Testing in IEC 61850-based PACS
Focus on Maintenance Testing Isolation

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Secure and Efficient Testing of IEC 61850-Based Protection and Control Systems

Agenda

What are the challenges during testing
(focus on maintenance testing)

Requirements for testing IEC 61850-based PACS

Doble's simulation test devices and software tools

Testing Challenges

- "**Software switches**" replace conventional physical test switches for **isolating injected signals and outputs** of device under test (DUT) from the rest of the system in normal service
- Test signals (SV and GOOSE) are seen by DUT as well as devices in normal service – a **major security concern**
- Test Isolation features of IEC 61850 are not understood by most testers
- Similar GOOSE messages from Test Sets and Real IEDs (under test and in normal service) are difficult to be differentiated by testers and by some IEDs (Edition 1)
- Existing packet sniffing tools are difficult to use for data visualization by testers
- Issuing of control sequences through MMS client is extremely difficult from the data model IED explorer tree and list views
- How to prepare the IEDs for testing
- A complete substation and its system configuration description file (SCD) can contain 100s of IEDs and it is difficult to manage the test scenarios without errors
- Configuring some complex tests is often times a trial-and-error process
- **No room for errors** when doing maintenance **testing in a live substation**

Testing Challenges

- A single IED can have **numerous** protection & control functions
- Many functions can share a **common trip output**. How to test a specific protection element (e.g., Zone 2 AB loop, Neutral OC stage 2, etc.) if the **element of interest is not in the dataset**
- **Not allowed to change** protection settings or re-map I/O signals for maintenance
- Some schemes have functional elements that are **distributed across multiple physical IEDs**
- Some protection functions require 2 or more simultaneous sets of sampled values
- Some **hybrid systems** use both conventional voltages and currents and sampled values

Testing Requirements and Doble Solutions

- Import SCL files; read data model and configuration from IEDs; compare files
- Scan network for GOOSE & SV messages
- Mask complexity of IEC 61850 from user
- Easy setup of test configuration for SV publishing and GOOSE subscription and publishing.
- Real-time data visualization
  - Tabular list of selected signals
  - Annunciator panel with widgets
  - Oscillography (SV, GOOSE, Reports)
- Record SV and data (GOOSE, Reports) in COMTRADE files; Viewer/Analysis module
- Logging of GOOSE, Report and Polling data
- User-friendly MMS Client w/ descriptive semantic information
- Easy-to-use interface for
  - control of breakers and other controllable objects
  - preparing the IEDs for simulation and testing
- GOOSE simulator for publishing and subscription; with programmable logic
- Support IEC 61850 testing features
- Default to secure simulation/quality states
- Save and re-use Configuration Setup files and Test Plans that have been fully verified to be working correctly – This ensures security, avoids errors during actual testing and improves efficiency and management of the testing process

Test Features – **Isolation** during Maintenance

Test signals injected by test set should be:

- **Accepted only** by Devices *(IEDs or Logical devices)* under test (**DUT**)
- **Rejected** by devices that are in normal service

Simulation:

- Test set publishes SV and GOOSE messages with Simulation flag = true
- **DUT set to Simulation** will process messages with Simulation flag = true
- Devices in **normal service** (Simulation not set) will not process simulated messages

Output Signals of DUT

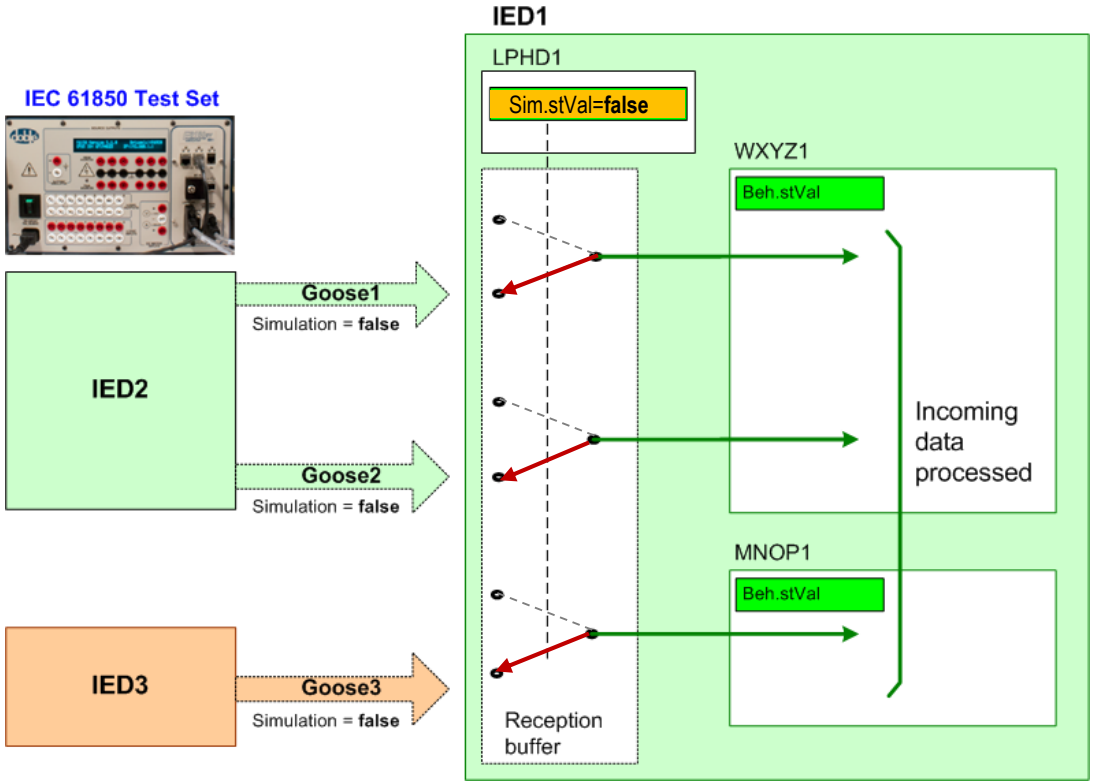
- Outputs signals should be accepted by other devices also under test
- **rejected** by other devices in normal service
- Hard-wired outputs of the DU should be **blocked** from operating on the process

Mode/Behavior: – Test, Test/blocked

- GOOSE outputs of DUT are identified with **q.test=true.** They are **processed as valid** by other devices also **under test**
- Devices in normal service reject (or **process as Invalid**) signals with q.test=true.

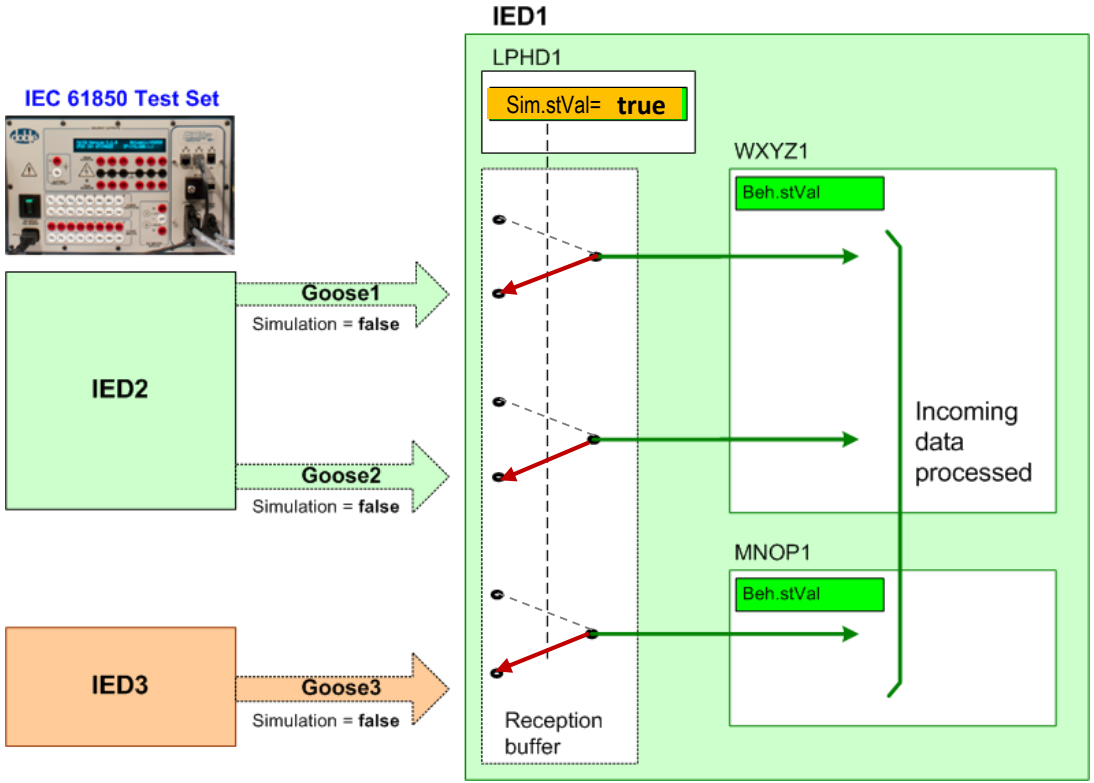
Test/blocked mode: Physical outputs **blocked**

IEC 61850 Test Simulation Features (Edition2)



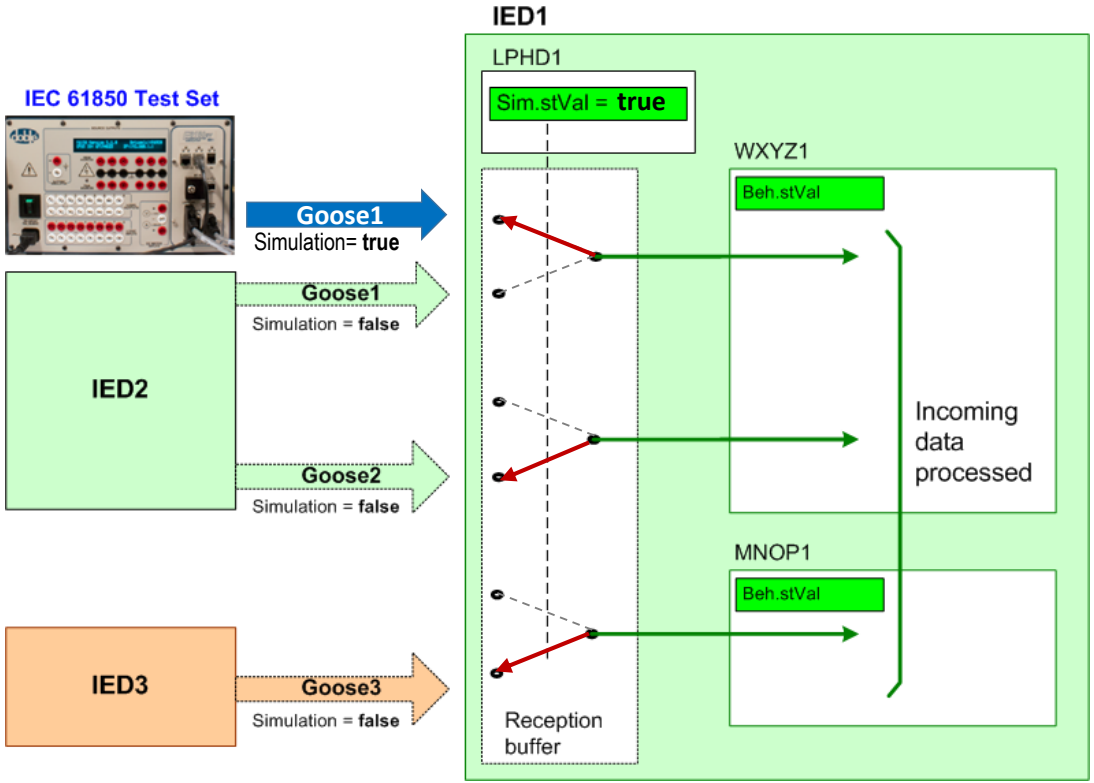
- Devices in normal service with Simulation=**false** will process GOOSE messages from real IEDs

IEC 61850 Test Simulation Features (Edition2)



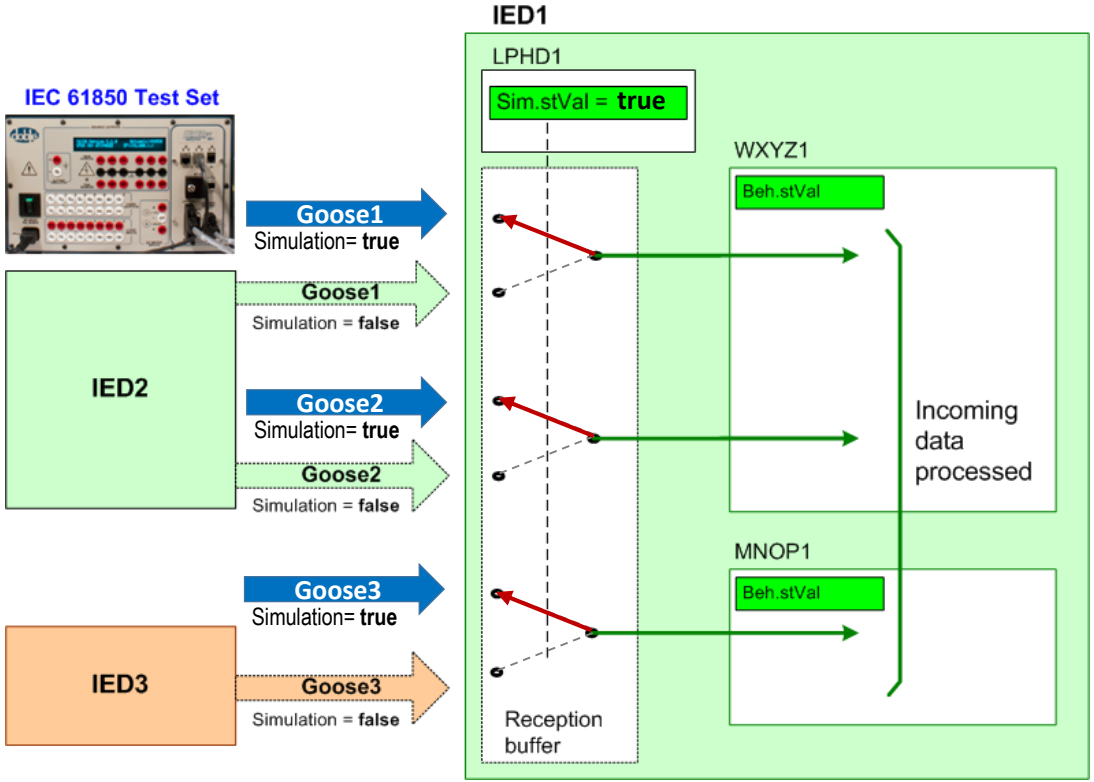
- Devices in normal service with Simulation=**false** will process GOOSE messages from real IEDs
- Device with Simulation changed to **true** will still continue processing GOOSE messages (with simulation flag = false) from real IEDs, if there are **no** simulated messages from the test set

IEC 61850 Test Simulation Features (Edition2)



- Test set publishes GOOSE msgs with Simulation flag = true
- DUT with Simulation = true will
  - Start accepting messages with Simulation flag = true
  - Reject messages from real IED with Simulation flag = false

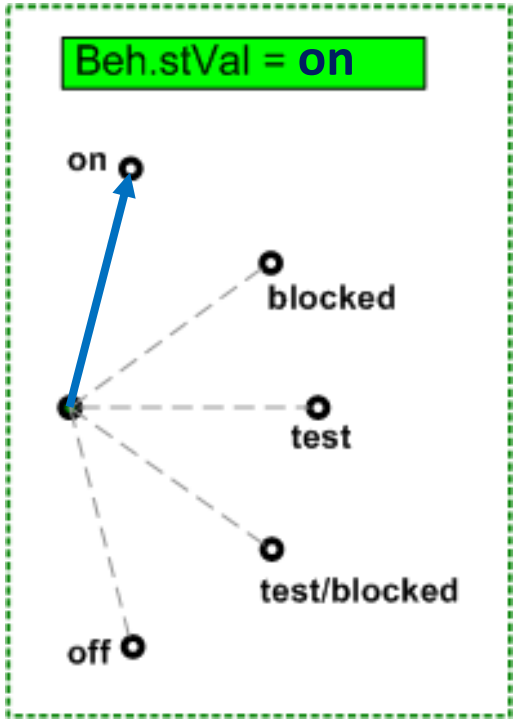
IEC 61850 Test Simulation Features (Edition2)

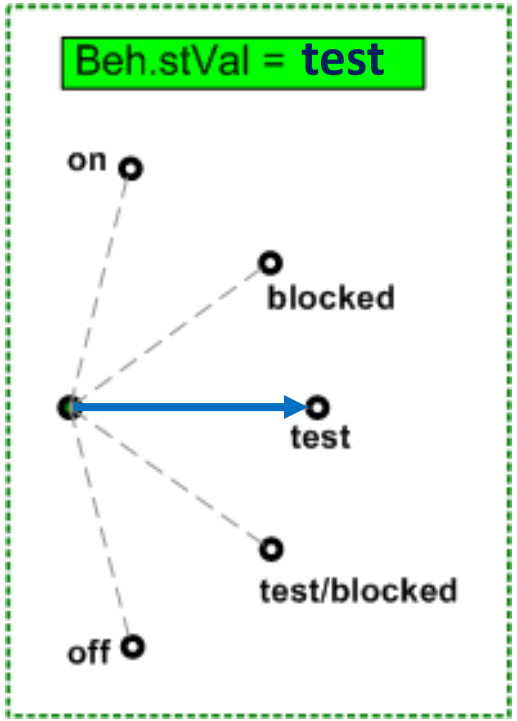


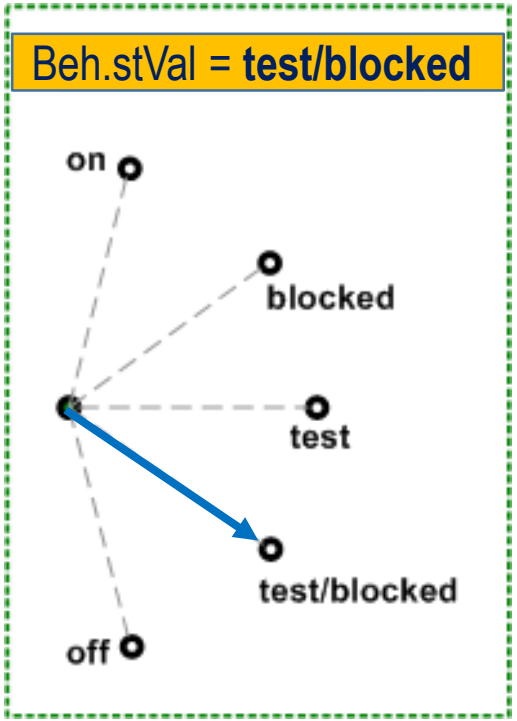
- Test set publishes GOOSE msgs with Simulation flag = true
- Devices in Simulation = **true** will **accept** incoming simulated messages with Simulation flag also set to **true**
- All GOOSE messages from the real IEDs (**Sim=false**) that have the same names as the simulated ones will now be rejected.

This concept also applies to Sampled Values

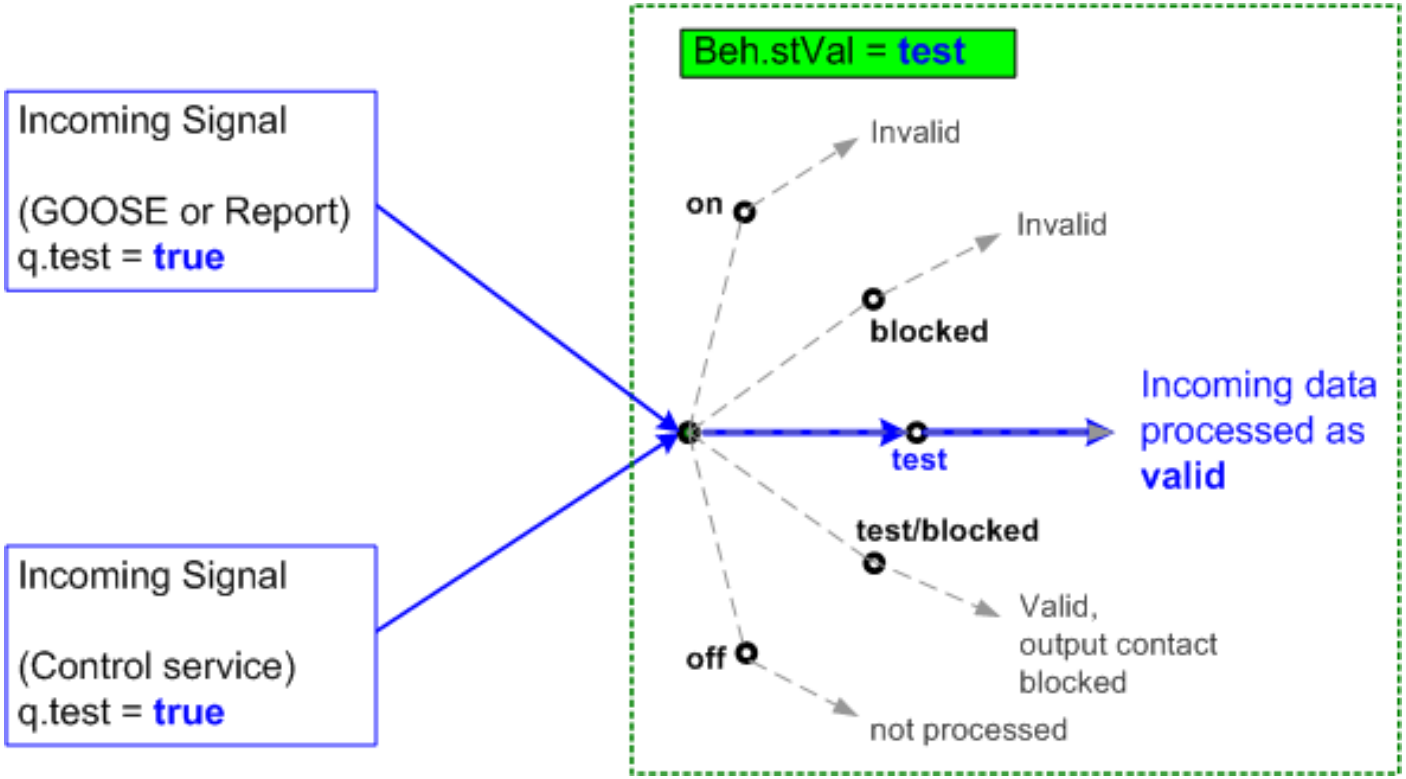
Mode and Behavior of Logical Devices and Logical Nodes



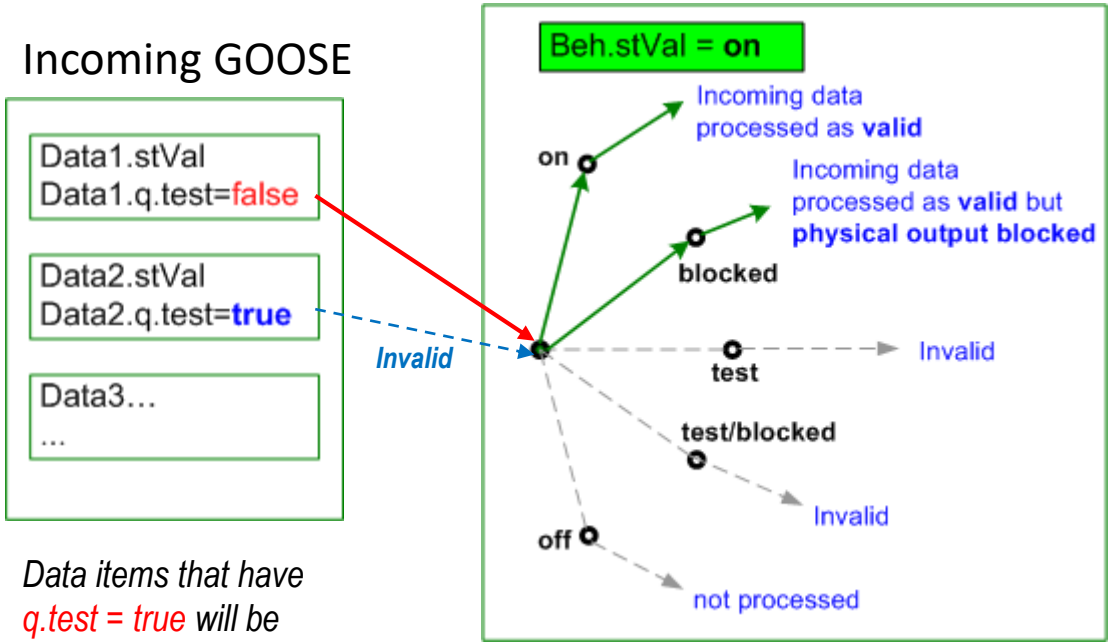




Mode/Behavior, Data Quality and Processing



Mode/Behavior, Data Quality and Processing

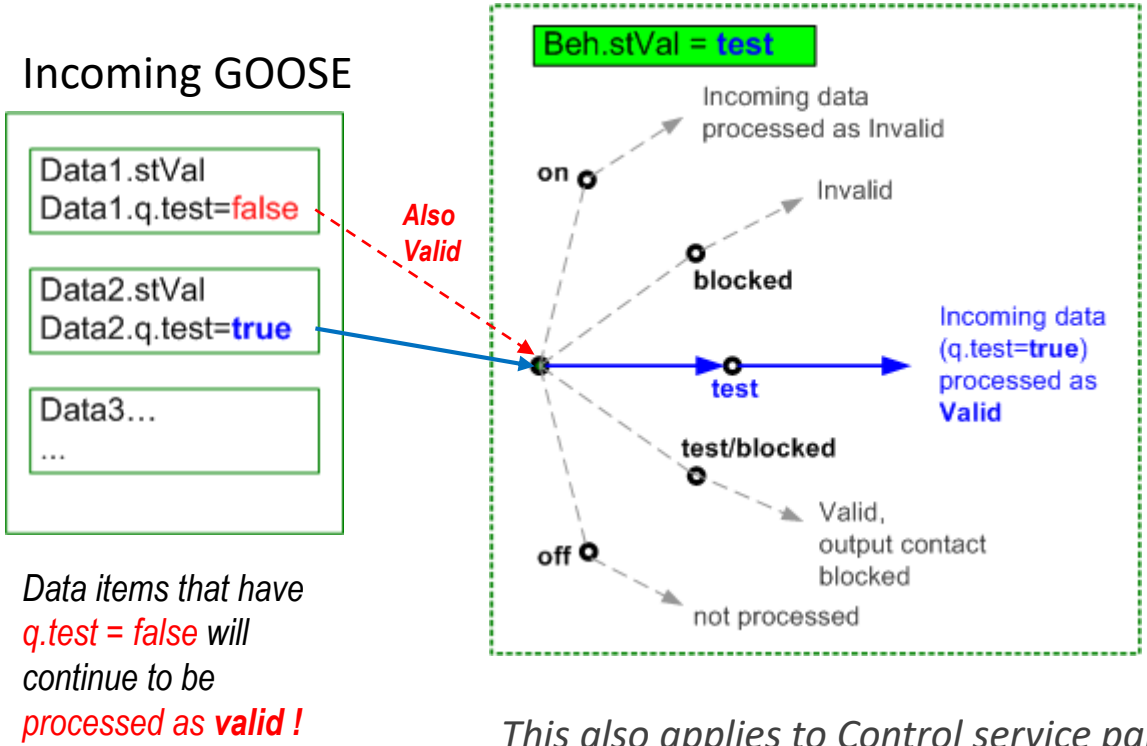


*Data items that have q.test = true will be processed as **invalid***

- Data items with q.test=false (normally from real IEDs) will be **processed as valid**
- DUT/LD with Behavior = **on** will **process as invalid** incoming data with **q.test = true**

This also applies to Control service messages

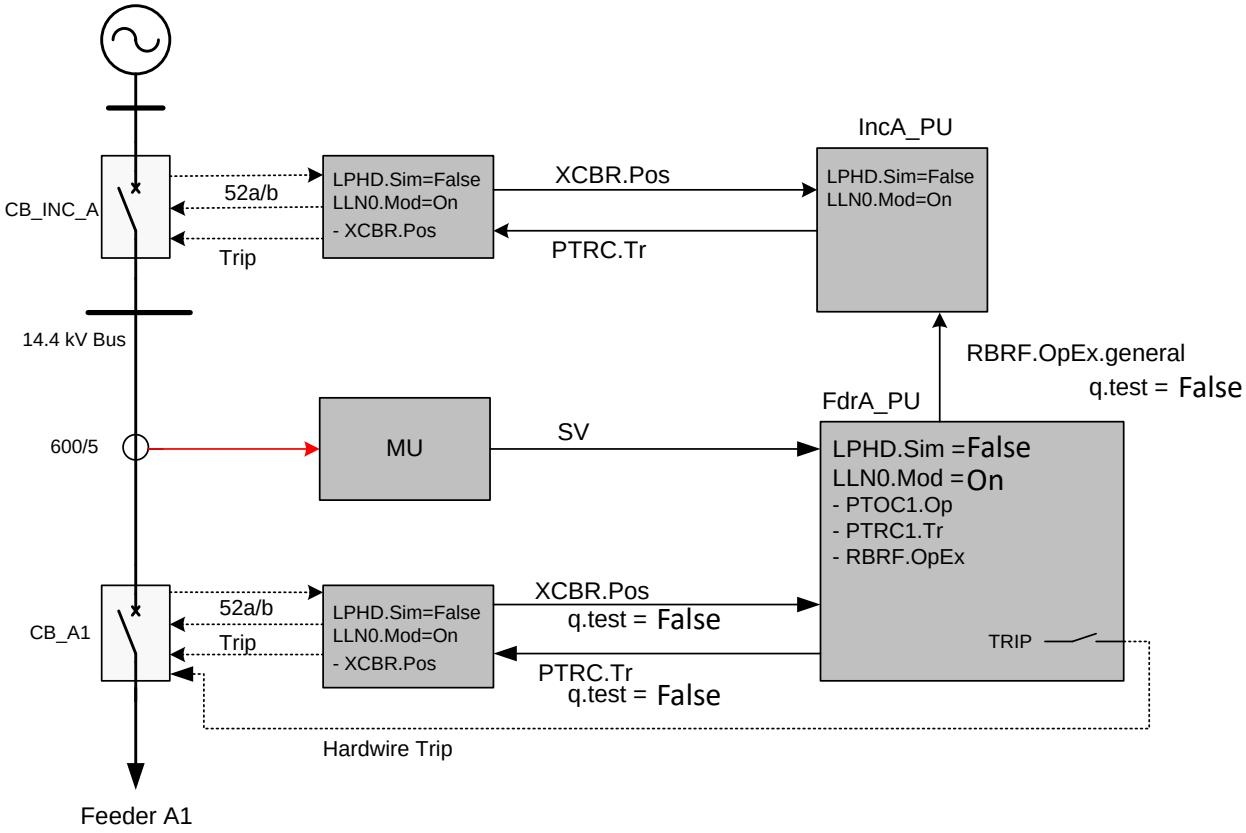
Mode/Behavior, Data Quality and Processing

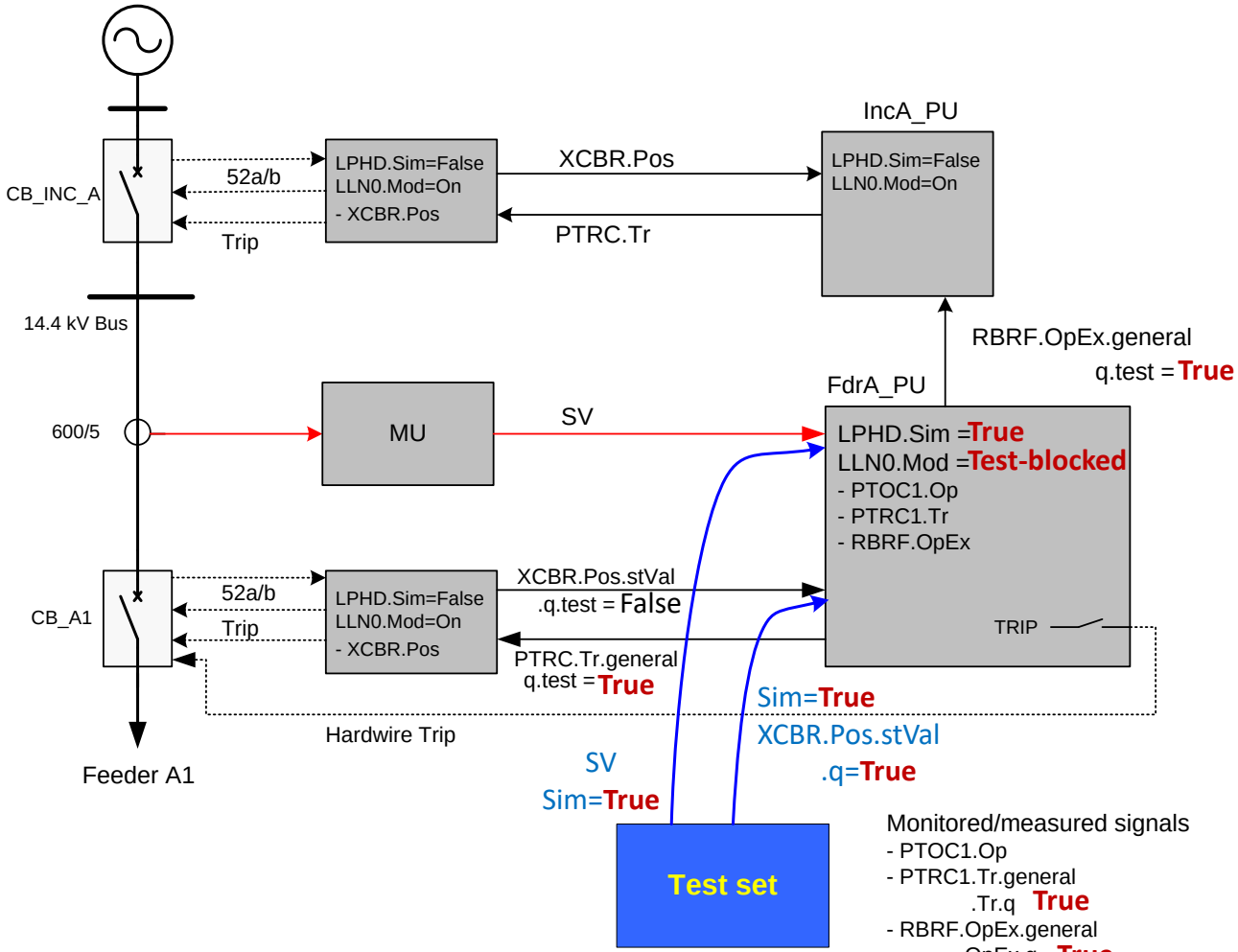


*Data items that have q.test = false will continue to be processed as **valid !***

- DUT/LD with Behavior = **test** or **test/blocked** will **process as valid** incoming data with **q.test = true**
- Data items with q.test=false will be continue to be **processed as valid !**

This also applies to Control service parameter Test


IncA_PU
CB_INC_A
52a/b
Trip
LPHD.Sim=False
LLN0.Mod=On
- XCBR.Pos
XCBR.Pos
PTRC.Tr
LPHD.Sim=False
LLN0.Mod=On
14.4 kV Bus
RBRF.OpEx.general
q.test = False
FdrA_PU
600/5
MU
SV
LPHD.Sim =False
LLN0.Mod =On
- PTOC1.Op
- PTRC1.Tr
- RBRF.OpEx
TRIP
CB_A1
52a/b
Trip
LPHD.Sim=False
LLN0.Mod=On
- XCBR.Pos
XCBR.Pos
q.test = False
PTRC.Tr
q.test = False
Hardwire Trip
Feeder A1

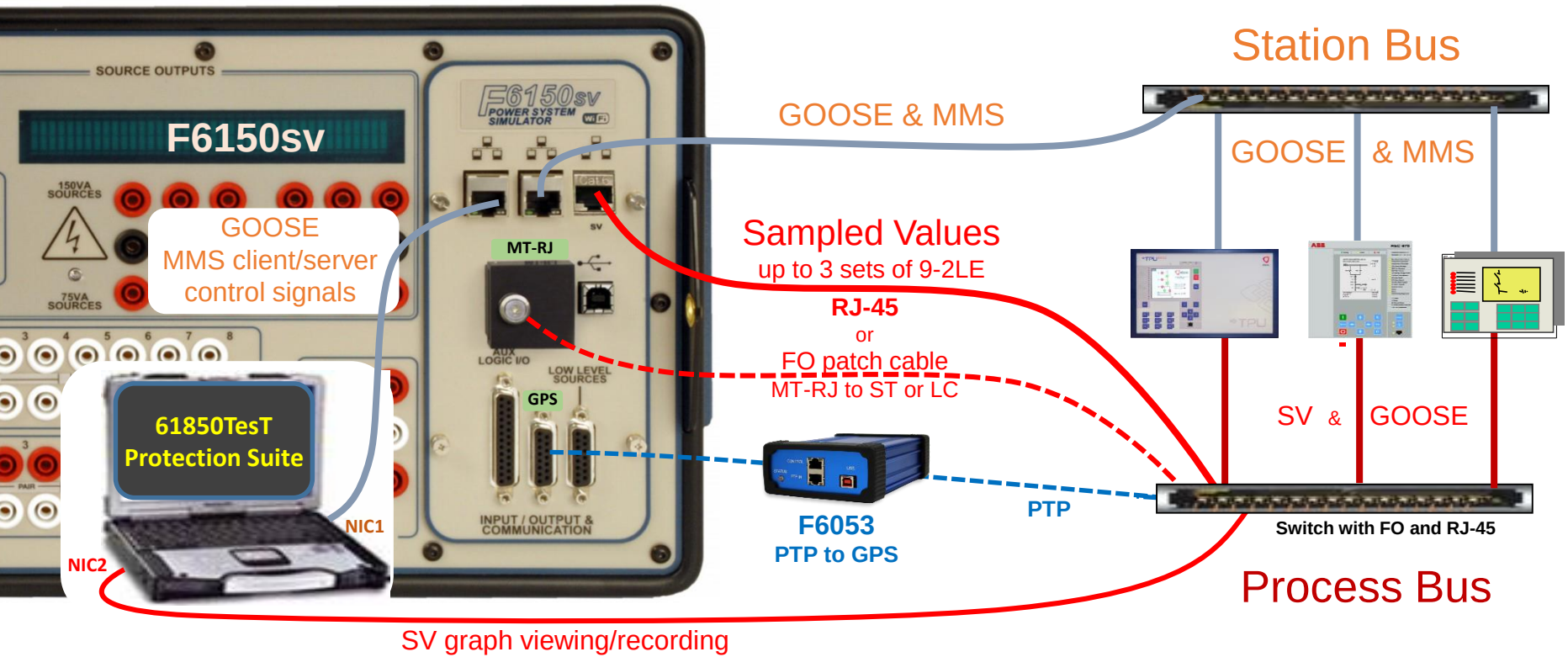

IncA_PU
CB_INC_A
52a/b
Trip
LPHD.Sim=False
LLN0.Mod=On
- XCBR.Pos
XCBR.Pos
PTRC.Tr
LPHD.Sim=False
LLN0.Mod=On
14.4 kV Bus
RBRF.OpEx.general
q.test = True
FdrA_PU
600/5
MU
SV
LPHD.Sim =True
LLN0.Mod =Test-blocked
- PTOC1.Op
- PTRC1.Tr
- RBRF.OpEx
CB_A1
52a/b
Trip
LPHD.Sim=False
LLN0.Mod=On
- XCBR.Pos
XCBR.Pos.stVal
.q.test = False
PTRC.Tr.general
q.test = True
TRIP
Hardwire Trip
Feeder A1
Sim=True
XCBR.Pos.stVal
.q=True
SV
Sim=True
Test set
Monitored/measured signals
- PTOC1.Op
- PTRC1.Tr.general
.Tr.q True
- RBRF.OpEx.general
.OpEx.q True

Doble Solutions

for

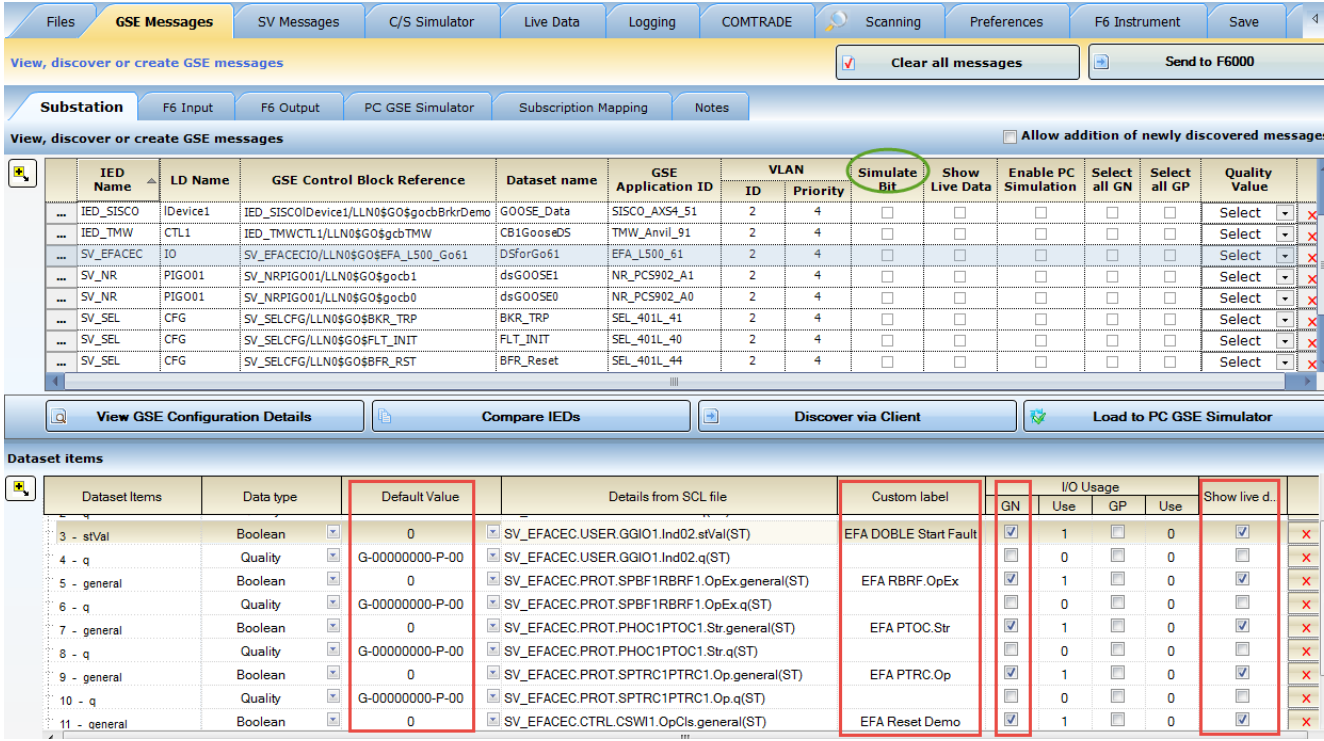
Testing IEC 61850-based Protection and Control Systems

Tools for Testing IEC 61850-based PACS



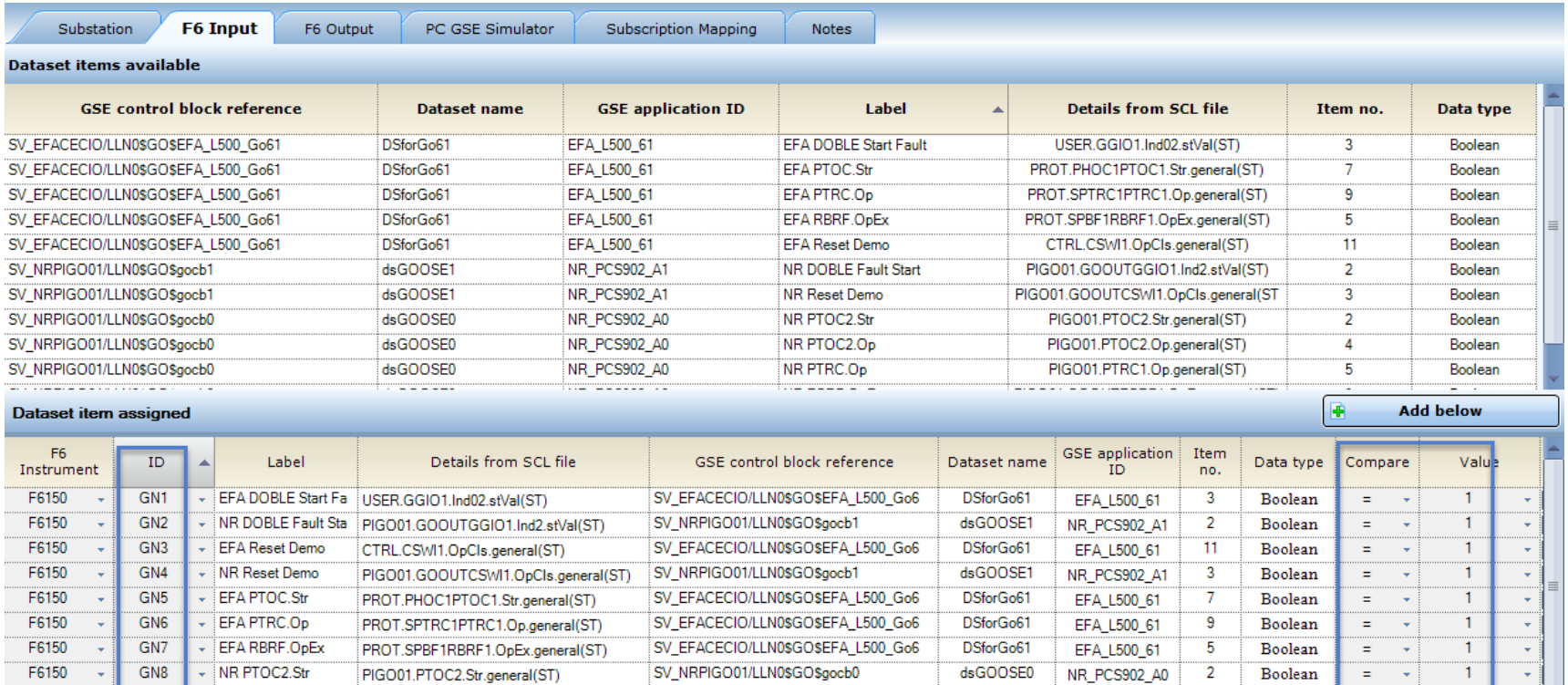
GOOSE Messages and Datasets

- Import SCL file or discover IEDs
- Add custom labels for easy identification, esp. for GGIO data items
- Select data items for
  - –Use as Inputs/Outputs
  - –Viewing in live data
- For GOOSE simulation
  - –Set Sim flags
  - –Set data q.bits
  - –Verify default data values



Configuring Doble F6150sv test set for Signal Inputs(GOOSE Subscription)

- Map selected data signals to **Inputs** (GN#) of F6150sv test set
- Verify “compare” values signal triggering for use during testing



Substation | **F6 Input** | F6 Output | PC GSE Simulator | Subscription Mapping | Notes

Dataset items available

GSE control block reference	Dataset name	GSE application ID	Label	Details from SCL file	Item no.	Data type
SV_EFACECIO/LLN0GOEFA_L500_Go61	DSforGo61	EFA_L500_61	EFA DOBLE Start Fault	USER.GGIO1.Ind02.stVal(ST)	3	Boolean
SV_EFACECIO/LLN0GOEFA_L500_Go61	DSforGo61	EFA_L500_61	EFA PTOC.Str	PROT.PHOC1PTOC1.Str.general(ST)	7	Boolean
SV_EFACECIO/LLN0GOEFA_L500_Go61	DSforGo61	EFA_L500_61	EFA PTRC.Op	PROT.SPTRC1PTRC1.Op.general(ST)	9	Boolean
SV_EFACECIO/LLN0GOEFA_L500_Go61	DSforGo61	EFA_L500_61	EFA RBRF.OpEx	PROT.SPBF1RBRF1.OpEx.general(ST)	5	Boolean
SV_EFACECIO/LLN0GOEFA_L500_Go61	DSforGo61	EFA_L500_61	EFA Reset Demo	CTRL.CSWI1.OpCls.general(ST)	11	Boolean
SV_NRPIGO01/LLN0GOgocb1	dsGOOSE1	NR_PCS902_A1	NR DOBLE Fault Start	PIGO01.GOOUTGGIO1.Ind2.stVal(ST)	2	Boolean
SV_NRPIGO01/LLN0GOgocb1	dsGOOSE1	NR_PCS902_A1	NR Reset Demo	PIGO01.GOOUTCSWI1.OpCls.general(ST	3	Boolean
SV_NRPIGO01/LLN0GOgocb0	dsGOOSE0	NR_PCS902_A0	NR PTOC2.Str	PIGO01.PTOC2.Str.general(ST)	2	Boolean
SV_NRPIGO01/LLN0GOgocb0	dsGOOSE0	NR_PCS902_A0	NR PTOC2.Op	PIGO01.PTOC2.Op.general(ST)	4	Boolean
SV_NRPIGO01/LLN0GOgocb0	dsGOOSE0	NR_PCS902_A0	NR PTRC.Op	PIGO01.PTRC1.Op.general(ST)	5	Boolean

Dataset item assigned — Add below

F6 Instrument	ID	Label	Details from SCL file	GSE control block reference	Dataset name	GSE application ID	Item no.	Data type	Compare	Value
F6150	GN1	EFA DOBLE Start Fa	USER.GGIO1.Ind02.stVal(ST)	SV_EFACECIO/LLN0GOEFA_L500_Go6	DSforGo61	EFA_L500_61	3	Boolean	=	1
F6150	GN2	NR DOBLE Fault Sta	PIGO01.GOOUTGGIO1.Ind2.stVal(ST)	SV_NRPIGO01/LLN0GOgocb1	dsGOOSE1	NR_PCS902_A1	2	Boolean	=	1
F6150	GN3	EFA Reset Demo	CTRL.CSWI1.OpCls.general(ST)	SV_EFACECIO/LLN0GOEFA_L500_Go6	DSforGo61	EFA_L500_61	11	Boolean	=	1
F6150	GN4	NR Reset Demo	PIGO01.GOOUTCSWI1.OpCls.general(ST)	SV_NRPIGO01/LLN0GOgocb1	dsGOOSE1	NR_PCS902_A1	3	Boolean	=	1
F6150	GN5	EFA PTOC.Str	PROT.PHOC1PTOC1.Str.general(ST)	SV_EFACECIO/LLN0GOEFA_L500_Go6	DSforGo61	EFA_L500_61	7	Boolean	=	1
F6150	GN6	EFA PTRC.Op	PROT.SPTRC1PTRC1.Op.general(ST)	SV_EFACECIO/LLN0GOEFA_L500_Go6	DSforGo61	EFA_L500_61	9	Boolean	=	1
F6150	GN7	EFA RBRF.OpEx	PROT.SPBF1RBRF1.OpEx.general(ST)	SV_EFACECIO/LLN0GOEFA_L500_Go6	DSforGo61	EFA_L500_61	5	Boolean	=	1
F6150	GN8	NR PTOC2.Str	PIGO01.PTOC2.Str.general(ST)	SV_NRPIGO01/LLN0GOgocb0	dsGOOSE0	NR_PCS902_A0	2	Boolean	=	1

Configuring Doble F6150sv test set for Signal Output Simulation (GOOSE Publishing)

- Map selected GOOSE data signals to logic **Outputs** (GP#) of test set
- Verify "True value" and "False value" for signals simulated during testing

Substation | F6 Input | **F6 Output** | PC GSE Simulator | Subscription Mapping | Notes

Dataset items available

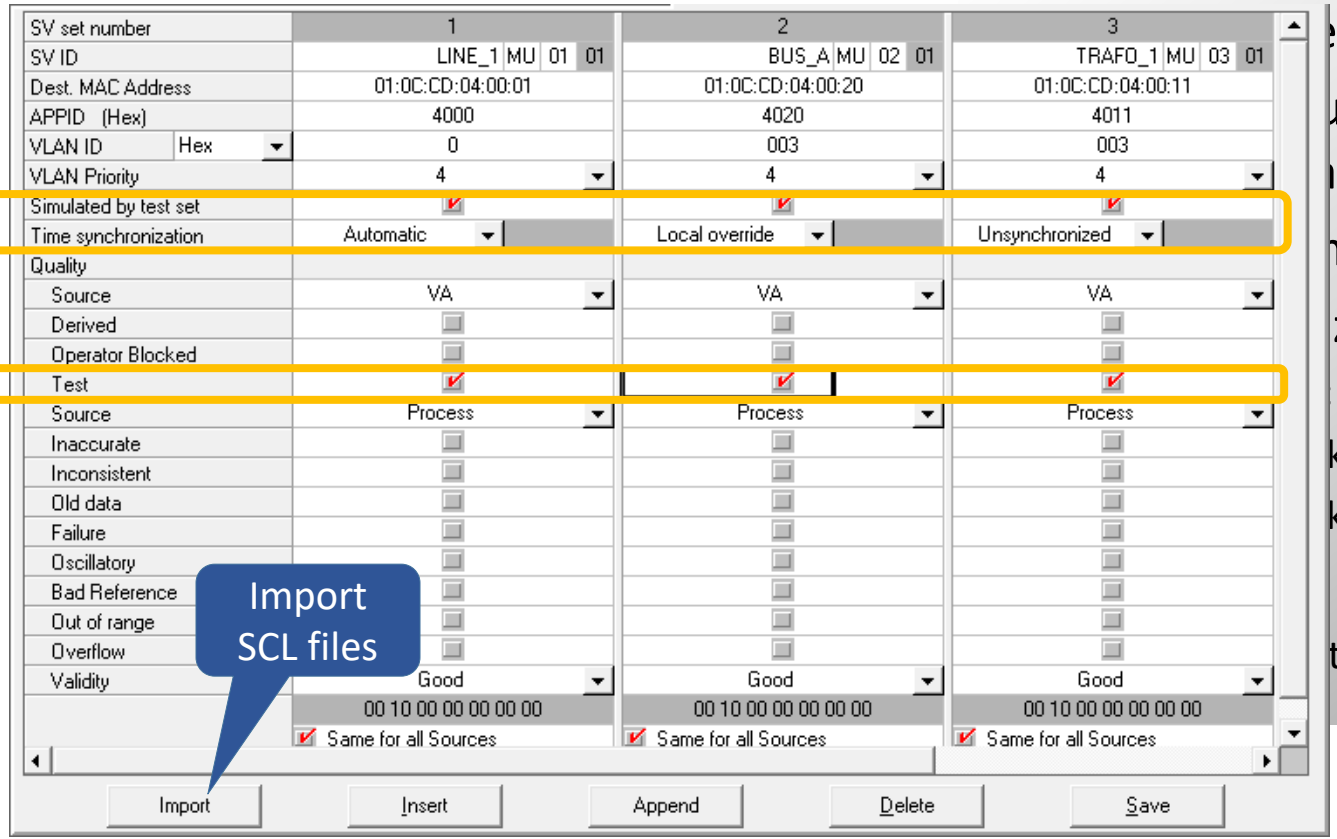
GSE control block reference	Dataset name	GSE application ID	Label	Details from SCL file	Item no.	Data type
XCBR_DOBLESystem/LLN0GOgcb01	Dset1_CBStatus	DOBLE_F6150sv_20	DOBLE XCBR	CtlCB1.CB1XCBR1.Pos.stVal(ST)	1	CodedEnum

Dataset item assigned — Add below

F6 Instrument	ID	Label	Details from SCL file	GSE control block reference	Dataset name	GSE application ID	Item no.	Data type	True value	False value	Delete
F6150	GP1	DOBLE XCBR	CtlCB1.CB1XCBR1.Pos.stVal(ST)	XCBR_DOBLESystem/LLN0GOgcb0	Dset1_CBStatus	DOBLE_F6150sv	1	CodedEnu	2 (10)	1 (01)	

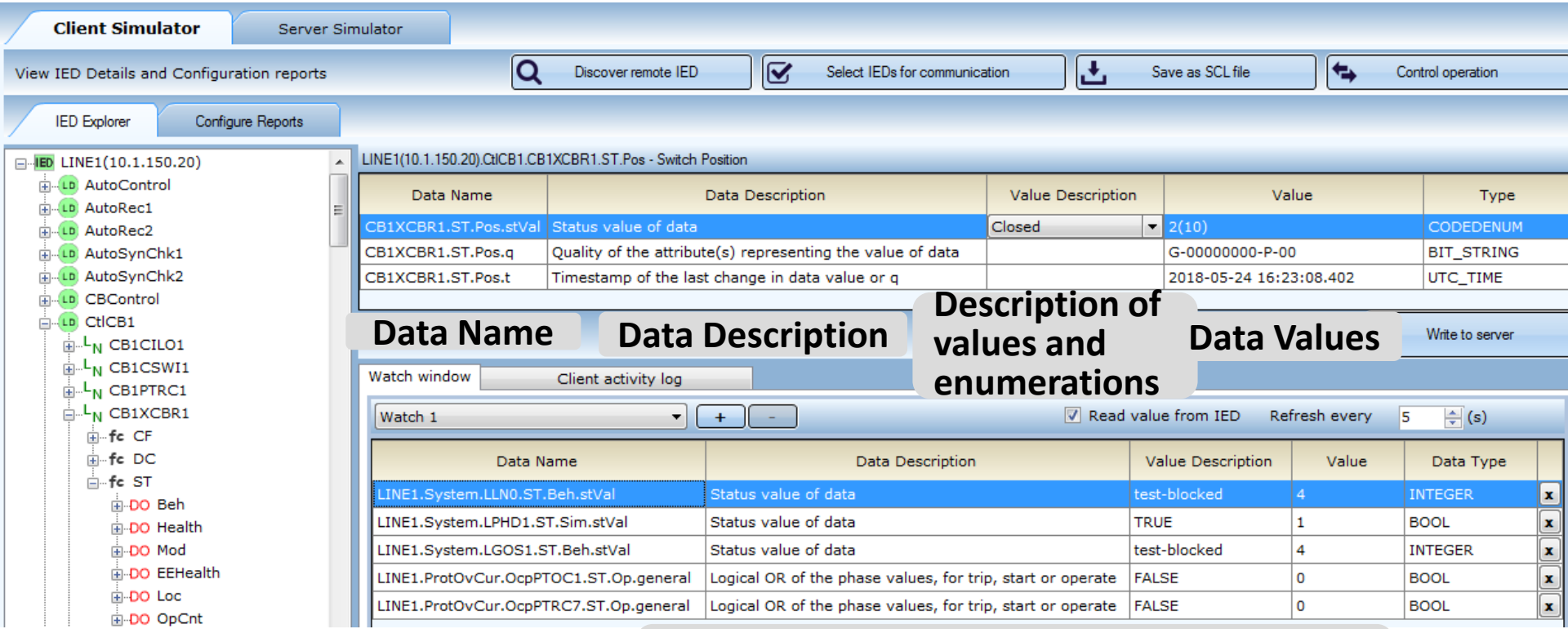
Signal Name	Output No	2 AB Flt1 90% Line	3 CBTripTime1	4 Zero Values	5 Prefault2	6 AB Flt2 90% Line
Ch1 Goose InSe	GP6					
Ch1 POTT Rx	GP7					
CB1 Pos	GP3					

Configuring F6150sv test set for Simulation of Sampled Values



- SV sets for Substation
- ulate up to 3 sets of SV
  neously for each test
- nulation flag
- zation
  - (based on GPS signal)
  - ke Local & Global
  - ke Unsynchronized
  - –
  - tc.

MMS Client, Reporting and Control

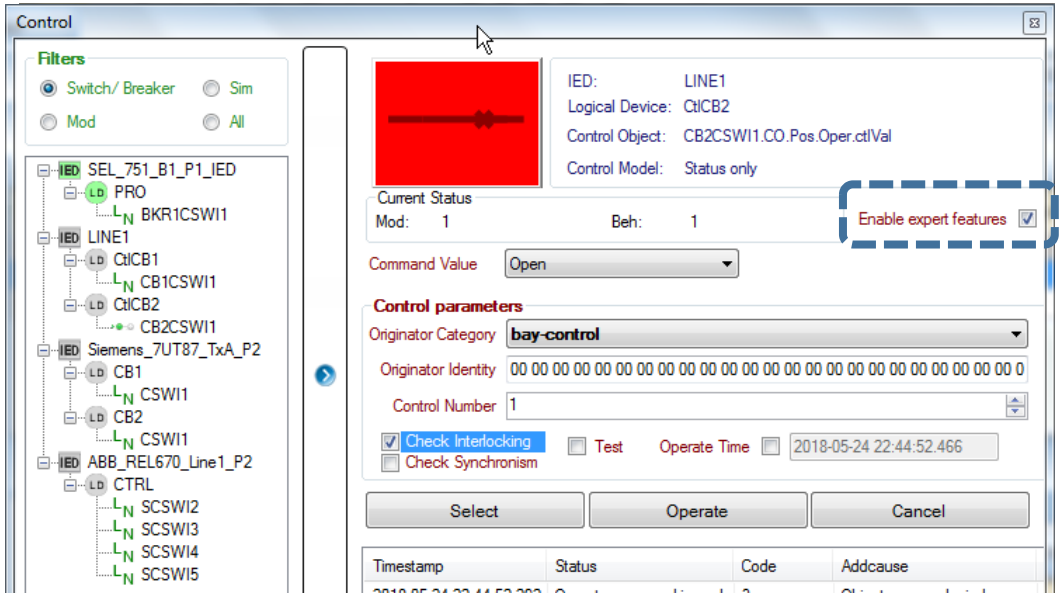


Watch window – Automatically polls and updates selected data

Control User Interface

- Test sequences of control operations with ease
  - **Non-expert mode** hides/disable buttons and fields and allows only valid operations
  - **Expert mode** enables everything and allows testing of invalid sequences

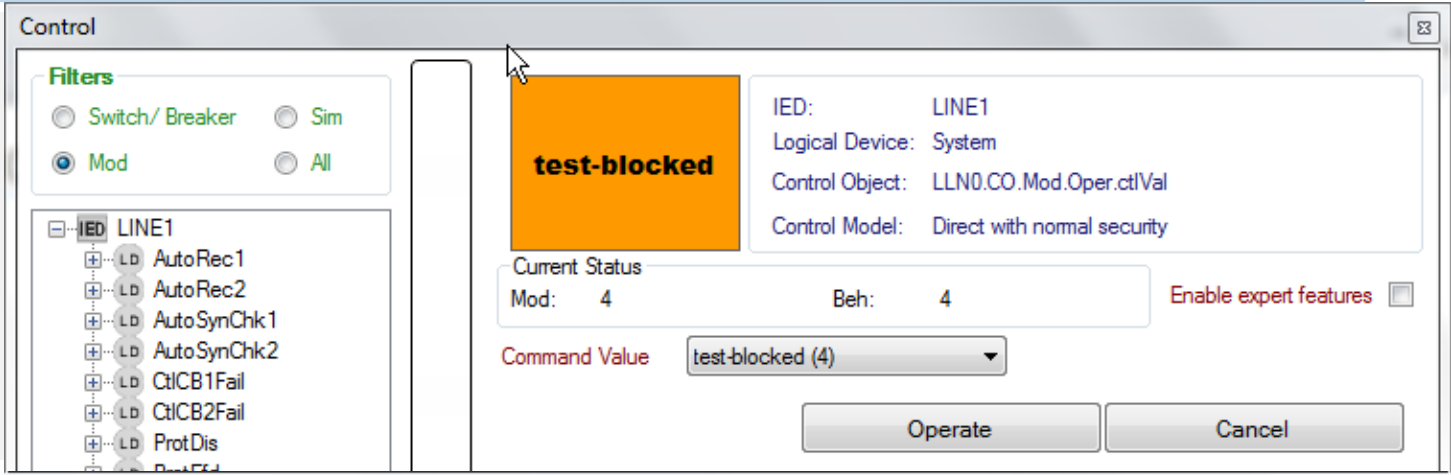
- Filters for easy selection of objects
- Support all control models –
  - **status** only
  - **direct** with normal or enhanced security
  - **SBO (select-before-operate)** with normal security
  - **direct** with enhanced security
  - **SBO** with enhanced security
- Test control operations with checks of **interlocking** and **synchronization**
- Perform tests with IEDs in test mode with the control sequence **Test flag** set
- Status info of requests and responses

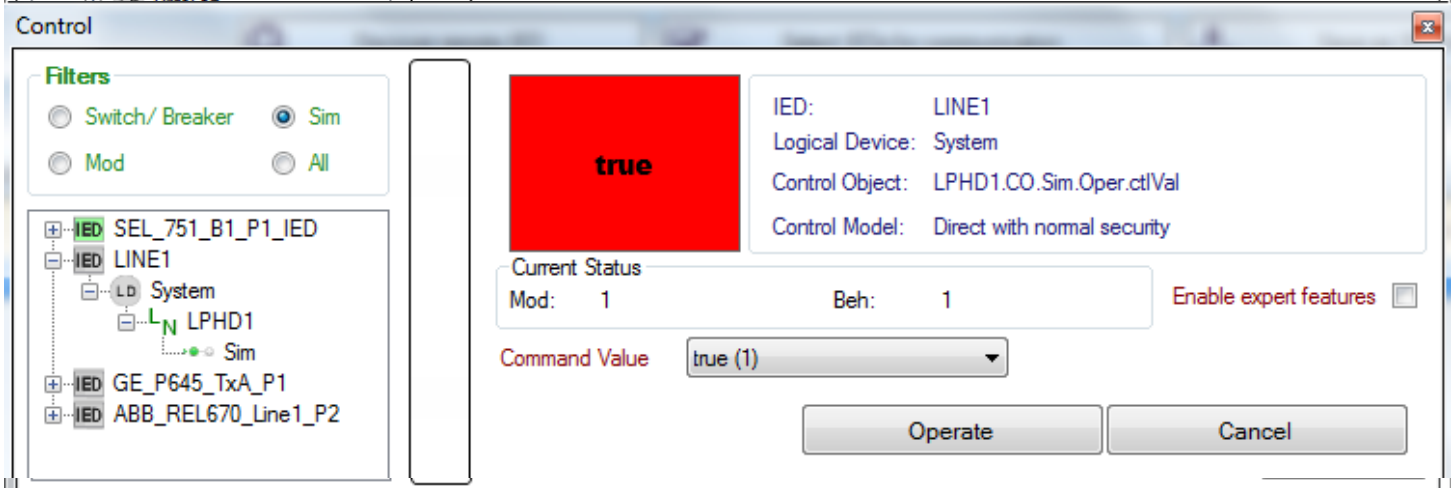


User Control of IED's modes for Testing

- LD or LN.Mod
  - on (1)
  - blocked (2)
  - test (3)
  - test-blocked (4)
  - off (5)

- LPHD.Sim
  - false (0)
  - true (1)

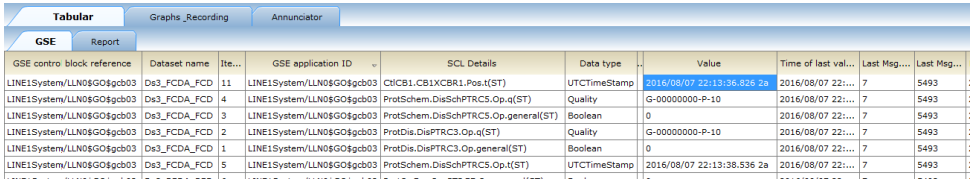




Real-time Data Visualization and Recording – GOOSE, Reports, Sampled Values

Live Tabular view - Selected signals only or All signals

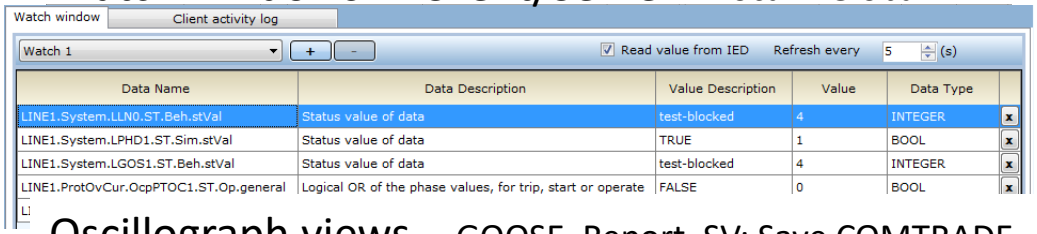
Identify identical sources (real & test); Sim = true or false



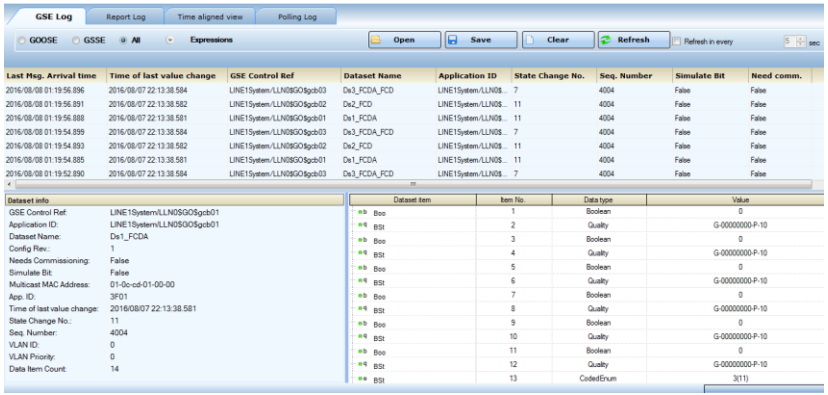
Annunciator view - with animated widgets

(user configurable); Detect if GOOSE is disconnected

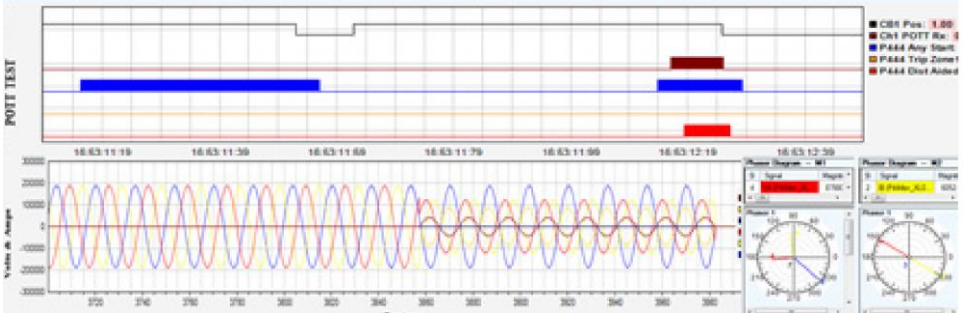
Watch windows in Client/Server – Local + Global



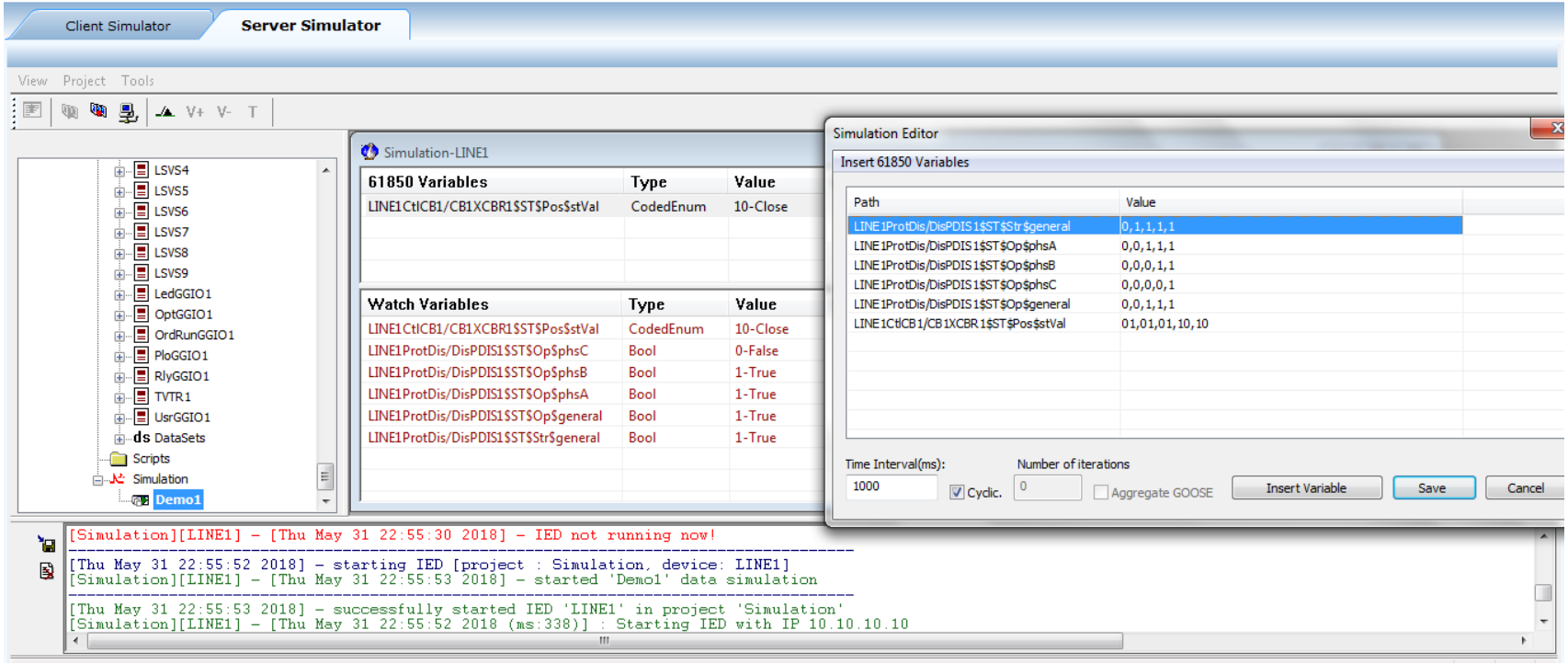
Logging view- GOOSE &Reports + dataset details



Oscillograph views – GOOSE, Report, SV; Save COMTRADE

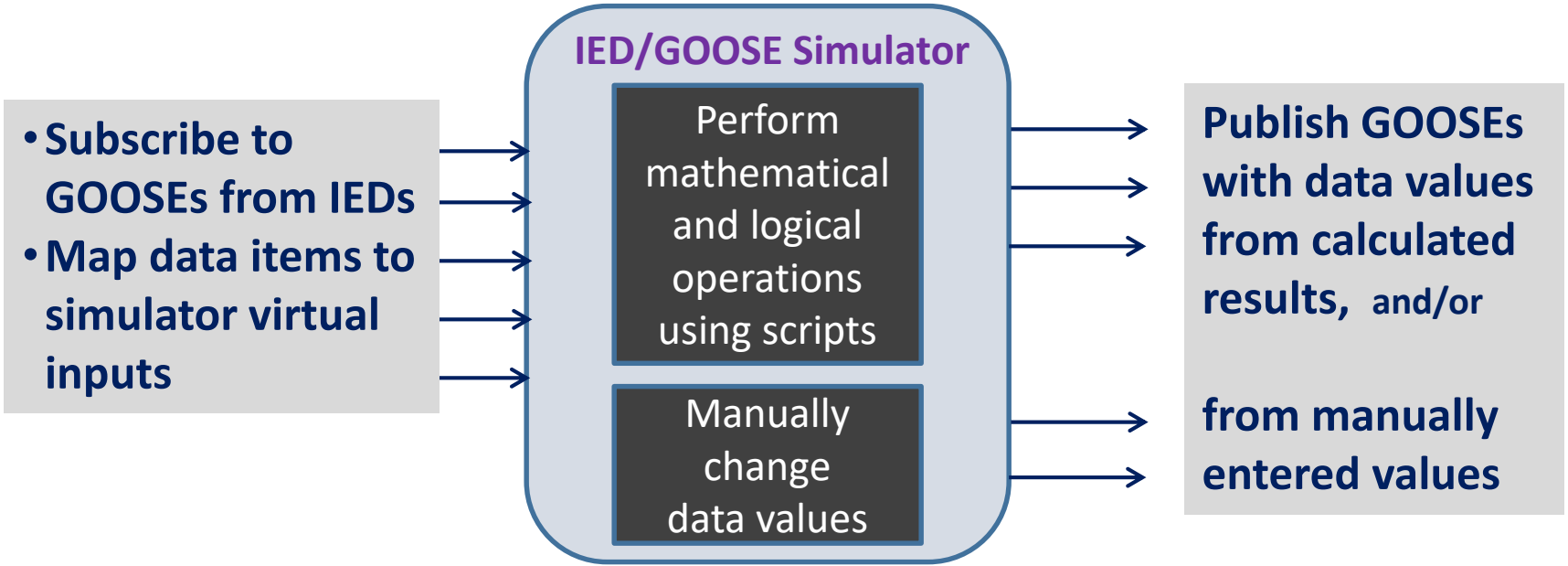


Server Simulator



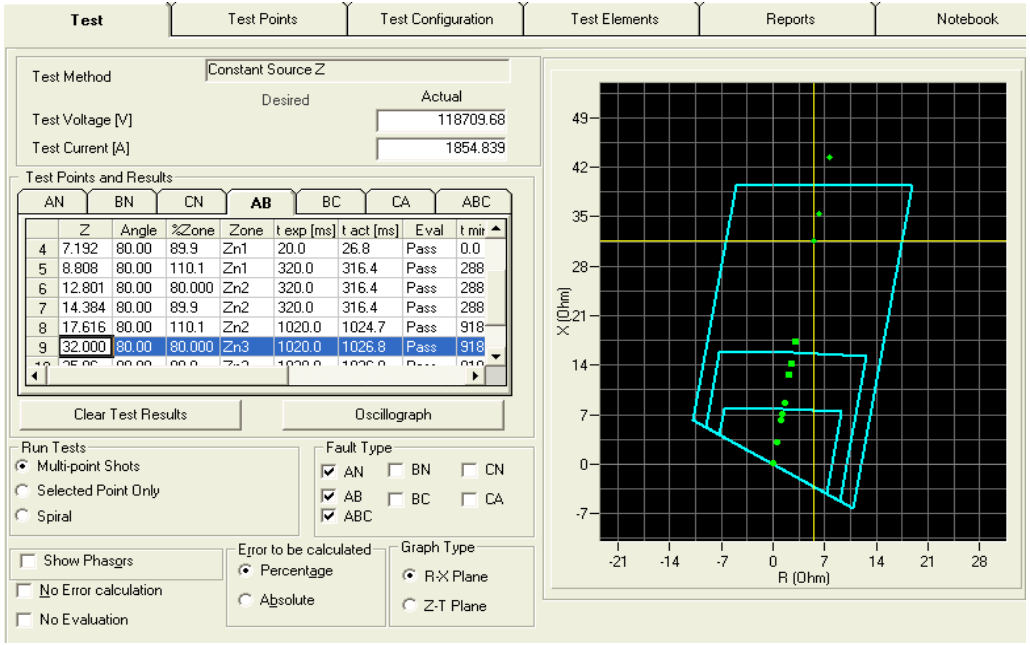
- **Use for simulating missing IEDs during any testing phase**
- **Use to simulate special test conditions**

PC-based GOOSE Simulator



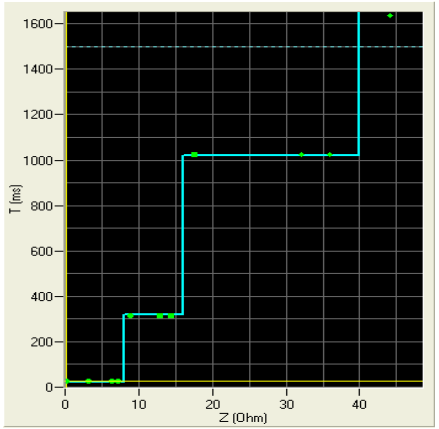
- Use for simulating missing IEDs during any testing phase
- Use to simulate special test conditions

Protection Test software solutions

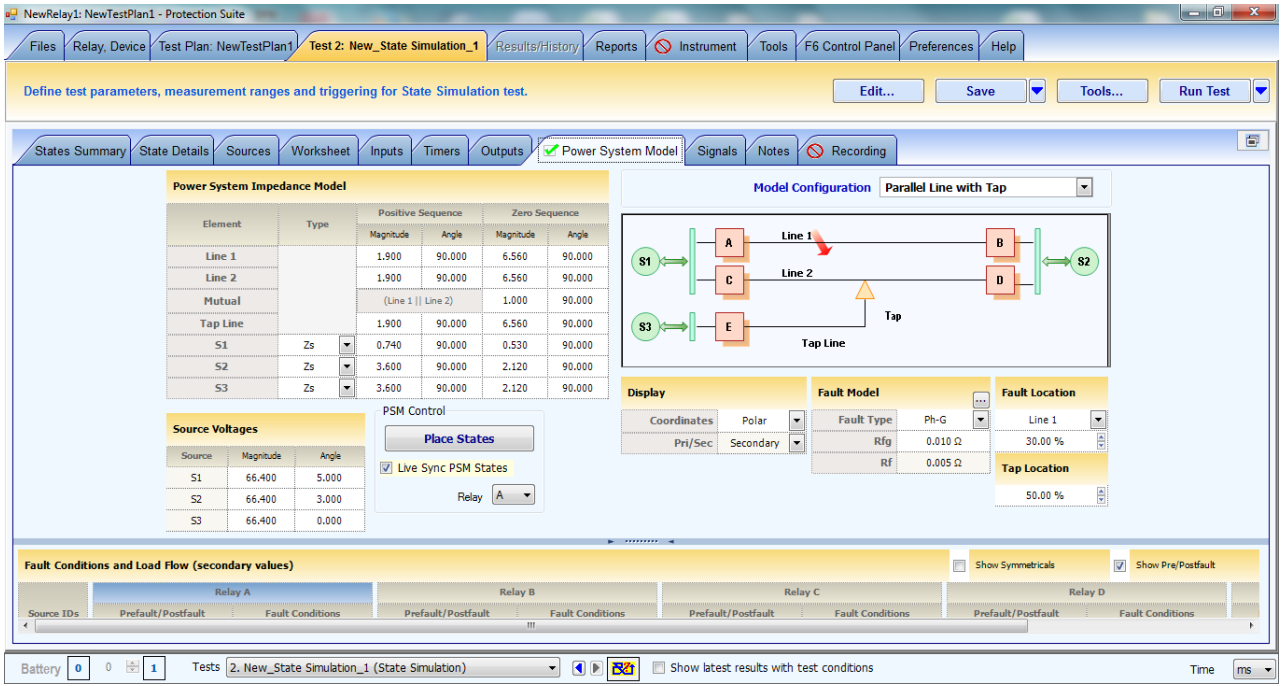


- Automatically identifies the elements that operated based on measured operate times and/or status of data signal

- Visual modeling and testing to verify settings and characteristics
- Avoid changing settings and signal mappings
- Smart testing targets specific functional elements by applying correct voltages and currents



Protection Test software solutions



Protection Suite sw

- Power system models
- Transient testing

Test Preparation for Ensuring Security and Efficiency

- **Import SCD file**
- **Divide substation into manageable sub-systems**
- **Identify standard or similar sub-systems**

- Identify and select related IEDs for each PAC sub-system
- Matrix of GOOSE messages and signals
  - Publishing
  - Subscriptions/external references
- SV massages

- **Develop 61850 Test configuration files**
- **System conditions**
  - **Normal**
  - **Simulation / Test**

- Map GOOSE Signals to F6150sv Logic I/O
- Simulation: sequence tables and scripts
- Live Data visualization and recording (GOOSE, SV, Report)
- Client config. for control, report, watch/polling

- **Develop automated test plans**
- **Normal and test conditions**

- Functional element tests
- Multi-element tests of main functions
- Fault conditions and control sequences
- Multi-IED scheme tests

- **Collection of well-organized files and test plans**
- **Select, use, reuse applicable files and plans for:**

- Factory Acceptance Tests
- Commissioning tests
- Maintenance tests

Fully tested and properly documented configuration and test files promotes efficiency and ensures security during testing

- Provide special attention to test isolation and security to prevent inadvertent operation of devices in normal operation while performing test on other devices.
- Thoroughly test and vet configuration files and test plans
- Document configuration files and test plans and provide clear procedures and instructions for test personnel