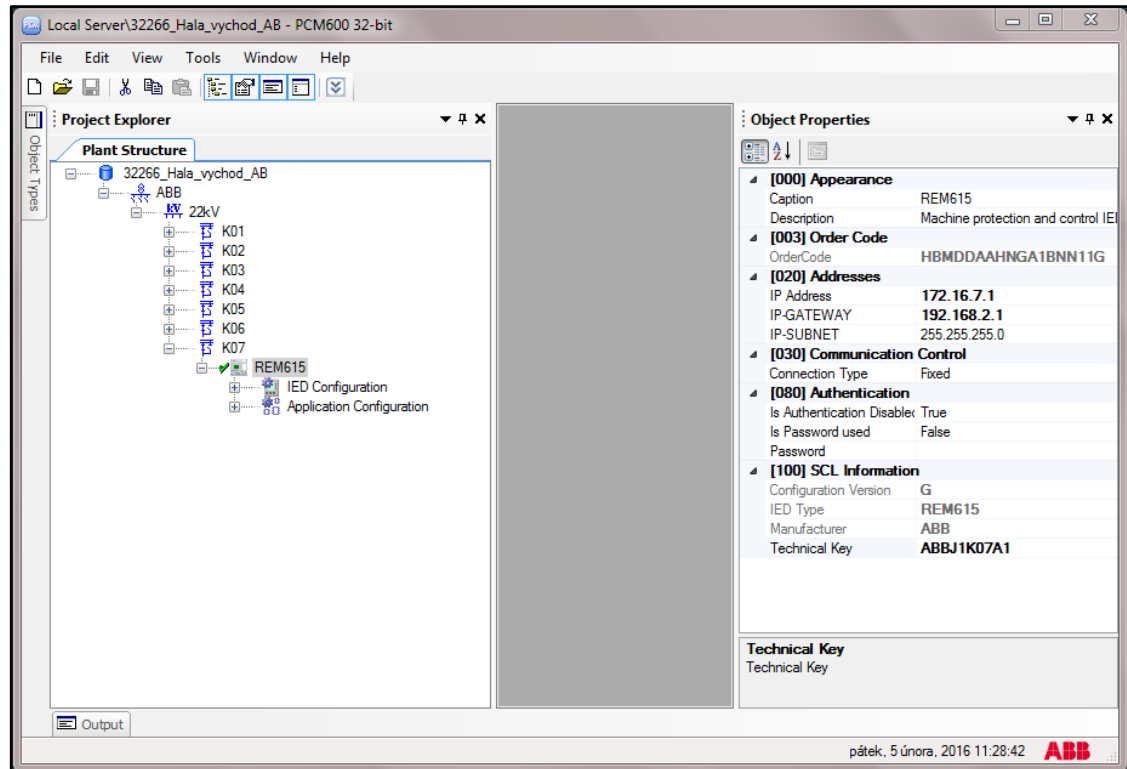


Figure 33: Example of Plant Structure in PCM600

### Network redundancy

Check the availability of voltage measurements and GOOSE signals when the managed Ethernet switch, communication link or protection relay fails.

### GOOSE and Process bus

The GOOSE / SMV alarm is assigned to a configurable LED via the PCM600 and it relates to function blocks (GSELPRT1 – GOOSE supervision and ULTVTR1 – SMV supervision).

Check if No GOOSE / SMV alarm is reported by the receiver protection relays.

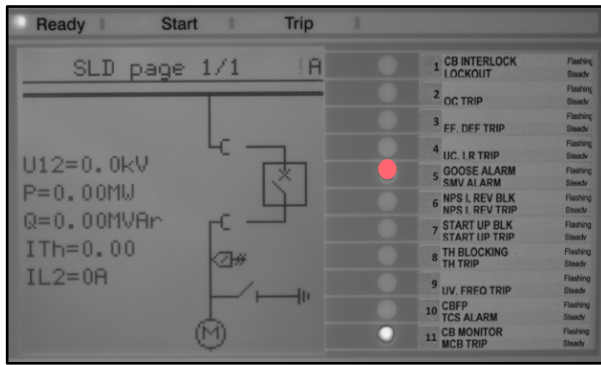


Figure 34: GOOSE / SMV alarm is activated on a configurable LED

Check the Measurements view on the voltage receiver protection relays if voltage values are not in brackets.



Brackets indicate an invalid or a questionable measurement due to, for example, a time synchronization error.

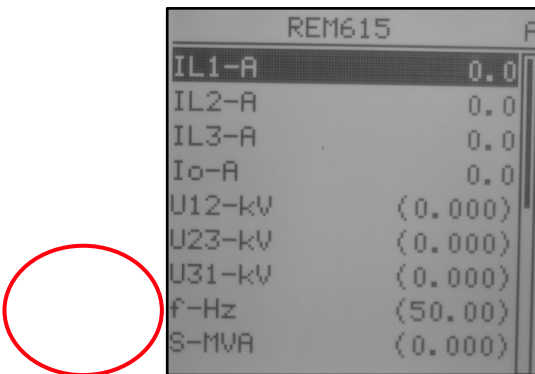


Figure 35: Measurements view, voltage receiver protection relay is not synchronized with the Master clock

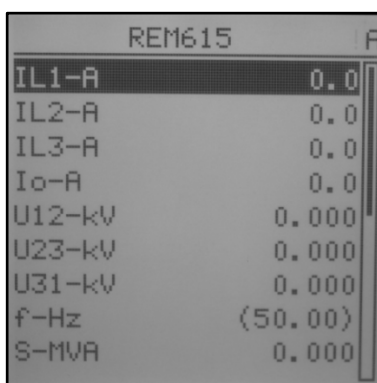


Figure 36: Measurements view, voltage receiver protection relay is synchronized with the Master clock



Frequency information in the Measurements view is in brackets if no voltage is measured by the protection relay

## 4 Primary testing

Primary testing is valuable for verification of the whole measurement chain in the application including switching equipment (circuit breaker or contactor). The measuring chain includes the sensor, cable connections and settings of the protection relay.

UniGear with Current and voltage sensors and IEC 61850 vs. traditional UniGear switchgear family

- No complex checks of inter-panel wiring are required
- Ethernet network fault detection is available
- Higher protection relay engineering skills is required in case of modifications
- Licensed software is not required
- For pre-testing, secondary tester with sensor support (low voltage output signals) is required
- The setting of sensors in the protection relay is described in the UniGear Smart solutions – Current and voltage sensors and IEC 61850 Engineering guide.

### 4.1 Recommended primary testing device

For primary current and voltage injection you can use existing devices. There are multifunctional primary test systems, such as the Omicron CPC 100, available on the market which enables entering sensor correction factors and the display of a directly correct value for both current and voltage sensors.

Introduction of CPC 100 – key features:

- Supply up to 800 A or 2000 V with max. 5 kVA power output, over a frequency range of 15 Hz – 400 Hz or 400 A DC
- Supply up to 2000 A or 12 kV using external current or voltage amplifiers



Figure 37: Primary test system CPC 100 from Omicron

## 4.2 Current sensors

Primary testing verifies the whole measurement chain including the sensor, cable connections and settings of the protection relay. Each current sensor has unique physical polarity. Therefore, no polarity (physical test) is needed. The current sensor polarity can be changed via parameter setting. Secondary winding resistance and magnetization curve tests are not applicable either.

### 4.2.1 Supervision

In the protection relay, current metering is supervised by the CMMXU function. Metering accuracy is stated in Table 1.

Table 1: Current metering accuracy

Characteristic	Value
Operation accuracy	<ul style="list-style-type: none"> <li>Depending on the frequency of the measured current: <math>f_n \pm 2</math> Hz</li> <li><math>\pm 0.5\%</math> or <math>\pm 0.002 \times I_n</math> (at currents in the range of <math>0.01...4.00 \times I_n</math>)</li> </ul>

A measured value under the zero-point clamping limit is forced to zero. This allows the noise in the input signal to be ignored. Read more details in the technical manual of the protection relay.

Table 2: Zero-clamping limits

Function	Zero-clamping limit
Three-phase current measurement (CMMXU)	1% of nominal ( $I_n$ )
Residual current measurement (RESCMMXU)	1% of nominal ( $I_n$ )
Phase sequence current meas. (CSMSQI)	1% of nominal ( $I_n$ )

### 4.2.2 Installed busbars in the switchgear panel

This testing procedure includes the influence of applications such as the circuit breaker or contactor. Installed busbars are used to make the electrical circuit between two neighboring panels.



If high voltage cables are terminated to switchgear panel, check the installation is dead.

Protect against any other live parts.

**Step 1/5**

Verify sensor parameters set in the protection relay with sensor rating plates placed on the circuit breaker door.

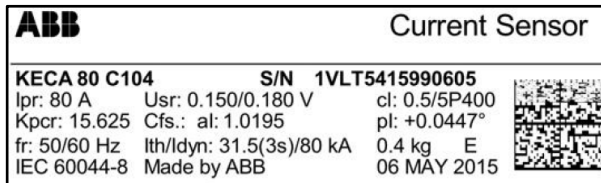


Figure 38: Example of a current sensor label

On protection relay LHMI go to -> **Main Menu/Configuration/Analog inputs/Current (3I, CT)**

- Primary current = Application nominal current
- Amplitude Corr A = sensor rating plate, phase A
- Amplitude Corr B = sensor rating plate, phase B
- Amplitude Corr C = sensor rating plate, phase C
- Nominal current = Primary current
- Rated secondary Val = Rated secondary value in mV/Hz
- Angle Corr A = sensor rating plate, phase A
- Angle Corr B = sensor rating plate, phase B
- Angle Corr C = sensor rating plate, phase C

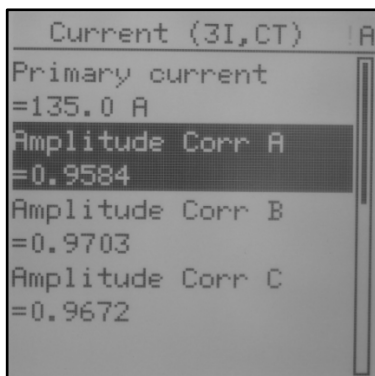


Figure 39: Current sensor parameters

**Step 2/5**

Move two neighboring circuit breakers into the service position and close them.



Default values of overcurrent, earth fault and unbalance protection functions can operate the circuit breaker during primary injection. Disable all related protection functions in the protection relay or disconnect the tripping coil (MO) from the negative potential of power supply in the low voltage compartment before primary injection to avoid unwanted tripping of the circuit breaker.

**Step 3/5**

In the cable compartments, connect the injection device to the cable sealing end of the same phase.

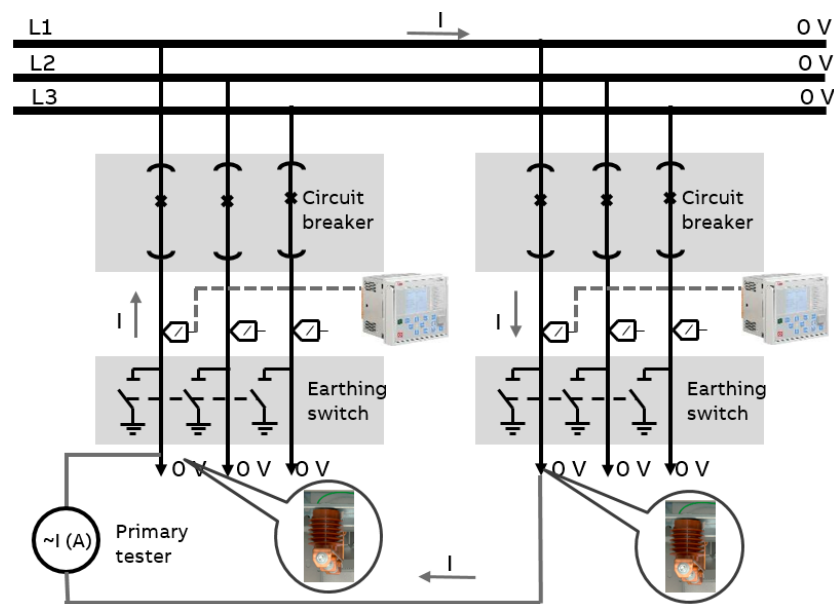


Figure 40: Primary test setup for current sensors when busbars are installed

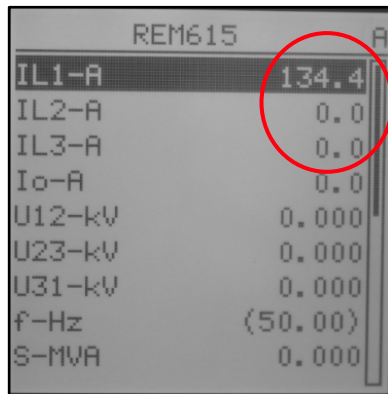
**Step 4/5**

Inject a current equal to the application nominal current or equal to the maximal current supported by the primary testing device if the application nominal current is out of the device setting range.

**Step 5/5**

Check the current metering for the phase and measured current in other phases on the protection relay LHMI Measurements view.

Current must be zero in phases which are not under the primary injection test.



REM615		A
IL1-A	134.4	
IL2-A	0.0	
IL3-A	0.0	
Io-A	0.0	
U12-kV	0.000	
U23-kV	0.000	
U31-kV	0.000	
f-Hz	(50.00)	
S-MVA	0.000	

Figure 41: Measurements view



“Io-A” in Measurements view is a measured value, not a calculated one.

### 4.2.3 Non-installed busbars in the switchgear panel or restricted access to the busbar compartment

This testing method does not include the influence of application, such as the circuit breaker or contactor. Metering cables from the primary testing device are used to make the electrical circuit between the cable and bus compartments.



If high voltage cables are terminated to switchgear panel, check the installation is dead.

Protect against any other live parts.

#### Step 1/6

Verify the sensor parameters set in the protection relay with the sensor rating plates placed on the circuit breaker door.


ABB		Current Sensor	
<b>KECA 80 C104</b>	<b>S/N 1VLT5415990605</b>		
Ipr: 80 A	U <sub>sr</sub> : 0.150/0.180 V	cl: 0.5/5P400	
K <sub>pr</sub> : 15.625	Cfs.: al: 1.0195	pl: +0.0447°	
fr: 50/60 Hz	I <sub>th</sub> /I <sub>dyn</sub> : 31.5(3s)/80 kA	0.4 kg E	
IEC 60044-8	Made by ABB	06 MAY 2015	

Figure 42: Example of a current sensor label

On the protection relay LHMI go to -> **Main Menu/Configuration/Analog inputs/Current (3I, CT)**

- Primary current = Application nominal current
- Amplitude Corr A = sensor rating plate, phase A
- Amplitude Corr B = sensor rating plate, phase B
- Amplitude Corr C = sensor rating plate, phase C
- Nominal current = Primary current
- Rated secondary Val = Rated secondary value in mV/Hz
- Angle Corr A = sensor rating plate phase A
- Angle Corr B = sensor rating plate phase B
- Angle Corr C = sensor rating plate, phase C

Current (3I,CT) IA	
Primary current	=135.0 A
Amplitude Corr A	=0.9584
Amplitude Corr B	=0.9703
Amplitude Corr C	=0.9672

Figure 43: Current sensor parameters

**Step 2/6**

Remove the circuit breaker out of the switchgear panel.

**Step 3/6**

If there is the high voltage on busbars, secure top shutter with a padlock

**Step 4/6**

In the cable compartment, connect the injection test set to the cable sealing end and the circuit breaker compartment to the branch conductor behind the lower shutter of the same phase.

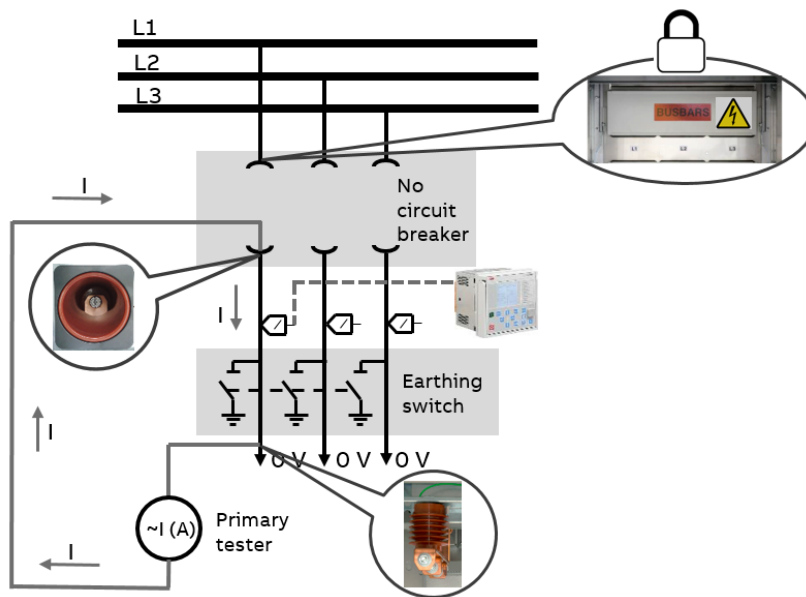


Figure 44: Test setup for current sensors testing when busbars are not installed or there is restricted access to the busbar compartment

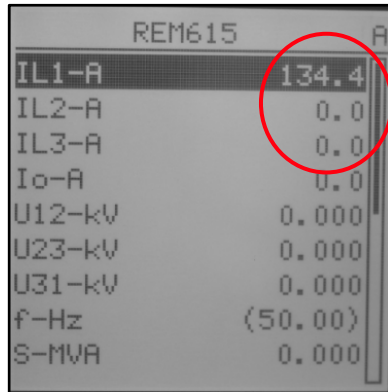
**Step 5/6**

Inject current equal to the Application nominal current or equal to the maximal current supported by the primary testing device if the application nominal current is out of the device setting range.

**Step 6/6**

Check current metering for the phase and the measured current in other phases on the protection relay LHMI Measurements view.

Current must be zero in all phases which are not under the primary injection test.



Parameter	Value
IL1-A	134.4
IL2-A	0.0
IL3-A	0.0
Io-A	0.0
U12-kV	0.000
U23-kV	0.000
U31-kV	0.000
f-Hz	(50.00)
S-MVA	0.000

Figure 45: Measurements view



“Io-A” in Measurements view is a measured value, not a calculated one.

### 4.2.4 Non-installed busbars in the switchgear panel

This testing method includes the influence of application, such as the circuit breaker or contactor, which are used to make an electrical circuit between the cable and busbar compartments. The abovementioned testing method is preferred by switchgear factories for the primary testing of current sensors in a workshop.



If high voltage cables are terminated to switchgear panel, check the installation is dead.

Protect against any other live parts.

#### Step 1/7

Verify the sensor parameters set in the protection relay with the sensor rating plates placed on the circuit breaker door.

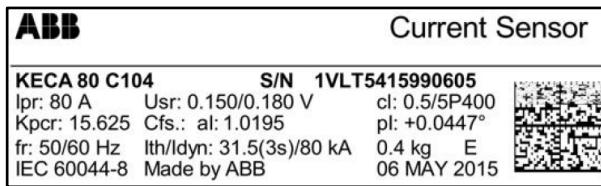


Figure 46: Example of a current sensor label

On the protection relay LHMI go to -> **Main Menu/Configuration/Analog inputs/Current (3I, CT)**

- Primary current = Application nominal current
- Amplitude Corr A = sensor rating plate, phase A
- Amplitude Corr B = sensor rating plate, phase B
- Amplitude Corr C = sensor rating plate, phase C
- Nominal current = Primary current
- Rated secondary Val = Rated secondary value in mV/Hz
- Angle Corr A = sensor rating plate, phase A
- Angle Corr B = sensor rating plate, phase B
- Angle Corr C = sensor rating plate, phase C

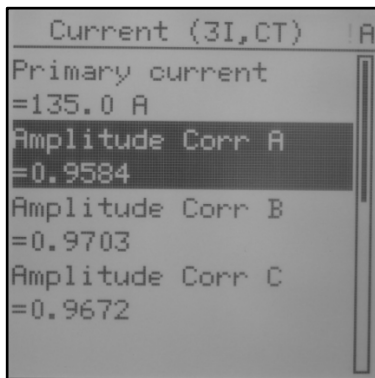


Figure 47: Current sensor parameters

**Step 2/7**

Move the circuit breaker into the service position and close it.

**i** Default values of overcurrent, earth fault and unbalance protection functions can operate the circuit breaker during primary injection. Disable all related protection functions in the protection relay or disconnect the tripping coil (MO) from the negative potential of power supply in the low voltage compartment before the primary injection to avoid unwanted tripping of the circuit breaker.

**Step 3/7**

Remove the Overpressure relief flap from the busbar compartment to get access for one end of the primary injection test set. If Ith limiters are installed, make sure they will not trip your circuit breaker, for example, by disconnecting them from the tripping circuit.

**Step 4/7**

In the cable compartment, connect the second end of the primary injection test set to the cable sealing end and the busbar compartment to the branch conductor of the same phase. See the picture below.

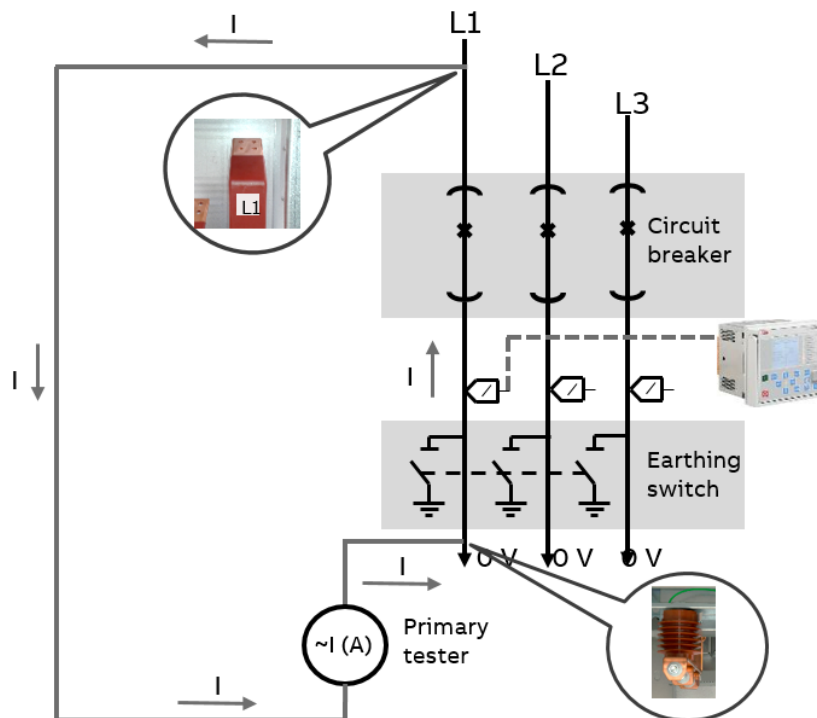


Figure 48: Test setup for current sensors when busbars are not installed

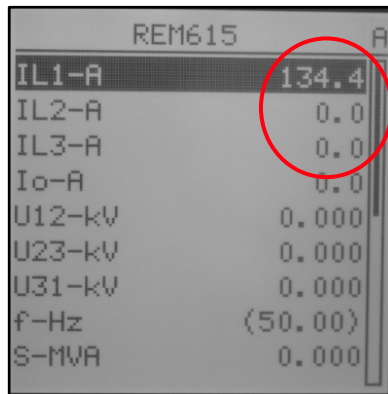
**Step 5/7**

Inject current equal to the application nominal current or equal to the maximal current supported by the primary testing device if the application nominal current is out of the device setting range.

**Step 6/7**

Check current metering for the phase and measured current in other phases on the protection relay LHMI Measurements view.

Current must be zero in phases which are not under the primary injection test.



Parameter	Value
IL1-A	134.4
IL2-A	0.0
IL3-A	0.0
Io-A	0.0
U12-kV	0.000
U23-kV	0.000
U31-kV	0.000
f-Hz	(50.00)
S-MVA	0.000

Figure 49: Measurements view



“Io-A” in Measurements view is a measured value, not a calculated one.

**Step 7/7**

After testing of all 3 phases, install the back-overpressure relief flap. Set up the lth limiter and verify its function in the switchgear panel.



Protection functions trip the signal block Tripping coil supervision function.

## 4.3 Voltage sensors

Primary testing verifies the whole measurement chain including the sensor, cable connections and settings of the protection relay. Physical polarity of the voltage sensor is unique, only one-way installation is possible. Therefore, no polarity (physical test) is needed.

### 4.3.1 Supervision

In the protection relay, voltage metering is supervised by the VMMXU function. Metering accuracy is stated in Table 3.

Table 3: Voltage metering accuracy

Characteristic	Value
Operation accuracy	<ul style="list-style-type: none"> <li>Depending on the frequency of the measured voltage: <math>f_n \pm 2</math> Hz</li> <li><math>\pm 0.5\%</math> or <math>\pm 0.002 \times U_n</math> (at voltages in range <math>0.01-1.15 \times U_n</math>)</li> </ul>

A measured value under the zero-point clamping limit is forced to zero. This allows the noise in the input signal to be ignored. Read more details in the technical manual of the protection relay.

Table 4: Zero-clamping limits

Function	Zero-clamping limit
Three-phase voltage measurement (VMMXU)	1% of nominal ( $U_n$ )
Residual voltage measurement (RESVMMXU)	1% of nominal ( $U_n$ )
Phase sequence voltage meas. (VSMSQI)	1% of the nominal ( $U_n$ )

### 4.3.2 Voltage sensor installed in the cable compartment

#### Step 1/7

Verify sensor parameters set in the protection relay with the sensor rating plates placed on the circuit breaker door.

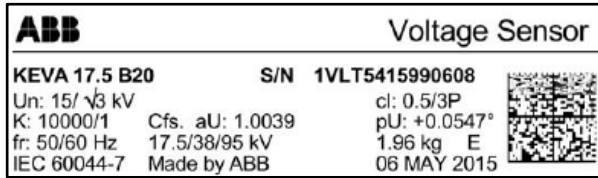


Figure 50: Example of a voltage sensor label

On the protection relay LHMI go to -> **Main Menu/Configuration/Analog inputs/Voltage (3U, VT)**

- Primary voltage = nominal voltage of the network
- VT connection = Wye (star connection)
- Amplitude Corr A = sensor rating plate, phase A
- Amplitude Corr B = sensor rating plate, phase B
- Amplitude Corr C = sensor rating plate phase C
- Division ration = 10 000
- Voltage input type = CVD sensor
- Angle Corr A = sensor rating plate, phase A
- Angle Corr B = sensor rating plate, phase B
- Angle Corr C = sensor rating plate, phase C

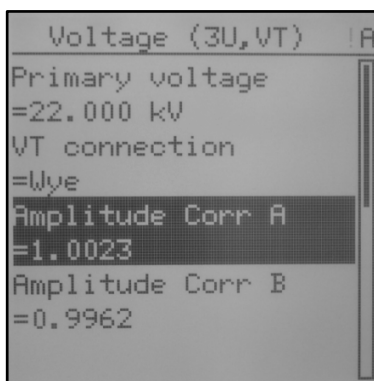


Figure 51: Voltage sensor parameters

#### Step 2/7

Isolate tested phases. Remove the circuit breaker out of the switchgear panel. Any high voltage cables terminated at the panel should be disconnected for safety reasons.

#### Step 3/7



If there is the high voltage on busbars, secure top shutter with a padlock

**Step 4/7**

Except the tested phase, connect all other phases together to the grounding bar.

**Step 5/7**

Connect the primary tester to the cable sealing end of the isolated phase and to the grounding bar inside the switchgear panel.

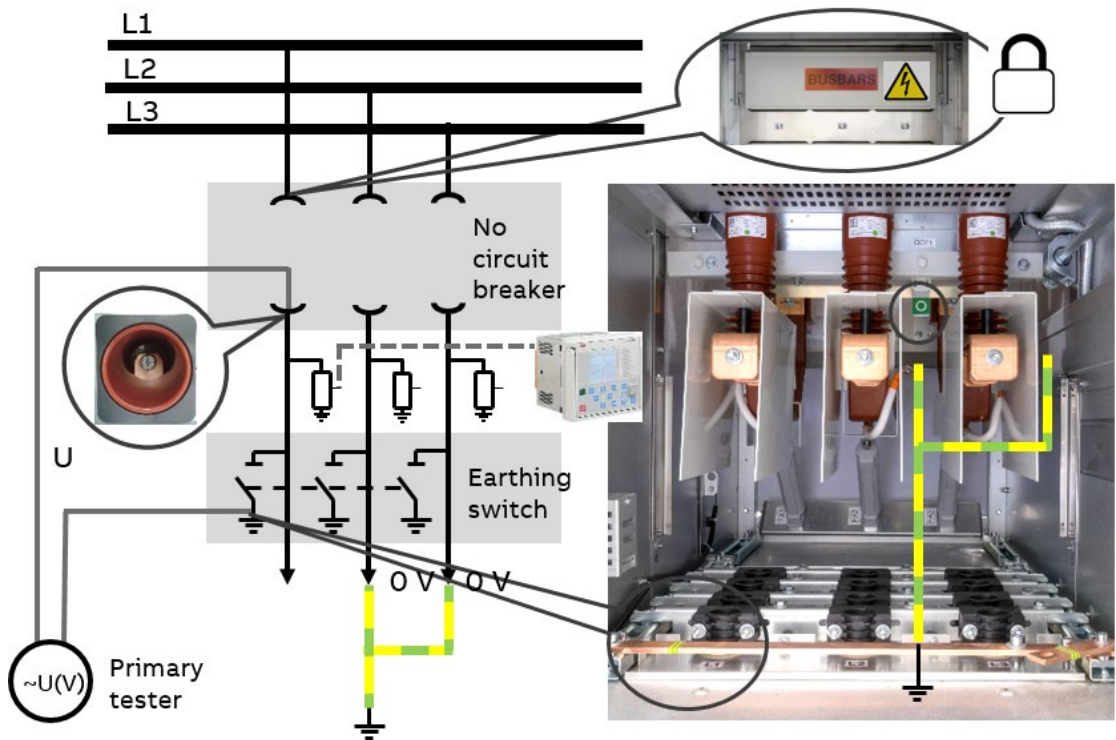


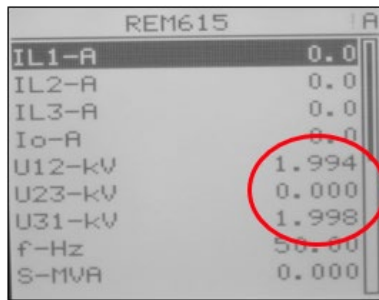
Figure 52: Test setup for voltage sensors installed in the cable compartment

**Step 6/7**

Inject voltage higher than 1% of primary (nominal) value.

**Step 7/7**

Check voltage metering for the phase on the protection relay LHMI Measurements view.



Measurement	Value
IL1-A	0.0
IL2-A	0.0
IL3-A	0.0
I0-A	0.0
U12-kV	1.994
U23-kV	0.000
U31-kV	1.998
f-Hz	50.00
S-MVA	0.000

Figure 53: Measurements view, injected phase 1

Since the protection relay is reporting phase-to-phase voltages, two identical measurements will appear on the display. For example, if voltage is applied between phase 1 and the ground, then the protection relay shows  $U_{12} = U_{31}$  and  $U_{23} = 0$ .

### 4.3.3 Voltage sensor installed on busbars

#### Step 1/8

Verify sensor parameters set in the protection relay with the sensor rating plates placed on the circuit breaker door.

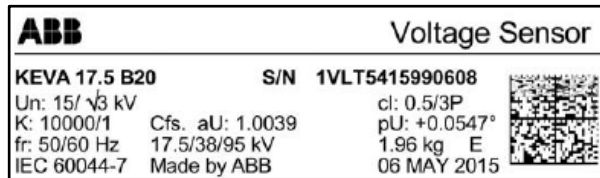


Figure 54: Example of a voltage sensor label

On the protection relay LHMI go to -> **Main Menu/Configuration/Analog inputs/Voltage (3U, VT)**

- Primary voltage = nominal voltage of the network
- VT connection = Wye (star connection)
- Amplitude Corr A = sensor rating plate, phase A
- Amplitude Corr B = sensor rating plate, phase B
- Amplitude Corr C = sensor rating plate, phase C
- Division ration = 10 000
- Voltage input type = CVD sensor
- Angle Corr A = sensor rating plate, phase A
- Angle Corr B = sensor rating plate, phase B
- Angle Corr C = sensor rating plate, phase C

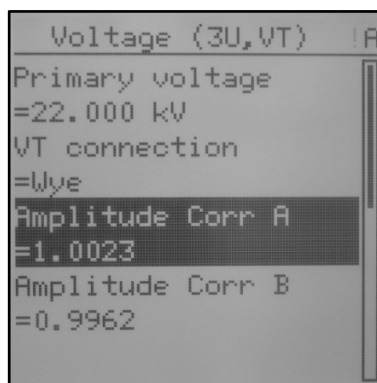


Figure 55: Voltage sensor parameters

#### Step 2/8

Isolate the whole bus section. All circuit breakers belong to the relative busbar section move into the test position.

#### Step 3/8

Select one outgoing switchgear panel in the section to apply voltage on the main bus. Remove the circuit breaker out of the switchgear panel and close the earthing switch

**Step 4/8**

Make sure there is no voltage on the busbar.

Open the top shutter in the circuit breaker compartment.

**Step 5/8**

Except the tested phase, connect all other phases together to the grounding bar.

**Step 6/8**

Connect the tester to the isolated (measured) phase and grounding bar.

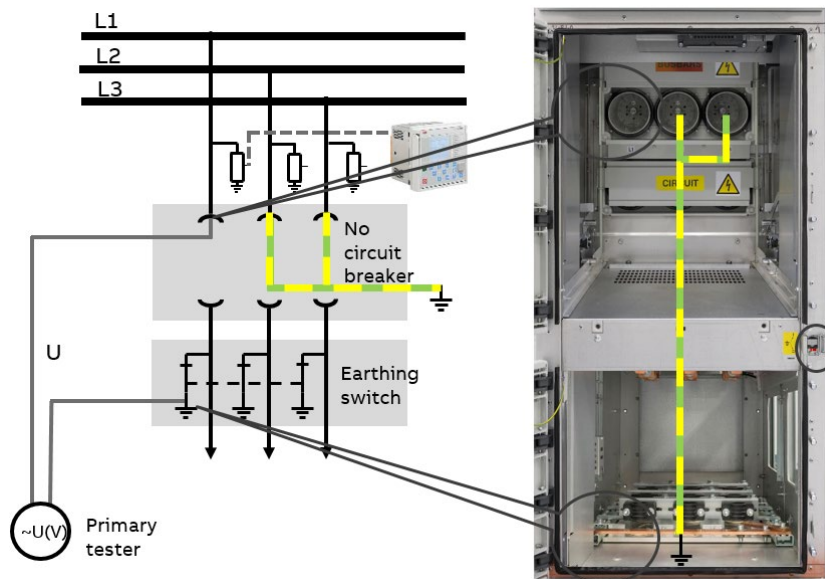


Figure 56: Test setup for voltage sensors installed on busbars

**Step 7/8**

Inject voltage higher than 1% of the primary (nominal) value.

**Step 8/8**

Check voltage metering for the phase on the **voltage sender protection relay** LHMI Measurements view.

Measurement	Value
IL1-A	0.0
IL2-A	0.0
IL3-A	0.0
Io-A	0.0
U12-kV	1.994
U23-kV	0.000
U31-kV	1.998
f-Hz	50.00
S-MVA	0.000

Figure 57: Measurements view, injected phase 1

Check voltage values for the phase on the **voltage receiver protection relays** LHMI Measurements view.

The voltage value must be identical with the voltage sender protection relay and without brackets around the value.

Measurement	Value
IL1-A	0.0
IL2-A	0.0
IL3-A	0.0
Io-A	0.0
U12-kV	1.994
U23-kV	0.000
U31-kV	1.998
f-Hz	50.00
S-MVA	0.000

Figure 58: Measurements view, injected phase 1

Since the protection relay is reporting phase-to-phase voltages, two identical measurements will appear on the display. For example, if voltage is applied between phase 1 and the ground, then the protection relay shows  $U_{12} = U_{31}$  and  $U_{23} = 0$ .

# 5 Apparatus control testing

It is recommended to test panel internal interlocking and interlocks between panels during maintenance.

## 5.1 Panel internal interlocking

To prevent hazardous situations and incorrect operation, there is a series of interlocks to protect both personnel and equipment. Apparatus interlocking is mechanical and electrical. The protection relay includes designated functions for each apparatus and enables operation by means of blocking coils. Under medium voltage the switchgear panel can operate only one apparatus at a time.

### 5.1.1 Circuit breaker truck (Disconnecter)

**i** The circuit breaker truck can only be moved from the Test / Disconnected position (and back) when the circuit breaker and the earthing switch are off and the earthing switch crank is not inserted.

The dedicated protection function for supervision of the circuit breaker truck operation is DCSXWI or DCSXSWI.

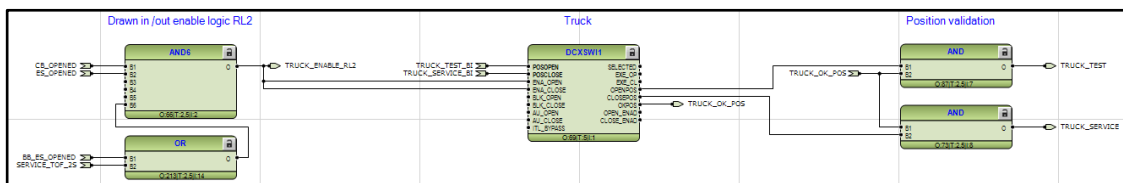


Figure 59: Blocking conditions of the circuit breaker truck in PCM600

#### Step 1/6

Move the circuit breaker into the test position and keep it open. Check the circuit breaker status on the protection relay LHMI.

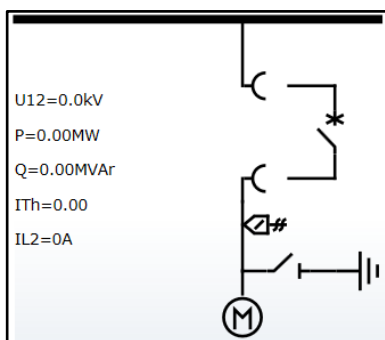


Figure 60: Single line diagram, the circuit breaker is open and in the test position

**Step 2/6**

Insert the earthing switch crank on the shaft. Check the status on the protection relay LHMI.

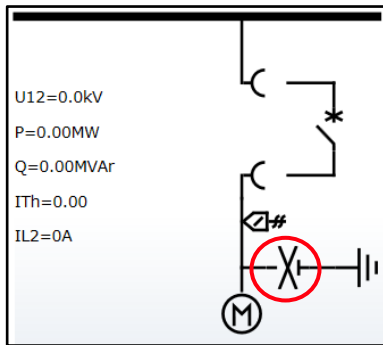


Figure 61: Single line diagram, the earthing switch shutter is open

**Step 3/6**

Check that the circuit breaker cannot be moved into service position when the earthing switch crank is inserted.

**Step 4/6**

Remove the earthing switch crank from the shaft. The shutter must be closed. Check the earthing switch status on the protection relay LHMI.

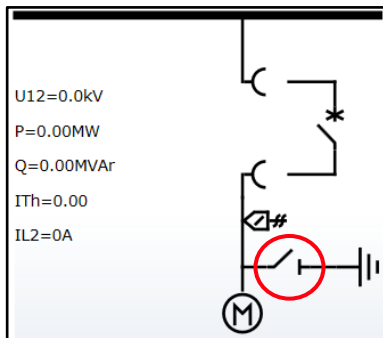


Figure 62: Single line diagram, the earthing switch shutter is closed

**Step 5/6**

Move the circuit breaker truck out of the test position about a half turn of the crank. Check the circuit breaker status on the protection relay LHMI.

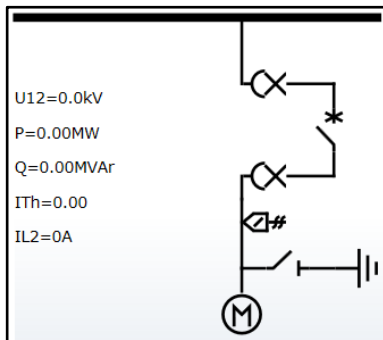



Figure 63: Single line diagram, the circuit breaker is in the intermediate position


**Step 6/6**

Check that the circuit breaker compartment door cannot be open if the circuit breaker is out of the test position

### 5.1.2 Circuit breaker

 The circuit breaker can only be closed when the circuit breaker truck is in the test or service position, not in the intermediate position.

The dedicated protection function for supervision of the circuit breaker operation is CBXCBR.

 The circuit breaker can only be closed in the service position if the blocking coil RL1 is energized.

Usually closing operation of the circuit breaker in the service position is supervised by the protection relay (CBXCBR function). Protection relay controls blocking coil RL1.

In the test position the circuit breaker can be closed at any time. Blocking coil RL1 is not controlled by the protection relay.

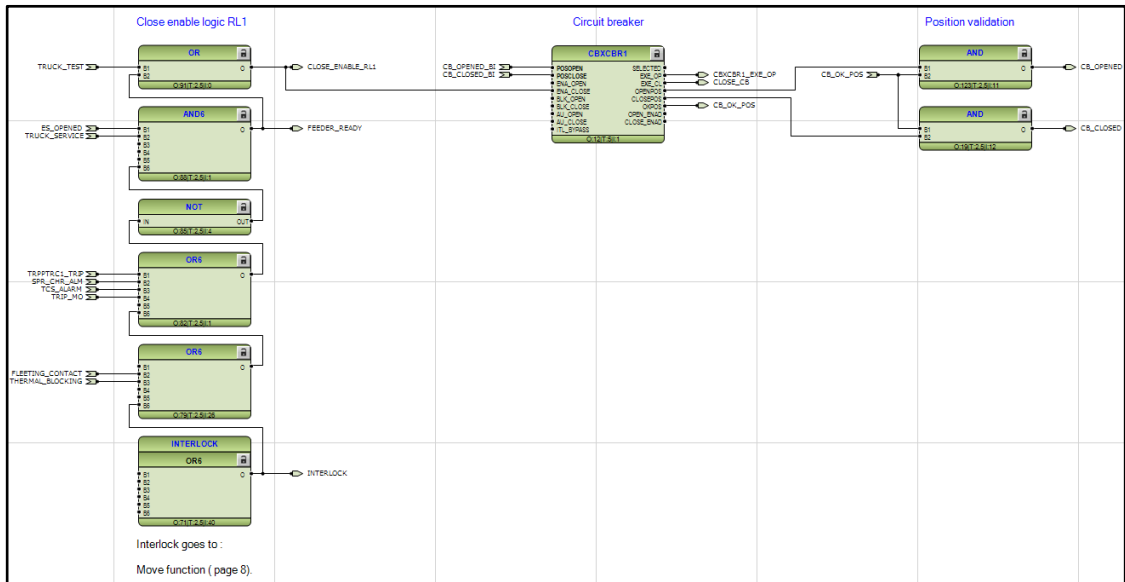


Figure 64: Blocking conditions of the circuit breaker in PCM600

#### Step 1/7

Move the circuit breaker into the test position and close it. Check the circuit breaker status on the protection relay LHMI.

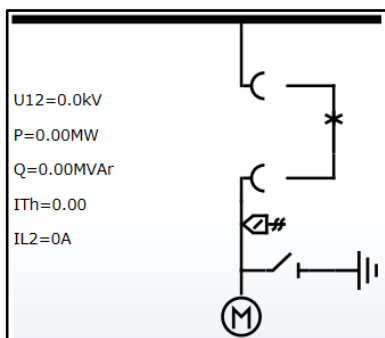


Figure 65: Single line diagram, the circuit breaker is closed and in the test position

**Step 2/7**

Check the impossibility of inserting the circuit breaker into service when it is closed.

**Step 3/7**

Open the circuit breaker. Check the circuit breaker status on the protection relay LHMI.

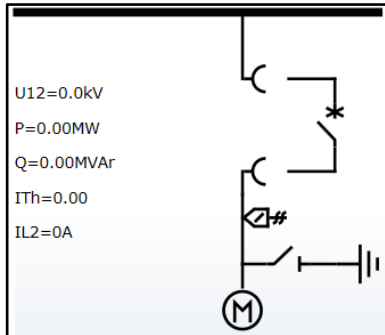


Figure 66: Single line diagram, the circuit breaker is open and in the test position

**Step 4/7**

Move the circuit breaker truck out of the test position about a half turn of the crank. Check the circuit breaker truck status on the protection relay LHMI.

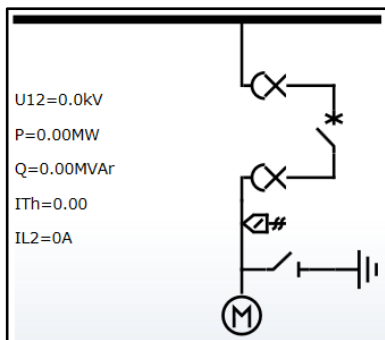


Figure 67: Single line diagram, the circuit breaker is in the intermediate position

**Step 5/7**

Check that the interlock prevents the circuit breaker contacts closing if the truck is positioned between the service and test position.

**Step 6/7**

Move the circuit breaker truck into the service position. Close the circuit breaker. Check the circuit breaker status on the protection relay LHMI.

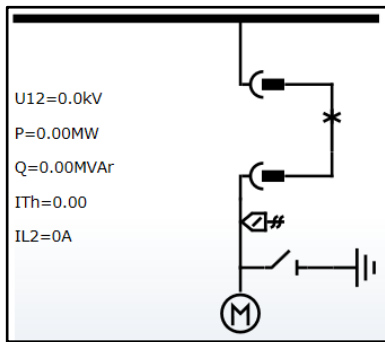


Figure 68: Single line diagram, the circuit breaker is closed and in the service position

**Step 7/7**

Check the impossibility of isolating the circuit breaker from service when it is closed.

### 5.1.3 Earthing switch



The earthing switch can only be closed if the circuit breaker is in the test position or the plug is out.

The dedicated protection function for supervision of the earthing operation is ESSXWI or ESSXSWI.

Relay control access to the shutter of the earthing switch shaft by means of blocking coil RL3.

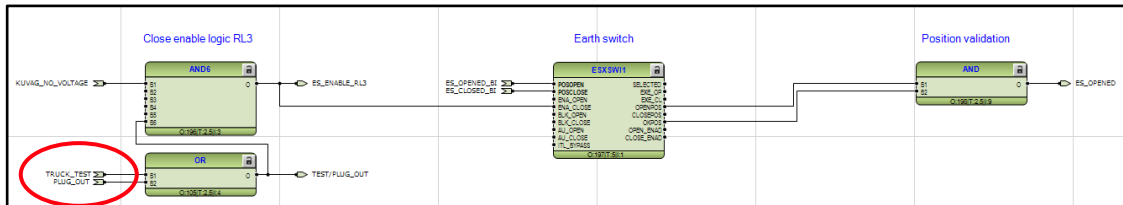


Figure 69: Blocking conditions of the earthing switch in PCM600

#### Step 1/7

Move the circuit breaker into the test position and keep it open. Check the circuit breaker status on the protection relay LHMI.

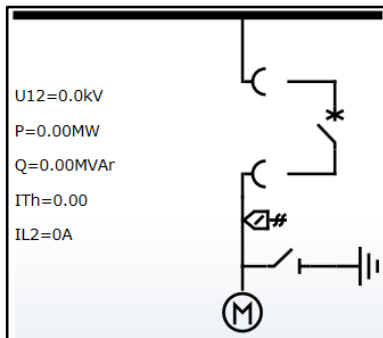


Figure 70: Single line diagram, the circuit breaker is open and in the test position

#### Step 2/7

Move the circuit breaker truck out of the test position about a half turn of the crank. Check the circuit breaker truck status on the protection relay LHMI.

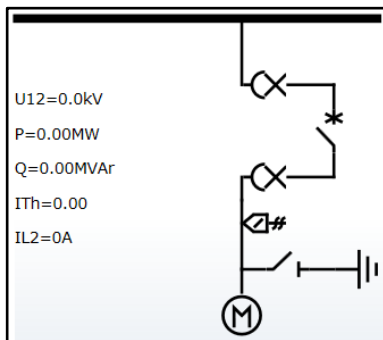


Figure 71: Single line diagram, the circuit breaker is in the intermediate position

**Step 3/7**

Check that the earthing switch cannot be closed when the circuit breaker is out of the test position.

**Step 4/7**

Move the circuit breaker truck back into the test position. Check the circuit breaker truck status on the protection relay LHMI.

**Step 5/7**

Check that the cable compartment door cannot be open if the earthing switch is open.

**Step 6/7**

Close the earthing switch and open the cable compartment door. Check the earthing switch status on the protection relay LHMI.

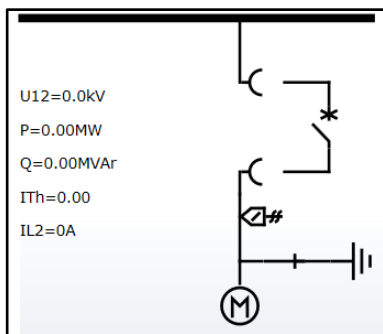


Figure 72: Single line diagram, the earthing switch is closed

**Step 7/7**

Check that the earthing switch cannot be open if the cable compartment door is open.

## 5.2 Interlocks between panels

In UniGear with current and voltage sensors and IEC 61850, the ordinary inter-panel wiring used for interlocking/tripping is replaced with IEC 61850 GOOSE communication, using the existing Ethernet network inside switchgear. The realized logic in UniGear with current and voltage sensors over IEC 61850 GOOSE can be as follows:

- Busbar earthing switch / Busbar earthing truck
- Circuit breaker failure protection
- Logic bus bar protection
- Overpressure flaps inter-trip
- Arc protection inter-trip
- and other

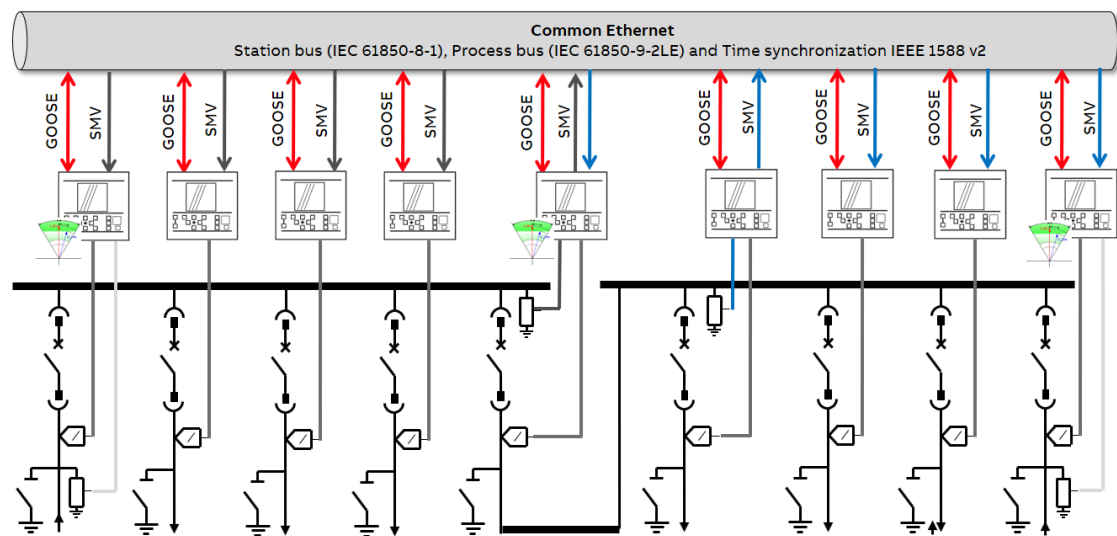


Figure 73: Example of Process bus application in medium voltage switchgear

### 5.2.1 Busbar earthing switch / truck

- The busbar earthing switch can only be closed when all circuit breaker trucks in the relative busbar section are in the Test / Disconnected position (term used for disconnected position is "Plug Out").
- When the busbar earthing switch is closed or the shutter for the lever is not in the closed position, the circuit breaker trucks in the relative section cannot be moved from the Test position to the Service position.

The Busbar earthing switch can be replaced with the earthing truck. Since the earthing truck uses the same compartment as the circuit breaker, this one must be removed first to earth the main busbars. Blocking conditions are identical with the closing conditions of the busbar earthing switch. Enabling the signal for other circuit breaker trucks in the relative section consists from the position of the earthing truck in the test or inserted circuit breaker inside the compartment.

The Busbar earthing switch / truck blocking logic operates bi-directionally and therefore require two tests:

- Busbar earthing switch / truck interlock
- Circuit breaker trucks interlock

**Busbar earthing switch / truck interlock**

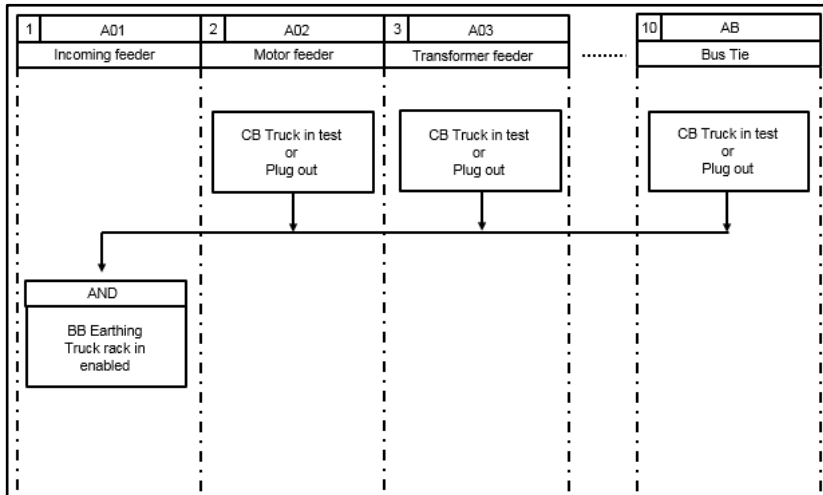


Figure 74: Logic scheme of the busbar earthing truck interlock

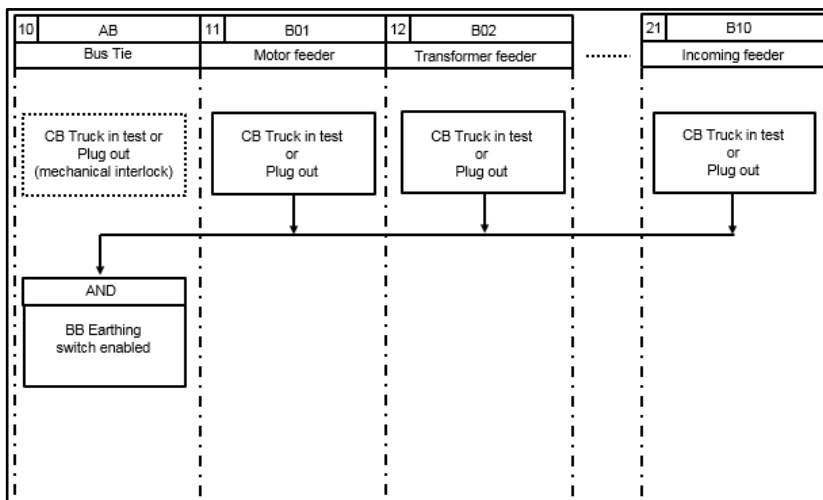


Figure 75: Logic scheme of the busbar earthing switch interlock

**Step 1/5**

All circuit breakers must be in the test position. Check their status on the protection relay LHMI on the Single line diagram.

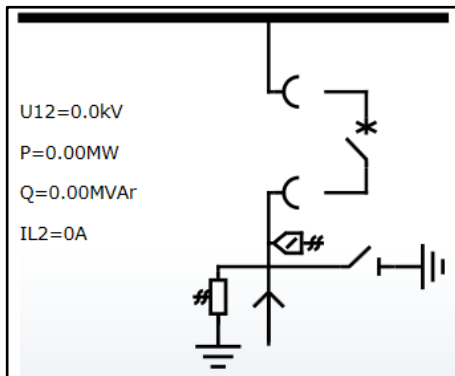


Figure 76: Single line diagram, the circuit breaker is in the test position

**Step 2/5**

Check the busbar earthing switch shutter. It can be open and the crank inserted.

**Step 3/5**

Move the circuit breaker out of the test position about a half-turn of the crank in one feeder. Check the circuit breaker position on the protection relay LHMI.

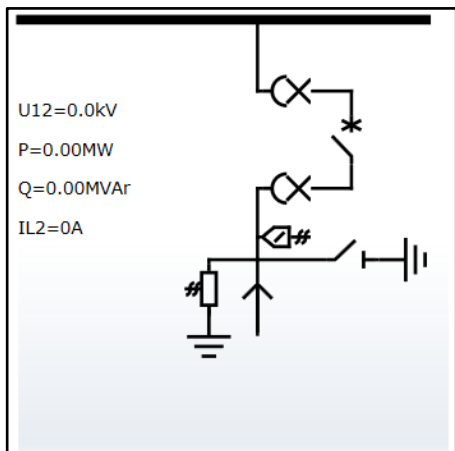


Figure 77: Single line diagram, the circuit breaker is in the intermediate position

**Step 4/5**

Check the busbar earthing switch shutter. It cannot be open (crank cannot be inserted).

**Step 5/5**

Repeat step 3 and 4 for each feeder in the relative section

**Circuit breaker trucks interlock**

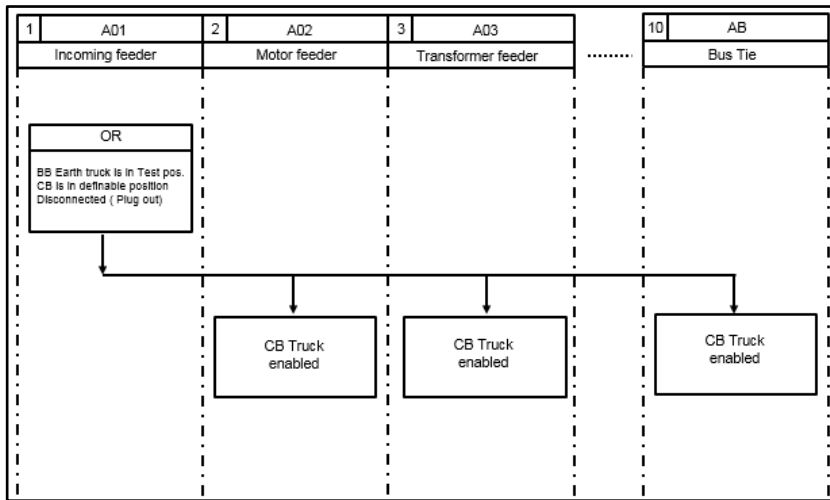


Figure 78: Logic scheme of trucks interlock by the busbar earthing truck

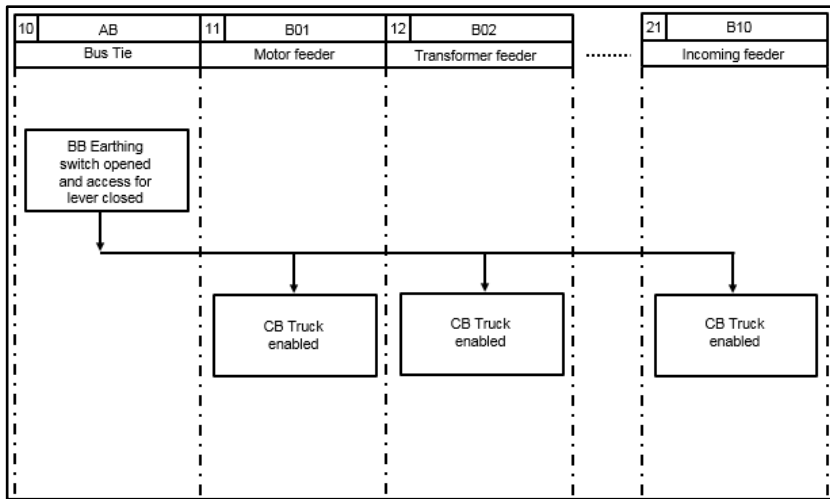


Figure 79: Logic scheme of trucks interlock by the busbar earthing switch

**Step 1/4**

All circuit breakers in the relative section are in the test position. Check the circuit breakers status via the protection relay LHMI's.

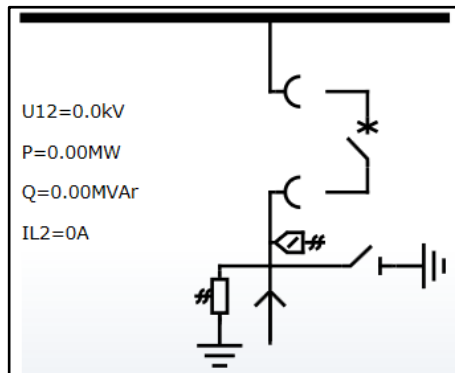


Figure 80: Single line diagram, the circuit breaker is in the test position

**Step 2/4**

Check the busbar earthing switch shutter. It can be open and the crank inserted.

**Step 3/4**

Fix the shutter in the open position.

**Step 4/4**

Check that no circuit breakers in the section can be moved out of the test position no more than a half turn of the crank.

### 5.2.2 Circuit breaker failure protection (CBFP)

The protection relay supervise trip command is processed by the Circuit breaker in the expected “tripping” time. For medium voltage the application usually uses a time delay of 300 ms. In case of a delay, the protection relay sends the tripping command to the upstream circuit breaker, typically to the Incomer and Bus tie.

It is good practice to block the CCBRBRF function if the circuit breaker is in the test or a disconnected position.

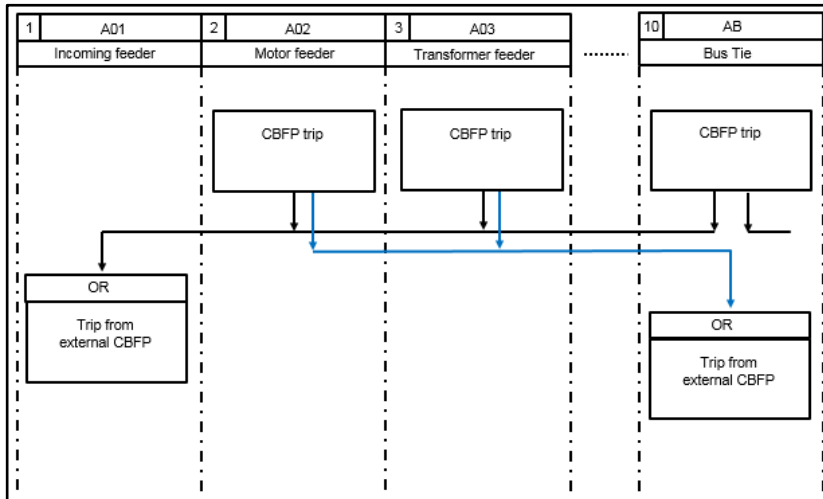


Figure 81: Logic scheme of CBFP

#### Step 1/10

Move all circuit breakers into the service position in the relative section. Check all the circuit breakers status on the protection relay LHMI.

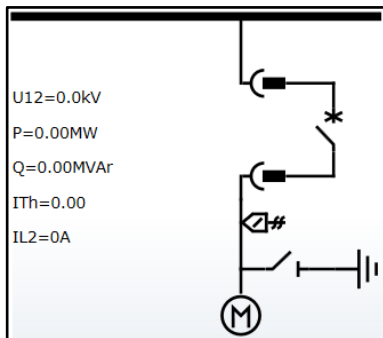


Figure 82: Single line diagram, the circuit breaker in the service position

**Step 2/10**

Close the circuit breaker in the feeder to be tested. Check the circuit breaker status on the protection relay LHMI.

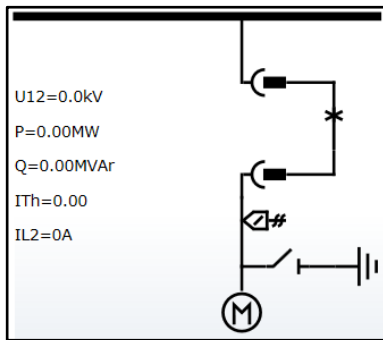


Figure 83: Single line diagram circuit, the circuit breaker is closed and in the service position

**Step 3/10**

Close all upstream breakers in the relative section, such as the Incomer, Generator and Bus tie.

**Step 4/10**

On the protection relay LHMI (upstream breaker receiving CBFP trip command) go to -> Main Menu/Test/IED test

- Test mode = IED test

The ready LED is flashing when the protection relay is in the test mode.

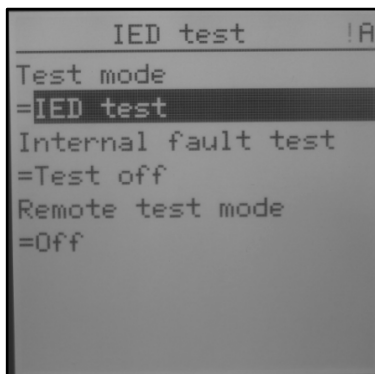


Figure 84: Entering test mode

**Step 5/10**

On the protection relay LHMI (tested feeder) go to -> Main Menu/Test/IED test

- Test mode = IED test

The ready LED is flashing when the protection relay is in the test mode.

**Step 6/10**

On the protection relay LHMI (tested feeder) go to -> **Main Menu/Test/Function tests/Other protection**

- CCBRBRF1 = Activate TRBU (backup trip logic output)

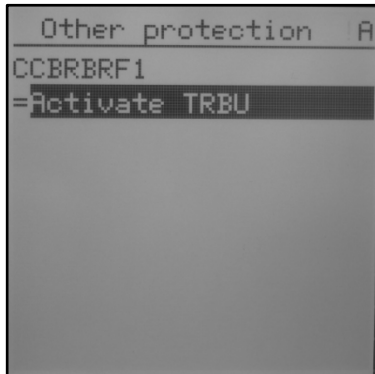


Figure 85: Activating backup trip

The Incomer and Bus tie circuit breakers must trip immediately.

Then

On the protection relay LHMI (tested feeder) go to -> **Main Menu/Test/Function tests/Other protection**

- CCBRBRF1 = Deactivate TRBU

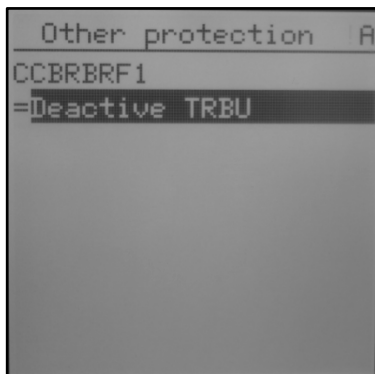


Figure 86: Deactivating backup trip

**Step 7/10**

Check the interlocking logic. Clear Lockouts.

**Step 8/10**

On the protection relay LHMI (tested feeder) go to -> **Main Menu/Test/IED test**

- Test mode = Normal mode

The ready LED is flashing when the protection relay is in the test mode.

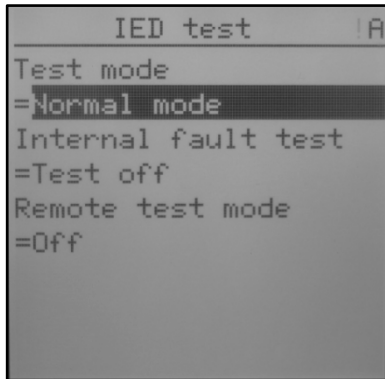


Figure 87: Entering test mode

**Step 9/10**

Repeat steps 3 to 8 for all feeders.

**Step 10/10**

On the protection relay LHMI (upstream breaker receiving CBFP trip command) go to -> **Main Menu/Test/IED test**

- Test mode = Normal mode

The ready LED is steady ON.

### 5.2.3 Logic busbar protection (LBBP)

Logic bus bar protection trips selectively the circuit breaker according to the logic scheme. The start signal of the Overcurrent or Earth fault protection is sent from the Outgoing feeders to the upstream circuit breaker, such as the Incomer, Generator and Bus tie, to block superior Overcurrent or Earth fault protection. For safety reasons, the Logic busbar protection can only be used with Circuit breaker failure protection.

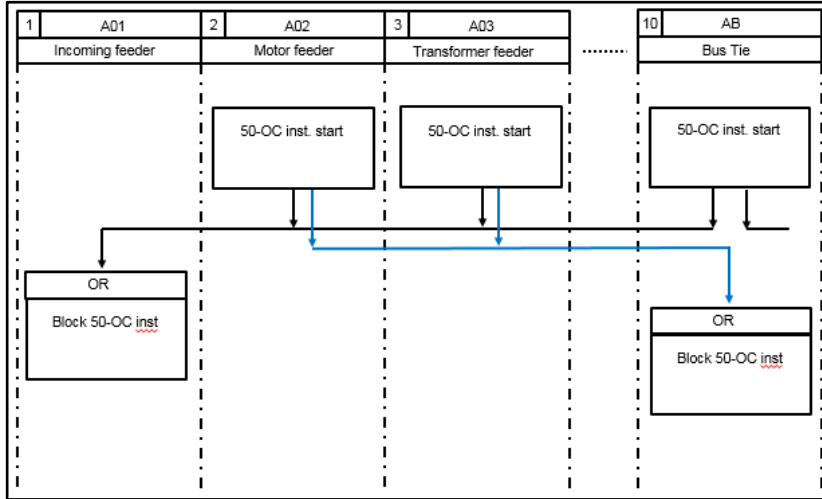


Figure 88: Logic scheme of the Logic busbar protection

#### Step 1/10

Move all circuit breaker trucks into the service position in the relative section. Check all the circuit breakers status on the protection relay LHMI's.

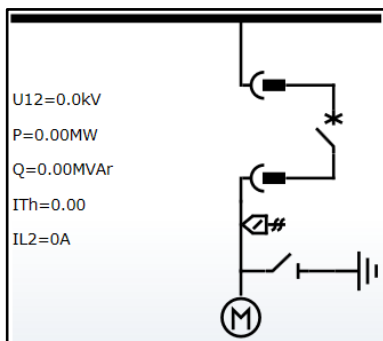


Figure 89: Single line diagram, the circuit breaker is in the service position

**Step 2/10**

On the protection relay LHMI (upstream circuit breaker such as the Incomer, Generator and Bus tie receiving LBBP blocking signal) go to -> **Main Menu/Test/IED test**

- Test mode = IED test

The ready LED is flashing when the protection relay is in the test mode.

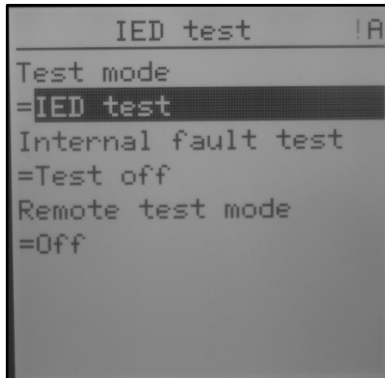


Figure 90: Entering test mode

**Step 3/10**

On the protection relay LHMI (tested feeder) go to -> **Main Menu/Test/IED test**

- Test mode = IED test

The ready LED is flashing when the protection relay is in the test mode.

**Step 4/10**

On the protection relay LHMI (tested feeder) go to -> **Main Menu/Test/Function tests/Current protection**

- PHIPTOC1 = Activate START

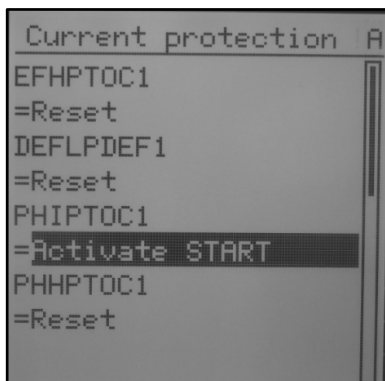


Figure 91: Activating START signal

**Step 5/10**

On the protection relay LHMI (upstream circuit breaker) go to -> **Main Menu/Monitoring/I/O status/Current protection/PHIPTOC1/Inputs**

- BLOCK = True

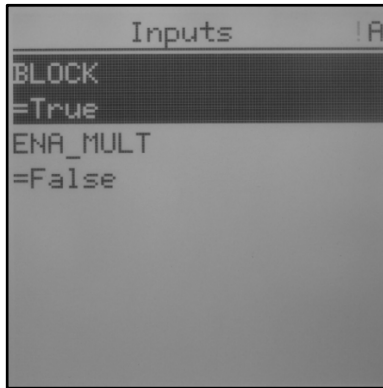


Figure 92: Activating blocking mode

**Step 6/10**

On the protection relay LHMI (tested feeder) go to-> **Main Menu/Test/Function tests/Current protection**

- PHIPTOC1 = Deactivate START

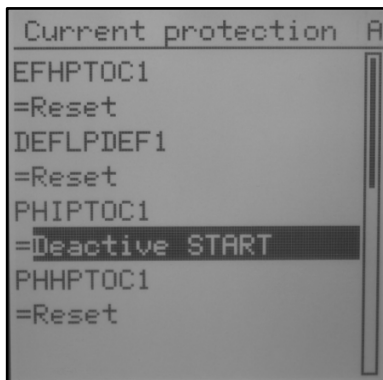


Figure 93: Deactivating START signal

**Step 7/10**

On the protection relay LHMI (upstream circuit breaker) go to -> **Main Menu/Monitoring/I/O status/Current protection/PHIPTOC1/Inputs**

- BLOCK = False

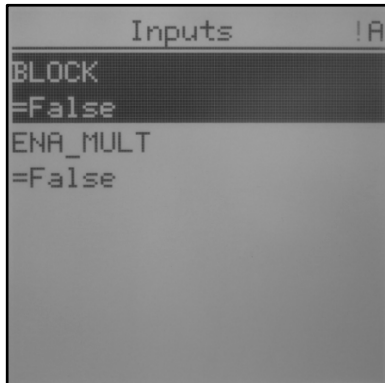


Figure 94: Deactivating blocking mode

**Step 8/10**

On the protection relay LHMI (tested feeder) go to -> **Main Menu/Test/IED test**

- Test mode = Normal mode

The ready LED is steady ON.

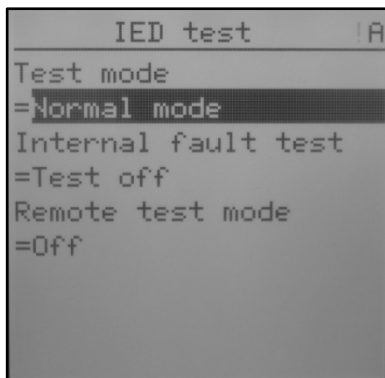


Figure 95: Entering test mode

**Step 9/10**

Repeat steps 3 to 8 for all feeders.

**Step 10/10**

On the protection relay LHMI (upstream circuit breaker) go to -> **Main Menu/Test/IED test**

- Test mode = Test off

### 5.2.4 Overpressure flaps inter-trip

The Overpressure relief flaps are fitted with Ith limiters. These send a trip command to the circuit breaker in case of an electrical Arc inside the switchgear. The trip signal is further distributed over the switchgear based on the location of the electrical Arc.

It is good practice to also forward the inter-trip to outgoing feeders in the section to interrupt the current contribution from the load like motors.

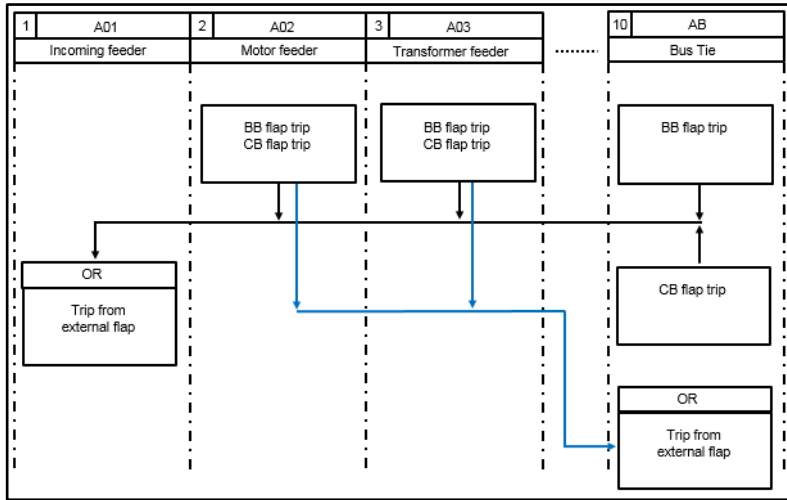


Figure 96: Logic scheme of Ith limiters trip

Table 5: Inter-tripping rules for Ith limiters

Arc location	Inter-trip to
Cable compartment of Outgoing feeder	-
Circuit breaker or Busbar compartment of Outgoing feeder	Incoming feeders and Bus Tie
Cable or Circuit breaker compartment of Bus Tie	Incoming feeders
Circuit breaker or Busbar compartment of Bus Tie	Incoming feeders
Cable or Circuit breaker compartment of Incoming feeder	Upstream breaker
Busbar compartment of Incoming feeder	Bus Tie

It is assumed that the flaps have been properly set and the connection to the protection relay has been tested after busbar assembly onsite.

**Step 1/6**

Move all circuit breaker trucks into the service position in the relative section. Check all the circuit breakers trucks status on the protection relay LHMI.

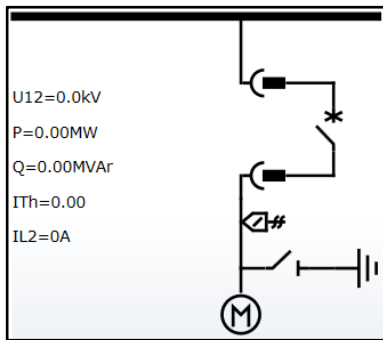


Figure 97: Single line diagram, the circuit breaker is in the service position

**Step 2/6**

Close all circuit breakers in the relative section. Check all the circuit breakers status on the protection relay LHMI.

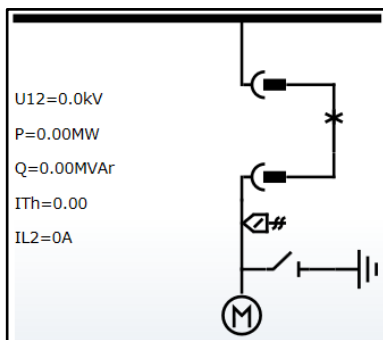


Figure 98: Single line diagram, the circuit breaker is closed and in the service position

**Step 3/6**

Select the feeder to be tested. Simulate a trip of the first flap (order of flap to be tested no matter). Bring potential to the binary input for a short time. The circuit breaker must trip and, according to inter-trip logic scheme, forward the trip command to the upstream breaker (In-comer, Generator and Bus tie). The upstream circuit breaker must trip immediately all feeders in the relative section shall trip at the same time if inter-trip is designed.

**Step 4/6**

Check interlocking logic. Clear Lockouts

**Step 5/6**

Repeat step 3 for next two flaps in the same feeder.

**Step 6/6**

Repeat steps 2 to 5 for all feeders.

### 5.2.5 Arc protection inter-trip

The switchgear is fitted with lenses detecting flashlight from an electrical Arc in each compartment. Sensors are connected to the protection relay. In case of flashlight detection, the protection relay immediately sends the trip command to the circuit breaker. The trip command is further distributed over the switchgear based on the location of the Arc.

It is good practice to also forward the inter-trip to outgoing feeders in the section to interrupt the current contribution from the load like motors.

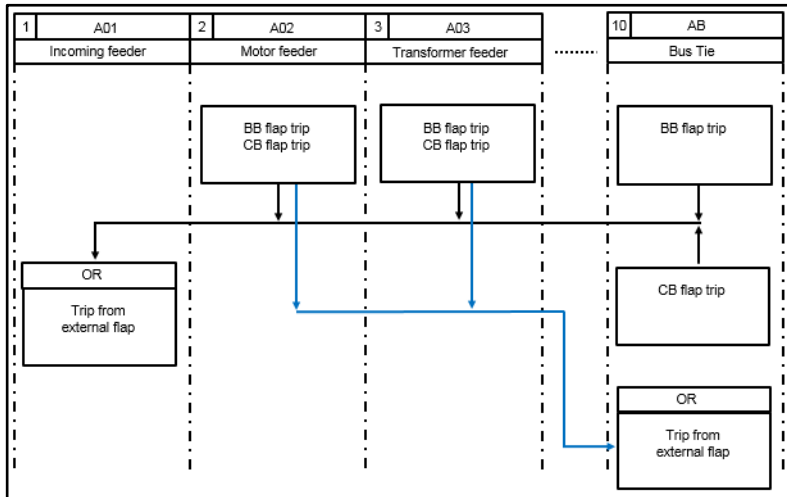


Figure 99: Logic scheme of ARC trip

#### Step 1/11

Move all the circuit breaker trucks into the service position in the relative section, Check the circuit breakers truck status on the protection relay LHMI's.

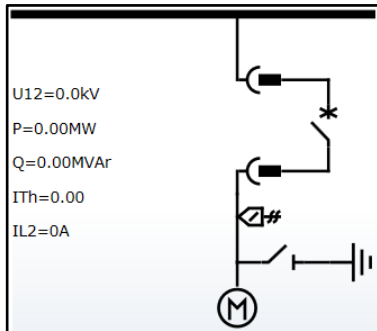


Figure 100: Single line diagram, the circuit breaker is in the service position

**Step 2/11**

On the protection relay LHMI (upstream circuit breaker such as the Incomer, Generator and Bus tie receiving the ARCSARC trip signal) go to -> **Main Menu/Test/IED test**

- Test mode = IED test

The ready LED is flashing when the protection relay is in test mode.

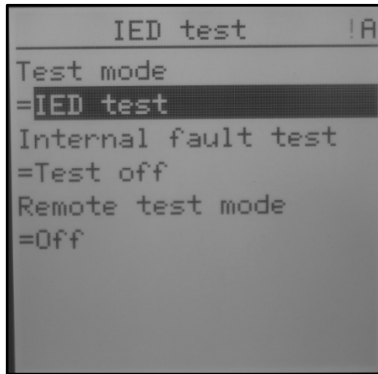


Figure 101: Entering test mode

**Step 3/11**

On the protection relay LHMI (tested feeder) go to -> **Main Menu/Test/IED test**

- Test mode = IED test

The ready LED is flashing when the protection relay is in test mode.

**Step 4/11**

Close all circuit breakers in the relative section. Check all the circuit breakers status on the protection relay LHMI's.

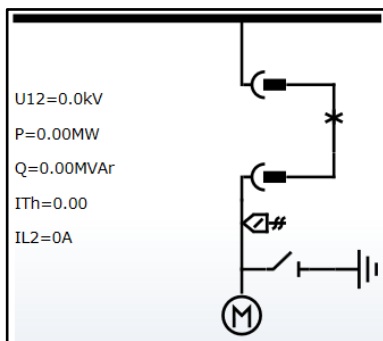


Figure 102: Single line diagram, the circuit breaker is closed and in the service position

**Step 5/11**

On the protection relay LHMI (tested feeder) go to-> **Main Menu/Test/Function tests/Other protection**

- ARCSARC1 = Activate OPERATE

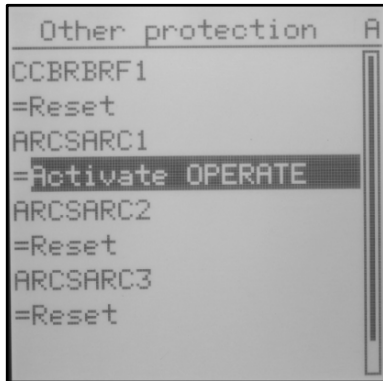


Figure 103: Activating OPERATE signal

The circuit breaker must trip and, according to inter-trip logic scheme, forward the trip command to the upstream circuit breaker (Incomer, Generator and Bus tie). The upstream circuit breaker must trip immediately. All feeders in the relative section shall trip at the same time if inter-trip is designed.

Then

On the protection relay LHMI (tested feeder) go to-> **Main Menu/Test/Function tests/Other protection**

- ARCSARC1 = deactivate OPERATE

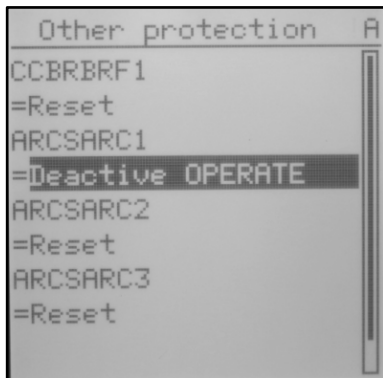


Figure 104: Deactivating OPERATE signal

**Step 6/11**

Check interlocking logic. Clear lockouts.

**Step 7/11**

Close all circuit breakers in the relative section.

**Step 8/11**

Repeat step 5 for other stages of Arc protection (represent other compartments of switch-gear)

On the protection relay LHMI go to-> **Main Menu/Test/Function tests/Other protection**

- ARCSARC2 = Activate OPERATE
- ARCSARC2 = Deactivate OPERATE
- ARCSARC3 = Activate OPERATE
- ARCSARC3 = Deactivate OPERATE

**Step 9/11**

On the protection relay LHMI (tested feeder) go to -> **Main Menu/Test/IED test**

- Test mode = Normal mode

Ready LED is steady ON.

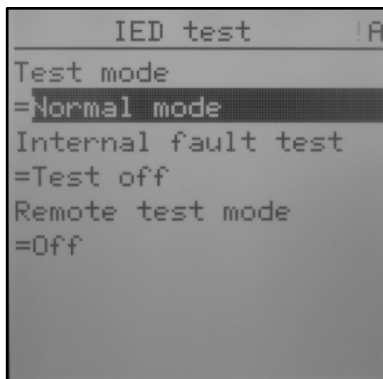


Figure 105: Entering test mode

**Step 10/11**

Repeat steps 4-8 for all feeders.

**Step 11/11**

On the protection relay LHMI (upstream circuit breaker) go to -> **Main Menu/Test/IED test**

- Test mode = Norma mode

## 6 Secondary testing of protection relays

In comparison with traditional UniGear switchgear, the overall testing procedure of protection relays has not changed. Protection and metering functions of the protection relay are tested with a secondary injection tester. It is supposed that protection relays are loaded with the final setting. We recommend testing protection relay metering functionality (U, I, P,  $\cos \phi$ , E) as a part of secondary injections. To get the best performance of the protection relays, simulate a real network by means of running two sequences – Pre-fault for at least 1second and Fault.



Testers for secondary injections do not support the amplitude and angle correction factors of sensors. Therefore, it is recommended to set default values of current and voltage sensors for testing.

On the protection relay LHMI go to -> **Main Menu/Configuration/Analogue inputs/Current (3I, CT) and Voltage (3U, VT)**

- Amplitude Corr x = 1.0000 (default)
- Angle Corr x = 0.0000 deg (default)

where "x" represents A, B or C phase

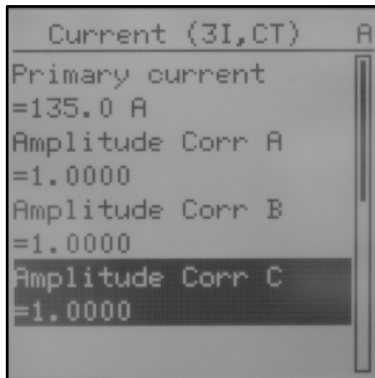


Figure 106: Changing correction factors for amplitude

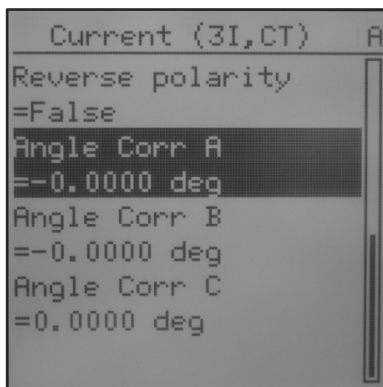


Figure 107: Changing correction factors for angle

### 6.1 Pin assignment

Secondary testers have typically RJ45 Pin assignment complying with IEC 60044 (Black booth) is for current - PIN 4 – S1, PIN 5 – S2 and for Voltage - PIN 7 – a, PIN 8 –  $\frac{1}{n}$ .

ABB sensors have pin assignment complying with IEC 61869 (Red booth) where for current is - PIN 1 – S1, PIN 2 – S2 and for Voltage - PIN 7 – a, PIN 8 –  $\frac{1}{n}$ .

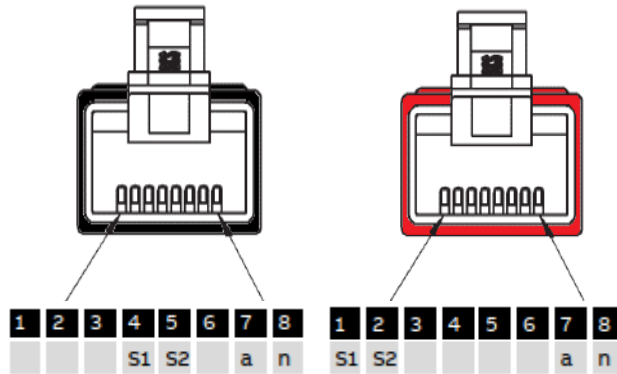


Figure 108: Comparison between the pin assignment complying with IEC 60044 and IEC 61869

The red dot marked coupler adapter AR5 or ESSAILEC® test blocks are made to comply with IEC 60044 and IEC 61869 standards. Therefore, there is no need to use any additional adapter e.g. Omicron Climb REF6xx can be connected directly to the test block.

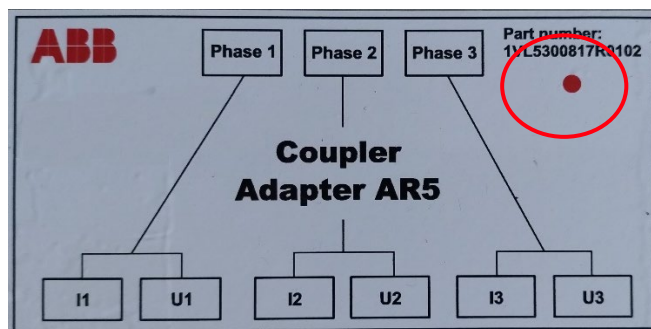


Figure 109: Coupler adapter AR5

## 6.2 ESSAILEC test blocks

ESSAILEC® test blocks are used for efficient testing of protection and control relay during regular maintenance. The test blocks are flush mounting type on the low voltage compartment door. The testing of protection and control relay's sensor inputs is possible without opening the low voltage compartment door.

### ESSAILEC® RJ45 test block

A test block is used for efficient testing of a protection and control relay with sensor inputs. Vertical layout for the test block is recommended. One test block is intended for one phase, and it consists of a plug, a lid and a socket.



Figure 110: ESSAILEC® RJ45 test block (the plug, the lid and the socket)

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

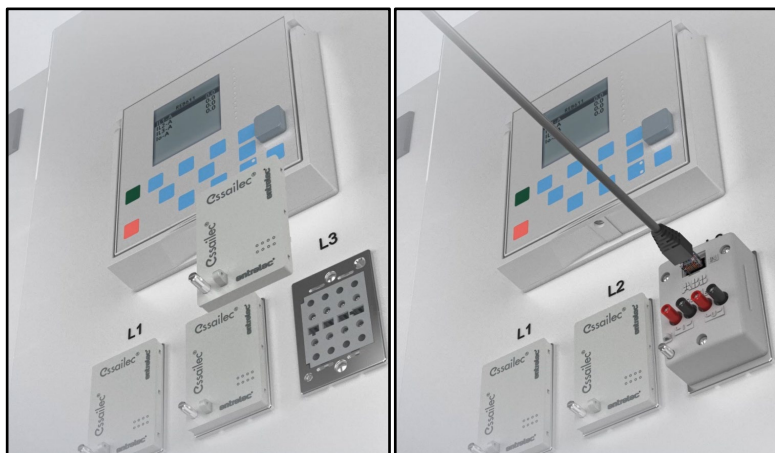


Figure 111: Low Voltage Compartment door of UniGear panel with ESSAILEC® RJ45 test blocks

### ESSAILEC® Trip or Polarity range test block

The test block allows the testing without circuit breaker tripping.

#### Testing procedure

##### Step 1/5

Remove the lid from ESSAILEC® Trip / Polarity test socket and insert the test plug. The test plug disconnects tripping signal from a protection relay.

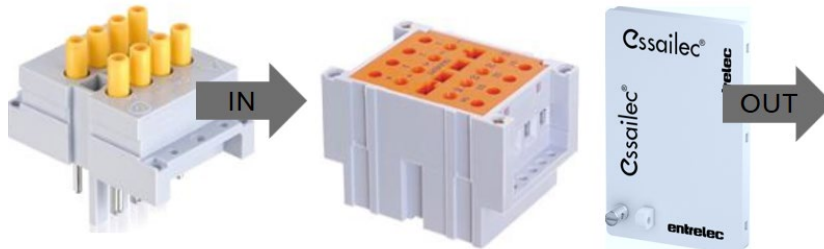


Figure 112: ESSAILEC® Trip test block – Testing

##### Step 2/5

Remove the lids from ESSAILEC® RJ45 test sockets for all three phases and insert the test plugs



Figure 113: ESSAILEC® RJ45 test block – Testing

**Step 3/5**

Secondary testing

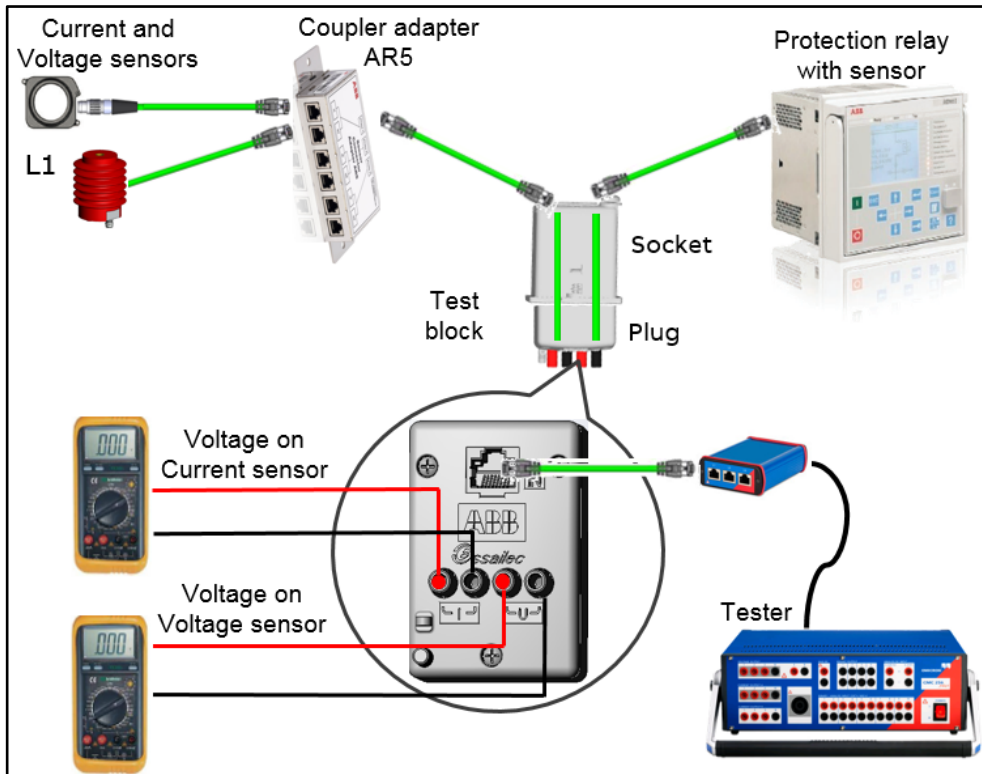


Figure 114: The testing (one phase testing setup is shown on the picture)

**Step 4/5**

Remove the test plugs from ESSAILEC® RJ45 test sockets for all three phases and cover them by the lids.



Figure 115: ESSAILEC® RJ45 test block – Normal operation

**Step 5/5**

Remove the test plug from ESSAILEC® Trip test socket and cover it by the lid.



Figure 116: ESSAILEC® Trip test block – Normal operation

### 6.3 Secondary test setups

There are different secondary testers with a wide range of additional functionality available on the market. The testers are primarily operated over a PC with corresponding software which brings additional functionality to the end user. The secondary tester providing support to low level outputs (linear, Rogowski) is connected via a testing cable or via adapter to the sensor input of the protection relay. This section describes how to use testers from Omicron and Megger. Moreover, it is indicated how these testers can be used for 3 phase testing and 1 phase testing of protection relays.

#### Test setup for Omicron – 3 phases

Low-level outputs of the CMC tester (for example CMC 850; CMC 356; CMC 256plus; CMC 353 / CMC 430) are connected to an adapter CMLIB REF6xx / LLX1 used to connect ABB’s Relion® 615, 620 and 640 series fitted with combined sensor inputs. The testing adapter is usually connected to the protection relay through ESSAILEC® test blocks via connecting shielded cables terminated with RJ45 connectors. If the ESSAILEC® test blocks are not installed, then the testing adapter is connected directly to the protection relay via connecting shielded cables terminated with RJ45 connectors.

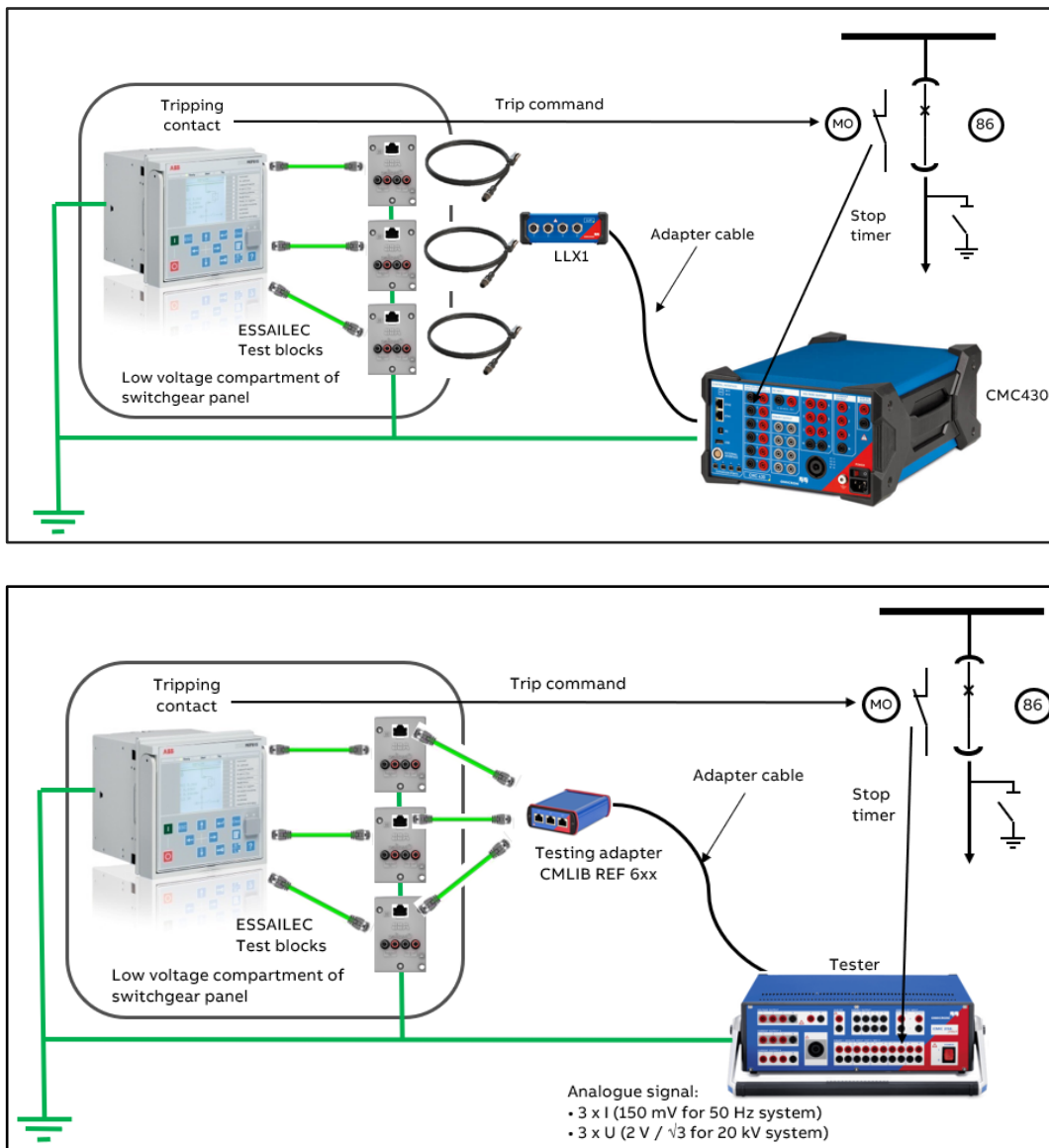


Figure 117: 3 phases test setup for the Omicron testers

The maximal low-level output from

- CM430 + LLX1 is 48 V
- CMC tester (for example CMC 850; CMC 356; CMC 256plus; CMC 353 + CMLIB REF6xx) is 7.07 Vrms. Two dynamic amplitude range modes (normal = default and high) can be selected for Rogowski coil simulation. In Normal, the dynamic range amplitude is limited to  $5.9 \times 150 \text{ mV}$  when harmonics up to 400 Hz are considered ( $5.9 \times 400 / 50 \times 0.15 = 7.08$ ). The high mode permits amplitudes of up to  $37 \times 150 \text{ mV}$  and is permitted via Windows registry settings (details can be found in Omicron technical documentation).

An alternative solution for pure 50 or 60 Hz sine wave simulation is to define a linear current sensor instead of the Rogowski current sensor. Low level output signals up to 7.07 Vrms are then available.

- 80 A / 0.150 V                      maximal simulated current is 3 770 A, 50 / 60 Hz

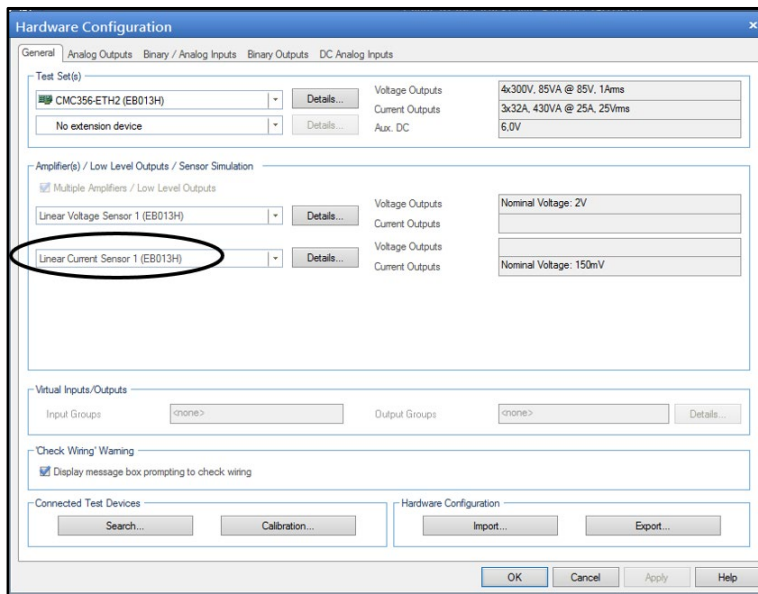


Figure 118: Linear current sensor instead of the Rogowski setting in the Omicron tester

**Test Setup for Omicron – 1 phase**

For high setting of Overcurrent protection, you may need to apply at max. 93.75 Vrms, 50 Hz which represents 50 kA of symmetrical short circuit current on the primary side. Low level output of CMC tester has limitation. Therefore, it is recommended to use high voltage outputs situated on the front side of the tester. These can only be connected to the relay as a 1 phase connection.

**Step 1/3**

The protection relay and tester must be grounded on the same electrical potential.

**Step 2/3**

Omicron tester is connected via connecting cable terminated with banana connectors and RJ45 connector on the other one end to the ESSAILEC® test block or directly to the protection relay if the ESSAILEC® test block is not installed. Wires for the voltage sensor are connected to the voltage output 4 output as Phase – Earth voltage. Wires for the current sensor are connected to the voltage outputs 1, 2. Neutral N is connected to the ground.

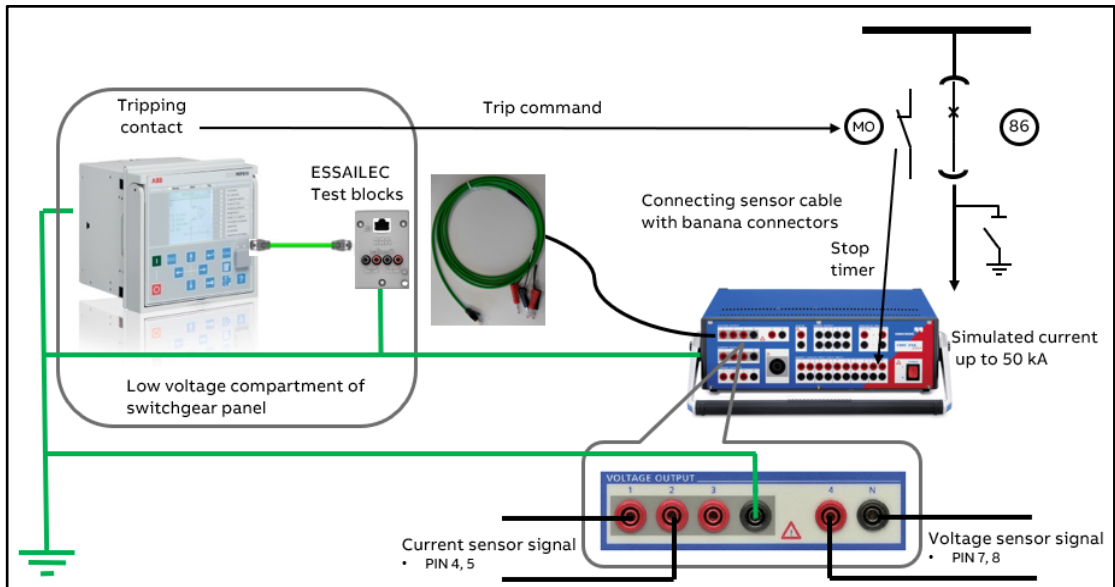


Figure 119: 1 phase test setup for the Omicron tester



Figure 120: Connecting cable with RJ45 connector and banana contacts (it is available on client request)

**Step 3/3**

Simulate high currents on the current sensor input via the front voltage outputs 1, 2.

- U1 = U2 with 180° phase shift (symmetrical source).

Simulate voltage on the voltage sensor input via the front voltage output U4, N.

- $U4 = \frac{U_n}{\sqrt{3}}$

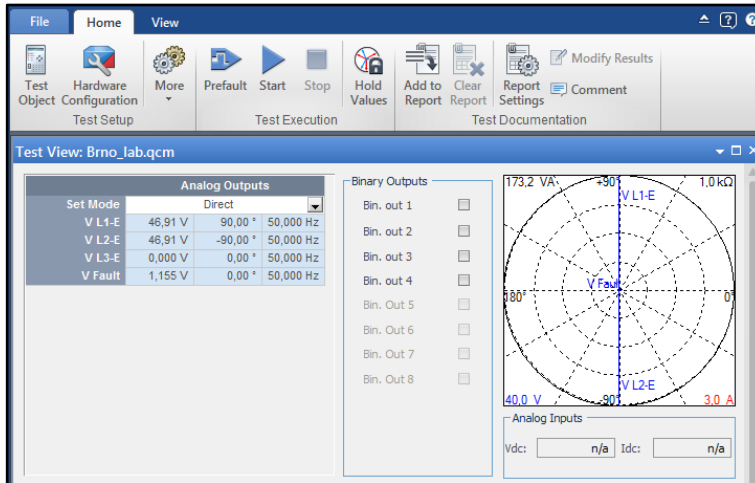


Figure 121: Setting of high voltage analogue outputs in the Test Universe program

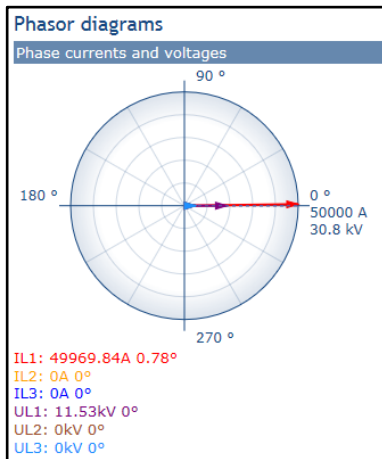


Figure 122: Phasor diagram on the protection relay's WebHMI

REM615 !A	
IL1-A	49969.0
IL2-A	0.0
IL3-A	0.0
Io-A	0.0
U12-kV	11.534
U23-kV	0.000
U31-kV	11.531
f-Hz	50.00
S-MVA	576.198

Figure 123: Measurements view

**Test Setup for Megger – 3 phases**

FREJA 546 (Low Level Output Hardware option) is interconnected with a Low-level test adapter. The test adapter provides the interface between ABB’s Relion® 615/620 series fitted with combined sensor inputs and the tester. The test adapter is usually connected to the protection relay through ESSAILEC® test blocks via connecting shielded cables terminated with RJ45 connectors. If the ESSAILEC® test blocks are not installed, then the test adapter is connected directly to the protection relay via connecting shielded cables terminated with RJ45 connectors.

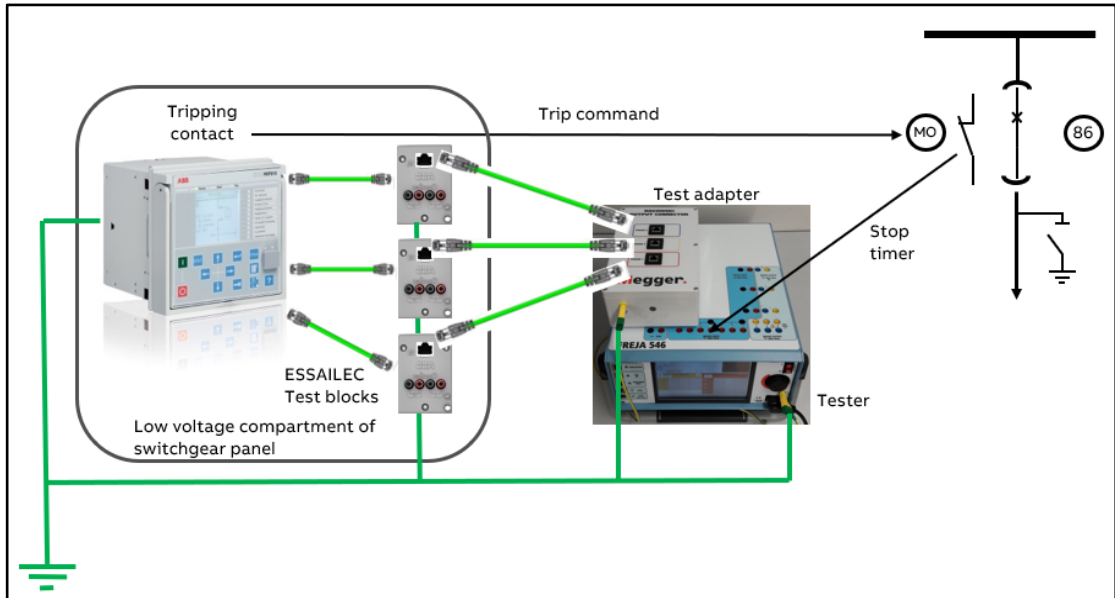


Figure 124: 3 phases test setup for the Megger tester

Maximal low-level output from the Megger tester is 40 V at 50/60 Hz

- 80 A/0.150 V                      maximal simulated current 21.3 kA, 50/60 Hz

**Test Setup for Megger – 1 phase**

For high setting of overcurrent protection, you may need to apply at max. 93.75 Vrms, 50 Hz which represent 50 kA symmetrical short circuit current on the primary side. Therefore, it is recommended to use high voltage outputs situated on the front side. These can be connected to the protection relay as a 1 phase tester.

**Step 1/3**

The protection relay and tester must be grounded on the same potential.

**Step 2/3**

Megger tester is connected via connecting cable terminated with banana connectors and RJ45 connector on the other one end to the ESSAILEC® test block or directly to the protection relay if the ESSAILEC® test block is not installed. Wires for the voltage sensor are connected to the Uref output as Phase – Earth voltage. Wires for the current sensor are connected to the UL1, UL2 voltage output.

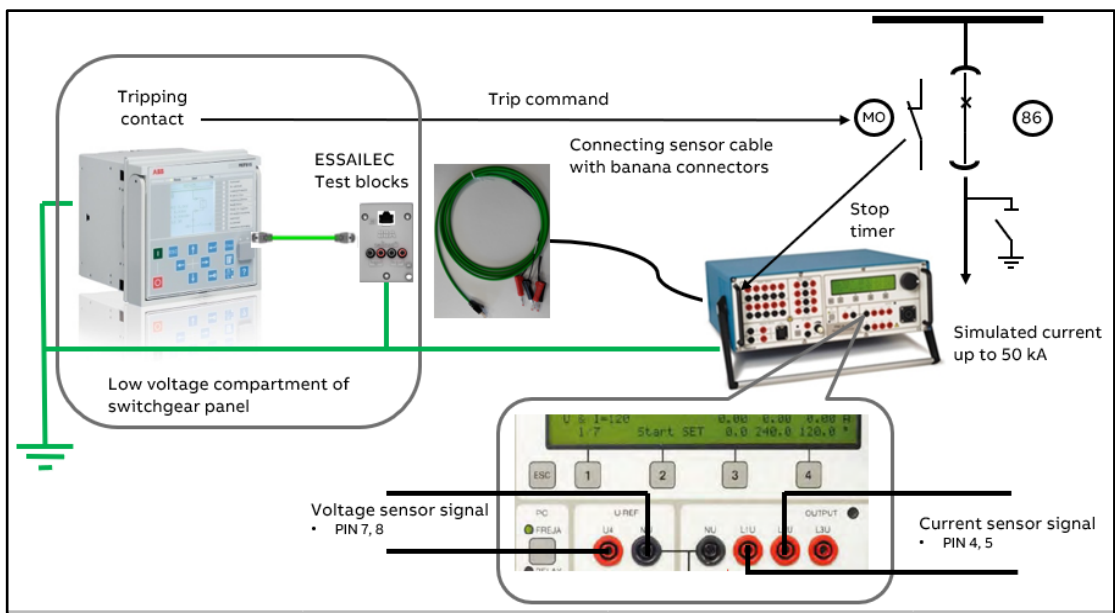


Figure 125: 1 phase test setup for the Megger tester



Figure 126: Connecting cable with RJ45 connector and banana contacts (it is available on client request)

**Step 3/3**

Simulate high currents on the current sensor input via the front voltage outputs L1U, L2U.

- $U1 = U2$  with  $180^\circ$  phase shift (symmetrical source)

Simulate voltage on the voltage sensor input via the front voltage output U4, NU.

- $U4 = \frac{U_n}{\sqrt{3}}$

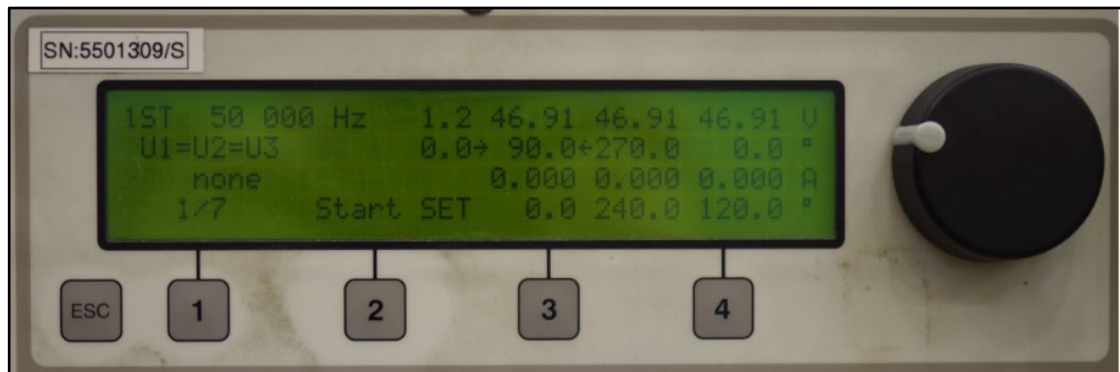


Figure 127: Setting of high voltage analogue outputs on the Freja 300 HMI

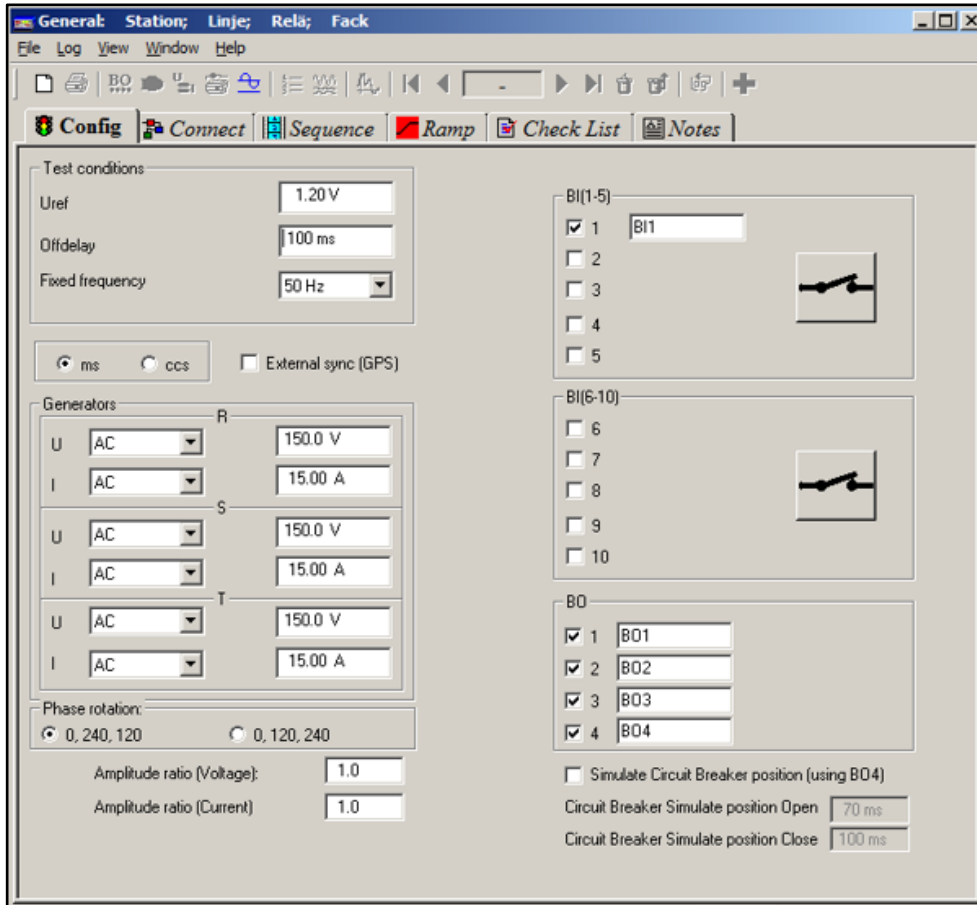


Figure 128: Setting of high voltage analogue outputs in the Megger configuration program

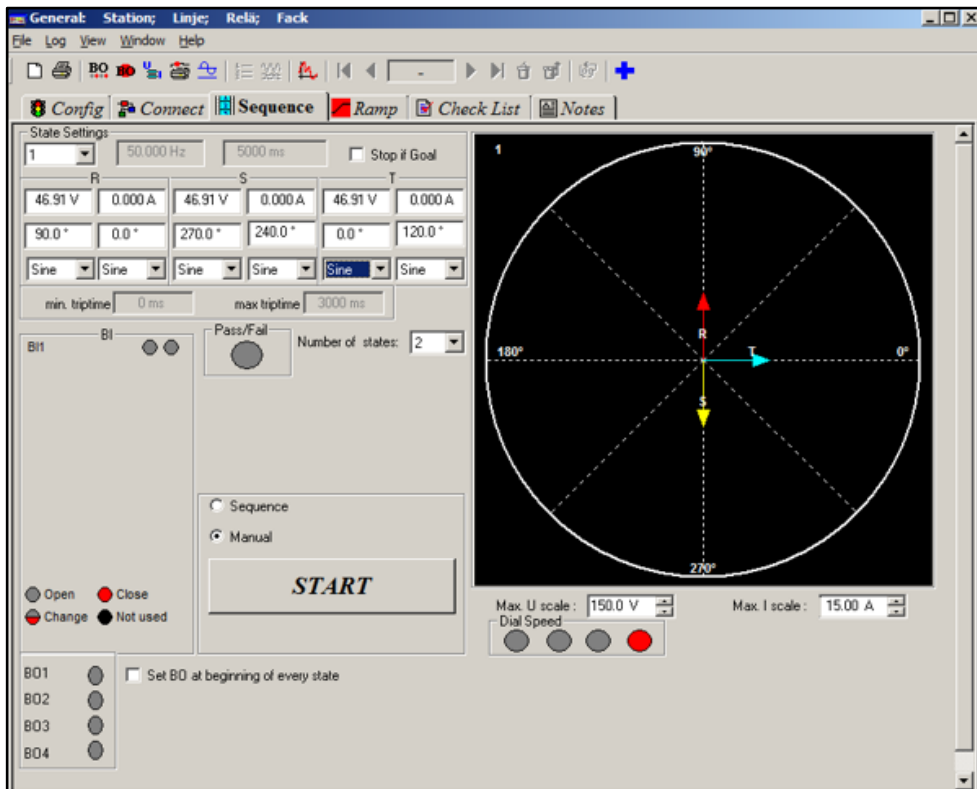


Figure 129: Setting of high voltage analogue outputs in the Megger configuration program

REM615		!A
IL1-A	49969.0	
IL2-A	0.0	
IL3-A	0.0	
Io-A	0.0	
U12-kV	11.534	
U23-kV	0.000	
U31-kV	11.531	
f-Hz	50.00	
S-MVA	576.198	

Figure 130: Measurements view

# 7 Recommended Troubleshooting tools

## ITT SA Explorer

Integrated testing tool ITT600 SA Explorer (manufactured by ABB) s designed for easy diagnosis and troubleshooting of IEC 61850-based substation automation systems and applications.

The ITT600 SA Explorer can be divided in five main parts:

**Explore IEDs** enables the user to either browse SCL file contents or retrieving the IEC 61850 related configuration from any compliant IED over the network. Its full-fledged IEC 61850 client allows to do various operations on multiple IEDs in parallel. Additionally, it provides the functionality to simulate one IED of the loaded SCL file.

**Explore Ethernet** is an easy-to-use protocol analyzer that supports SA related protocols. It can present the transmitted IEC 61850 data in a user readable form, without having a deep knowledge about the protocols. This functionality simplifies troubleshooting of communication problems significantly.

**Explore Models** enables the user to compare SCL related data. It does not matter whether two SCL compatible files or online data are compared. This functionality again simplifies troubleshooting because every configuration can be compared against a reference.

**Explore GOOSE** visualizes GOOSE data in an Oscilloscope style. Several individual Data Attributes sent in GOOSE frames can easily be compared and measured. This enables faster debugging and comprehension of distributed application logic using GOOSE.

**Explore SV** visualizes IEC 61850-9-2 LE data streams using a polar chart. Two different data streams can easily be visualized and compared at the same time. The Oscilloscope view shows current and voltage trends, allowing the user to inspect the content of each SMV packet.

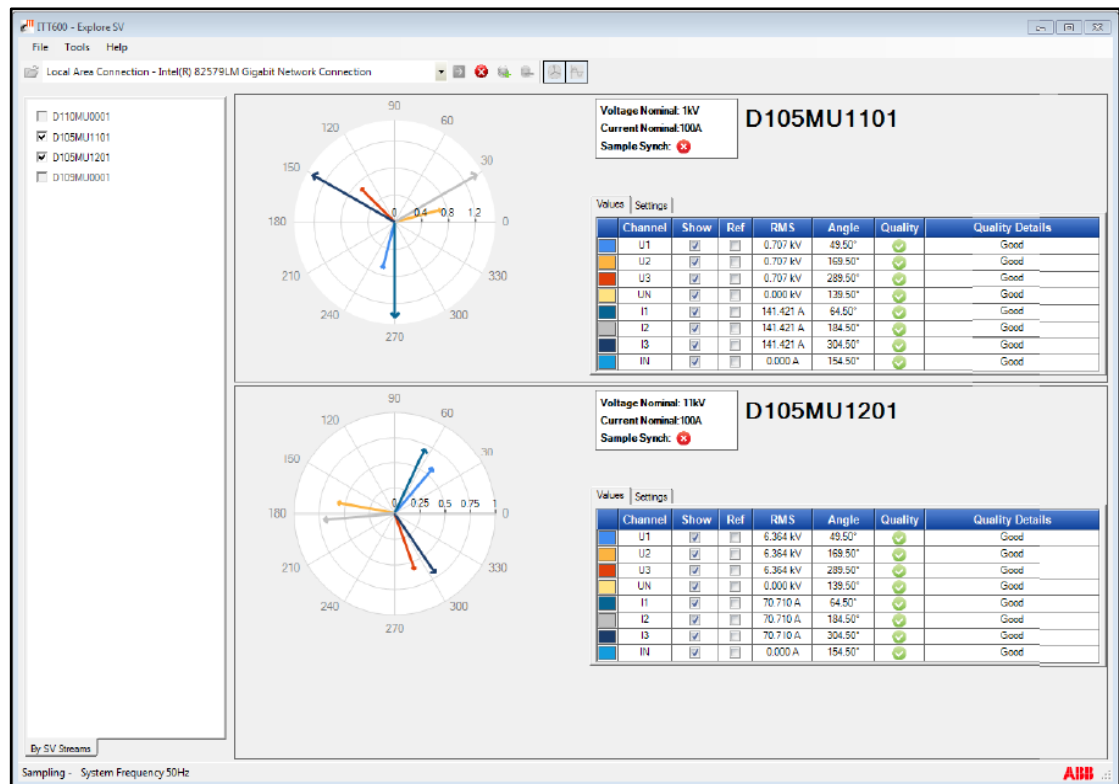


Figure 131: ITT600 – Explore SV – two selected streams and the polar diagrams are shown

**Local HMI of 640 series**

The LHMI supports the engineer during the relay’s testing, commissioning and troubleshooting activities. The information, traditionally accessible through different paths within the menu structure, is provided in collectively grouped and visualized format.

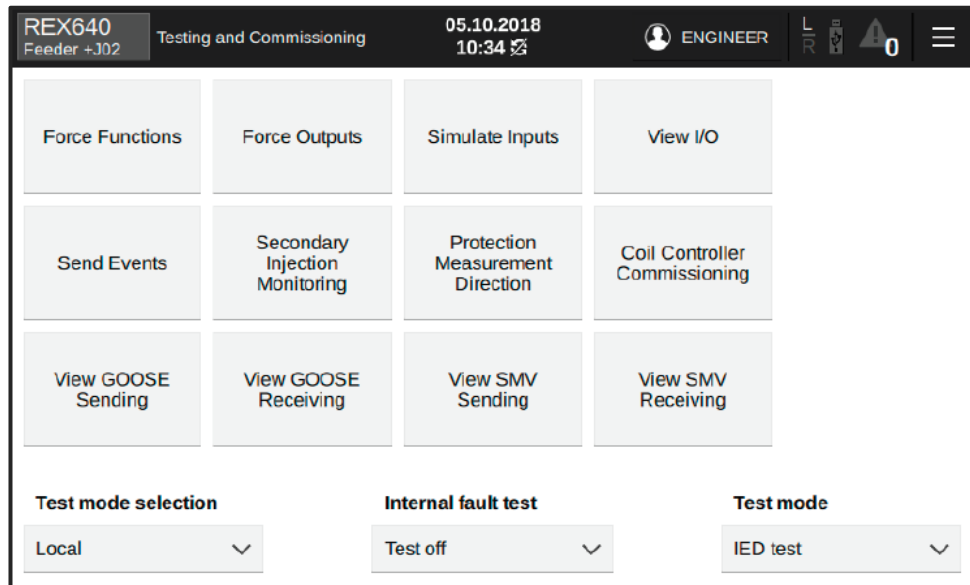


Figure 132: Home page for Testing and Commissioning pages

Checking GOOSE data

On the **GOOSE Receiving** page, check the GOOSE data that the relay subscribes from the Ethernet network. The left side of this page shows a list of devices that send GOOSE messages to the relay. These devices that publish data for the relay are defined in the relay configuration. The right side of the page shows the GOOSE data the relay receives from the network. The data set consists of value and quality attributes. The received data has status indicators where green means all OK, yellow warning and red error.

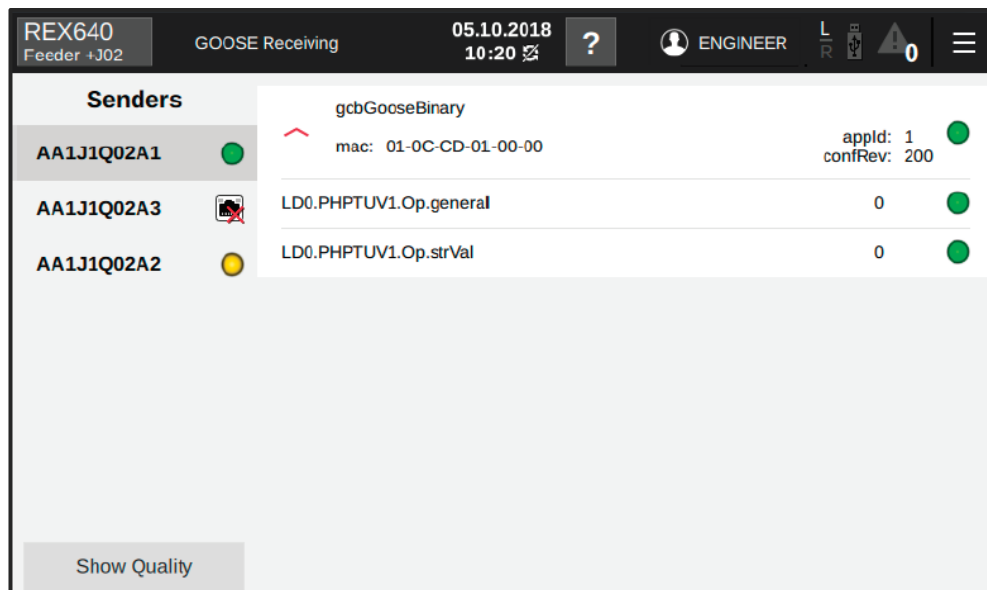


Figure 133: GOOSE Receiving Page

On the **GOOSE Sending** page, check the status of the relay's configured GOOSE control blocks and the values of the sent data. The left side of this page shows a list of the devices where the relay sends GOOSE messages. In the system there may be more devices, but these devices are according to relay configuration the ones subscribing the data from the relay. The right side of the page shows the GOOSE data that the relay sends to the network. The data set consists of value and quality attributes. The sent data has status indicators where green means all OK, yellow warning and red error.

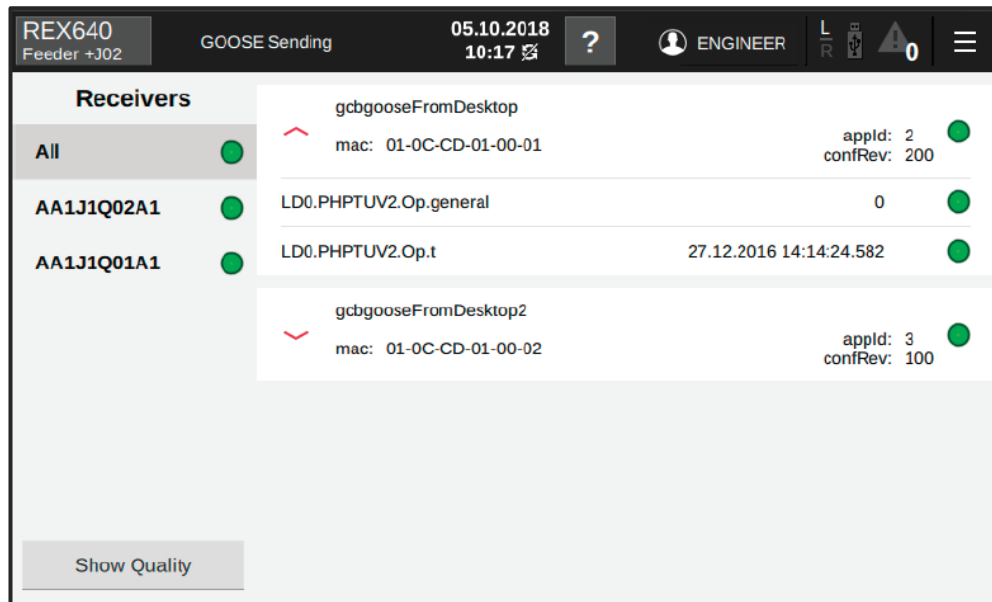


Figure 134: GOOSE Sending Page

On the **SMV Receiving** page, check the sampled values data that the relay subscribes from the Ethernet network. The left side of this page shows a list of devices that send SMV messages to the relay. These devices that publish data for the relay are defined in the relay configuration. The right side of the page shows the SMV data that the relay receives from the network. The data set consists of value and quality attributes. The received data has status indicators where green means all OK, yellow warning and red error.

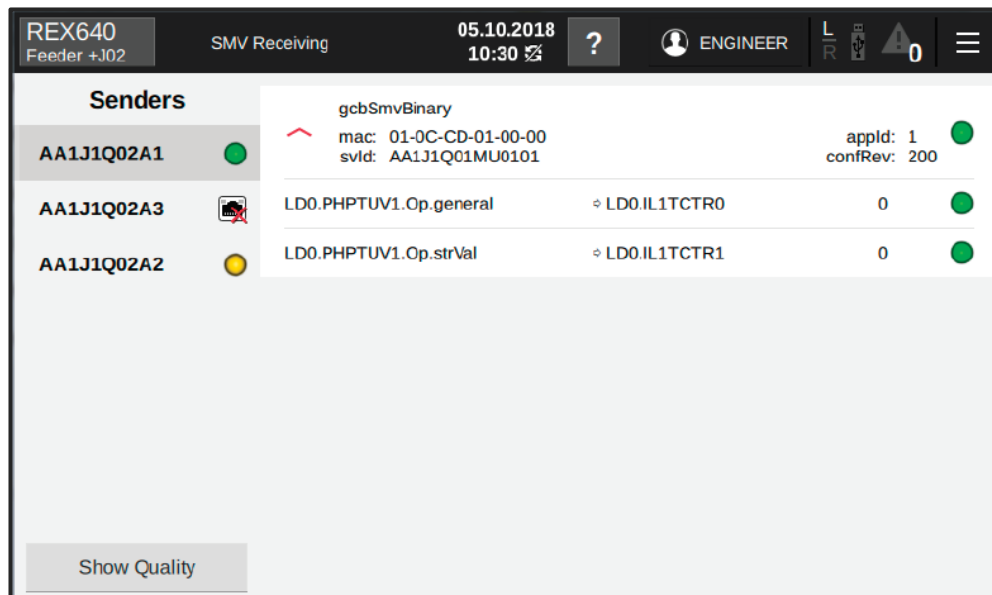


Figure 135: SMV Receiving Page

On the **SMV Sending** page, check the status of the relay's configured SMV control blocks and the values of the sent IEC 61850-9-2 sampled value data. The left side of this page shows a list of the devices where the relay sends SMV messages. In the system there may be more devices, but these devices are according to relay configuration the ones subscribing the data from the relay. The right side of the page shows the SMV data the relay sends to the network. The sent data has status indicators where green means all OK, yellow warning and red error.

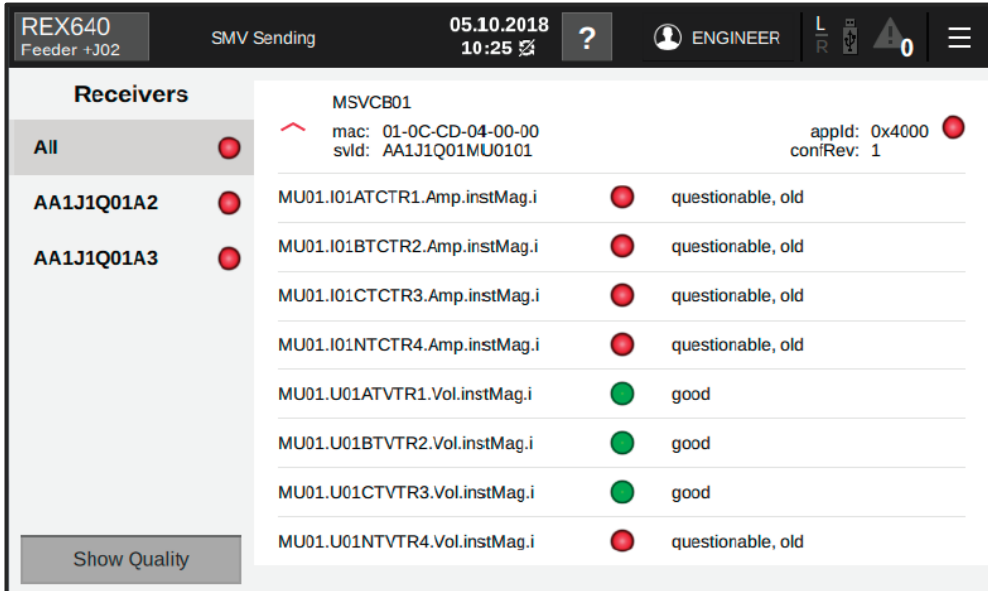


Figure 136: SMV Sending Page

Detailed information on Testing and Commissioning can be found in the operation manual of 640 series.

### Wireshark Network analyzer

Wireshark is an open-source network packet analyzer. A network packet analyzer captures network packets and displays that packet data as detailed as possible. Refer to [www.wireshark.org](http://www.wireshark.org) for additional information.

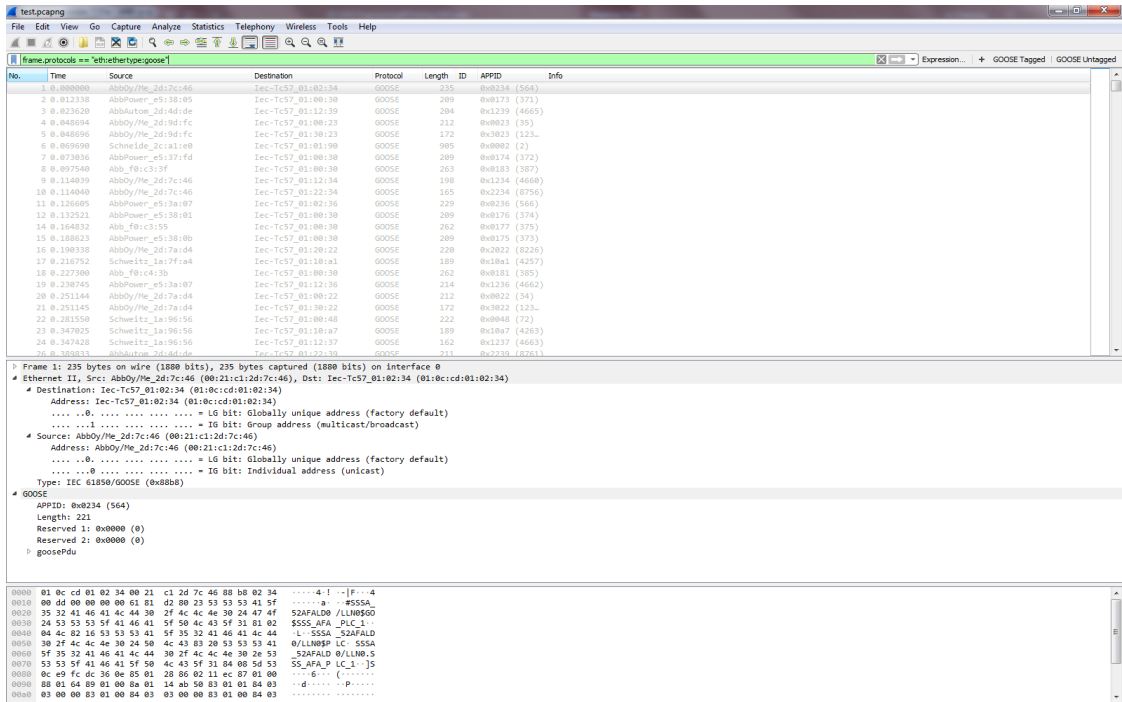


Figure 137: Example of captured packets by Wireshark

### GridEx® IEC 61850 test tool

GridEx is the test tool for IEC 61850 (GOOSE, SMV) network troubleshooting and maintenance manufactured by –FMTP+, no computer is needed. Refer to [www.fmtppower.com](http://www.fmtppower.com) for additional information.

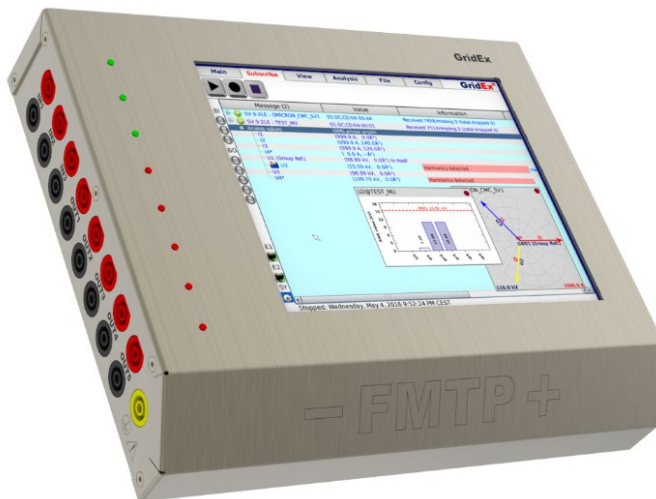


Figure 138: GridEx IEC 61850 test tool

## Glossary

615 series	Relion <sup>®</sup> 615 series protection and control relays
620 series	Relion <sup>®</sup> 620 series protection and control relays
640 series	Relion <sup>®</sup> 640 series protection and control relays
ACT	Application Configuration Tool
AFS Family	ABB FOX Switch family for utility applications
BB	Busbar
CB	Circuit Breaker
CBFP	Circuit Breaker Failure protection
CT	Current Transformer
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
GOOSE	Generic Object-Oriented Substation Event
HMI	Human Machine Interface
HSR	High Availability Seamless Redundancy
ID	Identifier
IEC	International Electrotechnical Commission
IEC 60044	International standard for Instrument transformers
IEC 61869	International standard for Instrument transformers
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
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
IP	Internet Protocol
ITT	Integrated Testing Toolbox for efficient testing and commissioning of IEC 61850 based Substation Automation Systems
I/O	Input / Output
LAN	Local area network
LBBP	Logic Busbar protection
LE	Light Edition (Lite Edition)
LED	Light Emitting Diode
LHMI	Local Human Machine Interface

L1U	Voltage in phase 1
L2U	Voltage in phase 2
MACH	Hirschmann Switch family for utility applications
MMS	Manufacturing Message Specification
MV	Medium voltage
PC	Personal computer
PCM600	Protection and control relay Manager
PRP	Parallel Redundancy Protocol
PTPv2	Precision Time Protocol Version 2
RJ45	Galvanic connector type
RMS	Root mean square
RSP	Hirschmann Switch family for utility applications
SA	Substation Automation
SCADA	Supervisory Control and Data Acquisition
SCL	XML-based substation description configuration language defined by IEC 61850
SMV	Sampled Measured Value
SNMP	Simple Network Management Protocol
SV	Sampled Value
SW	Software
TC	Transparent clock
U-REF	Amplitude of the voltage reference generator
VLAN	Virtual LAN
VT	Voltage Transformer



## Revision History

Rev.	Page	Change Description	Date / Initial
A	all	Initial release	2016-03-15
B	all	ESSAILEC® test blocks for the secondary testing without opening a low voltage compartment door Recommended Troubleshooting tools	2017-03-27
C	all	Recommended 3 phase test set up extended about FREJA 546 with low level output hardware option and about Omicron CMC 430 with low level output accessories LLX1 Recommended Troubleshooting tools extended about Local HMI of 640 series and Wireshark Network analyzer	2019-12-19
D	all	Managed Ethernet Switches AFS have been replaced by Hirschmann RSP, MACH family IEC 60044 and IEC 61869 standards sensors pin assignment comparison	2024-04-30



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