



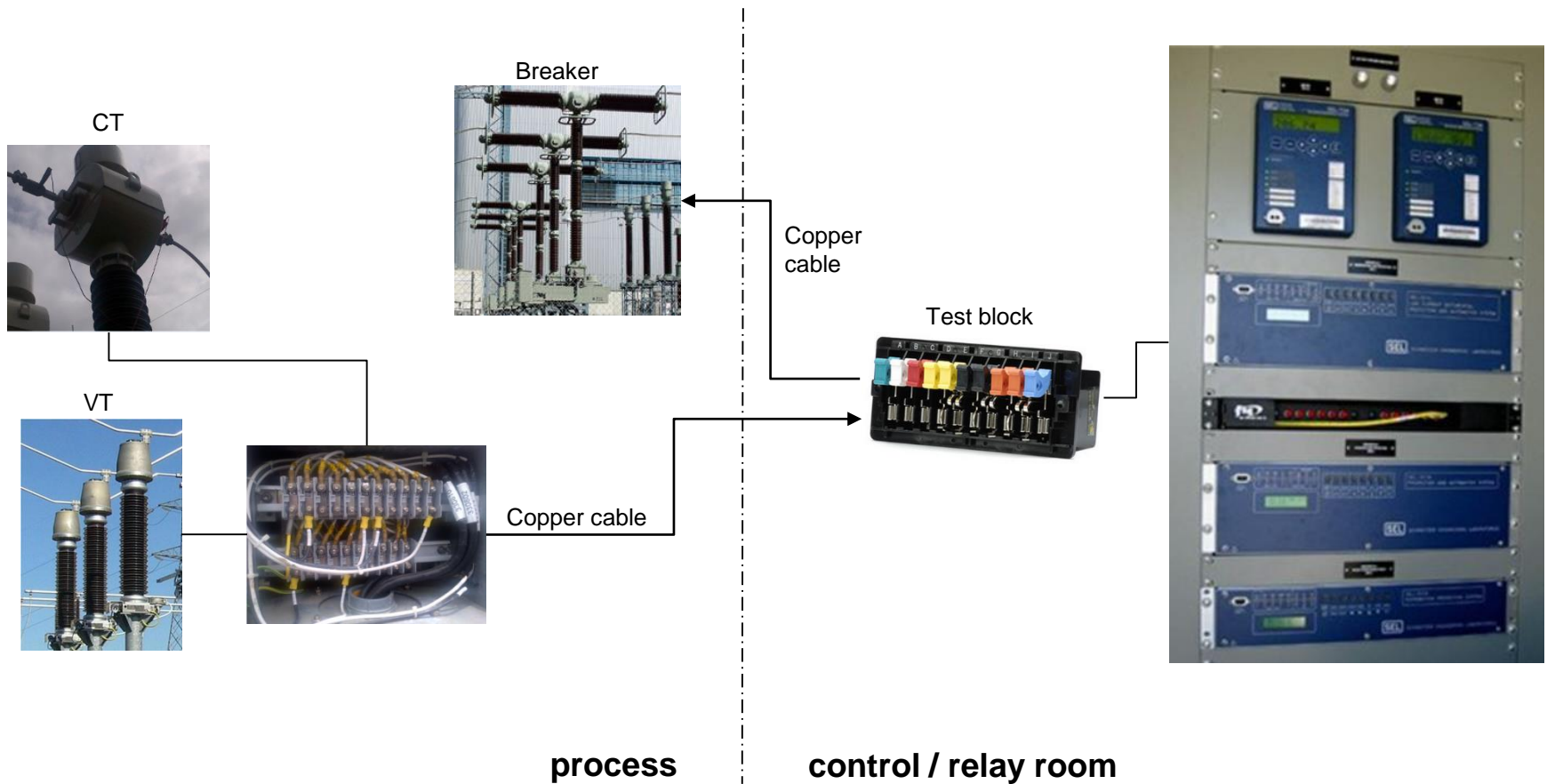
Testing Protection, Automation and Control

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OMICRON

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

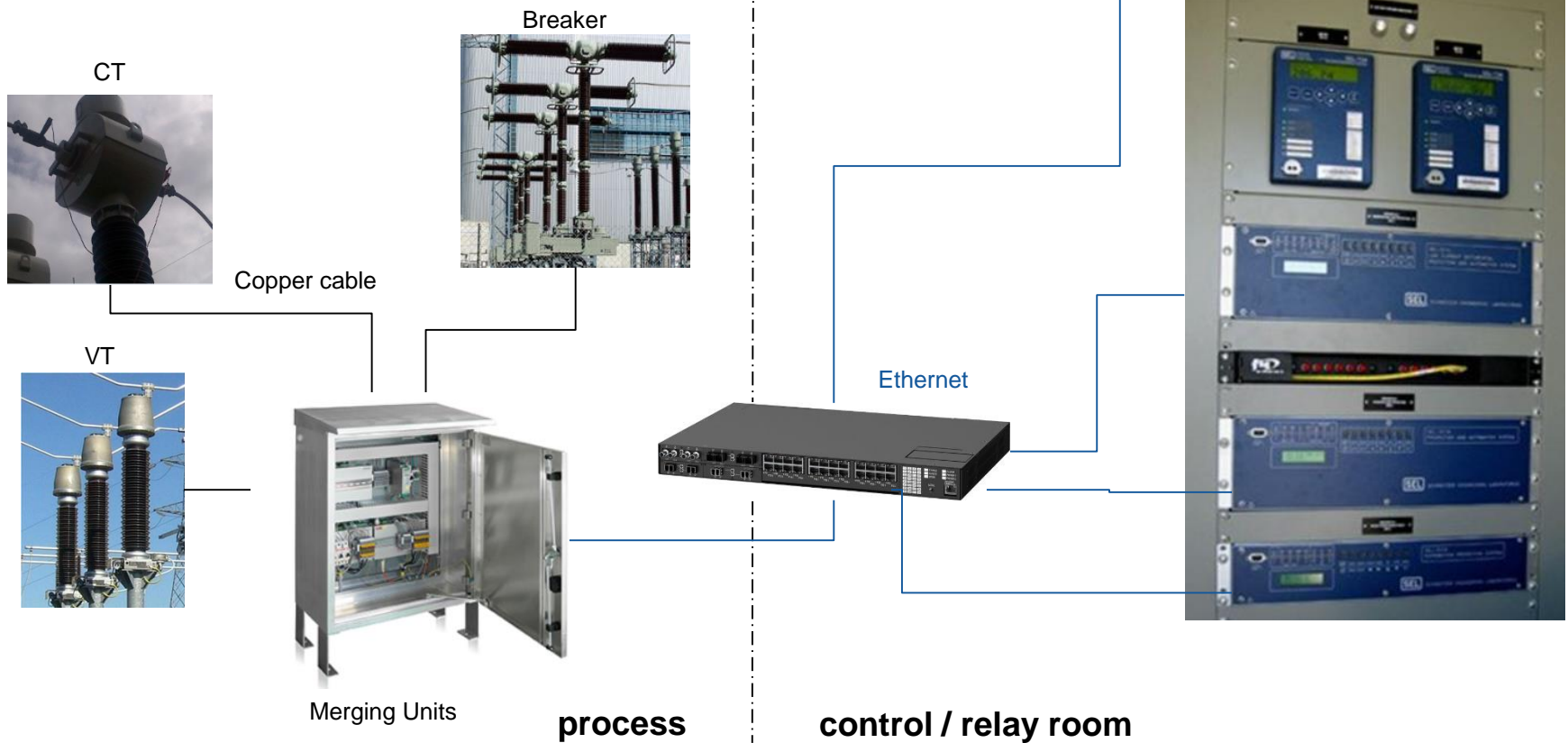
22 September 2019

Evolution from Conventional to Digital Substations



Evolution from Conventional to Digital Substations

- > Move Analog and Physical I/O to the yard



Testing Digital Substations



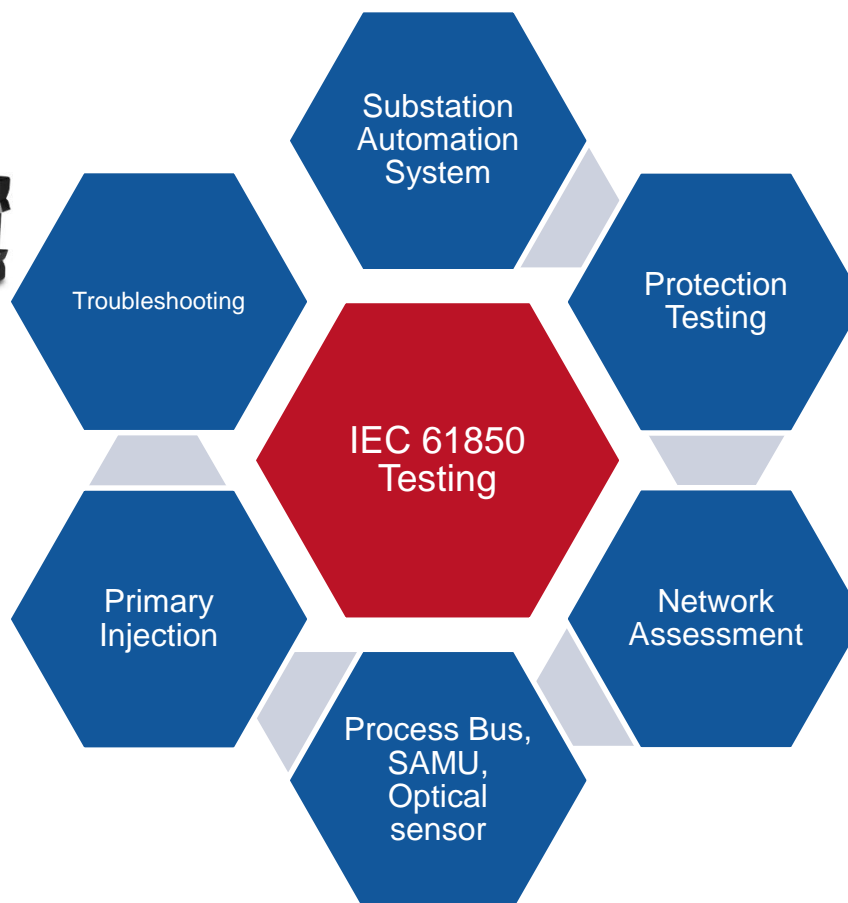
StationScout



DANEO 400



CMC



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

PTP Sniffer - DANE0 1 (AJ023D)

PTP sources

Status	Port	Protocol	Domain
✓	B	IEEE 802.3	0
✓	ETH	IEEE 802.3	11
✓	ETH	IEEE 802.3	0

PTP source details

Delay mechanism	Peer-to-Peer
Announce interval	1 s
Sync interval	1 s
Other peers	1
Best master available	True
Packet errors	0

PTP masters

1@20-B7-C0-FF-FE-00-39-42 (Best master)

Power profile GM Id	3
Power profile version	1
MAC address	20-B7-C0-00-39-42
VLAN ID	not present
VLAN priority	not present
GM identity	20-B7-C0-FF-FE-00-39-42
GM priority 1	128
GM priority 2	128
GM clock accuracy	WITHIN_100_NS (0x21)
GM clock class	PRIMARY_REF_PTP (6)
GM clock variance	18465
Qualified	Yes
Alternate	No
TLV count	2
UTC offset	35
UTC offset valid	True
Leap 59	False
Leap 61	False
Time traceable	True
Frequency traceable	True
PTP time scale	True
Time source	GPS (0x20)

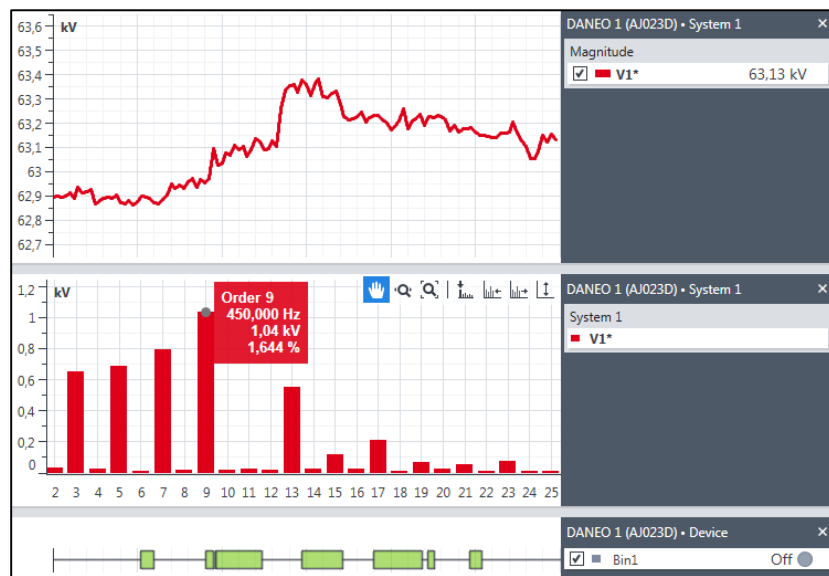
Restart

Ok

Cancel

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

G ISIO_AM174KCB/LLN0\$GO\$GCB				
Details				
Statistics				
	A	B	ETH	
Receive time			2017-02-01 16:09:12.054	
Packet count			656	
Status changes seen			136	
Status changes missed			3	
Retransmissions missed			12	
Duplicates seen			0	
Time to live expired			False	
Time to live expired count			2	
Packet delay:				
Minimum			2,60 ms	
Maximum			4,09 s	
Average			32,93 ms	
DataSet - ISIO_AM174KCB/LLN0\$GooseDataSet1				
Name	Type	Value	Ports	
DA XCBR1.Pos.stVal	Dbpos	01	A B	ETH
DA XCBR1.Pos.q	Quality	Good	A B	ETH
DA XCBR2.Pos.stVal	Dbpos	00	A B	ETH
DA XCBR2.Pos.q	Quality	Good	A B	ETH

GOOSE data values and statistics

Supervision of Network Traffic

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

Event list		
Date and Time	Device	Category
2015-10-16 15:49:35.049	DANEO 1 (AJ023D)	GOOSE
2015-10-16 15:48:44.576	DANEO 1 (AJ023D)	Device
2015-10-16 15:48:43.109	DANEO 1 (AJ023D)	GOOSE
2015-10-16 15:48:34.576	DANEO 1 (AJ023D)	Device
2015-10-16 15:45:56.572	DANEO 1 (AJ023D)	Device
2015-10-16 15:45:47.571	DANEO 1 (AJ023D)	Device
2015-10-16 15:45:27.099	DANEO 1 (AJ023D)	Recording
2015-10-16 15:45:23.672	DANEO 1 (AJ023D)	PTP
2015-10-16 15:45:23.672	DANEO 1 (AJ023D)	Device
2015-10-16 15:45:21.950	DANEO 1 (AJ023D)	Recording
2015-10-16 15:45:18.663	DANEO 1 (AJ023D)	PTP

Details	
Severity	Error
Date and Time	2015-10-16 15:49:35.049
Device	DANEO 1 (AJ023D)
Category	GOOSE
Type	Out of sequence
Port	8
Control block reference	ISIO_AM174KBX/LLN0\$GO\$GCB
Destination MAC address	01-0C-CD-01-00-00
Source MAC address	20-B7-C0-00-3E-89
Application ID	1
GOOSE ID	GoID
DataSet reference	ISIO_AM174KBX/LLN0\$GooseDataSet1
Simulation/Test	False
Status number	1 (previous: 1)
Sequence number	0 (previous: 34)

Supervisor
event list

Action	
Name	My Action
Binary	<input checked="" type="checkbox"/>
Name	GOOSE_Error
Hold time	2,00 s
Email	<input checked="" type="checkbox"/>
Recipients	supervisor@omicron.at
Lockout	60,00 s

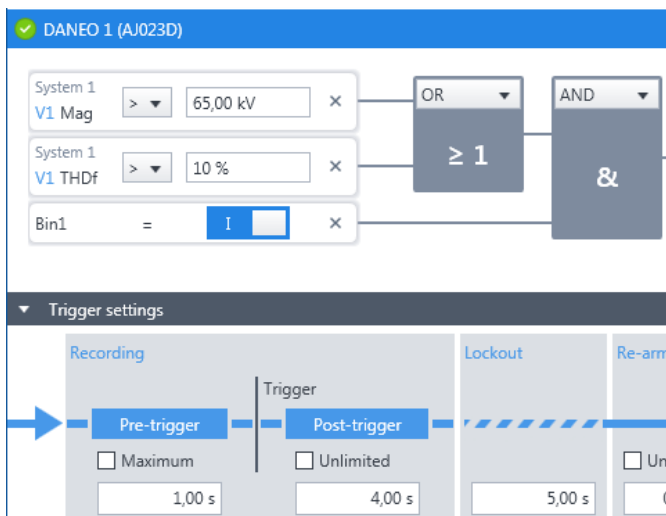
Filter	
Devices	Severity
<input checked="" type="checkbox"/> DANEO 1 (AJ023D)	<input checked="" type="checkbox"/> Error
	<input type="checkbox"/> Warning
	<input type="checkbox"/> Information

Advanced	
<input checked="" type="checkbox"/> GOOSE	<input type="checkbox"/> Sampled Values
<input checked="" type="checkbox"/> Time to live expired	<input type="checkbox"/> Timeout
<input checked="" type="checkbox"/> Out of sequence	<input type="checkbox"/> Out of sequence
<input checked="" type="checkbox"/> Parsing error	<input type="checkbox"/> Parsing error
<input type="checkbox"/> Never seen	<input type="checkbox"/> Never seen
<input type="checkbox"/> Validity not 'Good'	<input type="checkbox"/> Validity not 'Good'
<input type="checkbox"/> Quality Test changed	<input type="checkbox"/> Quality Test changed
<input type="checkbox"/> PTP	<input type="checkbox"/> Clock drift
<input type="checkbox"/> Synchronization lost	<input type="checkbox"/> Device
<input type="checkbox"/> Grandmaster accuracy changed	<input type="checkbox"/> Operation error
	<input type="checkbox"/> Operation warning

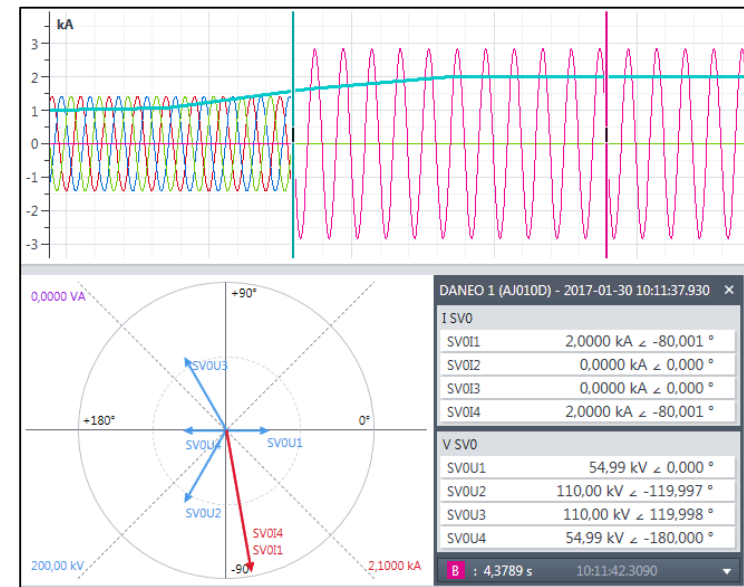
Supervisor
actions

Recording – Time Signal Analysis

- > Configuration signals and network traffic for capturing
- > Definition of trigger condition and recording duration

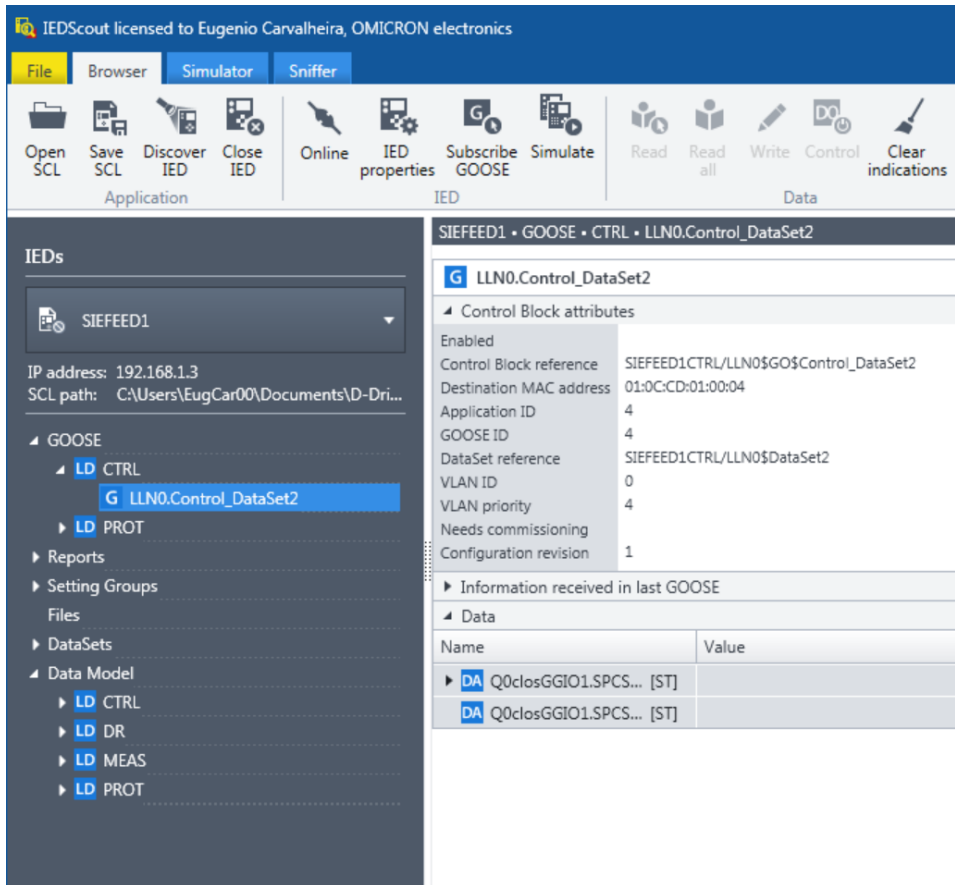


Trigger condition and recording duration

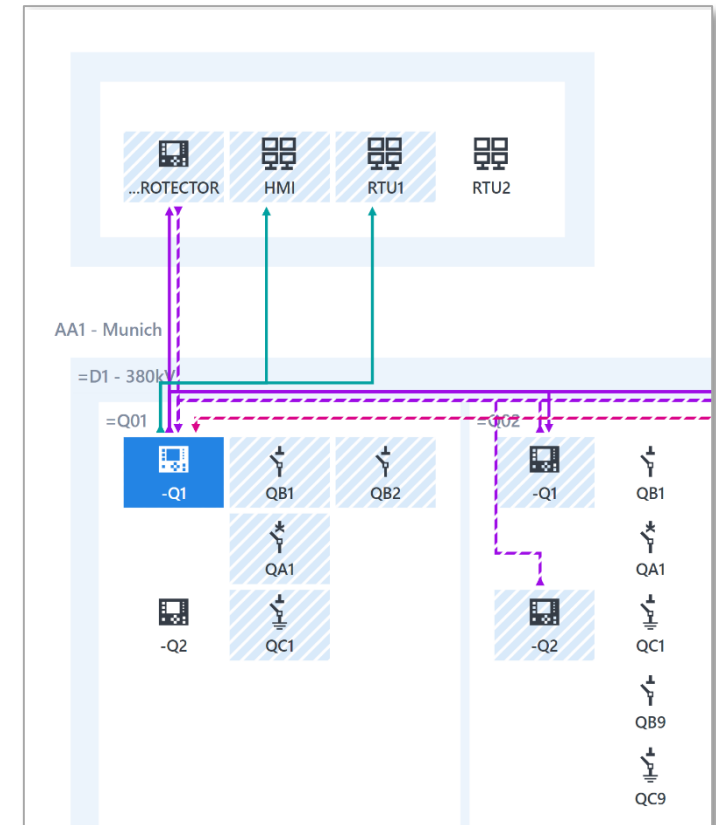


Time signal analysis

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

=AA1 - Substation Name

=D1 - 380 kV

Bay =Q01

=Q02

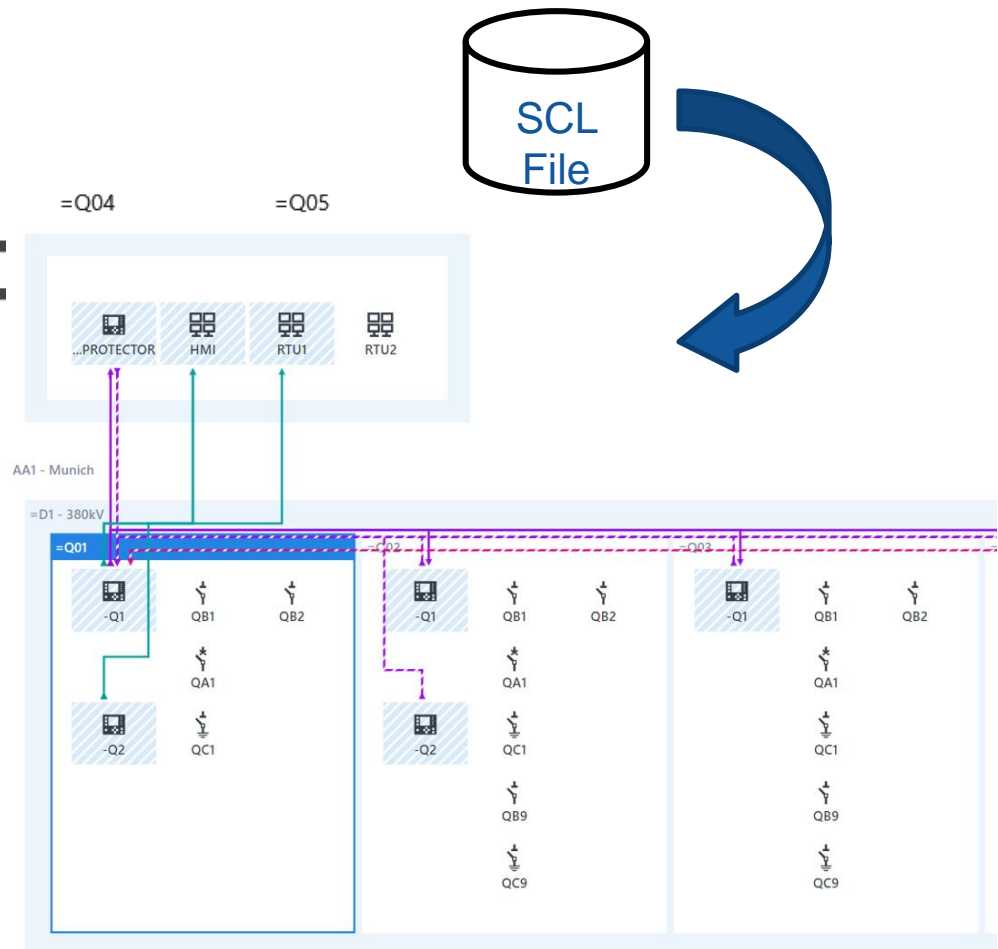
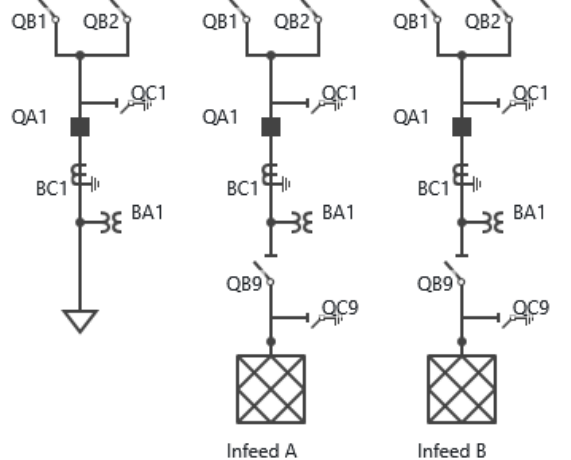
=Q03

=Q04

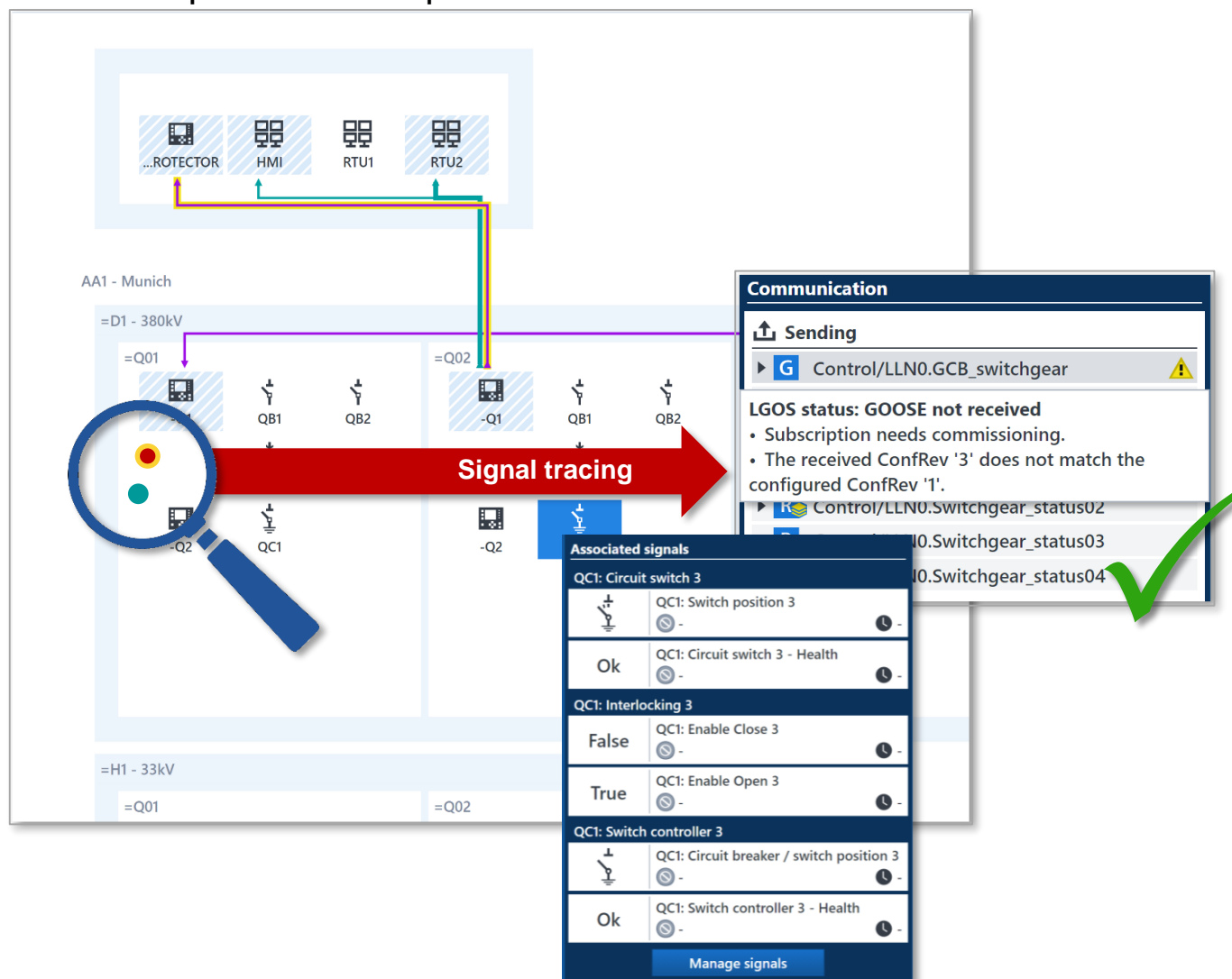
=Q05

Bus A

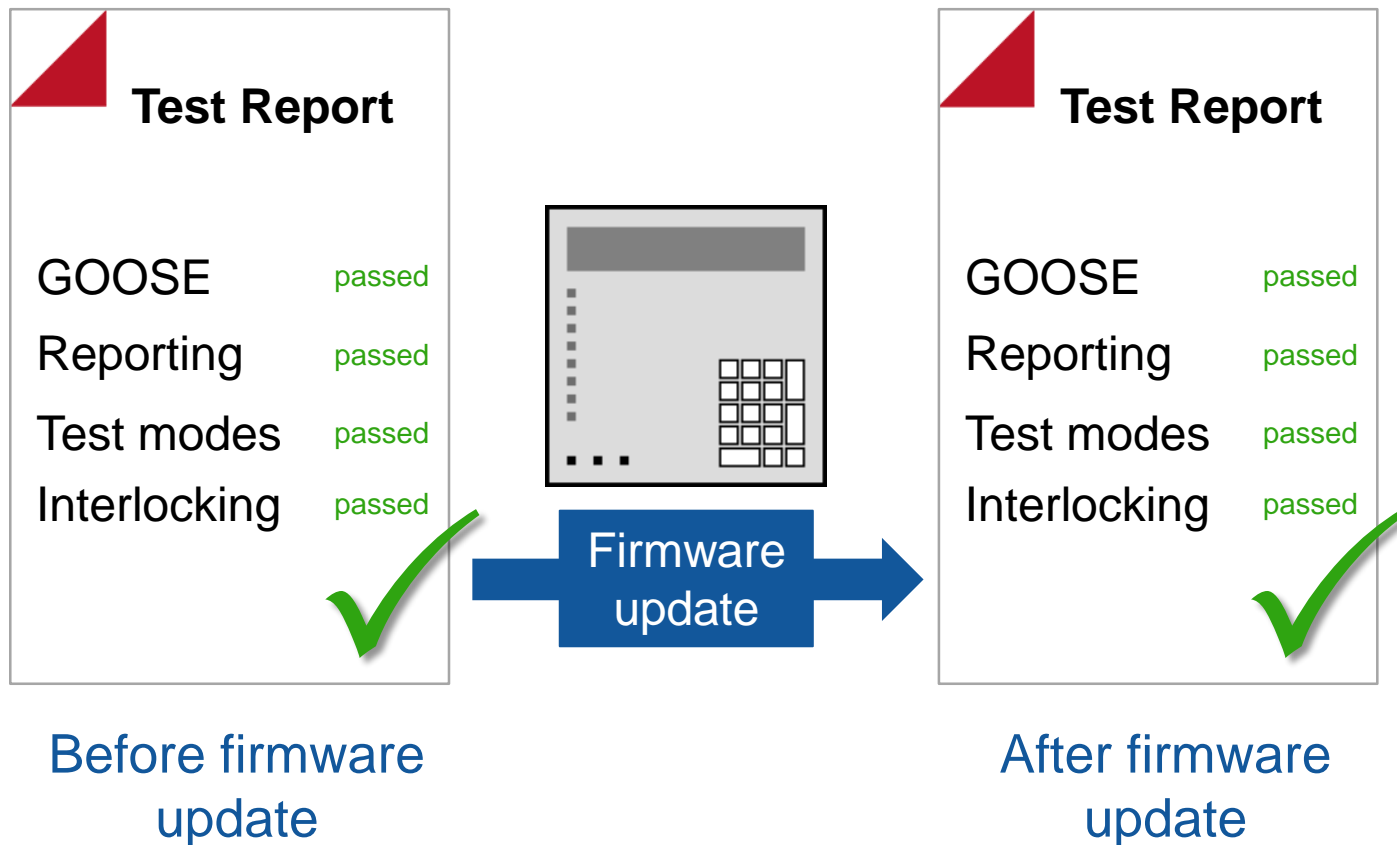
Bus B



- > Smart Overview visualizes communication links and status information of IEDs and primary assets
- > GOOSE subscriptions and Report issues can be observed

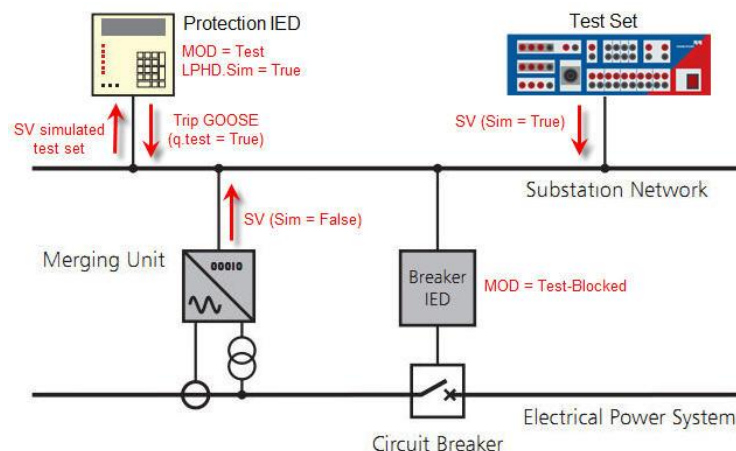
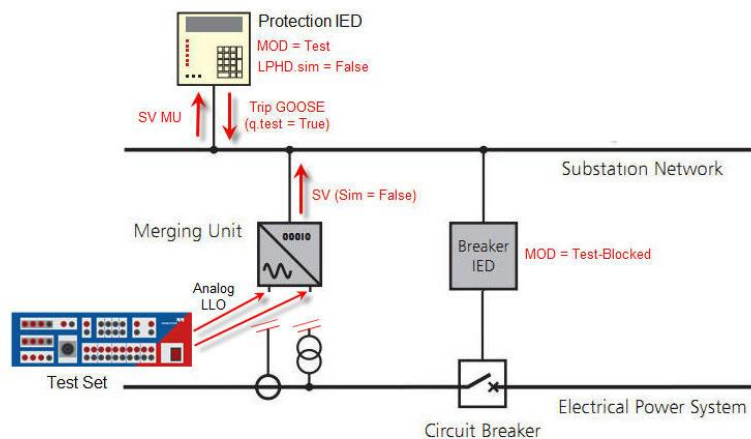


Testing after firmware update



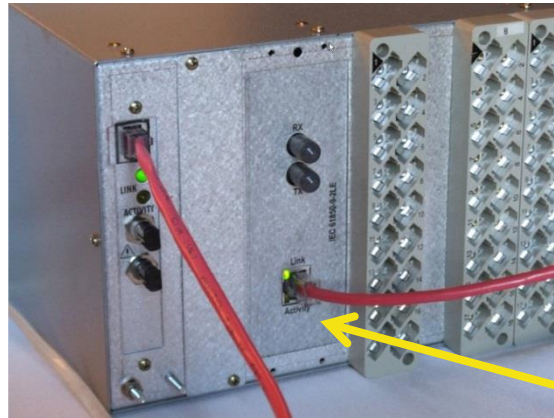
Protection Testing in Digital Substations

- > 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?

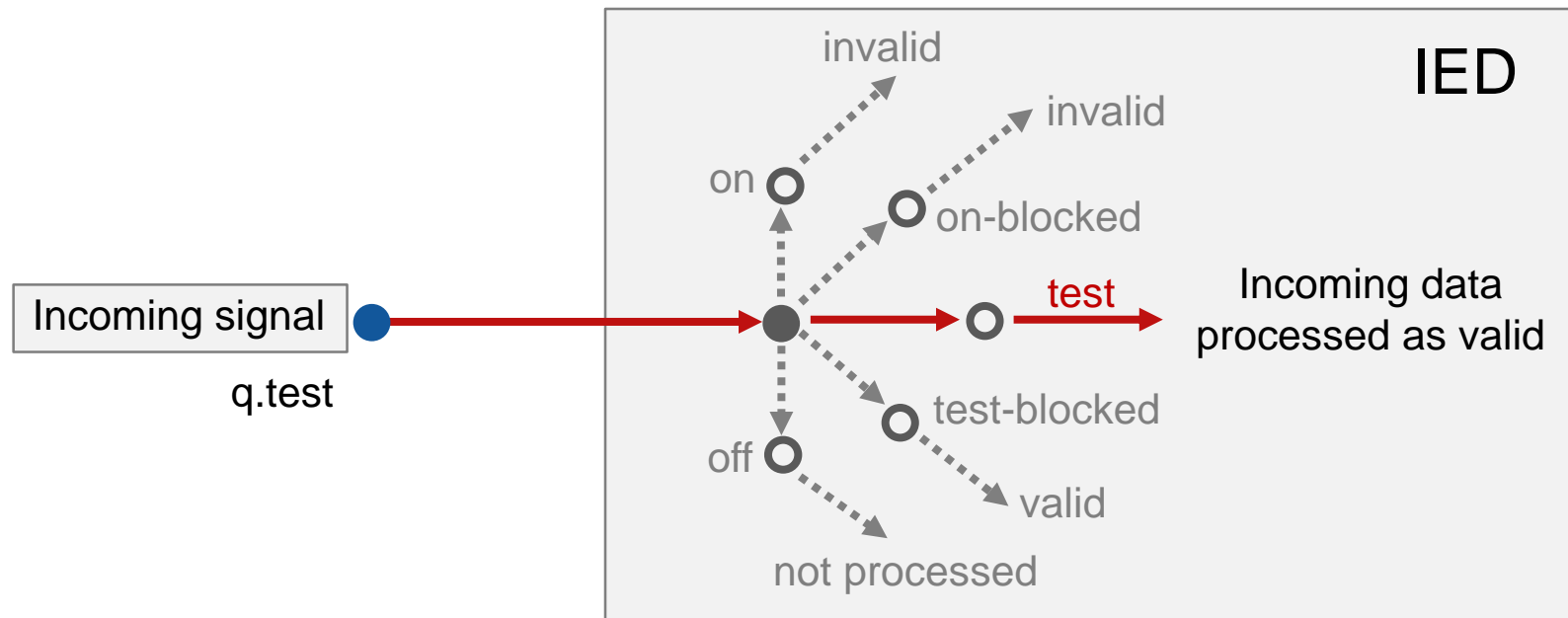
Protection Testing: Test Isolation

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

LDMode
LLNO.Mod
on
on-blocked
test
test/blocked
off

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



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

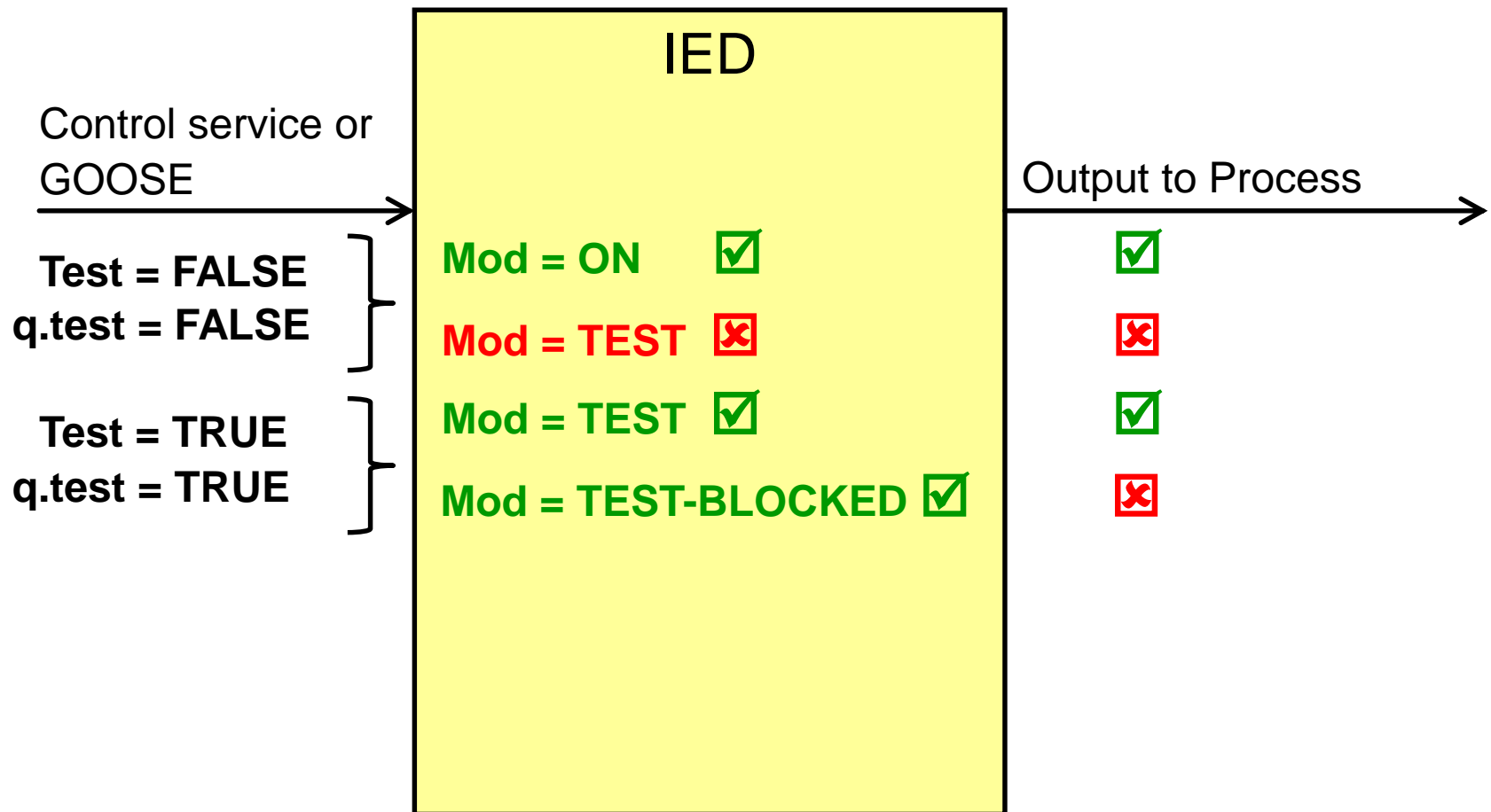
Test Features

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

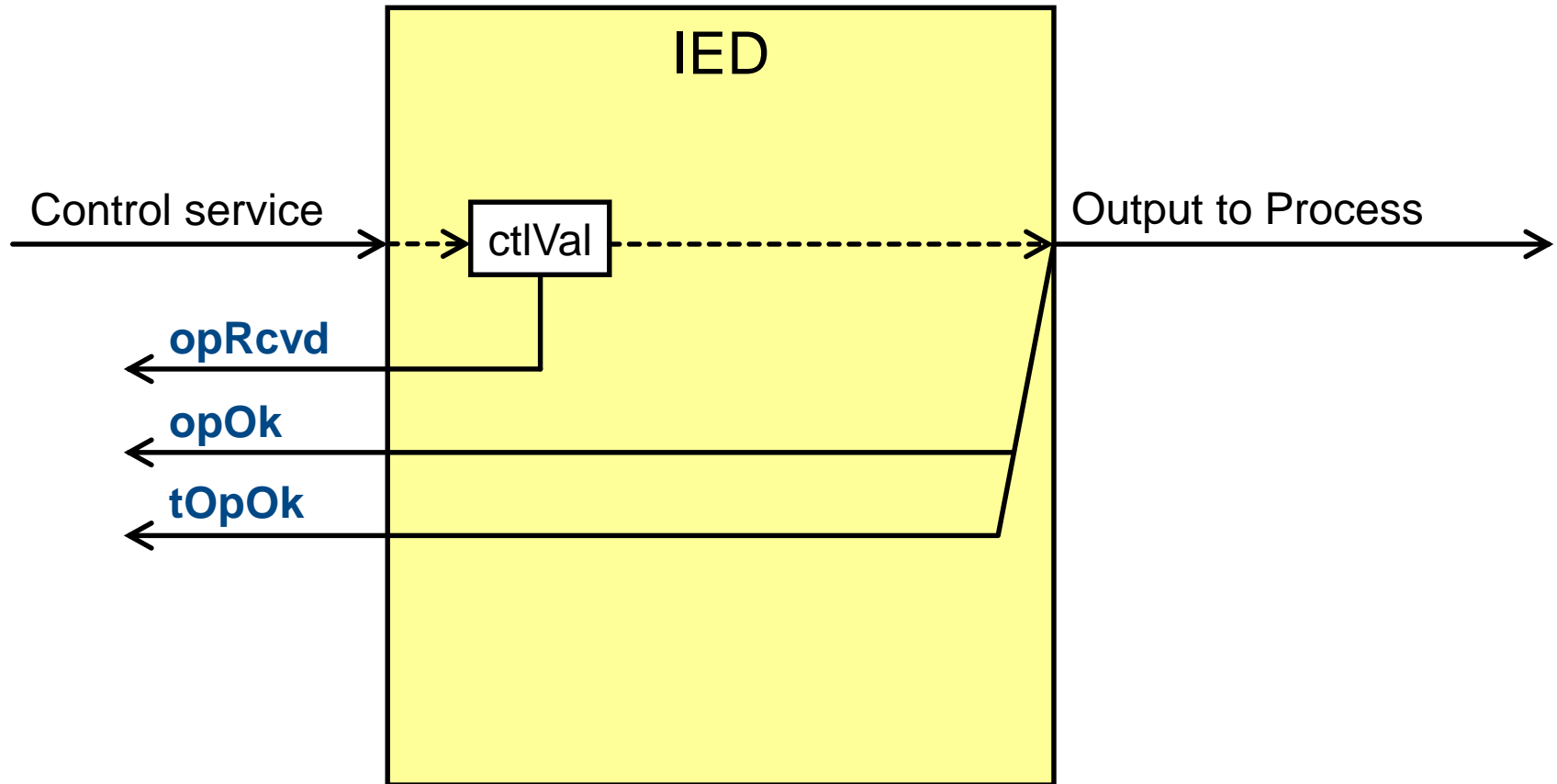
MODE/BEHAVIOUR	on	on-blocked	test	test/blocked	off
Function behind LN	ON	ON	ON	ON	OFF
Output to the Process (Switchgear) via a non-IEC 61850 link for example wire (typical for X...,Y... and GGIO LNs)	YES	NO	YES	NO	NO
Output of FC ST, MX (issued independently from Beh)	value is relevant q is relevant	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

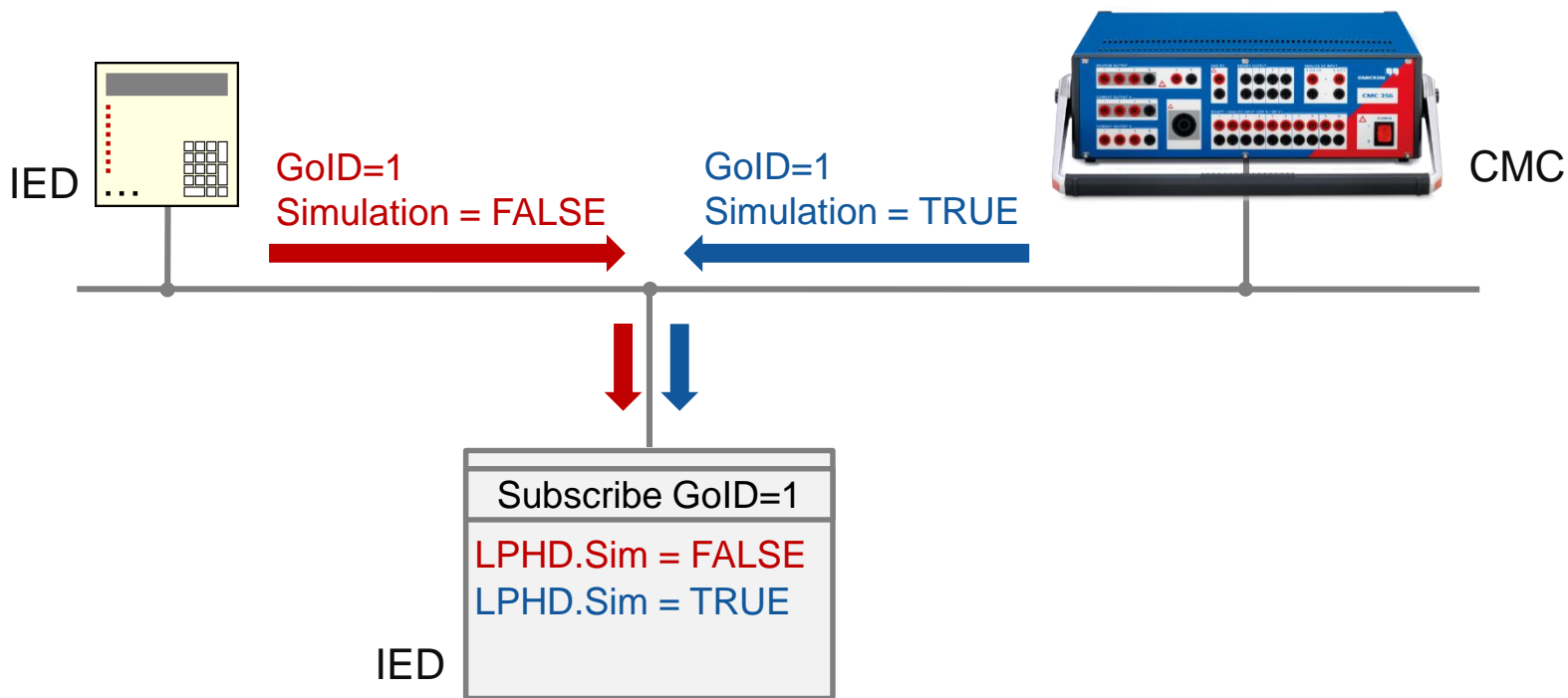


Mirroring of Control Service Requests



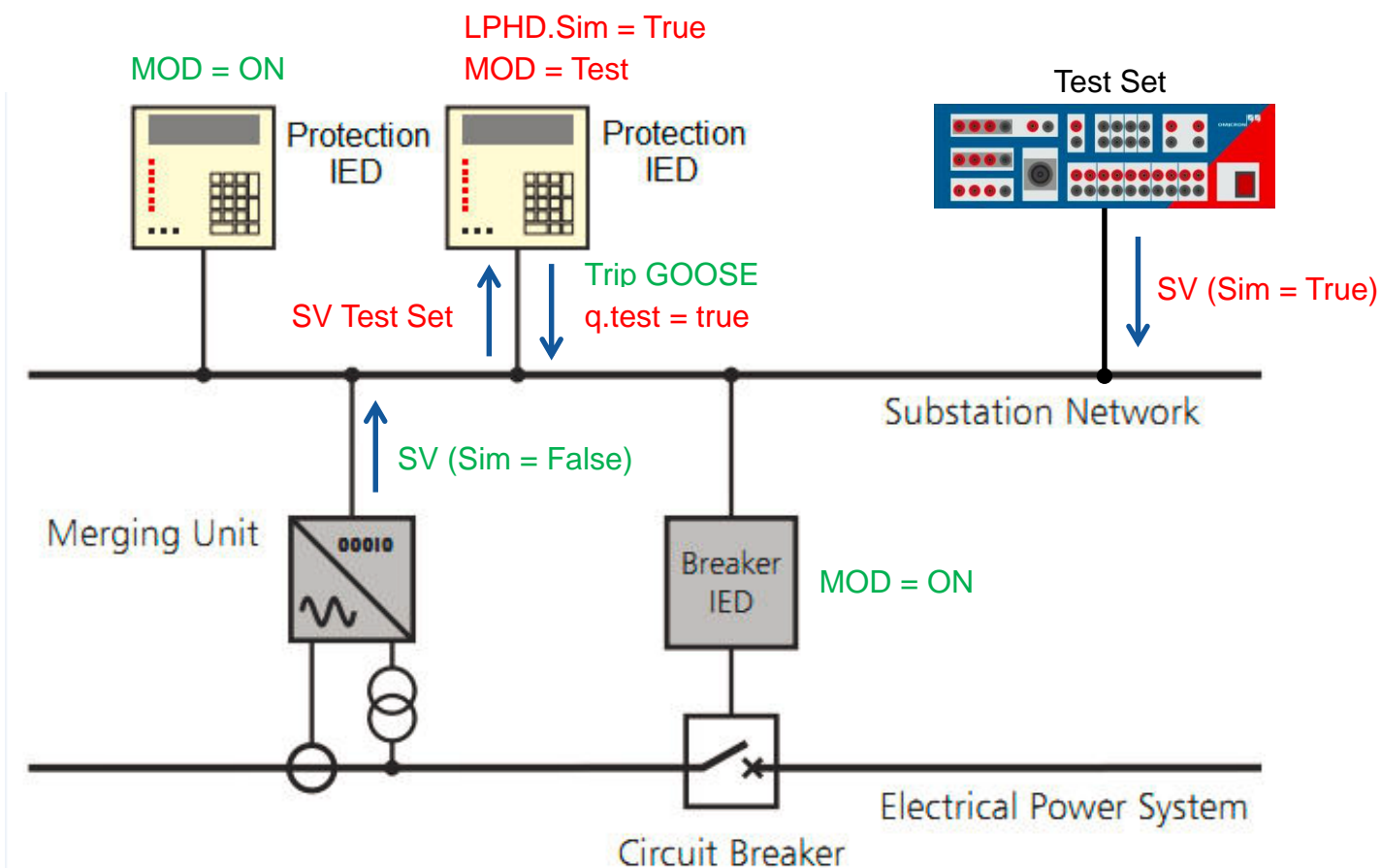
Separating Simulated and Normal messages

- > 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

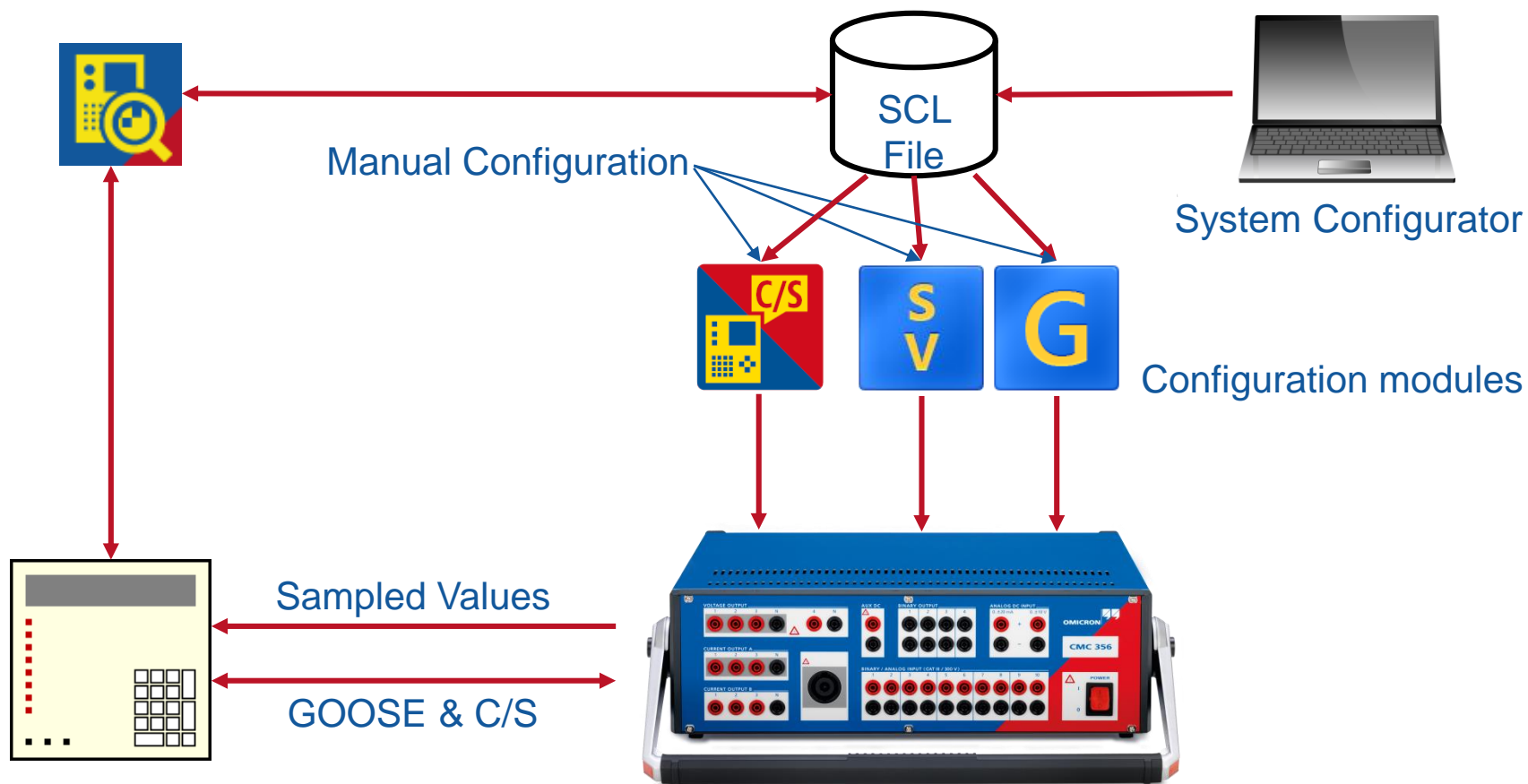


Complete Test Isolation

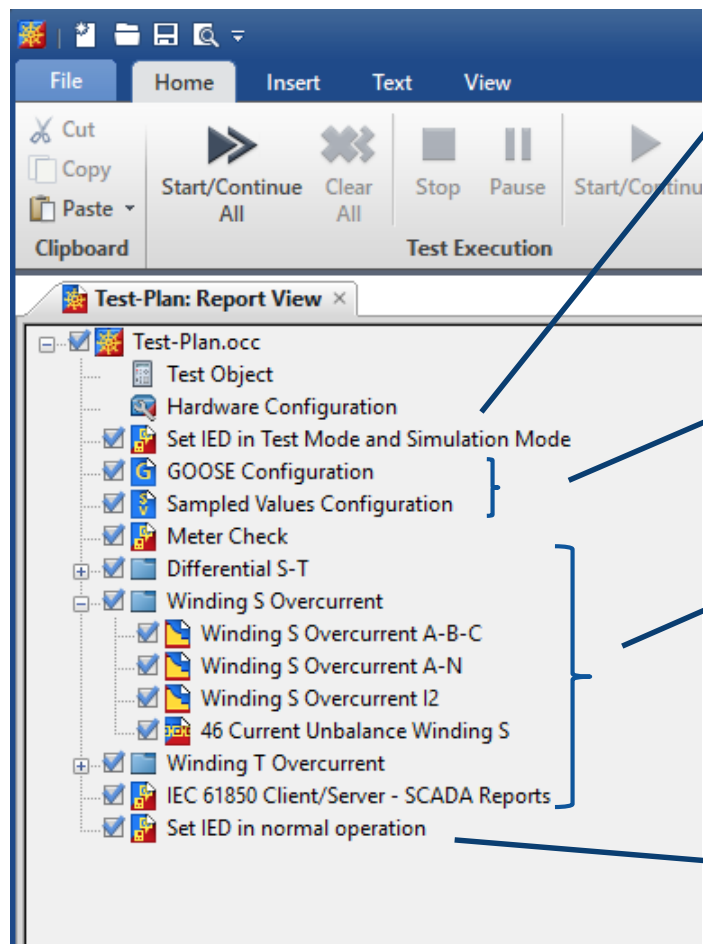
> Simulation Flag and Test Mode



Protection IED Testing



Test Plan example

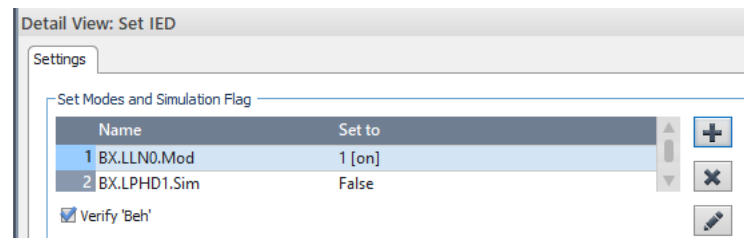
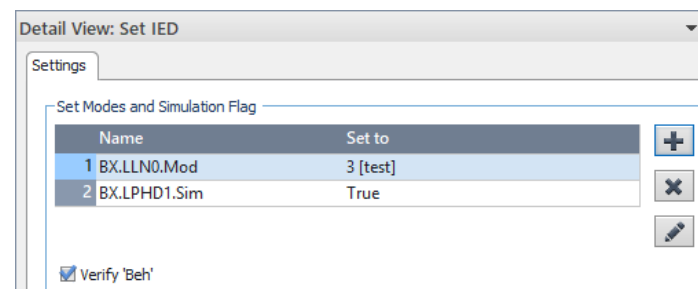


Set Test Mode
and Simulation

GOOSE and SV
Configuration

Testing

Reset IED to
ON



Thanks!