IEC 61850 Testing and Commissioning Advantages Using GOOSE Messaging

Antonio Riccardo Jr.– National grid

2019 Texas A&M Conference for Protective Relay Engineers

Agenda

- Introduction
- Traditional Relay Testing Practices
- IEC 61850 Testing Functionality
- IEC 61850 Data Model Approach to Testing
- IEC 61850 Test Plan Example

Introduction

- The use of IEC 61850 and associated standards paved the road to digital substations

- IEC 61850 digital substation can
  - Be engineered & designed faster
  - Reduce physical wiring
  - Reduce control house size
  - Build a substation faster

- IEC 61850 service protocols can reduce the testing time of an Intelligent Electronic Device (IED)

- Concept can be used even in conventional substation
  - e.g. hard wired analogs and discrete IO for normal service, but GOOSE or MMS can be communicated via an ethernet port for testing purposes only.

Traditional Relay Testing Practices

Requires testing of every element that is used in an IED. e.g. Line impedance zone pick ups & Operate, directional overcurrent pickups & Operates, fault detectors, etc.

Test switches and test devices are used to isolate the relay

Test sets are used to:

- Inject analog signals (currents & voltages)
- Monitor discrete inputs and outputs

Test Set Software is used to create relay-specific test plans

Relay settings are modified during testing to test each individual element

Time wasted to modify relay settings, configure test scenario per step, and repeat…

Line Protection test plan has 250+ steps

Regulatory Category	Inherit	Retest Interval	72 mo
Last Compliant Test Run		Retest Due	

Test Steps — Settings Group 1 — Hide disabled tests

#	Test Name	Test Enabled	Type	Auto Run	Comments	Compliance/ Required	Last Run		Modified
40	PH1-2 RCH Z1	☑	RCHLRI	☑	PH1-2 ZONE 1	☐	2017-Jan-17	✓	2017-Jul-17
41	PH1-2 MTA Z1	☑	MAXTAI	☑		☐	2017-Jan-17	✓	2017-Jul-17
42	PH1-2 PLOT Z1	☑	ZPXBOI	☑		☐	2017-Jan-17	✓	2017-Jul-17
43	PH2-3 RCH Z1	☑	RCHLRI	☑	PH2-3 ZONE 1	☐	2017-Jan-17	✓	2017-Jul-17
44	PH2-3 MTA Z1	☑	MAXTAI	☑		☐	2017-Jan-17	✓	2017-Jul-17
45	PH2-3 PLOT Z1	☑	ZPXBOI	☑		☐	2017-Jan-17	✓	2017-Jul-17
46	PH3-1 RCH Z1	☑	RCHLRI	☑	PH3-1 ZONE 1	☐	2017-Jan-17	✓	2017-Jul-17
47	PH3-1 MTA Z1	☑	MAXTAI	☑		☐	2017-Jan-17	✓	2017-Jul-17
48	PH3-1 PLOT Z1	☑	ZPXBOI	☑		☐	2017-Jan-17	✓	2017-Jul-17
49	INSTRUCTIONS	☑	Documen...	☑	MASK H1 = PH DIST Z1 OP	■	*		2017-Jul-17
50	PH3-1 PU TIME Z1	☑	TIMEI	☑	Z1 TIMING	☐	2017-Jan-17	✓	2017-Jul-17
51	PH3-1 BLOCK Z1	☑	TIMEI	☑	BLOCK: W/FUSE FAIL	☐	2017-Jan-17	✓	2017-Jul-17
52	INSTRUCTIONS	☑	Documen...	☑	MASK H1 = PH DIST Z2 PKP	■	*		2017-Jul-17
53	PH1-2 RCH Z2	☑	RCHLRI	☑	PH1-2 ZONE 2	☐	2017-Jan-17	✓	2017-Jul-17
54	PH1-2 MTA Z2	☑	MAXTAI	☑		☐	2017-Jan-17	✓	2017-Jul-17
55	PH1-2 PLOT Z2	☑	ZPXBOI	☑		☐	2017-Jan-17	✓	2017-Jul-17
56	PH2-3 RCH Z2	☑	RCHLRI	☑	PH2-3 ZONE 2	☐	2017-Jan-17	✓	2017-Jul-17
57	PH2-3 MTA Z2	☑	MAXTAI	☑		☐	2017-Jan-17	✓	2017-Jul-17
58	PH2-3 PLOT Z2	☑	ZPXBOI	☑		☐	2017-Jan-17	✓	2017-Jul-17
59	PH3-1 RCH Z2	☑	RCHLRI	☑	PH3-1 ZONE 2	☐	2017-Jan-17	✓	2017-Jul-17
60	PH3-1 MTA Z2	☑	MAXTAI	☑		☐	2017-Jan-17	✓	2017-Jul-17
61	PH3-1 PLOT Z2	☑	ZPXBOI	☑		☐	2017-Jan-17	✓	2017-Jul-17
62	INSTRUCTIONS	☑	Documen...	☑	MASK H1 = PH DIST Z2 OP	■	*		2017-Jul-17
63	PH3-1 PU TIME Z2	☑	TIMEI	☑	Z2 TIMING	☐	2017-Jan-24	✓	2017-Jul-17
64	PH3-1 BLOCK Z2	☑	TIMEI	☑	BLOCK: W/FUSE FAIL	☐	2017-Jan-18	✓	2017-Jul-17
65	INSTRUCTIONS	☑	Documen...	☑	MASK H1 = PH DIST Z4 PKP	■	*		2017-Jul-17
66	PH1-2 RCH Z4	☑	RCHLRI	☑	PH1-2 ZONE 4	☐	2017-Jan-18	✓	2017-Jul-17
67	PH1-2 MTA Z4	☑	MAXTAI	☑		☐	2017-Jan-18	✓	2017-Jul-17
68	PH1-2 PLOT Z4	☑	ZPXBOI	☑		☐	2017-Jan-18	✓	2017-Jul-17
69	PH2-3 RCH Z4	☑	RCHLRI	☑	PH2-3 ZONE 4	☐	2017-Jan-18	✓	2017-Jul-17
70	PH2-3 MTA Z4	☑	MAXTAI	☑		☐	2017-Jan-18	✓	2017-Jul-17

IEC 61850 Testing Functionality – Quality Attribute

Within the IEC 61850 standard (7-4)

- Every Logical node within a data set is accompanied by the quality attribute (q)
- The attribute is 13 bits long
- The data is good if all bits are false
- Each bit represents a quality issue.

Bit(s)	IEC 61850-7-3		Bit-String	
	Attribute name	Attribute value	Value	Default
0-1	Validity	Good	0 0	0 0
		Invalid	0 1	
		Reserved	1 0	
		Questionable	1 1	
2	Overflow		TRUE	FALSE
3	OutofRange		TRUE	FALSE
4	BadReference		TRUE	FALSE
5	Oscillatory		TRUE	FALSE
6	Failure		TRUE	FALSE
7	OldData		TRUE	FALSE
8	Inconsistent		TRUE	FALSE
9	Inaccurate		TRUE	FALSE
10	Source	Process	0	0
		Substituted	1	
11	Test		TRUE	FALSE
12	OperatorBlocked		TRUE	FALSE

- Validity:
  - **good:** The value shall be marked good if no abnormal condition of the acquisition function or the information source is detected.
  - **invalid:** The value shall be marked invalid when an abnormal condition of the acquisition function or the information source (missing or non-operating updating devices) is detected.
  - **questionable:** The value shall be marked questionable if a supervision function detects an abnormal behavior, however the value could still be valid. The user shall be responsible for determining whether or not values marked "questionable" should be used.

Test bit shall be an additional identifier that may be used to classify a value being a test value and not to be used for operational purposes. The processing of the test quality in the client shall be as described in IEC 61850-7-4.

IEC 61850 Testing Functionality – Test Mode

Within the IEC 61850 standard

- If test bit is set to true, then any devices not in test mode won't interact with the message if it was configured to normally subscribe to the message.
- Any other device in test mode will respond to the message from another device in test mode if it was configured to normally subscribe to the message.
- The device in test mode will operate for messages from devices not in test mode.
- A logical node or a logical device can be put in test mode using the data object Mod of the logical node of LLN0.

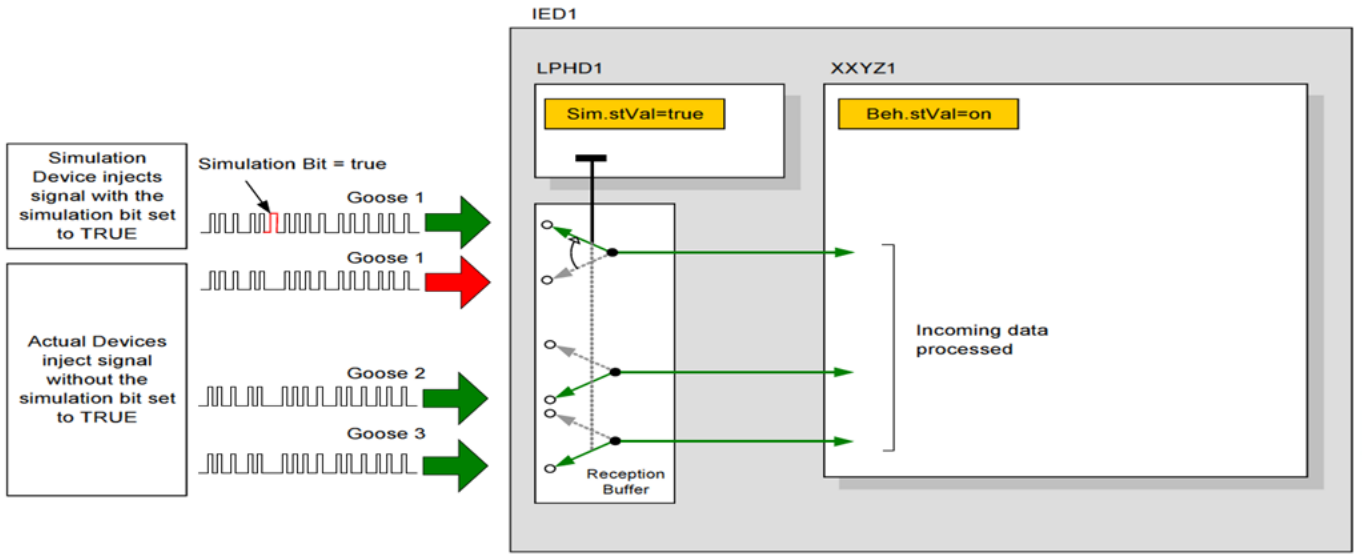
Test Mode Overview

- Verify system reliability and availability without interrupting the system process
- Modes are initiated with represented LN
- 5 Modes:
  - ON – Communication services work correctly
  - ON-BLOCKED – Control commands & output data will be rejected
  - TEST – "Quality test" control commands are accepted
  - TEST/BLOCKED – "Quality test" data is accepted, but output data is rejected
  - OFF – No process output or control commands are accepted

IEC 61850 Testing Functionality – Simulation Mode

Within the IEC 61850 standard

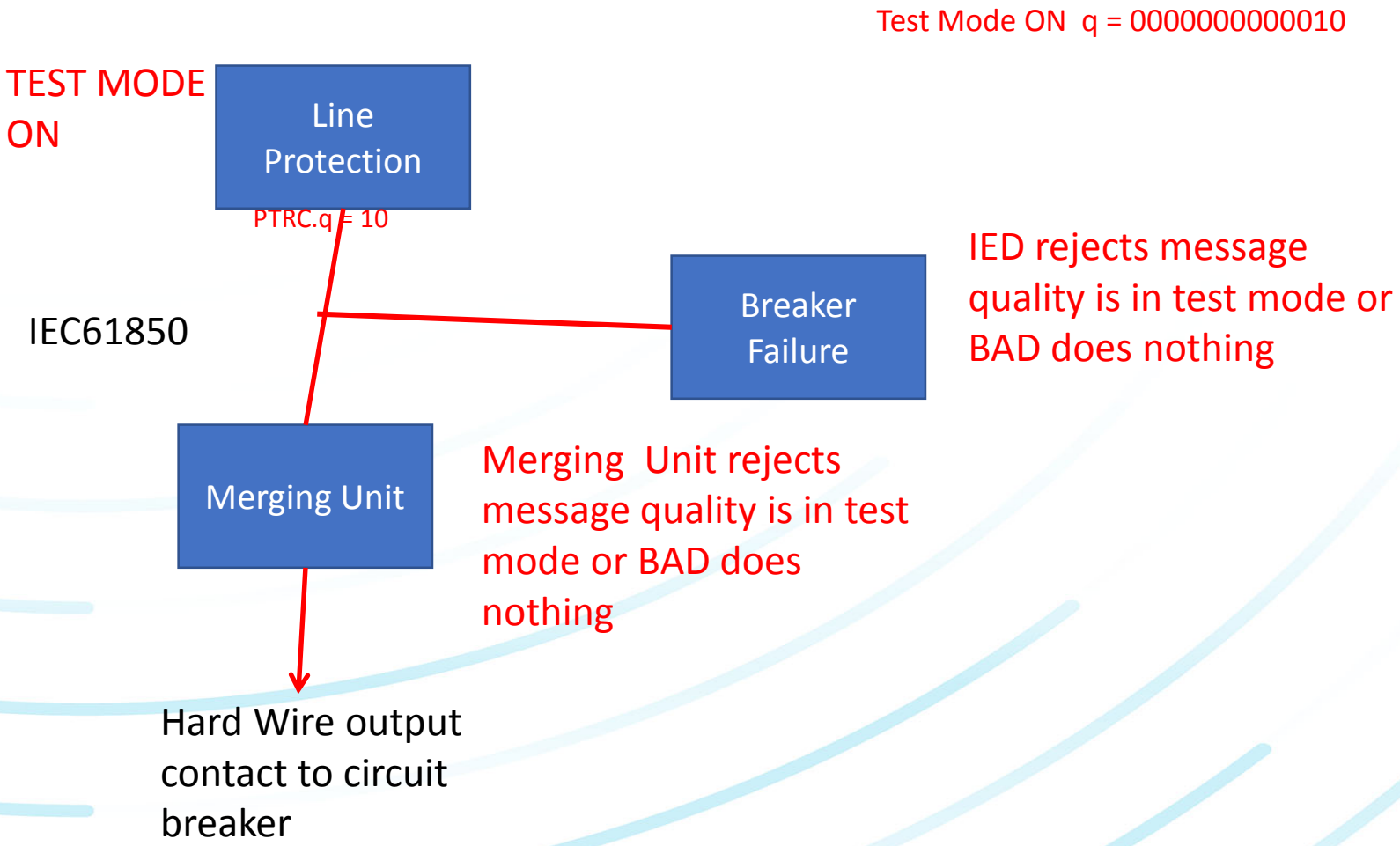
- Simulation mode can be enabled by using Logical Node LPHD and Data Object SIM. LPHD.SIM.stVal=TRUE
- To allow the IED to process the simulated message instead of actual message
- Not only applies to GOOSE, but Sampled Values as well



IEC 61850-7-1

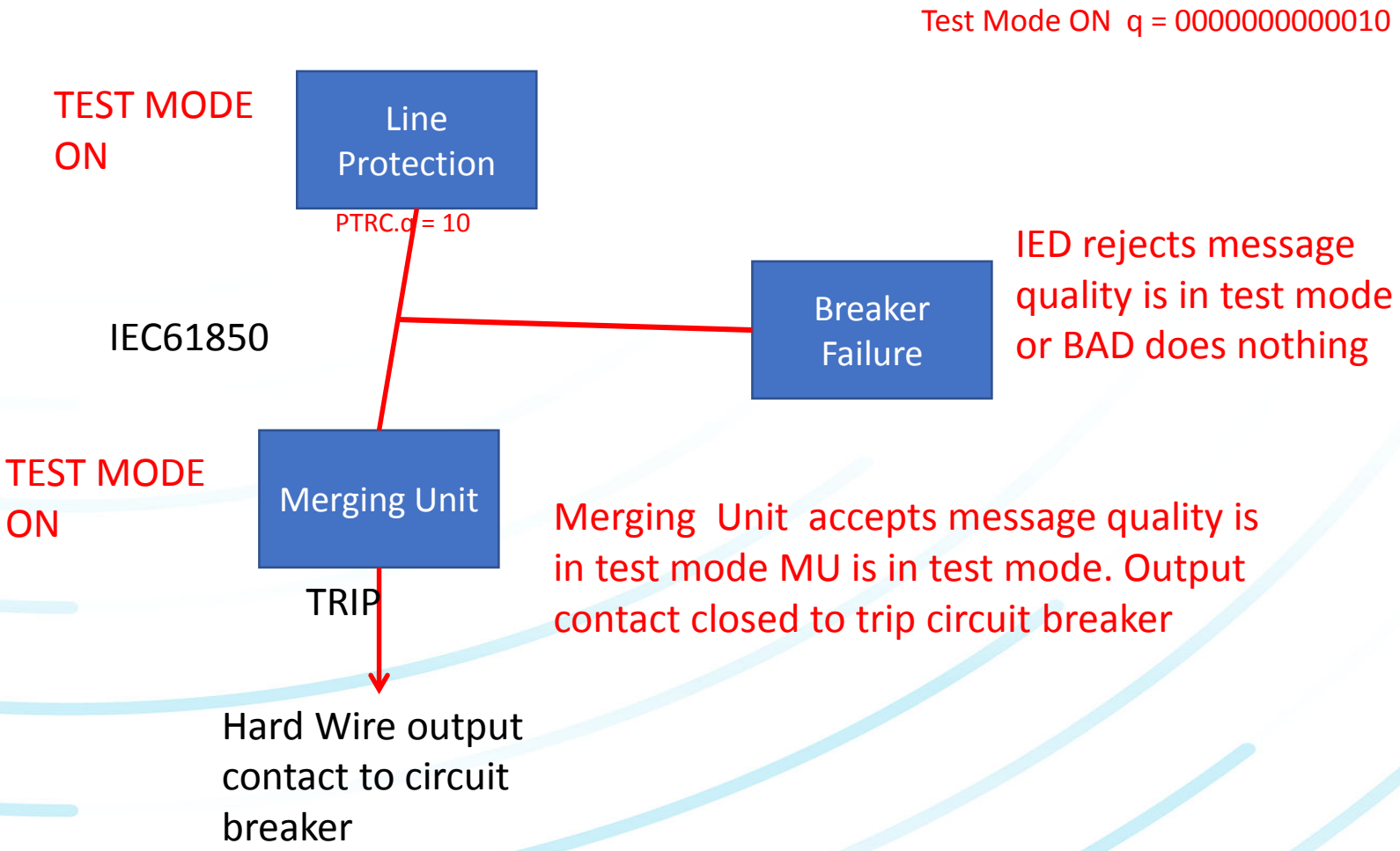
IEC 61850 Testing Functionality – Example 1

Example 1: Test Mode in Single Device



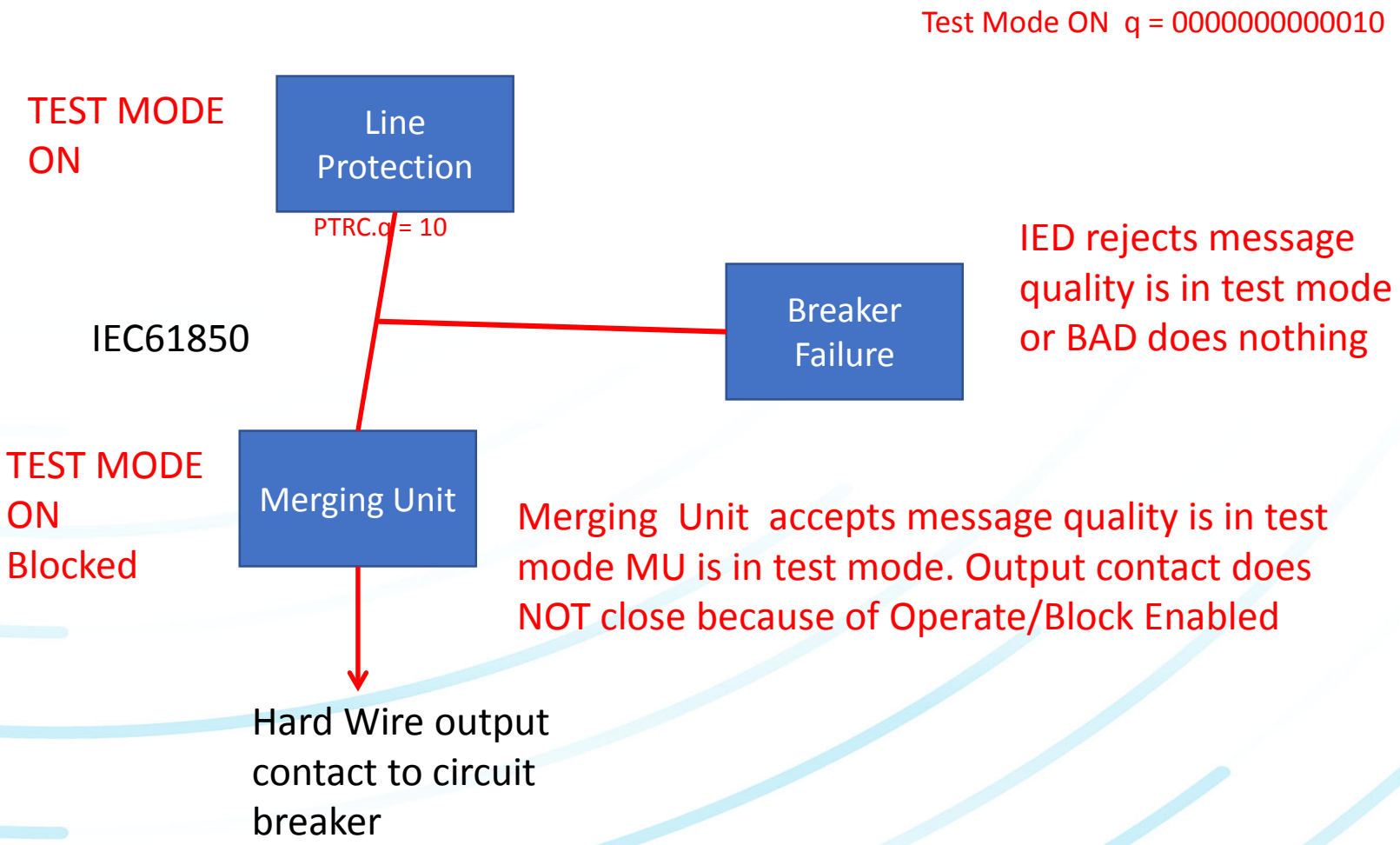
IEC 61850 Testing Functionality – Example 2

Example 2: Test Mode in Two Devices



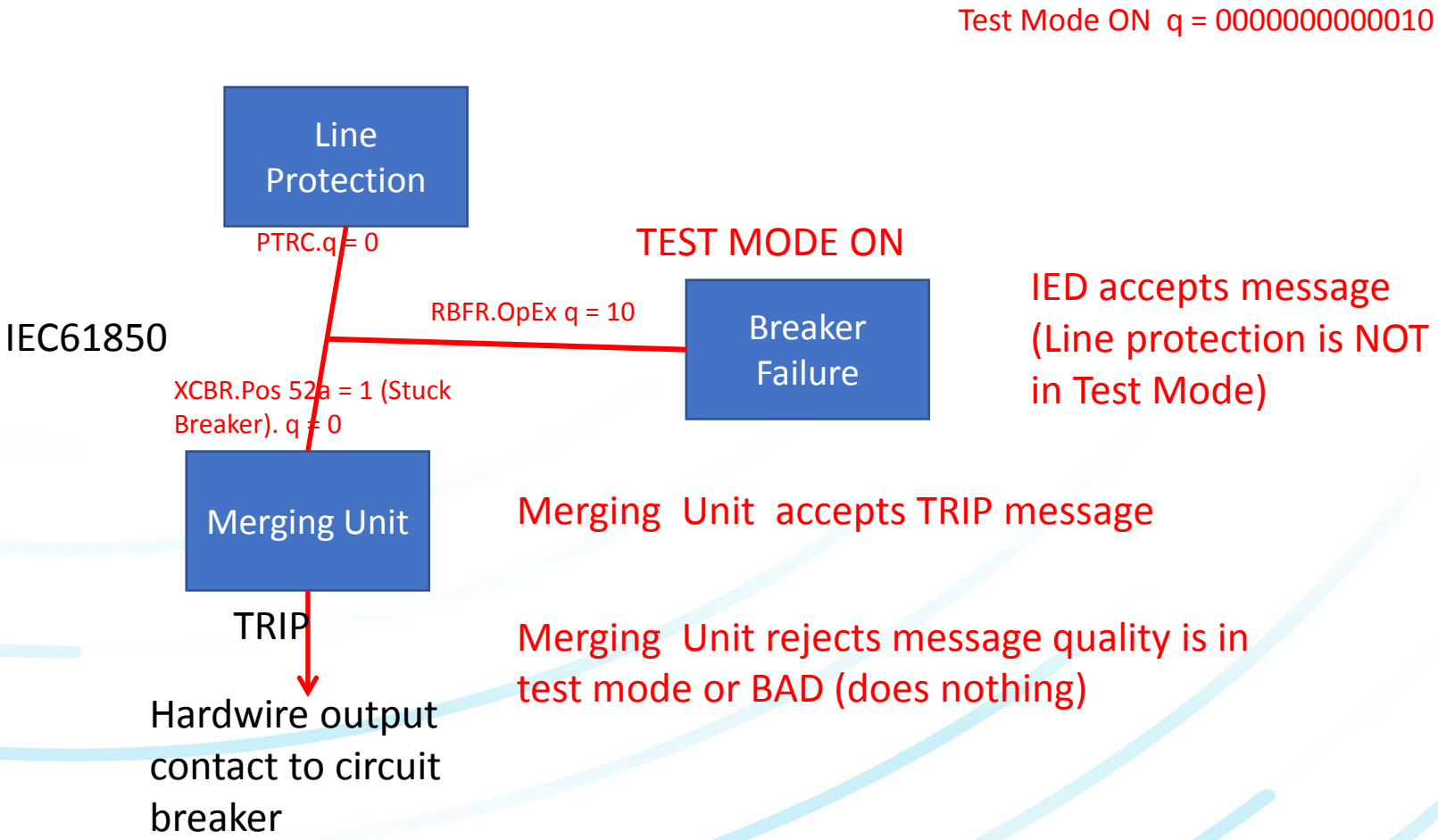
IEC 61850 Testing Functionality – Example 3

Example 3: Test Mode/Blocked

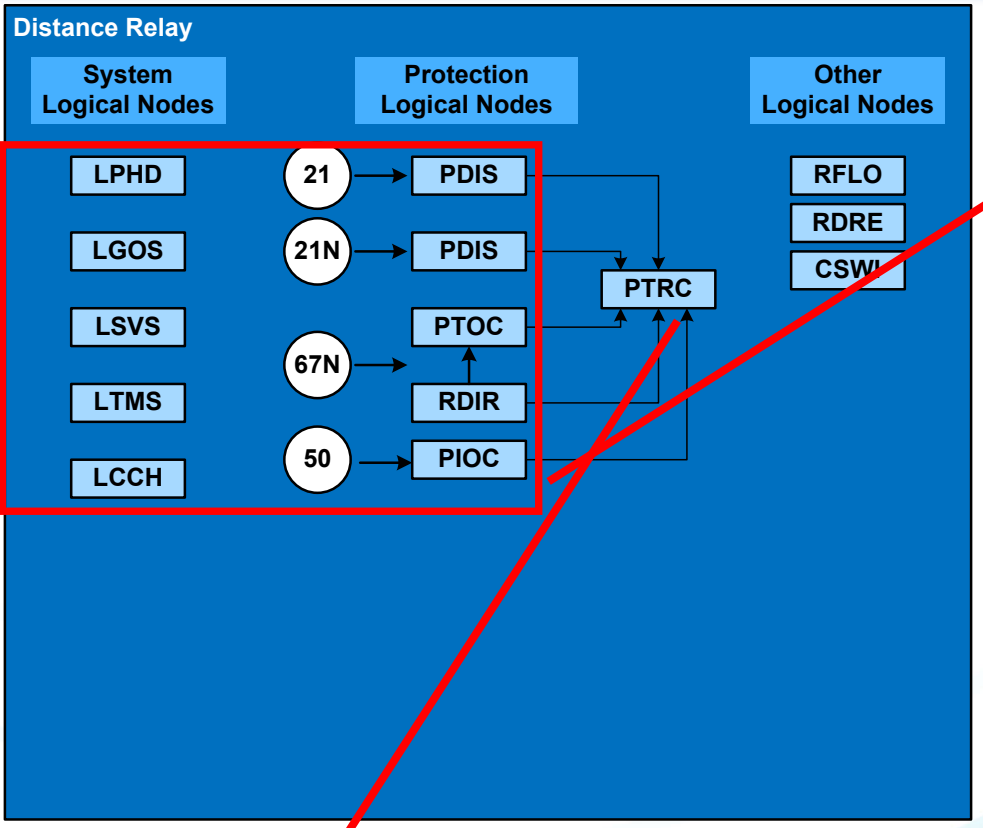


IEC 61850 Testing Functionality – Example 4

Example 4: In Service Test Mode with Stuck Circuit Breaker



IEC 61850 Data Model Approach to Testing Line



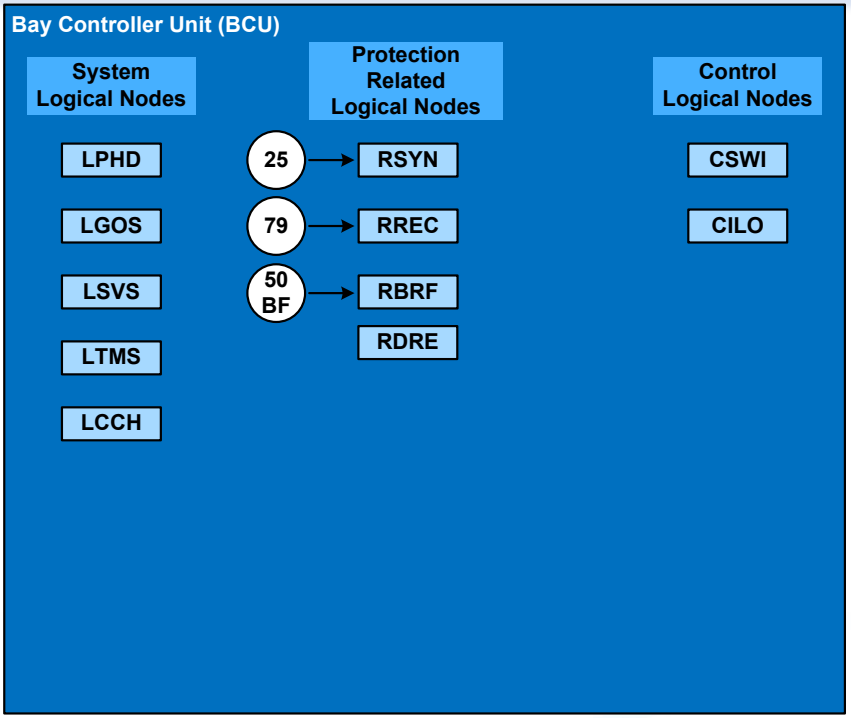
Normal Service GOOSE Message

IEC 61850-7-4 Logical Node/DO	IEEE C37.2	Comments
PTRC1.Op	94	Trip
PSCH1.Tx	85	Carrier/Pilot Scheme POTT

Testing GOOSE Message

IEC 61850-7-4 Logical Node/DO	IEEE C37.2	Comments
LLN0.Mod	-	Test Mode
LPHD.Sim	-	Simulation Mode
LCCH1.ChLiv	-	Channel/Port Status
EFPIOC1.Op	50	Directional Inst. Overcurrent
EFPTOC1.Str	67N	Directional Time Overcurrent pick up
EFPTOC1.Op	67N	Directional Time Overcurrent Trip
PHPDIS1.Op	21	Zone 1 Phase Line Imp. Distance Trip
GNDPDIS1.Op	21N	Zone 1 Ground Line Imp. Distance Trip
PHPDIS2.Op	21	Zone 2 Phase Line Imp. Distance Trip
GNDPDIS2.Str	21N	Zone 2 Ground Line Imp. Distance Pick Up
STBPTOC1.Op	51	Stub Bus Time Overcurrent Trip
STBPTOC1.Str	51	Stub Bus Time Overcurrent Pick Up

IEC 61850 Data Model Approach to Testing Bay Control



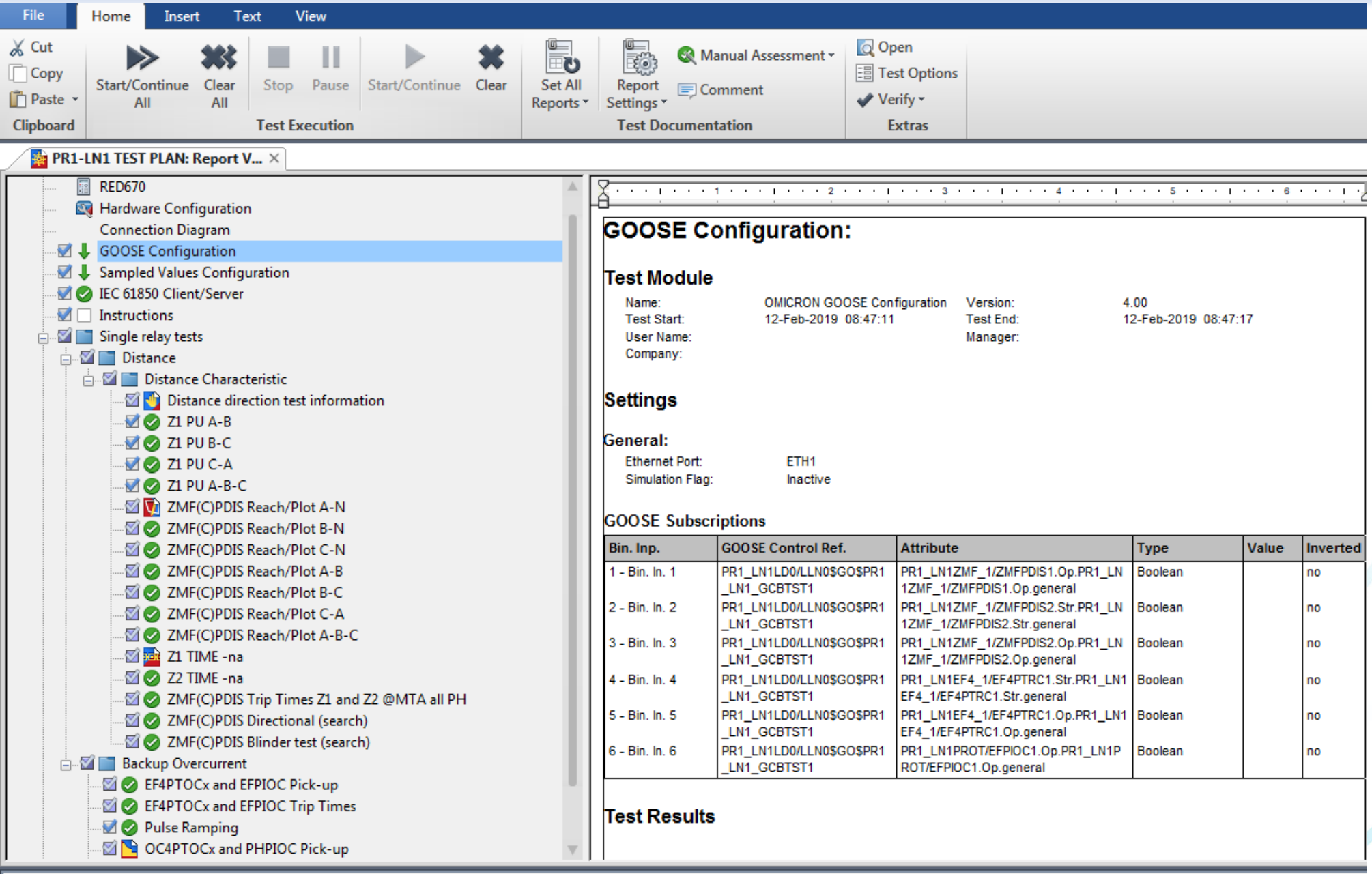
Normal Service GOOSE Message

IEC 61850-7-4 Logical Node/DO	IEEE C37.2	Comments
RBRF1.OpEx	50BF	Breaker Failure External Trip
RBRF1.OpIn	50BF	Breaker failure Re-Trip
RREC1.OpCls	79	AutoReclose Close Command
CSWI.OpOpn	-	Control Open command
CSWI.OpCls	-	Control Close command

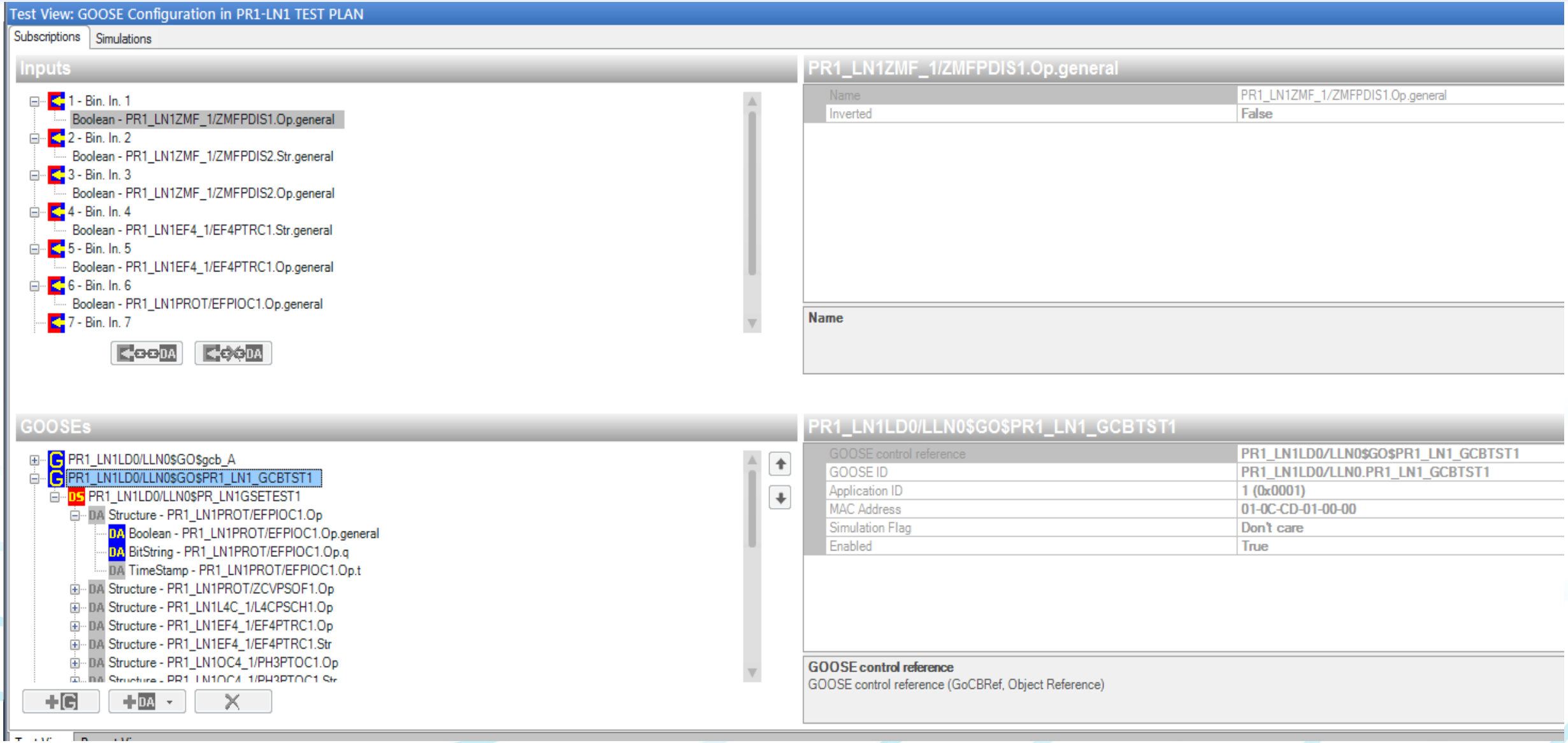
Testing GOOSE Message

IEC 61850-7-4 Logical Node/DO	IEEE C37.2	Comments
LLN0.Mod	-	Test Mode
LPHD.Sim	-	Simulation Mode
LCCH1.ChLiv	-	Channel/Port Status
SYNRSYN1.REL	25	Synch Check
SYNRSYN1.FailSynch	25	Synch Check fail
SYNRSYN1.SynPrg	25	Synch Check in Progress
SYNRSYN1.VInd	25	Synch Check Voltage indication
RREC1.AutoRecSt	79	Auto Reclose Status
RREC1.PrgRec	79	Auto Reclose in Progress

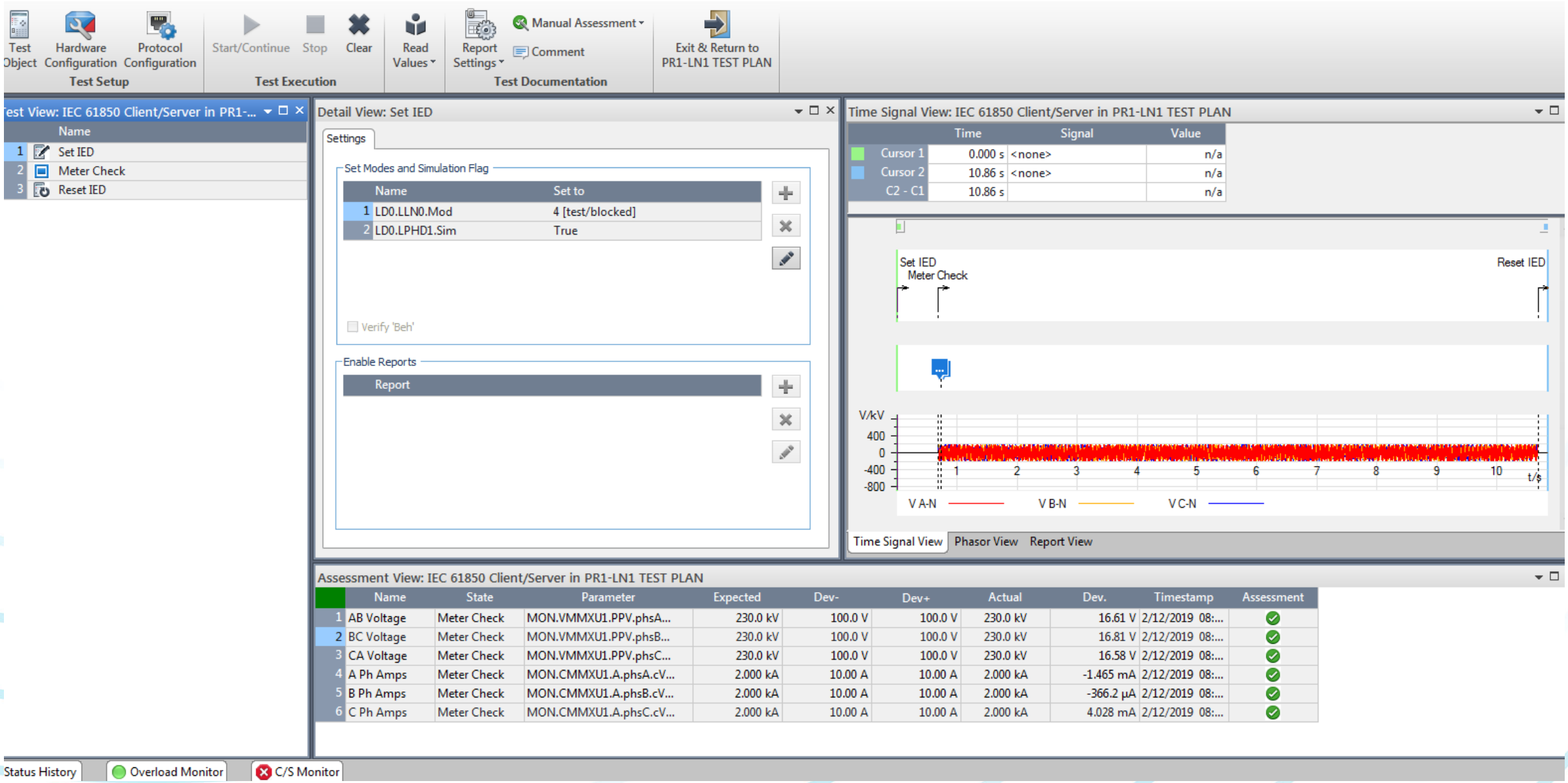
IEC 61850 Test Plan Example



IEC 61850 Test Plan Example – GOOSE Configuration



IEC 61850 Test Plan Example – Test Mode



IEC 61850 Test Plan Example – Zone 2 Operate

Table View: Z2 TIME -na in PR1-LN1 TEST PLAN

	1			2			3		
Name	PREFAULT			Z2 FAULT			POST FAULT		
V A-N	132.8 kV	0.00 °	60.000 Hz	160.9 kV	-15.87 °	60.000 Hz	0.000 V	0.00 °	60.000 Hz
V B-N	132.8 kV	-120.00 °	60.000 Hz	160.9 kV	-104.13 °	60.000 Hz	0.000 V	-120.00 °	60.000 Hz
V C-N	132.8 kV	120.00 °	60.000 Hz	230.9 kV	120.00 °	60.000 Hz	0.000 V	120.00 °	60.000 Hz
I A	0.000 A	0.00 °	60.000 Hz	2.000 kA	-52.20 °	60.000 Hz	0.000 A	0.00 °	60.000 Hz
I B	0.000 A	-120.00 °	60.000 Hz	2.000 kA	-232.20 °	60.000 Hz	0.000 A	-120.00 °	60.000 Hz
I C	0.000 A	120.00 °	60.000 Hz	0.000 A	0.00 °	60.000 Hz	0.000 A	120.00 °	60.000 Hz
CMC Rel	0 output(s) active			0 output(s) active			0 output(s) active		
Trigger		60.00 cy			60.00 cy			60.00 cy	

Detail View: Z2 TIME -na in PR1-LN1 TEST PLAN

Analog Out | Binary Out | Trigger | General

PREFAULT			
Set Mode	Direct		
V A-N	132.8 kV	0.00 °	60.000 Hz
V B-N	132.8 kV	-120.00 °	60.000 Hz
V C-N	132.8 kV	120.00 °	60.000 Hz
I A	0.000 A	0.00 °	60.000 Hz
I B	0.000 A	-120.00 °	60.000 Hz
I C	0.000 A	120.00 °	60.000 Hz

Force absolute phases

Time Signal View: Z2 TIME -na in PR1-LN1 TEST PLAN

	Time	Signal	Value
Cursor 1	0.0000 cy	<none>	n/a
Cursor 2	145.4940 cy	<none>	n/a
C2 - C1	145.4940 cy		n/a

Export COMTRADE ...

PREFAULT POST FAULT

Time Signal View | Phasor View | Impedance View | Report View

Time Assessments: Z2 TIME -na in PR1-LN1 TEST PLAN

	Time Assessment								
	Name	Ignore before	Start	Stop	Tnom	Tdev-	Tdev+	Tact	Tdev	Assessment
1	Z2 TIME TEST	Z2 FAULT	Z2 FAULT	Z2 OP 0>1	24.00 cy	1.500 cy	1.500 cy	25.49 cy	1.494 cy	✓

Time Assessments | State Assessments

Thank You

Questions?