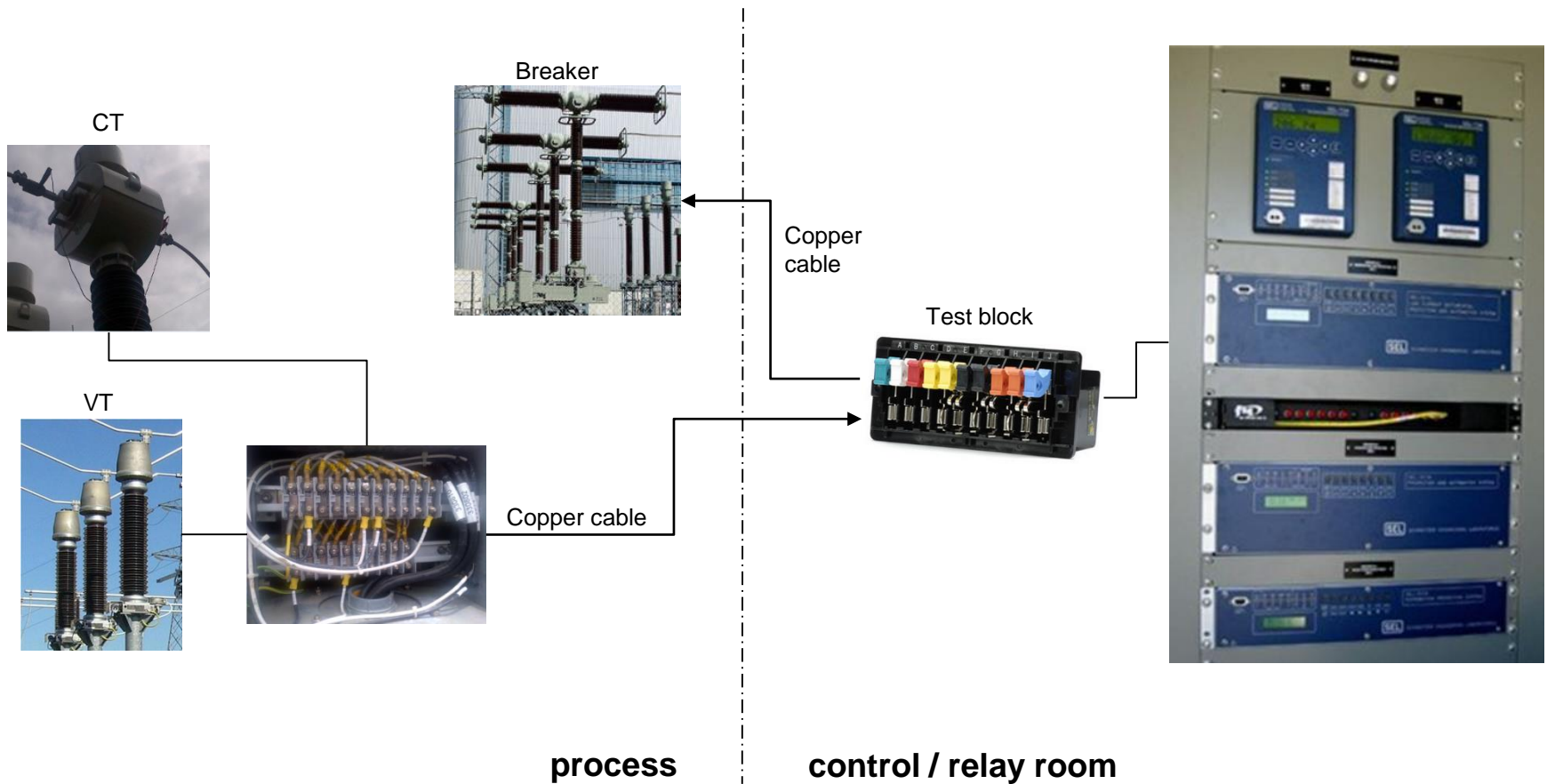# Testing Protection, Automation and Control

Eugenio Carvalheira
OMICRON

Boot Camp IEC 61850 IOP
2019-09-22, Charlotte, NC
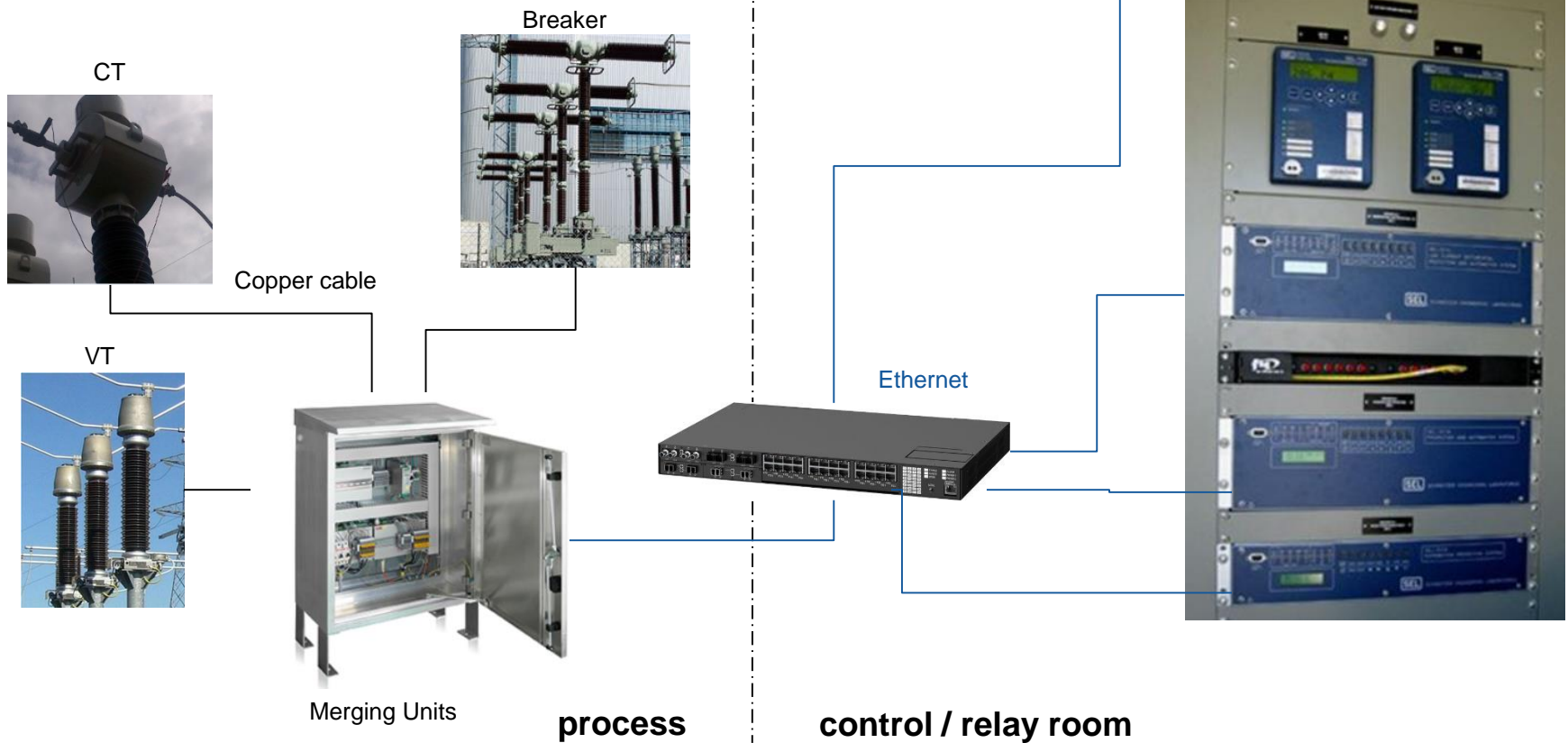
22 September 2019

Evolution from Conventional to Digital Substations

CT

VT

Breaker

Copper cable

Copper cable

Test block

process

control / relay room

Evolution from Conventional to Digital Substations

> Move Analog and Physical I/O to the yard

SCADA

CT

Breaker

Copper cable

VT

Ethernet

Merging Units

process   **control / relay room**

Testing Digital Substations

StationScout

DANEO 400

CMC

Substation Automation System

Troubleshooting

Protection Testing

IEC 61850 Testing

Primary Injection

Network Assessment

Process Bus, SAMU, Optical sensor
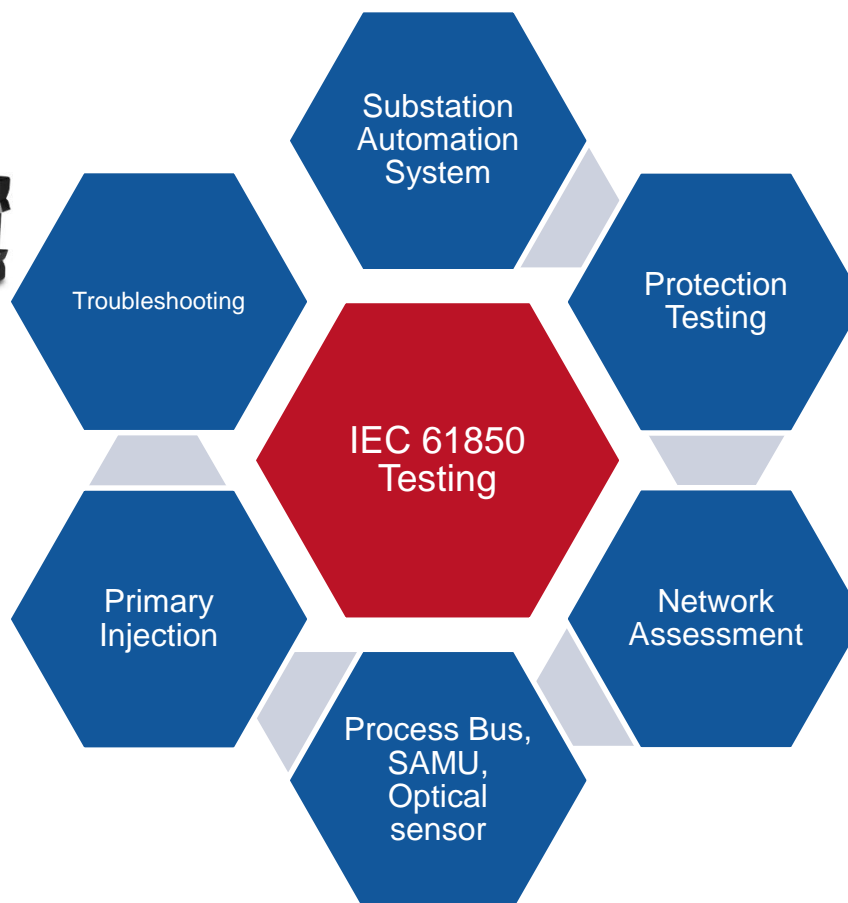
Testing Digital Substations

> Troubleshooting live system:
>> PTP
>> Process Bus
>> Network Supervision

> Testing the Substation Automation System:
>> Testing Communication
>> Testing Control and Interlocking Logics
>> Checking IED Health Status

> Protection Testing:
>> MMS: Control Test Mode (DO Mod) and Simulation (DO Sim)
>> GOOSE and SV

Portable Digital Fault Recorder for Troubleshooting

> Hybrid and distributed **measurement** and **recording**

> **Live observation** of values and IEC 61850 messages

> Time signal and traffic **analysis**

> Measurement of **propagation delays**

> System **supervision** and event notification
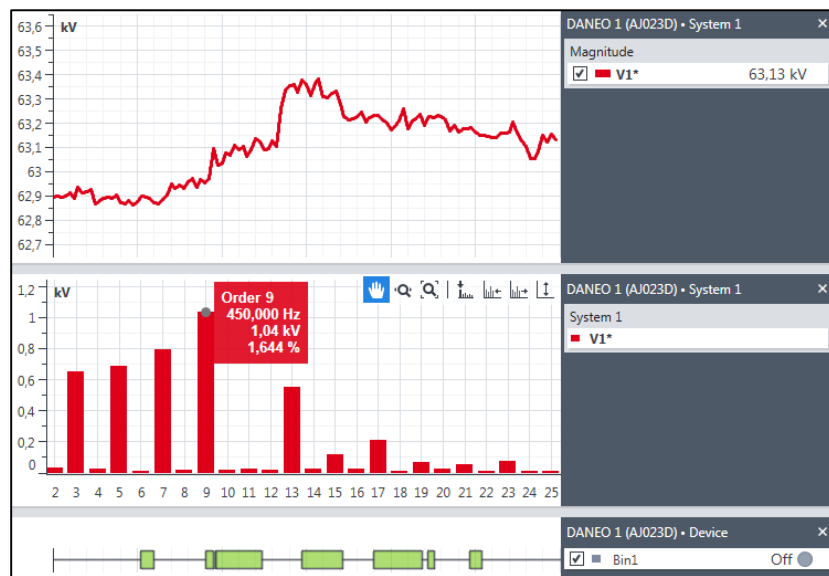
> **Documentation** of results

Time synchronization testing: PTP Sniffer

Observation – Live View of Data

> Measurement of live values and most recent history
> Oscilloscope view, phasor diagrams, harmonics spectrum...
> GOOSE and SV data values and statistics

Live values and recent history

GOOSE data values and statistics

Supervision of Network Traffic

> Supervisor event list with details about events
> Actions for triggering recordings or sending email notifications

Supervisor
event list

Supervisor
actions

Recording – Time Signal Analysis

> Configuration signals and network traffic for capturing
> Definition of trigger condition and recording duration
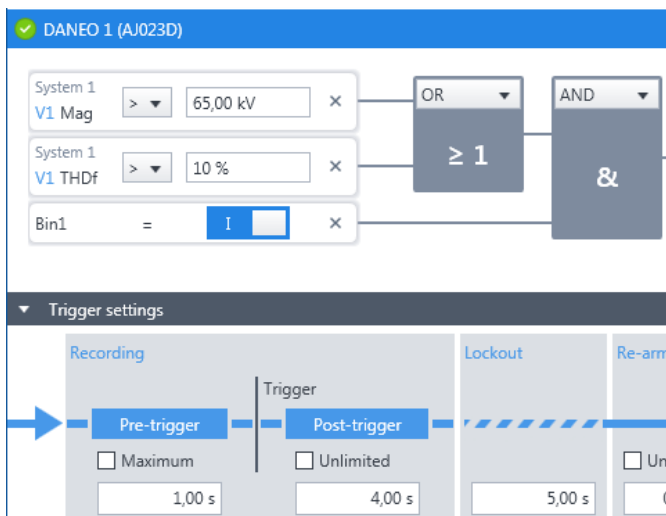
Trigger condition and
recording duration
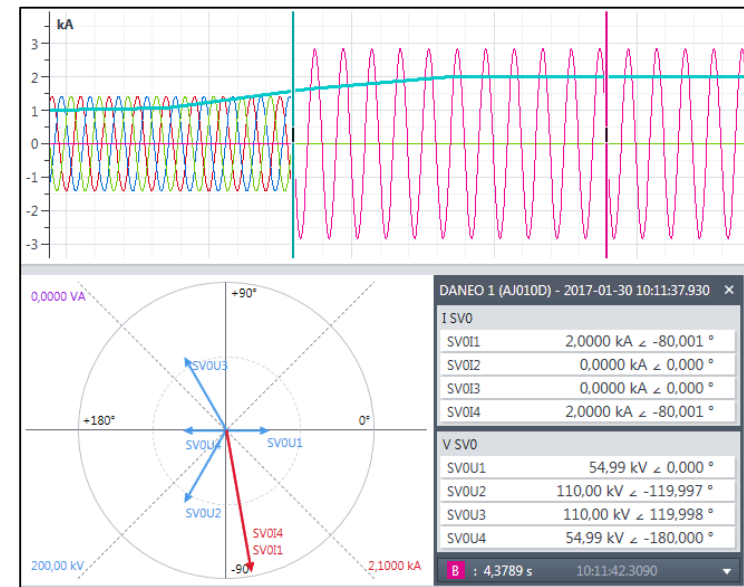
Time signal
analysis

A different View of the Substation Automation System
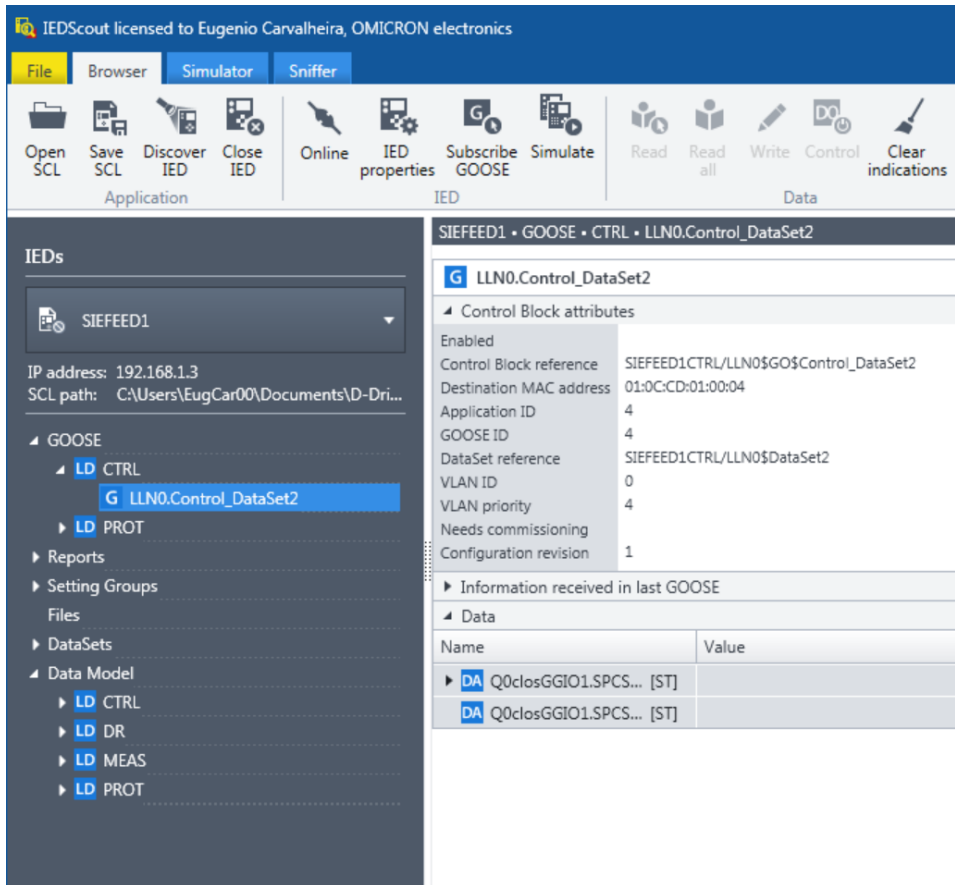
> The IED's View
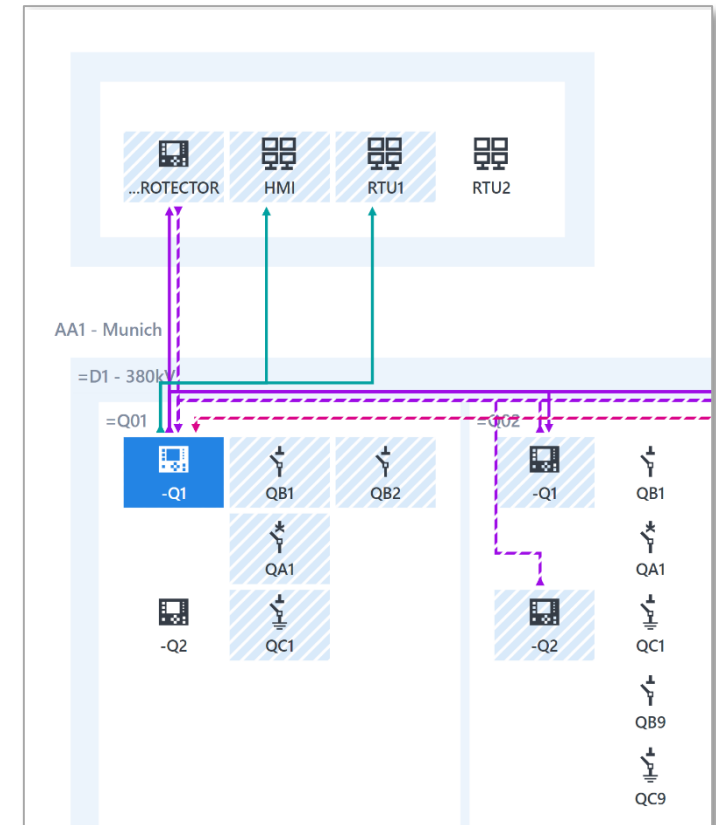
> The Station's View

Testing the SAS

> Based on SCL Information

> Visualize and Test entire Substation Automation System

Smart Overview with signal tracing
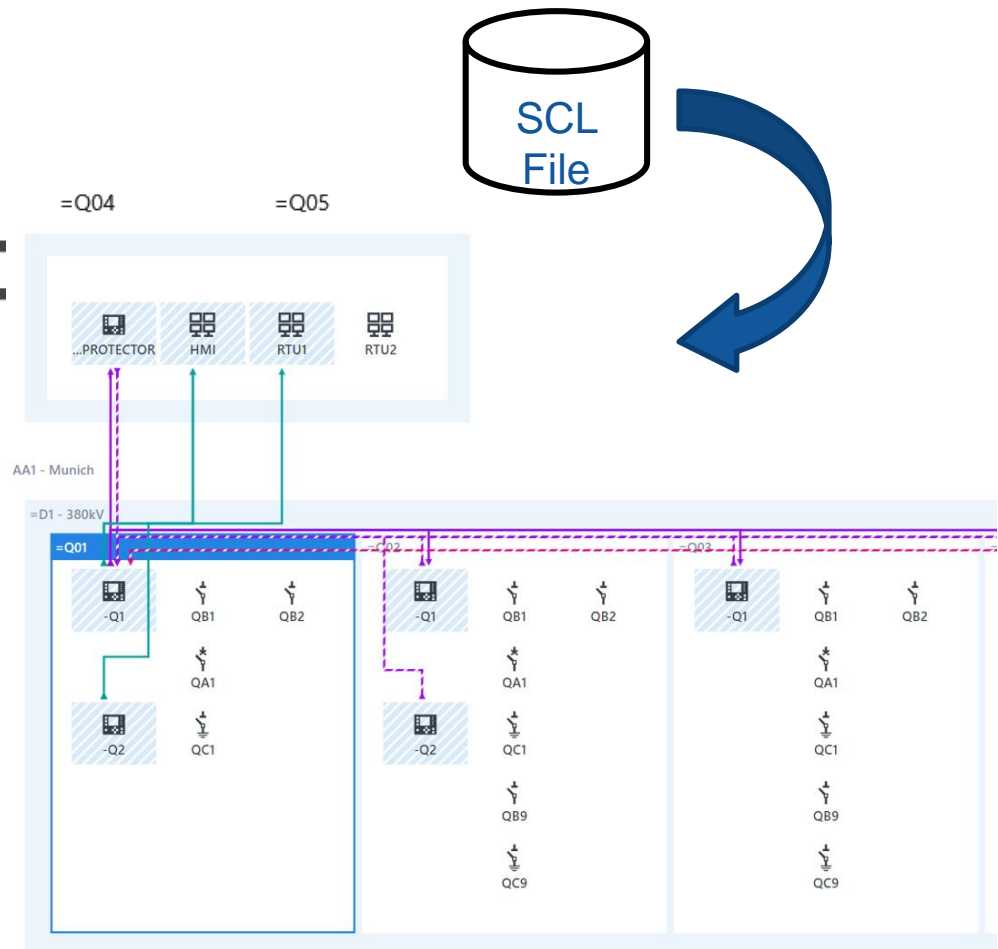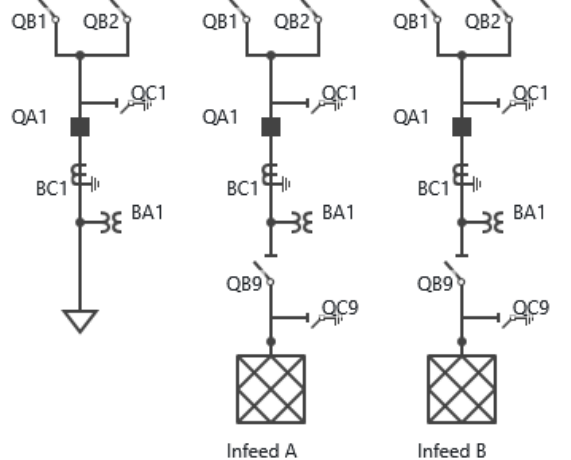
> Smart Overview visualizes communication links and status information of IEDs and primary assets

> GOOSE subscriptions and Report issues can be observed
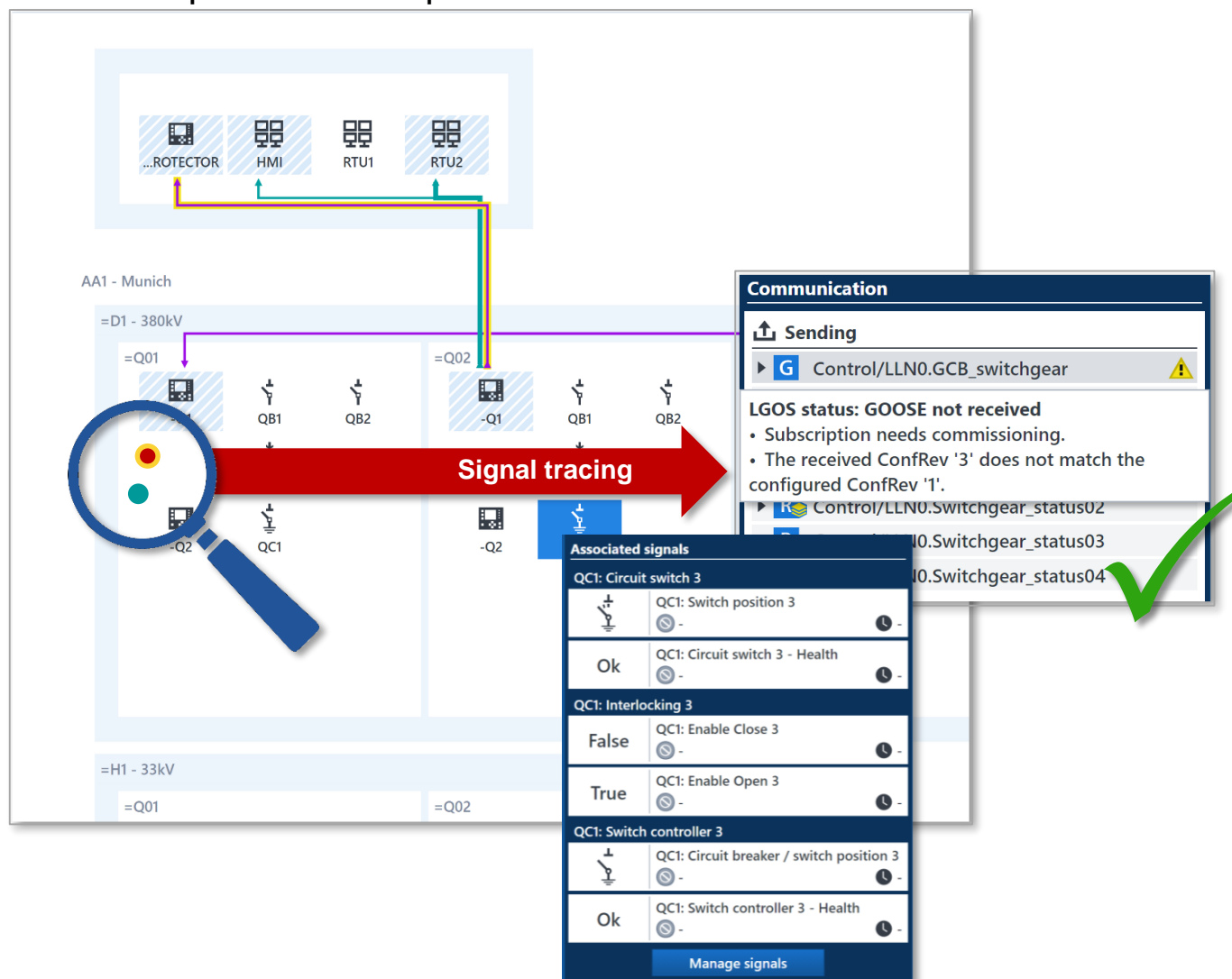
Testing after firmware update

Test Report

GOOSE	passed
Reporting	passed
Test modes	passed
Interlocking	passed

Firmware update

Test Report

GOOSE	passed
Reporting	passed
Test modes	passed
Interlocking	passed

Before firmware update

After firmware update
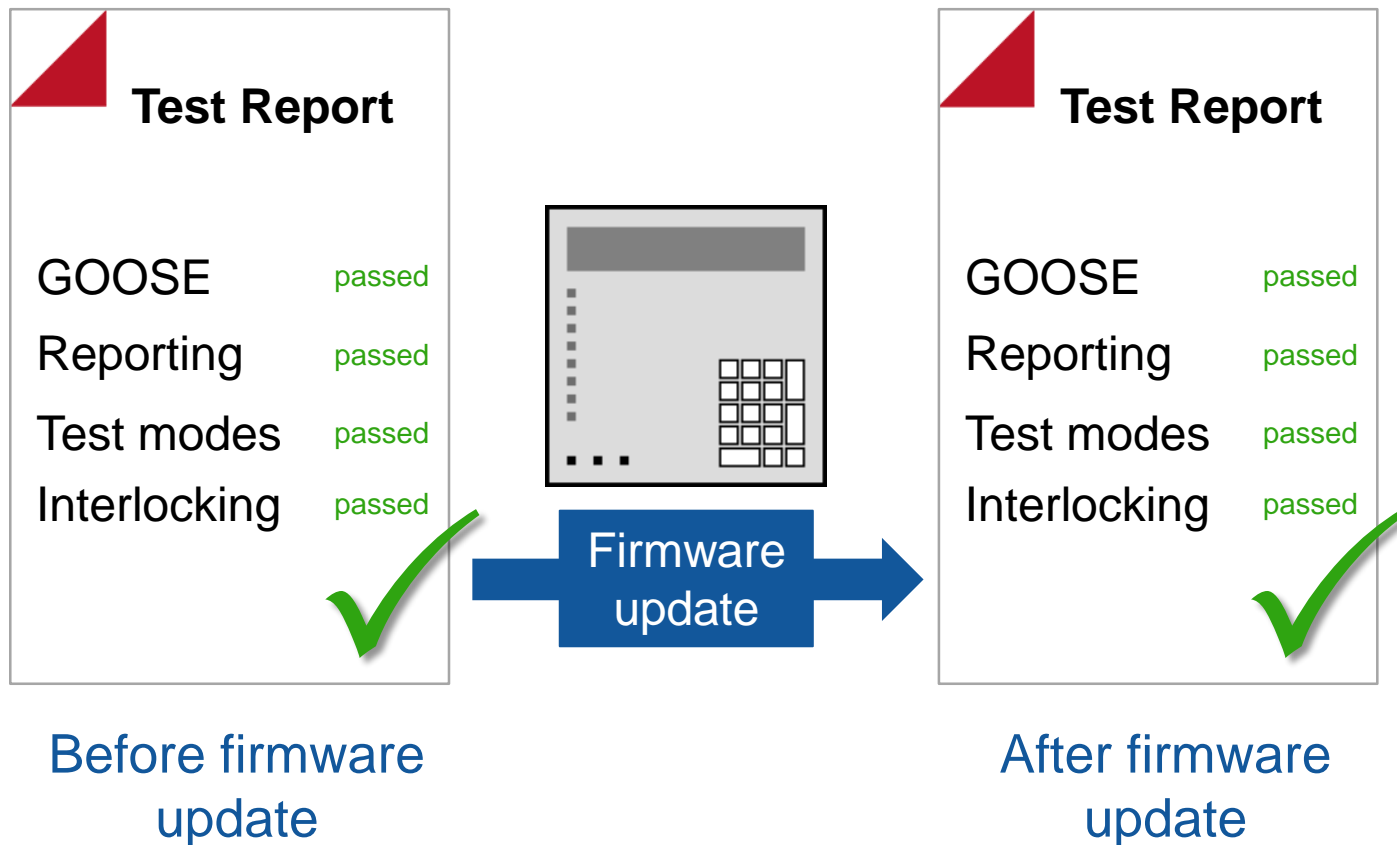
Protection Testing in Digital Substations

> Different scenarios:
> > Commissioning, maintenance...
> > Utility procedures

> Combined Protection + Metering Circuit + IO Check
> > Secondary Injection at MU
> > Monitor Trip/Close at physical output of Breaker IO
> > Monitor Breaker status at Breaker IO GOOSE

> Test subsystems separately:
> > Primary injection at CT/VT and check SV
> > Test Protection IED by injecting SV and monitoring GOOSEs
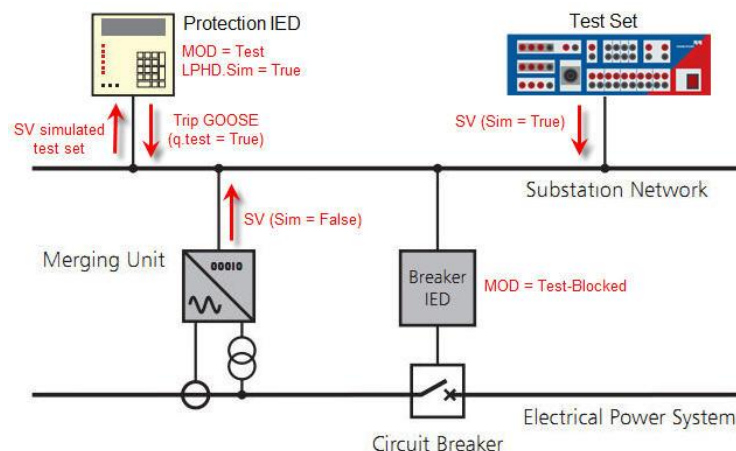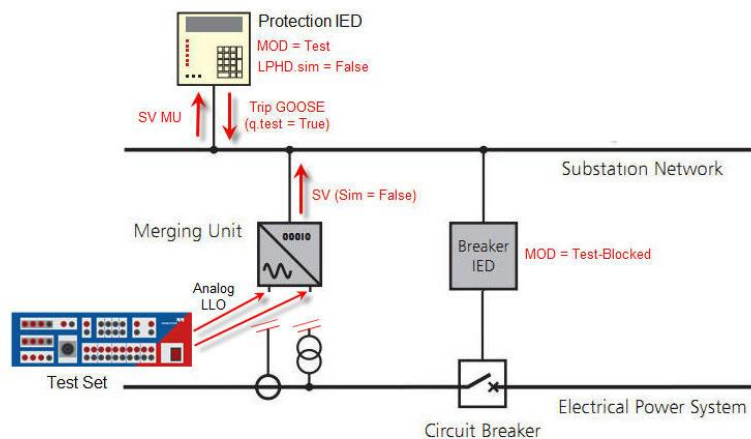
Protection Testing Challenges

> Where are the analog inputs in the relay?
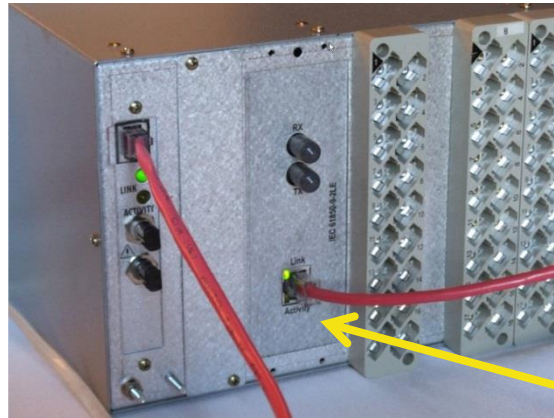
> Where is the test switch?

> How to isolate the relays under test?

Protection Testing: Test Isolation

> IEC 61850 Edition 2 defines functionalities supporting isolation for testing

> Separating Test and Normal information
>> Data Object Mod and Beh in IED
>> "Test bit" in Quality attribute q.test

| **LDMode** |
| LLN0.Mod |
| on |
| on-blocked |
| test |
| test/blocked |
| off |

> Separating Simulated and Normal messages
>> Simulation flag in GOOSE and SV messages
>> Data Object LPHD.Sim in IED

Test Mode: separating Test and Normal information

> Test mode can be available per logical **node** like PROTECTION.PDIS1, per logical **device** like PROTECTION or for entire IED

> More than a simple „Test mode":
>> on; on/blocked; test; test/ blocked; off

> Incoming signal is only accepted if sender and receiver are in the same mode

IED

invalid

invalid

on
on-blocked

Incoming signal ●————————→ •——→ test **Incoming data processed as valid**

q.test

test-blocked

off

valid

not processed
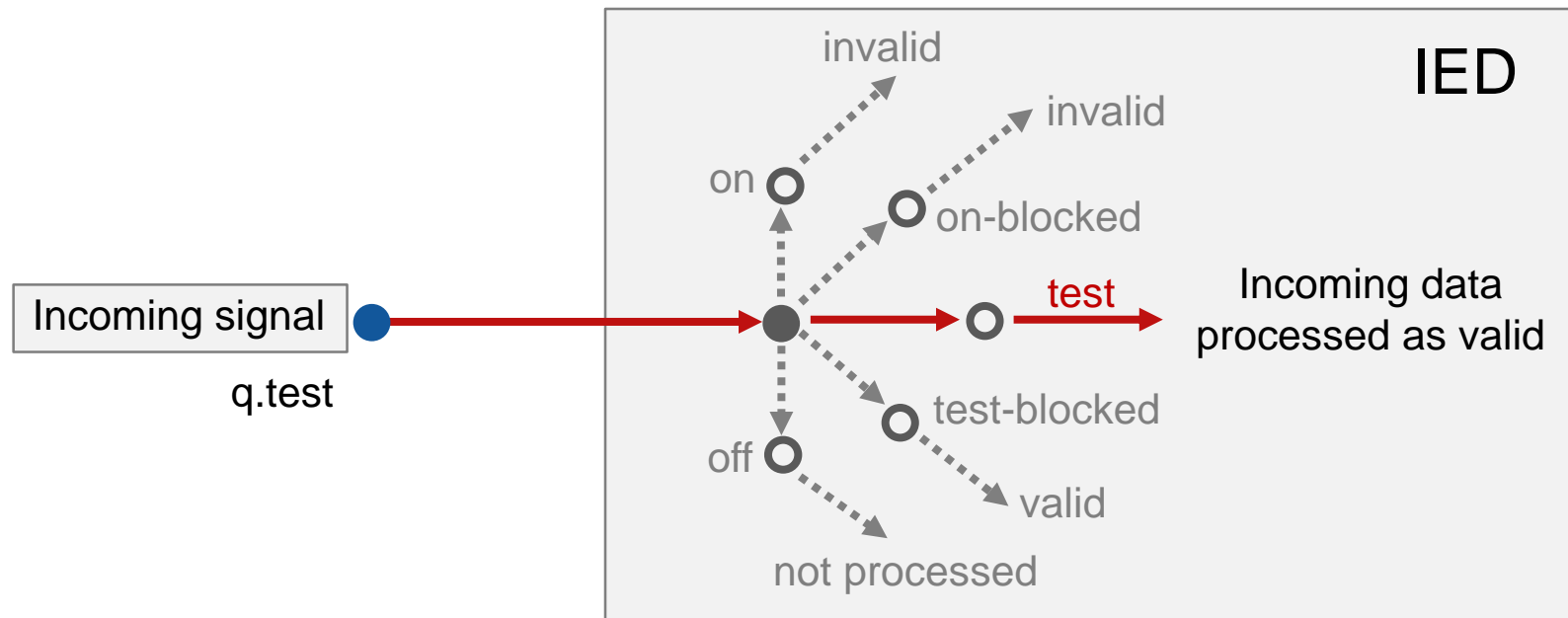
Test Features

> Test Mode of a function...

| LNMode XXXX.Mod	LDMode LLN0.Mod	LNBeh (read only) XXXX.Beh	LNBeh Value
on	on	on	1
on	on-blocked	on-blocked	2
on	test	test	3
on	test/blocked	test/blocked	4
on	off	off	5
on-blocked	on	on-blocked	2
on-blocked	on-blocked	on-blocked	2
on-blocked	test	test/blocked	4
on-blocked	test/blocked	test/blocked	4
on-blocked	off	off	5
test	on	test	3
test	on-blocked	test/blocked	4
test	test	test	3
test	test/blocked	test/blocked	4
test	off	off	5
test/blocked	on	test/blocked	4
test/blocked	on-blocked	test/blocked	4
test/blocked	test	test/blocked	4
test/blocked	test/blocked	test/blocked	4
test/blocked	off	off	5
off	on	off	5
off	on-blocked	off	5
off	test	off	5
off	test/blocked	off	5
off	off	off	5

Test Features

> GOOSE/Control for test purpose...
  > test bit in Quality (q) attribute

MODE/BEHAVIOUR	on	on-blocked	test	test/blocked	off
Function behind LN	ON	ON	ON	ON	OFF
Output to the Process (Switchgear) via a non-IEC 61850 link for example wire (typical for X...,Y... and GGIO LNs)	YES	NO	YES	NO	NO
Output of FC ST, MX (issued independently from Beh)	value is relevant q is relevant	value is relevant q is relevant	value is relevant q.test=true	value is relevant q.test=true	value is irrelevant q.validity=invalid
Response to (Normal) Command from Client (a+ / a- acknowledgement)	a+ pos. ack.	a- neg. ack.	a- neg. ack.	a- neg. ack.	a- neg. ack.
Response to TEST Command from Client (a+ / a- acknowledgement)	a- neg. ack.	a- neg. ack.	a+ pos. ack.	a+ pos. ack.	a- neg. ack.
Incoming data with q=normal	Processed as valid	Processed as valid	Processed as valid	Processed as valid	Not Processed
Incoming data with q=operatorBlocked	Processed as blocked	Processed as blocked	Processed as blocked	Processed as blocked	Not Processed
Incoming data with q=test	Processed as invalid	Processed as invalid	Processed as valid	Processed as valid	Not Processed
Incoming data with q=test+operatorBlocked	Processed as invalid	Processed as invalid	Processed as blocked	Processed as blocked	Not Processed
Incoming data with q=invalid	Processed as invalid	Processed as invalid	Processed as invalid	Processed as invalid	Not Processed
Non-IEC 61850 binary (relay, contact) inputs and analogue (instrument transformer) inputs	Processed	Processed	Processed	Processed	Not Processed

NOTE   A precondition of the use of different modes (Mod/Beh) is the processing of the quality status (q) of the receiving information.
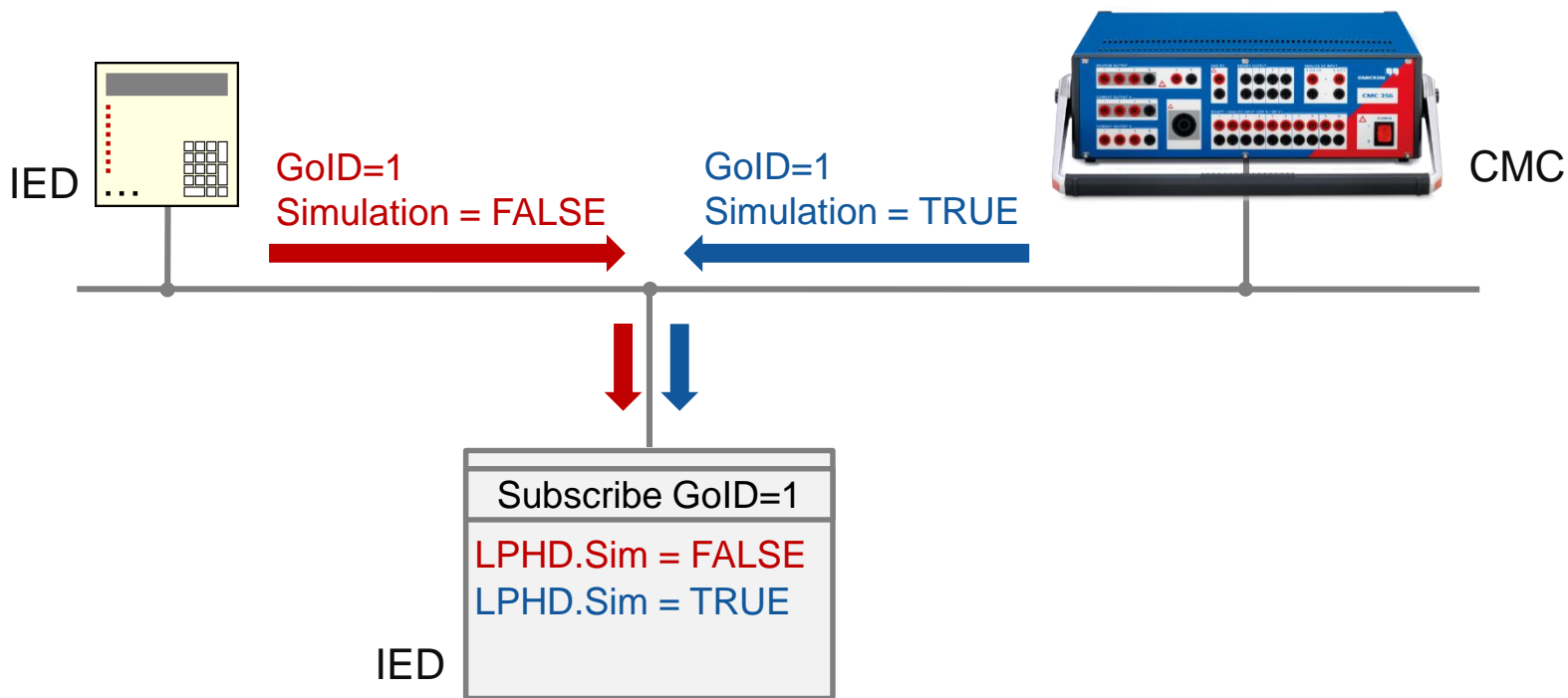
Test bit and Test Mode
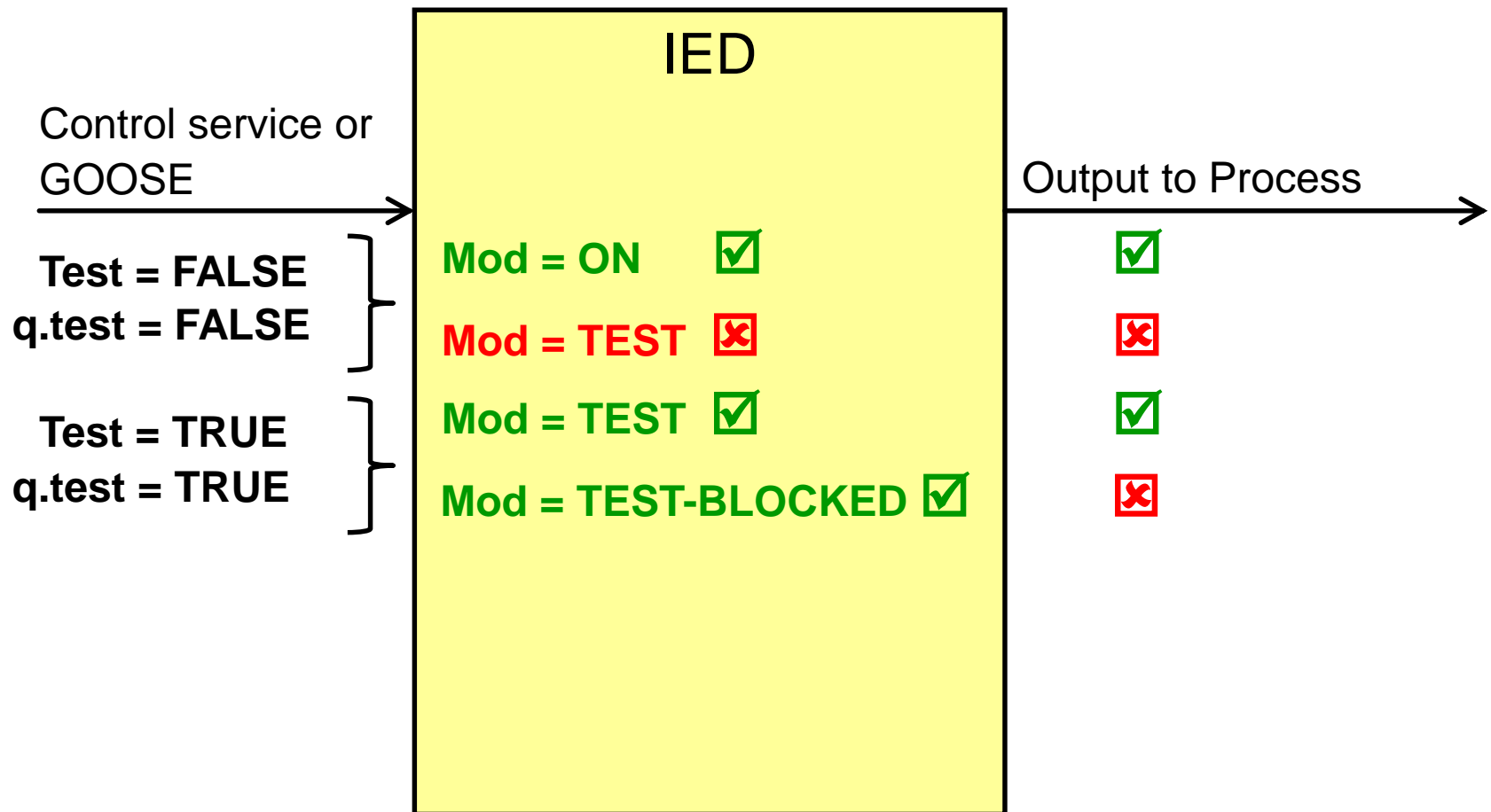
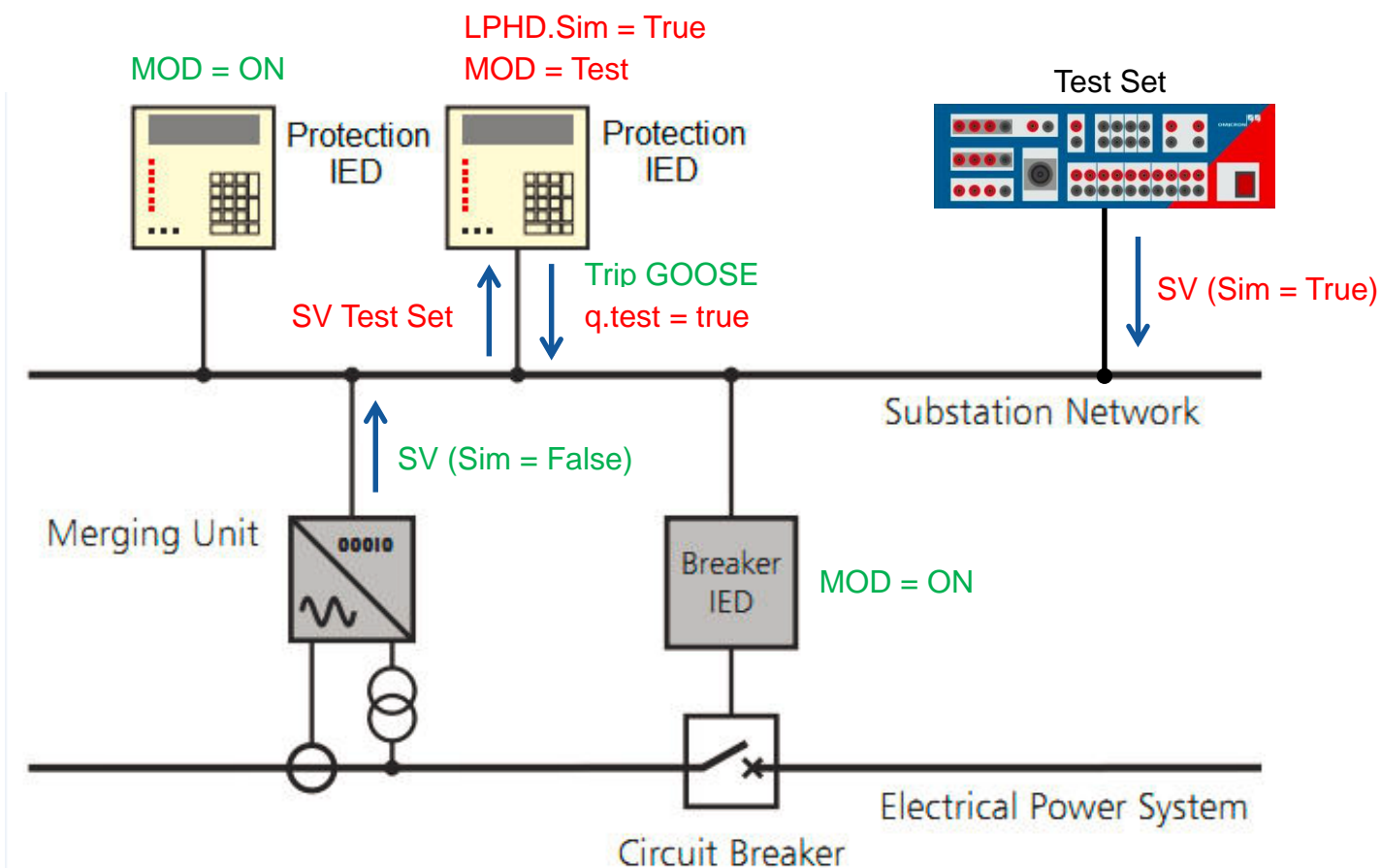# Mirroring of Control Service Requests
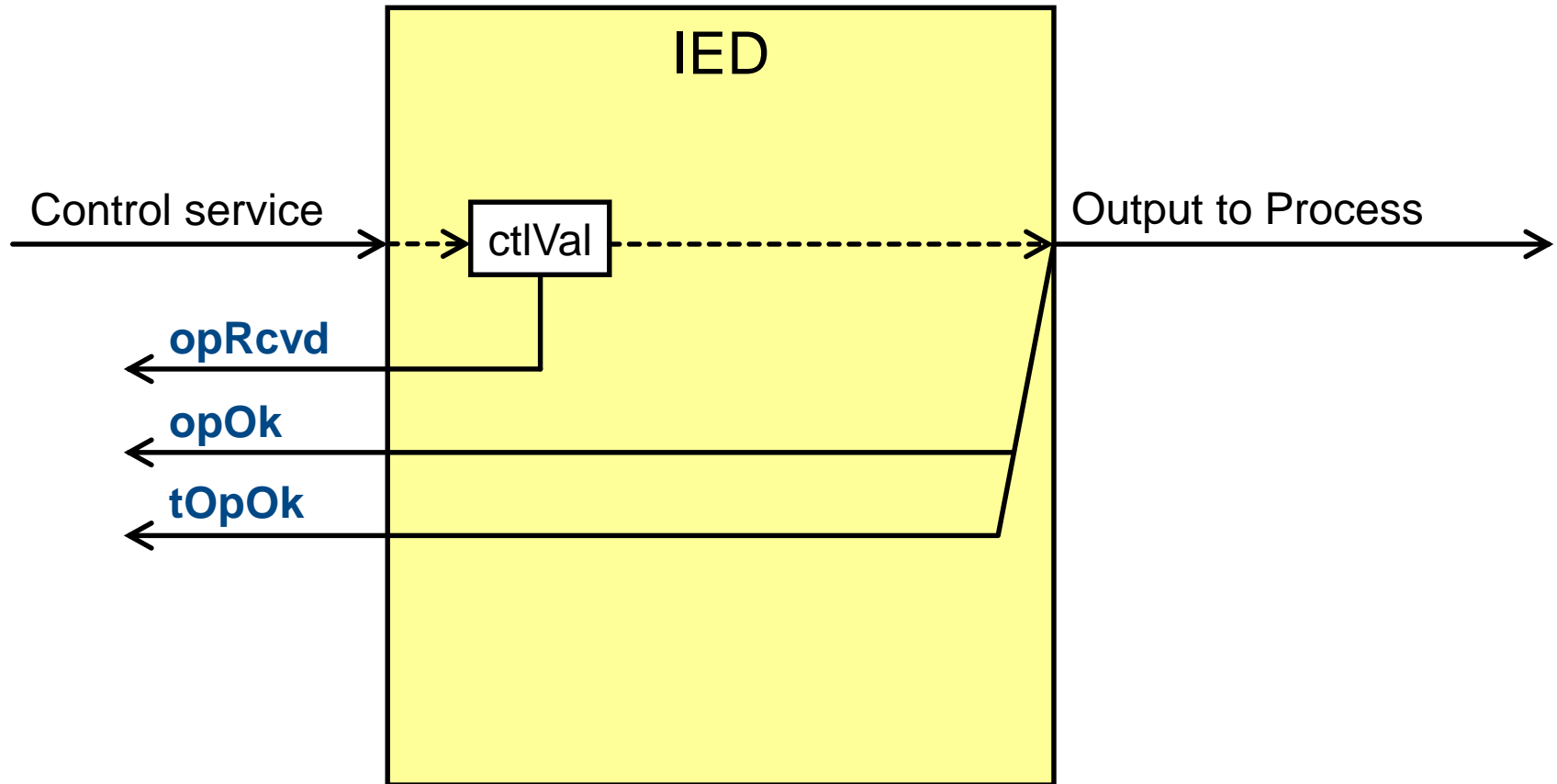
Separating Simulated and Normal messages

> How to distinguish between "real" signals and simulated ones?

> Simulation flag bit at GOOSE and SV Ethernet frame

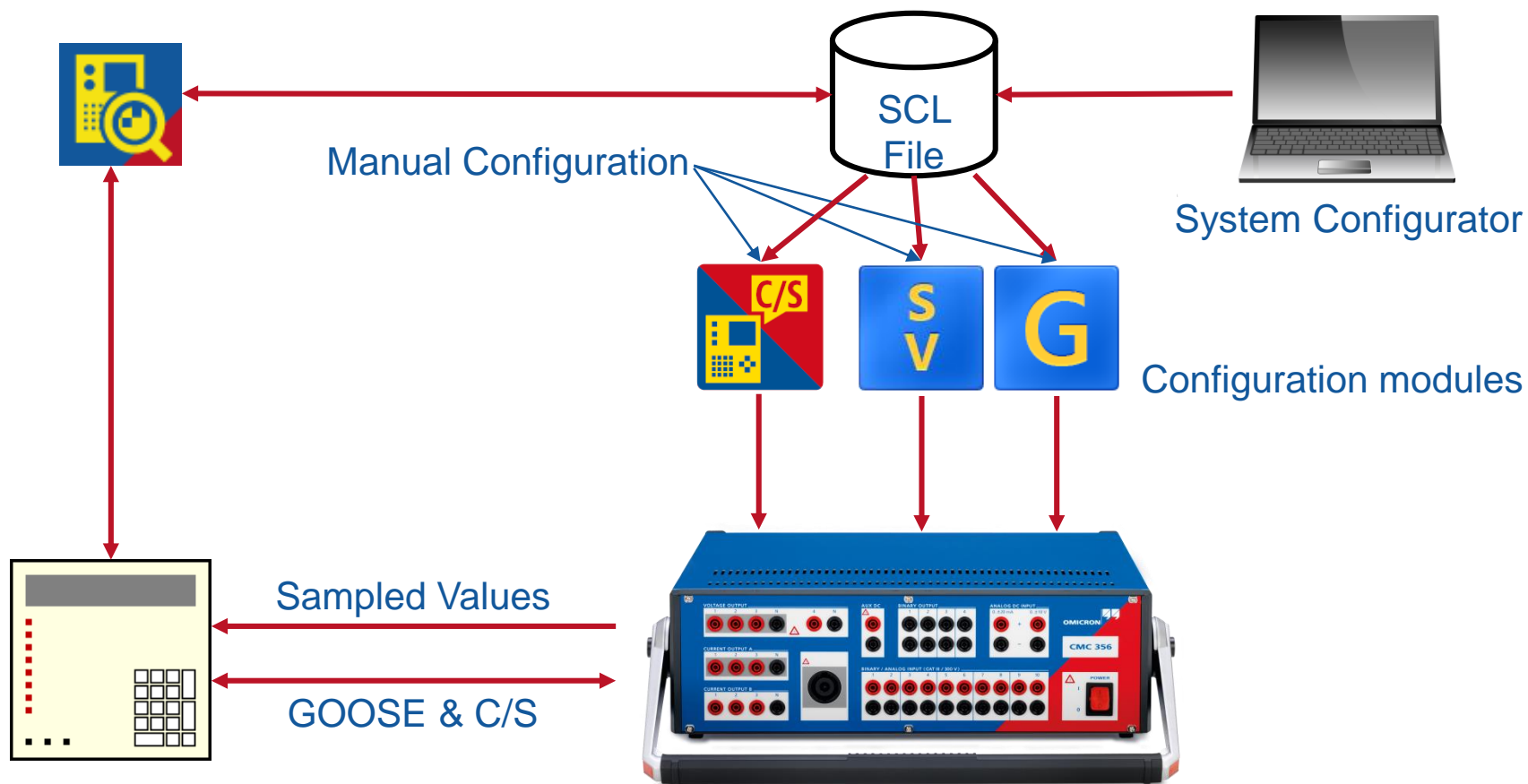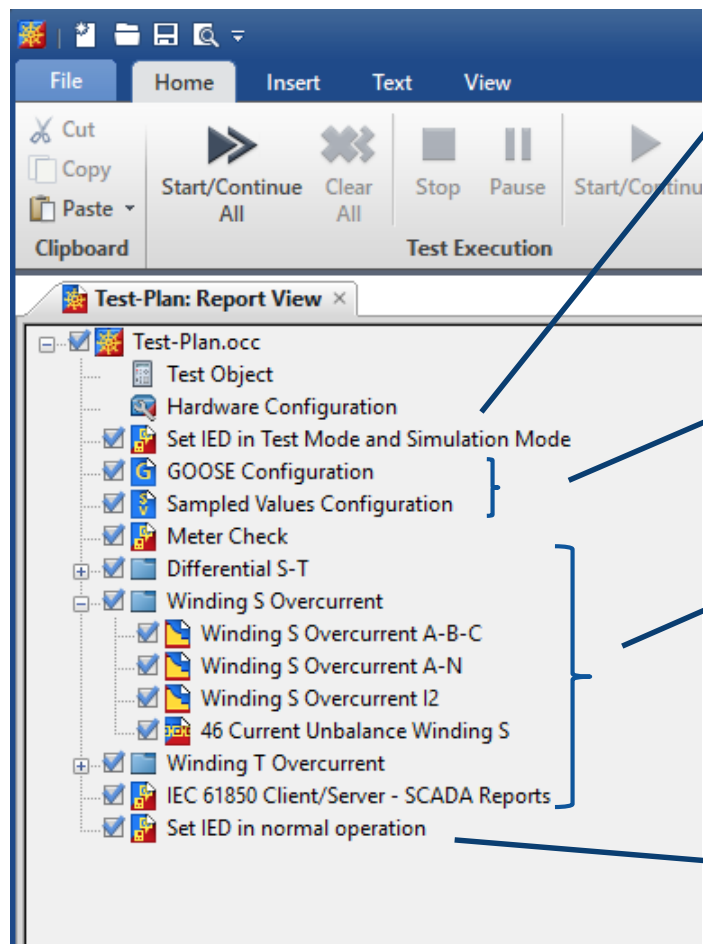> Sets the entire IED ("physical device") in simulation mode LPHD.Sim = True

IED

GoID=1
Simulation = FALSE

GoID=1
Simulation = TRUE

CMC

Subscribe GoID=1
LPHD.Sim = FALSE
LPHD.Sim = TRUE

IED

Complete Test Isolation

> Simulation Flag and Test Mode

LPHD.Sim = True
MOD = Test

MOD = ON

Test Set

Protection
IED

Protection
IED

Trip GOOSE
q.test = true

SV (Sim = True)

SV Test Set

SV (Sim = False)

Substation Network

Merging Unit

Breaker
IED

MOD = ON

Circuit Breaker

Electrical Power System

Protection IED Testing

SCL File

System Configurator

Manual Configuration

Configuration modules

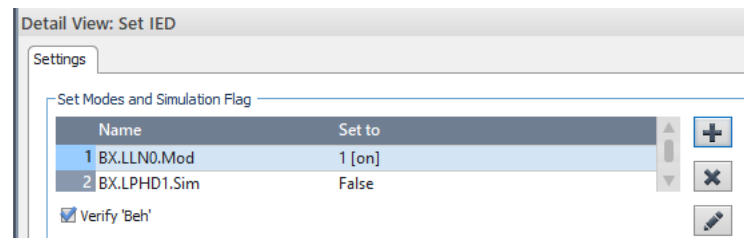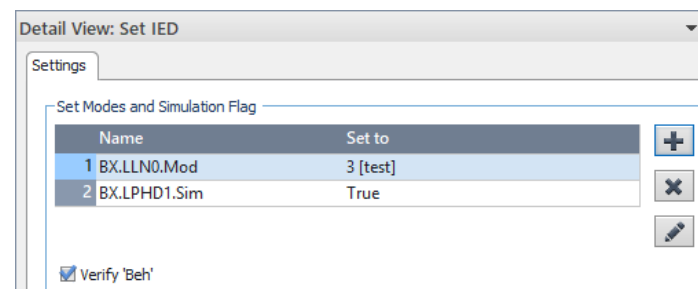Sampled Values

GOOSE & C/S

Test Plan example

Set Test Mode and Simulation

GOOSE and SV Configuration

Testing

Reset IED to ON

Thanks!

OMICRON