IEC 61850 Testing and Commissioning Advantages Using GOOSE Messaging

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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
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.

- **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.
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
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
Example 1: Test Mode in Single Device

IEC 61850 - Testing Functionality

- **Hard Wire output contact to circuit breaker**
- **Line Protection**
  - PTRC.q = 10
- **Merging Unit**
  - IED rejects message quality is in test mode or BAD does nothing
- **Breaker Failure**
  - IED rejects message quality is in test mode or BAD does nothing

Test Mode ON  q = 0000000000010
Example 2: Test Mode in Two Devices

IEC 61850 Testing Functionality Example 2

IEC 61850

TEST MODE ON

Merging Unit

Line Protection

Breaker Failure

Test Mode ON \( q = 000000000010 \)

IED rejects message quality is in test mode or BAD does nothing

Merging Unit accepts message quality is in test mode MU is in test mode. Output contact closed to trip circuit breaker

Hard Wire output contact to circuit breaker

TRIP

PTRC.q = 10
Example 3: Test Mode/Blocked

Test Mode ON  $q = 0000000000010$

IED rejects message quality is in test mode or BAD does nothing

Merging Unit accepts message quality is in test mode. Output contact does NOT close because of Operate/Block Enabled

Hard Wire output contact to circuit breaker
Example 4: In Service Test Mode with Stuck Circuit Breaker

**Line Protection**

- PTRC.q = 0

**Breaker Failure**

- XCBR.Pos 52a = 1 (Stuck Breaker), q = 0
- RBFR.OpEx q = 10
- IED accepts message (Line protection is NOT in Test Mode)

**Merging Unit**

- TRIP
- Hardwire output contact to circuit breaker
- Merging Unit accepts TRIP message
- Merging Unit rejects message quality is in test mode or BAD (does nothing)

**IEC61850**

- TEST MODE ON q = 000000000010
IEC 61850 Data Model Approach to Testing Line Distance Relay

- **System Logical Nodes**: LPHD, LGOS, LSVS, LTMS, LCCH
- **Protection Logical Nodes**: PDIS, PTOC, PTRC, PTSC, RDIR, RDRE, CSWI

### Testing GOOSE Message

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

Normal Service GOOSE Message

- **PTRC1.Op**: 94, Trip
- **PSCH1.Tx**: 85, Carrier/Pilot Scheme POTT
IEC 61850 Data Model Approach to Testing Bay:

### System Logical Nodes
- LPHD
- LGOS
- LSVS
- LTMS
- LCCH

### Protection Related Logical Nodes
- 25 RSYN
- 79 RREC
- 50 BF RBRF
- RDRE

### Control Logical Nodes
- CSWI
- CILO

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<td>LCCH1.ChLiv</td>
<td>-</td>
<td>Channel/Port Status</td>
</tr>
<tr>
<td>SYNRSYN1.REL</td>
<td>25</td>
<td>Synch Check</td>
</tr>
<tr>
<td>SYNRSYN1.FailSynch</td>
<td>25</td>
<td>Synch Check fail</td>
</tr>
<tr>
<td>SYNRSYN1.SynPrg</td>
<td>25</td>
<td>Synch Check in Progress</td>
</tr>
<tr>
<td>SYNRSYN1.VInd</td>
<td>25</td>
<td>Synch Check Voltage indication</td>
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<tr>
<td>RREC1.AutoRecSt</td>
<td>79</td>
<td>Auto Reclose Status</td>
</tr>
<tr>
<td>RREC1.PrgRec</td>
<td>79</td>
<td>Auto Reclose in Progress</td>
</tr>
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<td>RBRF1.OpEx</td>
<td>50BF</td>
<td>Breaker Failure External Trip</td>
</tr>
<tr>
<td>RBRF1.OpIn</td>
<td>50BF</td>
<td>Breaker failure Re-Trip</td>
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<tr>
<td>RREC1.OpCls</td>
<td>79</td>
<td>AutoReclose Close Command</td>
</tr>
<tr>
<td>CSWI.OpOpn</td>
<td>-</td>
<td>Control Open command</td>
</tr>
<tr>
<td>CSWI.OpCls</td>
<td>-</td>
<td>Control Close command</td>
</tr>
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</table>
IEC 61850 Test Plan Example
IEC 61850 Test Plan Example

GOOSE Configuration

[Image of a software interface showing GOOSE Configuration for IEC 61850]
IEC 61850 Test Plan Example: Mode

Test View: IEC 61850 Client/Server in PRI-LN1 TEST PLAN

Detail View: Set IED

Settings:
- Set Nodes and Simulation Flag
  - LD0.LLN03.Rol
  - LD0.LLN03.Sim

Enable Reports:
- Report

Assessment View: IEC 61850 Client/Server in PRI-LN1 TEST PLAN

<table>
<thead>
<tr>
<th>Name</th>
<th>State</th>
<th>Parameter</th>
<th>Expected</th>
<th>Dev</th>
<th>Dev</th>
<th>Actual</th>
<th>Dev</th>
<th>Timestamp</th>
<th>Assessment</th>
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</thead>
<tbody>
<tr>
<td>APh Amps</td>
<td>Meter Check</td>
<td>MON.COM001.APheA.CV+</td>
<td>2.000 kA</td>
<td>0.00</td>
<td>0.00</td>
<td>2.000 kA</td>
<td>0.00</td>
<td>2/12/2019</td>
<td>X</td>
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<tr>
<td>BPh Amps</td>
<td>Meter Check</td>
<td>MON.COM001.APheB.RV+</td>
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<td>0.00</td>
<td>2.000 kA</td>
<td>0.00</td>
<td>2/12/2019</td>
<td>X</td>
</tr>
<tr>
<td>CPh Amps</td>
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<td>MON.COM001.APheC.CV+</td>
<td>2.000 kA</td>
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IEC 61850 Test Plan Example 2 Operate
Thank You

Questions?