# IEC 61850 Interoperability Testing
## Oct 2019

## Charlotte, NC USA

# Final Test Report

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# 1 Executive Summary

Figure 1: 2019 IOP

The 2019 IEC 61850 Interoperability (IOP) Testing activity represented the most aggressive testing campaign in the series of UCA IUG sponsored activities dating back to 2011. The previous testing activities in 2011, 2013, and 2015 concentrated on interoperability testing one-to-one between individual IEDs and/or applications. At the request of IEC 61850 vendors and utilities, requested testing an "integrated application" in 2017. The emphasis of testing through the lens of an integrated application continued in 2019.

There were two major areas of testing:

- An integrated application, including but not limited to:
    - SCL Engineering Process
    - SCL ICD verification
    - Client/Server
    - GOOSE

  - Sampled Values
  - Security
  - PTP
  - Substation Maintenance

- Substation Configuration Language (SCL) tool testing (SED exchange).

There was a major emphasis on using the integrated application to represent a digital utility utilizing Sampled Value merging units.  There were ten (10) merging units split across HSR and PRP process bus networks that exchanged information between each other in order to provide information to protection relays that supported the other technology.  Station Bus was PRP.  PTP Grandmaster, boundary, and ordinary clocks were distributed throughout the network with synchronization being provided from Station Bus to Process Bus.

The highlight of testing was using the integrated application was used to demonstrate differential protection, utilizing Sample Values,  with the following control center Single Line Diagram (SLD) being used to monitor the substation (see page 41).

Other test areas were cyber security, protection scheme testing, simulation, maintenance isolation, and time synchronization.  There were several “firsts” achieved:

- Secured layer 2 GOOSE (encrypted and signed) were exchanged;
- IEC 61850 Key Distribution was tested.

## 1.1 Participation

The participation in the 2019 IOP was lower than the participation in 2017.

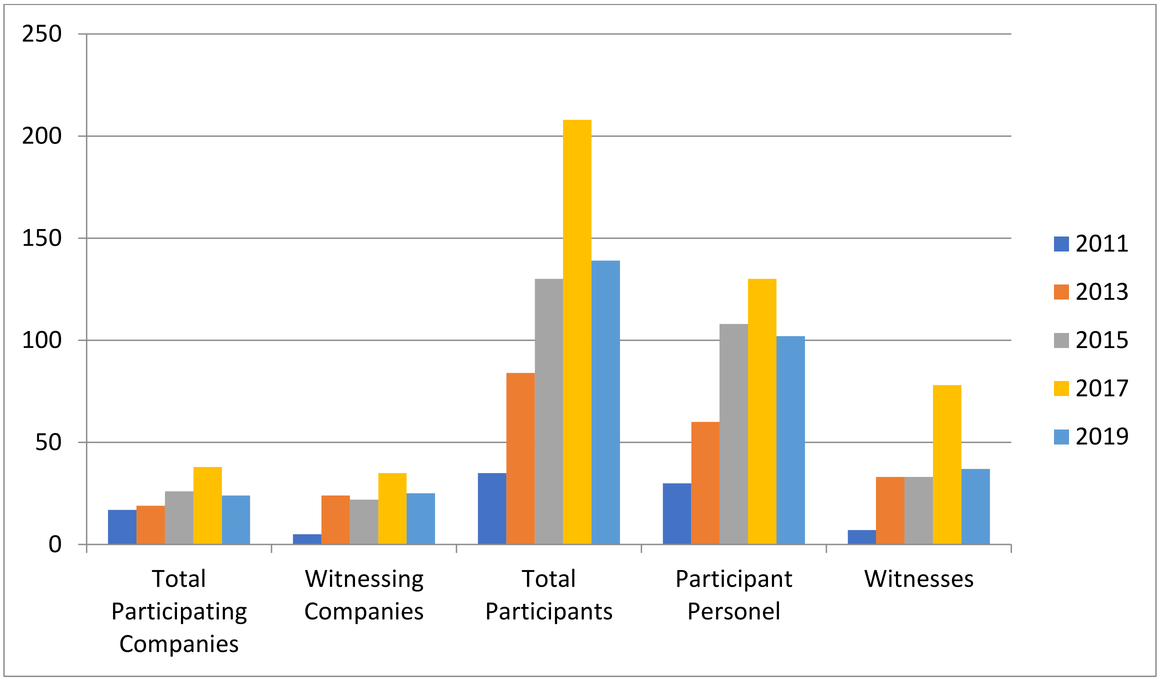


**Figure 2: Participation in 2017 IOP versus past IOPs**

There were 24 total participating companies and 25 witnessing companies. There was a drop-off in attendance since this was the second IOP in the United StatesTable 1 shows that many of the participating companies were also participants in 2017, but some from 2017 did not attend.

The IOP was a global activity and the following chart shows the countries that were represented.

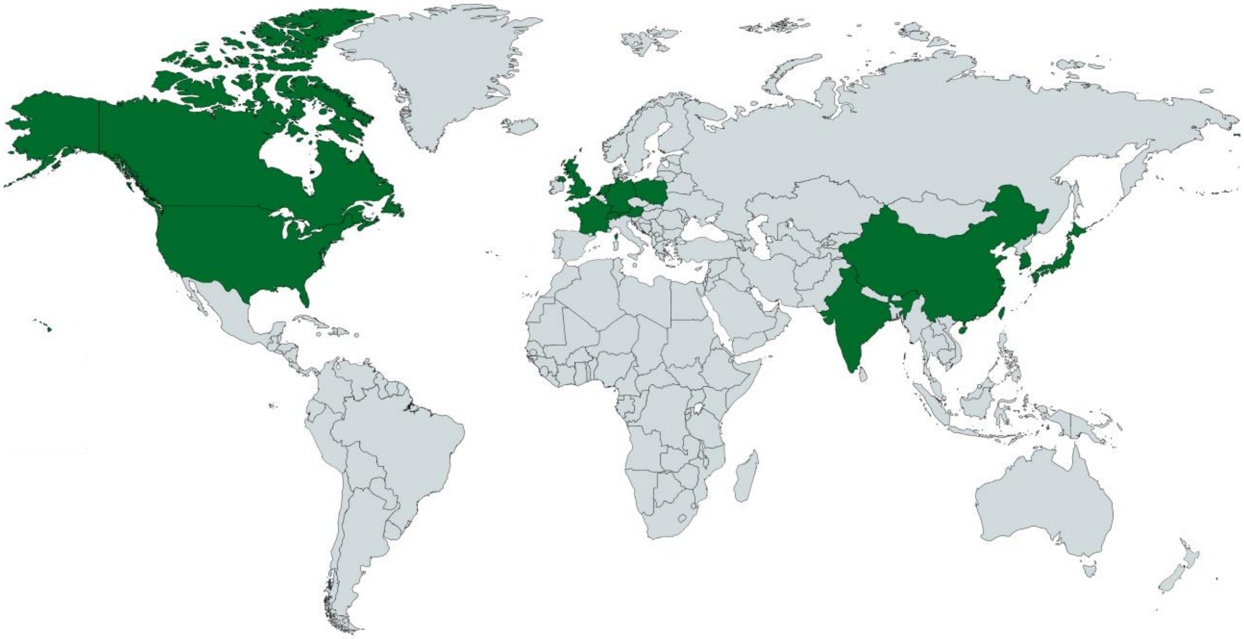


Figure 3: Global Company Distribution at IOP (Green)

| | Year of Participation | | | | |
|---|---|---|---|---|---|
| Participant | 2011 | 2013 | 2015 | 2017 | 2019 |
| ABB | | x | x | x | x |
| Alstom(now GE) | x | x | x | x | x |
| ARC Informatique | x | x | x | | x |
| Belden/Hirschman | x | | | x | |
| CISCO | | x | | x | x |
| CopaData | | | x | x | x |
| CYG Sunri | | | | x | |
| Doble | | | x | x | x |
| DoWoo Digitech | | | | x | |
| Efacec | x | x | x | | |
| ERLPhase | | | | x | |
| General Electric | x | x | x | x | x |
| Helinks | | x | x | x | x |
| JPEmbedded | | | | | x |
| Kalkitech | | | x | x | x |
| KEPCO | | | | x | x |

| | Year of Participation | | | | |
|---|---|---|---|---|---|
| Participant | 2011 | 2013 | 2015 | 2017 | 2019 |
| KERI | | | | | x |
| Koncar | | | x | | |
| Meinberg Radioclocks | | | | x | |
| Moxa | | | x | x | |
| NovaTech | | | x | x | x |
| NR Electric | | | x | x | x |
| OMICRON | | x | x | x | x |
| OPAL-RT | | | | x | |
| OSIsoft | x | | | x | |
| Palo Alto Networks | | | | x | |
| PCItek | | | | | x |
| Reinhausen | | | | x | |
| RTDS | x | x | x | x | x |
| SAC China | | | | x | |
| Schneider Electric | x | x | x | | |
| Schweitzer Engineering Laboratories | x | x | x | x | x |
| Sertel Electronics | | | x | | |
| Siemens | x | x | x | x | x |
| Siemens/RuggedCom | x | X | x | x | x |
| Sifang | | | | | x |
| SISCO | x | x | x | x | x |
| Subnet Solutions | | | x | x | |
| SystemCORP Embedded Technology | | | | x | |
| Toshiba | x | x | x | x | x |
| Triangle Microworks | x | x | x | x | x |
| Vizimax | | | x | x | x |
| WAGO | | | | x | |
| Xelas | | | x | x | |

Table 1: 2017 Participants and their participation in past IOPs

Table 2 shows the witnessing company participation in the 2017 IOP and the company's past participation.

| | Year of Participation | | | | |
|---|---|---|---|---|---|
| Participant | 2011 | 2013 | 2015 | 2017 | 2019 |
| AEP | | | | x | x |
| Amprion GmbH | | | | x | |
| Bonnevile Power Administration | | | | x | |
| Center Point Energy | | | | x | |
| Centro de Investigação em Energia REN - STATE GRID | | | x | | |
| Central Research Institute of Electric Power Industry (CRIEPI) | | | | | x |
| ComEd | | | | x | x |
| Cyber Sciences | | | | x | |
| Dominion Energy | | | | x | |
| DNVGL | | x | x | x | x |
| EANDIS | | | | x | |
| EDF | x | x | x | x | x |
| Electronics Testing Center | | | | | x |
| Elia | | x | x | | |
| EMS/EMC | | x | x | | |
| Entergy | | | | x | |
| Entsoe | | x | x | | |
| ENSO Test | | | x | | |
| EPRI | | x | x | x | x |
| Entergy | | | x | x | |
| FMTP Power AB | | | x | | |
| GridClone | | | | x | x |
| Groupe Conseil PM SCADA Inc. | | | | x | |
| Hubell Power Systems | | | | | x |
| Hydro Quebec | | x | x | x | x |
| Hydro One | | | | | x |
| It4Power | | x | x | x | x |
| Joulz Energy Solutions | | | | x | |

| | Year of Participation | | | | |
|---|---|---|---|---|---|
| **Participant** | **2011** | **2013** | **2015** | **2017** | **2019** |
| **KERI** | | x | x | x | Participant |
| **KETOP** | | | | | x |
| **KTL** | | x | x | x | x |
| **Leidos Engineering** | | | | x | |
| **National Grid** | | | | x | x |
| **NIST** | | | | x | x |
| **NuGrid Power Corp** | | | | x | |
| **Pacific Northwest National Laboratories** | | | | x | x |
| **Power Grid Corporation of India** | | | | x | x |
| **Quanta Technology, LLC** | | | | x | |
| **RED Electrica de Espana** | x | x | x | | |
| **RTE** | | x | x | x | x |
| **SGEPRI** | | | | | x |
| **Southern California Edison (SCE)** | | | | x | x |
| **Southern Company** | | | | | x |
| **Salt River Project (SRP)** | | | | x | |
| **Stedin** | | | | | Registered but did not attend |
| **Taipower** | | | | | x |
| **TECNALIA** | | | | x | |
| **Tesco Automation** | | | x | | Registered but did not attend |
| **Tuv Rheinland** | | x | x | x | |
| **Tuv Sud** | | x | x | x | |
| **UCA IUG** | x | x | x | x | x |
| **Xanthus Consulting International** | | | | x | |
| **Zamerin** | | x | x | | x |

Table 2: 2019 Witnesses and their participation in past IOPs

It is through the efforts of the individuals, both witnessing and participating, that made the 2019 IOP a success.

Figure 4: The 2019 IOP Team

## 1.2 Integrated Application

The emphasis of the 2017 IOP was the engineering and deployment of an integrated application that consisted of one (1) substations and one control center. The substation engineering was performed as two different projects which were: High and Low voltage. The engineered solution provided an environment was created that supported the testing of protection schemes, cyber security, SCADA monitoring, SCADA control, as well as substation maintenance and isolation of equipment.

The control center and substation were their own Electronic Security Perimeter. The connection between the two areas was done through the use of routers and firewalls at the edge of each area.  The connection between the areas supported the routing protocols as shown in Figure 5.

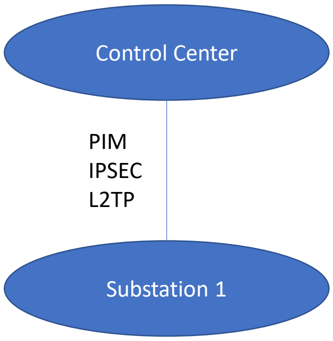


**Figure 5: High Level Routing Network Design**

For further information regarding the network design and the support of PRP and HSR, see page 32.

The network was designed to support the following Single Line Diagram/application.

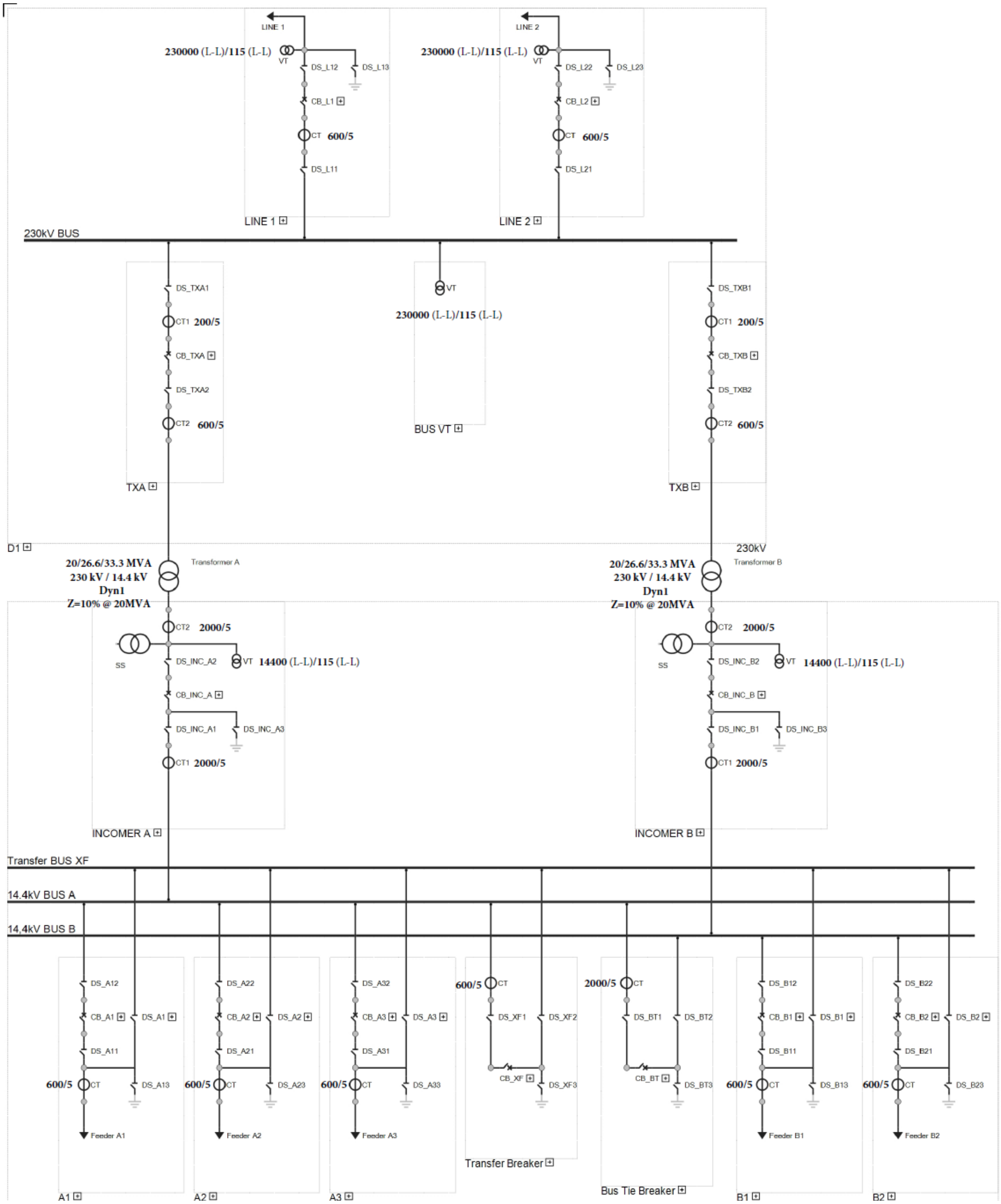
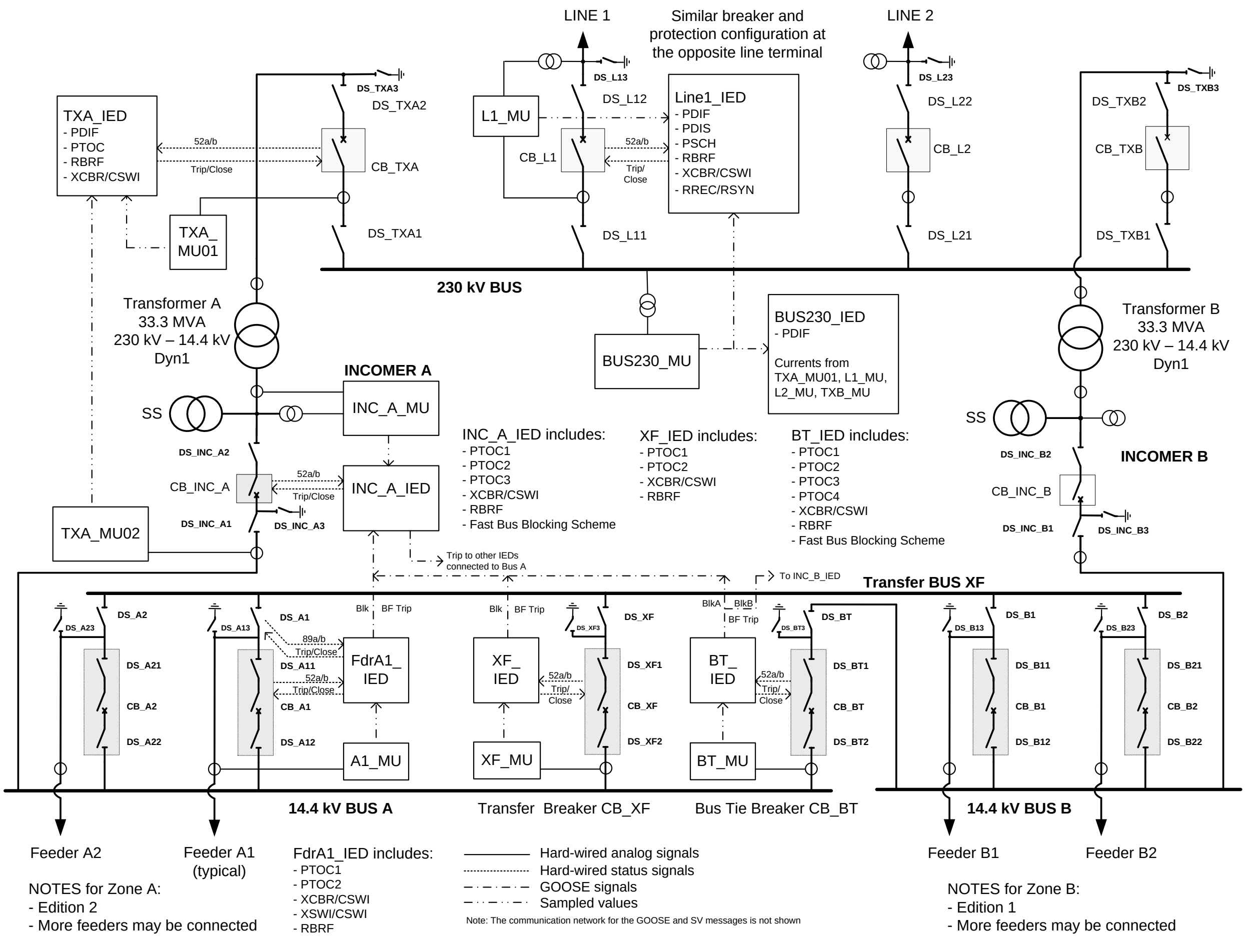


Figure 6: HLD Single Line Diagram



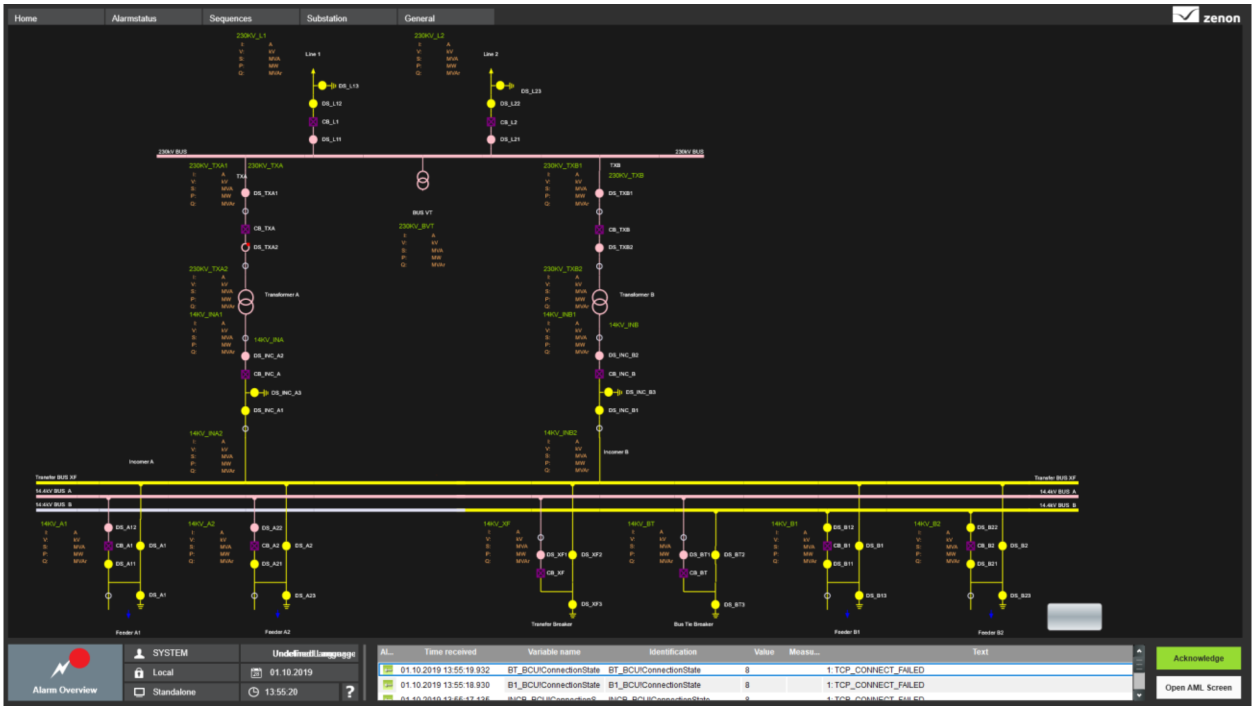
NOTES for Zone A:
- Edition 2
- More feeders may be connected

FdrA1_IED includes:
- PTOC1
- PTOC2
- XCBR/CSWI
- XSWI/CSWI
- RBRF

NOTES for Zone B:
- Edition 1
- More feeders may be connected

Figure 7 Partial Single Line Diagram showing typical objects, devices and signals

Besides device interoperability, protection scheme testing was done using the following SCADA/HMI display.



```
Al...  Time received            Variable name             Identification            Value  Measu...  Text
       01.10.2019 13:55:19.932  BT_BCU!ConnectionState    BT_BCU!ConnectionState    8                1: TCP_CONNECT_FAILED
       01.10.2019 13:55:18.930  B1_BCU!ConnectionState    B1_BCU!ConnectionState    8                1: TCP_CONNECT_FAILED
```

Figure 8: SCADA/HMI display for Integrated Application

SCL design of the system was done utilizing two System Configuration Tools (SCTs) provided by Helinks and ASE/Kalkitech. These companies also provided the actual engineering of system in addition to the tools. In past IOPs, the SCL engineering caused an extensive delay in the staging and integration of the application. In 2019, SCL delays were due to issues with the vendor ICDs and one tool being under revision. However, the initial delays were minimal. Other problems occurred during the iterative process and merging of replacement ICDs.

Of a greater issue was network flooding created by:

- A device PRP's implementation acting as a PRP Bridge
- Another device publishing the same GOOSE on the process Bus and station bus. Since there was only a single VLAN utilized for GOOSE, regardless of process bus/station bus, this created a loop.

The network flooding was difficult to diagnose, isolate, and correct. Therefore, care needs to be taken in network design and staging. Staging should occur in steps so that the network can be verified. Unfortunately, due to time constraints, the IOP network was integrated all at once.

The distribution issues encountered are shown in Figure 2:

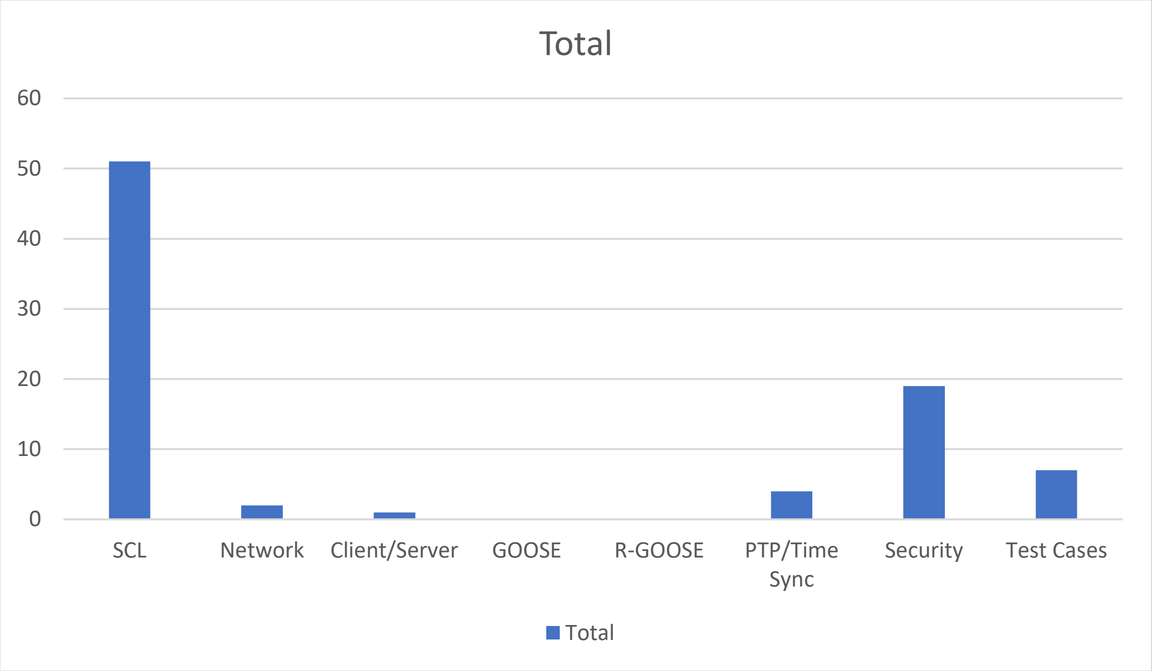


Figure 9: Total Number of Issues Reported by Category

There were eight-four (84)  total issues reported. Twenty-three of these issues were reviewed and classified as implementation issues.  The following sections details non-implementation testing areas/campaigns issues.

A comparison of the issues from the various interop is shown in the following table and charts.

| Interop Year | | | | |
|---|---|---|---|---|
| **Item** | 2013 | 2015 | 2017 | 2019 |
| **Total number of issues** | 82 | 38 | 57 | 84 |
| **SCL** | 58 | 24 | 32 | 52 |
| **8-1 Client/Server** | 15 | 9 | 9 | 1 |
| **GOOSE** | 5 | 0 | 6 | 0 |
| **R-GOOSE** | Not Tested | Not Tested | 3 | 0 |
| **Sampled Values** | 2 | 2 | 2 | 0 |
| **R-SV** | Not Tested | Not Tested | Demonstrated | 0 |
| **Security** Client/Server | Not Tested | Not Tested | 7 | 11 |

| | | | | |
|---|---|---|---|---|
| R-GOOSE | Not Tested | Not Tested | Not Tested | 3 |
| Key Management | Not Tested | Not Tested | Not Tested | 5 |
| **Time Sync** | Not Tested | 1 | 11 | 4 |
| **Network** | 2 | 2 | 2 | 2 |

Table 3: Comparison Table of Issues from IOPs

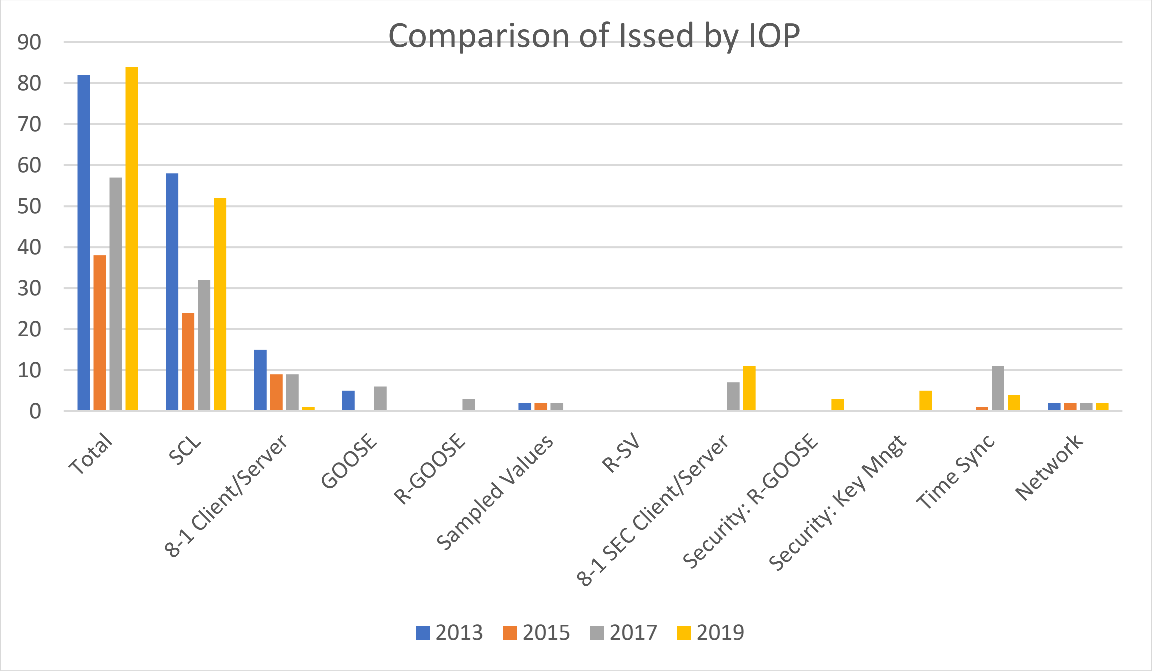


Figure 10: Comparison Graph of Issues from IOPs

The comparison shows a substantial increase in issues reported on SCL, due in large part to a major emphasis on SCL and engineering of the Integrated Application. The other reason for such an increase is the SCL validation tool maturity is increasing and detecting more issues.

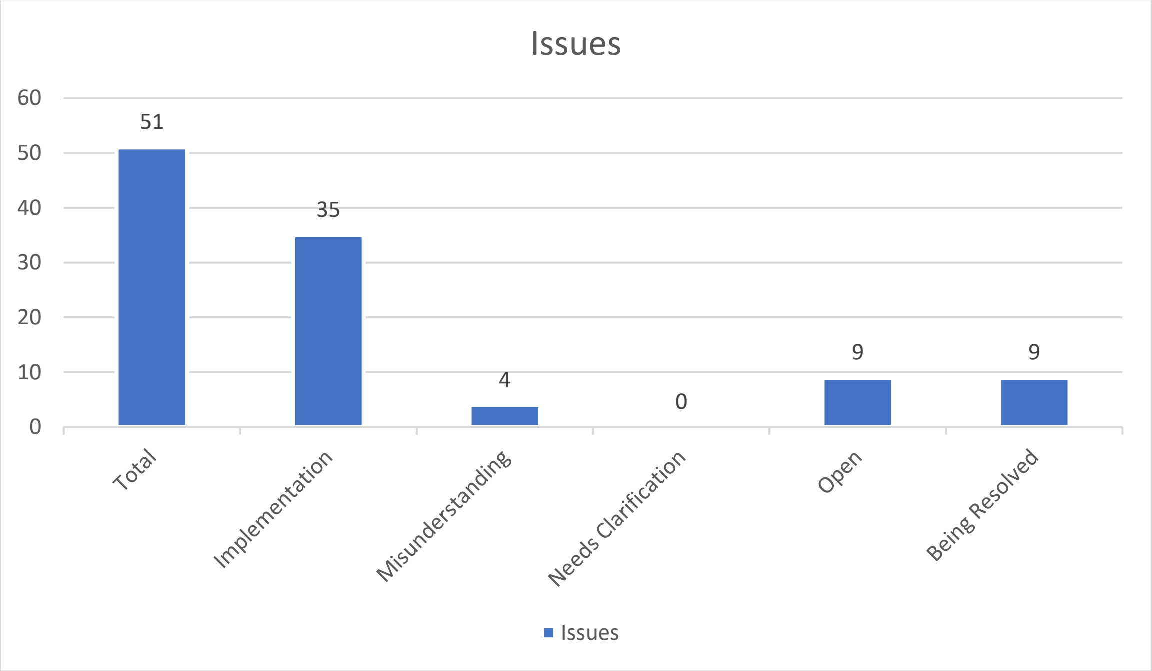


Figure 11: Analysis of SCL Issues

The analysis of SCL issues provides a glimpse that approximately 43% of the reported issues were implementation issues. A total of 76% of the issues were either implementation errors or misunderstanding of the standard. Some of the implementation and misunderstanding issues were considered enough of an issue to be referred to IEC TC57 WG10 for resolution. Of the 18 reported to WG10, 9 have solutions already. Pre-IOP testing of vendor SCL ICD files still indicates that the ICDs still are the major source of issues. Therefore, the UCAIug Test Procedure Working Group is in the process of requiring SCL ICD validation as part of the normal conformance testing process.

The following sections have tables that provide a description of reported

## 1.3 Security

In 2019, the following aspects of IEC 61850 security were tested:

- Client/Server
- Layer 2 GOOSE security (new)
- Routable GOOSE Security
- Key Distribution and Management (new)

There were a total of 19 recorded Security related issues at the IOP. Some of the issues were implementation issues due to mis-understanding. Thus, they were categorized in multiple categories.

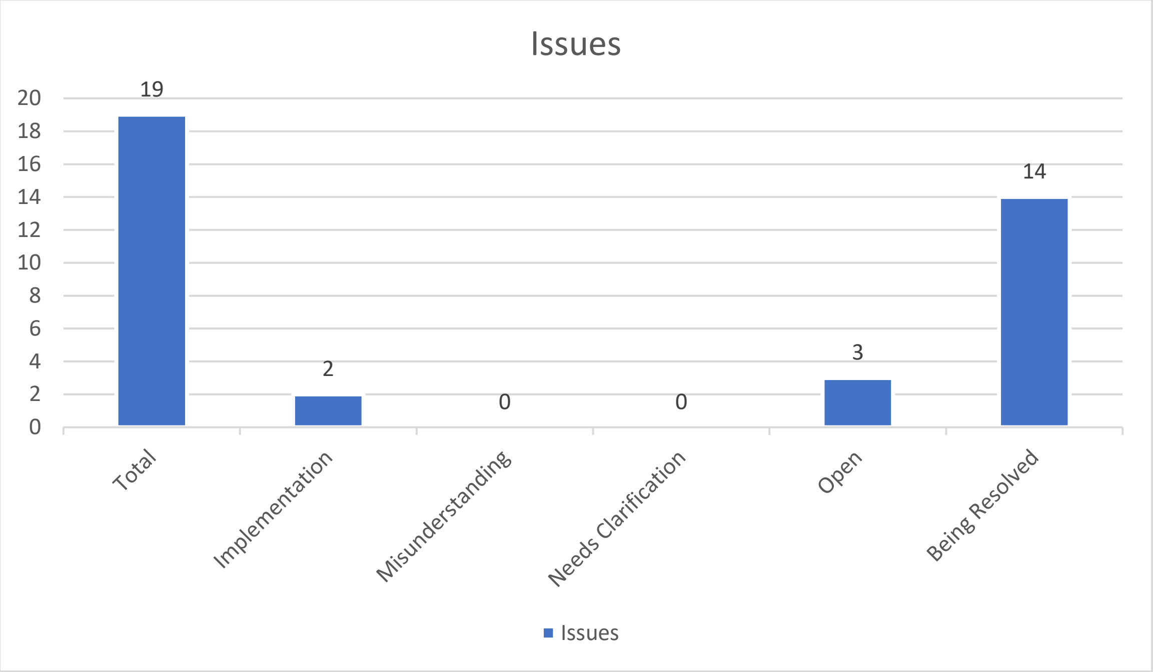


Figure 12: Analysis of Security Issues by Type

The following figure shows the distribution of issues based upon standards that will require revision to standards.

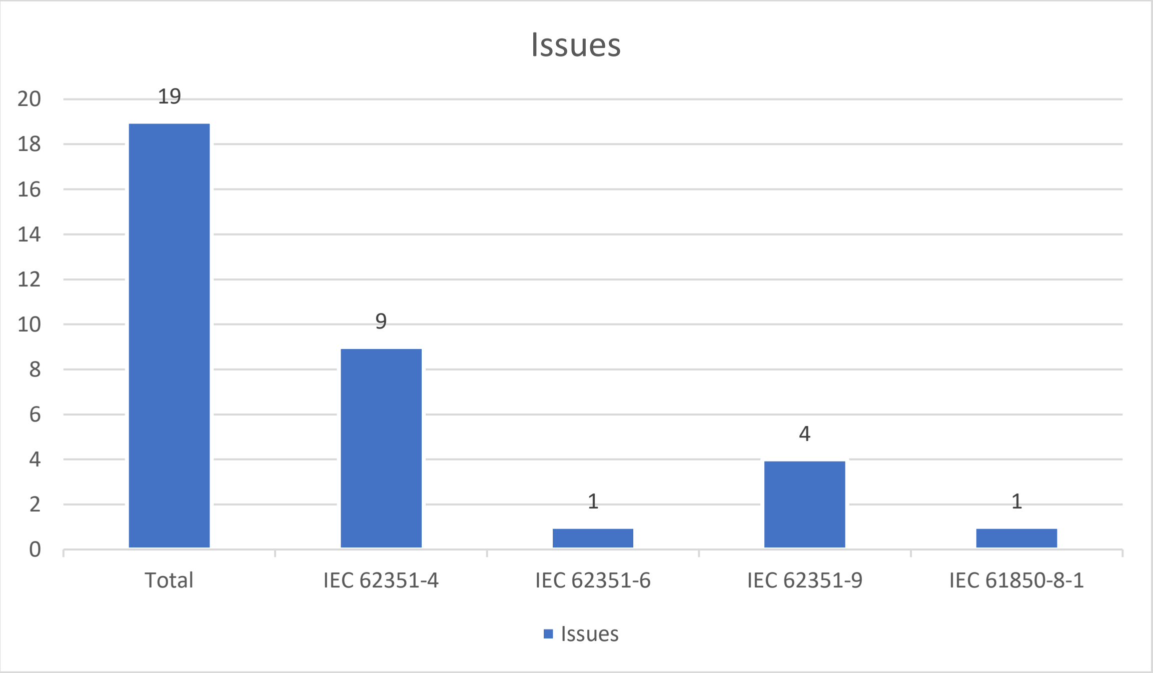


Figure 13: Distribution of Issues vs Standards Needing Revision

Of the 19 issues, 9 were logged due to backward compatibility issues introduced due to the recent revision of IEC 62351-4. An amendment is being created for IEC 62351-4 that provides the needed backward compatibility. IEC 62351-6 will be revised to resolve the issue once the amendment to IEC 62351-4 is stable.

The 2019 IOP was the first IOP that actually tested interoperability of IEC 62351-9 key distribution and 4 issues were found in the standards specified for IEC 61850 multicast key distribution. The editor of IEC 62351-9 has captured and agreed to issues/solutions proposed by the IOP and IEC 62351-9 is beginning a revision process.

## 1.4 SCL

The SCL validation of vendor ICDs was done prior to the start of the IOP. However, the quality of the ICDs is still lacking and as a result, the UCAIug TPWG is undertaking to improve the conformance test procedures to include validation of the ICDs.

There were a total of 52 recorded SCL related issues at the IOP. Some of the issues were implementation issues due to mis-understanding. Thus, they were categorized in multiple categories. Therefore, the following chart appears to have more that the recorded number of errors.

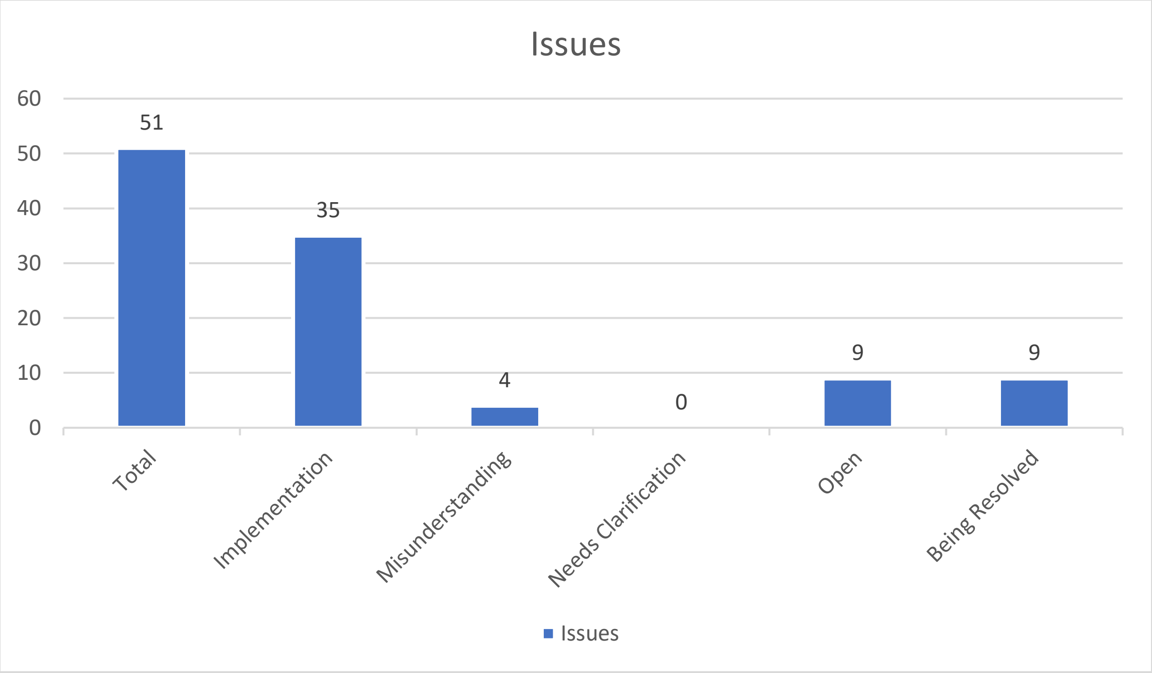


Figure 14: Distribution SCL Issues

## 1.5 Precision Time Protocol (PTP)

The following table shows the companies that declared providing PTP clocks and/or compatible applications.

| Company | | | | |
| --- | --- | --- | --- | --- |
| | Time Sync | | | |
| | GM | BC | TC | Slave |
| GE | x | x | x | x |
| ABB | | x | x | x |
| SEL | x | | x | x |
| VIZIMAX | x | | | x |
| SIFANG | | | | x |
| DOBLE | x | | | x |
| JPE | | | | x |
| SIEMENS | x | x | x | x |
| RTDS | x | | | x |
| Toshiba | | | x | x |
| OMICRON | x | | | x |
| NR | x | | | x |
| CISCO | | x | x | x |

Table 4: IOP PTP Providers of Clocks and Compatible IEDs

There were 13 companies that provided IEC 61850-9-3/ IEEE C37.238  compatible equipment. There were 8 grandmasters, 4 boundary clocks, and 6 transparent clock providers.  13 companies also provided compatible applications or IEDs.

There were no particular PTP tests for the clocks except that the best grand-master algorithm was implicitly tested due to the number of clocks present on the integrated applications.

One major system issue was encountered during disruptive testing.  The disruptive test consisted of skewing "the grandmaster" time source ahead by 1 hour.  After the clocks, IEDs, and applications resynced the clock's source was restored to the correct time (e.g. backwards 1 hour). One of the boundary clocks gradually ramped to the adjusted time.  This is allowed by IEEE C37.238 and IEC 61850-9-3.  However, IEC 61869-9 (e.g. Sampled Value Profiles) states the SV implementation should not ramp, but due a jump to the new time.  Since the boundary clock did not jump, the units synchronized to the ramping clock could not jump.  The issue is if different publishers receive SV streams that are synchronized to clocks with different behavior, mis-operation may be possible. Participation

# 2 Philosophy (new)

The Single Line Diagram (SLD), shown in Figure 15, represents the High Level Design (HLD) template for the application to be used as the framework for testing. Figure 16 depicts some of the intended signal and message exchanges that will be used.

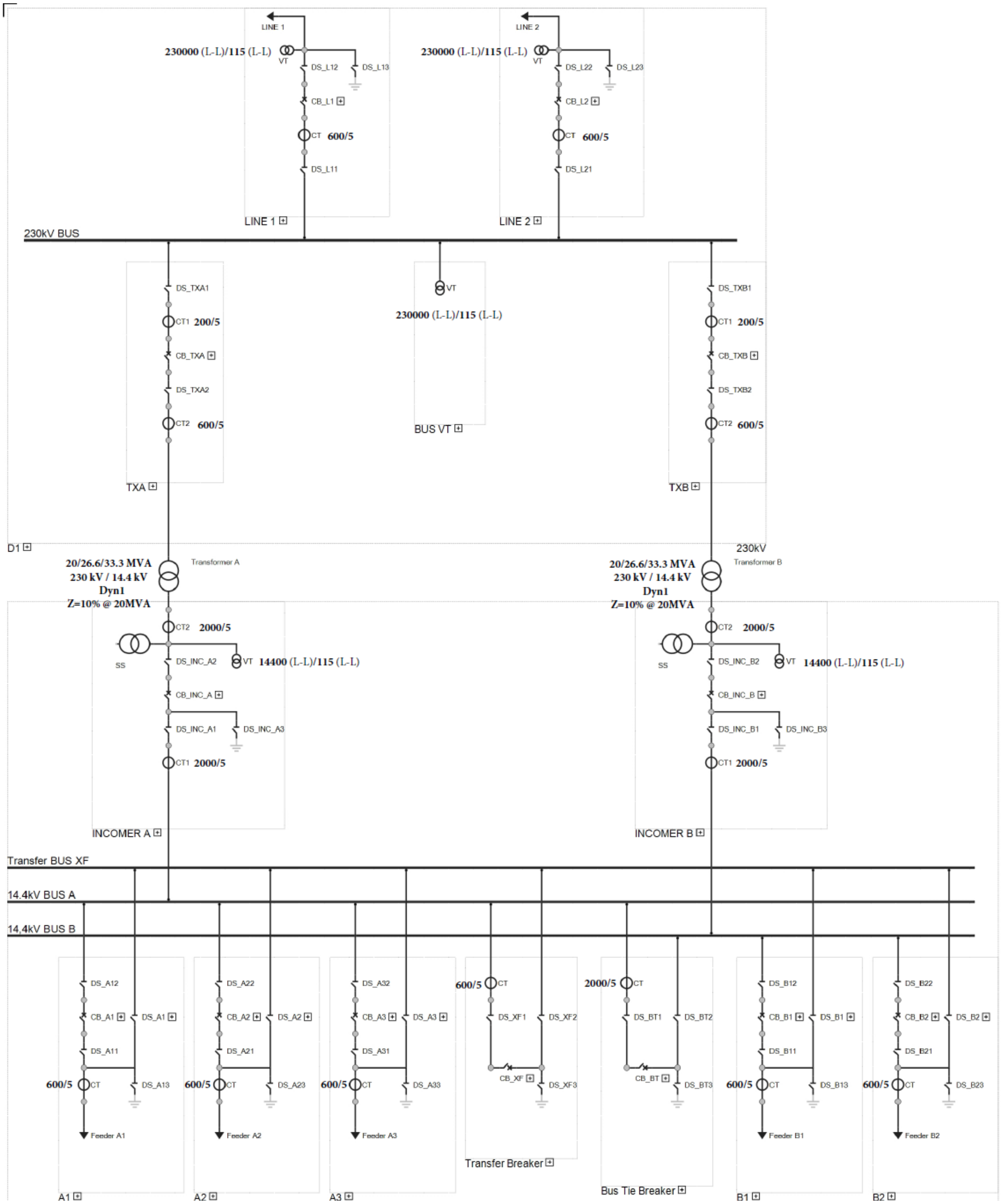


Figure 15: HLD Single Line Diagram

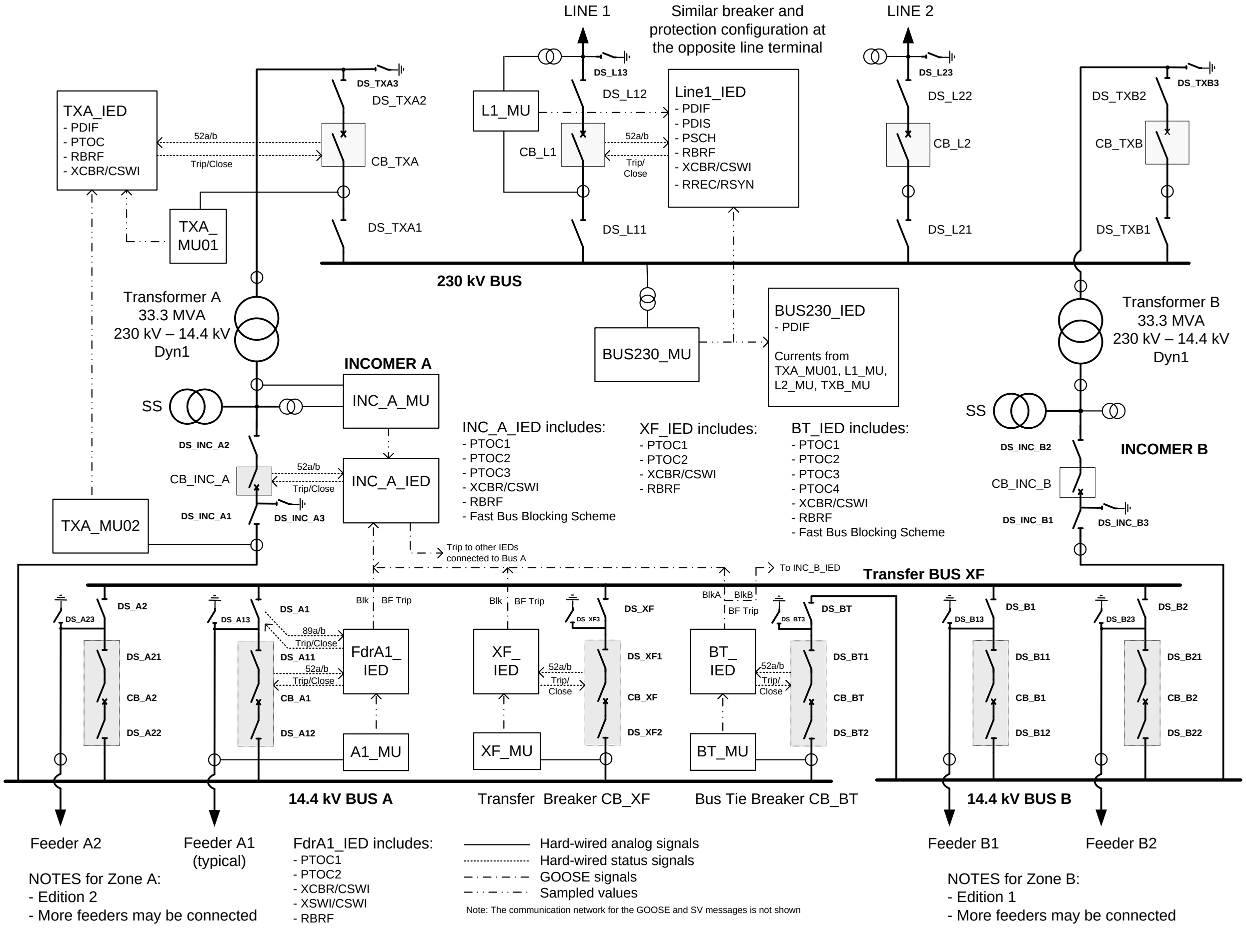


**Figure 16 Partial Single Line Diagram showing typical objects, devices and signals**

The integrated application is intended to consist of two (2) substations and 1 control center. This construct is to allow testing of information exchange/substation functions such as:

- Intra-substation application functions
  - Breaker and a half scheme
  - Breaker fail/reclose
  - Ring bus

- Inter-substation
  - Line differential protection or distance protection

- Substation to/from Control Center
  - Typical SCADA functions

In order to accomplish these functions, sampled values will be used to provide CT/PT information for the devices implementing the application functions.

There are two additional service capabilities that are to be utilized within the scope of the integrated application: security and time synchronization.

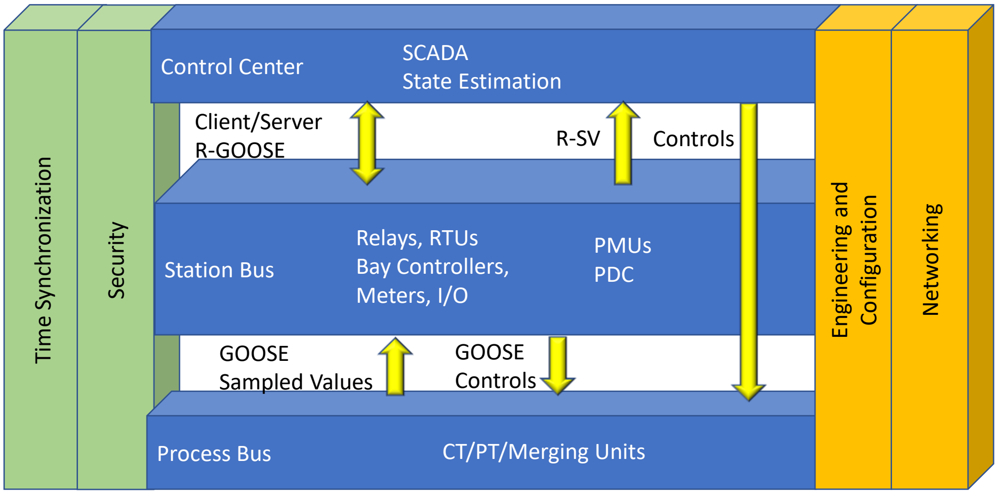


Figure 17: Overview of Integrated Applications Services and Interfaces

Figure 17 depicts the different IEC 61850 levels showing the equipment that may be part of the integrated application and the communication services used to exchange information between the various levels.

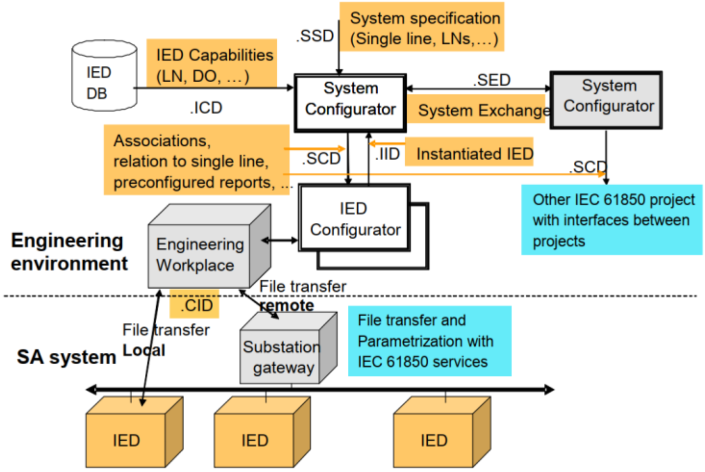
New in 2019 is the ability to exchange synchrophasor information through the use of Routable Sampled Values (R-SV) from devices that have Phasor Measurement Unit (PMU) capability. Many utilities deploy IEEE C37.118 for synchrophasors today, however these are not secured in a standard mechanism. There is an IEEE report D0.90 that specifies how to convert from C37.118 to R-SV and that type of conversion is shown as a Phasor Data Concentrator (PDC) in the figure.

The figure shows the various communication services that are to be utilized in the in the integrated application and form the basis for the test cases in this document. Additionally, there are test cases/considerations that need to address system engineering including device and network configuration.

The following subclauses provide a high level of the types of testing that are intended to be performed.

## 2.1 Engineering Configuration

This set of tests are more offline than online tests and involve the substation configuration language. The purpose is to validate that each implementation provides a valid IED Capability Description (ICD) file and that the System Configuration Tool (SCT) to/from IED Configuration Tool (ICT) exchanges are supported as defined in IEC 61850-6.



.SSD
System specification (Single line, LNs,…)
IED DB
IED Capabilities (LN, DO, …)
.ICD
System Configurator
.SED
System Exchange
System Configurator
Associations, relation to single line, preconfigured reports, …
.SCD
.IID
Instantiated IED
.SCD
IED Configurator
Other IEC 61850 project with interfaces between projects
Engineering environment
Engineering Workplace
File transfer
remote
.CID
File transfer
Local
SA system
Substation gateway
File transfer and Parametrization with IEC 61850 services
IED
IED
IED

Figure 18: IEC 61850-6 Defined Exchanges

The use of System Specification Description (SSD) files and System Exchange Description (SED) files are out-of-scope of the integrated application testing and should be covered in the SCL testing area. The use of Configured IED Description (CID) files are for ICT to device exchange and are not required to be supported by an ICT. Thus, the testing of CIDs is out-of-scope.

There are two types of tests that need to occur:  Initial configuration and configuration changes to operational systems.

## Initial Configuration

These steps/tests are required in order to create an operational system:

- ICD validation – tests that the IED Capability Description (ICD) files provided by the vendors are valid.
- SCT to ICT Exchange – tests that the engineered solution can be exchanged to the IED Configuration Tool and that the tool can correctly configure the device based upon the System Configuration Description (SCD) file.  This test may cover:
    - Later binding of Inref and Blkrefs
    - Ability of SCT to generate an Edition 1 SCD.
- ICT to SCT exchange and IED Instantiation Description (IID) file in order to provide any changes that the ICT made in order to configure the device.

## Changes to Operational Systems

These steps/tests are typical changes that may occur to an operational system:

- Addition of a new device into the operational system.
- Removal of a device from an operational system (disruptive).

### 2.1.1 Prior SCL ICD Validation

The 2017 IOP, as well as previous IOPs, indicated quality issues with the IED Capability Description (ICD) files provided by participants. In order to increase the overall quality of the ICDs, all ICDs used at the IOP were requested to go through a validation process prior to being provided to the System Configuration Tools (SCTs) that were designing the Integrated Application.

In order to adequately validate vendor ICD files prior to including the files in the system engineering, five vendors/entities have volunteered to use their tooling to validate the vendor ICD files.

The vendor/entities (e.g. validators) are:

- DNV/GL
- EDF/Hydro Quebec
- Gridclone
- Triangle Microworks
- Bruce Muschlitz (UCAIug Tooling)
- Beijing Sifang Automation

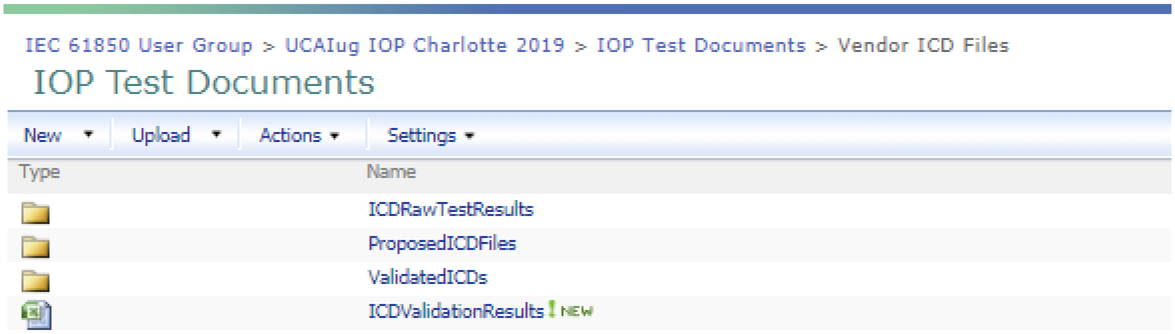
Of these tools, the EDF/Hydro Quebec ,Triangle Microworks, and UCAIug tools are available for general use. These are available through the following means:

- EDF/Hydro Quebec: The tool is known as rise-eclipse. A downloadable version was not available during the IOP. Therefore, the web based version (https://rise-clipse.pam-retd.fr/) was used and is still available for use.

- Triangle Microworks: Triangle Microworks has a validation tool that can be downloaded as a demo license and can be found at: http://www.trianglemicroworks.com/products/testing-and-configuration-tools/scl-navigator-pages/overview

- UCAIug Tooling: These are a set of tools that are used as part of the conformance certification process and are available to UCAIug members at: http://www.ucaiug.org/org/TechnicalO/Testing/Shared%20Documents/Tools.

The process involves a set of directories and files that shall be used by vendors and validators to facilitate the process.



IEC 61850 User Group > UCAIug IOP Charlotte 2019 > IOP Test Documents > Vendor ICD Files

IOP Test Documents

| Type | Name |
|---|---|
| 📁 | ICDRawTestResults |
| 📁 | ProposedICDFiles |
| 📁 | ValidatedICDs |
| 📄 | ICDValidationResults ! NEW |

#### 2.1.1.1 Process

The process is as follows:

- Vendors post their files into the ProposedICDFiles directory with no vendor specific subdirectories. The files shall be named as follows:

  <vendor>_<yyyymmdd_<Header.version-Header.revision>_filename>.icd

  where:

  - yyyymmdd: year month day of the modification/creation of the file.
  - Header.version-Header.revision: Header.version and Header.revision values should match the values found within the Header section of the actual ICD. These are both xml attributes of the Header section and not HItems. Although, the values should also match the latest values found within the list of HItems.

    The values shall be separated by a "-".
  - vendor: is a unique name that the vendor gives to themselves.
  - filename: is the ICD name that the vendor assigns for a device/application.

    Example name of the file (xxx is the vendor name):

    20190528_1-2_xxx_example.icd

- Validating companies will check the files in the ProposedICDFiles and generate test results. The resulting result files will be placed into the ICDRawTestResults directory. The files will be named per the following format:

<icdfilename w/o ext>_res_<ValidatorName>[_<ValidatingTool>]_<yyyymmdd>.xxx

Where:

- Icdfilename w/o ext: is the name of the ICD file checked by the validator without the ".icd" extension.
- ValidatorName: The unique name of the company that performed the check.
- ValidatingTool: Is an optional value that give the name of the tool that performed the check.
- yyyymmdd: year month day of the execution of the validation check of the icd file.
- xxx: The extension generated by the validation tool for result output. PDF files are not to be utilized.

  Example:

  20190528_1-2_xxx_example_UCA_20190529.xml

- Validators will then update the "Result" tab of the spreadsheet named ICDValidationResults
  - This file is to be used to capture a running list of issues. The columns are:

| Vendor | ICDFileName | Tool | Validation Executed Date | Problem |
|---|---|---|---|---|

- The ICDFileName shall include the extension.

As vendors correct validation issues, revised files are placed into the ProposedICDFiles directory without deleting or modifying the previously uploaded file(s). The validation process would then repeat. No previous results should be deleted or modified in the results directory or spreadsheet.

## 2.2 Networking

In order to stage an operational system, the communication network(s) must be designed, deployed, and tested.

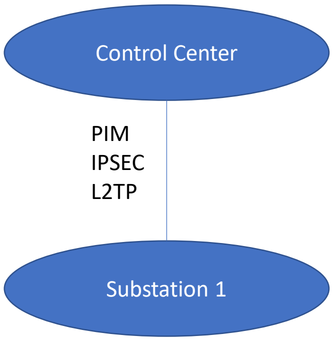


Figure 19: High Level Routing Network Design

Figure 19 shows the communication requirements for the routers between the substations and control center.

- Protocol Independent Multicast (PIM) required to support R-GOOSE and R-SV
- Virtual Private Network (VPN) – The actual protocol to be utilized will be chosen during the network design activity. The intent of the VPN is to provide encryption of packets as they are exchanged over the simulated wide are connections.

It is intended that the VPN provide the confidentiality protection for packets whereas the IEC 62351-6 security mechanisms will provide packet integrity and authentication. This separation is done so that the requirement of NERC edge packet inspection can be met.

The edge of each interface (e.g. Control Center->Substation and Substation<-> Substation) requires a firewall that can provide access control and potentially packet inspection capability. The routers are responsible for supporting IGMPv3 and PIM in order to support R-GOOSE and R-SV. The depending upon the positioning of the firewall (e.g. outward of the router or inside of the router) must not block the protocols required for use inside the perimeters.

The switches provided in the substations shall support Precision Time Protocol, IGMP snooping, extended Ethernet frame size (required to support PRP) and shall be configured with a single mirror port.

Network resiliency, within the substation(s), shall be provided through the use of PRP or HSR.

The test cases for PRP, or HSR, connected Dual Attached Network (DAN) device need to include the following:

- Normal operation
- Failure of a single connection
- Failure of both connections (disruptive)

For PRP an additional test for DANs shall be added:

- Single switch failure

  In order for this test to be non-disruptive, the switch that is failed must not have a Single Attached Node (SAN) connected to it.

## 2.3 Security

The intent of security testing is to test IEC 62351-6 and network security based upon NERC expectations. The actual test cases will be detailed in a specific section not within the integrated application testing document.

- For Client/Server:
  - The support of integrity only TLS cypher suites to facilitate edge packet inspection
  - The support of encrypting TLS cypher suites to facilitate end-to-end confidentiality.
  - The support of strong Authentication at the application level.

- For R-GOOSE/R-SV:
  - The support of integrity only to facilitate edge packet inspection
  - The support of encryption to facilitate end-to-end confidentiality.

- Key and certificate management:
  - Key management for R-GOOSE and R-SV.
  - Certificate management including but not limited to:
    - Certificate expiration
    - Certificate revocation
    - Certificate Authority chaining

It is also intended to stage other non-IEC 61850 required security services (in the control center) consisting of Radius and Syslog.

## 2.4 Time Synchronization

Two types of time services are intended to be provided as part of the integrated application: SNTP and PTP protocols of IEC 61850-9-3/IEEE C37.238.

For PTP, there shall be multiple grand masters within the substations all using the same PTP domain: 93.

- Operational – Do devices all pick the same best PTP master.

- Fail the selected grandmaster and check that the devices select the same best master (disruptive).
- Fail all grandmasters and observe behavior (disruptive).
    - For sampled value publishers, observe hold over time
    - For sampled value subscribers, observe behavior when holdover time expires.
- Power-up a single grandmaster and observe the behavior (time jump or ramp) of the devices.

## 2.5 Process Bus

It is intended that process bus testing shall concentrate on the issues related to Layer 2 Sampled Values.

- Redundant source failover of subscribing devices.
- System behavior as all SV publishers are failed one at a time (disruptive)

## 2.6 Substation Maintenance (disruptive)

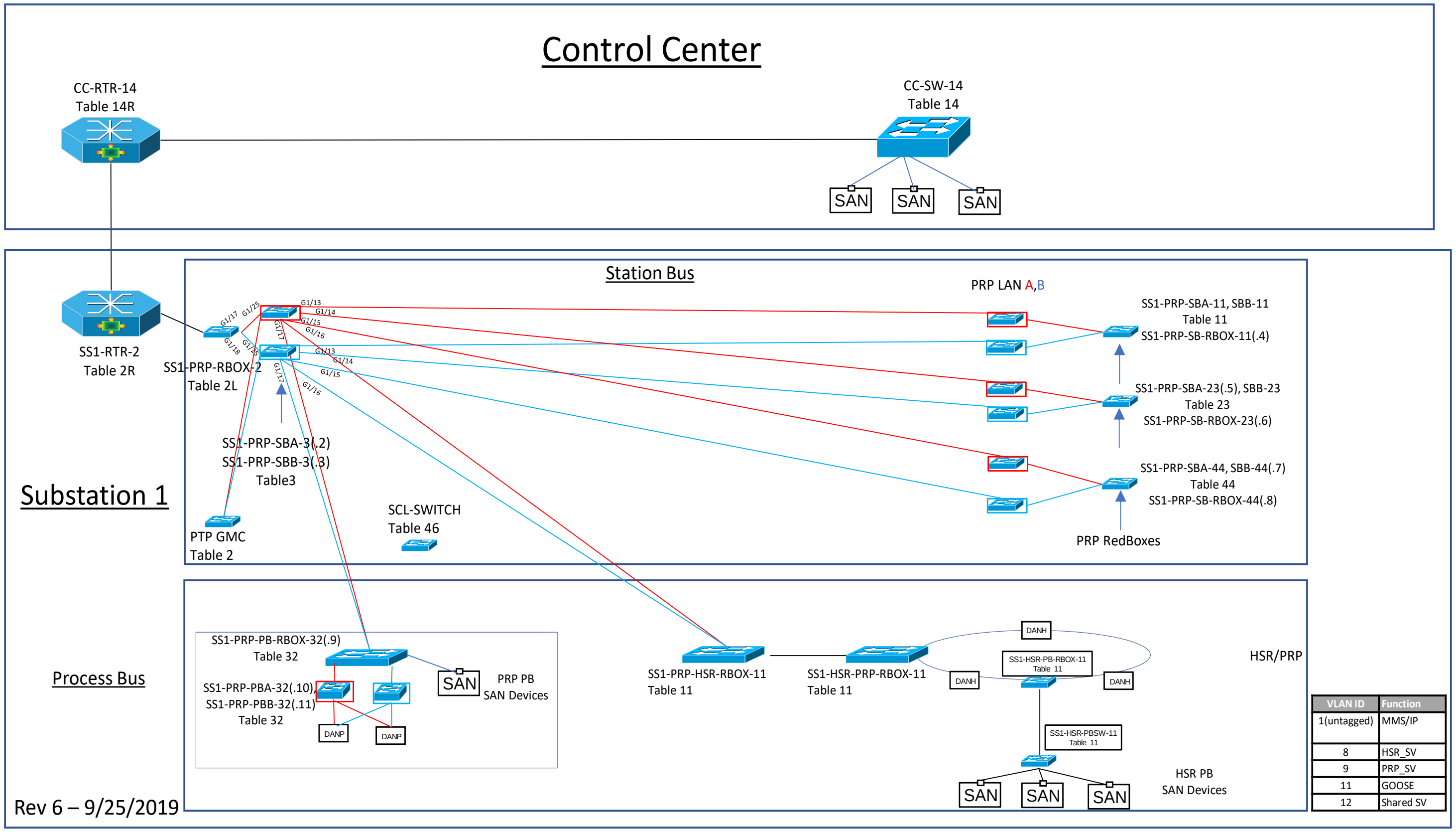
A set of testcases will be provided so that IED isolation, behavior, simulation, and test modes can be tested.

# 3 Network Design

The IOP network was designed to simulate/emulate real deployment scenario's that might be found within a utility implementation.  At the conceptual level, the IOP network consisted of two routed domains being the control center domain and a single substation domain.  The edges of both domains included firewalls and routers.

Within the substation domain, the station bus was deployed utilizing PRP.  The process bus was split into an HSR ring and a PRP network. Due to the Integrated Application use of process bus information, the HSR and PRP information needed to be exchanged through a Red Box. In order to facilitate station bus and the process bus(s) to exchange GOOSE messages. In order to accomplish this, the same GOOSE VLAN was used for process bus and station bus GOOSE messages.

The high level network diagram is shown in Figure 20 :



| VLAN ID | Function |
|---|---|
| 1(untagged) | MMS/IP |
| 8 | HSR_SV |
| 9 | PRP_SV |
| 11 | GOOSE |
| 12 | Shared SV |

Figure 20: High Level Design for Integrated Application Network

There were several infrastructure providers which are shown in the Table 5:

| Company | Model | Use | Network Designation |
|---|---|---|---|
| **Cisco** | E4010 | Substation Central PRP LAN B | SS1-PRP-SBB-3 |
| | IE4010 | Substation Central PRP LAN A | SS1-PRP-SBA-3 |
| | | Station Bus Redbox | SS1-PRP-SB-RBOX-11 |
| | | Station Bus PRP LAN A | SS1-PRP-SBA-23 |
| | | Station Bus Redbox | SS1-PRP-SB-RBOX-23 |
| | | Process Bus PRP LAN A | SS1-PRP-PBA-32 |
| | | Process Bus PRP LAN B | SS1-PRP-PBB-32 |
| | | Process Bus to Station Bus Redbox | SS1-PRP-PB-RBOX-32 |
| | | Station Bus PRP LAN B | SS1-PRP-SBB-44 |
| | | SCL Testing Switch | SCL-SWITCH |
| | IE5000 | Substation Central Redbox | SS1-PRP-RBOX-2 |
| **GE** | S20 | Process Bus Switch to connect to HSR Ring | SS1-HSR-PBSW-11 |
| **KERI** | KRB200 | Process Bus HSR Ring Redbox | SS1-HSR-PRPA-11 |
| **SEL** | 2740S | Control Center Switch | Control Center |
| | GMC | Clock | GMC |
| **Siemens** | RSG2488 | Station Bus PRP LAN B | SS1-PRP-SBB-11 |
| | | Station Bus PRP LAN B | SS1-PRP-SBA-44 |
| | RSG909R | PRP to HSR Coupling Switch A | SS1-HSR-PRPA-11 |
| | | PRP to HSR Coupling Switch B | SS1-HSR-PRPA-11 |
| | RST2288 | Station Bus PRP LAN A | SS1-PRP-SBA-11 |
| | | Station Bus PRP LAN B | SS1-PRP-SBB-23 |
| | RX1400 | Substation 1 Router | SS1-RTR-2 |
| | | Control Center Router | CC-RTR-14 |

**Table 5: Network Equipment, Providers, and Placement**

Due to the use of the same VLAN and an IED implementation issue (e.g. the same GOOSE was published to both the process bus and station bus, network storms were created.  Although, this was not the only cause for the network bandwidth consumption.  Use of the same GOOSE VLAN being published on station bus and process bus should be avoided.

# 4 General Notation for Test Results

The test result tables, in the following section utilize the following notation for results:

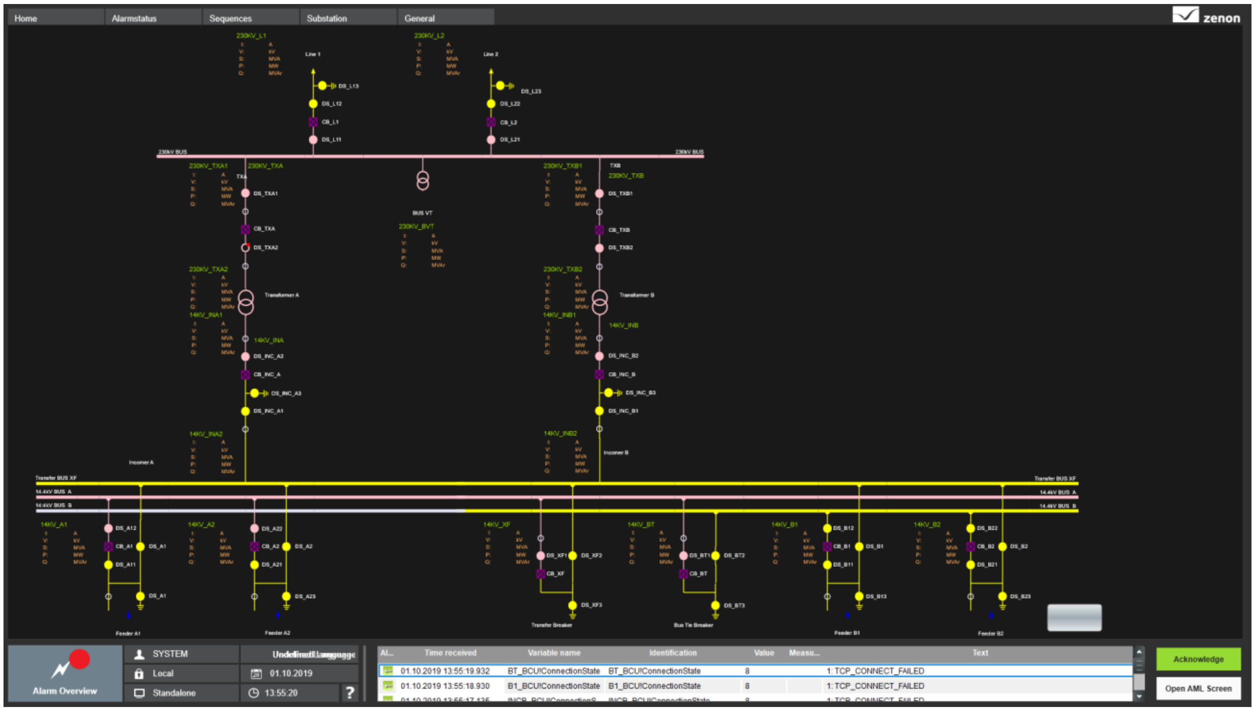
| Result | Notation | Description |
|---|---|---|
| **Fail** | Fail or F | Indicates that the test case expected results were not observed during the execution of the test case. |
| **Pass** | Pass or P | Indicates that the test case expected results were observed during the execution of the test case. |
| **Notation** | n<x> | Indicates that there is additional information provided in the test result table. <x> indicates the notation number so that multiple notations can be provided in the same summary table. |
| **Questionable** | Q | Indicates that the test case expected results were not observed during the execution of the test case as described and there were questions about the results.  A "Q" is typically entered along with a notation. |

# 5 Integrated Application Testing

| Company | SCL | Client/ Server | GOOSE | Sampled Values | Isolation | PTP | IED Failure | Merging Unit Failure |
|---|---|---|---|---|---|---|---|---|
| ABB | | x | | x | x | | | |
| ARC Informatique | | x | | | x | | x | x |
| ASE-Kalkitech | x | x | | | x | | | |
| Copadata | x | x | | | | x | | |
| Doble | | x | | x | | x | x | x |
| General Electric | x | x | x | x | x | | x | |
| KEPCO | | x | | | x | | | |
| KERI | | x | | x | | x | | x |
| Novatech | | X | | | | | | |
| NR Electric | | | | x | | | | x |
| OMICRON | | x | x | | x | | | |
| RTDS | | | | x | | | | |
| Schweitzer Engineering Labs | x | x | x | x | x | | x | x |
| Siemens | | | | x | | | | |
| Sifang | x | x | x | x | | | | |
| SISCO | x | x | | | | | | |
| Toshiba | | x | | x | x | | | x |
| Triangle Microworks | x | x | x | | | | | |
| Vizimax | x | | x | x | | | | |

## 5.1 Application Level Testing

The highlight of testing was using the integrated application was used to demonstrate differential protection, utilizing Sample Values,  with the following control center Single Line Diagram (SLD) being used to monitor the substation. The purpose of the test was to ensure that appropriate maintenance and isolation of various components of the system worked safely and that the information was appropriately available to a SCADA system.



| Al... | Time received | Variable name | Identification | Value | Measu... | Text |
|---|---|---|---|---|---|---|
| | 01.10.2019 13:55:19.932 | BT_BCU!ConnectionState | BT_BCU!ConnectionState | 8 | | 1: TCP_CONNECT_FAILED |
| | 01.10.2019 13:55:18.930 | B1_BCU!ConnectionState | B1_BCU!ConnectionState | 8 | | 1: TCP_CONNECT_FAILED |
| | 01.10.2019 13:55:17.135 | INCB_BCU!ConnectionS | INCB_BCU!ConnectionState | 8 | | 1: TCP_CONNECT_FAILED |

Figure 21: Integrate Application SLD in CopaData Zenon Software

The SLD was constructed based upon three SCL projects (control center, substation high voltage, and substation low voltage).  The test consisted of utilizing the CopaData Zenon HMI as a SCADA master.

The application test sequence was:

1. Monitor SLD in steady state mode.
2. Vary inputs to SV publishers in a manner to trigger protection.  Make sure GOOSE and protection occurs properly and the SLD changes appear appropriately.
3. Reset inputs to SV publishers to steady state inputs and verify that the SLD reverts to appropriate steady state.
4. Using the HMI place SV publisher into test mode, vary SV unit input and make sure no protection action was taken or reflected in the SLD.
5. Remove test mode for SV publisher.
6. Repeat step 4 and 5 for other SV units.
7. Using the HMI, place selected protection devices into test/blocked mode.

8. Vary inputs to SV publishers in a manner to trigger protection.
9. Using the HMI SLD that only the non-test/blocked devices actually impacted protection.
10. Repeat steps 7-9 for other protection devices.

After the successful differential protection test, the same test was executed but using isolation and maintenance processes prescribed by IEC 61850 (e.g. test, test/blocked, and simulation) to show that the IEC 61850 process could be used to isolate and test the system.

Participation in the Integrated Application can be found in the following table.

| Company | SCL | Client/ Server | GOOSE | Sampled Values | Isolation | PTP | IED Failure | Merging Unit Failure |
|---|---|---|---|---|---|---|---|---|
| ABB | | x | | x | x | | | |
| ARC Informatique | | x | | | x | | x | x |
| ASE-Kalkitech | x | x | | | x | | | |
| Copadata | x | x | | | | x | | |
| Doble | | x | | x | | x | x | x |
| General Electric | x | x | x | x | x | | x | |
| KEPCO | | x | | | x | | | |
| KERI | | x | | x | | x | | x |
| Novatech | | X | | | | | | |
| NR Electric | | | | x | | | | x |
| OMICRON | | x | x | | x | | | |
| RTDS | | | | x | | | | |
| Schweitzer Engineering Labs | x | x | x | x | x | | x | x |
| Siemens | | | | x | | | | |
| Sifang | x | x | x | | | | | |
| SISCO | x | x | | | | | | |
| Toshiba | | x | | x | x | | | x |
| Triangle Microworks | x | x | x | | | | | |
| Vizimax | x | | x | x | | | | |

Table 6: Areas of Participation in the Integrated Application

## 5.2 Normal Testing

### 5.2.1 SCL

### *5.2.1.1 Test Cases*

#### 5.2.1.1.1 Test case name:NORM-SCL-01

Configure Client network addressing from SCL

Expected result

4. Network addressing in Client can be configured from SCL.
5. Client establishes TPAA with Server.

Test description

1. Run SCL file through various SCL checkers and validators; report results for documentation.
2. Start Client without any configuration of a server.
3. Client selects the server (IED) with which the test is being conducted from the SCD file using local means.
4. Client shall configure the network addressing information that is necessary for it to establish communication with the selected Server.
5. While Server is online, establish TPAA from Client.

Comment

Link Layer: IP address, IP port

Application Layer ISO 8650-1(ACSE): Calling (client), Called (server)

#### 5.2.1.1.2 Test case name:NORM-SCL-02

Equivalency of Object Model derived from SCL vs. ACSI based discovery

Expected result

5. The namespace - configured from SCL and available via ACSI. (online) services - are equivalent.

Test description

1. Start Client without configuration of Server data model.
2. Client selects the server (IED) with which the test is being conducted from the SCD file using local means.
3. Client shall configure the server namespace for the IED selected from the SCD file.
4. Associate Client and Server.
5. Check equivalency of Server data model derived from SCL vs. derived via online services.

Comment

The separate import of the same SCL file for this test may not be required when the namespace has already been configured.

It may not be feasible under all circumstances with large data models to perform an exact comparison of the complete data model. Witness to note if the complete data model is compared or a subset of the data model: Logical Device(s), Logical Nodes, Data Objects and/or Functional Constrains.

#### 5.2.1.1.3 Test case name: NORM-SCL-03

Configure RCB Subscription(s) from SCD discovery

Expected result

5. The Client connects to the Server, enables the RCB and processes ***Reports***.
   The Server is providing ***Report***s according to the RCB settings; it provides correct values in URCB.Resv -a) 1, b) 0, BRCB.ResvTms -a) -1, b) 0, and RCB.Owner attributes (if present).
7. Client makes correct attempt to enable RCBs - according Client's configuration.
   Server provides correctly updated RCB attributes - according Server's configuration.
   If possible, to force mismatch: Server refuses the Client's attempt to enable RCB assigned to mismatching ClientLN.

Test description

1. Start Client without configuration of Server's RCBs.
2. Using local means Client selects RCBs:
   a) of own ClientLN (if exist)
   b) and/or selects instances of not assigned RCBs.
3. Using local means Server updates RCBs and/or datasets from SCD/CID.
4. Associate Client and Server.
5. Client reserves, configures and enables RCBs.
6. Abort TPAA and reconfigure the Server and/or Client to mismatch ClientLN by a URCB and a BRCB.
7. Associate Client and Server. Client attempts to enable RCBs.

Comment

The separate import of the same SCL file for this test case may not be required when the client has already configured the reports.

SCT creates SCD based on the ICD/IID files provided by Client and Server:

- New Datasets can be added, or existing can be changed.
- New RCB can be added, or existing attributes can be changed.
- Available ClientLN can be assigned to RCBs in Server's devices.
- Input section with ExtRef can be added to the LN of the Client.

Server shall set URCB.Resv=TRUE and BRCB.ResvTms=-1 if RCB is pre-assigned to ClientLN; else FALSE resp. 0

Client reserves URCB using Reserve= TRUE in the SetURCBRequest, respectively BRCB using ReserveTms > 0 in the SetBRCBValues.

Steps 6-7 are optional as this requires manual manipulation in SCL and/or "freeze" of ConfRev

#### 5.2.1.2 Test Results

The following are the test results for the Integrated Application SCL Tests

| IED Only Test Results: SCL Test Cases (NORM-SCL) | | | | |
|---|---|---|---|---|
| Clients | | Test Case | | |
| Vendor | Model | 01 | 02 | 03 |
| ASE-Kalkitech | ASE61850-TestSet | Pass | Pass | Pass |
| Copadata | Zenon | Pass | Q,n3 | Pass |
| General Electric | MU320 | | Pass | Pass |
| Schweitzer Engineering Lab | SEL-3555 | Pass | Pass | Pass |
| Schweitzer Engineering Lab | SEL-487E | Pass | Pass,n1 | Pass |
| Schweitzer Engineering Labs | SS_CONT_SEL_3560 | Pass | n2 | Pass |
| SIFANG | CSD-1321 | Pass | Pass | Pass |
| SISCO | AXS4-61850 | Pass | Not Executed | Pass |
| Triangle Microworks | Client | Pass | n3 | Pass |
| n1 - reported MinTime and MaxTime did not match what is configured in the SCL file<br>n2 – Not supported<br>n3 – Model comparison had errors | | | | |

### 5.2.2 Client/Server

### 5.2.2.1 *Data acquisition of FCD or FCDA*

This section shall verify acquiring data (service: ***Read*** or ***Report***) at the various levels of Object Reference.

#### 5.2.2.1.1 Test case name: NORM-FCD-01 and NORM-FCD-02

Expected result

1. Client values of the Server's data attributes of FC in acquired DO match.
   For Data Objects with FC=ST/MX also Quality and Timestamp match.

Test description

1. Client issues a ***Read*** (or process ***Report***) of a FCD, e.g. LLN0.Mod and FC=ST.

Comment

##### *5.2.2.1.1.1 Test Results*

There were test results reported for both FCD-01 and FCD-02. However, there was no test case documented for NORM-FCD-01. Both sets of recorded results are found in the following table.

| Test Case Results: NORM-FCD-01 and NORM-FCD-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | Pass | | | | | |
| GE | P443 | | | Pass | | | Pass | |
| KERI | KMU100 | | | | Pass | Pass | Pass | |
| Novatech | PX24 | Pass | | | Pass | Pass | | |
| Omicron | Station Scout | | | Pass | | | | |
| OMICRON | IEDScout | Pass | | | | | | |
| SEL | 3555 | Pass | | | | | | |
| SEL | 401 | | Pass | | | | | |
| SEL | 421 | | Pass | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 478B | | | | | | | |
| SEL | 487E | | Pass | | | | | |
| SEL | 751 | Pass | | | | | | |
| Sifang | CSI-200E | | Pass | | | | | |

| Test Case Results: NORM-FCD-01 and  NORM-FCD-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Sifang | CSC-211-EB | Pass | | | Pass | | Pass | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | Pass | |
| Toshiba | GRT200 | | | Pass | | | | |

| Test Case Results: NORM-FCD-01 and  NORM-FCD-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | | | | | |
| GE | D60 | | Pass | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | Pass | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 478B | | | Pass | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | Pass | | | |
| | | | | | | | | |

#### 5.2.2.1.2 Test case name: NORM-FCDA-01

Expected result

1, 3. Client value of the Server's data attribute matches.
On Client the Quality of Data Object - if not acquired separately - stays unchanged or changes to local default value.
On Client the Timestamp of Data Object is local.

Test description

1. Client issues a ***Read*** (or process ***Report***) of a FCDA, e.g. LLN0.Mod.stVal
2. In case of ST/MX data attributes: force on Server the change of Quality and Timestamp of the Data Object.
3. Client issues a ***Read*** (or process ***Report***) of the FCDA.

Comment

Observer takes note what (local meanings) Server and Client are using to assure that Data Object (of CDC listed in -7-2 Table 64, q and t) with ST/MX has Quality and Timestamp in case of access limited to FCDA level

##### *5.2.2.1.2.1 Test Results*

| Test Case Results: NORM-FCDA-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | Pass | | | | | |
| GE | P443 | | | Pass | | | Pass | |
| KERI | KMU100 | | | | Pass | Pass | Pass | |
| Novatech | PX24 | Pass, n1 | | | | Pass | | |
| Omicron | Station Scout | | | Pass | | | | |
| OMICRON | IEDScout | Pass,n1 | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | Pass | | | | | |
| SEL | 421 | | Pass | | | | | |
| SEL | 451 | | | | Pass | | | |

| Test Case Results: NORM-FCDA-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | Pass, n1,n2 | | | | | | |
| Sifang | CSI-200E | | Pass | | | | | |
| Sifang | CSC-211-EB | | | | Pass | | Pass,n2 | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | Pass | |
| Toshiba | GRT200 | | | | | | | |
| n1- Client unable to ignore quality (e.g. quality must be present).<br>n2 – Server unable to change quality (e.g. manually) for the test. | | | | | | | | |

| Test Case Results: NORM-FCDA-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | | | | | |
| GE | D60 | | Pass | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | Pass | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 478B | | | Pass | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | Pass | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### 5.2.2.1.3 Test case name: NORM-READ-FLOAT

Expected result

1..4. Client value of the Server’s Floating-point value shall match within possible rounding errors. Also Quality and Timestamp shall match if q and t are included.

Test description

Client and Server are to process a ***Read*** service at the DO, DA and/or other node levels:

1. Level of DO, e.g. MMXU1.PhV.phsA [MX]
2. Level of DA, e.g. MMXU1.PhV.phsA.cVal.mag.f [MX]
3. Level of part of structured DO, e.g. MMXU1.PhV [MX]
4. Level of part of structured DA, e.g. MMXU1.PhV.phsA.cVal [MX]

Comment

Float attribute to be selected from Server’s data model.

Observer takes note what (local meanings) Server and Client are using to assure that MX data has Quality and Timestamp in case of access limited to FCDA level.

#### *5.2.2.1.3.1 Test Results*

| Test Case Results: NORM-READ-FLOAT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | NE, n1 | | | | | |
| GE | P443 | | | | | | Pass | |
| KERI | KMU100 | | | | Pass | Pass | Pass | |
| Novatech | PX24 | Pass | | | Pass | Pass | | |
| Omicron | Station Scout | | | Pass | | | | |

| Test Case Results: NORM-READ-FLOAT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| OMICRON | IEDScout | Pass | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | Pass | | | | | |
| SEL | 421 | | Pass | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | Pass | | | | | | |
| Sifang | CSI-200E | | Pass | | | | | |
| Sifang | CSC-211-EB | | | | Pass | | Pass | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | Pass | |
| Toshiba | GRT200 | | | | | | | |
| n1 – Server did not expose floating point data. | | | | | | | | |

| Test Case Results: NORM-READ-FLOAT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | | | | | |
| GE | D60 | | Pass | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | Pass | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 478B | | | Pass | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | Pass | | | | | | |
| TMW | DTM | | Pass | | | | | |

| Test Case Results: NORM-READ-FLOAT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | Pass | | | |
| | | | | | | | | |

### 5.2.2.1.4 Test case name: NORM-FLOAT-02

Expected result

1..4. Client value of the Server's Floating-point value shall match within possible rounding errors. Also Quality and Timestamp shall match if q and t are included in referred part.

Test description

Client is to acquire ***Reports*** with float at the DO, DA and/or other node levels:

1. Level of DO, e.g. MMXU1.PhV.phsA [MX]
2. Level of DA, e.g. MMXU1.PhV.phsA.cVal.mag.f [MX]
3. Level of part of structured DO, e.g. MMXU1.PhV [MX]
4. Level of part of structured DA, e.g. MMXU1.PhV.phsA.cVal [MX]

Comment

Float attribute to be selected from Server's data model.

Observer takes note what (local meanings) Server and Client are using to assure that MX data has Quality and Timestamp in case of access limited to FCDA level.

#### *5.2.2.1.4.1 Test Results*

| Test Case Results: NORM-FLOAT-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | NE, n1 | | | | | |
| GE | P443 | | | | | | Pass | |
| KERI | KMU100 | | | | | | NE,n2 | |
| Novatech | PX24 | Pass | | | | Pass | | |
| Omicron | Station Scout | | | NE,n1 | | | | |
| OMICRON | IEDScout | Pass | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | Pass | | | | | |
| SEL | 421 | | Pass | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 478B | Pass | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | Pass | | | | | | |
| Sifang | CSI-200E | | Pass | | | | | |
| Sifang | CSC-211-EB | Pass | | | Pass | | Fail,n4 | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | NE, n3 | |
| Toshiba | GRT200 | | | | | | | |

n1 – Server did not expose floating point data.
n2 - Server does not support required setup.
n3 – Client is unable to create dynamic dataset.
n4 – Client failed to process proper information.

| Test Case Results: NORM-FLOAT-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | | | | | |
| GE | D60 | | Pass | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | Pass | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |

| Test Case Results: NORM-FLOAT-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 478B | | | Pass | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | Pass | | | |
| | | | | | | | | |

#### *5.2.2.2 Datasets*

This section shall verify Datasets containing members at various Object Reference levels.

##### 5.2.2.2.1 Test case name: NORM-DATASET-01

Reason: FCD and FCDA in predefined Dataset

Expected result

1. Client values of the members of the dataset match with the Server.

Test description

1. Perform ***GetDataSetValues*** and *data-change* ***Report*** on a predefined dataset with at least 4 members:
    a. with at least one member being a FCD;
    b. with at least one member being a FCDA.

Comment

Observer takes note if Dataset members are FCD or FCDA and takes note of what (local meanings) Server and Client are using to assure that MX data has Quality and Timestamp in case of access limited to FCDA level.

###### *5.2.2.2.1.1 Test Results*

| Test Case Results: NORM-DATASET-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | Pass,n2 | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | Pass | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | n1 | | | | NE,n4 | | |
| Omicron | Station Scout | | | NE,n2 | | | | |
| OMICRON | IEDScout | n1 | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | Pass | | | | | |

| Test Case Results: NORM-DATASET-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | n1 | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | Pass | | Fail, n3 | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1 – Client must be preconfigured.<br>n2 - No DS with mix of FCD and FCDA<br>n3 – IED did not send datachange<br>n4 – No DataSet configured containing FCDA | | | | | | | | |

| Test Case Results: NORM-DATASET-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Fail, n2 | | | | | |
| GE | D60 | | Pass | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | Pass | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 478B | | | Pass | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |

| Test Case Results: NORM-DATASET-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1 – only tested with FCDs<br>n2 – Server did not allow including DataSet (e.g. Optfld) in report. | | | | | | | | |

### 5.2.2.2.2 Test case name: NORM-DATASET-02

Reason:Array in predefined Dataset

Expected result

1. Client values of the members of the dataset match with the Server.

Test description

1. Perform ***GetDataSetValues*** and *data-change* ***Report*** on a dataset that contains members of datatype ARRAY.

Comment

Observer notices if Dataset members are FCD or FCDA with indexing.

Example of FCDA with indexing (from part 6):

<FCDA ldInst="C1" lnInst="1" lnClass="PVOC" doName=" TmASt " fc="SP" daName="curvPts(2).xVal" ix="2"/>

<FCDA ldInst="C1" lnInst="1" lnClass="MHAI" doName="HPhV.phsAHar(3)" fc="MX" daName="mag" ix="3"/>

#### *5.2.2.2.2.1 Test Results*

| Test Case Results: NORM-DATASET-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | NE,n2 | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | NE,n2 | | | | | |
| GE | P443 | | | | | | NE, n2 | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | n1 | | | | NE,n2 | | |
| Omicron | Station Scout | | | NE,n2 | | | | |
| OMICRON | IEDScout | n1 | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 478B | Pass | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | n1 | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |

n1 – Client must be preconfigured.
n2 – Server did not provide array data.

| Test Case Results: NORM-DATASET-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | NE, n1 | | | | | |
| GE | D60 | | NE, n1 | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | P NE, n1 | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |

| Test Case Results: NORM-DATASET-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | NE, n1 | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1 – Server did not provide array data. | | | | | | | | |

### 5.2.2.2.3 Test case name: NORM-DATASET-03

Reason: FCD and FCDA in dynamic Dataset

Expected result

1. DataSet on Server is defined correctly.
2. Client values for the members of the data set should match those of Server.
3. DataSet is deleted from Server.

Test description

1. ***CreateDataSet*** with at least 4 members:
    a. with at least one member being a FCD;
    b. with at least one member being a FCDA.
2. Perform ***GetDataSetValues*** (or ***Report***) on the dataset.
3. ***DeleteDataSet*** (created in step 1).

Comment

Observer takes note of what (local meanings) Server and Client are using to assure that ST/MX data has Quality and Timestamp in case of access limited to FCDA level.

#### *5.2.2.2.3.1 Test Results*

| Test Case Results: NORM-DATASET-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | NE,n2, n3 | | | | | |
| GE | P443 | | | | | | NE,n3 | |
| KERI | KMU100 | | | | | | Pass | |
| Novatech | PX24 | n1 | | | | NE,n3 | | |
| Omicron | Station Scout | | | Pass | | | | |
| OMICRON | IEDScout | n1 | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | n1 | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | Pass | | Pass | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |

n1 – Client must be preconfigured.
n2 – Client did not support dynamic DataSets.
n3 – Server did not support dynamic DataSets.

### 5.2.3 Reporting

The previous test cases are already covering basic scenarios for RCB enable and data acquisition via Reporting. This section shall verify more sophisticated or (system) specific dependencies resulting from flexibility of the Standard.

The focus is also how to detect and solve situations resulting from configuration (SCL, human) mistakes via online services.

#### *5.2.3.1 Test case name: NORM-RPT-01*

Reason: Initial RCB enable

Expected result

1. Client is able to enable RCB.
2. Client is able to update RCB and enable it.
   Server accepts ***SetRCBValues*** of "Dyn" attributes.
3. Server and Client process ***Report*** services.
   Server process ***Report*** according RCB attributes.
   Client gives some indication that data being acquired via reporting.
   Client values (and quality and timestamp) match those of Server.

Test description

1. Enable RCB with "Fix/Conf" attributes fulfilling minimal Client's requirements.
2. ***SetRCBValues*** on "Dyn" attributes: TrgOps, OptFlds, IntgPd, BufTm; then enable RCB.
3. Process ***Reports*** on triggers: GI or integrity, and on data-change.

Comment

Minimal RCB attributes requirements are in client's PIXIT (not ICD), thus in SCD a mismatch is possible.

##### 5.2.3.1.1 Test Results

| Test Case Results: NORM- RPT-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | Pass | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | Pass | | | | | | |
| Omicron | Station Scout | | | Fail, n1 | | | | |
| OMICRON | IEDScout | Pass | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | Pass | | | | | | |
| Sifang | CSI-200E | | Pass | | | | | |
| Sifang | CSC-211-EB | Pass | | | Pass | | Pass | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | Pass | |
| n1 - Setting of "OptFlds" returned success but did not update | | | | | | | | |

| Test Case Results: NORM-RPT-01 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | | |
| Server | | | | | | | | | |
| Vendor | Model | | | | | | | | |
| ABB | RET670 | | Pass | | | | | | |
| GE | D60 | | Pass | | | | | | |
| GE | MU320 | | | | | | | | |
| GE | P443 | | Pass | | | | | | |
| KERI | KMU100 | | | | | | | | |
| Novatech | PX24 | | | | | | | | |
| Omicron | IEDScout | | | | | | | | |

| Test Case Results: NORM-RPT-01 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | | |
| Server | | | | | | | | | |
| Vendor | Model | | | | | | | | |
| Omicron | Station Scout | | | | | | | | |
| SEL | 3555 | | | | | | | | |
| SEL | 401 | | | | | | | | |
| SEL | 421 | | | | | | | | |
| SEL | 451 | | | | | | | | |
| SEL | 478B | | | Pass | | | | | |
| SEL | 487E | Pass | | | | | | | |
| SEL | 751 | | | | | | | | |
| Sifang | CSI-200E | | | | | | | | |
| Sifang | CSC-211 | | | | | | | | |
| TMW | DTM | | | | | | | | |
| Toshiba | GRD200 | | | | | | | | |
| Toshiba | GRT200 | | | | | | | | |
| | | | | | | | | | |

### 5.2.3.2 Test case name: NORM-RPT-02

Reason: Release RCB.RptEna by connection loss

Expected result

3. Client and Server detect connection loss.
   Client gives indication of connection loss.
   Server sets RptEna = false in all RCBs assigned to the Client.
4. Client and Server associate and enables the RCBs successfully.

Test description

1. Associate Client and Server.
2. Client reserves and enables at least one URCB and one BRCB.
3. Disconnect Ethernet between Client and Server.
4. Reconnect Ethernet, associate Client and Server and enables the RCBs.

Comment

Prefer to use the loss detection via mandatory TCP_KEEPALIVE, not local loss of TCP link; and not via MMS services (no/slow Integrity, no/slow polling).

Note: URCB.Resv and BRCB.ResvTms handling will be tested in a next case. Reservation using SetRCBValue(Reserve) is required from Ed2.1 on.

#### 5.2.3.2.1 Test Results

| Test Case Results: NORM- RPT-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | Pass | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | Pass | | | | | | |
| Omicron | Station Scout | | | Pass | | | | |
| OMICRON | IEDScout | Pass | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |

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| Test Case Results: NORM- RPT-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | Pass | | | | | | |
| Sifang | CSI-200E | | Pass | | | | | |
| Sifang | CSC-211-EB | Pass | | | Pass | | Pass | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | Pass | |
| | | | | | | | | |

| Test Case Results: NORM-RPT-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | Pass | | | | | |
| GE | D60 | | Pass | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | Pass | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 478B | | | Pass | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | Pass | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |

| Test Case Results: NORM-RPT-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Toshiba | GRT200 | | | | Pass | | | |
| | | | | | | | | |

### 5.2.3.3 *Test case name: NORM-RPT-03*

Reason: RCB without Dataset

<u>Expected result</u>

1. optionally, in case the Server does not support dynamical datasets:
   Server allows only RCB to be configured with a valid Datset. Server's ICT gives indication about the case.
3. Depending step 1 and local meanings in Server and Client:
   a) Client detects missing/invalid Dataset in the RCB and gives indication about the case. Client does not try to enable RCB or configures dynamical or an existing dataset.
   b) While RCB.Datset is invalid, Server responds ***SetRCBValues***( RptEna) negative.

<u>Test description</u>

1. Configure Server to have a RCB with empty (or not existing) Datset attribute.
2. Configure Client to try to enable the RCB.
3. Associate Client and Server. Force Client to ***SetRCBValues***(Reserve, RptEna ).

<u>Comment</u>

Reservation using SetRCBValue(Reserve) is required from Ed2.1 on.

#### 5.2.3.3.1 Test Results

| Test Case Results: NORM- RPT-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | NE, n2 | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | NE, n3 | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | NE, n1 | | | | | | |
| Omicron | Station Scout | | | NE, n2 | | | | |
| OMICRON | IEDScout | Pass | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | NE,n2 | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | Pass | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | Pass | |
| n1 – Server does not support adding additional DataSets (allowed)<br>n2 - Server does not support control blocks without DataSets (allowed) | | | | | | | | |

| Test Case Results: NORM-RPT-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |

| Test Case Results: NORM-RPT-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 478B | | | Q, n1 | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1- Steps 1-3 PASSED. Steps 4-6 couldn't be run. Report ID didn't match on unbuffered and buffered report. | | | | | | | | |

### 5.2.3.4 Test case name: NORM-RPT-04

Reason: Empty or ambiguous Report ID

Expected result

2. Client reserves and enables RCB.
3. Server provides the correct RCB reference in ***Report***.RptID value.
   Client values of the members of the dataset should match those of Server.
5. Client may (try to) update RptID or OptFlds.
   Server accepts updates (if related ReportSettings are "Dyn").
   Client enables updated RCB or indicates failure.
6. If update was possible the Client values of the members of the dataset should match those of Server.

Test description

1. Configure Server to have a RCB with empty RptID attribute and minimal required OptFlds by the Client.
2. Associate Client and Server. Client to reserve and enable the RCB.
3. Process (in Server and Client) at least one ***Report*** on data- or quality-change and one GI or Integrity.
4. Abort TPAA and configure Server to have 2 RCBs with identical RptID but different Dataset. Configure RCBs with OptFlds not containing *data-set-name* nor *data-reference*.
5. Associate Client and Server. Client reserves and enables the RCBs or indicates failure.
6. For both RCBs: process (in Server and Client) at least one ***Report*** on data- or quality-change and one GI or Integrity.

Comment

Reservation using SetRCBValue(Reserve) is required from Ed2.1 on.

### 5.2.3.4.1 Test Results

| Test Case Results: NORM- RPT-04 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | NE,n5 | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | n3 | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | NE, n1 | | | | | | |

| Test Case Results: NORM- RPT-04 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Omicron | Station Scout | | | NE, n4 | | | | |
| OMICRON | IEDScout | Pass,n2 | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | NE,n1 | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | Pass | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | Pass | |

n1 – Client does not support changing RPTID in server (allowed).

n2 – Server does not support duplicate RPTIDs (implementation issue)

n3 – Server does not support changing of RPTIDs (implementation issue)

n4 – Only 1 RCB, therefore could not execute.

n5 – Server was not easily configured with a blank RPTID.

| Test Case Results: NORM-RPT-04 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| GE | D60 | | Pass | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |

| Test Case Results: NORM-RPT-04 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

#### *5.2.3.5 Test case name: NORM-RPT-05*

Reason: Analogue (MX) data Reports dependency to BufTm and Deadband

Expected result

3, 6. Server process ***Reports*** according BufTm and correctly applies the deadband for the measured values - from instant values, considering deadband (the attribute db [CF]). Client values of the Server's measured values shall match within possible rounding errors.

Test description

1. Configure Server to have a RCB with deadbanded, analogue values, e.g. attribute mag in the CDC MV like MMXU1.PhV.phsA [MX].
2. Associate Client and Server. Client reserves and enables the RCB.
3. Process at least one ***Report*** on data-change or data-update.
4. Abort TPAA or disable RCB; reconfigure RCB.BufTm and MMXU1.PhV.phsA.db [CF] in SCL or via online services.
5. (Associate) Client enables the RCB.
6. Process at least one ***Report*** on data-change or data-update.

Comment

RCB.BufTm and db [CF] are parameters making possible to limit Ethernet traffic caused by reporting of measured values; the use-case are instantly fluctuating measured values. The data attribute db is optional in CDC MV. If the db attribute is a member of Dataset is not relevant for the test.

##### 5.2.3.5.1 Test Results

| Test Case Results: NORM- RPT-05 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | Fail, n1 | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |

| Test Case Results: NORM- RPT-05 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | NE,n1 | | | | |
| OMICRON | IEDScout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 478B | | | Q, n1 | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | Pass | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1 - Server doesn't support deadbands. BufTm is not respected (The report is sent immediately). | | | | | | | | |

| Test Case Results: NORM-RPT-05 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |

| Test Case Results: NORM-RPT-05 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### *5.2.3.6 Test case name: NORM-RPT-06*

Reasone: URCB.Resv handling by connection loss

Expected result

1. Server sets URCB.Resv = true in preassigned URCB.
2. Client does ***SetURCBValues***( Resv ); and enables the URCB correctly.
3. Server and Client detects connection loss. The value of URCB.Resv does not change.
4. Server sets URCB.Resv = false.
5. Client does ***SetURCBValues***( Resv=true ) and enables the URCB.
6. Server and Client detects connection loss. Server changes URCB.Resv to false.

Test description

1. Configure in Server an URCB with an instance preassigned to ClientLN of the Client.
2. Associate Client and Server. Client reserves and enables the URCB.
3. Abort TPAA.
4. Configure in Server an URCB without any ClientLN.
5. Associate Client and Server. Client enables the URCB.
6. Abort TPAA.

Comment

Results depend on Ed.1 / Ed.2 / Ed2.1. Observers may notice the meanings the Client and the Server are using to solve eventual differences in reservation handling.

Reservation using SetURCBValue(Reserve=TRUE) is required from Ed2.1 on.

#### 5.2.3.6.1 Test Results

| Test Case Results: NORM- RPT-06 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | NE,n2 | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | NE, n1 | | | | | |
| GE | P443 | | | | | | | |

| Test Case Results: NORM- RPT-06 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | NE,n2 | | | | |
| OMICRON | IEDScout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | Pass | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1- The server cannot preassign Resv to true.<br>n2 – Server did not support URCBs. | | | | | | | | |

| Test Case Results: NORM-RPT-06 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |

| Test Case Results: NORM-RPT-06 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

#### *5.2.3.7 Test case name: NORM-RPT-07*

Reason: Acquisition of Reports buffered during TPAA loss

Expected result

4. Client sends correct EntryID - the last completely received before TPAA loss.
   Server:

- if no buffer overflow then respond EntryID positive;
- If there is buffer overflow, then respond EntryID negative and in step 5 process like EntryID=0 - sends from the first entry in the buffer.

5. Server sends ***Reports*** starting by next after received EntryID or all buffered in case of overflow. In case of overflow, if OptFlds, the BufOvfl is in the first ***Report***.
   Client process data from buffered reports and gives some indication that data being acquired via reporting and in case of overflow. Client values (and quality and timestamp) match those of Server also for data from period of connection loss.
7. Results depend if Client uses resynchronization (a)
   or mismatch detection/auto-description (b):
   a) Server responds EntryID negative and in step 8 process like EntryID=0 - sends from the first entry in the buffer.
   b) Client resynchronizes using EntryID=0 or ***SetBRCBValues***( PurgeBuf and/or GI)
8. Client process data from buffered reports and gives some indication that data being acquired via reporting.
   If buffer is purged, and if OptFlds, Server sets BufOvfl in the first ***Report***.

Test description

1. Associate Client and Server, Client reserves and enables at least one BRCB.
2. Server and Client process at least one ***Report*** with valid EntryID. Then force TPAA loss.
3. During connection loss Server buffers at least one data- or quality-change or data-update report.
4. Associate Client and Server. Client reserves and resynchronizes the BRCB - ***SetBRCBValues***( EntryID).
5. Client enables the BRCB and process buffered ***Report****s.*
6. Force TPAA loss and reconfigure on Server some members of Dataset in the BRCB.
7. Associate Client and Server. Client reserves and resynchronizes the BRCB or - if detects mismatch or uses auto-description - it purges the buffer.
8. Client enables the BRCB and process buffered ***Reports*** or GI.

Comment

According IEC 61850-7-2, 17.2.2.1, a server shall first respond SetBRCBValues( EntryID ) and then may send Reports. And - according TISSUE 1454 - a server may send Report by reception of SetBRCBValues( RptEna ) - already before the write response. Thus, the test result depends if Client maps SetBRCBValues for EntryID and RptEna in only one, or few MMS services.

#### 5.2.3.7.1 Test Results

| Test Case Results: NORM- RPT-07 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Fail, n1 | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | Pass | | | | | |
| GE | P443 | | | | | | Pass | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | Pass | | | | |
| OMICRON | IEDScout | Pass | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | Pass | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1 - Set entryid denied with Object-Value-Invalid | | | | | | | | |

| Test Case Results: NORM-RPT-07 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| GE | D60 | | Pass | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |

| Test Case Results: NORM-RPT-07 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### 5.2.3.8 *Test case name: NORM-RPT-08*

Reason: BRCB.ResvTms handling by connection loss

Expected result

1. Server sets BRCB.ResvTms = -1 in pre-assigned URCB.
2. Client does ***SetBRCBValues***( ResvTms >0); and enables the BRCB correctly.
3. Server and Client detects connection loss. The value of BRCB.ResvTms = -1 not change.
4. Server sets BRCB.ResvTms = 0.
5. Client does ***SetBRCBValues***( ResvTms > 0 ) and enables the BRCB.
6. Server and Client detects connection loss. Server counts down BRCB.ResvTms.

Test description

1. Configure in Server a BRCB with an instance preassigned to ClientLN of the Client.
2. Associate Client and Server. Client reserves and enables the BRCB.
3. Abort TPAA. Use local Server's meanings of additional client to check BRCB attributes.
4. Configure in Server a BRCB without any ClientLN.
5. Associate Client and Server. Client enables the BRCB.
6. Abort TPAA. Use local Server's meanings of additional client to check BRCB attributes.

Comment

BRCB.ResvTms is optional in Ed1/Ed2, mandatory from Ed2.1. Results depend on Ed.1 / Ed.2 / Ed2.1. Observers may notice the meanings the Client and the Server are using to solve eventual differences in reservation handling.

#### 5.2.3.8.1 Test Results

| Test Case Results: NORM- RPT-08 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | NE,n1 | | | | |
| GE | D60 | | | | | | | |
| **GE** | MU320 | | NE,n1 | | | | | |
| GE | P443 | | | | | | | |

| Test Case Results: NORM- RPT-08 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | Pass | | | | |
| OMICRON | IEDScout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | | |
| TMW | DTM | | Pass | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1 - The server cannot preassign ResvTms to true. | | | | | | | | |

### 5.2.3.9 Test case name: NORM-RPT-09

Reason: Data in Reports from BRCB instances enabled by redundant Clients

Expected result

5. During connection loss Server process Reports for connected Client with identical data (value, quality and timestamp) as data in buffered Reports processed to second Client.
   On both Clients, the values of the members of the dataset should match those of Server.

Test description

1. Configure system where 2 BRCBs with the same Dataset are enabled by duplicated (redundant) Clients, e.g. use two instances of a BRCB.
2. Associate Server with both Clients. Reserve and enable reporting, produce at least one ***Report***.
3. Disconnect Ethernet by one Client.
4. Process few ***Reports*** on trigger *data-change*.
5. (re)Associate the Client. Client reserves and enables reporting without resynchrozing. Client acquires buffered data.

Comment

Demands redundant clients or the compare using two clients configured in parallel.

#### 5.2.3.9.1 Test Results

| Test Case Results: NORM- RPT-09 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | Pass | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | Pass | | | | |
| OMICRON | IEDScout | Pass | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |

| Test Case Results: NORM- RPT-09 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### 5.2.4 Control Services

Cases are focusing on tracking of control services in multi-client systems.

#### 5.2.4.1 Test case name: NORM-CNTRL-01

Reason: Tracking of service Select/SelectWithValue negative

Expected result

3. Server process Service Tracking about the control service with correct information (ServiceType, ErrorCode, originator, AddCause etc).
   Client gives indication about the control service processed by another client.

Test description

1. Configure reporting of LTRK.SpcTrk or LTRK.DpcTrk.
2. Associate Client and Server.
3. Another client process ***Select*** or ***SelectWithValue*** on interlocked or already selected SPC or DPC in control mode 2 or 4.

Comment

Ed.2 only.
Demands use of multiple clients.

##### 5.2.4.1.1 Test Results

| Test Case Results: NORM- CNTRL-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | NE,n1 | | | | |
| OMICRON | IEDScout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |

| Test Case Results: NORM- CNTRL-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | Pass | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1 – LTRK not supported by Server | | | | | | | | |

| Test Case Results: NORM-CNTRL-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Omicron | SISCO | TMW | SEL | SIFANG | | |
| | Model | IED Scout | AXS4-61850 | Test Suite Pro | 3560 | CSC-2000(V2) | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | IEDScout | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211 | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### 5.2.4.2 Test case name: NORM-CNTRL-02

Reason: Tracking of service Operate from another client

Expected result

3. Similar like 5.2.4.1;
   Optional test of the use-case: suppressing of trip detection on Client.

Test description

1. Configure reporting of LTRK.SpcTrk or LTRK.DpcTrk.
2. Associate Client and Server.
3. Another client process successfully ***Operate*** on SPC or DPC.

Comment

Ed.2 only.
Demands use of multiple clients.

#### 5.2.4.2.1 Test Results

| Test Case Results: NORM- CNTRL-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | Pass | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | NE,n1 | | | | |
| OMICRON | IEDScout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |

| Test Case Results: NORM- CNTRL-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | | | Pass | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| n1 – LTRK not supported by Server | | | | | | | | |

## 5.2.5 Settings Group

### *5.2.5.1 Test case name: NORM-SGCB-01*

Reason: Ability to change Active Group

Expected result

1. Active setting group is changed
2. Settings are shown to have actually been changed.

Test description

1. Client changes active setting group

#### 5.2.5.1.1 Test Results

| Test Case Results: NORM- SGCB-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | Pass | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| OMICRON | IEDScout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | Pass | | Pass | Pass |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### 5.2.5.2 *Test case name: NORM-SGCB-02*

Reason: Ability to change setting and then activate the revised group

Expected result

1. Active setting group is changed
2. Settings are shown to have actually been changed.

Test description

1. Client sets edit group.
2. Client changes a setting as is appropriate (must coordinate with IED vendor).
3. Client saves group.
4. Client activates group.

#### 5.2.5.2.1 Test Results

| Test Case Results: NORM- SGCB-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| GE | D60 | | | | | | | |
| GE | MU320 | | | | | | | |
| GE | P443 | | | | | | Pass | |
| KERI | KMU100 | | | | | | | |
| Novatech | PX24 | | | | | | | |
| Omicron | Station Scout | | | | | | | |
| OMICRON | IEDScout | | | | | | | |
| SEL | 3555 | | | | | | | |
| SEL | 401 | | | | | | | |
| SEL | 421 | | | | | | | |
| SEL | 451 | | | | | | | |
| SEL | 487B | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 751 | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| Sifang | CSC-211-EB | | | | Pass | | Pass | Pass |

| Test Case Results: NORM- SGCB-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Client | | | | | | |
| | Vendor | Novatech | ARC Informatique | ASE Kalkitech | CopaData | Doble | KEPCO | KERI |
| | Model | OrionLXm | PcVue | ASE61850 Testset | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| TMW | DTM | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### *5.2.5.3 Test case name:NORM-SGCB-03*

Reason: Verification that Setting Group Change are persisted

Expected result

1. Active setting group is changed
2. Settings are shown to have actually been changed.

Test description

1. Client changes active setting group
2. DUT is power-cycled
3. Client re-establishes connection.
4. Client verifies active setting group.

#### 5.2.5.3.1 Test Results

| Test Case Results: NORM- SGCB-03 | | | | | |
|---|---|---|---|---|---|
| | Client | | | | |
| | Vendor | CopaData | Doble | KEPCO | KERI |
| | Model | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | |
| Vendor | Model | | | | |
| ABB | RET670 | | | | |
| GE | D60 | | | | |
| GE | MU320 | | | | |
| GE | P443 | | | | |
| KERI | KMU100 | | | | |
| Novatech | PX24 | | | | |

| Test Case Results: NORM- SGCB-03 | | | | | |
|---|---|---|---|---|---|
| | Client | | | | |
| | Vendor | CopaData | Doble | KEPCO | KERI |
| | Model | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | |
| Vendor | Model | | | | |
| Omicron | Station Scout | | | | |
| OMICRON | IEDScout | | | | |
| SEL | 3555 | | | | |
| SEL | 401 | | | | |
| SEL | 421 | | | | |
| SEL | 451 | | | | |
| SEL | 487B | | | | |
| SEL | 487E | | | | |
| SEL | 751 | | | | |
| Sifang | CSI-200E | | | | |
| Sifang | CSC-211-EB | Pass | | Pass | Pass |
| TMW | DTM | | | | |
| Toshiba | GRD200 | | | | |
| Toshiba | GRT200 | | | | |

### 5.2.5.4 Test case name: NORM-SGCB-04

Reason: Verification that Setting Changes are persisted

Expected result

1. Active setting group is changed
2. Settings are shown to have actually been changed.

Test description

1. Client sets edit group.
2. Client changes a setting as is appropriate (must coordinate with IED vendor).
3. Client saves group.
4. DUT is power-cycled
5. Client re-establishes association.
6. Client activates group.

#### 5.2.5.4.1 Test Results

| Test Case Results: NORM- SGCB-04 | | | | | |
|---|---|---|---|---|---|
| | Client | | | | |
| | Vendor | CopaData | Doble | KEPCO | KERI |
| | Model | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | |
| Vendor | Model | | | | |
| ABB | RET670 | | | | |
| GE | D60 | | | | |
| GE | MU320 | | | | |
| GE | P443 | | | | |
| KERI | KMU100 | | | | |
| Novatech | PX24 | | | | |
| Omicron | Station Scout | | | | |
| OMICRON | IEDScout | | | | |
| SEL | 3555 | | | | |
| SEL | 401 | | | | |
| SEL | 421 | | | | |
| SEL | 451 | | | | |
| SEL | 487B | | | | |
| SEL | 487E | | | | |
| SEL | 751 | | | | |
| Sifang | CSI-200E | | | | |
| Sifang | CSC-211-EB | Pass | | Pass | Pass |
| TMW | DTM | | | | |
| Toshiba | GRD200 | | | | |
| Toshiba | GRT200 | | | | |

### *5.2.5.5 Test case name:NORM-SGCB-NEG-01*

Reason: Verification that Settings are persisted

Expected result

1. Active setting group is changed
2. The settings are shown to have not  changed.

Test description

1. Client sets edit group.
2. Client changes a setting as is appropriate (must coordinate with IED vendor).
3. Client cancels the edit.
4. Client activates group.

#### 5.2.5.5.1 Test Results

| Test Case Results: NORM- SGCB-NEG-01 | | | | | |
|---|---|---|---|---|---|
| | Client | | | | |
| | Vendor | CopaData | Doble | KEPCO | KERI |
| | Model | Zenon | 61850Test | IED Explorer | KMU100 |
| Server | | | | | |
| Vendor | Model | | | | |
| ABB | RET670 | | | | |
| GE | D60 | | | | |
| GE | MU320 | | | | |
| GE | P443 | | | | |
| KERI | KMU100 | | | | |
| Novatech | PX24 | | | | |
| Omicron | Station Scout | | | | |
| OMICRON | IEDScout | | | | |
| SEL | 3555 | | | | |
| SEL | 401 | | | | |
| SEL | 421 | | | | |
| SEL | 451 | | | | |
| SEL | 487B | | | | |
| SEL | 487E | | | | |
| SEL | 751 | | | | |
| Sifang | CSI-200E | | | | |
| Sifang | CSC-211-EB | Pass | | Pass | Pass |
| TMW | DTM | | | | |
| Toshiba | GRD200 | | | | |
| Toshiba | GRT200 | | | | |

### 5.2.6 GOOSE

Precondition: LLN0.Mod should be set to a value of ON. All participating LNx.Mod value should be ON. The LLN0.Beh value should reflect a value of ON (same with the LNx values). This needs to be verified through HMI/Client interaction and represents a test case as part of the client/server part of this test. The purpose of the test cases is to prove that units can properly process simulated GOOSE messages (e.g. Sim bit = true) .

#### *5.2.6.1 Test case name: NORM-GOOSE-01*

Reason: To make sure that IEDs process the appropriate information as part of a normal maintenance process.

Test steps:

1. LPHD.Sim is set to false in the IED under test.
2. Test set is configured to emulate all the GOOSE messages for which an IED subscribes for from a particular IED.Test set begins publishing the GOOSE messages with the Simulation bits set and data quality=good.

Expected Results:

1. Because LPHD.Sim is false or non-existent in the Subscriber device model, It is expected that the IED under test will not take action on the test set information.
2. If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked based on the implemented DataObjects and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St shoud be True with good quality, LGOS.ConfRevNum's value should equal the value in RxConfRevNum.  Additionally, LGOS.SimSt should be false.
3. The rest of the IEDs in the system should be unaffected.

#### 5.2.6.1.1 Test Results

| Test Case Results: NORM-GOOSE-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | Vizimax | OMICRON | SEL | GE | OMICRON | TMW | |
| | Model | MGU01000 | IED Scout | 487B | MU320 | CMC850 | DTM | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| GE | P443 | Pass | Pass | | | | | |
| GE | MU320 | | | Pass | | | | |
| SEL | 487B | | | | Pass | | | |
| Sifang | CSI-200E | | | | | Pass | | |
| Vizimax | PMU01000 | | | | | | Pass | |
| | | | | | | | | |
| | | | | | | | | |

### *5.2.6.2 Test case name: NORM-GOOSE-02*

Reason: To make sure that IEDs process the appropriate information as part of a normal maintenance process.

Test steps:

1. LPHD.Sim is set to false in the IED under test.
2. Test set is configured to emulate all the GOOSE messages for which an IED subscribes for from a particular IED.

3. Test set begins publishing the GOOSE messages with the Simulation bits set and data quality=good.
4. The LPHD.Sim value is set to true in the IED under test.
5. After some time, and observing the reaction of the IED under test, set the LPHD.Sim value to false in the IED under test.

Expected Results:

1. After step 3, it is expected that the IED under test will not take action on the test set information.
    a. If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked based on the implemented DataObjects and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St shoud be True with good quality, LGOS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LGOS.SimSt should be false.
    The witness should note that value of LGOS.LastStNum as it will be used for the next step expected results.
2. After step 4, it is expected that the IED under test will take action on the test set information.
    a. If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked based on the imlemented DataObects and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St shoud be True with good quality, LGOS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LGOS.SimSt should be true.
    It is highly probable that the LGOS.LastStNum value will be different than the one observed in step 1. This would be typical and is worthwhile to check.
    The value should be recorded prior to the next test step execution.
    b. The other IEDs in the system should be unaffected.

3. After step 5, it is expected that the IED under test will not take action on the test set information.

If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked based on the implemented DataObjects and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St shoud be True with good quality, LGOS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LGOS.SimSt should be false.
It is highly probable that the LGOS.LastStNum value will be different than the one observed in step 1. This would be typical and is worthwhile to check.

#### 5.2.6.2.1 Test Results

| Test Case Results: NORM-GOOSE-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | Vizimax | OMICRON | SEL | GE | OMICRON | TMW | |
| | Model | MGU01000 | IED Scout | 487B | MU320 | CMC850 | DTM | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| GE | P443 | Pass | Pass | | | | | |
| GE | MU320 | | | Pass | | | | |
| SEL | 487B | | | | Pass | | | |
| Sifang | CSI-200E | | | | | Pass | | |
| Vizimax | PMU01000 | | | | | | Pass | |
| | | | | | | | | |
| | | | | | | | | |

### *5.2.6.3 Test case name: NORM-GOOSE-03*

*Reason:* To make sure that all IEDs which are currently not being tested ignore the simulated GOOSE.

Test steps:

1. LPHD.Sim is set to false or is not present in the IED under test.
2. Test set is configured to emulate all the GOOSE messages for which an IED subscribes for from a particular IED. Test set begins publishing the GOOSE messages with the Simulation bits set and data quality=good.

Expected Results:

1. After step 3 it is expected that the IED under test will not take action on the test set information.
2. If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked based on imlementted DataObjects and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St shoud be True with good quality, LGOS.ConfRevNum's value should equal the value in RxConfRevNum.  Additionally, LGOS.SimSt should be false.
3. The rest of the IEDs in the system should be not operate upon the information provided by the IED under test.

#### 5.2.6.3.1 Test Results

| Test Case Results: NORM-GOOSE-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | Vizimax | OMICRON | SEL | GE | OMICRON | TMW | |
| | Model | MGU01000 | IED Scout | 487B | MU320 | CMC850 | DTM | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| GE | P443 | Pass | Pass | | | | | |
| GE | MU320 | | | Pass | | | | |
| SEL | 487B | | | | Pass | | | |
| Sifang | CSI-200E | | | | | | | |
| Vizimax | PMU01000 | | | | | | Pass | |
| | | | | | | | | |
| | | | | | | | | |

## 5.2.7 Sampled Values

### *5.2.7.1 Tests of behavior of LPHD.Sim*

#### 5.2.7.1.1 Test case name: NORM-SV-01

Reason: To make sure that IEDs process the appropriate information as part of a normal maintenance process.

Test steps:

1. LPHD.Sim is set to false or is not present in the IED under test.

2. Test set is configured to emulate all the SV messages for which an IED subscribes for from a particular IED.Test set begins publishing the SV messages with the Simulation bits set and data quality=good. The test set contains a fault current in the SV messages in attempt to trip the IED.

Expected Results:

1. It is expected that the IED under test will not take action on the test set information.
2. If there is a monitoring substation HMI/Client (s), the instance of LSVS should be checked based on implemented DataObjects and normal operation of LSVS.NdsCom=false, LSVS.St shoud be True with good quality, LSVS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LSVS.SimSt should be false.
3. The rest of the IEDs in the system should be unaffected. How do we observe this? A measurement value in the IED not affected could be observed.

#### 5.2.7.1.2 Test Results

| Test Case Results: NORM-SV-01 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | ABB | Vizimax |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | SAM600-MU | |
| Subscriber | | | | | | | | | |
| Vendor | Model | | | | | | | | |
| SEL | 487E | Pass | | | | | | | |
| SEL | 451 | | Pass | | | | | | |
| NR | PCS-978S | | Pass | | | | | | |
| OMICRON | IED Scout | | Pass | | | | | | |
| SEL | 487B | Pass | | | | | | | |
| Sifang | CSI-200E | | | Pass | | | | | |
| GE | D60 | | | | Pass,n1 | | | | |
| Toshiba | GRD200 | | Pass | | | | | | |
| Toshiba | GRT200 | | | Pass | | Pass | Pass | | |
| RTDS | GTNETx2_SV | | Pass | | | | | Pass | Pass |
| n1 – LSVS.SimSt did not change state properly. | | | | | | | | | |

### 5.2.7.1.3 Test case name: NORM-SV-02

*Reason:* To make sure that IEDs process the appropriate information as part of a normal maintenance process.

Test steps:

1. LPHD.Sim is set to false in the IED under test.
2. Test set is configured to emulate all the SV messages for which an IED subscribes for from a particular IED.
3. Test set begins publishing the SV messages with the Simulation bits set and data quality=good. The test set contains a fault current in the SV messages to trip the IED.
4. The LPHD.Sim value is set to true in the IED under test.
5. After some time, and observing the reaction of the IED under test, set The LPHD.Sim value is set to false in the IED under test.

Expected Results:

1. After step 3, it is expected that the IED under test will not take action on the test set information.
    a. The IED shall use the not-simulated values.
    b. If there is a monitoring substation HMI/Client (s), the instance of LSVS should be checked based on implemented DataObjects and normal operation of

LSVS.NdsCom=false, LSVS.St shoud be True with good quality, LSVS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LSVS.SimSt should be false.

2. After step 4, it is expected that the IED under test will take action on the test set information.
    a. The IED shall use the simulated values.
    b. If there is a monitoring substation HMI/Client (s), the instance of LSVS should be checked based on imlpemetned DataObjects and normal operation of LSVS.NdsCom=false, LSVS.St shoud be True with good quality, LSVS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LSVS.SimSt should be true.
    c. The other IEDs in the system should be unaffected. How do we observe this? Check the response of their protection function (which should be ignoring the simulated SV).
3. After step 5, it is expected that the IED under test will not take action on the test set information.

    a. If there is a monitoring substation HMI/Client (s), the instance of LSVS should be checked based on implemented DataObjects and normal operation of LSVS.NdsCom=false, LSVS.St shoud be True with good quality, LSVS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LSVS.SimSt should be false.

#### 5.2.7.1.4 Test Results

| Test Case Results: NORM-SV-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 451 | | Pass | | | | | |
| NR | PCS-978S | | Pass | | | | | |
| OMICRON | IED Scout | | Pass | | | | | |
| SEL | 487B | Pass | | | | | | |
| Sifang | CSI-200E | | | Pass | | | | |
| GE | D60 | | | | Pass | | | |
| Toshiba | GRD200 | | Pass | | | | | |
| Toshiba | GRT200 | | | Pass | | Pass | Pass | |
| RTDS | GTNETx2_SV | | Pass | | | | | |
| | | | | | | | | |

### 5.2.7.2 Redundant Merging Unit

In a digital substation, Stand Alone Merging Unit (SAMU) provides information from primary equipment to the protective relays via an ethernet network. This information is used for the protection and control of these equipment. To minimize single point of failure and improve the availability of a protection system, redundant SAMUs, redundant protection communications network, and redundant protective relays are often applied. Many breaker and transformer cabinets have redundant current transformers installed in them. It makes sense to install redundant SAMUs in these cabinets to avoid single point of failure. When a redundant SAMU is not available locally, other SAMUs in the system can also act as a redundant unit. A protective relay subscribes to data from primary SAMUs and the redundant SAMUs. When primary SAMUs are available, the protective relay uses its data from protection and control. If a primary SAMU fails, the protective relay can switch to the redundant SAMU to keep the protection system available.

*Figure 22* shows a section of the single line diagram from Figure 2 (General Integrated Application Test Cases – IOP 2019). The transformer relay (TXA_IED) protects the transformer using two primary SAMUs, TXA_MU01 and TXA_MU02. The sum of currents measured by feeder SAMUs, A1_MU and A2_MU, is same as that of current measured by TXA_MU02. Hence, two feeder SAMUs, A1_MU and A2_MU, can act as redundant SAMU for TXA_MU02. When TXA_MU02 is healthy, TXA_IED provides differential protection to Transformer A using TXA_MU01 and TXA_MU02 SAMUs. If TXA_MU02 fails, it will be replaced by A1_MU and A2_MU in TXA_IED for differential protection.

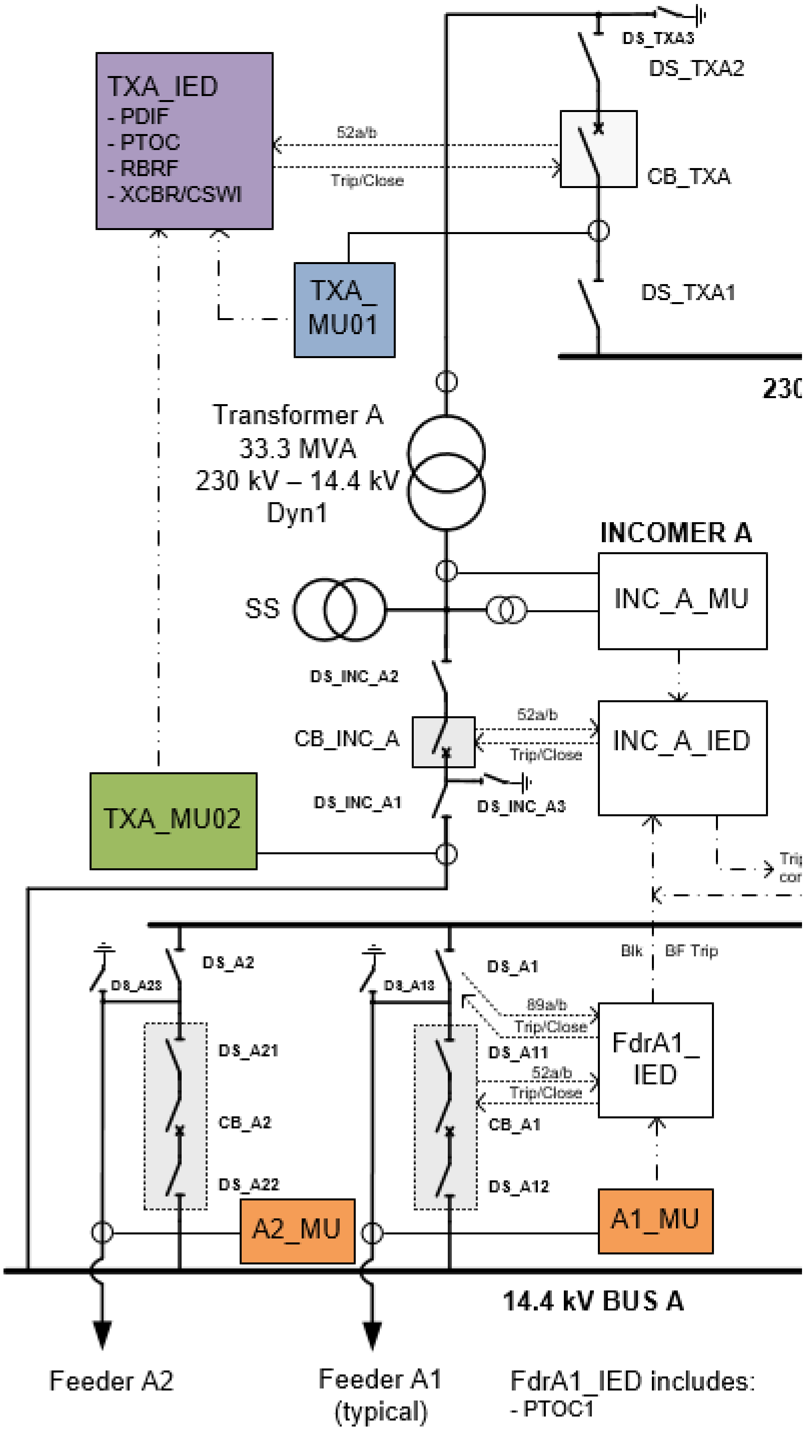


Figure 22: Primary and redundant SAMUs for a transformer IED

### Initial Configuration:

Following steps are required to create an operational system before executing two test cases below.

- Configure TXA_IED to subscribe SV streams from four SAMUS, i.e., TXA_MU01, TXA_MU02, A1_MU, and A2_MU
- Map three phase currents from the TXA_MU01 to Current Terminal #1 in the TXA_IED.
- Map three phase currents from the TXA_MU02 to Current Terminal #2 in the TXA_IED.
- Sum three phase currents from A1_MU and A2_MU and map it to Current Terminal #3 in the TXA_IED.
- Configure transformer differential protection (87T) to use Current Terminals as shown below:
  - Terminal #1 and Terminal #2 when TXA_MU02 is healthy
  - Terminal #1 and Terminal #3 when TXA_MU02 is unavailable
- Configure transformer differential protection (87T) for Transformer A parameters shown in the figure.

#### 5.2.7.2.1 Test case name: NORM-SV-RED-SAMU-01

Precondition: All SAMUs are operating under normal conditions.

*Test steps:*

1. Apply current signals to all four SAMUs. Apply currents in such a way that power flows from the transformer to two feeders (Normal condition).
2. Use IED metering function to read the current of all three current terminals.
3. Use IED built-in function to verify Current Terminals used for transformer differential protection (87T).
4. Apply currents associated with transformer internal fault to all four SAMUs (Fault condition).
5. Apply current signals from test step 1.

*Expected results:*

1. After step 1, it is expected that the IED subscribes to SV streams from all four SAMUs.
2. After step 2, the IED metering functions shall correctly display the current signals measured by all four SAMUs.
3. After step 3, the IED shall indicate that it uses Current Terminal #1 (TXA_MU01) and Current Terminal #2 (TXA_MU02) for transformer differential protection (87T).
4. After step 4, the IED’s transformer differential protection (87T) shall operate to indicate internal fault.
5. After step 5, the IED metering functions shall correctly display the current signals measured by all four SAMUs.

#### 5.2.7.2.2 Test Results

| Test Case Results: NORM-SV RED-SAMU-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | RTDS |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | GTFPGA_SV |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 451 | | | | | | | |
| NR | PCS-978S | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| SEL | 487B | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| GE | D60 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| SEL | 487 | | | | | | | Pass |
| | | | | | | | | |

### 5.2.7.2.3 Test case name: NORM-SV-RED-SAMU-02

**SAMU: sending SV on multiple SV flux**

*Purpose:*

Verify that a SAMU can send its sample values on several flux, so that each protection get only their data.

A typical use casa is as follow:

- The “line” is a combination of cable and overhead lines.

*PreCondition*

The following devices shall be on and configured as follow:

- One SAMU is sampling 3CT, the 3 VT and an I0 CT.
- A distance protection (IED1), need 3I and 3 voltages
- A frequency protection (IED2), need 3 voltages
- A cable protection (IED3), need only I0.

- The three SV flux for IED1, IED2, and IED3 have a specific SV_ID and SV Control block and can trip the breaker independently.

*Why ?*

- This is to mimic the traditional implementation with the wires: each protection is connected to the appropriate voltage and current.

*Verification*

- The three relays are receiving and using the individual flux.
- Appropriate fault injection allows to verify each protection individually thanks to the separated SV_ID / VLAN / SC Control block

*Investigation / disruptive case:*

- The SV flux from A is interrupted during a short period of time (100ms)
- After this delay, a fault is injected on B
- Goal determine how long it takes to change-over

#### 5.2.7.2.3.1 Test Results

None recorded.

### 5.2.7.2.4 Test case name: NORM-SV-RED-SAMU-03

**Purpose**:

Verify that a protection relay can switch from a SV flux to another

*PreCondition*

The following devices shall be on and configured as follow:

- One Samu device (‘SAMUA’) is set-up so that a protection relay can use a simple SV flux from it.
- A second Samu (‘SAMUB’) device, set-up so that the same protection relay can also subscribe simple SV flux from it.
- SAMUA and SAMUB have different destination MAC address for their SV flux as well as different smvID
- The SV flux from A consist in nominal Voltage and typical current (no fault injected).

- The SV flux from B consist in half the Voltage and half the current compared A (or another way to be sure which one is being used, but not 0…)
- The protection is initially using the flux from SAMUA ( ? not obvious)
- The protection can display average value from the SV received

*PreCondition verification*

- The protection relay show the value of the flux A on the local HMI.
- SvScout / WireShark is used to check the validity of both SV flux.

*Trigger case / expected behavior:*

- SAMU A is turned off
  - The protection relay show the value of the flux B on the local HMI.
  - There is no changes in *.Health Data Object (several DO might be available).
  - There is “another event” that should be visible regarding the loss of SAMU A, on the HMI.

- Both SAMU are on
  Step1

  - On SAMU A, the injection of I/U is modified so that the quality of one or several TVTR.VolSv is invalid
  - Change Over is expected

  Step 2

  - Back to initial status

  - The quality of one or several TCTR.AmpSv is invalid or questionable.

*Investigation / disruptive case:*

- The SV flux from A is interrupted during a short period of time (100ms)
- After this delay, a fault is injected on B
- Goal determine how long it takes to change-over

On a given bay we have:

- One SAMU has its LPHD.Health set to Warning or Alarm.
- The quality of one or several TVTR.VolSv is invalid or questionable.
- The quality of one or several TCTR.AmpSv is invalid or questionable.

- We are looking at one given failure at a time. We do not expect the relay to use Voltages from A and Currents from B for example.

#### *5.2.7.2.4.1 Test Results*

No results recorded.

### 5.2.8 SOE testing (logging mechanism)

Purpose: To verify logging mechanism in close to real life application of SOE between server and clients.

Use cases:

1. IED has configured LCB and Log with the same DS that is referenced in URCB. Initiate changes od DO in DS. Compare records in reported URCB and recorded Log (Timestamp, ReasonCode, Value, quality)
2. Instantiate 2 LCB (different DS) with same Log. Enable logging and disconnect. Initiate change and connect again with clients to check that all changes are recorded (if PIXIP Lg3 is supported - Multiple Journal Entries).
3. Instantiate 2 LCB (same DS) with different Logs. Enable logging. Initiate change DO in DS and connect again with client to check that all changes are recorded in both Logs.

### *5.2.8.1 Test case name: NORM-LOG-01*

IED has configured LCB and Log with the same DS that is referenced in URCB. Initiate changes od DO in DS. Compare records in reported URCB and recorded Log (Timestamp, ReasonCode, Value, quality)

Prerequisites:

IED has been preconfigured (using configuration tool):
1 x DS with at least 4 DO that can be changed either by simulation or forced externally
1 x URCB with: DatSet = DS, TrgOps= DataChange, OptFlds = all
1 x LCB with: DatSet = DS, LogRef = Log, TrgOps = DataChange

Test steps:

1. Connect Client to the IED (server)
2. Reserve URCB (set Resv = True)
3. Read URCB (request GetURCBValues)
4. Enable URCB (set RptEna = True)
5. Read LCB (request GetLCBValues)
6. Enable LCB (set LogEna = True)
7. Initiate several DataChanges of DO within DS in IED and monitor changes in received URCBs.
8. Read LCB, verify OldEntrTm, NewEntrTm, OldEnt, NewEnt (request GetLCBValues)
9. Read Log entries (QueryLogAfter with NULL EntryTime)
10. Compare Log and URCB records (Timestamp, Quality, Value, ReasonCode)
11. Disable URCB, remove reservation (RptEna = False, Resv = False)
12. Disable LCB (set LogEna = False).

Expected results:

3. URCB is configured as defined in prerequisites
4. URCB is enabled
5. LCB is configured as defined in prerequisites
6. LCB is enabled
7. Verify reports with DataChanges
8. OldEntrTm, NewEntrTm, OldEnt, NewEnt changed comparing to initial state from step 3
9. Log enties have all records of DataChange with ReasonCode = DataChange
10. Reports data correspond to Log data (Timestamp, ReasonCode, Value, quality)
11. URCB disabled and reservation removed
12. LCB disabled.

#### 5.2.8.1.1 Test Results

None recorded.

### *5.2.8.2 Test case name: NORM-LOG-02*

Instantiate 2 LCB (different DS) with same Log. Enable logging and disconnect. Initiate change and connect again with clients to check that all changes are recorded (if PIXIP Lg3 is supported - Multiple Journal Entries).

Prerequisites:

IED has been preconfigured (using configuration tool):
2 x DS's with at least 4 DO that can be changed either by simulation or forced externally
1 x LCB1 with: DatSet = DS1, LogRef = Log, TrgOps = DataChange
1 x LCB2 with: DatSet = DS2, LogRef = Log, TrgOps = DataChange

Test steps:

1. Connect Client to the IED (server)
2. Read LCB1 (request GetLCBValues)
3. Enable LCB1 (set LogEna = True),
4. Read LCB2 (request GetLCBValues)
5. Enable LCB2 (set LogEna = True)
6. Disconnect Client from IED.
7. Initiate several DataChanges of DO within DS1 and DS2 in IED.
8. Connect Client to the IED (server)
9. Read LCB1 and LCB2, verify OldEntrTm, NewEntrTm, OldEnt, NewEnt (request GetLCBValues)
10. Read Log entries (QueryLogAfter with NULL EntryTime )
11. Disable LCB1, LCB2 (set LogEna = False).

Expected results:

2. LCB1 is configured as defined in prerequisites
3. LCB1 is enabled
4. LCB2 is configured as defined in prerequisites
5. LCB2 is enabled
9. OldEntrTm, NewEntrTm, OldEnt, NewEnt changed comparing to initial (read in LCB1 and LCB2 step 2 and 4). Values in LCB1 and LCB2 are same (at least OldEntrTm, NewEntrTm)
10. Log enties have all records of DataChange with ReasonCode = DataChange. Timestamp, ReasonCode, Value and quality correspond to initiated values.
11. LCB1 and LCB2 disabled.

#### 5.2.8.2.1 Test Results

None recorded.

### *5.2.8.3 Test case name: NORM-LOG-03*

Instantiate 2 LCB (same DS) with different Logs. Enable logging. Initiate change DO in DS and connect again with client to check that all changes are recorded in both Logs.

Prerequisites:

IED has been preconfigured (using configuration tool):
1 x DS’s with at least 4 DO that can be changed either by simulation or forced externally
1 x LCB1 with: DatSet = DS1, LogRef = Log1, TrgOps = DataChange
1 x LCB2 with: DatSet = DS1, LogRef = Log2, TrgOps = DataChange

Test steps:

1. Connect Client to the IED (server)
2. Read LCB1 (request GetlCBValues)
3. Enable LCB1 (set LogEna = True),
4. Read LCB2 (request GetlCBValues)
5. Enable LCB2 (set LogEna = True)
6. Initiate several DataChanges of DO within DS1 in IED.
7. Read LCB1 and LCB2, verify OldEntrTm, NewEntrTm, OldEnt, NewEnt (request GetLCBValues)
8. Read Log entries (QueryLogAfter with no parameters)
9. Disable LCB1, LCB2 (set LogEna = False).

Expected results:

2. LCB1 is configured as defined in prerequisites
3. LCB1 is enabled
4. LCB2 is configured as defined in prerequisites
5. LCB2 is enabled
7. OldEntrTm, NewEntrTm, OldEnt, NewEnt changed comparing to initial (read in LCB1 and LCB2 step 2 and 4). Values in LCB1 and LCB2 are same (at least OldEntrTm, NewEntrTm)
8. Log entries have all records of DataChange with ReasonCode = DataChange. Timestamp, ReasonCode, Value and quality correspond to initiated values
9. LCB1 and LCB2 disabled.

#### 5.2.8.3.1 Test Results

None recorded.

## 5.3 Substation Maintenance

### 5.3.1 Change SCD Communication Configuration: DIS-SCL-01

### 5.3.2 IED Addition to Bay or Additional Bay

Purpose: To verify the engineering process required to add a new IED into an existing IEC 61850 system, including:

- SCT can import SCD file
- SCT can import ICD file of the IED also from older SCL version
- SCT can configure communication parameters
- SCT can perform dataflow (DataSets, Reports, GOOSE, SV) and Log engineering within the limits declared as part of the capabilities in the service section
- SCT can draw single line diagram
- SCT can draw communication diagram
- SCT can create a valid SCD file and export in older SCL version
- ICT can accept modifications in the communication section (e.g. Subnet name, IP address), IED section (e.g. LN attribute lnType), and data type template section (e.g. LNodeType attribute id) as they are required to build a consistent SCD file.
- ICT can accept configurations of Report, GOOSE, SV and Log control blocks and data sets from an SCD file if they are within the limits declared as part of the capabilities in the service section and or PIXITS.
- ICT can import and use GOOSE and SV subscription information from other IEDs contained within the SCD file.
- ICT can accept instantiations of IEDs based on ICD files through an SCD file.
- ICT can configure IED to perform implemented protection and control schemes.

*Preconditions and explanation:*

Adding an IED into an existing IEC 61850 system requires a “round trip” engineer cycle involving the System Configuration Tool and all IEDs (and their respective IED Configuration Tools) that exchange data with the new IED. Therefore, these tests require the cooperation of several parties.

Test Support Delivers

- SCD file
- ICD file for the IED being added

Participant SCT Prepares

- SCT with SCD and ICD file from test support already processed (SICS S23, S41)

Participant ICT Prepares

- ICT with ICD file for the IED that will be physically present in the test

### *5.3.2.1 Test case name: SUBMAINT-01*

Description: Verify Engineering with SCT

Test Steps:

1. Check SCD file
   - Run SCD file through various SCL checkers and validators; report results for documentation
2. Check ICD file
   - Run ICD file through various SCL checkers and validators; report results for documentation
3. SCT imports SCD file
   - SCT is able to import SCD file (SICS S71, S72)
4. SCT imports ICD file and creates the instance of IED
   - SCT is able to import ICD file and to create instance (SICS S11 – S15, S111)
5. SCT adds the new IED to the already existing subnetwork modifying possibly predefined addressing information as required
   - (SICS S21, S22)
6. SCT associates the LNs in the IED to the related LNs in the single line diagram / substation section
   - (SICS S43)
7. SCT adds the new IED to the communication diagram and configures physical connections (PhysConn)
   - (SICS S24)
8. SCT configures datasets and report control blocks with the data required to be transmitted to the gateway and to the local HMI (if supported by the IED) including configuration of ClientLN and trgOps
   - Verify that tool does not provide capability to configure / change dataset and report control block if not allowed by the IED (SICS S56)
9. SCT configures signal flow, GOOSE control blocks, SV control blocks and associated datasets to implement the needed functions
   - Verify that tool does not provide capability to configure / change dataset and GOOSE/SV control block if not allowed by the IED (SICS S56)
10. SCT configures Log control blocks and associated datasets
    - Verify that tool does not provide capability to configure / change dataset and Log control block if not allowed by the IED (SICS S56)
11. SCT exports SCD file
    - SCT is able to produce SCD file (SICS S61, S62, S64, S66, S67)

#### 5.3.2.1.1 Test Results

| SUBMAINT-01 | | | |
|---|---|---|---|
| | SCL Tool | | |
| | Vendor | Helinks | |
| | Model | STS | |
| Server | | | |
| Vendor | Model | | |
| SEL | | Pass | |
| | | | |

### *5.3.2.2 Test case name: SUBMAINT-02*

Description: SCD file inspection

Test Steps:

1. Verify step A4
   - In the SCD file, verify that IED section has been added for the IED
2. Verify step A5
   - In the SCD file, verify that the IED have been added in the communication section to the already existing subnetwork (SICS S22)
3. Verify step A6
   - In the SCD file, verify the association of the LNs from the IED with the respective LNs in the substation section (SICS S43)
4. Verify step A7
   - In the SCD file, verify that PhysConn elements are configured (SICS S24)
5. Verify step A8
   - In the SCD file, verify that the report control blocks, and data sets are configured(SICS S31 – S35, S56)
6. Verify step A8
   - In the SCD file, verify that the ClientLN element is configured for the report control blocks (SICS S361)
7. Verify step A9
   - In the SCD file, verify that GOOSE/SV control blocks and data sets are configured (SICS S31 - S35, S56)
8. Verify step A9
   - In the SCD file, verify that IEDName elements are configured for GOOSE and SV messages (SICS S361)

9. Verify step A9
    - In the SCD file, verify that the data subscription is configured (input section and external references)  (SICS S37, S381, S382, S39)
10. Verify step A10
    - In the SCD file, verify that Log control blocks and data sets are configured (SICS S31-35, S56)
11. Check SCD file
    - Run SCD file through various SCL checkers and validators; report results for documentation.
    - Export using older SCL version and verify that the downgraded rules were applied

#### 5.3.2.2.1 Test Results

| SUBMAINT-01 | | | |
|---|---|---|---|
| | SCL Tool | | |
| | Vendor | Helinks | |
| | Model | STS | |
| Server | | | |
| Vendor | Model | | |
| SEL | | Pass | |
| | | | |

### 5.3.2.3 *Test case name: SUBMAINT-03*

Description: Engineering with ICT

Test Steps:

**Note**: Steps C1 – C5 should be done for the newly added IED and for all existing IEDs that are receiving data from the new IED.

1. ICT imports SCD file
    - ICT is able to import SCD file and create the instances of the IED in the ICT (SICS I21, I22)
2. Final IED engineering as required
    - ICT uses the subscription information from SCT
        i. **Note**: verification to be done by witness during test by observing what needs to be done in the IED tool by the engineer to create the binding of incoming external signals to internal signals (SICS I213, I42, I43)
3. ICT configures the IED

- IED can be configured

4. ICT exports IID/XFactor file
   - ICT is able to produce IID/XFactor file with updated ExtRefs
5. Check IID/XFactor file
   - Run IID/XFactor file through various SCL checkers and validators; report results for documentation

#### 5.3.2.3.1 Test Results

| SUBMAINT-01 | | | |
|---|---|---|---|
| | SCL Tool | | |
| | Vendor | Helinks | |
| | Model | STS | |
| Server | | | |
| Vendor | Model | | |
| SEL | | Pass | |
| | | | |

### *5.3.2.4 Test case name: SUBMAINT-04*

Description: Verify IED Behavior

**Note**: Steps D1 – D5 should be done for the newly added IED and for all existing IEDs that are receiving data from the new IED.

Test Steps:

1. Verify step A5
   - Connect with a test client to the IED
2. Verify step A9
   - Verify
3. Verify step A8
   - Verify that reports are sent to the test client with the content as configured by the SCT (SICS I25 - I28)
4. Verify step A9 Simulate GOOSE message
   - Verify (SICS I25 – I28)
5. Verify step A9 Simulate SV stream
   - Verify (SICS I25 – I28)

#### 5.3.2.4.1 Test Results

| SUBMAINT-01 | | | |
|---|---|---|---|
| | SCL Tool | | |
| | Vendor | Helinks | |
| | Model | STS | |
| Server | | | |
| Vendor | Model | | |
| SEL | | Pass | |
| | | | |

### 5.3.2.5 *Test case name: SUBMAINT-05*

Description: Update SCD file

Test Steps:

1. SCT imports IID/XFactor files
    - SCT is able to import IID/XFactor files (SICS S110)
2. Update data flow based on updated ExtRefs
3. Export updated SCD file
    - (SICS S61, S62)

#### 5.3.2.5.1 Test Results

| SUBMAINT-01 | | | |
|---|---|---|---|
| | SCL Tool | | |
| | Vendor | Helinks | |
| | Model | STS | |
| Server | | | |
| Vendor | Model | | |
| SEL | | Pass | |
| | | | |

### 5.3.2.6 *Test case name: SUBMAINT-06*

Description: SCD file inspection

Test Steps:

1. Verify step E2

- In the SCD file, verify that the ExtRefs of the IEDs are updated based on what has been returned by the IID/XFactor files for IEDs

2. Check SCD file
    - Run SCD file through various SCL checkers and validators; report results for documentation

#### 5.3.2.6.1 Test Results

| SUBMAINT-01 | | | |
|---|---|---|---|
| | SCL Tool | | |
| | Vendor | Helinks | |
| | Model | STS | |
| Server | | | |
| Vendor | Model | | |
| SEL | | Pass | |
| | | | |

### 5.3.3 IED Replacement

#### *5.3.3.1 Test case name: SUBMAINT-07*

Purpose: Determine if a failed IED can be replaced by an unconfigured spare of the same type.

Preconditions and explanation: The test case begins with a fully functional IED which fails. It is assumed that a backup configuration of the IED is available. The “spare” IED is the same device as the “failed” IED except that it has a “factory default” configuration and the factory default IP address.
The test case continues with online loading of the configuration followed by verification that the configuration is now valid.

Preparation: Create a “backup configuration” as well as a “factory default configuration” for the IED. The incorrect configuration MUST have a different IP address than the IED is normally configured.

Test Steps:

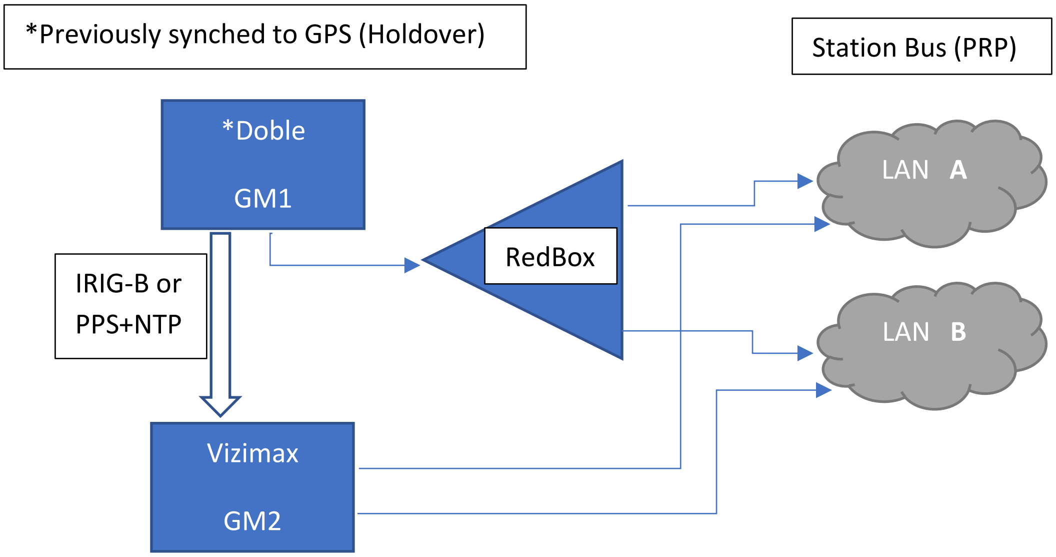
1. Verify the configuration version of the IED by polling <LDRoot>/LLN0.NamPlt.configRev. Record the configRev
2. Reconfigure the IP address to factory default. If power cycling is needed, perform it in the next step.
3. Disconnect power supply to IED, maybe wait 60 seconds to ensure GOOSE subscribers timeout?
4. Restore power to the IED

5. Use the ICT to inject the “factory default” configuration and verify that the IP address differs and NamPlt.configRev reports a different value than before.
6. Use the ICT to inject the “backup configuration” into the IED
7. Restore the IP address to the original value
8. Verify that NamPlt.configRev reports the original value

###### 5.3.3.1.1 Test Results

None recorded.

## 5.4 PTP



The Doble Grandmaster clock can be synchronized outdoor using a battery pack and then brought inside. This GM1 device should stay synchronized within required accuracy for hours. The second GM will then be connected to GM1 sync pulse using IRIG-B or PPS+NTP. GM2 will follow GM1 synchronization and will act as alternate GM on the network. Disconnecting GM1 will trigger change-over to GM2.

### 5.4.1 Process bus clock failure Test Cases

Nominal set-up

The following test cases assume that there are (minimum) two PTP master clocks from two devices connected to the process bus. It shall be possible to disconnect them from the network without disconnecting other essential functions (e.g. a client IED) or there shall be a possibility to disable it.

### 5.4.2 Basic Clock Test: PTP-NORM-01

This test is used to check that all IED are synchronized with the grandmaster Clock.

Requirements:

- All IEDs are fully configured and in operation.

- All master clock devices have been up and running for an enough time to ensure stabilization of the oscillator.

The test Description:

1. Connect a client to the IED
2. Read LTMS.TmSrc and LTMS.TmSyn (if available) on the IED under test.
   LTMS.TmSrc Indicates GM ID use and LTMS.TmSyn shall indicate true

#### 5.4.2.1 Test Results

| Test Case Results: PTP-NORM-01 | | | |
|---|---|---|---|
| | Client | | |
| | Vendor | CopaData | Doble |
| | Model | Zenon | 61850Test |
| Server | | | |
| Vendor | Model | | |
| ABB | RET670 | | |
| GE | D60 | | |
| GE | MU320 | | |
| GE | P443 | | |
| KERI | KMU100 | Pass | Pass |
| Novatech | PX24 | | |

## 5.5 IED Isolation Testing

Purpose: To determine if IEDs can be tested as part of an integrated system. There are two major use cases:

1. The ability of an IED to operate of test unit data instead of real process data while still participating in the overall system. This allows IEDs to be provided test data and drive the whole system reaction based upon the test data. This will be referred to as **non-isolated testing/system testing**.

2. The ability of an IED to operate of test unit data instead of real process data and to be logically isolated from the rest of the system (e.g. the system knows not to use the information provided by the IED). This will be referred to as **isolated testing/unit testing**.

The following table summarizes the test cases and if they are mandatory or optional for IED Isolation.

| | | m/o | Server/Publisher | Subscriber |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Normal execution in system | ISO-01 | m | x | |
| Local/Remote Testing | ISO-02 | m | x | |
| Test Mode | ISO-03<br>ISO-04 | m<br>m | x | <br>x |
| Test/Blocked Mode | ISO-05<br>ISO-06 | c1<br>m | x | <br>x |
| Local Mode Lockout of Remote Controls | ISO-07 | m | x | |

c1 – if IED supports Blocking.

c2- must support LLN0.LocSta or LLN0.Loc or LLN0.LocKey.

Preconditions and explanation: In order to perform these tests, especially for GOOSE, dataSets must be created that include the appropriate quality values for the information being conveyed. This is due to the fact that for use case 2, it will be the quality that conveys either the q.test = true. It is this indication that other IEDs will need to use in order to determine if the data is usable for processing. In order to be conformant, subscribing IEDs have to ignore data with q.test=true unless the subscribing IED is in test mode itself.

Please note that there are two bits for simulation/test: one in the GOOSE Ethernet reserved field, and one in the application level.

### 5.5.1 Client/Server

#### *5.5.1.1 Precondition Test - Non-Isolated Testing/System Testing (IED mode "on"): ISO-01*

Purpose: This test is to ensure that an individual IED can utilize test set data and still participate in the overall system (i.e. the data sent by that IED has q.test=false). This allows the system application to be tested using test sets.

Precondition: The Server IEDs shall support LLN0.LocSta or LLN0.Loc or LLN0.LocKey. If these DataObjects are not present, the witness shall make note and ISO-07 will not be able to be executed.

Precondition Verification: IED is in mode "on" (Test Case 1)

##### 5.5.1.1.1 Test Results

| Test Case Results: ISO-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | Pass | Pass | | | | | |
| SEL | 487E | | | Pass | Pass | | | |
| GE | P443 | | | | | Pass | | |
| Toshiba | GRD200 | | | | | | Pass | |
| OMICRON | IED Scout | | Pass | | | | | Pass |
| Toshiba | GRT200 | | | | | Pass | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| Test Case Results: ISO-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| SEL | 487E | | | | Pass | | | |
| GE | P443 | | | Pass | | | | |
| Toshiba | GRD200 | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| ASE Kalkitech | ASE-61850 Test Set | Pass | | | | | | |
| ARC Informatique | PcVue | Pass | | | | | | |
| Vizimax | PMU01000 | | Pass | | | | | |
| SEL | 751 | | | | Pass | | | |
| | | | | | | | | |

### 5.5.1.2 Test case name: ISO-02

Reason: To make sure that IEDs process the appropriate information as part of a normal maintenance process.

Precondition: The IED under test must allow to switch Mod/Beh (must support LLN0.LocSta or LLN0.Loc or LLN0.LocKey). The IED must be in Remote. The IED being tested has LLN0.Beh = "on".

Test steps:

1. The client will monitor the value of LLN0.Mod and LLN0.Beh.
2. If the value is ON, no further action is required. Otherwise, the client will set the value of Mod to ON.

Expected Results: It is expected that the value of Mod.Beh will be ON.

#### 5.5.1.2.1 Test Results

| Test Case Results: ISO-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | Pass | Pass | | | | | |
| SEL | 487E | | | Pass | Pass | | | |
| GE | P443 | | | | | Pass | | |
| Toshiba | GRD200 | | | | | | Pass | |
| OMICRON | IED Scout | | Pass | | | | | Pass |
| Toshiba | GRT200 | | | | | Pass | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| Test Case Results: ISO-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| SEL | 487E | | | | | | | |
| GE | P443 | | | Q,n1 | | | | |
| Toshiba | GRD200 | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| ASE Kalkitech | ASE-61850 Test Set | Pass | | | | | | |

| Test Case Results: ISO-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ARC Informatique | PcVue | Pass | | | | | | |
| Vizimax | PMU01000 | | Pass | | | | | |
| SEL | 751 | | | | Pass | | | |
| n1 – change not displayed on HMI | | | | | | | | |

### *5.5.1.3 Test case name: ISO-03*

Reason: To make sure that IEDs can set the test quality bit.

Precondition: The IED under test must allow to switch Mod/Beh (must support LLN0.LocSta or LLN0.Loc or LLN0.LocKey). The IED must be in Remote. The IED being tested has LLN0.Beh = "on".

Test steps:

1. The client will monitor the value of LLN0.Mod and LLN0.Beh. The LLN0 shall be the highest in the Logical Device hierarchy.
2. The client shall monitor if received
3. The client will set LLN0.Mod = Test.
4. The client will read a MX FCD that has quality and the witness shall check that the quality.Test = true.

   If the LLN0 was not the highest in the hierarchy, then the MX FCD must be within the Logical Device for which the LLN0.Mod was set.

5. The witness shall check that the qualities in published GOOSE/R-GOOSE messages have quality.Test = true.
6. The witness shall check that the qualities in published SV/R-SV messages have quality.Test = true.

Expected Results: It is expected the witness shall be able to observe that the client differentiates between process and test data.

### 5.5.1.3.1 Test Results

| Test Case Results: ISO-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | Pass | Pass | | | | | |
| SEL | 487E | | | Pass | Pass | | | |
| GE | P443 | | | | | Pass | | |
| Toshiba | GRD200 | | | | | | Pass | |
| OMICRON | IED Scout | | | | | | | Pass |
| Vizimax | PMU01000 | | | | | | | |
| | | | | | | | | |
| Toshiba | GRT200 | | | | | Pass | | |
| | | | | | | | | |
| | | | | | | | | |

| Test Case Results: ISO-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| SEL | 487E | | | | | | | |
| GE | P443 | | | Pass | | | | |
| Toshiba | GRD200 | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| ASE Kalkitech | ASE-61850 Test Set | Pass | | | | | | |
| ARC Informatique | PcVue | Pass | | | | | | |
| Vizimax | PMU01000 | | | | | | | |
| SEL | 751 | | | | Pass | | | |
| | | | | | | | | |

### 5.5.1.4 Test case name: ISO-04

Reason: To make sure that subscriber IEDs can process the test quality bit.

Precondition: The IED under test must allow to switch Mod/Beh (must support LLN0.LocSta or LLN0.Loc or LLN0.LocKey). The IED must be in Remote. The IED being tested has LLN0.Beh = “on”.

Test steps:

1. The client will monitor the value of LLN0.Mod and LLN0.Beh. The LLN0 shall be the highest in the Logical Device hierarchy.
2. The client shall be placed into Test mode so that it can receive and process test data.
3. The client will set LLN0.Mod = Test.
4. The client will read a MX FCD that has quality and the witness shall check that the quality.Test = true.

   If the LLN0 was not the highest in the hierarchy, then the MX FCD must be within the Logical Device for which the LLN0.Mod was set.

5. The witness shall check that the qualities in published GOOSE/R-GOOSE messages have quality.Test = true.
6. The witness shall check that the qualities in published SV/R-SV messages have quality.Test = true.
7. The subscriber to GOOSE, R-GOOSE, SV, and R-SV should have LLN0.Beh = “on”.
8. The witness should observe that the subscriber shall not process the data that has quality.test=true.

Expected Results: It is expected that the value of Subscriber Mod.Beh will be “one”. That the quality values provided by the server have the test bit=true. That the subscriber does not process the information that has the quality test bit set.

#### 5.5.1.4.1 Test Results

| Test Case Results: ISO-04 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | Pass | Pass | | | | | |

| Test Case Results: ISO-04 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | | | Pass | Pass | | | |
| GE | P443 | | | | | Pass | | |
| Toshiba | GRD200 | | | | | | Pass,n1 | |
| OMICRON | IED Scout | | Pass | | | | | Pass |
| Toshiba | GRT200 | | | | | Pass | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| n1 – Could not verify 100% since another GOOSE subscriber for the GOOSE could not be observed. | | | | | | | | |

| Test Case Results: ISO-04 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| SEL | 487E | | | | Pass | | | |
| GE | P443 | | | Pass | | | | |
| Toshiba | GRD200 | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| ASE Kalkitech | ASE-61850 Test Set | Pass | | | | | | |
| ARC Informatique | PcVue | Pass | | | | | | |
| Vizimax | PMU01000 | | Pass | | | | | |
| SEL | 751 | | | | | | | |
| | | | | | | | | |

### 5.5.1.5 Test case name: ISO-05

Reason: To make sure that IEDs can set the test quality bit test/blocked.

Precondition: The IED under test must allow to switch Mod/Beh (must support LLN0.LocSta or LLN0.Loc or LLN0.LocKey). The IED must be in Remote. The IED being tested has LLN0.Beh = "on".

Test steps:

1. The client will monitor the value of LLN0.Mod and LLN0.Beh. The LLN0 shall be the highest in the Logical Device hierarchy.
2. The client shall be placed into Test/Blocked mode so that it can receive and process test data.
3. The client will set LLN0.Mod = Test.
4. The client will read a MX FCD that has quality and the witness shall check that the quality.Test = true.

   If the LLN0 was not the highest in the hierarchy, then the MX FCD must be within the Logical Device for which the LLN0.Mod was set.

5. The witness shall check that the qualities in published GOOSE/R-GOOSE messages have quality.Test = true.
6. The witness shall check that the qualities in published SV/R-SV messages have quality.Test = true.

Expected Results: It is expected that the value of Mod.Beh will be Test. That the quality values provided by the server have the quality.Test bit=true

### 5.5.1.5.1 Test Results

| Test Case Results: ISO-05 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | Pass | Pass | | | | | |
| SEL | 487E | | | Pass | Pass | | | |
| GE | P443 | | | | | Pass | | |
| Toshiba | GRD200 | | | | | | Fail, n1 | |
| OMICRON | IED Scout | | Pass | | | | | Pass |
| Toshiba | GRT200 | | | | | Pass | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| n1 – Server did not support Test/Blocked | | | | | | | | |

| Test Case Results: ISO-05 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| SEL | 487E | | | | | | | |
| GE | P443 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| ASE Kalkitech | ASE-61850 Test Set | Pass | | | | | | |
| ARC Informatique | PcVue | Pass | | | | | | |
| Vizimax | PMU01000 | | | | | | | |
| SEL | 751 | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

### 5.5.1.6 Test case name: ISO-06

Reason: To make sure that subscriber IEDs can process the test quality bit.

Precondition: The IED under test must allow to switch Mod/Beh (must support LLN0.LocSta or LLN0.Loc or LLN0.LocKey). The IED must be in Remote. The IED being tested has LLN0.Beh = “on”.

Test steps:

1. The LLN0 shall be the highest in the Logical Device hierarchy.
2. The client will set LLN0.Mod = Test/Block.
3. The client will read a MX FCD that has quality and the witness shall check that the quality.Test = true.

   If the LLN0 was not the highest in the hierarchy, then the MX FCD must be within the Logical Device for which the LLN0.Mod was set.

4. Need to attempt to operate a physical output of the IUT that is in test/blocked mode. Two options may be used:
   a. Client Operates a control point that is tied to a physical output indicating operate.test attribute = true;
   b. Publisher changes a GOOSE value that triggers an output.

Expected Results: It is expected that the IUT shall not change the physical output.

### 5.5.1.6.1 Test Results

| Test Case Results: ISO-06 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | Pass | Pass | | | | | |
| SEL | 487E | | | Pass | Pass | | | |
| GE | P443 | | | | | Pass | | |
| Toshiba | GRD200 | | | | | | Fail, n1 | |
| OMICRON | IED Scout | | Pass | | | | | Pass |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| n1 – Server did not support Test/Blocked | | | | | | | | |

| Test Case Results: ISO-06 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| SEL | 487E | | | | | | | |
| GE | P443 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| ASE Kalkitech | ASE-61850 Test Set | Pass | | | | | | |
| ARC Informatique | PcVue | Pass | | | | | | |
| Vizimax | PMU01000 | | | | | | | |
| SEL | 751 | | | | Pass | | | |
| | | | | | | | | |

### 5.5.1.7 Test case name: ISO-07

Reason: To make sure that IEDs can be placed into Local.

Precondition: The IED under test must allow to switch Mod/Beh (must allow control i.e. LLN0.LocSta = false or LLN0.Loc=false or LLN0.LocKey=false). The IED shall be in Remote. The IED being tested has LLN0.Beh = “on”.

Test steps:

1. The client will monitor the value of all DataObjects Loc (LLN0, CSWI, XSWI/XCBR, Yxxx, …). The LLN0 shall be the highest in the Logical Device hierarchy.
2. The IED shall be transitioned to Local mode through changing the values of . LLN0.LocSta, LLN0.Loc, or LLN0.LocKey. IED should be in Local.

The client will issue a control to the IED.

Expected Results: It is expected that the control of equipement over communication fails, as long as the IED is in local. Logical Nodes that expose the Loc/LocSta DataObject are testing the value during the control operation.

#### 5.5.1.7.1 Test Results

| Test Case Results: ISO-07 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | Pass | Pass | | | | | |
| SEL | 487E | | | Pass | | | | |
| GE | P443 | | | | | | | |
| Toshiba | GRD200 | | | | | | Q, n1 | |
| OMICRON | IED Scout | | | | | | | Pass |
| Toshiba | GRT200 | | | | | Pass | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| n1 - IED does not have LLN0.LocSta | | | | | | | | |

| Test Case Results: ISO-07 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | | |
| Server | | | | | | | | | |
| Vendor | Model | | | | | | | | |
| ABB | RET670 | | | | | | | | |
| SEL | 487E | | | | | | | | |
| GE | P443 | | | | | | | | |
| Toshiba | GRD200 | | | | | | | | |
| OMICRON | IED Scout | | | | | | | | |
| ASE Kalkitech | ASE-61850 Test Set | | | | | | | | |
| ARC Informatique | PcVue | | | | | | | | |
| Vizimax | PMU01000 | | Pass | | | | | | |
| SEL | 751 | | | | Pass | | | | |
| | | | | | | | | | |

### 5.5.1.8 Test case name: ISO-08

Reason: To make sure that IEDs can set the test quality bit test and block outputs.

Precondition: The IED under test must allow to switch Mod/Beh (must support LLN0.LocSta or LLN0.Loc or LLN0.LocKey). The IED must be in Remote. The IED being tested has LLN0.Beh = “on”.

Test steps:

1. The client will monitor the value of LLN0.Mod and LLN0.Beh. The LLN0 shall be the highest in the Logical Device hierarchy.
2. The client shall be placed into Test/Blocked mode so that it can receive and process test data.
3. The client will set LLN0.Mod = Test.
4. The client will read a MX FCD that has quality and the witness shall check that the quality.Test = true are set.

   If the LLN0 was not the highest in the hierarchy, then the MX FCD must be within the Logical Device for which the LLN0.Mod was set.

5. The witness shall check that the qualities in published GOOSE/R-GOOSE messages have quality.Test = true.
6. The witness shall check that the qualities in published SV/R-SV messages have quality.Test = true.

Expected Results: It is expected that the value of Mod.Beh will be Test. That the quality values provided by the server have the quality.Test bit=true

### 5.5.1.8.1 Test Results

| Test Case Results: ISO-08 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | ARC Informatique | ASE Kalkitech | OMICRON | KEPCO | SEL |
| | Model | 401 | 421 | PcVue | ASE61850 Testset | IED Scout | IED Explorer | 487B |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| SEL | 487E | | | Pass | | | | |
| GE | P443 | | | | | Pass | | |
| Toshiba | GRD200 | | | | | | Fail, n1 | |
| OMICRON | IED Scout | | Pass | | | | | Pass |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| n1 – Server did not support Test/Blocked | | | | | | | | |

| Test Case Results: ISO-08 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SEL | SEL | Vizimax | Vizimax | | | |
| | Model | 487E | 751 | MGU01000 | PMU01000 | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| SEL | 487E | | | | | | | |
| GE | P443 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| ASE Kalkitech | ASE-61850 Test Set | | | | | | | |
| ARC Informatique | PcVue | | | | | | | |
| Vizimax | PMU01000 | | | | | | | |
| SEL | 751 | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

### 5.5.2 GOOSE

#### *5.5.2.1 Test case name: ISO-08*

*Reason:* To make sure that all IEDs which are currently not being tested ignore the simulated GOOSE.

Test steps:

3. LPHD.Sim is set to false in the IED under test.
4. Test set is configured to emulate all the GOOSE messages for which an IED subscribes for from a particular IED.
5. Test set begins publishing the GOOSE messages with the Simulation bits set and data quality=good.

Expected Results:

4. After step 3 it is expected that the IED under test will not take action on the test set information.
5. If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St shoud be True with good quality, LGOS.ConfRevNum's value should equal the value in RxConfRevNum.  Additionally, LGOS.SimSt should be false.
6. The rest of the IEDs in the system should be not operate upon the information provided by the IED under test.

##### 5.5.2.1.1 Test Results

| Test Case Results: ISO-08 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | SEL | SEL | OMICRON | SEL | SEL | SEL |
| | Model | 401 | 421 | 487E | CMC 850 | 421 | 451 | 487B |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| ARC Informatique | PcVue | | | Pass | | | | |
| GE | P443 | | | | Pass | | | |
| IED | Scout | | | | | | Pass | |
| Toshiba | GMU200 | | | | | | | Pass |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

### 5.5.2.2 Test case name: ISO-09

Reason: When an IED is switched to test mode, it has to send all data with quality=test to inform the IEDs receiving (subscribing) data from this IED this data is the result from a test. This test case serves as a precondition for the following test case. If this test case fails, the following test case will also fail.

*Precondition:* The IED has to allow switching the behavior.

Test steps:

1. The client switches the LD to test mode with a control sequence on LLN0.Mod and set it to test.
2. The client switches the LD back to mode "on" with the same control sequence.

Expected results:

1. After step 1 LLN0.Beh shows "test".
2. The GOOSE sent by this LD contain quality=test (but simulation=false)
3. The clients receiving Reports from this LD will receive a Report with reason quality-change and the data contains quality=test.
4. When a client reads data from this LD
   a. all data in FC=ST in the LD will show up with quality.test = true.
   b. all LNs in this LD show behavior "test" and the client is not able to change the behavior by changing Mod.
5. If the IED has other LDs with a GrRef pointing to the LD in test mode
   a. also, these other LDs (and their LNs) have to show behavior "test" and the data in these LD has quality.test = true.
6. GOOSE or Reports sent by other LDs which don't have behavior=test must have quality.test = false (note that other LDs may have a GrRef to the LD in test mode, thus they inherit the behavior from that LD).
7. After step 2 LLN0.Beh shows "on" again.
8. The GOOSE sent by this LD contain quality= good, quality.test = false (and simulation=false)
9. The clients receiving Reports from this LD will receive a Report with reason quality-change and the data contains quality=good, quality.test = false.
10. When a client reads data from this LD, all data in FC=ST in the LD will show up with quality= good, quality.test = false.

#### 5.5.2.2.1 Test Results

| Test Case Results: ISO-09 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | SEL | SEL | OMICRON | SEL | SEL | SEL |
| | Model | 401 | 421 | 487E | CMC 850 | 421 | 451 | 487B |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| ARC Informatique | PcVue | | | Pass | | | | |
| GE | P443 | | | | Pass | | | |
| IED | Scout | | | | | Pass | Pass | |
| Toshiba | GMU200 | | | | | | | Pass |
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### 5.5.2.3 Test case name: ISO-10

*Reason:* An IED is currently being tested as part of a normal maintenance process. Other IEDs subscribe to GOOSEs from the IED under test and the HMI/SCADA receives Reports from the IED under test. The IEDs which subscribe to the IED under test (and the HMI/SCADA), shall process the test data as test data. For instance, they have to ignore the data from the IED under test (marked with quality.test = true). Since the device is in test mode, process outputs are not blocked.

*Precondition:* The previous test case was passed (the LD in test mode correctly sends data with quality.test = true).

Test steps:

1. The client switches the LD to test mode by changing LLN0.Mod of that LD.
   An LD has to be used which is publishing a GOOSE that is subscribed by one of the other IEDs.
2. The LPHD.Sim is set to true on the IED under test.
3. Test set is configured to emulate all the GOOSE messages for which an IED subscribes for from a particular IED.
4. The test set sends a GOOSE with simulated=true and data quality=normal.
5. The test set changes a data value in the simulated GOOSE so that the IED under test will react with a data change.
   a. If possible, this value change is accompanied by a process output change e.g., binary output.

Expected result:

1. After step 1 the GOOSE sent by the LD in test mode contain quality.test = true (but simulation=false)
2. It may be observable that the IEDs subscribing to this GOOSE ignore the data contained in this GOOSE (because their behavior is on).
3. After step 5 the GOOSE sent by the LD in test mode shows a data change, but still with quality.test = true.
    a. The test set may also recognize a process output change.
4. The other IEDs don’t react on this data change.

#### 5.5.2.3.1 Test Results

| Test Case Results: ISO-10 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | SEL | SEL | OMICRON | SEL | SEL | SEL |
| | Model | 401 | 421 | 487E | CMC 850 | 421 | 451 | 487B |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| ARC Informatique | PcVue | | | Pass | | | | |
| GE | P443 | | | | Pass | | | |
| IED | Scout | | | | | | Pass | |
| Toshiba | GMU200 | | | | | | | Pass |
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| Test Case Results: ISO-10 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | | | | | | |
| | Model | 487E | | | | | | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| ARC Informatique | PcVue | | | | | | | |
| GE | P443 | | | | | | | |
| Omicron | IED Scout | | | | | | | |
| Toshiba | GMU200 | | | | | | | |

| Test Case Results: ISO-10 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | | | | | | |
| | Model | 487E | | | | | | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ARC Informatique | PcVue | Pass | | | | | | |
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### 5.5.2.4 Test case name: ISO-11

*Reason:* An IED is currently being tested as part of a normal maintenance process. To avoid tripping the breaker during the test, the IED is set into mode “test-blocked”.

*Precondition:* The IED has behavior “normal”.

Test steps:

1. The LPHD.Sim is set to true on the IED under test.
2. Test set is configured to emulate all the GOOSE messages for which an IED subscribes for from a particular IED.
3. The test set sends a GOOSE with simulated=true and data quality.test = false.
4. The test set changes a data value in the GOOSE so that a process output change (e.g. binary output change) is triggered on the IED under test.
5. The IED under test is set to mode “test-blocked”.
6. The test set changes a data value in the GOOSE so that a process output change would be triggered on the IED under test.

Expected result:

1. After step 4, a process output change is observed by the test set.
2. After step 5, the GOOSE sent by the IED under test contains quality.test = true and quality.operatorBlocked=false
3. After step 6, no process output shall happen. The status value of the DataObject changes, but there is no activation of the physical output/ output relay.

#### 5.5.2.4.1 Test Results

| Test Case Results: ISO-11 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | SEL | SEL | OMICRON | SEL | SEL | SEL |
| | Model | 401 | 421 | 487E | CMC 850 | 421 | 451 | 487B |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| ARC Informatique | PcVue | | | | | | | |
| GE | P443 | | | | Pass | | | |
| Omicron | IED Scout | | | | | | Pass | |
| Toshiba | GMU200 | | | | | | | Pass |
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| Test Case Results: ISO-11 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | | | | | | |
| | Model | 487E | | | | | | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| ARC Informatique | PcVue | | | | | | | |
| GE | P443 | | | | | | | |
| Omicron | IED Scout | | | | | | | |
| Toshiba | GMU200 | | | | | | | |
| ARC Informatique | PcVue | | | | | | | |
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### 5.5.3 Sampled Values

Precondition: LLN0.Mod should be set to set to a value of test resp.test-blocked. All participating LNx.Mod value should be test resp.test-blocked. The LLN0.Beh value should reflect a value of test resp. test-blocked (same with the LNx values). This needs to be verified through HMI/Client interaction and represents a test case as part of the client/server part of this test.

#### *5.5.3.1 IED in test-blocked mode does not operate process output: ISO-12*

*Reason:* An IED is currently being tested as part of a normal maintenance process. To avoid tripping the breaker during the test, the IED is set into mode “test-blocked”.

*Precondition:* The IED has behavior “On”.

Test steps:

1. The LPHD.Sim is set to true on the IED under test.
2. Test set is configured to emulate all the SV streams for which an IED subscribes for from a particular IED.
3. The test set sends the SV stream with simulated=true and data quality.test = false.
4. The test sends fault values in the SV stream so that the IED under test trips (i.e. a binary output is operated).
5. The test sends nominal values in the SV stream so that the IED under test opens the trip contact.
6. The IED under test is set to mode “test-blocked”.
7. The test set sends fault values again, so that the IED would trip.

Expected result:

1. After step 4, the protection trip is observed by the test set.
2. After step 5, the test set sees that the trip contact is opened.
3. After step 6, the GOOSE sent by the IED under test contains quality.test = true and quality.operatorBlocked=false
4. After step 6
   a. No change of the trip contact shall happen.
   b. The test set and HMI/Client observes that the protection LN operated (PXXX.Op.general=true with quality.test = true).

Function with behavior off does not operate

##### 5.5.3.1.1 Test Results

| Test Case Results: ISO-12 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | SEL | SEL | SEL | SEL | SEL | Doble |
| | Model | 401 | 421 | 487E | 487B | 487E | 451 | F6150SV |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| ARC Informatique | PcVue | | | | | | | |

| Test Case Results: ISO-12 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | SEL | SEL | SEL | SEL | SEL | Doble |
| | Model | 401 | 421 | 487E | 487B | 487E | 451 | F6150SV |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| Toshiba | GMU200 | | | | Pass | | | |
| ARC Informatique | PcVue | | | | | Pass | | |
| OMICRON | IED Scout | | | | | | Pass | |
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### *5.5.3.2 Test case name: ISO-13*

*Reason:* An IED in operation contains functions out of service or they are switched off for testing purposes.

*Precondition:* The IED has behavior “On”.

Test steps:

1. The LPHD.Sim is set to true on the IED under test.
2. Test set is configured to emulate all the SV streams for which an IED subscribes for from a particular IED.
3. The test set sends the SV stream with simulated=true and data quality.test = true.
4. The test sends fault values in the SV stream so that the IED under test trips (i.e. a binary output is operated).
5. The LN or LD with the function is set to Mod=off.
6. The test sends the same fault values in the SV stream so that the IED under test would trip (i.e. a binary output is operated).
7. The test sends nominal values in the SV stream so that the IED under test trips.

Expected result:

1. After step 4, the protection trip is observed by the test set.
2. After step 5
    a. PXXX.Op.general=irrelevant with quality.validity = invalid
    b. No change of the trip contact shall happen.

#### 5.5.3.2.1 Test Results

| Test Case Results: ISO-13 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | SEL | SEL | SEL | SEL | SEL | Doble | |
| | Model | 401 | 421 | 487E | 487B | 487E | F6150SV | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| ABB | RET670 | | | | | | | |
| ARC Informatique | PcVue | | | | | | | |
| Toshiba | GMU200 | | | | Pass | | | |
| ARC Informatique | PcVue | | | | | Pass | | |
| Toshiba | GRT200 | Pass | Pass | | | | Pass | |
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## 5.6 Disruptive Testing

### 5.6.1 GOOSE

Precondition: LLN0.Mod should be set to a value of ON. All participating LNx.Mod value should be ON. The LLN0.Beh value should reflect a value of ON (same with the LNx values). This needs to be verified through HMI/Client interaction and represents a test case as part of the client/server part of this test.

#### *5.6.1.1 IED with LPHD.Sim=true get timeout if simulated GOOSE is missing: ABN-GOOSE-01*

Reason: An IED with LPHD.Sim= true which received the simulated GOOSE once must not react on the not-simulated GOOSE anymore (note tissue 1151). This simulates the situation when the test set is removed after the test, but somebody forgets to reset the Sim bit in the IED.

Test steps:

1. LPHD.Sim is set to false in the IED under test.
2. Test set is configured to emulate **one of** the GOOSE messages for which an IED subscribes for from a particular IED.
3. Test set begins publishing **one** GOOSE message with Simulation bits set and data quality=good.
4. The LPHD.Sim value is set to true in the IED under test.
5. After some time, and observing the reaction of the IED under test, the test set is unplugged from the network.
6. Restore LPHD.Sim to a value of false.

Expected Results:

1. After step 3, it is expected that the IED under test will not take action on the test set information.
   If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St shoud be True with good quality, LGOS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LGOS.SimSt should be false.

2. After step 4, It is expected that the IED under test will take action on the test set information.
   If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St

shoud be True with good quality, LGOS.ConfRevNum’s value should equal the value in RxConfRevNum. Additionally, LGOS.SimSt should be true.

3. After step 5, the IED under test will show a timeout.
   If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked and the LGOS should indicate SimSt = true, while St = false.
4. After step 6, it is expected that the IED under test reacts on the normal GOOSE.
   If there is a monitoring substation HMI/Client (s), the instance of LGOS should be checked based on implemented DataObjexts and normal operation of LGOS.NdsCom=false, LGOS.LastStNum should have good quality, LGOS.St shoud be True with good quality, LGOS.ConfRevNum’s value should equal the value in RxConfRevNum. Additionally, LGOS.SimSt should be false.

#### 5.6.1.1.1 Test Results

| Test Case Results: ABN-GOOSE-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | Vizimax | OMICRON | SEL | GE | OMICRON | TMW | |
| | Model | MGU01000 | IED Scout | 487B | MU320 | CMC850 | DTM | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| GE | P443 | | Pass | | | | | |
| GE | MU320 | | | Pass | | | | |
| SEL | 487B | | | | Pass | | | |
| Sifang | CSI-200E | | | | | | | |
| Vizimax | PMU01000 | | | | | | Pass | |
| | | | | | | | | |

### 5.6.1.2 *IED in on mode with LPHD.Sim=true ignores simulated GOOSE with data quality=test: ABN-GOOSE-02*

Reason: An IED with behavior “on” must not process data with quality=test, regardless of the LPHD.Sim status.

Test steps:

1. Test set is configured to emulate all the GOOSE messages for which an IED subscribes for from a particular IED.
2. LPHD.Sim is set to true in the IED under test.
3. Test set begins publishing the GOOSE messages with the Simulation bits set and **quality.test = true**.

4. The test set changes values in the GOOSE message in an attempt to trigger a change in the receiving IED.

Expected results:

1. After step 3 and 4 the receiving IED process the simulated GOOSE as invalid – see 7-4. The real publisher data are not seen anymore.

##### 5.6.1.2.1 Test Results

| Test Case Results: ABN-GOOSE-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | Vizimax | OMICRON | SEL | GE | OMICRON | TMW | |
| | Model | MGU01000 | IED Scout | 487B | MU320 | CMC850 | DTM | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| GE | P443 | | Pass | | | | | |
| GE | MU320 | | | Pass | | | | |
| SEL | 487B | | | | Pass | | | |
| Sifang | CSI-200E | | | | | | | |
| Vizimax | PMU01000 | | | | | | | |
| | | | | | | | | |

### 5.6.2 Sampled Values

Precondition: LLN0.Mod should be set to a value of ON. All participating LNx.Mod value should be ON. The LLN0.Beh value should reflect a value of ON (same with the LNx values). This needs to be verified through HMI/Client interaction and represents a test case as part of the client/server part of this test.

#### *5.6.2.1 IED with LPHD.Sim=true will get timeout if simulated SV is missing : ABN-SV-01*

Reason: An IED with LPHD.Sim=true which received the simulated SV once must not react on the not-simulated SV anymore (note tissue 1151). This simulates the situation when the test set is removed after the test, but somebody forgets to reset the Sim bit in the IED.

Test steps:

1. LPHD.Sim is set to false in the IED under test.
2. Test set is configured to emulate all the SV messages for which an IED subscribes for from a particular IED.
3. Test set begins publishing the SV messages with the Simulation bits set and data quality.validity= good, quality.test = false.
4. The LPHD.Sim value is set to true in the IED under test.
5. After some time, and observing the reaction of the IED under test, the test set is unplugged from the network.
6. Restore LPHD.Sim to a value of false.

Expected Results:

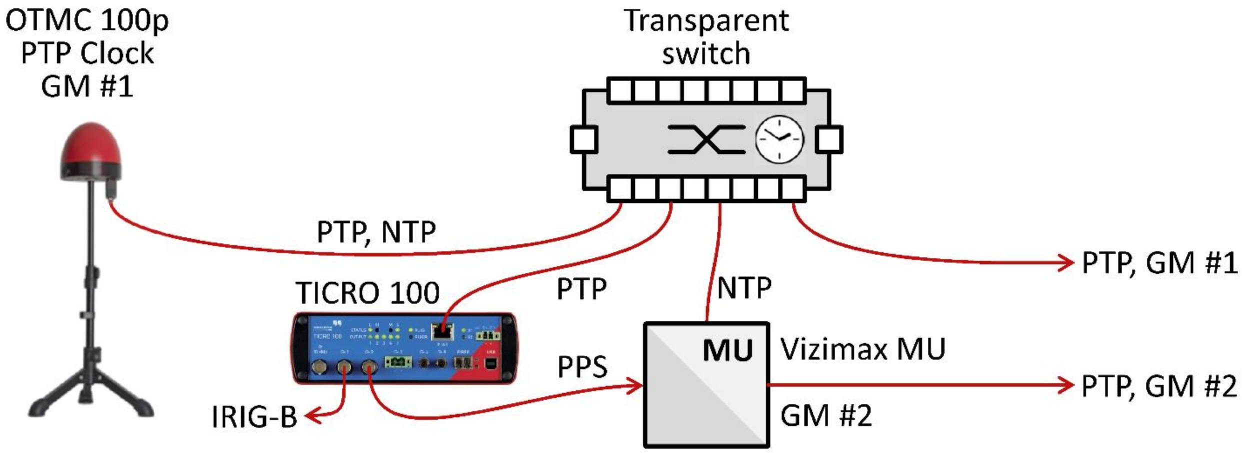
1. After step 3, it is expected that the IED under test will not take action on the test set information.
   If there is a monitoring substation HMI/Client (s), the instance of LSVS should be checked based on implelemted DataObjects and normal operation of LSVS.NdsCom=false, LSVS.St shoud be True with good quality, LSVS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LSVS.SimSt should be false.
2. After step 4, it is expected that the IED under test will take action on the test set information.
   If there is a monitoring substation HMI/Client (s), the instance of LSVS should be checked and normal operation of LSVS.NdsCom=false, LSVS.St shoud be True with good quality, LSVS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LSVS.SimSt should be true.
3. After step 5, the IED under test will get a timeout of the simulated SV stream.
   If there is a monitoring substation HMI/Client (s), the instance of LSVS should be checked and it should indicate that the stream is not received anymore: St = false while SimSt = true
4. After step 6, it is expected that the IED takes action on the normal SV stream.
   If there is a monitoring substation HMI/Client (s), the instance of LSVS should be checked and normal operation of LSVS.NdsCom=false, LSVS.St shoud be True with good quality, LSVS.ConfRevNum's value should equal the value in RxConfRevNum. Additionally, LSVS.SimSt should be false.

#### 5.6.2.1.1 Test Results

| Test Case Results: ABN-SV-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | | | | | | | |

| Test Case Results: ABN-SV-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 451 | | | | | | | |
| NR | PCS-978S | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| SEL | 487B | Pass | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| GE | D60 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | Pass | | Pass | Pass | |
| | | | | | | | | |

## 5.6.3 PTP



The following test cases assume that there are (minimum) two PTP master clocks from two devices connected to the process bus using the same PTP time domain: 93. It shall be possible to disconnect them from the network without disconnecting other essential functions (e.g. a client IED) or there shall be a possibility to disable it.

### *5.6.3.1 Antenna Lost Test: PTP-Disruptive-01*

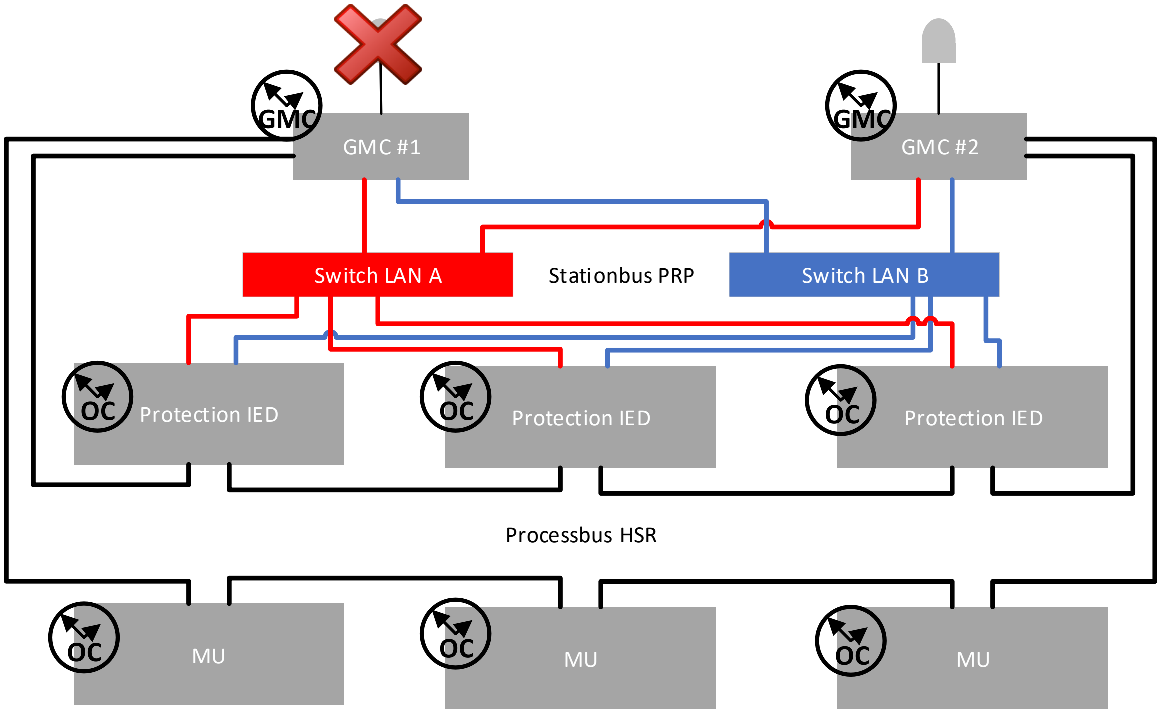
This test is used to check that all IED can seamlessly transfer between two GMC's in synch.

Requirements:

- All IEDs are fully configured and in operation.
- All master clock devices have been up and running for an enough time to ensure stabilization of the oscillator.
- GMC's connect to Process bus and Station Bus as redundant attached nodes (GMC's see each other, only one active GMC)

The test Description:

1. Disconnect Antenna on Active GMC (GMC #1)

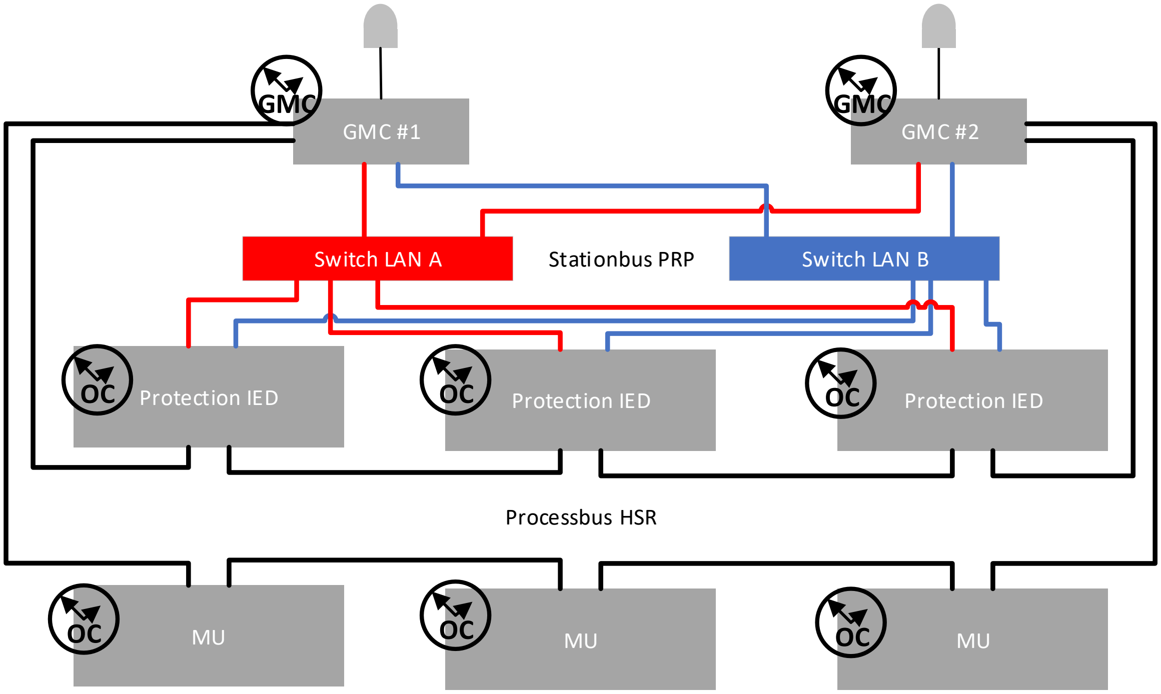


Expected Results

- GMC #1 drops clock class from 7-> 6 and goes to passive
- GMC #2 goes to active
- MU and IED's seamless transfer from GMC #1 to GMC #2
    a. No jump in SmpCnt
    b. SmpSynch remains Global
    c. No blocking protection functions
       No false Trip or Start
    d. MU's and IED's indicate Grandmaster Identity of GMC2 if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

2. Reconnect Antenna on Passive GMC (GMC1)



Expected Results

- GMC #1 increase clock class from 6-> 7 and goes to active
- GMC #2 goes to passive
- MU and IED's seamless transfer from GMC #2 to GMC #1
    a. No jump in SmpCnt
    b. SmpSynch remains global
    c. No blocking protection functions
       No false Trip or Start
    d. MU's and IED's indicate Grandmaster Identity of GMC #1 if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

#### 5.6.3.1.1 Test Results

| Test Case Results: ABN-PTP-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |

| Test Case Results: ABN-PTP-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 451 | | Pass | | | | | |
| NR | PCS-978S | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| GE | D60 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### 5.6.3.2 One of two GMC Lost Test: PTP-Disruptive-02

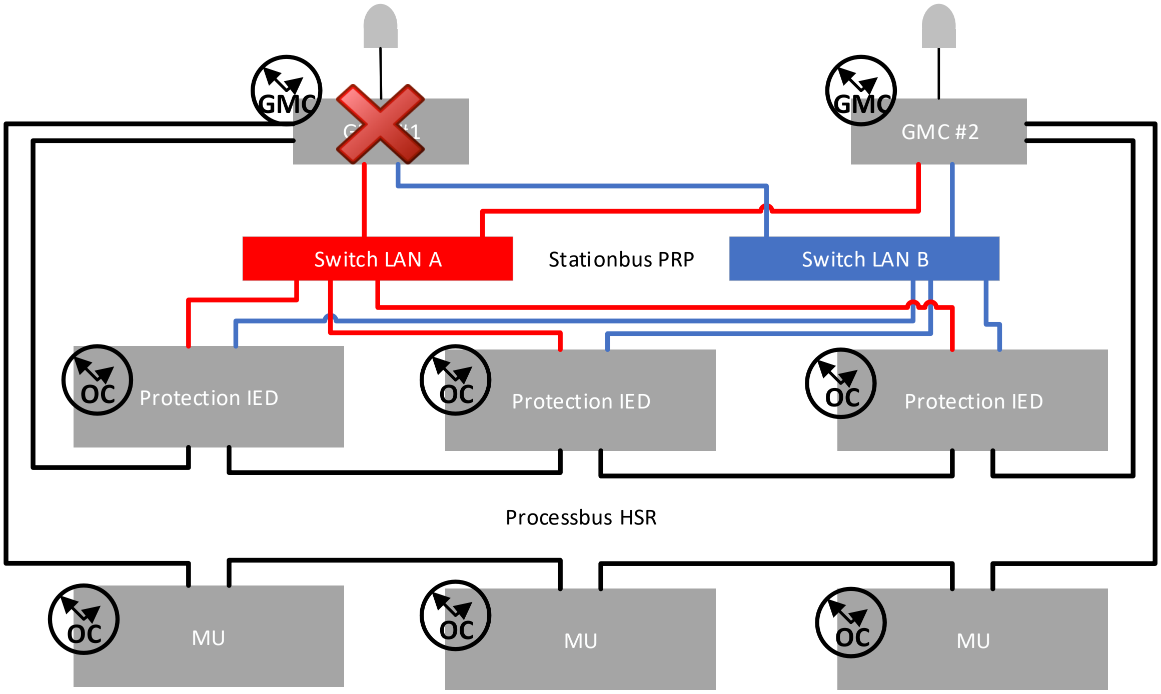
This test is used to check that all IED can handle local and global clocks and indicate correctly the current synchronization status. Protection IED's are capable to distinguish between SV Streams subscribed that are local or global synched.

Requirements:

- All IEDs are fully configured and in operation.
- All master clock devices have been up and running for an enough time to ensure stabilization of the oscillator.
- GMC's connect to Process bus and Station Bus as redundant nodes (GMC's see each other, only one Active GMC)

The test Description:

1. Power off Active GMC (GMC #1)



Expected Results

- GMC #2 goes to active
- MU and IED's seamless transfer from GMC #1 to GMC #2
  a. No jump in SmpCnt
  b. SmpSynch remains Global
  c. No blocking protection functions
     No false Trip or Start
  d. MU's and IED's indicate Grandmaster Identity of GMC #2 if supported (SVStream / LTMS.TmSrc)

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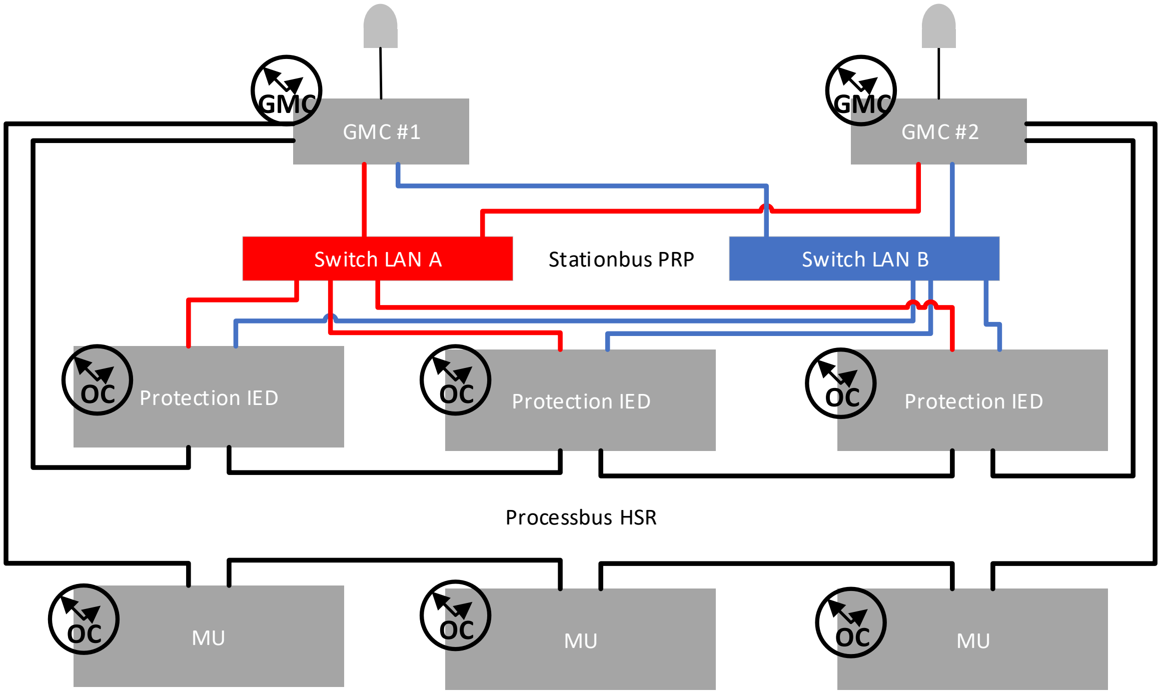
Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

2. Power on GMC (GMC #1)



Expected Results

- GMC #2 goes to passive
- GMC #1 goes active
- MU and IED's seamless transfer from GMC #2 to GMC #1
    a. No jump in SmpCnt
    b. SmpSynch remains Global
    c. No blocking protection functions
    No false Trip or Start
    d. MU's and IED's indicate Grandmaster Identity of GMC #1 if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

#### 5.6.3.2.1 Test Results

| Test Case Results: ABN-PTP-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 451 | | Pass | | | | | |
| NR | PCS-978S | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| GE | D60 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### *5.6.3.3 Transition from Global to Local to Global: PTP-Disruptive-03*

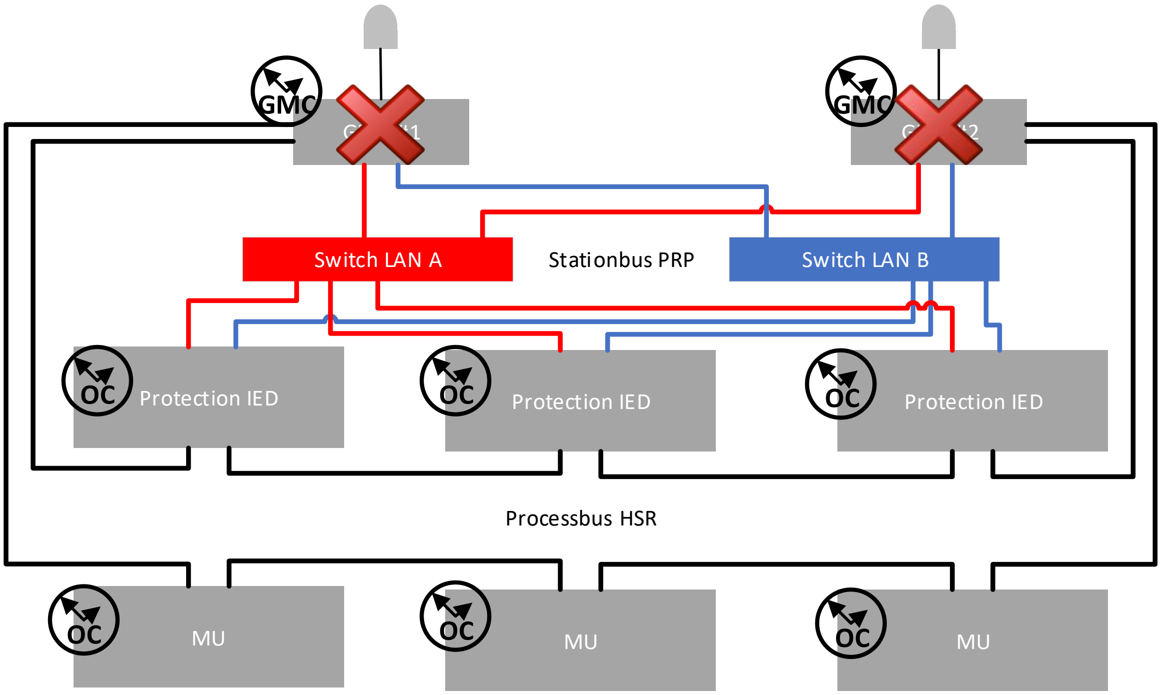
This test is used to check that all IED can seamlessly transfer between two GMC's in synch.

Requirements:

- All IEDs are fully configured and in operation.
- All master clock devices have been up and running for an enough time to ensure stabilization of the oscillator.
- GMC's connect to Process bus and Station Bus as redundant attached nodes (GMC see each other)

The test Description:

1. Power off Active GMC's (GMC #1 and GMX #2)

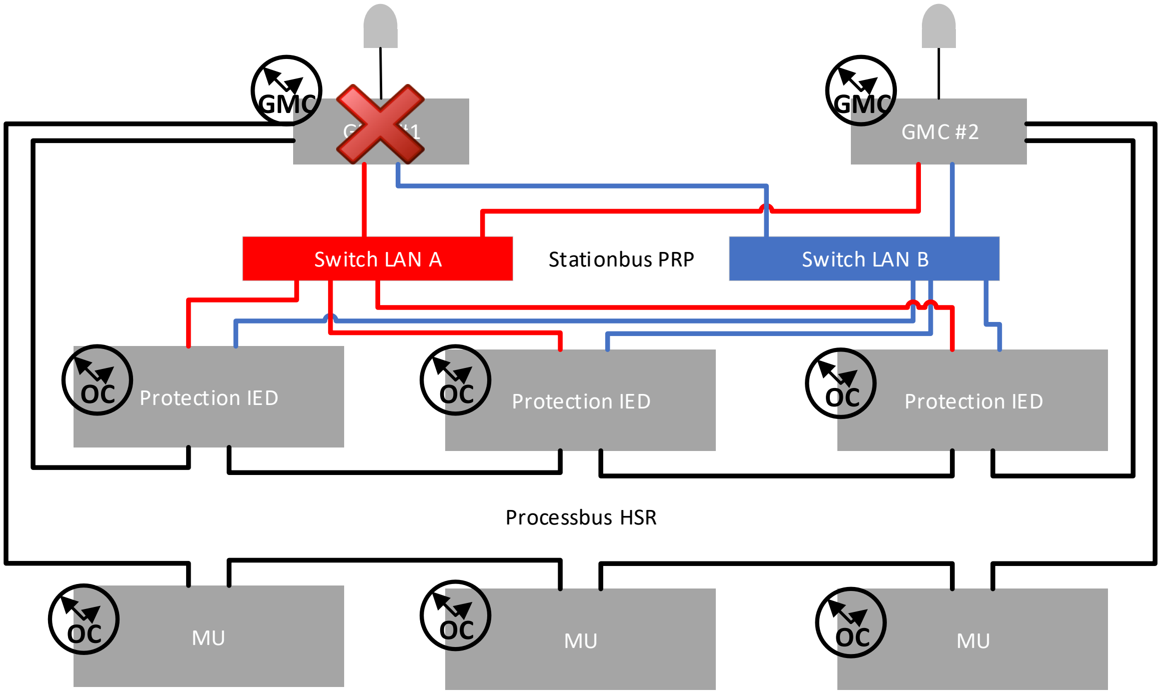


Expected Results

- MU's and IED's will select Best Master
- MU and IED's seamless transfer from GMC to Best Local Master
  a. No jump in Smpcnt
  b. SmpSynch degrades from Global to Local (within hold over time)
  c. Protection functions depending on multiple sources might get blocked
     No false Trip or Start
  d. ALL MU's and IED's indicate Grandmaster Identity of Best Master selected if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

2. Power on GMC (GMC #2) before IED drift exceeds 4 usec

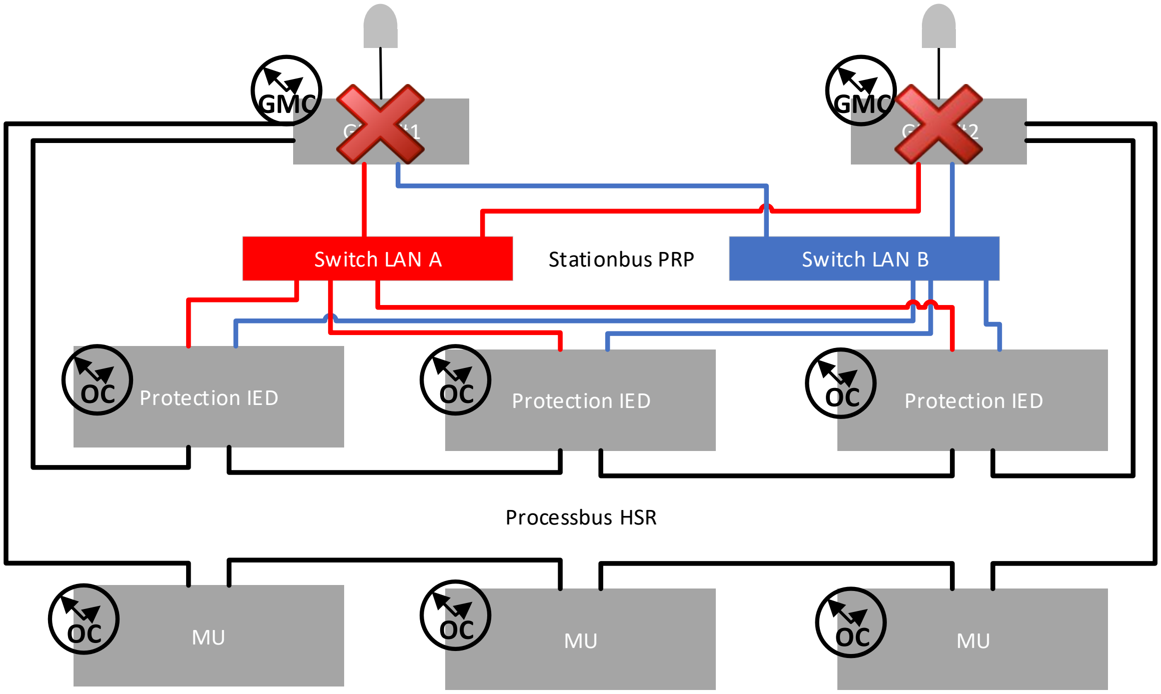


Expected Results

- GMC #2 goes to active
- MU and IED's seamless transfer from Local Best Master to GMC #2
  a. No jump in Smpcnt
  b. SmpSynch goes from Local to Global
  c. Protection functions depending on multiple sources get unblocked
     No false Trip or Start
  d. MU's and IED's indicate Grandmaster Identity of GMC #2 if supported
     (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

3. Repeat Step 2 Power off Active GMC (GMC2)

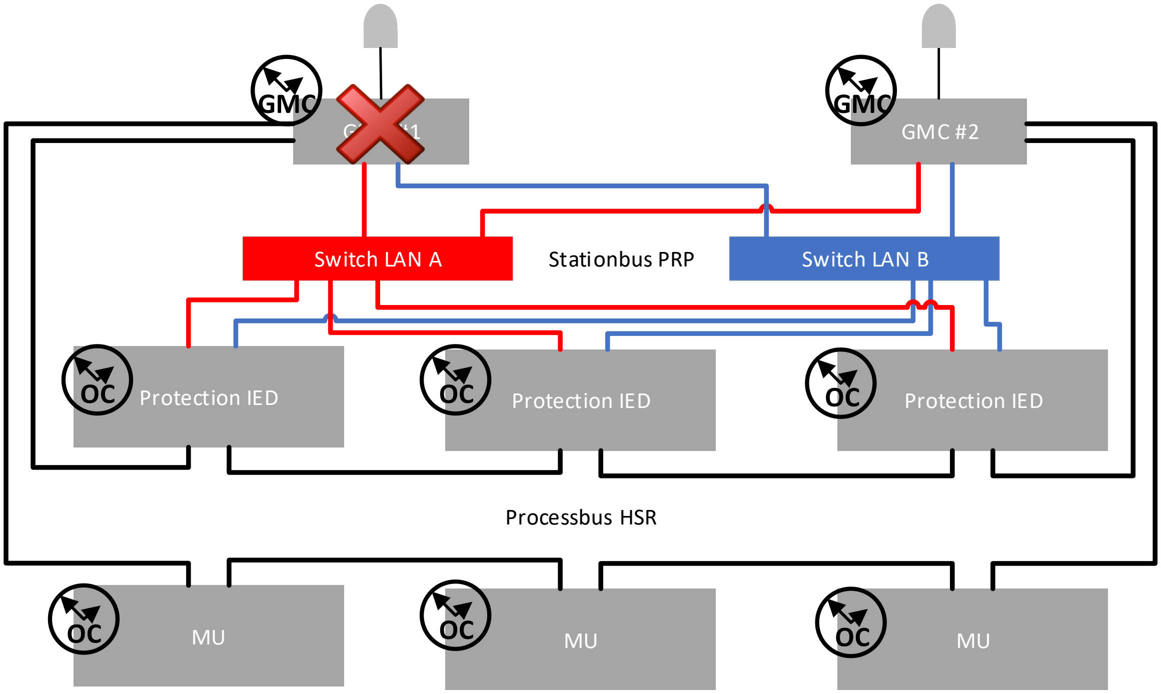


Expected Results

- MU's and IED's will select Best Master
- MU and IED's seamless transfer from GMC to Best Local Master
    a. No jump in Smpcnt
    b. SmpSynch degrades from Global to Local
    c. Protection functions depending on multiple sources might get blocked
       No false Trip or Start
    d. ALL MU's and IED's indicate Grandmaster Identity of Best Master selected if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

4. Power on GMC (GMC2) after IED drift exceeds 4 usec

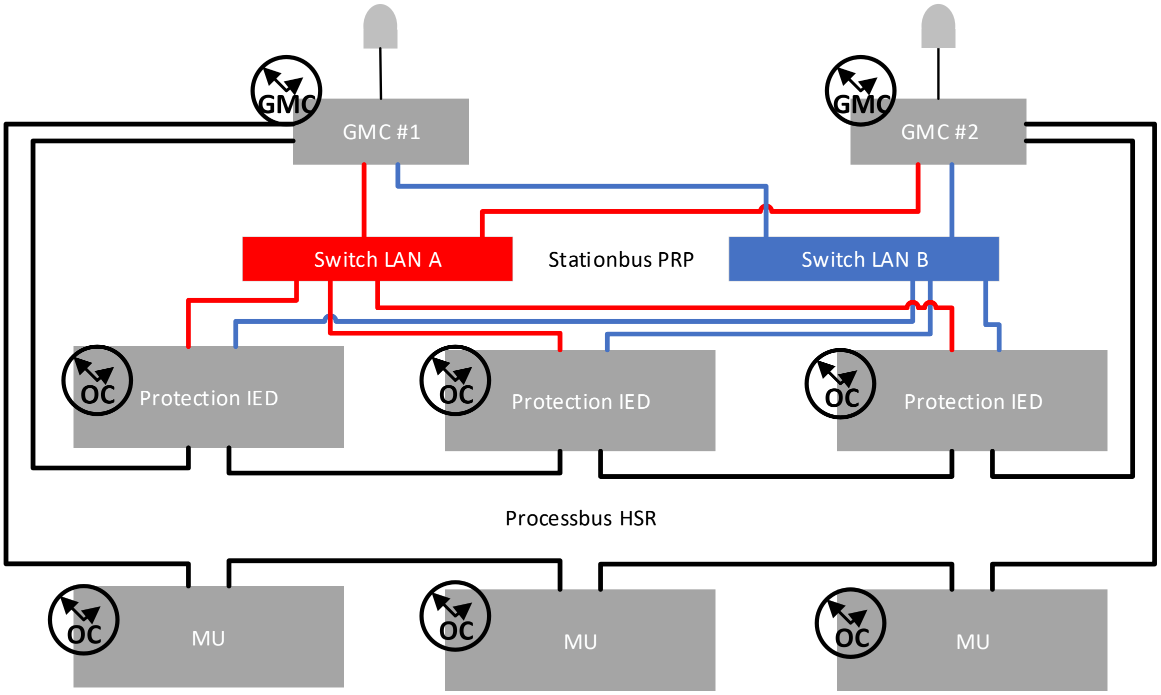


Expected Results

- GMC #2 goes to active
- MU and IED’s resynch and transfer from Local Best Master to GMC #2
  a. jump in SmpCtn
  b. SmpSynch goes finally to Global (drop to 0 might happen if hold over time exceeded)
  c. Protection functions depending on multiple sources get unblocked
     No false Trip or Start
  d. MU’s and IED’s indicate Grandmaster Identity of GMC #2 if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

5. Power on GMC (GMC #1)



Expected Results

- GMC #1 goes to active
- GMC #2 goes passive
- MU and IED’s seamless transfer from GMC #2 to GMC #1
  a. No jump in SmpCnt
  b. SmpSynch remains Global
  c. No blocking protection functions
     No false Trip or Start
  d. MU’s and IED’s indicate Grandmaster Identity of GMC2 if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

#### 5.6.3.3.1 Test Results

| Test Case Results: ABN-PTP-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| SEL | 451 | | | | | | | |
| NR | PCS-978S | | | | | | | |

| Test Case Results: ABN-PTP-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| GE | D60 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | | | |
| | | | | | | | | |

### 5.6.3.4 Transition from Global to Local GMC Single Attached: PTP-Disruptive-04

This test is used to check that all IED can handle local and global clocks and indicate correctly the current synchronization status.

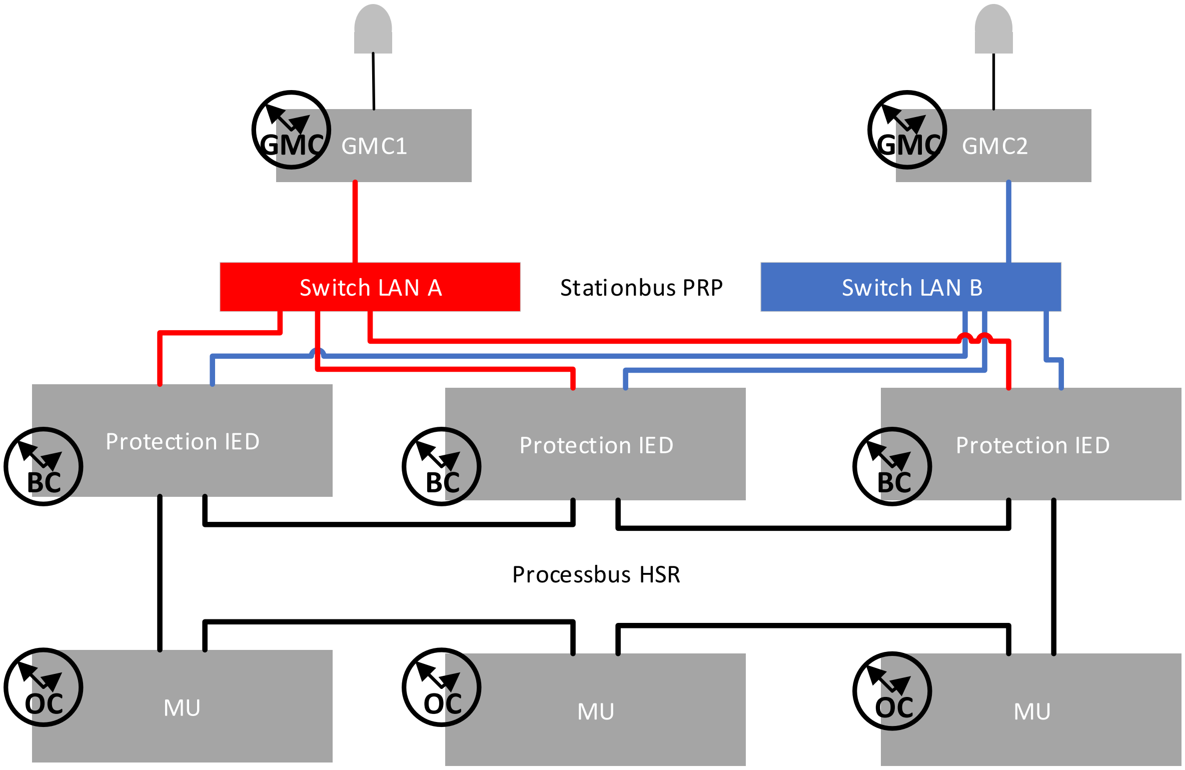
Protection IED's are capable to distinguish between SV Streams subscribed that are local or global synched.

Requirements:

- All IEDs are fully configured and in operation.
- All master clock devices have been up and running for an enough time to ensure stabilization of the oscillator.
- GMC's connect to Station Bus as single attached nodes (GMC's does not see each other, both GMC's are active)
- The Process Bus is synchronized via Boundary Clocks.

The test Description:

1. All IED's synchronized to same GMC (GMC #1)



Expected Results

- MU's and IED's will select same GMC (e.g GMC #1)
    a. SmpSynch is Global

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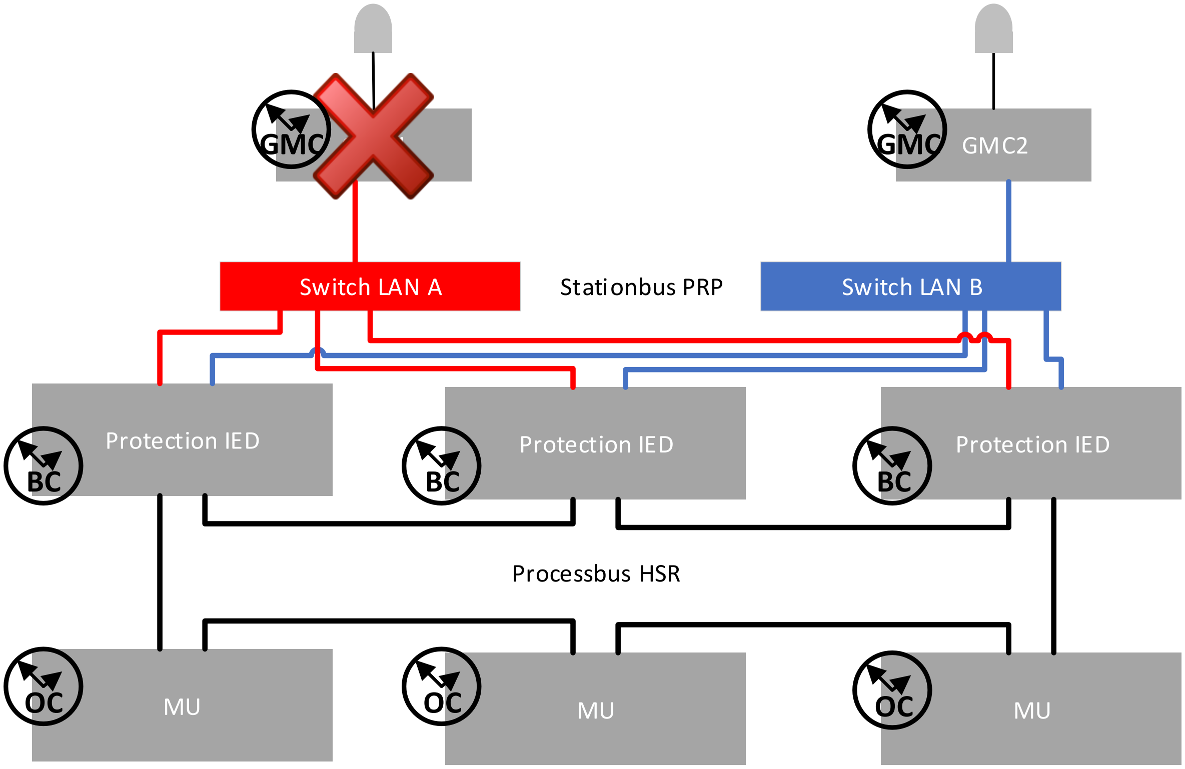
b. Protection functions not blocked
   No false Trip or Start
c. ALL MU's and IED's indicate Grandmaster Identity of Best Master selected if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

2. Power off Active GMC (GMC #1)

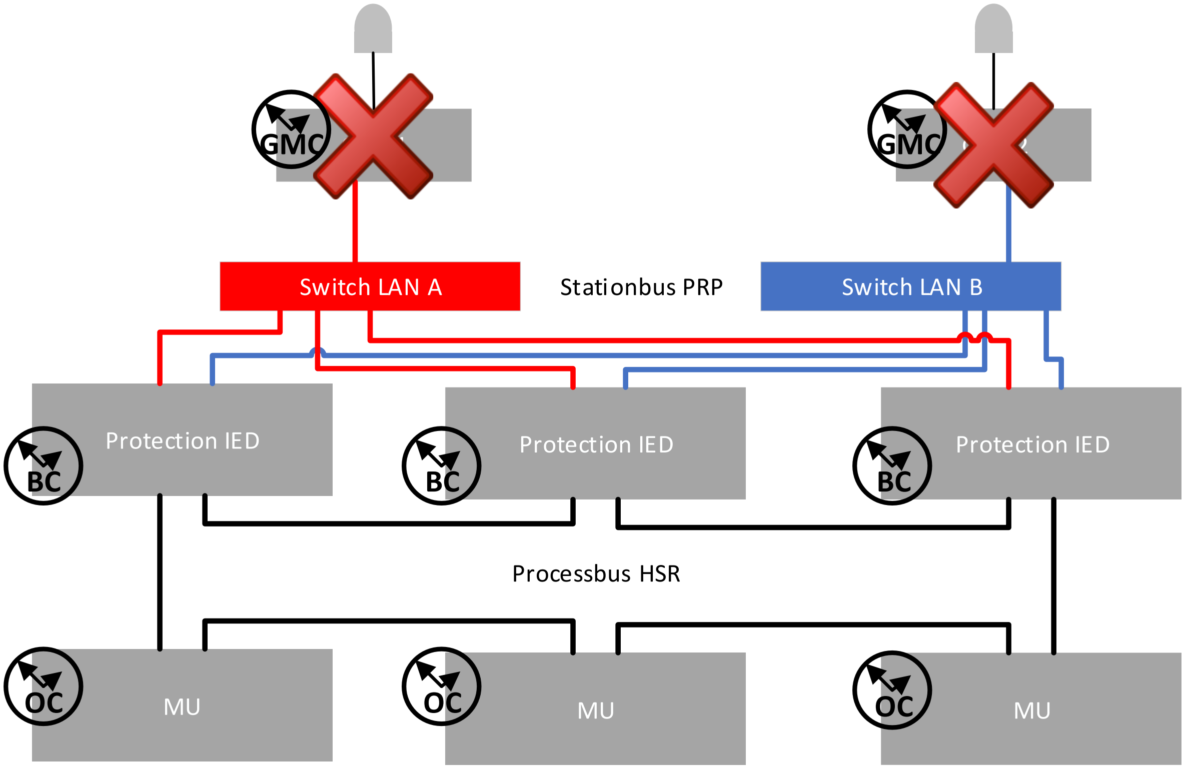


Expected Results

- MU and IED's seamless transfer from GMC #1 to GMC #2
  a. No jump in SmpCnt
  b. SmpSynch remains Global
  c. No blocking protection functions
     No false Trip or Start
  d. MU's and IED's indicate Grandmaster Identity of GMC #2 if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

3. Power off Active GMC’s (GMC #1 and GMX #2)

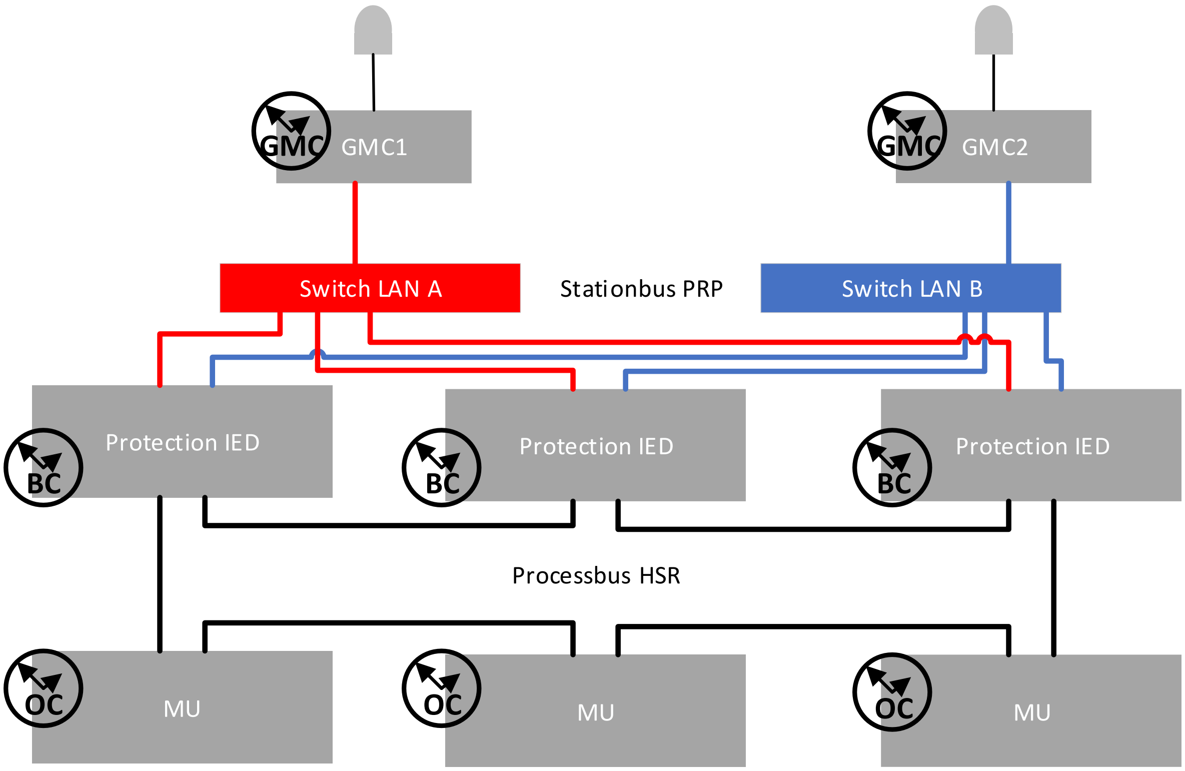


Expected Results

- MU’s and IED’s will select Best Master
- MU and IED’s seamless transfer from GMC #2 to Best Local Master
    a. No jump in SmpCnt
    b. SmpSynch degrades from Global to Local
    c. Protection functions depending on multiple sources might get blocked
       No false Trip or Start
    d. ALL MU’s and IED’s indicate Grandmaster Identity of Best Master selected if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

4. Power on all GMC's before IED drift exceeds 4 usec



Expected Results

- MU's and IED's will select same GMC (e.g GMC #1)
- MU and IED's seamless transfer from Local Best Master to Global Best Master (e.g. GMC #1)
  a. No jump in Smpcnt
  b. SmpSynch is Global
  c. Protection functions not blocked
     No false Trip or Start
  d. ALL MU's and IED's indicate Grandmaster Identity of Best Master selected if supported (SVStream / LTMS.TmSrc)

Note: GM ID in SVStream can only be done by Ed2.1 publisher. Configuration can only be done in an 2007B4 environement. GM ID in LTMS.TmSrc can only be expected with Ed2.1 device.

##### 5.6.3.4.1 Test Results

None recorded.

### *5.6.3.5 System Robustness: PTP-Disruptive-05*

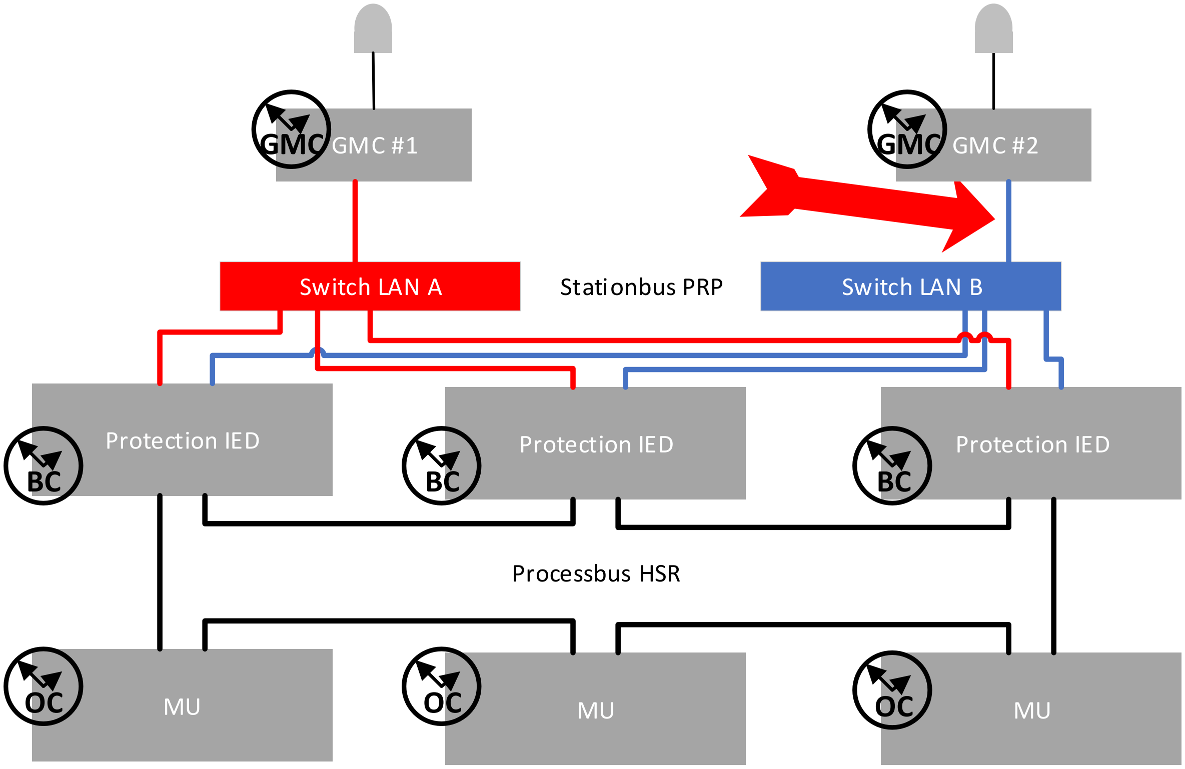
This test is used to check behavior of all IED's and MU's in case of disruptive GMC connection.

Requirements:

- All IEDs are fully configured and in operation.
- All master clock devices have been up and running for an enough time to ensure stabilization of the oscillator.
- GMC's connect to Station Bus as single attached nodes (GMC's does not see each other, both GMC's are active)
- The Process Bus is synchronized via Boundary Clocks.

The test Description:

1. All IED's synchronized to same GMC (GMC #2)
   a. Identify the port on the switch where the GPS clock PTP message in coming
   b. Remove and replace Fiber a number of times in quick succession (faster than 3 seconds).



Expected Results

- No effect Time synchronisation is maintained
- No jump in SmpCnt
- SmpSynch remains Global
- No blocking protection functions

No false Trip or Start

- MU's and IED's indicate Grandmaster Identity of GMC2 if supported (SVStream / LTMS.TmSrc)

#### 5.6.3.5.1 Test Results

None recorded.

## 5.6.4 IED Failure/Power Down

### *5.6.4.1 Client/Server*

#### 5.6.4.1.1 IED Failure / Power down Testing: ABN-IEDFAIL-01

*Purpose:* To determine if an IED disconnect from /reconnect to an integrated system is detected. There are two major use cases:

1. IED A is integrated as a GOOSE publisher. As such, it publishes at least one GOOSE message and at least one other IED B subscribes to this GOOSE.

2. IED A is integrated as a server to provide integrity reports. At least one client is associated with this server and enabled the report in the server IED A.

*Preconditions and explanation:* Under idle condition, i.e. without state changes (value, quality) of events which are configured for transmission,

IED A issues

- GOOSE message(s) at the maximum time interval(s) of re-transmission
- integrity report(s) at the time interval(s) set by the individual client(s)
- 'TCP Keep alive' messages at a time interval specified for the IED communication unit
- 'TCP Keep alive' responses to the 'TCP Keep alive' request(s) of the client(s)

The client issues

- 'TCP Keep alive' messages at a time interval specified for the client communication unit
- 'TCP Keep alive' responses to the 'TCP Keep alive' request of IED A

For this test case, 'IED failure' is understood as an impact to the device which completely disables its ability to communicate, similar to at a power loss. It is not assumed that an IED delivers self-supervision signals or indications of a degraded mode before ceasing communications. Also, it is of no relevance whether or not the IED saves communication related data to a non-volatile memory upon the detection of a failure/power down.

##### 5.6.4.1.1.1 *Test Results*

| Test Case Results: ABN-IED-FAIL-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | ARC Informatique | Doble | | | | | |
| | Model | PcVue | FM61850 | | | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| GE | MU320 | | Q,n1 | | | | | |
| | | | | | | | | |
| n1 – Keepalive could not be set | | | | | | | | |

#### 5.6.4.1.2 Test case name: ABN-IEDFAIL-02

After the expiration of ‘TCP Keep alive’, the client supervision shall detect a communication loss.

Test description:

| | |
|---|---|
| A1 | Power down IED A |
| R1a | (using a protocol analyser)<br>• no more integrity reports from IED A<br>• ‘TCP Keep alive’ messages from the client<br>• no more ‘TCP Keep alive’ responses from IED A<br>• no more ‘TCP Keep alive’ messages from the IED<br>• no more ‘TCP Keep alive’ responses from the client |
| R1a | (if provided by the client) indication of the loss of communication with IED A |

##### 5.6.4.1.2.1 *Test Results*

| Test Case Results: ABN-IED-FAIL-02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | ARC Informatique | Doble | | | | | |
| | Model | PcVue | FM61850 | | | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| GE | MU320 | | Pass | | | | | |
| | | | | | | | | |
| | | | | | | | | |

### 5.6.4.1.3 Testing IED restart / power up of a report server: ABN-IEDFAIL-03

*Purpose:* This test is to ensure that after an server IED restart reporting is re-established.

Precondition:

1. IED A is configured with a report control block, an associated data set including at least one data object.

2. The client is configured to consume the IED A report.

3. IED A is powered down.

Precondition Verification:

- Results as per TC IEDfailReport-1

#### *5.6.4.1.3.1 Test Results*

| Test Case Results: ABN-IED-FAIL-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | ARC Informatique | Doble | | | | | |
| | Model | PcVue | FM61850 | | | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| GE | MU320 | | Pass | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| Test Case Results: ABN-IED-FAIL-03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | ARC Informatique | Doble | | | | | |
| | Model | PcVue | FM61850 | | | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

### 5.6.4.1.4 Test case name: ABN-IEDFAIL-04

Test description:

| | |
|---|---|
| A1 | Power up IED A, wait for restart completed |
| R1a | (using a protocol analyser)<br>• 'TCP Keep alive' messages from the client<br>• 'TCP Keep alive' responses from IED A<br>• 'TCP Keep alive' messages from IED A<br>• 'TCP Keep alive' responses from the client |
| R1b | (using a protocol analyser)<br>• [The client establishes an association with IED A]<br>• The client writes to the report control block in IED A (OptFlds, TrgOps [integrity, IntgPd], RptEna) |
| R1c | (using a protocol analyser) The client issues a GI command for the report |
| R1d | (using a protocol analyser) IED A issues a report |
| R1e | (using a protocol analyser) integrity reports from IED A |

Remarks:

No test of client reservation, since the secure client identification is not yet standardized.

No test of resynchronization to the last proper report (in case of buffered reporting), since after the restart of an faulty/powered down IED the report buffer does not contain the elements sent earlier any longer.

##### 5.6.4.1.4.1 *Test Results*

| Test Case Results: ABN-IED-FAIL-04 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | ARC Informatique | Doble | | | | | |
| | Model | PcVue | FM61850 | | | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | Pass | | | | | | |
| GE | MU320 | | Pass | | | | | |
| | | | | | | | | |
| | | | | | | | | |

### 5.6.5 GOOSE

#### 5.6.5.1.1 Testing the GOOSE publisher IED failure / power down: ABN-IEDFAIL-05

*Purpose:* This test is to ensure that losing the GOOSE message stream from IED A is detected by the subscribing IED B.

Precondition:

1. IED A is configured with a GOOSE control block, an associated data set including at least one pair of stVal/q data attributes.  GOOSE publishing is enabled.

IED B is configured to subscribe the IED A GOOSE data.

Precondition Verification:

- (using a protocol analyser) IED A publishes GOOSE messages
- (using a protocol analyser) The sequence numbers SqNum of the published GOOSE messages increment with each GOOSE message.
- If there is a monitoring substation HMI/Client(s) connected to IED B, the instance of LGOS based on omplemented DataObjects is checked for
    - LGOS.NdsCom=False
    - LGOS.LastStNum=[don't care], good quality

- LGOS.St=True, good quality
- LGOS.ConfRevNum=RxConfRevNum
- LGOS.SimSt=False (no simulation testing here)

###### 5.6.5.1.1.1 *Test Results*

| Test Case Results: ABN-IED-FAIL-05 | | | | |
|---|---|---|---|---|
| | Subscriber/Client | | | |
| | Vendor | ARC Informatique | Doble | |
| | Model | PcVue | FM61850 | |
| Publisher | | | | |
| Vendor | Model | | | |
| SEL | 487E | Pass | | |
| | | | | |

##### 5.6.5.1.2 Test case name: ABN-IEDFAIL-06

After the expiration of the TAL, the IED B GOOSE supervision shall signal a communication loss.

Test description:

| | |
|---|---|
| A1 | Power down IED A |
| R1 | (using a protocol analyser) no more GOOSE messages from IED A |
| A2 | Wait for a time longer than 2 x TAL |
| R2 | IED B LGOS instance: LGOS.St=False, good quality |

###### 5.6.5.1.2.1 *Test Results*

| Test Case Results: ABN-IED-FAIL-06 | | | | |
|---|---|---|---|---|
| | Subscriber/Client | | | |
| | Vendor | ARC Informatique | Doble | |
| | Model | PcVue | FM61850 | |
| Publisher | | | | |
| Vendor | Model | | | |
| SEL | 487E | Pass | | |

| Test Case Results: ABN-IED-FAIL-06 | | | | |
|---|---|---|---|---|
| | Subscriber/Client | | | |
| | Vendor | ARC Informatique | Doble | |
| | Model | PcVue | FM61850 | |
| Publisher | | | | |
| Vendor | Model | | | |
| | | | | |
| | | | | |

### 5.6.5.1.3 Testing IED restart / power up of a GOOSE publisher: ABN-IEDFAIL-07

*Purpose:* This test is to ensure that after an IED restart GOOSE publishing is recommenced and GOOSE subscription is re-established.

Precondition:

1. IED A is configured with a GOOSE control block, an associated data set including at least one pair of stVal/q data attributes. GOOSE publishing is enabled.

2. IED B is configured to subscribe the IED A GOOSE data.

3. IED A is powered down.

Precondition Verification:

- Results as per TC IEDfailGOOSE-1

#### *5.6.5.1.3.1 Test Results*

| Test Case Results: ABN-IED-FAIL-07 | | | | |
|---|---|---|---|---|
| | Subscriber/Client | | | |
| | Vendor | ARC Informatique | Doble | |
| | Model | PcVue | FM61850 | |
| Publisher | | | | |
| Vendor | Model | | | |
| SEL | 487E | Pass | | |
| | | | | |
| | | | | |

#### 5.6.5.1.4 Test case name: ABN-IEDFAIL-08

After the restart of IED A, IED A resumes GOOSE publishing, IED B GOOSE supervision indicates a trustful communication.

Test description:

| | |
|---|---|
| A1 | Power up IED A, wait for restart completed |
| R1a | (using a protocol analyser) IED A publishes GOOSE messages |
| R1b | IED B LGOS instance: LGOS.St=True, good quality |

Testing IED restart / power up of a GOOSE subscriber

*Purpose:* This test is to ensure that after an subscribing IED restart GOOSE subscription is re-established.

Precondition:

1. IED A is configured with a GOOSE control block, an associated data set including at least one pair of stVal/q data attributes. GOOSE publishing is enabled.

2. IED B is configured to subscribe the IED A GOOSE data.

3. IED B is powered down.

Precondition Verification:

- (using a protocol analyser) IED A publishes GOOSE messages

- (using a protocol analyser) The sequence numbers SqNum of the published GOOSE messages increment with each GOOSE message.

- If there is a monitoring substation HMI/Client(s), IED B cannot be reached.

##### *5.6.5.1.4.1 Test Results*

| Test Case Results: ABN-IED-FAIL-08 | | | | |
|---|---|---|---|---|
| | Subscriber/Client | | | |
| | Vendor | ARC Informatique | Doble | |
| | Model | PcVue | FM61850 | |
| Publisher | | | | |
| Vendor | Model | | | |
| SEL | 487E | Pass | | |
| | | | | |

| Test Case Results: ABN-IED-FAIL-08 | | | | |
|---|---|---|---|---|
| | Subscriber/Client | | | |
| | Vendor | ARC Informatique | Doble | |
| | Model | PcVue | FM61850 | |
| Publisher | | | | |
| Vendor | Model | | | |
| | | | | |
| | | | | |

### 5.6.5.1.5 Test case name: ABN-IEDFAIL-09

After the restart of IED B, IED B GOOSE supervision indicates a trustful communication.

Test description:

| | |
|---|---|
| A1 | Power up IED B, wait for restart completed |
| R1 | IED B LGOS instance: LGOS.St=True, good quality |

Testing the server IED failure / power down impact on Reporting

*Purpose:* This test is to ensure that losing the reporting from server IED A is detected by the client.

Precondition:

1. IED A is configured with a report control block, an associated data set including at least one data object.

2. The client is configured to consume the IED A report.

3. The client established an association with IED A

4. The client wrote to the report control block in IED A

- OptFlds
- TrgOps [integrity, IntgPd]
- RptEna

Precondition Verification:

- (using a protocol analyser) IED A issues reports at the time interval set by the client
- (using a protocol analyser) ‘TCP Keep alive’ messages from the client

- (using a protocol analyser) ‘TCP Keep alive’ responses from the IED
- (using a protocol analyser) ‘TCP Keep alive’ messages from the IED
- (using a protocol analyser) ‘TCP Keep alive’ responses from the client

#### 5.6.5.1.5.1 *Test Results*

| Test Case Results: ABN-IED-FAIL-09 | | | | |
|---|---|---|---|---|
| | Subscriber/Client | | | |
| | Vendor | ARC Informatique | Doble | |
| | Model | PcVue | FM61850 | |
| Publisher | | | | |
| Vendor | Model | | | |
| SEL | 487E | Pass | | |
| | | | | |
| | | | | |

### 5.6.6 Sampled Values

#### *5.6.6.1* Test case name: ABN-SV- RED-SAMU-01

Preconditions: All SAMUs are operating under normal conditions.

*Test steps:*

1. Apply current signals to all four SAMUs. Apply currents in such a way that power flows from the transformer to two feeders (Normal condition).
2. Use IED metering function to read the current of all three current terminals.
3. Use IED built-in function to verify Current Terminals used for transformer differential protection (87T).
4. Disrupt power to TXA_MU02 SAMU.
5. Use IED metering function to read the current of all three current terminals.
6. Use IED built-in function to verify Current Terminals used for transformer differential protection (87T).
7. Apply currents associated with transformer internal fault to all four SAMUs (Fault condition).
8. Apply current signals from test step 1.

*Expected results:*

1. After step 1, it is expected that the IED subscribes to SV streams from all four SAMUs.
2. After step 2, the IED metering functions shall correctly display the current signals measured by all four SAMUs.
3. After step 3, the IED shall indicate that it uses Current Terminal #1 (TXA_MU01) and Current Terminal #2 (TXA_MU02) for transformer differential protection (87T).
4. After step 4, the IED shall lose SV subscription from TXA_MU02 SAMU. SV streams from remaining three SAMUs shall be good.
5. After step 5, the IED metering functions shall correctly display the current signals measured by TXA_MU01 and A1_MU+A2_MU SAMUs. The current measurement at Terminal #2 shall be 0.
6. After step 6, the IED shall indicate that it uses Current Terminal #1 (TXA_MU01) and Current Terminal #3 (A1_MU+A2_MU) for transformer differential protection (87T).
7. After step 7, the IED's transformer differential protection (87T) shall operate to indicate internal fault.
8. After step 8, the IED metering functions shall correctly display the current signals measured by TXA_MU01 and A1_MU+A2_MU SAMUs.

##### 5.6.6.1.1 Test Results

| Test Case Results: ABN-SV-01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL | |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 | |
| Subscriber | | | | | | | | |
| Vendor | Model | | | | | | | |
| SEL | 487E | | | | | | | |
| SEL | 451 | | | | | | | |
| NR | PCS-978S | | | | | | | |
| OMICRON | IED Scout | | | | | | | |
| SEL | 487B | Pass | | | | | | |
| Sifang | CSI-200E | | | | | | | |
| GE | D60 | | | | | | | |
| Toshiba | GRD200 | | | | | | | |
| Toshiba | GRT200 | | | | | Pass | Pass | |
| | | | | | | | | |

### 5.6.7 Merging Unit Failure

Stand Alone Merging Unit (SAMU) will typically have functions to indicate the operational status of the device. The indications can be visual by the use of LEDS, mechanical by the use of contacts, and electronically by the use of a graphical user interface and/or inherent indications in the IEC 61850-9-2 sampled value protocol or IEC 61850 GOOSE messaging.

A typical setup with the use of contacts to indicate the operational status of a SAMU is shown in the figure below.

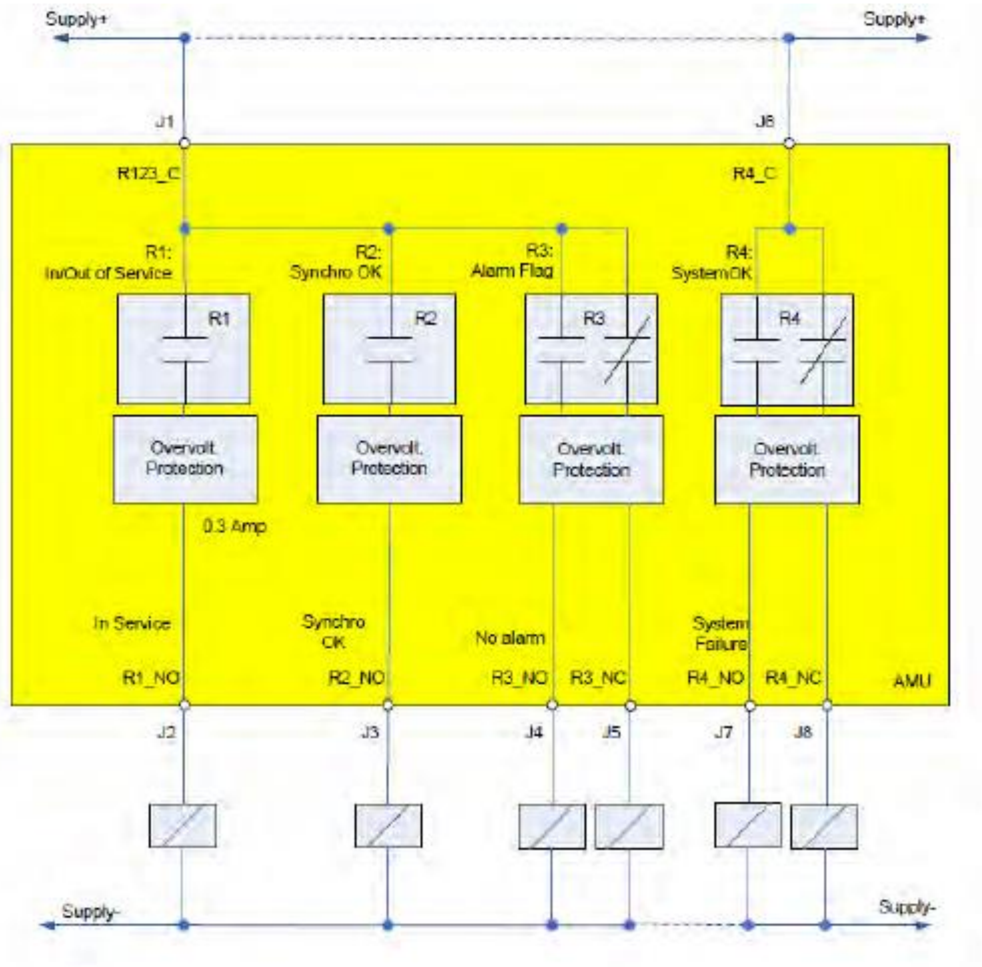


FIGURE 18 SIGNALIZATION OUTPUTS CONNECTIONS (DRY CONTACTS)

Operational status of whether or not the SMAU is In Service, GPS time synchronization, internal alarm, and system failure are typical.

The SAMU may have a configuration interface that provides the device health to an operator with access to the device. The front panel of a SAMU may have LEDs to visually indicate the health of the device.

A brief summary of a typical SAMU indication of health is as follows:

**Equipment Healthy:** Shows the device health, which is classified as follow:

- OK: Device is totally functional, no alarms reported. IN SERVICE LED: ON; ALARM LED: OFF; IN SERVICE RELAY: OPEN.
- WARNING: The device is functional, but has alarms reported. IN SERVICE LED: ON; ALARM LED: ON; IN SERVICE RELAY: OPEN.
- ALARM: The device is not functional. IN SERVICE LED: OFF; ALARM LED: ON; IN SERVICE RELAY: CLOSED

### *5.6.7.1 USES CASES*

#### 5.6.7.1.1 Hardware Failure

The internal watchdog functions of a SAMU are not accessible and do not have access points that would allow testing of these function. Disrupting the power supply to the SAMU during normal operation would simulate failure of the SAMU and cause the device to become non-operational.

#### 5.6.7.1.2 Time Synchronization Failure

The synchronization algorithm in a SAMU maybe quite different between SAMU, but there should be a common function amongst SAMU from different manufacturers. This function is the “Holdover Time” that occurs after the time sync signal is not detected by the SAMU. The SAMU is designed to provide accurate operation during the “Holdover Time” duration, the duration will be different amongst SMAU manufacturers.

#### 5.6.7.1.3 Quality Bit Indications (Out of Range, Failure etc…)

The SV telegram will contain information about the quality of the data contained in the telegram. The SAMU will have a default setting for the various bits in the quality field, the default setting may also be changed by the SAMU. There may be an option to change certain quality bits for test purposes.

### *5.6.7.2 TEST CASES*

#### 5.6.7.2.1 Hardware Failure: MERG-FAIL-01

Precondition:

The SAMU is operating under normal conditions

Test Step:

Disrupt power to the SAMU

Expected Results:

The IN-SERVICE contact should change to indicate failure. The contact should be a NC contact such that it is closed during failure.

##### *5.6.7.2.1.1 Test Results*

| Test Case Results: MERG-FAIL-01 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Subscriber/Client | | | | | | |
| | Vendor | ARC Informatique | Doble | KERI | SEL | GE | ABB |
| | Model | PcVue | FM61850 | KMU100 | 487B | D60 | 670 |
| Publisher | | | | | | | |
| Vendor | Model | | | | | | |
| GE | MU320 | | Pass | | | | |

| Test Case Results: MERG-FAIL-01 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Subscriber/Client | | | | | | |
| | Vendor | ARC Informatique | Doble | KERI | SEL | GE | ABB |
| | Model | PcVue | FM61850 | KMU100 | 487B | D60 | 670 |
| Publisher | | | | | | | |
| Vendor | Model | | | | | | |
| NR | PCS-978S | | | Pass | | | |
| Toshiba | GMU200 | | | | Pass | Pass | Pass |
| | | | | | | | |

### 5.6.7.2.2 Time Synchronization Failure: MERG-FAIL-02

Precondition:

The SAMU is operating under normal conditions

Test Step:

1. Disconnect the time source signal to the SAMU
2. The SAMU “Holdover Time” duration will start timing.  The SV telegrams still indicate that the SAMU is synchronized
3. When the SAMU “Holdover Time” duration has expired the SAMU will enter into a free running mode
4. The Synchronization contact and/or LED should indicate failure of the time synchronization
5. The SV telegrams should indicate the unsynchronized condition within the telegram
6. Reconnect the time source signal to the SAMU

Expected Results:

1. The SAMU will enter into a process of resynchronization and this process will be dependant on the manufacturer’s implementation
2. The SAMU should enter into a new state of normal operation with all alarms and indications reset.

#### *5.6.7.2.2.1 Test Results*

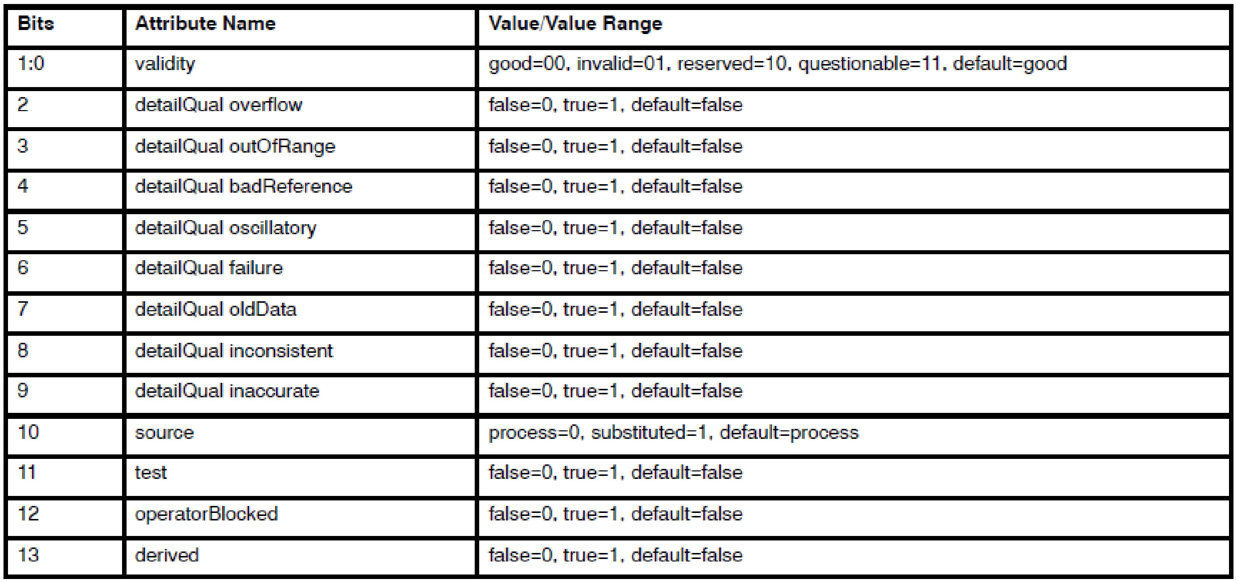
| Test Case Results: MERG-FAIL-02 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Subscriber/Client | | | | | | |
| | Vendor | ARC Informatique | Doble | KERI | SEL | GE | ABB |
| | Model | PcVue | FM61850 | KMU100 | 487B | D60 | 670 |
| Publisher | | | | | | | |
| Vendor | Model | | | | | | |
| GE | MU320 | | Pass | | | | |

| Test Case Results: MERG-FAIL-02 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Subscriber/Client | | | | | | |
| | Vendor | ARC Informatique | Doble | KERI | SEL | GE | ABB |
| | Model | PcVue | FM61850 | KMU100 | 487B | D60 | 670 |
| Publisher | | | | | | | |
| Vendor | Model | | | | | | |
| NR | PCS-978S | | | Pass,n1 | | | |
| Toshiba | GMU200 | | | | Pass | Pass | Pass |
| | | | | | | | |

### *5.6.7.3 Quality Bit Indications (Out of Range, Failure etc…)*

The test conditions necessary to create the scenarios where the quality bits will be changed by the SAMU are difficult to produce and potentially dangerous due to the magnitudes of the input signals required. The SAMU may have an interface whereby the various quality bits can be set by the user for test purposes.  The SAMU user manual should be consulted for the manufacturer specific cases necessary to operate the quality bits.

Bits 2, 4, 5, 7, 8, 12 should always be set to False as compliant to IEC 6189-9



| Bits | Attribute Name | Value/Value Range |
|---|---|---|
| 1:0 | validity | good=00, invalid=01, reserved=10, questionable=11, default=good |
| 2 | detailQual overflow | false=0, true=1, default=false |
| 3 | detailQual outOfRange | false=0, true=1, default=false |
| 4 | detailQual badReference | false=0, true=1, default=false |
| 5 | detailQual oscillatory | false=0, true=1, default=false |
| 6 | detailQual failure | false=0, true=1, default=false |
| 7 | detailQual oldData | false=0, true=1, default=false |
| 8 | detailQual inconsistent | false=0, true=1, default=false |
| 9 | detailQual inaccurate | false=0, true=1, default=false |
| 10 | source | process=0, substituted=1, default=process |
| 11 | test | false=0, true=1, default=false |
| 12 | operatorBlocked | false=0, true=1, default=false |
| 13 | derived | false=0, true=1, default=false |

Note: conformance to IEC 61869-9 requires conformance to Ed2.1

### 5.6.7.3.1 Test case name: MERG-FAIL-03

Precondition:

The SAMU is operating under normal conditions

Test Step:

1. Set the Out of Range Quality bit 2 to True
2. The Validity bits 1:0 should indicate invalid

Expected Results:

Check the SV telegram

#### 5.6.7.3.1.1 *Test Results*

| Test Case Results: MERG-FAIL-03 | | | | | |
|---|---|---|---|---|---|
| | Subscriber/Client | | | | |
| | Vendor | ARC Informatique | Doble | KERI | SEL |
| | Model | PcVue | FM61850 | KMU100 | 487B |
| Publisher | | | | | |
| Vendor | Model | | | | |
| GE | MU320 | | | | |
| NR | PCS-978S | | | Pass | |
| Toshiba | GMU200 | | | | |
| | | | | | |

### 5.6.7.3.2 Test case name: MERG-FAIL-04

Precondition:

The SAMU is operating under normal conditions

Test Step:

Set the Failure Quality bit 6 to True

Expected Results:

Check the SV telegram

#### 5.6.7.3.2.1 Test Results

| Test Case Results: MERG-FAIL-04 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Subscriber/Client | | | | | | |
| | Vendor | ARC Informatique | Doble | KERI | SEL | GE | ABB |
| | Model | PcVue | FM61850 | KMU100 | 487B | D60 | 670 |
| Publisher | | | | | | | |
| Vendor | Model | | | | | | |
| GE | MU320 | | | | | | |
| NR | PCS-978S | | | Pass | | | |
| Toshiba | GMU200 | | | | | Pass | Pass |
| | | | | | | | |

### 5.6.7.3.3 Test case name: MERG-FAIL-05

Precondition:

The SAMU is operating under normal conditions

Test Step:

Set the Inaccurate Quality bit 9 to True

Expected Results:

Check the SV telegram

#### 5.6.7.3.3.1 Test Results

| Test Case Results: MERG-FAIL-05 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Subscriber/Client | | | | | | |
| | Vendor | ARC Informatique | Doble | KERI | SEL | GE | ABB |
| | Model | PcVue | FM61850 | KMU100 | 487B | D60 | 670 |
| Publisher | | | | | | | |
| Vendor | Model | | | | | | |
| GE | MU320 | | | | | | |
| NR | PCS-978S | | | Pass | | | |
| Toshiba | GMU200 | | | | | Pass | Pass |
| | | | | | | | |

### 5.6.7.3.4 Test case name: MERG-FAIL-06

Precondition:

The SAMU is operating under normal conditions in test mode

Test Step:

Set the device to test mode

Expected Results:

Check the SV telegram

#### *5.6.7.3.4.1 Test Results*

| Test Case Results: MERG-FAIL-06 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Subscriber/Client | | | | | | |
| | Vendor | ARC Informatique | Doble | KERI | SEL | GE | ABB |
| | Model | PcVue | FM61850 | KMU100 | 487B | D60 | 670 |
| Publisher | | | | | | | |
| Vendor | Model | | | | | | |
| GE | MU320 | | Pass | | | | |
| NR | PCS-978S | | | Pass | | | |
| Toshiba | GMU200 | | | | Pass | Pass | Pass |
| | | | | | | | |

### 5.6.8 Network Failure

#### *5.6.8.1 Test case name: NET-FAIL-01*

Purpose: Verify that devices on both ends of the connection-oriented association recover from a network failure.

Precondition: Intact network with the client associated with the server.

Narrative: The network usually consists of a server, at least one intervening Ethernet switches, and a client. Sometimes an IED can detect loss of the physical link but often this detection is based upon lack of TCP keep-alive. Thus, test verifies the 8 cases of client/server and physical-link-loss-detection yes/no. The 60 second delay before network restoration simulates a long-term failure, 2 seconds a short-term failure.

##### 5.6.8.1.1 Test case 1a: Short/Long disconnection at the server switch

Test Steps 1a:

1. Remove the connection between the server/PC/switch and the remainder of the network.
2. Wait for 2 seconds
3. Re-attach the network
4. Verify that the client has restored the connection to the server within 60 seconds
5. Remove the connection between the server/PC/switch and the remainder of the network.
6. Wait for more than 60 seconds (or less if both sides acknowledge loss of connection)
7. Re-attach the network
8. Verify that the client has restored the connection to the server within 60 seconds

##### 5.6.8.1.2 Test case 1b: Short/Long disconnection at the server

Test Steps 1b:

1. Remove the connection at the server
2. Wait for 2 seconds
3. Re-attach the network
4. Verify that the client has restored the connection to the server within 60 seconds
5. Remove the connection at the server
6. Wait for more than 60 seconds (or less if both sides acknowledge loss of connection)
7. Re-attach the network
8. Verify that the client has restored the connection to the server within 60 seconds

#### 5.6.8.2 Test case name: NET-FAIL-02

##### 5.6.8.2.1 Test case 2a: Short/Long disconnection at the client switch

Test Steps 2a:

1. Remove the connection between the client /PC/switch and the remainder of the network.
2. Wait for 2 seconds
3. Re-attach the network
4. Verify that the client has restored the connection to the server within 60 seconds
5. Remove the connection between the client /PC/switch and the remainder of the network.
6. Wait for more than 60 seconds (or less if both sides acknowledge loss of connection)
7. Re-attach the network
8. Verify that the client has restored the connection to the server within 60 seconds

##### 5.6.8.2.2 Test case 2b: Short/Long disconnection at the client

Test Steps 2b:

1. Remove the connection at the client
2. Wait for 2 seconds
3. Re-attach the network
4. Verify that the client has restored the connection to the server within 60 seconds
5. Remove the connection at the client
6. Wait for more than 60 seconds (or less if both sides acknowledge loss of connection)
7. Re-attach the network
8. Verify that the client has restored the connection to the server within 60 seconds

#### 5.6.8.3 Test Results

| IED Only Test Results: Network Failure (NET-FAIL) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Clients | | Test Case | | | | | | |
| Vendor | Model | 01a | 01b | 02a | 02b | | | |
| Novatech | OrionLXm | | | | | | | |
| SIFANG | CSD-1321 | Pass | Pass | | | | | |

### 5.6.9 EAP failure

*Purpose:* This suite of testing is to determine the reaction to failures of the EAP Firewall function. In general, there are two types of firewalls that need to be tested and the expected behavior is different based upon the type of firewall. The known types of firewalls, for the purposes of this testing are:

- Firewalls with failsafe/pass-through capability.

In this particular instance, if a firewall fails or has power removed, Ethernet traffic is not interrupted. In this mode, no access control, deep packet inspection, or other firewall/EAP functions would be expected.

- Firewalls implemented as a redundant/failover pair.

In this particular instance, if a firewall fails or has been power removed, the “standby” firewall will begin processing information within a specific period of time.

- Firewalls with no-failsafe/pass-through capability.

In this particular instance, if a firewall fails, or has power removed, communication is expected to be interrupted.

In either event, monitoring of the firewall itself needs to provide an indication of the failure of the firewall.

### *5.6.9.1 Firewall with Failsafe Testing*

#### 5.6.9.1.1 Test case Name: EAP-PDF-01

Precondition: Firewall is operational. All client/server and GOOSE communication should be operational and validated. Firewall needs to document the failsafe time.

Test Step: Remove power from Firewall

Expected Results:

Client/Server: No interruption of communication

GOOSE: No TAL expirations should be detected except < failsafe time.

Monitoring of firewall: monitoring should indicate that firewall is failed

###### *5.6.9.1.1.1 Test Results*

None Recorded.

#### 5.6.9.1.2 Test case Name: EAP-PD-REC-02

Precondition: Firewall is powered-down. All client/server and GOOSE communication should be operational and validated. Firewall must document the power-up time.

Test Step: Power-up the Firewall

Expected Results:

Client/Server: No interruption of communication

GOOSE: No TAL expirations should be detected except < power-up time

Monitoring of firewall: After power-up time, monitoring should indicate that firewall is operational.

###### *5.6.9.1.2.1 Test Results*

None Recorded.

### *5.6.9.2 Redundant Firewall*

#### 5.6.9.2.1 Test case Name: EAP-RED-PDF-01

Precondition: Both primary and secondary Firewalls are operational. All client/server and GOOSE communication should be operational and validated. Firewall needs to document the failsafe time.

Test Step: Remove power from Primary Firewall

Expected Results:

Client/Server: No interruption of communication

GOOSE: TAL expirations may occur and should be documented as the redundancy is not bumpless due to source MAC changes < failsafe time. Subscribers that "bump" should be documented.

Monitoring of firewall: Should indicate that Primary Firewall is failed and that the Standby firewall is active and operational.

###### *5.6.9.2.1.1 Test Results*

None recorded.

#### 5.6.9.2.2 Recovery from failure: EAP-RED-PDF-02

Precondition: Primary Firewall is powered-down. All client/server and GOOSE communication should be operational and validated. Firewall needs to document the power-up time.

Test Step: Power-up the Primary Firewall

Expected Results:

Client/Server: No interruption of communication

GOOSE: No TAL expirations should be detected except.

Monitoring of firewall: Should indicate that the primary firewall is operational and that the secondary firewall is operational and active.

##### *5.6.9.2.2.1 Test Results*

None recorded.

### *5.6.9.3 Firewall with no failsafe*

#### 5.6.9.3.1 Test case Name: EAP-NOSAFE-PDF-01

Precondition: Firewall is operational. All client/server and GOOSE communication should be operational and validated. Firewall needs to document the failsafe time.

Test Step: Remove power from Firewall

Expected Results:

Client/Server: Clients should provide an indication that the connections have been interrupted within 1 minute.

GOOSE: TAL expirations should be detected within 1 minute.

Monitoring of firewall: monitoring should indicate that firewall is failed

##### *5.6.9.3.1.1 Test Results*

None recorded.

#### 5.6.9.3.2 Recovery from failure: EAP-NOSAFE-PDF-02

Precondition: Firewall is powered-down. All client/server and GOOSE communication should be failed. Firewall needs to document the power-up time.

Test Step: Power-up the Firewall

Expected Results:

Client/Server: Communication should be re-established within 1 minute of completion of power-up.

GOOSE: GOOSE should be received within 1 minute of power-up.

Monitoring of firewall: After power-up time, monitoring should indicate that firewall is operational.

###### *5.6.9.3.2.1 Test Results*

None recorded.

## 5.7 Process Bus Client

### 5.7.1 Test case name: MU-61869 Ed2.1 learning from IEC 61869-9 Compliant MU

Purpose: IEC 61869-9 MUs advertise their settings via: Clip, AccProt, AccMeas, HoldTmms. The Prcess Bus client configurations learns from the stadardized MU settings. No need to further configure the characteristic of the process bus client interface. Precondition: Use Ed2.1 Merging Units compliant to IEC 61869-9 product standard.

The rated current, and voltage are inidcated on the SLD for each merging unit. The rated frenquency is given for the Int App (60 Hz?).

Expected result: the protection configuration does not need to have aditional configuration of clipping, accuracy or holdover time.

#### *5.7.1.1 Test Results*

| Test Case Results: ABN-SV-01 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Publisher | | | | | | |
| | Vendor | GE | KERI | Doble | Siemens | SEL | SEL |
| | Model | MU320 | KMU100 | F6150SV | 7SJ MU | 401 | 421 |
| Subscriber | | | | | | | |
| Vendor | Model | | | | | | |
| SEL | 487E | | | | | | |
| SEL | 451 | | | | | | |
| NR | PCS-978S | | | | | | |
| OMICRON | IED Scout | | | | | | |
| SEL | 487B | Pass | | | | | |
| Sifang | CSI-200E | | | | | | |
| GE | D60 | | | | | | |
| Toshiba | GRD200 | | | | | | |
| Toshiba | GRT200 | | | | | Pass | Pass |

### 5.7.2 Verify that the rated current, voltages and frequency exposed in the TxTR settings are matching the SMV stream.

Test Steps :

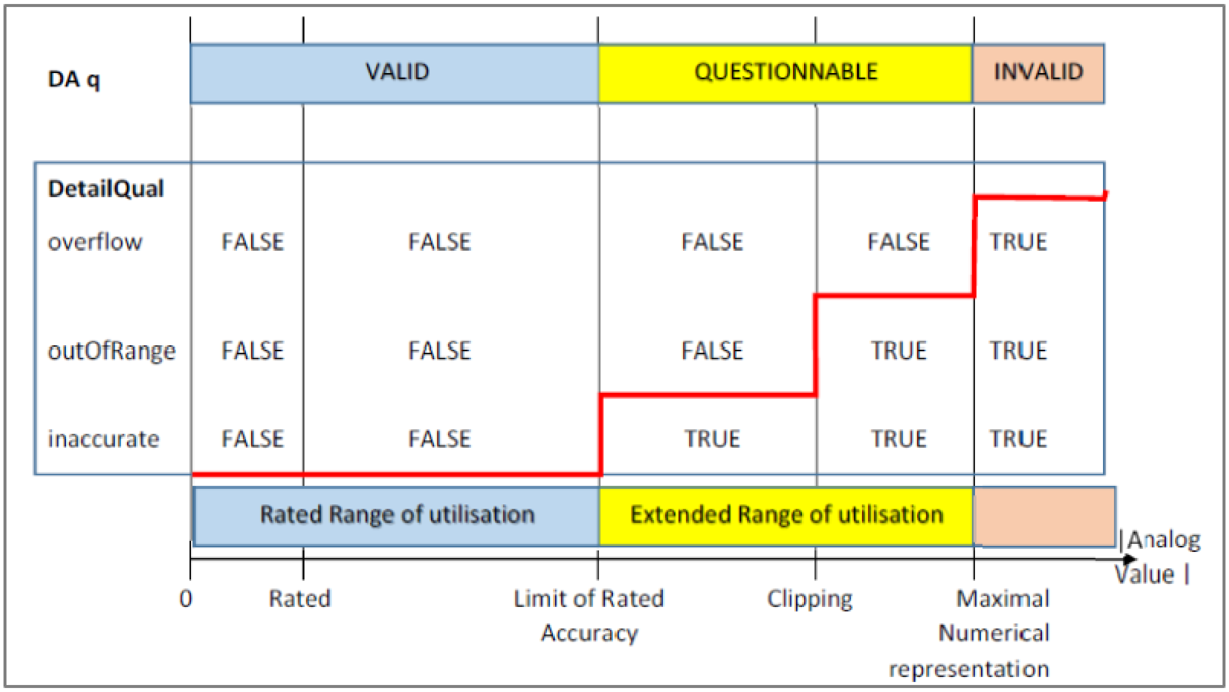
1. Verify in the SCD file that the setting of the TxTR are matiching the SLD.

2. Verify that the published samples (volage and current) are matching the expected rated voltage and current.

### 5.7.3 Verify that the indicated clipping in the TxTR leads to quality changes in the published stream.

Test Steps :

1. Based on the TC95 specification, increase injected current to go the exteded range of utilisation. Verify the quality vs the indicated clipping settings



| | | | | | |
|---|---|---|---|---|---|
| DA q | VALID | | QUESTIONNABLE | | INVALID |
| DetailQual | | | | | |
| overflow | FALSE | FALSE | FALSE | FALSE | TRUE |
| outOfRange | FALSE | FALSE | FALSE | TRUE | TRUE |
| inaccurate | FALSE | FALSE | TRUE | TRUE | TRUE |
| | Rated Range of utilisation | | Extended Range of utilisation | | |

#### *5.7.3.1 Test Results*

None recorded.

### 5.7.4 Verify that Overcurrent is working during clipping of the publisher

Test Steps :

1. Repear 9.2.1 with an active overcurrent protection. Verify that the overcurrent protection Is starting and tripping while the MU is sending current in the extended range of utilisation.

#### *5.7.4.1 Test Results*

None recorded.

# Annex A (Informative)

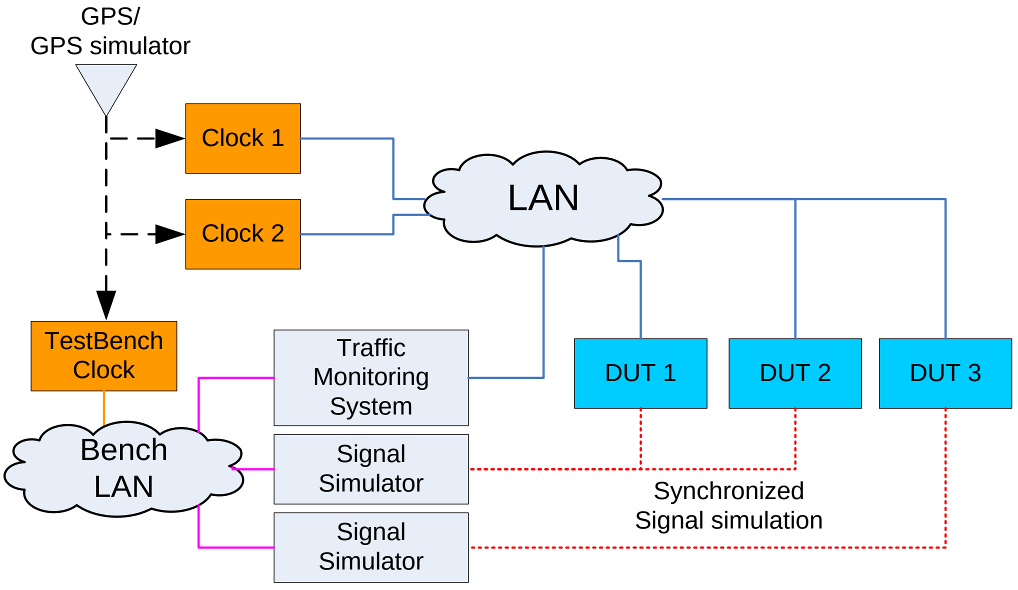
### 5.7.5 Validation of device synchronization (used by most clock synchronization tests)

The following procedure explains how time synchronization of each device, will be validated on the application level.

Depending on the device under test, different methodologies could be used to validate time synchronization.  In all case, this will be done using a synchronized simulation signal which is synchronized to the time server and then by retrieving timestamped process data triggered by this simulated signal.

The simulated signal could be of different types: Digital IOs, Analog (i.e.  synchrophasor simulation, time synchronized fault event), integer (counter), GOOSE(software simulated), etc.

The following diagram shows how synchronized signals could be generated from externally synchronized signal simulators:



The easiest way to produce timestamped data is probably using a synchronized toggling digital signal.  Most of the devices under tests support digital inputs.  Simply by publishing the status of the digital input using GOOSE or MMS, it will be possible to monitor the timestamp of this digital point.  A simple PPS signal (1Hz) is sufficient to easily verify the synchronization.

In order to simplify the analysis of the resulting application values, the monitoring system collecting the application level values shall also be synchronized.  This way, it is quite easy to make sure that timestamps are marked with the correct second.  (This requirement can be a bit tricky when testing leap seconds, since windows systems doesn't nicely handle leap second.  For those tests, the monitoring system clock synchronization can be first synchronized, then disabled in order to collect sequential data during the leap second.)

Using a digital signal, the validation is done as follow:

1. Validate that the rising edge of the digital signal occurs on the top of the second.
    a. For GOOSE check the timestamp of the value in the message when stVal change to true.
    b. For MMS, check the timestamp of the value in the reports when stVal change to true.
2. Validate that the time (second) of the timestamp is matching the time of the monitoring system.
3. Validate time quality
    a. Quality bits should match expected test result: LeapSecondKnown (LSK), ClockNotSynchronized (CNS), ClockFailure (CF)
    b. In all cases, the difference between the observed timestamp and the simulation shall be within the uncertainty defined by the (timestamp time quality + simulation uncertainty).

(The falling edge of the signal can also be used; it should match the duty cycle of the simulation signal.)

#### *5.7.5.1 Test Results*

None recorded.

# 6 Security Testing

In order to test IEC 61850-4 security, there are several types of certificates that need to be exchanged and used as the basis of the actual tests.

- Certificate Authority Certificate: "In cryptography, a **certificate authority** or **certification authority** (**CA**) is an entity that issues digital certificates. A digital certificate certifies the ownership of a public key by the named subject of the certificate. This allows others (relying parties) to rely upon signatures or on assertions made about the private key that corresponds to the certified public key. A CA acts as a trusted third party—trusted both by the subject (owner) of the certificate and by the party relying upon the certificate. The format of these certificates is specified by the X.509 standard." [From Wikipedia]

- TLS Certificates: These X.509 certificates are used to provide encrypted or protected transport layer messaging and are provided by a CA.

- Application Certificates: These X.509 certificates are used to provide authentication at the application layer. The next version of 62351-4 will also use this certificate to provide application level encryption and authentication, but this is out-of-scope of these tests.

"There are several commonly used filename extensions for X.509 certificates. Unfortunately, some of these extensions are also used for other data such as private keys.

- `.pem` – (Privacy-enhanced Electronic Mail) Base64 encoded DER certificate, enclosed between "-----BEGIN CERTIFICATE-----" and "-----END CERTIFICATE-----"
- `.cer`, `.crt`, `.der` – usually in binary DER form, but Base64-encoded certificates are common too (see `.pem` above)
- `.p7b`, `.p7c` – PKCS#7 SignedData structure without data, just certificate(s) or CRL(s)
- `.p12` – PKCS#12, may contain certificate(s) (public) and private keys (password protected)
- `.pfx` – PFX, predecessor of PKCS#12 (usually contains data in PKCS#12 format, e.g., with PFX files generated in IIS)

PKCS#7 is a standard for signing or encrypting (officially called "enveloping") data. Since the certificate is needed to verify signed data, it is possible to include them in the SignedData structure. A `.P7C` file is a degenerated SignedData structure, without any data to sign

PKCS#12 evolved from the *personal information exchange* (PFX) standard and is used to exchange public and private objects in a single file.". [From Wikipedia].

However, there are three types of objects that are exchanged:

1. Public CA root certificate (and any intermediate certificates – Note 1)

2. Public Server or Client “end entity” certificate issued (signed) by the CA root certificate (Note 1)

3. An out-of-band Private Key corresponding to the Client or Server certificate in 2. (Note 2)

All of these objects can be transported in one PKCS12 container (P12 file).

If private keys must be exchanged (Note 2), then only the PKCS12 format (P12 file) shall be used. This provides more protection for private keys, because the PKCS12 container (file) can be encrypted with a password. Although Private keys can also be transported in a PEM file, the PEM file format shall not be used because PEM does not support encryption of the contents and therefore increases the risk of loss or theft of the private key.

Notes:

1. There may be one or more “Intermediate” certificates in the chain between the Client or Server “End entity” certificate and the Public CA root certificate. The server will also need these intermediate certificates.
2. In a perfect world, with good security the private key is never exchanged. Instead the private key is generated on the device that needs a certificate, and the device supports “PKI enrolment”. In PKI enrolment, the device sends a certificate signing request (CSR) to a Certificate Authority for signing. The Certificate Authority authenticates the CSR, and signs the request. The result is a signed certificate that is sent back to the requesting device.

   The signed certificate corresponds to the private key generated on the device.

   However many devices today do not support PKI enrolment, or we may not have a tool that can act as a CA and sign CSRs.

   Without PKI enrolment, we need to generate the device private key somewhere else, and exchange/transport the private key and associated certificate to the device. This process is associated with the significant risk of the private key being compromised (lost or stolen) in transit, even if the private key is transported in a PKCS12 file encrypted with a password.

Exchanges between utilities (e.g. owners of the clients and servers) would be Public certificates (e.g. TLS, Application, and CA certificates). Exchanges from a CA to utilities would be of the Public CA Certificate and at a minimum the Private certificate and typically also a Public certificate.

For the IOP, it will be assumed to validate certificate exchanges between utilities/endpoints and not CA to utility since some manipulation may be required for the CA to utility exchange and CAs should supply certificates in a format that the utility can utilized. The IOP will also assume that there will be multiple CAs being utilized by different endpoints.

## 6.1 Pre-conditions for the IOP

Each participant will provide the following certificates for exchange to other endpoints:

- At least one CA Public certificate that does not expire during the IOP. The name of this certificate filenames shall be: <CA Name>_Public.<extension>

- At least two Application Level certificates and two TLS certificates OR two combined certificates (e.g. used for both TLS and Application) that do not expire during the IOP. The reason for two is that one will be revoked as part of a test and there will need to be a replacement certificate provided. The certificate filenames will be named as follows:

  <Company>_<IEDNAME>_<APP, TLS, COMBINED><_Revoke >.extension

  Where:

  Company: Name of the end-user company
  IEDName: IEC 61850 IED Name.
  APP: Indicates application level certificate.
  TLS: Indicates TLS level certificate
  COMBINED: indicates that the certificate is to be used for both application and TLS levels.
  _Revoke: This is an indication if a CRL is being provided that includes this certificate

- A Certificate Revocation List (CRL) that contains the _Revoke certificate.

## 6.2 Certificate Authority

The IOP requested that a utility IT department help stage a utility like X.509 PKI infrastructure. No utilities volunteered for this task.

Instead, the IOP utilized a Windows software package provided by Kaplan Software called Tekcert (https://www.kaplansoft.com/tekcert/). It proved to be a cost effective CA software package which support generation of CA X.509 certificates, X.509 Identity certificates, and supports OCSP and SCEP. In order to activate OCSP and SCEP capability, both Tekcert and TekSip were required to be purchased. The total cost was approximately $200 USD. The software proved to be adequate for the IOP but was not capable of generation of intermediate CA certificates.

It would seem appropriate for test, lab, and QA environments but not production environments.

There are several test cases that are associated with the application/IED interaction with the CA and/or certificates generated by the CA. These are described at a high level in the following table.

| Description of Testing Involving CA | Status |
|---|---|
| **Import of all required local CA Certificates** | Tested |
| **Certificate Signing Request** | Deferred to next IOP |
| **CA hierarchical trust** | Unable to test due to CA software |
| **Import of all Private Keys and associated certificates (e.g. local endpoint)** | Tested |
| **Import of all remote CA Certificates** | Tested |
| **Import of a certificate that has been previously revoked** | Tested |
| **Removal of Trusted CA certificate from local cache.** | Tested |
| **OSCP revocation of a certificate** | Tested |
| **OSCP validation of a certificate** | Tested |
| **SCEP** | Deferred to next IOP |

## 6.3 Planning for Test Cases

Many of these test cases require several different sets of certificates to be prepared and available from EACH participating entity. The purpose of this section is to allow participants to plan and generate the required certificates and CRLs in advance.

Each participant MUST bring the following:

- The CA certificate of the CA used to generate the certificates that are to be exchanged by the participant.

- One certificate that will not be on a revocation list (GOOD Certificate). If there are separate certificates required for TLS and ACSE, then two certificates shall be available.

- One certificate that will not be on a revocation list and will not be imported by the peer (NOT-IMPORTED-GOOD certificate). This certificate shall include a subject that is used in its other certificates.

- At least one certificate that is to be included on a CRL (PREVIOUSLY-REVOKED Certificate). It should be noted that the revocation test will result in these certificates no longer being able to be used between two peers.

- At least one certificate that is to be included on a CRL (TO-BE-REVOKED Certificate). It should be noted that the revocation test will result in these certificates no longer being able to be used between two peers.

- At least one certificate that is signed by the CA but is not to be exchanged with the peers out-of-band (NON-EXCHANGED certificate).

- A CRL that contains the PREVIOUSLY-REVOKED Certificate. This CRL shall not contain the TO-BE-REVOKED certificate.

- A different CRL that includes the TO-BE-REVOKED certificate.

Additionally, the following need to be provided by somebody participating or witnessing the tests:

- A CA certificate that will be used to create a hierarchical chain of CAs and a Certificate that utilizes that chain.

## 6.4 Normal Operation

### 6.4.1 Client/Server

#### *6.4.1.1 Application Authentication Only Testing : NORM-01*

Purpose: To prove that an implementation can perform strong authentication based upon the remote peer's ACSE public certificate.

Precondition: A participating vendor will need to have previously imported the CA and public certificate used by the remote peer. Appropriate configuration to perform strong authentication by both peers will need to be performed.

Procedure:

1. Calling Node (Client) attempts to establish an association with the peer (Server).

2. Association between the peers should occur.

3. Demonstration of information flow between the client and the server shall be demonstrated.

#### 6.4.1.1.1 Test Results

| Test Case Results: NORM--01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SISCO | NREC | Copadata | | | | |
| | Model | AXS4-61850 | PCS-9799 | Zenon | | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| NREC | PCS-978S | Pass | | Pass | | | | |
| SIFANG | CSC-211 | Pass | | | | | | |
| JP Embedded | Rasberry Demo GW | Pass | | Pass | | | | |
| TMW | Test Suite Pro | Pass | | Pass | | | | |
| Toshiba | GRD200 | | n1 | Pass | | | | |
| SISCO | AXS4-61850 | | Pass | Pass | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| n1 -Server didn't support auth only. | | | | | | | | |

### *6.4.1.2 Application Authentication and TLS Testing: NORM-02*

Purpose: To prove that an implementation can perform strong authentication based upon the remote peer's ACSE public certificate and encrypts the connection.

Precondition: A participating vendor will need to have previously imported the CA and public certificate used by the remote peer. Appropriate configuration to perform strong authentication by both peers will need to be performed.

It is also recommended that a network analyzer be available so that the use of encryption can be verified.

Procedure:

1. Calling Node (Client) attempts to establish an association with the peer (Server).
2. Association between the peers should occur.
3. Demonstration of information flow between the client and the server shall be demonstrated.
4. Verification that encryption is occurring is required in order to pass.

#### 6.4.1.2.1 Test Results

| Test Case Results: NORM--02 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SISCO | NREC | Copadata | | | | |
| | Model | AXS4-61850 | PCS-9799 | Zenon | | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| NREC | PCS-978S | Pass | | Pass | | | | |
| SIFANG | CSC-211 | Pass | | | | | | |
| JP Embedded | Rasberry Demo GW | Pass | | Pass | | | | |
| TMW | Test Suite Pro | Pass | | Pass | | | | |
| Toshiba | GRD200 | | Pass | Pass | | | | |
| SISCO | AXS4-61850 | | Pass | Pass | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

### *6.4.1.3 Ability to simultaneously support secure and non-secure associations :NORM-03*

Purpose: To prove that an application can support secure and non-secure communications simultaneously.

Precondition: A participating vendor will need to have previously imported the CA and public certificate used by the remote peer. Appropriate configuration to perform strong authentication by both peers will need to be performed. 62351-8 should be performed previously so that a secure connection is present.

.Procedure:

1. Calling Node (Client) attempts to establish an association with the peer (Server) using a non-authenticated and non-encrypted connection.

2. Association between the peers should occur.

3. Demonstration of information flow between the client and the server shall be demonstrated over the secure and non-secure connection is required.

#### 6.4.1.3.1 Test Results

| Test Case Results: NORM--03 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Client | | | | | | | |
| | Vendor | SISCO | NREC | Copadata | | | | |
| | Model | AXS4-61850 | PCS-9799 | Zenon | | | | |
| Server | | | | | | | | |
| Vendor | Model | | | | | | | |
| NREC | PCS-978S | Pass | | Pass | | | | |
| SIFANG | CSC-211 | Pass | | | | | | |
| JP Embedded | Rasberry Demo GW | Pass | | Pass | | | | |
| TMW | Test Suite Pro | | | | | | | |
| Toshiba | GRD200 | | n1 | | | | | |
| SISCO | AXS4-61850 | | Pass | Pass | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| n1 - Server didn't support secure and non-secure communications simultaneously. | | | | | | | | |

## 6.4.2 Credential Renewal

### *6.4.2.1 Manual*

#### 6.4.2.1.1 Import of All Required CA Certificates: NORM-04

Purpose: To prove that an implementation can import CA certificates from more than one CA.

Procedure:

1. The CA certificates used by the various participating vendors shall be provided to the participant.

2. The participant, being witnessed, will import the certificates and show that the certificates have been successfully imported. If successfully imported, this shall be a “pass”.

#### 6.4.2.1.2 Import of Local Keys : NORM-05

Purpose: To prove that an implementation can import private keys and associated certificates.

Precondition: A participating vendor will need to have previously imported CA certificate used to sign the certificate.

Procedure:

1. Import the private key and the associated certificate.

2. The participant, being witnessed, will import the certificate and key and show that the certificate has been successfully imported. If successfully imported, this shall be a “pass”.

#### 6.4.2.1.3 Import of Remote Certificates : NORM-06

Purpose: To prove that an implementation can import other vendor’s public certificates.

Precondition: A participating vendor will need to have previously imported the vendor’s CA certificate used to sign the certificate being provided.

Procedure:

1. Import the public certificate.

2. The participant, being witnessed will show that the certificate has been successfully imported. If successfully imported, this shall be a “pass”.

#### *6.4.2.2 SCEP*

##### 6.4.2.2.1 Certificate Signing Request: NORM-07

Purpose: To prove that an implementation can support a non-hierarchical trust signing.

Precondition: A participating vendor will need to prepare a non-hierarchical trust chain for a CA and use this hierarchy for its exchanges.

Procedure:

1. The CA certificates used by the vendor shall be provided to the participant.

2. The participant, being witnessed, will import the certificates and show that the certificates have been successfully imported. If successfully imported, this shall be a “pass”.

##### 6.4.2.2.2 Support for Hierarchical Trust: NORM-08

Purpose: To prove that an implementation can support hierarchical trust signing.

Precondition: A participating vendor will need to prepare a hierarchical trust chain for a CA and use this hierarchy for its exchanges.

Procedure:

3. The CA certificates used by the vendor shall be provided to the participant.

4. The participant, being witnessed, will import the certificates and show that the certificates have been successfully imported. If successfully imported, this shall be a “pass”.

#### *6.4.2.3 Certificate Validation*

##### 6.4.2.3.1 OCSP validation of a certificate : NORM-10

Purpose: To prove that an application will behave properly if an otherwise valid certificate is valid as indicated by using the Online Certificate Status Protocol (OCSP).

Precondition: A participating vendor will need to have previously imported the CA and GOOD certificates. The CA (as the OCSP server), client, and server must support OCSP. The certificate must be configured to include an OCSP server address. Appropriate configuration to perform strong authentication by both peers will need to be performed. The connection shall use the GOOD certificate.

Procedure:

1. Attempt to establish a connection between the client and server.
2. Verify the client queried the OCSP server (e.g., the CA) using OCSP, and received a “good” status.
3. The connection should be established

#### 6.4.2.3.2 OCSP validation of a certificate using OCSP Stapling: NORM-11

Purpose: To prove that an application will behave properly if an otherwise valid certificate is valid as indicated by using the Online Certificate Status Protocol (OCSP) status obtained when the certificate is validated (OCSP Stapling).

Precondition: A participating vendor will need to have previously imported the CA and GOOD certificates. The CA (as the OCSP server), client, and server must support OCSP and OCSP Stapling. Appropriate configuration to perform strong authentication by both peers will need to be performed. The connection shall use the GOOD certificate.

Procedure:

1. Verify the certificate status (the stapled status) is correct on the server.
2. Attempt to establish a connection between the client and server.
3. The client should verify the stapled OCSP status in the TLS handshake, and verify a “good” status.
4. Verify the client *did not* query the OCSP server (e.g., the CA) for a certificate status check
5. The connection should be established

#### 6.4.2.3.3 OCSP validation of a certificate using OCSP stapling: NORM-12

Purpose: To prove that an application will behave properly if an otherwise valid certificate has been removed/revoked as indicated by using the Online Certificate Status Protocol (OCSP).

Precondition: A participating vendor will need to have previously imported the CA and TO BE REVOKED certificates. The CA (as the OCSP server), client, and server must support OCSP and OCSP Stapling. Appropriate configuration to perform strong authentication by both peers will need to be performed. The connection shall use the TO BE REVOKED certificate.

Procedure:

1. Ensure the TO BE REVOKED certificate is not marked as "revoked" in the OCSP server (e.g., the CA), and the status is communicated to the server.
2. Establish a connection between the client and server. The connection should be established.
3. Disconnect between the client and server.
4. Mark the certificate as revoked in the OCSP server.
5. Verify the certificate status (the stapled status) is marked as "revoked" on the server. Refresh the server's OCSP status if necessary.
6. Attempt to establish a connection between the client and server.
7. The client should verify the stapled OCSP status in the TLS handshake, and verify a "revoked" status.
8. Verify the client *did not* query the OCSP server (e.g., the CA) for a certificate status check
9. The connection should not be established

#### 6.4.2.3.4 OCSP validation of a certificate – OCSP Server Failure: NORM-13

Purpose: To determine how an application responds when the Online Certificate Status Protocol (OCSP) server does not return a response to the OCSP query.

Precondition: A participating vendor will need to have previously imported the CA and GOOD certificates. The CA (as the OCSP server), client, and server must support OCSP. The certificate must be configured to include an OCSP server address. Appropriate configuration to perform strong authentication by both peers will need to be performed. The connection shall use the GOOD certificate. The OCSP server should be disabled

Procedure:

1. Verify the configurable OCSP response timeout value in the client
2. Attempt to establish a connection between the client and server.
3. Verify the client queried the OCSP server (e.g., the CA) using OCSP.
4. Verify the OCSP server did not return a response within the specified timeout.
5. Verify the client triggers an OCSP failure alarm.
6. The connection should be established

#### 6.4.2.3.5 OCSP validation of a certificate – OCSP Server Failure: NORM-14

Purpose: To determine how an application responds when the Online Certificate Status Protocol (OCSP) server does not return a response to the OCSP query.

Precondition: A participating vendor will need to have previously imported the CA and GOOD certificates. The CA (as the OCSP server), client, and server must support OCSP. The certificate must be configured to include an OCSP server address. Appropriate configuration to perform strong authentication by both peers will need to be performed. The connection shall use the GOOD certificate. The OCSP server should be disabled

Procedure:

1. Verify the configurable OCSP response timeout value in the client
2. Attempt to establish a connection between the client and server.
3. Verify the client queried the OCSP server (e.g., the CA) using OCSP.
4. Verify the OCSP server did not return a response within the specified timeout.
5. Verify the client triggers an OCSP failure alarm.
6. The connection should be established

#### 6.4.2.4 Test Results

| IED Only Test Results: Certificate Management (Norm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clients | | Manual | | | SCEP | | | Validation | | | | |
| Vendor | Model | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 |
| COPA-DATA | zenon | | | | | | Not Defined | | | | | |
| NREC | PCS-978S | | | | | | | | | | | |
| NREC | PCS-9799 | Pass | Pass | Pass | | | | | | | | |
| PCItek | Garabaldi | | | | | | | | | | | |
| SIFANG | CSC-211 | | | | | | | | | | | |
| SISCO | AXS4-61850 Client | Pass | Pass | Pass | | | | | | | | |
| n1- Server need reboot when delete CA cert | | | | | | | | | | | | |

### 6.4.3 GOOSE, R-GOOSE, SV, and R-SV

There are two different mechanisms that will be utilized to test the encryption of hash capabilities that support GOOSE, R-GOOSE, SV, and R-SV.

- Normal key distribution through the use of GDOI as specified by IEC 62351-9

- Use of a pre-shared key and set of policies instead of using GDOI.

The test shall revolve around the Encryption and Authentication/Hash algorithms in RFC 8052/IEC 62351-9. According to RFC 8052/IEC 62351-9, the supported cipher and hash algorithms for IEC 61235-9 are shown in the following table (typically delivered in the KD payload of GDOI). The mandatory/optional aspect are not defined in the sequence of documents. The following table represents a proposal (outcome of the IOP) for inclusion into IEC 62351-6 which is currently being drafted:

| Encryption | | Authentication/Hash | |
|---|---|---|---|
| Algorithm | m/o/x | Algorithm | m/o/x |
| None | | None | c1 |
| AES-CBC-128 | o | HMAC-SHA256-128 | o |
| AES-CBC-256 | m | HMAC-SHA256 | m |
| AES-GCM-128 | o | AES-GMAC-128 | o |
| AES-GCM-256 | m | AES-GMAC-256 | m |
| c1 – Only allowed for testing and not required. Should be interpreted by subscribers as ignore. | | | |

### 6.4.3.1 NERC CIP Implications

The use of end-to-end encryption can present issues with NERC CIP edge inspection, however, with the security for GOOSE, R-GOOSE, SV, and R-SV the edge inspector should be part of the group. It is unclear at this time if any packet inspector product has this ability at this time.

Should no such inspection capability be available, then to facilitate edge inspection, the fallback would be to not utilize end-to-end encryption (e.g. HASH and Authentication only). Should confidentiality need to be provided, VPN technology should be used to provide that protection.

### 6.4.3.2 Generic Test Cases

The philosophy of the following test cases, which are the foundation of pre-shared and GDOI based key distribution, are based upon observing a single publisher versus subscribers that are members in the group. Membership in the group shall be determined via SCL configuration and the use of <IEDName> within the SCL Control block definition to indicate the subscribers of the group. The SCD shall also be configured with a KDC declaration.

Each group shall be observed (e.g. the publisher publishes, and the subscribers receive and process the subscribed messages). It is required that the subscribers provide a mechanism to allow the observers to observe that the published information is actually received. The preferred mechanism would be through client monitoring of LGOS or LSVS.

In general, the group shall receive its keys and policies either through pre-configuration with shared keys or through the use of an IEC 62351-9 KDC.

Key security items to be tested are:

- Observation of IVs not being duplicated by the publisher (to be done through over the network observation) for AES-CBC encryption algorithms.
- The ability to be Authentication/Hash only for R-GOOSE and R-SV.
- The ability to encrypt R-GOOSE. The ability to encrypt R-SV for CT/PT/Merging unit exchanges is out-of-scope per the draft of IEC 62351-6 due to performance concerns.
- The ability to encrypt R-SV being utilized for synchrophasor exchanges.

#### *6.4.3.3 Pre-Shared Key*

**Disclaimer and Instructions for Use: The pre-shared key material provided in this document was generated in a non-production environment and is not from a particular vendor implementation. Use of this key should be configurable and be able to be enabled/disabled. If disabled after being enabled, the key should be deleted within the application so that no accidental use of this key can occur in a production environment as it would represent a significant attack vector. UCAIug takes not responsibility if the key ends up in a production system.**

The value of the pre-shared key is provided as a byte[]/octetstring and BigInteger formats.

The key size provided is 256 bits. 128 or 192 bit keys shall be derived by truncating the key and using only bytes [0]- byte[s] (where byte []0 is the 0x54 value).

**{byte[0x00000020]}**

**0x54 0x65 0x92 0xaa 0xf7 0x97 0x91 0xe4 0xdc 0x13 0xea 0x33 0xd3 0x78 0x64 0x33 0x2b 0xf5 0xeb 0xfb 0xb7 0x46 0xf1 0x32 0xf6 0xb2 0x54 0x71 0x62 0xd7 0xb8 0x2f**

**BigInteger Value**

**917642717628461745204799245286337811290276027866017626459821226151598902388904004663201045629781846405197277147118616293452216100024739352755072313962542256480446899221341011091467448461337091024126271876647605639927611418278281882998953975107823516241786982685457690270862061104994298366614515932551622573 88**

Testing with a pre-shared key, has other impacts on the R-GOOSE, R-SV APDU:

- The next ID should be zero.

- TimeToNext Key:

  In GDOI, per RFC 8052, the remaining lifetime value is defined as:

  ```
  "Remaining Lifetime value (4 octets) -- The number of seconds
  remaining before this TEK expires. A value of zero (0) shall
  indicate that the TEK does not have an expire time."

  However, this does not translate properly into IEC 61850-8-1 Edition
  2.1.  There needs to be a reserved value indicating no expiration.  For
  the purposes of the IOP, that value shall be a value of 0xFFFF.
  ```

- TimeOfCurrentKey: Should reflect the time of the selection of the pre-shared key.

Policies should be:

- Key ID shall be: 1234

- Encryption: AES_CBC256

- HMAC: HMAC_SHA256

#### 6.4.3.4 SCL

##### 6.4.3.4.1 SCL Import to define Group Membership: SCL-Group-Membership: SCL-01

Purpose: To prove that an ICT can import an SCD and configure a subscriber to be a member of a group.

Precondition: An SCD is created containing the group definition.

Procedure:

1. Import the SCD by the device's ICT function.

Expected Result: Device is properly configured by the ICT.

###### 6.4.3.4.1.1 Test Results

| IED Only Test Results: SCL Test Cases (SCL) | |
|---|---|
| Clients | Test Case |

| Vendor | Model | 01 | | |
|---|---|---|---|---|
| COPA-DATA | zenon | | | |
| NREC | PCS-978S | | | |
| NREC | PCS-9799 | | | |
| PCItek | Garabaldi | | | |
| SIFANG | CSC-211 | | | |
| SISCO | AXS4-61850 Client | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

### *6.4.3.5 Authentication Only Testing*

#### 6.4.3.5.1 Authentication and HMAC Test Cases: AUTH-HMAC-256

Purpose: To prove that a device can receive and process an Authentication value.

Precondition: The group is configured, or via GDOI, to utilize HMAC-256 without encryption.

Procedure:

1. Configure, or deliver policy from KDC, to use HMAC-256 without encryption.
2. Observe the publisher that it is publishing a HMAC.

Expected results: Subscribers are observed receiving and processing publication.

#### 6.4.3.5.2 Authentication and HMAC Test Cases: AUTH-HMAC-256-ABN

Purpose: To prove that a device can detect invalid authentication values.

Precondition: The group is configured, or via GDOI, to utilize HMAC-256 without encryption.

Procedure:

1. Configure, or deliver policy from KDC, to use HMAC-256 without encryption.

2. Power-down the publisher.

3. Power-up a publisher/simulator to replace the original publisher. The publisher shall be configured to utilize HMAC-512.

Expected results: Subscribers are observed to have TAL Timeout and/or do not receive or process the published message.

#### 6.4.3.5.3 Authentication and HMAC Test Cases: AUTH-GMAC-256

Purpose: To prove that a device can receive and process an Authentication value.

Precondition: The group is configured, or via GDOI, to utilize HMAC-256 without encryption.

Procedure:

3. Configure, or deliver policy from KDC, to use HMAC-256 without encryption.

4. Observe the publisher that it is publishing a HMAC.

Expected results: Subscribers are observed receiving and processing publication.

#### 6.4.3.5.4 Authentication and HMAC Test Cases: AUTH-GMAC-256-ABN

Purpose: To prove that a device can detect invalid authentication values.

Precondition: The group is configured, or via GDOI, to utilize HMAC-256 without encryption.

Procedure:

4. Configure, or deliver policy from KDC, to use HMAC-256 without encryption.

5. Power-down the publisher.

6. Power-up a publisher/simulator to replace the original publisher. The publisher shall be configured to utilize HMAC-512.

Expected results: : Subscribers are observed to have TAL Timeout and/or do not receive or process the published message.

#### *6.4.3.6 Encryption Testing*

##### 6.4.3.6.1 Encryption and HMAC Test Cases: ENC-AES-HMAC-256-01

Purpose: To prove that a device can receive and process an Authentication value.

Precondition: The group is configured, or via GDOI, to utilize HMAC-256 with AES-CBC-256.

Procedure:

1. Configure, or deliver policy from KDC, to use HMAC-256 and AES-CBC-256 encryption.
2. Observe the publisher that it is publishing a HMAC.

Expected results: Subscribers are observed receiving and processing publication.

##### 6.4.3.6.2 Encryption and HMAC Test Cases: ENC-AES-HMAC-256-02

Purpose: To prove that a device can receive and process an Authentication value.

Precondition: The group is configured, or via GDOI, to utilize HMAC-256 with AES-CBC-256.

Procedure:

1. Configure, or deliver policy from KDC, to use HMAC-256 and AES-CBC-256 encryption.
2. Observe the publisher that it is publishing a HMAC.
3. Using a network analyzer, ensure that the IV value is changing.

Expected results:

Subscribers are observed receiving and processing publication.

IV value is being changed by publisher for each published message (e.g. state changes and sequence number.

#### 6.4.3.6.3 Encryption and Authentication Test Cases: ENC-GMC- GMAC -256

Purpose: To prove that a device can receive and process an Authentication value.

Precondition: The group is configured, or via GDOI, to utilize AES-GMC-256 with AES-GMAC-256.

Procedure:

1. Configure, or deliver policy from KDC, to use AES-GMAC-256 and AES-GMC-256 encryption.
2. Observe the publisher that it is publishing a HMAC.

Expected results: Subscribers are observed receiving and processing publication.

### *6.4.3.7 Layer 2 GOOSE Testing*

The layer 2 GOOSE test cases inherit from the generic test cases and the inheritance is shown in the following table:

| **L2 GOOSE Test Case Name** | | **Generic Procedures used utilizing L2 GOOSE** |
|---|---|---|
| **Using GDOI** | **Using Pre-shared Key** | |
| GOOSE- AUTH-HMAC-256 | GOOSE- AUTH-HMAC-256-PRE | AUTH-HMAC-256 |
| GOOSE- AUTH-HMAC-256-ABN | GOOSE- AUTH-HMAC-256-ABN-PRE | AUTH-HMAC-256-ABN |
| GOOSE- AUTH-GMAC-256 | GOOSE- AUTH-GMAC-256-PRE | AUTH-GMAC-256 |
| GOOSE- AUTH-GMAC-256-ABN | GOOSE- AUTH-GMAC-256-ABN-PRE | AUTH-GMAC-256-ABN |
| GOOSE- ENC-AES-HMAC-256-01 | GOOSE- ENC-AES-HMAC-256-01-PRE | ENC-AES-HMAC-256-01 |
| GOOSE- ENC-AES-HMAC-256-02 | GOOSE- ENC-AES-HMAC-256-02-PRE | ENC-AES-HMAC-256-02 |

| | | |
|---|---|---|
| GOOSE- ENC-GMC-GMAC-256 | GOOSE- ENC-GMC-GMAC-256-PRE | ENC-GMC-GMAC-256 |

### 6.4.3.8 Layer 2 SV Testing

The layer 2 SV test cases inherit from the generic test cases and the inheritance is shown in the following table:

| L2 SV Test Case Name | | Generic Procedures used utilizing L2 SV |
|---|---|---|
| **Using GDOI** | **Using Pre-shared Key** | |
| SV- AUTH-HMAC-256 | SV- AUTH-HMAC-256-PRE | AUTH-HMAC-256 |
| SV- AUTH-HMAC-256-ABN | SV- AUTH-HMAC-256-ABN-PRE | AUTH-HMAC-256-ABN |
| SV- AUTH-GMAC-256 | SV- AUTH-GMAC-256-PRE | AUTH-GMAC-256 |
| SV- AUTH-GMAC-256-ABN | SV- AUTH-GMAC-256-ABN-PRE | AUTH-GMAC-256-ABN |

### 6.4.3.9 Routable GOOSE Testing

The R-GOOSE test cases inherit from the generic test cases and the inheritance is shown in the following table:

| R-GOOSE Test Case Name | | Generic Procedures used utilizing L2 GOOSE |
|---|---|---|
| **Using GDOI** | **Using Pre-shared Key** | |
| RGOOSE- AUTH-HMAC-256 | RGOOSE- AUTH-HMAC-256-PRE | AUTH-HMAC-256 |
| RGOOSE- AUTH-HMAC-256-ABN | RGOOSE- AUTH-HMAC-256-ABN-PRE | AUTH-HMAC-256-ABN |
| RGOOSE- AUTH-GMAC-256 | RGOOSE- AUTH-GMAC-256-PRE | AUTH-GMAC-256 |
| RGOOSE- AUTH-GMAC-256-ABN | RGOOSE- AUTH-GMAC-256-ABN-PRE | AUTH-GMAC-256-ABN |

| | | |
|---|---|---|
| RGOOSE- ENC-AES-HMAC-256-01 | RGOOSE- ENC-AES-HMAC-256-01-PRE | ENC-AES-HMAC-256-01 |
| RGOOSE- ENC-AES-HMAC-256-02 | RGOOSE- ENC-AES-HMAC-256-02-PRE | ENC-AES-HMAC-256-02 |
| RGOOSE- ENC-GMC-GMAC-256 | RGOOSE- ENC-GMC-GMAC-256-PRE | ENC-GMC-GMAC-256 |

#### *6.4.3.10 Routable SV Testing*

The R-SV test cases inherit from the generic test cases and the inheritance is shown in the following table:

| **R-SV Test Case Name** | | **Generic Procedures used utilizing L2 SV** |
|---|---|---|
| **Using GDOI** | **Using Pre-shared Key** | |
| RSV- AUTH-HMAC-256 | RSV- AUTH-HMAC-256-PRE | AUTH-HMAC-256 |
| RSV- AUTH-HMAC-256-ABN | RSV- AUTH-HMAC-256-ABN-PRE | AUTH-HMAC-256-ABN |
| RSV- AUTH-GMAC-256 | RSV- AUTH-GMAC-256-PRE | AUTH-GMAC-256 |
| RSV- AUTH-GMAC-256-ABN | RSV- AUTH-GMAC-256-ABN-PRE | AUTH-GMAC-256-ABN |

#### *6.4.3.11 Synchphasor*

The R-SV test cases, for synchrophasors,  inherit from the generic test cases and the inheritance is shown in the following table.  Since Synchrophasors are at a lower rate than CT/PT sampling, encryption may be utilized for this type of application.

| **R-GOOSE Test Case Name** | | **Generic Procedures used utilizing L2 GOOSE** |
|---|---|---|
| **Using GDOI** | **Using Pre-shared Key** | |
| SYNC- AUTH-HMAC-256 | SYNC- AUTH-HMAC-256-PRE | AUTH-HMAC-256 |

| | | |
|---|---|---|
| SYNC- AUTH-HMAC-256-ABN | SYNC- AUTH-HMAC-256-ABN-PRE | AUTH-HMAC-256-ABN |
| SYNC- AUTH-GMAC-256 | SYNC- AUTH-GMAC-256-PRE | AUTH-GMAC-256 |
| SYNC- AUTH-GMAC-256-ABN | SYNC- AUTH-GMAC-256-ABN-PRE | AUTH-GMAC-256-ABN |
| SYNC- ENC-AES-HMAC-256-01 | SYNC- ENC-AES-HMAC-256-01-PRE | ENC-AES-HMAC-256-01 |
| SYNC- ENC-AES-HMAC-256-02 | SYNC- ENC-AES-HMAC-256-02-PRE | ENC-AES-HMAC-256-02 |
| SYNC- ENC-GMC-GMAC-256 | SYNC- ENC-GMC-GMAC-256-PRE | ENC-GMC-GMAC-256 |

### 6.4.3.12 Test Results

Although there are test for L2/Routable GOOSE/SV, only L2-GOOSE yielded test results. These are provided in the following table.

| Test Case Results: L2 GOOSE | | | | | |
|---|---|---|---|---|---|
| Publisher | Vendor | NREC | SISCO | | |
| | Model | PCS-978S | MMS-Lite | | |
| Encryption Algorithm (Pre-shared Key) | | | | | |
| GOOSE- AUTH-HMAC-256-PRE | | Pass | Pass | | |
| GOOSE- AUTH-HMAC-256-ABN-PRE | | | | | |
| GOOSE- AUTH-GMAC-256-PRE | | Pass | Pass | | |
| GOOSE- AUTH-GMAC-256-ABN-PRE | | | | | |
| GOOSE- ENC-AES-HMAC-256-01-PRE | | | | | |
| GOOSE- ENC-AES-HMAC-256-02-PRE | | | | | |
| GOOSE- ENC-GMC-GMAC-256-PRE | | | | | |
| Encryption Algorithm (Pre-shared Key) | | | | | |
| GOOSE- AUTH-HMAC-256 | | | | | |
| GOOSE- AUTH-HMAC-256-ABN | | | | | |
| GOOSE- AUTH-GMAC-256 | | | | | |
| GOOSE- AUTH-GMAC-256-ABN | | | | | |
| GOOSE- ENC-AES-HMAC-256-01 | | | | | |

| Test Case Results: L2 GOOSE | | | | | |
|---|---|---|---|---|---|
| GOOSE- ENC-AES-HMAC-256-02 | | | | | |
| GOOSE- ENC-GMC-GMAC-256 | | | | | |
| Subscriber | Vendor | SISCO | NREC | | |
| | Model | MMS-Lite | PCS-978S | | |

## 6.5 GDOI

### 6.5.1 References

[1] Power systems management and associated information exchange - Data and communications security - Part 9: Cyber security key management for power system equipment

This section of the document has generic use cases followed by specific use cases for Authentication, Authentication&Encryption, and Key Delivery Assurance

### 6.5.2 Pull Test Cases

#### *6.5.2.1 Generic GDOI PULL : GDOI-PULL-01*

##### 6.5.2.1.1 Test case – Subscriber **Group** Member Attempts to pull keys from KDC (PULL-01)

Purpose:

To verify that GDOI security association (SA) between GM and KDC is established.<br>
That a Diffie Hellmann encrypted tunnel is established<br>
Keys are provided to the group member

Precondition:

No security association (SA) exists between GM and KDC.

Both GM and KDC have valid certificate.

Procedure:

1. GM initiates GDOI Phase 1 main mode exchange
2. KDC responds with suggested transform payload.
3. Exchange is successfully completed with correct step 2 (KE, Nx) and encrypted step 3 messages.

Expected results:

Both sides (GM and KDC) negotiate Diffie-Helman encryption key used for phase 2.

Content of step 1 and step 2 messages sent by GM and KDC could be verified with wireshark trace.

#### 6.5.2.1.2 Test case – Publishing  Group Member Attempts to pull keys from KDC: GDOI-PULL-02

Purpose:

To verify that GDOI security association (SA) between GM and KDC is established.
That a Diffie Hellmann encrypted tunnel is established
Keys are provided to the group member

Precondition:

No security association (SA) exists between GM and KDC.

Both GM and KDC have valid certificate.

Procedure:

1. GM initiates GDOI Phase 1 main mode exchange as described in sec 9.1.3 of [1], with single proposal/transform payload
2. KDC responds with suggested transform payload.
3. Exchange is successfully completed with correct step 2 (KE, Nx) and encrypted step 3 messages.

Expected results:

Both sides (GM and KDC) negotiate Diffie-Helman encryption key used for phase 2.
Content of step 1 and step 2 messages sent by GM and KDC could be verified with wireshark trace.

#### 6.5.2.1.3 Test case – Publisher and Subscriber exchange and Process messages

Purpose:

To insure that provided keys are in use.

Precondition:

PULL-01 and PULL-02 have been successful.

Procedure:

1. Using Wireshark, observe that the KeyIDs change.
2. Subscriber needs to be able to process information from publisher.

Expected results:

Subscriber processes the information provided by the publisher.

- Authentication and HMAC Test Cases: GDOI-PULL-AUTH-GMAC-256
- Authentication and HMAC Test Cases: GDOI-PULL-AUTH-GMAC-256-ABN

##### 6.5.2.2 GDOI PULL Authentication Test Cases

The test cases are the same as the generic except that the policy provided to the Group Members specifies Authentication (e.g. MAC[1]) only and no encryption.

The test cases shall be: GDOI-PULL- GDOI-MAC-01, GDOI-PULL-MAC-02, GDOI-PULL-MAC-03

##### 6.5.2.3 GDOI PULL Authentication and Encryption Test Cases:

The test cases are the same as the generic except that the policy provided to the Group Members specifies Authentication (e.g. HMAC) only and no encryption.

The test cases shall be: PULL-ENCRYPT-01, PULL- ENCRYPT -02, PULL- ENCRYPT -03

##### 6.5.2.4 GDOI PULL KDA: GDOI-PULL-04

The test cases are the same as the generic except that the policy provided to the Group Members specifies Key Delivery Assurance.

The test cases shall be: PULL-KDA -03

#### 6.5.3 PUSH Test Cases

##### 6.5.3.1 Generic GDOI PUSH: GDOI-PUSH-01

###### 6.5.3.1.1 Test case – KDC Pushes Policy to Subscriber **Group** (PUSH-01)

Purpose:

To verify that GDOI security association (SA) between GM and KDC is established.
That a Diffie Hellmann encrypted tunnel is established
Keys are provided to the group member

Precondition:

[1] MAC is used in the GDOI section to represent HMAC and GMAC options.

No security association (SA) exists between GM and KDC.

Both GM and KDC have valid certificate.

Procedure:

1. KDC initiates GDOI Phase 1 main mode exchange
2. Group Member responds with one of the suggested transform payloads.
3. Exchange is successfully completed with correct step 2 (KE, Nx) and encrypted step 3 messages.

Expected results:

Both sides (GM and KDC) negotiate Diffie-Helman encryption key used for phase 2.
Content of step 1 and step 2 messages sent by GM and KDC could be verified with wireshark trace.

#### 6.5.3.1.2 Test case – KDC Pushes to Publishing  Group Member Attempts to pull keys from KDC: GDOI-PUSH-01

Purpose:

To verify that GDOI security association (SA) between GM and KDC is established.
That a Diffie Hellmann encrypted tunnel is established
Keys are provided to the group member

Precondition:

No security association (SA) exists between GM and KDC.

Both GM and KDC have valid certificate.

Procedure:

1. KDC initiates GDOI Phase 1 main mode exchange
2. Group Member responds with one of the suggested transform payloads.
3. Exchange is successfully completed with correct step 2 (KE, Nx) and encrypted step 3 messages.

#### 6.5.3.1.3 Test case – Publisher and Subscriber exchange and Process messages

Purpose:

To insure that provided keys are in use.

Precondition:

PUSH-01 and PUSH-02 have been successful.

Procedure:

1. Using Wireshark, observe that the KeyIDs change.
2. Subscriber needs to be able to process information from publisher.

Expected results:

Subscriber processes the information provided by the publisher.

#### 6.5.3.2 GDOI PUSH Authentication Test Cases:

The test cases are the same as the generic except that the policy provided to the Group Members specifies Authentication (e.g. MAC[2]) only and no encryption.

The test cases shall be: PUSH-MAC-01, PUSH-MAC-02, PUSH-MAC-03

#### 6.5.3.3 GDOI PUSH Authentication and Encryption Test Cases

The test cases are the same as the generic except that the policy provided to the Group Members specifies Authentication (e.g. HMAC) only and no encryption.

The test cases shall be: PUSH-ENCRYPT-01, PUSH- ENCRYPT -02, PUSH- ENCRYPT -03

### 6.5.4 GDOI PUSH KDA

The test cases are the same as the generic except that the policy provided to the Group Members specifies Key Delivery Assurance.

The test cases shall be: PUSH-KDA -03

### 6.5.5 Test Results

| Test Case Results: GDOI | | | | | |
|---|---|---|---|---|---|
| KDC | Vendor | PCItek | PCItek | PCItek | |
| | Model | Garibaldi | Garibaldi | Garibaldi | |
| GROUP PULL | | | | | |
| GDOI-PULL-01 | | Pass | Fail, n1 | Fail, n2 | |
| GDOI-PULL-02 | | Pass | | | |
| GDOI-PULL- AUTH-HMAC-256 | | | | | |
| GDOI-PULL- AUTH-HMAC-256-ABN | | | | | |
| GDOI-PULL- GDOI-MAC-01 | | | | | |

[2] MAC is used in the GDOI section to represent HMAC and GMAC options.

| Test Case Results: GDOI | | | | | |
|---|---|---|---|---|---|
| GDOI-PULL- GDOI-MAC-02 | | | | | |
| GDOI-PULL- GDOI-MAC-03 | | | | | |
| GDOI-PULL-ENCRYPT-01 | | Pass | | | |
| GDOI-PULL-ENCRYPT-02 | | Pass | | | |
| GDOI-PULL-ENCRYPT-03 | | Pass | | | |
| GROUP-PUSH | | | | | |
| GDOI-PUSH-01 | | | | | |
| GDOI-PUSH-02 | | | | | |
| GDOI-PUSH- AUTH-HMAC-256 | | | | | |
| GDOI-PUSH- AUTH-HMAC-256-ABN | | | | | |
| GDOI-PUSH- GDOI-MAC-01 | | | | | |
| GDOI-PUSH- GDOI-MAC-02 | | | | | |
| GDOI-PUSH- GDOI-MAC-03 | | | | | |
| GDOI-PUSH-ENCRYPT-01 | | | | | |
| GDOI-PUSH-ENCRYPT-02 | | | | | |
| GDOI-PUSH-ENCRYPT-03 | | | | | |
| Group Member | Vendor | JPE | Toshiba | GE | |
| | Model | Demo Gateway | GRD 200 | D60 | |
| n1 – exchange failed on 3rd Group Member message due to encryption issues.<br>n2 – format issues in 2nd Group Member message. | | | | | |

## 6.6 Radius

It was discussed and decided that Radius testing would not be an explicit part of the IOP.

## 6.7 Syslog

It was discussed and decided that Syslog  testing would not be an explicit part of the IOP.

## 6.8 Disruptive

#### 6.8.1.1 GOOSE Subscriber Testing

#### 6.8.1.1.1 Intruder with different source MAC address and power-up: GOOSE-SEC-INT-01

*Precondition:* Subscriber(s) are subscribed to the expected publisher and the publisher is publishing and there are no TAL expirations occurring.

*Test Step:* The intruding publisher is configured to publish the expected GOOSE but from a different source MAC address from the expected publisher. Additionally, the Stnum shall be starting at 1 indicating power-up and a set of constant values so that observation in regard to which GOOSE is being used is facilitated.

Expected Results:

The standard does not define the expected behavior. The preferred behavior is that the intruder's GOOSE is ignored since there is no TAL and the source MAC is different.

Observer needs to record the behavior of the subscriber being that the subscriber either:

- Ignores the intruder's GOOSE
- Replaces the expected GOOSE with the intruder's GOOSE
- Subscriber switches back and forth from expected to intruder (etc).

Subscribers need to document their expected behavior.

#### 6.8.1.1.2 Intruder with the same source MAC address and power-up: GOOSE-SEC-INT-02

*Precondition:* Subscriber(s) are subscribed to the expected publisher and the publisher is publishing and there are no TAL expirations occurring.

*Test Step:* The intruding publisher is configured to publish the expected GOOSE but from and the same source MAC address from the expected publisher. Additionally, the Stnum shall be starting at 1 indicating power-up and a set of constant values so that observation in regard to which GOOSE is being used is facilitated.

Expected Results:

The standard does not define the expected behavior. The preferred behavior is that the intruder's GOOSE is ignored since there is no TAL and the Stnum is less than the expected publisher's Stnum.

Observer needs to record the behavior of the subscriber being that the subscriber either:

- Ignores the intruder's GOOSE
- Replaces the expected GOOSE with the intruder's GOOSE
- Subscriber switches back and forth from expected to intruder (etc).

#### 6.8.1.1.3 Intruder with the same source MAC address and future StNum: GOOSE-SEC-INT-03

*Precondition:* Subscriber(s) are subscribed to the expected publisher and the publisher is publishing and there are no TAL expirations occurring.

*Test Step:* The intruding publisher is configured to publish the expected GOOSE but from and the same source MAC address from the expected publisher. Additionally, the Stnum shall be starting at a large number and a set of constant values so that observation in regard to which GOOSE is being used is facilitated.

Expected Results:

The standard does not define the expected behavior. The preferred behavior is that the intruder's GOOSE is ignored since there is no TAL and the Stnum is greater than the expected publisher's Stnum.

Observer needs to record the behavior of the subscriber being that the subscriber either:

- Ignores the intruder's GOOSE
- Replaces the expected GOOSE with the intruder's GOOSE
- Subscriber switches back and forth from expected to intruder (etc).

#### 6.8.1.1.4 Test Results

None recorded.

## 6.9 Infrastructure Testing

### 6.9.1 Firewall/EAP and GOOSE Monitoring Testing

#### *6.9.1.1 Use Cases*

There are several use cases that are intended to be addressed by the following test cases. The use cases are described in the following sections. These are specific to non-secure Layer 2 GOOSE messages but could also be relevant to non-secure Layer 2 Sample Value messages. With the advent of IEC 62351-6, there are mechanisms being specified to detect spoof and replay and to encrypt/authenticate the Layer 2 messages in a similar fashion to routable GOOSE and Sample Values.

##### 6.9.1.1.1 Spoof

One of the documented issues with non-secure GOOSE/SV messages is the ability of a rogue node to publish incorrect information that subscribers accept as information and that the subscribers process and takes action on the incorrect information. Since the subscriber is only configured with the address to which the message is being published and datastream information (e.g. DataSet reference ,Control Block reference , etc.) the subscriber does is not configured with the source MAC address of the publisher. Therefore, rogue nodes can be attached to the network with either the same of different source MAC addresses.

IEC 62351-6 (draft) specifies a mechanism that provides partial protection to this spoof type of attack for non-secure messages. The purpose of the test cases is to test these protections.

##### 6.9.1.1.2 Replay

In a similar manner to a rogue node, there is an attack vector known as Replay where an entity records a set of messages and replays them onto the network. This could result in the subscribers processing incorrect information.

IEC 62351-6 (draft) specifies a mechanism that provides partial protection to replay type of attacks for non-secure messages. The purpose of the test cases is to test these protections.

#### *6.9.1.2 Test Cases*

##### 6.9.1.2.1 Test case name: GOOSE-SEC-INT-01

Precondition: Subscriber(s) are subscribed to the expected publisher and the publisher is publishing and there are no TAL expirations occurring.

Test Step: The intruding publisher is configured to publish the expected GOOSE but from a different source MAC address from the expected publisher. Additionally, the Stnum shall be starting at 0 indicating power-up and a set of constant values so that observation in regard to which GOOSE is being used is facilitated.

Expected Results:

> The EAP/Firewall and monitors should detect the intruder. EAP/Firewalls should use ACL to prevent the GOOSE through flowing through the EAP.

###### 6.9.1.2.1.1 Test Results

None recorded.

### 6.9.2 Certificate Revocation

#### 6.9.2.1 Validation of behavior in the case of a certificate being revoked : REV-01

Purpose: To prove that an application will properly disconnect if a certificate that is in use is revoked.

Precondition: A participating vendor will need to have previously imported the CA and public TO-BE-REVOKED certificate used by the remote peer. Appropriate configuration to perform strong authentication by both peers will need to be performed. 62351-8 should be performed previously so that a secure connection is present. The connection shall use the TO-BE-REVOKED certificates.

Procedure:

1. A CRL containing the Client's TO-BE-REVOKED certificate should be applied to the Server.

2. The expected behavior is that the server should abort the connection.

3. Client should establish another secure connection to the server using a non-revoked certificate but the TO-BE-REVOKED certificate of the server.

4. A CRL should be applied to the Client indicating that the TO-BE-REVOKED certificate being used by the server has been revoked.

5. The expected behavior is that the Client should abort the connection.

#### 6.9.2.2 Connection behavior regarding non-configured certificate: REV-02

Purpose: To prove that an TLS connection shall behave properly if a certificate signed by an imported CA is utilized in an exchange but has not been previously imported.

Precondition: A participating vendor will need to have previously imported the CA.

.

Procedure:

1. The Client shall attempt to establish a connection to the server using the NOT-IMPORTED-GOOD certificate.

2. The expected behavior is that the server should declare the expected behavior. The expected behavior is that the connection should occur.

#### *6.9.2.3 Removal of a Trusted CA Certificate : REV-03*

Purpose: To prove that an application behaves properly if a certificate signed by an imported CA is utilized in an exchange where the CA certificate has been removed/revoked.

Precondition: A participating vendor will need to have previously imported the CA and GOOD certificates.

Procedure:

1. Establish a connection between the client and server. The connection should be established.
2. Disconnect between the client and server.

3. Remove the Client's CA in the Server cache. A reboot should not be required.

4. Attempt to re-establish the connection. The connection should be refused.

5. Add the Client's CA back into the server.

6. Establish a connection between the client and server. The connection should be established.

7. Disconnect between the client and server.

8. Remove the server's CA in the client.

9. Attempt to re-establish the connection. The connection should be refused by the client.

10. Add the Client's CA back into the server.

11. Establish a connection between the client and server. The connection should be established.

### 6.9.2.4 OCSP revocation of a certificate: REV-04

Purpose: To prove that an application will behave properly if an otherwise valid certificate has been removed/revoked as indicated by using the Online Certificate Status Protocol (OCSP).

Precondition: A participating vendor will need to have previously imported the CA and TO BE REVOKED certificates. The CA (as the OCSP server), client, and server must support OCSP. The certificate must be configured to include an OCSP server address. Appropriate configuration to perform strong authentication by both peers will need to be performed. The connection shall use the TO BE REVOKED certificate.

Procedure:

1. Ensure the TO BE REVOKED certificate is not marked as "revoked" in the OCSP server (e.g., the CA).
2. Establish a connection between the client and server. The connection should be established.
3. Disconnect between the client and server.
4. Mark the certificate as "revoked" in the OCSP server.
5. Attempt to establish a connection between the client and server.
6. Verify the client queried the OCSP server using OCSP and received a "revoked" status.
7. The connection should not be established

### 6.9.2.5 Test Results

| IED Only Test Results: Disruptive Test Cases (REV) | | | | | |
|---|---|---|---|---|---|
| Clients | | Test Case | | | |
| Vendor | Model | 01 | 02 | 03 | 04 |
| COPA-DATA | zenon | Pass | | Pass | Pass |
| NREC | PCS-978S | | | | |
| NREC | PCS-9799 | Pass | Pass | Q,n1 | |
| PCItek | Garabaldi | | | | |
| SIFANG | CSC-211 | Pass | Pass | | |
| SISCO | AXS4-61850 Client | Pass | Pass | Pass | |
| n1- Server need reboot when delete CA cert | | | | | |

### 6.9.3 GOOSE Cyber Intrusion

*Purpose*: This suite of testing is to determine the reaction of subscribers and firewalls/EAPs to GOOSE messages from unexpected sources. There are several papers documenting the fact that if the real publisher is not operational, without security, subscribers will accept the intruder's GOOSE. Therefore, testing is intending to concentrate on the behavior when the expected publisher is publishing, and the subscribers have no TALs and then the intruder is introduced.

###### *6.9.3.1.1.1 Test case name: GOOSE-SEC-INT-02*

Precondition: Subscriber(s) are subscribed to the expected publisher and the publisher is publishing and there are no TAL expirations occurring.

Test Step: The intruding publisher is configured to publish the expected GOOSE but from and the same source MAC address from the expected publisher. Additionally, the Stnum shall be starting at 0 indicating power-up and a set of constant values so that observation in regard to which GOOSE is being used is facilitated.

Expected Results:

The EAP/Firewall and monitors should detect the intruder due to multiple different StNums. EAP/Firewalls should use ACL to prevent the GOOSE through flowing through the EAP.

###### *6.9.3.1.1.1.1 Test Results*

None recorded.

###### *6.9.3.1.1.2 Test case name: GOOSE-SEC-INT-03*

Precondition: Subscriber(s) are subscribed to the expected publisher and the publisher is publishing and there are no TAL expirations occurring.

Test Step: The intruding publisher is configured to publish the expected GOOSE but from and the same source MAC address from the expected publisher. Additionally, the Stnum shall be starting at a large number and a set of constant values so that observation in regard to which GOOSE is being used is facilitated.

Expected Results:

The EAP/Firewall and monitors should detect the intruder due to multiple different StNums. EAP/Firewalls should use ACL to prevent the GOOSE through flowing through the EAP.

###### *6.9.3.1.1.2.1 Test Results*

None recorded.

### 6.9.4 Infrastructure Test Case Procedures

The following test cases were planned but not executed and are being provided for documentation purposes.

#### *6.9.4.1 Overview*

The following tables provide a high level description of the test cases that follow:

| Test Case | Description |
|---|---|
| Infrastruct-1 | Normal traffic generating no ACL alerts |
| Infrastruct-2 | Invalid Client Source IP address from Control Center to Substations |
| Infrastruct-3 | Invalid L2 GOOSE source address from Substation to Substation |
| Infrastruct-4 | Invalid L2 GOOSE destination address from Substation to Substation |
| Infrastruct-5 | Invalid L2 GOOSE source address from Substation to Control Center |
| Infrastruct-6 | Invalid L2 GOOSE destination address from Substation to Control Center |
| Infrastruct-7 | Incorrect Port Number access |
| Infrastruct-8 | Invalid Ethernet Ethertype (e.g. non-GOOSE) |
| Infrastruct-9 | No Traffic on port (DOS test) |

**Table 7: Firewall and ACL testing**

| Test Case | Description |
|---|---|
| Syslog-1 | Firewall and ACL normal traffic generating no ACL alerts (execute as part of Infrastructure-1) |
| Syslog-2 | Firewall and ACL invalid Source address from Control Center to Substations (execute as part of Infrastructure-2) |
| Syslog-3 | Firewall and ACL  invalid L2 GOOSE source address from Substation to Substation (execute as part of Infrastructure-3) |
| Syslog-4 | Firewall and ACL invalid L2 GOOSE destination address from Substation to Substation (execute as part of Infrastructure-4) |

| | |
|---|---|
| Syslog-5 | Firewall and ACL invalid L2 GOOSE source address from Substation to Control Center (execute as part of Infrastructure-5) |
| Syslog-6 | Firewall and ACL invalid L2 GOOSE destination address from Substation to Control Center (execute as part of Infrastructure-6) |
| Syslog-7 | Firewall and ACL detection of invalid port number. |
| Syslog-8 | Firewall and ACL detection of invalid Ethertype |

**Table 8:Syslog Testing**

#### 6.9.4.2 General Pre-conditions

Infrastructure components that are to be tested need to be configured with the following set of information. The configuration is constrained to what the component can actually be configured to support. Therefore, not the entire following configuration is required to participate in the testing.

- Configuration of ACLs for Source and Destination IP addresses is configured
- Configuration of ACLs for Source and Destination L2 GOOSE address is configured.
- Ethertype for L2 GOOSE is configured.

#### 6.9.4.3 Test Cases

##### 6.9.4.3.1 Normal Traffic Monitoring (Infrastruct-1, Syslog-1)

Purpose: To prove that there are no false triggers based upon normal traffic and application patterns.

Procedure:

1. The infrastructure component will be monitored via Syslog or other means to make sure that no traffic has been disrupted/dropped due to ACL or filtering rule configuration. Monitoring shall be for 20-minutes.

   If the infrastructure component supports Syslog, Syslog-1 may be passed if the Unit Under Test can be proved to send information to Syslog even if it contains false triggers.

##### 6.9.4.3.2 Invalid Source IP Address (Infrastruct-2, Syslog-2)

Purpose: To prove that the Unit Under Test can detect and enunciate a filter/ACL violation based upon a non-configured source IP-Address.

Precondition: A 61850 Client will be configured with an un-assigned IP address.

Procedure:

1. Client will attempt to establish a non-secure MMS connection through the Unit Under Test.

   Based upon the UUT PICs, the connection will fail (e.g. PICS indicates dropped packets).

   If the infrastructure component supports Syslog, Syslog-2 may be passed if the Unit Under Test can be proved to send information to Syslog indicating the violation.

#### 6.9.4.3.3 Invalid Source L2 GOOSE MAC Address (Infrastruct-3 , Syslog-3)

Purpose: To prove that the Unit Under Test can detect and enunciate a filter/ACL violation based upon a non-configured source MAC Address.

Precondition: A GOOSE Publisher, whose configuration information has NOT been configured in the UUT. The GOOSE publisher will be configured to publish to a destination address that the UUT has been configured to allow.

Procedure:

1. Publisher will begin publishing.

   Based upon the UUT PICs, the packets must not traverse the UUT.

   If the infrastructure component supports Syslog, Syslog-3 may be passed if the Unit Under Test can be proved to send information to Syslog indicating the violation .

#### 6.9.4.3.4 Invalid Destination L2 GOOSE MAC Address (Infrastruct-4, Syslog-4)

Purpose: To prove that the Unit Under Test can detect and enunciate a filter/ACL violation based upon a non-configured destination MAC Address.

Precondition: A GOOSE Publisher, will be configured to send a GOOSE to an unexpected destination which has NOT been configured in the UUT. The GOOSE publisher will be configured to publish from a source address that the UUT has been configured to allow.

Procedure:

1. Publisher will begin publishing.

   Based upon the UUT PICs, the packets must not traverse the UUT.

   If the infrastructure component supports Syslog, Syslog-3 may be passed if the Unit Under Test can be proved to send information to Syslog indicating the violation.

#### 6.9.4.3.5 Invalid Source L2 GOOSE MAC Address (Infrastruct-5 , Syslog-5)

This is the same test procedure as Infrastruct-3, but for infrastructure components in a different Integrated Application location.

#### 6.9.4.3.6 Invalid Destination L2 GOOSE MAC Address (Infrastruct-6, Syslog-6)

This is the same test procedure as Infrastruct-4 , but for infrastructure components in a different Integrated Application location.

#### 6.9.4.3.7 Detection of incorrect Port Number Access (Infrastruct-7, Syslog-7)

Purpose: To prove that the Unit Under Test can detect and enunciate an attempt of a IEC 61850 Client connection to the incorrect port (e.g. not 102 or 3782).

Precondition: Telnet client will be used on a node whose IP address has been configured to be allowed to pass through the UUT. A node on the other side of the UUT must have a "TCP-Listen" posted for the port that is to be used by the Telnet client.

Procedure:

1. Telnet client is used to establish a connection using non-configured port to a destination IP address that is on a white list in the UUT and that has the TCP-Listen posted.

   The UUT is expected to block and enunciate the connection attempt. If the Telnet client succeeds in connecting, this represents a failure.

#### 6.9.4.3.8 Detection of incorrect Ethertype (Infrastruct-8, Syslog-8)

Purpose: To prove that the Unit Under Test can detect and enunciate a filter/ACL violation based upon a non-configured Ethertype.

Precondition: A GOOSE Publisher, will be configured to send a GOOSE to an allowed destination which. The GOOSE publisher will be configured to publish from to a non-configured Ethertype.

Procedure:

1. Publisher will begin publishing.

   Based upon the UUT PICs, the packets must not traverse the UUT.

### 6.9.4.3.9 DOS detection based upon no traffic (Infrastruct-9)

Purpose: To determine if the UUT can assist in preventing DOS attacks.

Precondition: Telnet client will be used on a node whose IP address has been configured to be allowed to pass through the UUT. The node on which the Telnet client is executed MUST not have the TCP KEEPALIVE set to less than 5 minutes.

Procedure:

1. Telnet client is used to establish a connection using port 102 to a destination IP address that is on a white list in the UUT and that has the TCP-Listen posted.

   The UUT would be expected to allow the connection to occur.

2. Wait 5 minute (remember the TCP-KEEPALIVE is supposed to be set to 1 Minute) and determine if the Telnet connection has been terminated.

   It would be expected if the UUT terminated the connection and enunciate the reason. The observer should record the time required for the UUT to terminate the connection.

# 7 SCL Tool Testing

## 7.1 Introduction

This document will have the list of test cases to be performed under SCL test area based on substation configuration language. The purpose is to validate that each implementation provides a valid IED Capability Description (ICD) file and that the System Configuration Tool (SCT) to/from IED Configuration Tool (ICT) exchanges are supported as defined in IEC 62351-6.

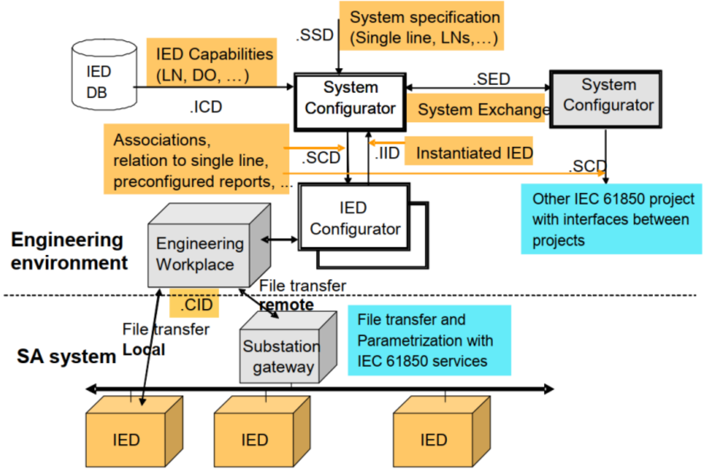


Figure 23: IEC 61850-6 Defined Exchanges

The use of System Specification Description (SSD) files and System Exchange Description (SED) files are also considered if more than one SCT vendors participate. Focus will be more on SCT - ICT tests.

There are two types of tests that need to occur:

1. Relevant SCL Tests based on Integrated Apps configuration

2. SCL Tests defined as part of SCL group discussion

### 7.1.1 Prerequisites

These steps/tests are required in order to perform SCL Tests:

- ICD validation – tests that the IED Capability Description (ICD) files provided by the vendors are valid. Cross checking using ICD verification tools
- Support of feature in the ICT, as mentioned under the Services section of the IED in SCL file
- Support of feature in the SCT, as claimed by the SCT vendor (Eg: SICS document)

## 7.2 Test Cases

### 7.2.1 Signal Mapping Tests

#### *7.2.1.1 Test 1 : Identify predefined Inputs in ICD (SCL-IDENTIFY_PRE_INPUT01)*

<u>Expected result</u>

1. SCT import the ICD file successfully and display the predefined inputs from ICT

#### *7.2.1.2 Test 2 : Identify mapping into predefined input (SCL-IDENTIFY_PRE_INPUT_MAP02)*

<u>Expected result</u>

1. ICT import the SCD file successfully and display the mapping into predefined inputs from SCT

#### *7.2.1.3 Test 3 : Identify mapping into IED (SCL-IDENTIFY_ INPUT_MAP03)*

<u>Expected result</u>

1. ICT import the SCD file successfully and display the mapping from SCT

### 7.2.2 Supervision Configuration Tests

#### *7.2.2.1 Test 1 : Identify LGOS mapping to subscribed GOOSE (SCL-IDENTIFY_LGOS_MAPPING01)*

<u>Expected result</u>

1. ICT import the SCD file successfully and display the mapping of LGOS into Subscribed GOOSE

#### *7.2.2.2 Test 2 : Identify LSVS mapping to subscribed SV (SCL-IDENTIFY_LSVS_MAPPING02)*

<u>Expected result</u>

1. ICT import the SCD file successfully and display the mapping of LSVS into Subscribed SV

#### *7.2.2.3 Test 3 : Identify LGOS mapping with LD Name (SCL-IDENTIFY_LGOS_LDNAME_MAPPING03)*

<u>Expected result</u>

1. ICT import the SCD file successfully and display the mapping of LGOS into Subscribed GOOSE with configured LDName

#### *7.2.2.4 Test 4 : Identify LSVS mapping with LD Name (SCL-IDENTIFY_ LSVS _LDNAME_MAPPING04)*

<u>Expected result</u>

1. ICT import the SCD file successfully and display the mapping of LSVS into Subscribed SV with configured LDName

### 7.2.3 Schema Version mismatch Tests

Note: Schema version supported by SCT should be greater than ICT

#### *7.2.3.1 Test 1 : Import of ICD into SCT (SCL-SCHEMADIFF_ICD_toSCT01)*

Expected result

1. Verify that results of this test by noting schema version of SCT and ICT
2. Also verify how the parameters not supported by ICT are displayed in SCT

#### *7.2.3.2 Test 2 : Import of SCD into ICT (SCL-SCHEMADIFF_SCD_toICT02)*

Expected result

1. Verify that file exported by SCT is as per the schema expected by ICT
2. Also verify how the parameters not supported by ICT are handled by SCT (Eg: Ed.2.0 signal mapping into Ed.1.0 IED)
2. Verify that results of this test by noting schema version of SCT and ICT

### 7.2.4 MustUnderstand Tests

Reference tests from UCA

1. tTf1 Mandatory

2. tSeh7 Mandatory

#### *7.2.4.1 Test 1 : Import ICD with MustUnderstand (SCL-MUSTUNDER_ICD_toSCT01)*

Expected result

1. SCT import the ICD file successfully and display the Parent node with mustunderstand tag as not editable / recognizable

#### *7.2.4.2 Test 2 : Import SCD with MustUnderstand (SCL-MUSTUNDER_SCD_toICT02)*

Expected result

1. ICT import the SCD file successfully and display the Parent node with mustunderstand tag as not editable / recognizable

## 7.3 Test Results

**Result 1: SCT SCL Test Results**

| | | | |
|---|---|---|---|
| | SCT Tool | | |
| | Vendor | Helinks | ASE KALKITECH |
| | Model | STS | SCL Manager |
| Test Case | | | |
| SCL-IDENTIFY_PRE_INPUT01 | | Pass | Pass |
| SCL-IDENTIFY_PRE_INPUT_MAP02 | | Pass | Pass |
| SCL-IDENTIFY_ INPUT_MAP03 | | Pass | Pass |
| SCL-IDENTIFY_LGOS_MAPPING01 | | Pass | Pass |
| SCL-IDENTIFY_LSVS_MAPPING02 | | Pass | Pass |
| SCL-SCHEMADIFF_ICD_toSCT01 | | Pass | Pass |
| SCL-SCHEMADIFF_SCD_toICT02 | | Pass | Pass |
| SCL-MUSTUNDER_SCD_toICT02 | | Pass | Pass |
| | Vendor | Toshiba | Toshiba |
| | Model | GR-TIEMS | GR-TIEMS |
| | ICT Tool | | |

# 8 Problem Reports

The overall issue breakdown, from the IOP, can be divided into implementation issues and issues requiring analysis, or action, via different standards bodies. Some of the issues referred to the standards body will eventually cause changes within the various standard. The categories of issues are:

- SCL: These are issues detected when attempting to use various aspects of the System Configuration Language. These issues were primarily detected during the integration efforts of the integrated application.

- 8-1 Client/Server: These are issues detected when attempting to communicate utilizing the IEC 61850-8-1 SCSM MMS profile. These issues were detected during testing of the integrated application.

- GOOSE: These issues were detected during the integration and use of Layer-2 GOOSE in the integrated application.

- R-GOOSE: These issues were detected during the integration and use of Routable GOOSE in the R-GOOSE test area of the interop. No testing during the previous IOPs had been performed.

- Sampled Values: These issues were detected during the integration and use of Layer-2 Sampled Values in the integrated application.

- R-SV: Although no problems were reported with Routable Sampled Values during the interop, this was since only one vendor demonstrated R-SV. This was performed using the integrated application infrastructure. No testing during the previous IOPs had been performed.

- 8-1 SEC Client/Server: These security issues were detected during the integration and use of IEC TR 62351-4 as part of the integrated application.

- Time Sync: These issues were primarily detected in the Time Sync area of the IOP. These encompass both IEC IEC/IEEE 61850-9-3and IEEE C37.238 issues.

- Network: These issues were detected during the integration and use of the network infrastructure of the integrated application.

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- Network: These issues were detected during the integration and use of the network infrastructure of the integrated application.

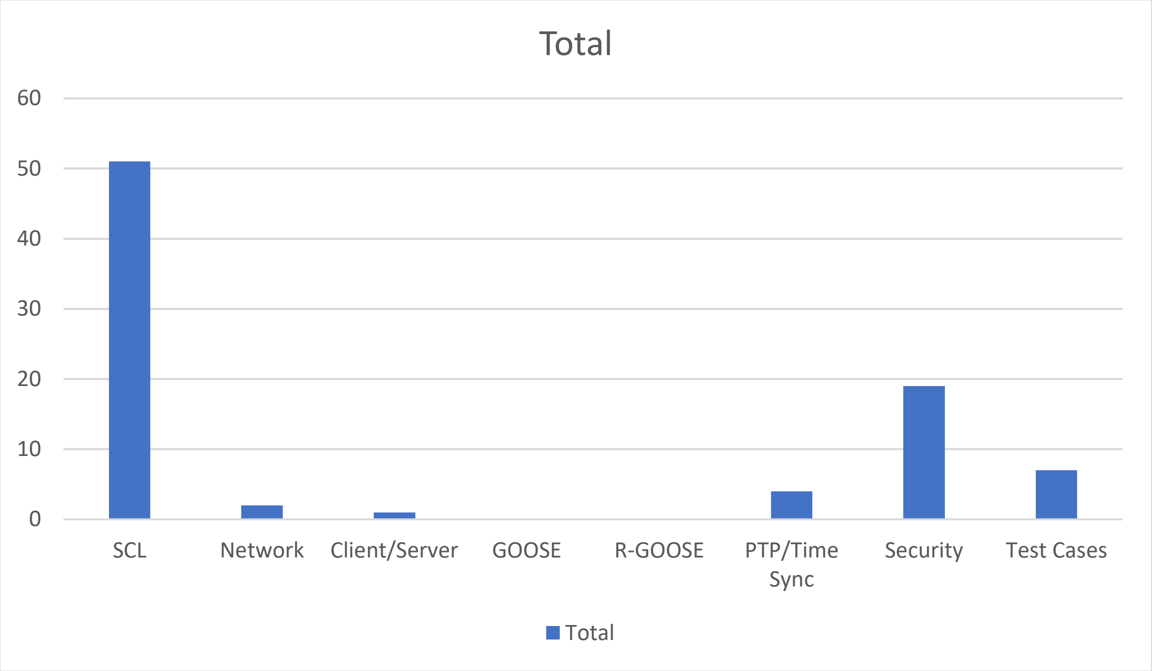


Figure 24: Total Number of Issues Reported by Category

There were eight-four (84)  total issues reported. Twenty-three of these issues were reviewed and classified as implementation issues.  The following sections details non-implementation testing areas/campaigns issues.

A comparison of the issues from the various interop is shown in the following table and charts.

| **Interop Year** | | | | |
|---|---|---|---|---|
| **Item** | 2013 | 2015 | 2017 | 2019 |
| **Total number of issues** | 82 | 38 | 57 | 84 |
| **SCL** | 58 | 24 | 32 | 52 |
| **8-1 Client/Server** | 15 | 9 | 9 | 1 |
| **GOOSE** | 5 | 0 | 6 | 0 |
| **R-GOOSE** | Not Tested | Not Tested | 3 | 0 |
| **Sampled Values** | 2 | 2 | 2 | 0 |
| **R-SV** | Not Tested | Not Tested | Demonstrated | 0 |
| **Security** Client/Server | Not Tested | Not Tested | 7 | 11 |

| | | | | |
|---|---|---|---|---|
| R-GOOSE | Not Tested | Not Tested | Not Tested | 3 |
| Key Management | Not Tested | Not Tested | Not Tested | 5 |
| **Time Sync** | Not Tested | 1 | 11 | 4 |
| **Network** | 2 | 2 | 2 | 2 |

Table 9: Comparison Table of Issues from IOPs

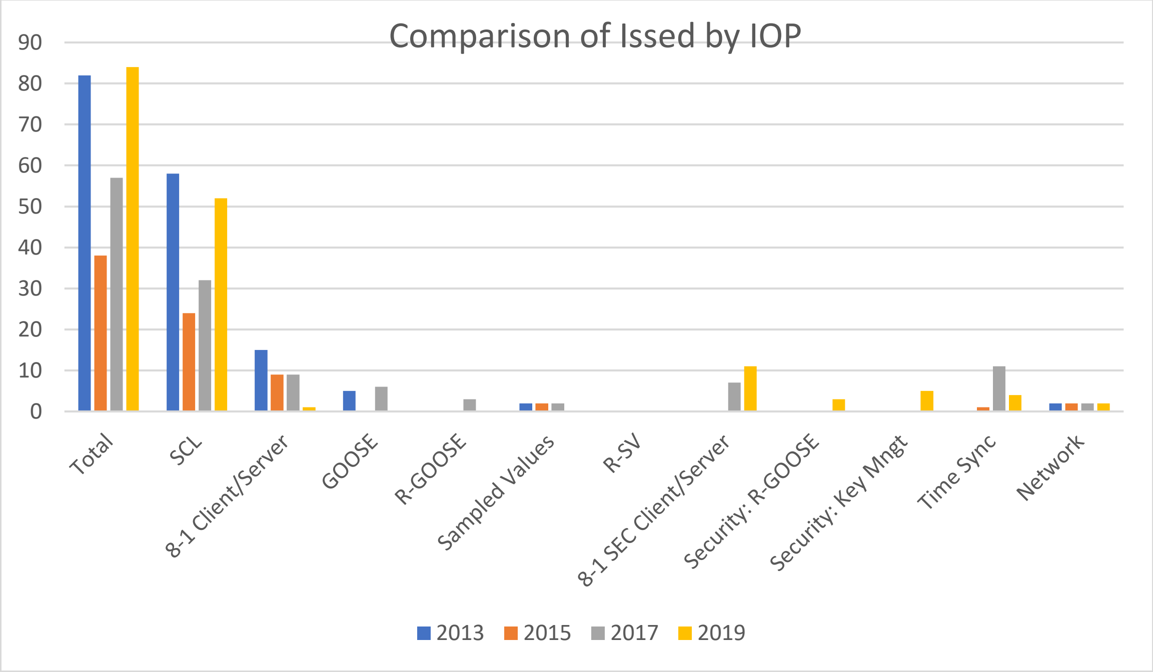


Figure 25: Comparison Graph of Issues from IOPs

The comparison shows a substantial increase in issues reported on SCL, due in large part to a major emphasis on SCL and engineering of the Integrated Application. The other reason for such an increase is the SCL validation tool maturity is increasing and detecting more issues.

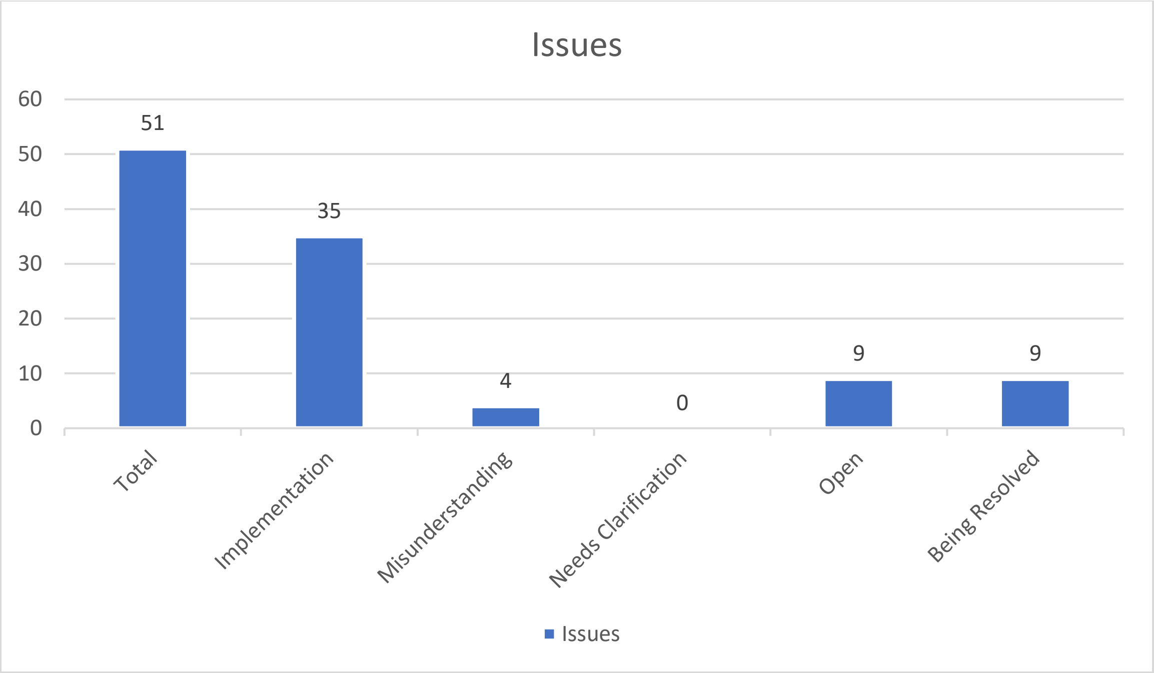


Figure 26: Analysis of SCL Issues

The analysis of SCL issues provides a glimpse that approximately 43% of the reported issues were implementation issues.  A total of 76% of the issues were either implementation errors or misunderstanding of the standard.  Some of the implementation and misunderstanding issues were considered enough of an issue to be referred to IEC TC57 WG10 for resolution.  Of the 18 reported to WG10, 9 have solutions already.  Pre-IOP testing of vendor SCL ICD files still indicates that the ICDs still are the major source of issues.  Therefore, the UCAIug Test Procedure Working Group is in the process of requiring SCL ICD validation as part of the normal conformance testing process.

The following sections have tables that provide a description of the reported problem, a categorization of the resolution, and an explanation of the resolution.

The categorization legend is:

M – misunderstanding

C – Needs Clarification

U – Issue either addressed or in process of being addressed

O – still open/un-resolved

I - Implementation

## 1.1 SCL Issues

### 9.1.1 Pre-IOP Validation

During past IOPs, the quality of the SCL files (e.g. ICDs and SCDs) was a major issue. Therefore, a process was put in place to pre-validate vendor ICD files prior to including the IEDs/Application in the SCD. The intent was to use only "passed" ICD files that validated.

Process was cyclic and for some of the vendor ICD files several versions were tested. Used validation tools have different scope of testing varying from XML schema and format testing, functional and engineering recommendation checks to partial and full conformance testing. Due to different approaches gathered results point to several aspects of ICD file problems.

It was observed that most of the issues in ICD files repeated through versions. One strong reason for reoccurrence is time necessary for vendors to fix their configuration tools. Few weeks of testing prior to IOP is not realistic time for that task. This should be taken in consideration for future IOP testing planning.

As can be seen in the following table, no ICD file passed all of the SCL checkers that were utilized for checking. The vendors/technology utilized for validation were provided by:

The vendor/entities (e.g. validators) are:

- DNV/GL (no pre-IOP results posted)
- EDF/Hydro Quebec
- GridClone
- Triangle Microworks
- Bruce Muschlitz (UCAIug Tooling)
- Beijing Sifang Automation (no results recorded and not shown).

It is also noted that the results shown are the results for the last version of the vendor ICDs that were "validated". Of all of the tools, several are available online or downloadable as demos:

EDF/Hydo-Quebec (contact aurelie.dehouck-neveu@edf.fr):

https://rise-clipse.pam-retd.fr/

Triangle Microworks (contact jgreene@trianglemicroworks.com ):

http://www.trianglemicroworks.com/products/testing-and-configuration-tools/scl-navigator-pages/overview

**Offline Tools:**

Bruce Muschlitz Open Tools (contact b.muschlitz@ieee.org ):

http://www.ucaiug.org/org/TechnicalO/Testing/Shared%20Documents/Tools

| | | **Validation Tools** | | | | |
|---|---|---|---|---|---|---|
| **Vendor** | **ICDFileName** | **SCL Checker** | **SCL Navigator** | **RiseClipse** | **ValCheck** | **Ed2Schema** |
| ABB | ABB_INC_A_MU_Rev2.icd | Error(s) | Passed | NoResult | Passed | NoResult |
| ABB | ABB_L1_MU_Rev2.icd | Error(s) | Passed | Error(s) | Passed | NoResult |
| ABB | ABB_TXA_IED.icd | Error(s) | Error(s) | Error(s) | Passed | NoResult |
| ARC | ARCInformatique_20190907_1-1_PcVue_Client1.icd | Passed | Passed | Error(s) | NoResult | NoResult |
| Bitronics | M871_6100000000000000D1p06v02p00_rev1.xml | NoResult | Error(s) | Error(s) | NoResult | NoResult |
| COPADATA | 20190829_1-1_COPADATA_zenonClient_PC2.icd | Error(s) | Passed | Error(s) | Passed | NoResult |
| Doble | Doble_20190907_61850TesT_Client1.icd | Error(s) | Passed | Error(s) | NoResult | NoResult |
| GE | GE_190816_1-1_MU3200304.icd | Error(s) | Passed | Error(s) | Passed | NoResult |
| GE | GE_20190905_P443.icd | Error(s) | Error(s) | Error(s) | Passed | NoResult |
| GE | GE_20190917_-_D60.icd | NoResult | Error(s) | NoResult | NoResult | NoResult |
| GE | GE_20190917_-_F60.icd | NoResult | Error(s) | NoResult | NoResult | NoResult |
| GE | GE_20190917_-_T60.icd | NoResult | Error(s) | NoResult | NoResult | NoResult |
| GE | GE_20190924_D60_UB5_HLH_H87.xml | NoResult | NoResult | Error(s) | NoResult | NoResult |
| JPE | 20190916_1-4_JPE_gwModbus.xml | Error(s) | Error(s) | Error(s) | NoResult | NoResult |

| | | Validation Tools | | | | |
|---|---|---|---|---|---|---|
| | | SCL | SCL | | | |
| **Vendor** | **ICDFileName** | **Checker** | **Navigator** | **RiseClipse** | **ValCheck** | **Ed2Schema** |
| KEPCO | KEPCO_KIE_Client_v1.icd | NoResult | NoResult | Error(s) | NoResult | NoResult |
| KERI | KERI _KMU100_20190906.icd | Passed | Passed | Error(s) | NoResult | NoResult |
| KERI | KERI_KMU100_20190917.xml | Passed | Passed | Error(s) | NoResult | NoResult |
| NovaTech | NovaTech_20190903_Client-1_LXm3Client.icd | Error(s) | Passed | Passed | Passed | NoResult |
| NovaTech | NovaTech_20190903_Server-1_LXm4Server.icd | Error(s) | Error(s) | Error(s) | Passed | NoResult |
| NR | NR_20190903_1-1_PCS978.icd | Error(s) | Error(s) | Error(s) | Passed | NoResult |
| NR | NR_20190922_1_1_PCS978S.xml | NoResult | Passed | Error(s) | NoResult | NoResult |
| OMICRON | OMICRON 20190903 AA1D1Q03Q1.icd | Error(s) | Error(s) | Error(s) | Passed | NoResult |
| PCITek | PCITek_20190903_r01_alpha_KDC.icd | Error(s) | NoResult | Error(s) | Passed | NoResult |
| RTDS | RTDS_IOP19_IED_v1.icd (20190913) | Error(s) | NoResult | NoResult | NoResult | NoResult |
| RTDS | RTDS_IOP19_intApp_v3.cid (20190913) | Error(s) | NoResult | NoResult | NoResult | NoResult |
| RTDS | RTDS_IOP19_intApp_v3.xml | NoResult | Error(s) | Error(s) | NoResult | NoResult |
| RTDS | RTDS_MU.icd | Error(s) | Passed | Error(s) | Passed | NoResult |
| RTDS | RTDS_PN51_r1.cid | Error(s) | Passed | Error(s) | Error(s) | NoResult |
| SEL | ASE61850Client.icd | Error(s) | Passed | Error(s) | NoResult | NoResult |
| SEL | SEL_20190923_03530_006.xml | NoResult | Error(s) | Passed | NoResult | NoResult |
| SEL | SEL_20190923_0451_6S_006.xml | NoResult | Error(s) | Error(s) | NoResult | NoResult |
| SEL | SEL_20190923_0487E_5S_006 - v1.icd | NoResult | Passed | NoResult | NoResult | NoResult |
| SEL | SEL_20190923_0751_006.xml | NoResult | Passed | Error(s) | NoResult | NoResult |
| SEL | SEL_20190924_0401_006.xml | NoResult | NoResult | Error(s) | NoResult | NoResult |
| SEL | SEL_20190924_0421_7P_006.xml | NoResult | NoResult | Error(s) | NoResult | NoResult |
| SEL | SEL_20190924_0487B_2S_006.xml | NoResult | NoResult | Error(s) | NoResult | NoResult |
| SEL | SEL_20190924_0487E_5S_006.xml | NoResult | NoResult | Error(s) | NoResult | NoResult |
| Siemens | Siemens_20190918_1-1_Siprotec_L1_MU.icd | Passed | Passed | NoResult | NoResult | NoResult |
| Siemens | Siemens_20190918_1-1_Siprotec_TXA_IED.icd | Passed | Passed | NoResult | NoResult | NoResult |
| Siemens | Siemens_20190918_2-1_Siprotec_INC_A_MU.icd | Passed | Passed | NoResult | NoResult | NoResult |
| Sifang | 20190925_CHINA_Sifang_CSC211EB-ED2.xml | NoResult | NoResult | Error(s) | NoResult | NoResult |
| Sifang | 20190925_CHINA_Sifang_CSI200E-ED2_V2.xml | NoResult | NoResult | Error(s) | NoResult | NoResult |

| | | Validation Tools | | | | |
|---|---|---|---|---|---|---|
| Vendor | ICDFileName | SCL Checker | SCL Navigator | RiseClipse | ValCheck | Ed2Schema |
| SISCO | SISCO_20190906_1-1_AXS4-Client_IntApp.icd | Passed | Passed | Passed | NoResult | NoResult |
| SISCO | SISCO_20190906_1-2_AXS4-Secure-Client.icd | Passed | Passed | Passed | NoResult | NoResult |
| SISCO | SISCO_20190906_1-3_AX-S4_61850_Server_Security.icd | Passed | Passed | Error(s) | NoResult | NoResult |
| SISCO | SISCO_20190906_1-3_GOOSEMON.icd | Passed | Passed | Passed | NoResult | NoResult |
| SISCO | SISCO_20190906_1-7_AX-S4_61850_Server_IntApp.icd | NoResult | Passed | Error(s) | NoResult | NoResult |
| SISCO | SISCO_20190910_1-4_GOOSE_SV_Security.icd | NoResult | Passed | NoResult | NoResult | NoResult |
| TMW | TMW_20190917_1-0_TSPclient.icd | NoResult | Passed | NoResult | NoResult | NoResult |
| TMW | TMW_20190919_1-0_IOP2019_PROT.icd | NoResult | Passed | Passed | NoResult | NoResult |
| TMW | TMW_20190922_3-1_IOP2019_BC_B2.icd | NoResult | Passed | Error(s) | NoResult | NoResult |
| TMW | TMW_20190922_3-1_IOP2019_BC_TXA.icd | NoResult | Passed | Error(s) | NoResult | NoResult |
| Toshiba | TOSHIBA_20190820_GMU200.icd | Error(s) | Error(s) | Error(s) | Passed | NoResult |
| Toshiba | TOSHIBA_20190905_GMU200.icd | Error(s) | Passed | NoResult | Passed | NoResult |
| Toshiba | TOSHIBA_20190905_GRD200.icd | Error(s) | Passed | NoResult | Error(s) | NoResult |
| Toshiba | TOSHIBA_20190905_GRT200.icd | Error(s) | NoResult | Error(s) | Passed | NoResult |
| Toshiba | TOSHIBA_GMU200_L1MU.icd | Error(s) | NoResult | NoResult | NoResult | NoResult |
| Toshiba | TOSHIBA_GRD200_INCA.icd | Error(s) | NoResult | NoResult | NoResult | NoResult |
| Toshiba | TOSHIBA_GRT200_TXA.icd | Error(s) | NoResult | NoResult | NoResult | NoResult |
| VIZIMAX | VIZIMAX_20190904_1.4-alpha.4_MGU010000-Ed2.icd | Passed | Passed | Error(s) | Passed | NoResult |
| VIZIMAX | VIZIMAX_20190904_1.4-alpha.4_PMU010000-SV-Ed2.icd | Passed | Passed | Error(s) | Passed | NoResult |
| VIZIMAX | VIZIMAX_20190917_1.4-alpha.5_MGU010000-Ed2.icd | NoResult | Passed | Error(s) | NoResult | NoResult |
| VIZIMAX | VIZIMAX_20190917_1.4-alpha.5_PMU010000-SV-Ed2.icd | NoResult | Passed | Error(s) | NoResult | NoResult |

The “raw” errors detected are too numerous to include in this report.  Participating vendors need to review the “raw” errors and correct there SCL technology to correct the problems.

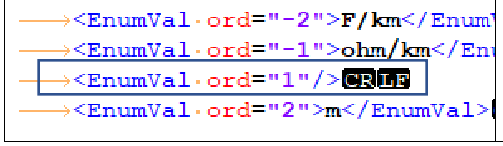
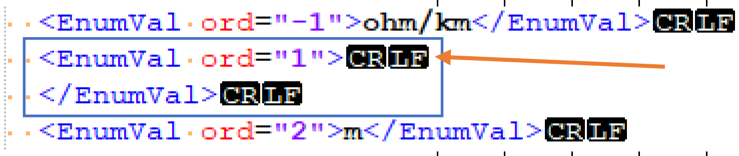
There was a category of issues involving the setting of values in the <Val> SCL statement that is worthy of mentioning.  There were various permutations of setting the values that did not meet the underlying types of the type definition (e.g. a string when it should be an integer value). This problem could be rectified by including the expected type as a P-Type in the schema.

### 9.1.2 Problems Encountered During IOP

The following table details the issues and the proposed resolution for SCL that were reported to IEC TC57 WG10 and does not include the implementation issues reported to the vendors.

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **1** | SCT optimized data type templates by removing a DO Type that had the same DOTypeid but a different sAddr in the DA name. This resulted in a DOType being stripped out and the IED rejecting the CID file as the remaining DOType was invalid for this IED.<br>The DOType was removed from the SCD even though it had a unique sAddr.<br><br>In the initial two ICD files, one ICD file had this definition in the data type template:<br>    <DOType id="healthENS" cdc="ENS"><br>        <DA name="stVal" fc="ST" bType="Enum" type="Health" dchg="true" esel:datasrc="db:EN?3:1" sAddr="datasrc=db:EN?3:1" dupd="true"/><br>        <DA name="q" fc="ST" bType="Quality" qchg="true" esel:datasrc="db:I60MOD" sAddr="datasrc=db:I60MOD"/><br>        <DA name="t" fc="ST" bType="Timestamp"/><br>    </DOType><br><br>Second ICD file had this:<br>    <DOType id="healthENS" cdc="ENS"><br>        <DA name="stVal" fc="ST" bType="Enum" dchg="true" type="Health" esel:datasrc="db:RELAY_EN?3:1" sAddr="datasrc=db:RELAY_EN?3:1"/><br>        <DA name="q" fc="ST" bType="Quality" qchg="true" esel:datasrc="db:RELAY_EN" sAddr="datasrc=db:RELAY_EN"/><br>        <DA name="t" fc="ST" bType="Timestamp"/><br>    </DOType><br><br>The SCT only included the second DOType, however both of these should have been preserved in the SCD file, as each ICD has its own DOType. | x | | | | | |
| **2** | Toshiba GTR20 (TXB_IED) does not support Test/Blocked mode. The device supports On and Test mode only. ICD enumerated values indicate support. | x | x | | | | |

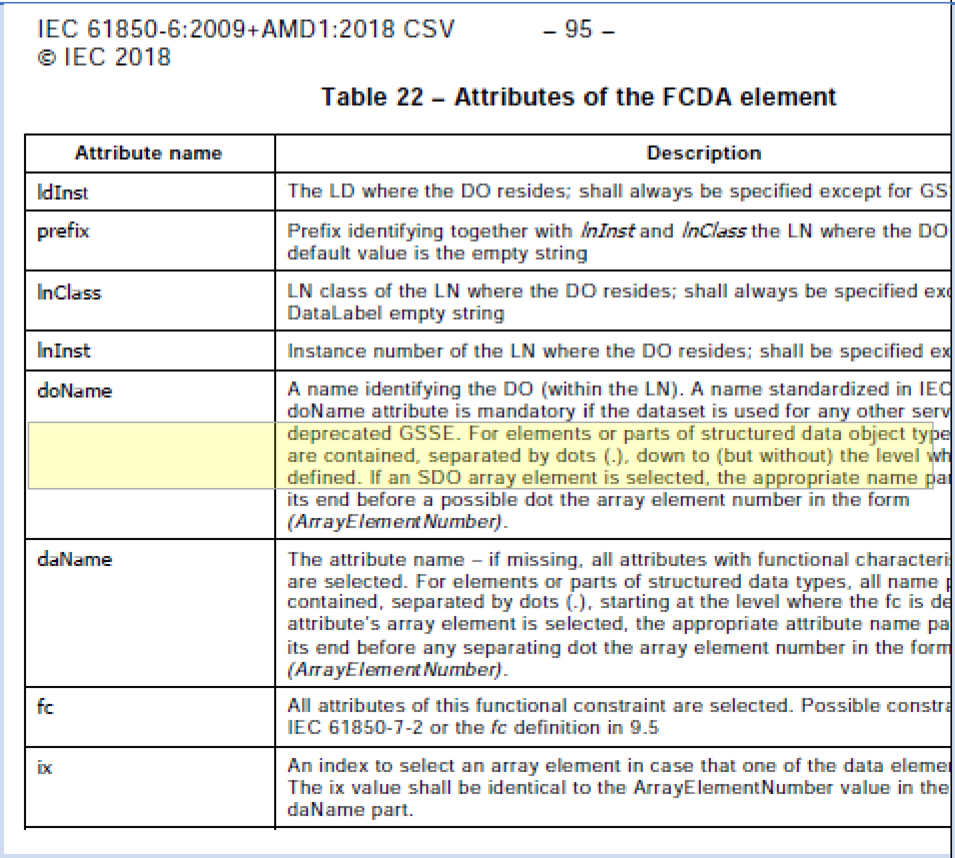
| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **3** | Various devices and tools<br>- Use of multicast MAC address outside the recommended range is not supported<br>- APPIDs are configured outside the valid range<br>- APPID interpreted as Integer instead of Hex<br>The predefined APPID range is a requirement – message need to be in that range.<br>On the other side, multicast MAC address range is only a recommendation. As we require the devices / tools to accept any range –do we need this recommendation at all? | x | x | | x | | Standards being updated to remove ambiguity. |
| **4** | BRCBs were indexed by the client when they were not supposed to be because an indexed=”false” attribute was not put into the ICD and was not included in the SCD.<br>Result was the client report subscriptions had to be done manually. | x | | | | | |
| **5** | SCTs exported SCD files with errors:<br>- namespaces,<br>- Schema errors (can be ignored without having the schema)<br>- CDC mismatches (ed.1 vs ed.2) – downgrade/upgrade issues<br>- protNs missing (should not have removed)<br>- many small other issues | x | | | | | One of the SCTs was in the midst of a code change. |

<table>
<tr><th colspan="2">SCL Issues</th><th colspan="5">Resolution</th><th></th></tr>
<tr><th>Issue Number</th><th>Description</th><th>I</th><th>M</th><th>C</th><th>U</th><th>O</th><th>Comment</th></tr>
<tr><td><b>6</b></td><td>SCL validation was performed on SCD file (IOP_2019_HV_v6_ed2.0.scd) with the RiseClipse tool.<br>The validation found that the SCD file contains enumerations with a (CR-LF) Carriage return line feed, whereas it is not present in the ICD files that were imported by the SCT tool :<br>(Problem concerning different IEDs)
<table>
<tr><th>ICD<br>Siemens_L1_MU_IED_2019_09_05.icd</th><th>SCD File<br>IOP_2019_HV_v6_</th></tr>
<tr><td>EnumType<br>id :<br>SIPROTEC5_EnType_SIUnit_V08.00.06_<br>V08.00.00<br><br><EnumVal ord="-2">F/km</Enum<br><EnumVal ord="-1">ohm/km</Enu<br><EnumVal ord="1"/>CRLF<br><EnumVal ord="2">m</EnumVal></td><td>EnumType<br>id : SIPROTEC5_EnType_SIUnit_V08.00<br><br><EnumVal ord="-1">ohm/km</EnumVal>CRLF<br><EnumVal ord="1">CRLF<br></EnumVal>CRLF<br><EnumVal ord="2">m</EnumVal>CRLF</td></tr>
</table>
This could cause problems at the import of the SCD file by the ICT tools.<br>Should enumerations structure remain in the same format as described in the ICD files ?<br>Answer:  SCT should not change enumeration values but may change names.</td><td>x</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

| **SCL Issues** | | **Resolution** | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **7** | In the LNodeType definition, there are 2 InRefs with names : **InRef1** and **InRef01**,<br>They are detected by RiseClipse validation as two DO InRefs with the same instance number.<br><DO name="InRef1" type="ORG_0"/><br><DO name="InRef01" type="ORG_0"/><br>RiseClipse error :<br>ERROR: [NSD validation] DO InRef01 in LNodeType (line 158609) already present with same instance number in LNClass IHMI<br>**Standard reference :**<br>NSD-DOC description of Omulti constraint in 61850-7-2 says :<br>« Zero or more elements may be present; all instances have an **instance number** within range [min, max] (see IEC 61850-7-1). »<br>Should InRef1 and InRef01 be interpreted as different or same instances ? | | | | x | x | |
| **8** | Novatech Orion Client<br>In the ConnectedAP section of the SCD file on Line 957, the Novatech_Orion_Client apName is referred to as “C1”:<br>ConnectedAP apName="C1" iedName="NOVATECH_ORION_CLIENT"><br>In all subsequent references to the Novatech Orion Client, the apRef is referred to as “S1”:<br><ClientLN apRef="S1" iedName="NOVATECH_ORION_CLIENT" ldInst="LD0" prefix="" lnClass="ITCI" lnInst="1"/><br>This is causing the processing of the SCL file to fail.<br>Determine why the apName – apRef link failed in the SCT. Correct the SCD. | x | | | | | |

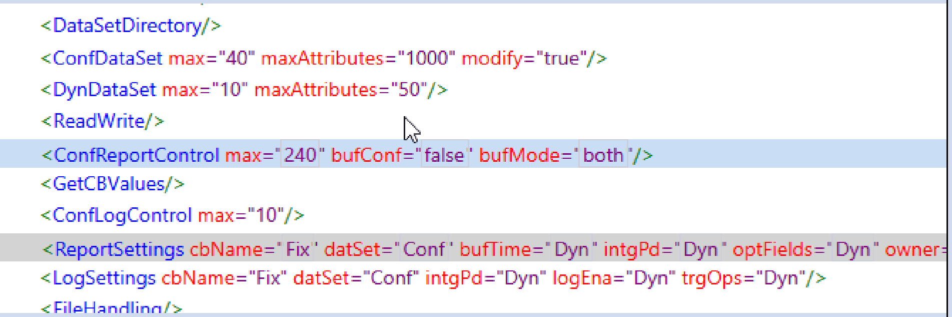
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **9** | **Issue Description:**<br>SCL validation was performed on ICD files (SEL_20190921_03530_006.icd) with the RiseClipse tool.  An error was raised: **ERROR**: [SemanticConstraints] FCDA (line 189) does not refer any existing DA or BDA in DataTypeTemplates section.<br><DataSet desc="Analog Data" name="DSet01"><br>  <FCDA ldInst="MET" prefix="MET" lnClass="MMXU" lnInst="1" doName="TotW" fc="MX" /><br>  <FCDA ldInst="MET" prefix="MET" lnClass="MMXU" lnInst="1" doName="Hz" daName="mag" fc="MX" /><br>  <FCDA ldInst="MET" prefix="MET" lnClass="MMXU" lnInst="1" doName="PhV" fc="MX" /><br>  <FCDA ldInst="ANN" prefix="ANN" lnClass="GGIO" lnInst="1" doName="AnIn01" daName="mag" fc="MX" /><br>  <FCDA ldInst="ANN" prefix="ANN" lnClass="GGIO" lnInst="1" doName="AnIn02" daName="mag" fc="MX" /><br>  <FCDA ldInst="ANN" prefix="ANN" lnClass="GGIO" lnInst="1" doName="AnIn03" daName="mag" fc="MX" /><br>  <FCDA ldInst="ANN" prefix="ANN" lnClass="GGIO" lnInst="1" doName="AnIn04" daName="mag" fc="MX" /><br>  <FCDA ldInst="ANN" prefix="ANN" lnClass="GGIO" lnInst="1" doName="AnIn05" daName="mag" fc="MX" /><br>  <FCDA ldInst="ANN" prefix="ANN" lnClass="GGIO" lnInst="1" doName="AnIn06" daName="mag" fc="MX" /><br>  <FCDA ldInst="ANN" prefix="ANN" lnClass="GGIO" lnInst="1" doName="AnIn07" daName="mag" fc="MX" /><br>  <FCDA ldInst="ANN" prefix="ANN" lnClass="GGIO" lnInst="1" doName="AnIn08" daName="mag" fc="MX" /><br> </DataSet><br>**Extract from DatatypeTemplates section:**<br><LNodeType id="MMXU_RTAC" iedType="" lnClass="MMXU"><br>  <DO name="Mod" type="ENC_mode_direct_enhanced_5032"/><br>  <DO name="Beh" type="ENS_behavior_5032"/><br>  <DO name="Health" type="ENS_health_5032"/><br>  <!-- Status information --><br>  <DO name="TotW" type="MV_5032"/><br>  <DO name="Hz" type="MV_5032"/> | | | | x | | |

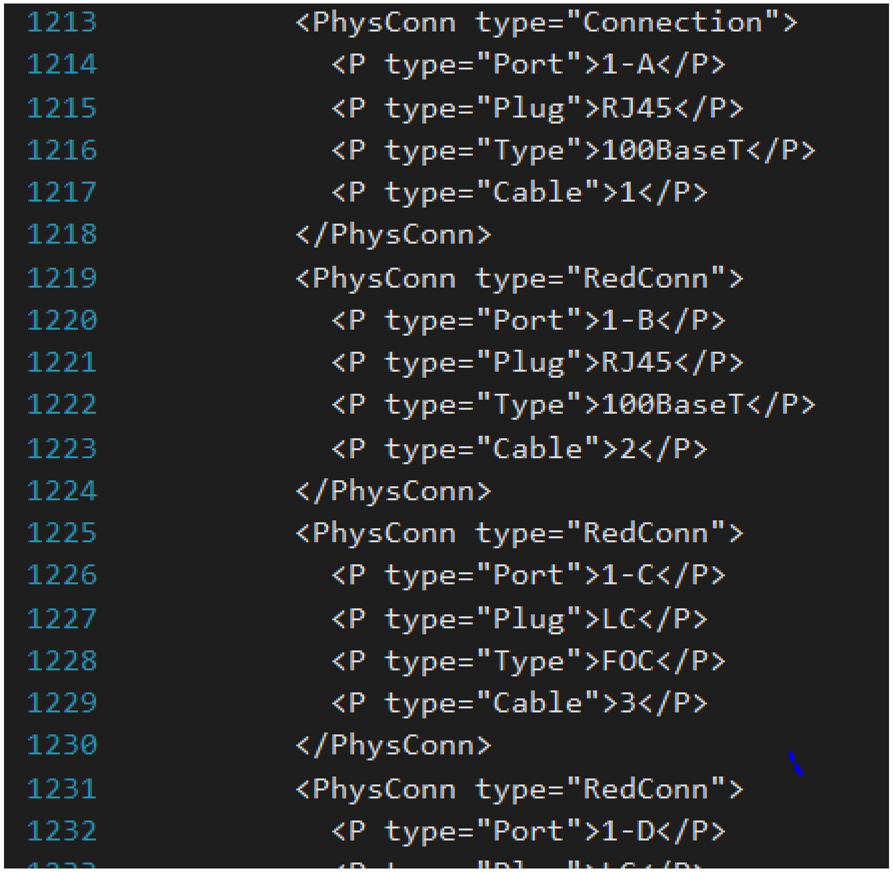
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | <DO name="PhV" type="WYE_RTAC"/> [1]<br></LNodeType><br><DOType id="WYE_RTAC" cdc="WYE"><br><SDO name="phsA" type="CMV_5032"/> [2]<br><SDO name="phsB" type="CMV_5032"/> [2]<br><SDO name="phsC" type="CMV_5032"/> [2]<br><DA name="phsToNeut" bType="BOOLEAN" valKind="RO" fc="CF"><br><Val>true</Val><br></DA><br></DOType><br><DOType id="CMV_5032" cdc="CMV"><br><DA name="instCVal" bType="Struct" type="Vector_5032" fc="MX"/><br><DA name="cVal" bType="Struct" type="Vector_5032" dchg="true" fc="MX"/><br><DA name="q" bType="Quality" qchg="true" fc="MX"/><br><DA name="t" bType="Timestamp" fc="MX"/><br></DOType><br>The doName "PhV" of type "WYE_RTAC" [1] is a structured object type (SDO)[2]<br>and RiseClipse validation was expecting the following FCDAs as per table 22 of **IEC 61850-6 Edition 2.1 2018-06** (Page: 95):<br><FCDA ldInst="MET" prefix="MET" lnClass="MMXU" lnInst="1" doName="PhV.phsA" fc="MX" /><br><FCDA ldInst="MET" prefix="MET" lnClass="MMXU" lnInst="1" doName="PhV.phsB" fc="MX" /><br><FCDA ldInst="MET" prefix="MET" lnClass="MMXU" lnInst="1" doName="PhV.phsC" fc="MX" /><br>**SCL Standard reference** | | | | | | |

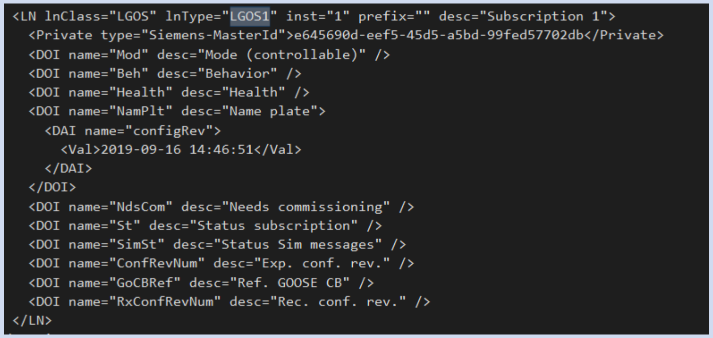
<table>
<tr><th colspan="2">SCL Issues</th><th colspan="5">Resolution</th><th></th></tr>
<tr><th>Issue Number</th><th>Description</th><th>I</th><th>M</th><th>C</th><th>U</th><th>O</th><th>Comment</th></tr>
<tr><td></td><td><br>IEC 61850-6:2009+AMD1:2018 CSV – 95 –<br>© IEC 2018<br><b>Table 22 – Attributes of the FCDA element</b>
<table>
<tr><th>Attribute name</th><th>Description</th></tr>
<tr><td>ldInst</td><td>The LD where the DO resides; shall always be specified except for GS</td></tr>
<tr><td>prefix</td><td>Prefix identifying together with <i>lnInst</i> and <i>lnClass</i> the LN where the DO default value is the empty string</td></tr>
<tr><td>lnClass</td><td>LN class of the LN where the DO resides; shall always be specified exc DataLabel empty string</td></tr>
<tr><td>lnInst</td><td>Instance number of the LN where the DO resides; shall be specified ex</td></tr>
<tr><td>doName</td><td>A name identifying the DO (within the LN). A name standardized in IEC doName attribute is mandatory if the dataset is used for any other serv deprecated GSSE. For elements or parts of structured data object type are contained, separated by dots (.), down to (but without) the level wh defined. If an SDO array element is selected, the appropriate name par its end before a possible dot the array element number in the form <i>(ArrayElementNumber)</i>.</td></tr>
<tr><td>daName</td><td>The attribute name – if missing, all attributes with functional characteri are selected. For elements or parts of structured data types, all name p contained, separated by dots (.), starting at the level where the fc is de attribute's array element is selected, the appropriate attribute name pa its end before any separating dot the array element number in the form <i>(ArrayElementNumber)</i>.</td></tr>
<tr><td>fc</td><td>All attributes of this functional constraint are selected. Possible constra IEC 61850-7-2 or the <i>fc</i> definition in 9.5</td></tr>
<tr><td>ix</td><td>An index to select an array element in case that one of the data eleme The ix value shall be identical to the ArrayElementNumber value in the daName part.</td></tr>
</table>
Should all name parts of PhV be contained in the doName?<br><br>Propose TISSUE to clarify text in -6</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

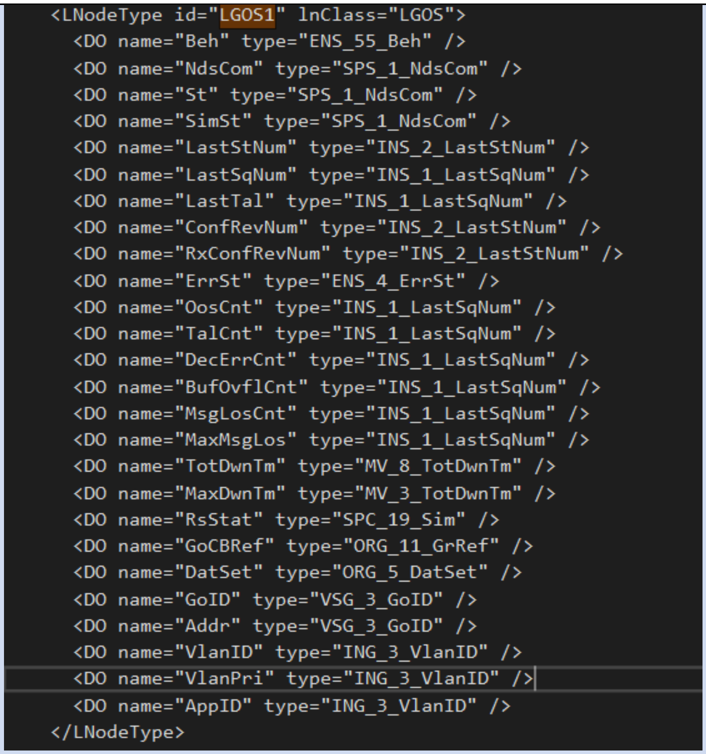
| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **10** | SEL device presents all ethernet ports as a single access point. SCTs unable to configure the device to communicate on multiple subnets due to having a single AP. SEL states IEC 61850-6 fails to clearly define what constitutes an AP and a subnet. Recommend discussion of standard implementation for APs and subnets. | | | | x | x | Major discussion item it WG10.  Upcoming changes are anticipated. |
| **11** | SCT optimized data type templates by removing a DO Type that had the same DOTypeid but a different sAddr in the DA name. This resulted in a DOType being stripped out and the IED rejecting the CID file as the remaining DOType was invalid for this IED.<br>The DOType was removed from the SCD even though it had a unique sAddr.<br>In the initial two ICD files, one ICD file had this definition in the data type template:<br><DOType id="healthENS" cdc="ENS"><br><DA name="stVal" fc="ST" bType="Enum" type="Health" dchg="true" esel:datasrc="db:EN?3:1" sAddr="datasrc=db:EN?3:1" dupd="true"/><br><DA name="q" fc="ST" bType="Quality" qchg="true" esel:datasrc="db:I60MOD" sAddr="datasrc=db:I60MOD"/><br><DA name="t" fc="ST" bType="Timestamp"/><br></DOType><br>Second ICD file had this:<br><DOType id="healthENS" cdc="ENS"><br><DA name="stVal" fc="ST" bType="Enum" dchg="true" type="Health" esel:datasrc="db:RELAY_EN?3:1" sAddr="datasrc=db:RELAY_EN?3:1"/><br><DA name="q" fc="ST" bType="Quality" qchg="true" esel:datasrc="db:RELAY_EN" sAddr="datasrc=db:RELAY_EN"/><br><DA name="t" fc="ST" bType="Timestamp"/><br></DOType><br>The SCT only included the second DOType, however both of these should have been preserved in the SCD file, as each ICD has its own DOType.<br>Both DOType templates need to be preserved in the SCD file.<br>SCT must consider sAddr and private namespace attributes when evaluating uniqueness of templates. | x | | | | | |

| **SCL Issues** | | **Resolution** | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **12** | ABB PCM600 crashes when attempting to import SCD file. ABB has rebuilt the SCD file with information relevant to their device only and are able to import that file successfully. They believe errors in the SCD caused the PCM600 import failure.<br>HV SCD 4 & 5 caused crashes. SCDs were validated.<br>The root cause was the illegal change of DOTypes in the SCT. | x | | | | | The root cause was the illegal change of DOTypes in the SCT. |
| **13** | Error found by 'rise-clipse' SCL File: IOP_2019_HV_v6_ed2.0.scd.<br>ERROR [RequiredAttributes] content shall be valid according to its type in P (line 1011)). The current value is 000 for type OSI-AP-Title.<br>This error occurs at lines:<br>• 507, IED: L2_PU_GE_P443<br>• 688, IED: TXA_PU1_SEL_487E<br>• 1011, IED: BUS_PU_SEL_487B.<br>As a consequence, the client application cannot connect to these IED, except for Copadata. The Copadata behavior remains to be examined.<br>This issue was detected when trying to connect to GE P443 relay. The value for AP-Title was not present in the ICD file, and a non-valid value was set by the SCT tool.<br>These values (000) are not correct for the application, although there are compliant with the SCL grammar (XSD schema). | x | | | | | |
| **14** | In DataTypeTemplate, 125 LNodeTypes are not used in the IED section of the ICD file.<br>Example of error :<br>ERROR: [SemanticConstraints] Unused LNodeType (id=LLN0_4) (line 156483) there is no LN or LNode referring this LNodeType<br>In addition, 3 DOTypes are not used in the IED section of the ICD file.<br>Example of error :<br>ERROR: [SemanticConstraints] Unused DOType (id=ENC_0) (line 161929) there is no DO or SDO referring this DOType<br>Is it allowed / usefull to keep all these unused LNodeTypes and DOTypes in the DataTypeTemplate section ? | | | | | x | According to WG10, it is allowed to have unused LNNodeTypes in the SCD. |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **15** | When the SCD states that the DynDataSet is supported, client could create dataset, which is correct. However, in this case it could Link that dataset also to the ReportControlBlock. The client was not configured in manual mode, therefore it tried to write the datset in the RCB. When set to SCL mode the client was respecting the SCL settings.<br>Client: COPA-DATA ZENON<br>Server: Sifang CSC-211-EB<br><br><DataSetDirectory/><br><ConfDataSet max="40" maxAttributes="1000" modify="true"/><br><DynDataSet max="10" maxAttributes="50"/><br><ReadWrite/><br><ConfReportControl max="240" bufConf="false" bufMode="both"/><br><GetCBValues/><br><ConfLogControl max="10"/><br><ReportSettings cbName="Fix" datSet="Conf" bufTime="Dyn" intgPd="Dyn" optFields="Dyn" owner=<br><LogSettings cbName="Fix" datSet="Conf" intgPd="Dyn" logEna="Dyn" trgOps="Dyn"/><br><FileHandling/> | x | | | | | Service capability to be aligned with implemented device capability.<br>Check client conformance testing |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| 16 | “S1”. In addition there are none redundant PhysConn on same AP. (SCD file LINE 1225)<br>Found in IOP_2019_HV_v7_ed2.1. Effected IED is NR Electric PCS-978S.<br><br>1213         &lt;PhysConn type="Connection"&gt;<br>1214           &lt;P type="Port"&gt;1-A&lt;/P&gt;<br>1215           &lt;P type="Plug"&gt;RJ45&lt;/P&gt;<br>1216           &lt;P type="Type"&gt;100BaseT&lt;/P&gt;<br>1217           &lt;P type="Cable"&gt;1&lt;/P&gt;<br>1218         &lt;/PhysConn&gt;<br>1219         &lt;PhysConn type="RedConn"&gt;<br>1220           &lt;P type="Port"&gt;1-B&lt;/P&gt;<br>1221           &lt;P type="Plug"&gt;RJ45&lt;/P&gt;<br>1222           &lt;P type="Type"&gt;100BaseT&lt;/P&gt;<br>1223           &lt;P type="Cable"&gt;2&lt;/P&gt;<br>1224         &lt;/PhysConn&gt;<br>1225         &lt;PhysConn type="RedConn"&gt;<br>1226           &lt;P type="Port"&gt;1-C&lt;/P&gt;<br>1227           &lt;P type="Plug"&gt;LC&lt;/P&gt;<br>1228           &lt;P type="Type"&gt;FOC&lt;/P&gt;<br>1229           &lt;P type="Cable"&gt;3&lt;/P&gt;<br>1230         &lt;/PhysConn&gt;<br>1231         &lt;PhysConn type="RedConn"&gt;<br>1232           &lt;P type="Port"&gt;1-D&lt;/P&gt;<br>1233           &lt;P type="Plug"&gt;LC&lt;/P&gt;<br>Need to resolve how RedCon are allowed. | | | | | x | |

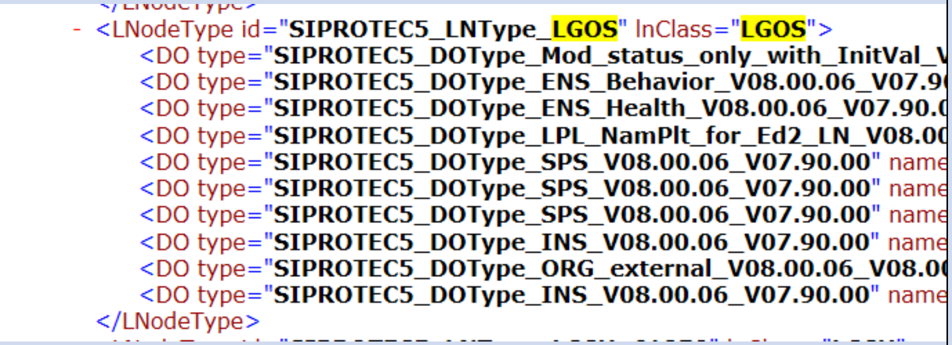
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **17** | Several Issues with Data Type Template Section in SCD file IOP_2019_HV_v7_ed2.1.<br>e.g. IED TXA_MU3_SIE_6MU8  -> LGOS<br>In the SCD file the LGOS LN instance looks like following:<br><br><LN lnClass="LGOS" lnType="LGOS1" inst="1" prefix="" desc="Subscription 1"><br>  <Private type="Siemens-MasterId">e645690d-eef5-45d5-a5bd-99fed57702db</Private><br>  <DOI name="Mod" desc="Mode (controllable)" /><br>  <DOI name="Beh" desc="Behavior" /><br>  <DOI name="Health" desc="Health" /><br>  <DOI name="NamPlt" desc="Name plate"><br>    <DAI name="configRev"><br>      <Val>2019-09-16 14:46:51</Val><br>    </DAI><br>  </DOI><br>  <DOI name="NdsCom" desc="Needs commissioning" /><br>  <DOI name="St" desc="Status subscription" /><br>  <DOI name="SimSt" desc="Status Sim messages" /><br>  <DOI name="ConfRevNum" desc="Exp. conf. rev." /><br>  <DOI name="GoCBRef" desc="Ref. GOOSE CB" /><br>  <DOI name="RxConfRevNum" desc="Rec. conf. rev." /><br></LN><br>The related lnType in SCD file looks as following: | x | | | | | The SCT shall not modify the LNodeType |



```
<LNodeType id="LGOS1" lnClass="LGOS">
  <DO name="Beh" type="ENS_55_Beh" />
  <DO name="NdsCom" type="SPS_1_NdsCom" />
  <DO name="St" type="SPS_1_NdsCom" />
  <DO name="SimSt" type="SPS_1_NdsCom" />
  <DO name="LastStNum" type="INS_2_LastStNum" />
  <DO name="LastSqNum" type="INS_1_LastSqNum" />
  <DO name="LastTal" type="INS_1_LastSqNum" />
  <DO name="ConfRevNum" type="INS_2_LastStNum" />
  <DO name="RxConfRevNum" type="INS_2_LastStNum" />
  <DO name="ErrSt" type="ENS_4_ErrSt" />
  <DO name="OosCnt" type="INS_1_LastSqNum" />
  <DO name="TalCnt" type="INS_1_LastSqNum" />
  <DO name="DecErrCnt" type="INS_1_LastSqNum" />
  <DO name="BufOvflCnt" type="INS_1_LastSqNum" />
  <DO name="MsgLosCnt" type="INS_1_LastSqNum" />
  <DO name="MaxMsgLos" type="INS_1_LastSqNum" />
  <DO name="TotDwnTm" type="MV_8_TotDwnTm" />
  <DO name="MaxDwnTm" type="MV_3_TotDwnTm" />
  <DO name="RsStat" type="SPC_19_Sim" />
  <DO name="GoCBRef" type="ORG_11_GrRef" />
  <DO name="DatSet" type="ORG_5_DatSet" />
  <DO name="GoID" type="VSG_3_GoID" />
  <DO name="Addr" type="VSG_3_GoID" />
  <DO name="VlanID" type="ING_3_VlanID" />
  <DO name="VlanPri" type="ING_3_VlanID" />
  <DO name="AppID" type="ING_3_VlanID" />
</LNodeType>
```

What for sure is missing are the Mod, Health and NamPlt in the lnType.

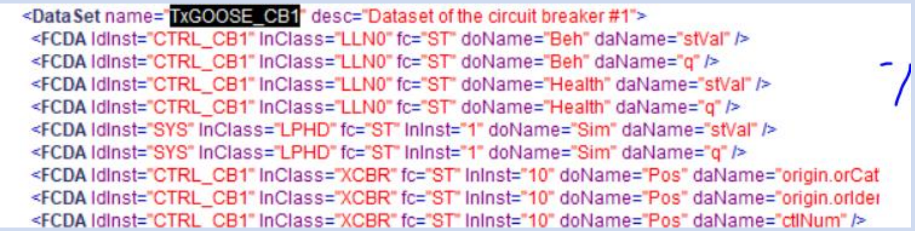
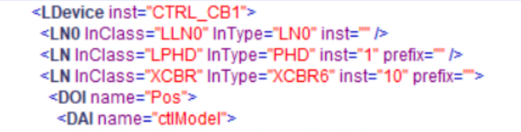
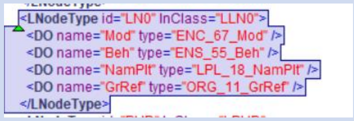
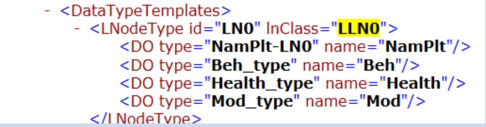
Below the lnType from the ICD of this specific IED, which looks fine.



```
    </LNodeType>
  - <LNodeType id="SIPROTEC5_LNType_LGOS" lnClass="LGOS">
        <DO type="SIPROTEC5_DOType_Mod_status_only_with_InitVal_V
        <DO type="SIPROTEC5_DOType_ENS_Behavior_V08.00.06_V07.9
        <DO type="SIPROTEC5_DOType_ENS_Health_V08.00.06_V07.90.
        <DO type="SIPROTEC5_DOType_LPL_NamPlt_for_Ed2_LN_V08.0
        <DO type="SIPROTEC5_DOType_SPS_V08.00.06_V07.90.00" name
        <DO type="SIPROTEC5_DOType_SPS_V08.00.06_V07.90.00" name
        <DO type="SIPROTEC5_DOType_SPS_V08.00.06_V07.90.00" name
        <DO type="SIPROTEC5_DOType_INS_V08.00.06_V07.90.00" name
        <DO type="SIPROTEC5_DOType_ORG_external_V08.00.06_V08.0
        <DO type="SIPROTEC5_DOType_INS_V08.00.06_V07.90.00" name
    </LNodeType>
```

Found several such issues on several IED's related to several LN's.

| **SCL Issues** | | **Resolution** | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| | SCT seems to handle the DTT not correctly in all cases. | | | | | | |
| **18** | Under the report block (below), the device was not able to process the code with “indexed” = FALSE and RptEnabled NOT EQUAL TO “1”. They had to change “indexed” to TRUE if RptEnabled is GREATER THAN “1”.<br>For the purposes of the IOP, RTDS changed “indexed” to “TRUE”.<br>From the SCD file V7:<br><ReportControl desc="Created by HELINKS STS" datSet="ds_rcb2" name="rcb4" intgPd="0" buffered="false" bufTime="0" confRev="10000" indexed="false" rptID="BT_BCUCCTBRK/LLN0.rcb4"><br><TrgOps dchg="true" dupd="false" gi="true" period="false" qchg="true"/><br><OptFields configRef="true" dataRef="false" dataSet="true" entryID="false" reasonCode="false" seqNum="false" timeStamp="true"/><br><RptEnabled max="7"><br>From IEC61850-6 (2018), “indexed” must = TRUE if the max number of enabled reports is greater than 1. | | | | x | | Was a discussion item in WG10 and clarification is being developed. |

| **SCL Issues** | | **Resolution** | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **19** | Found the following in IOP_2019_HV_v7_ed2.1.<br>The Element “CTRL_CB1/LLN0.Health.stVal” referenced by a member (FCDA) of the DataSet “TxGOOSE_CB1” does not exist.<br>Here the dataset:<br><br><DataSet name="TxGOOSE_CB1" desc="Dataset of the circuit breaker #1"><br><FCDA ldInst="CTRL_CB1" lnClass="LLN0" fc="ST" doName="Beh" daName="stVal" /><br><FCDA ldInst="CTRL_CB1" lnClass="LLN0" fc="ST" doName="Beh" daName="q" /><br><FCDA ldInst="CTRL_CB1" lnClass="LLN0" fc="ST" doName="Health" daName="stVal" /><br><FCDA ldInst="CTRL_CB1" lnClass="LLN0" fc="ST" doName="Health" daName="q" /><br><FCDA ldInst="SYS" lnClass="LPHD" fc="ST" lnInst="1" doName="Sim" daName="stVal" /><br><FCDA ldInst="SYS" lnClass="LPHD" fc="ST" lnInst="1" doName="Sim" daName="q" /><br><FCDA ldInst="CTRL_CB1" lnClass="XCBR" fc="ST" lnInst="10" doName="Pos" daName="origin.orCat<br><FCDA ldInst="CTRL_CB1" lnClass="XCBR" fc="ST" lnInst="10" doName="Pos" daName="origin.orIder<br><FCDA ldInst="CTRL_CB1" lnClass="XCBR" fc="ST" lnInst="10" doName="Pos" daName="ctlNum" /><br>The referenced LLN0:<br><br><LDevice inst="CTRL_CB1"><br><LN0 lnClass="LLN0" lnType="LN0" inst="" /><br><LN lnClass="LPHD" lnType="PHD" inst="1" prefix="" /><br><LN lnClass="XCBR" lnType="XCBR6" inst="10" prefix=""><br><DOI name="Pos"><br><DAI name="ctlModel"><br>and the related LNodeType:<br><br><LNodeType id="LN0" lnClass="LLN0"><br><DO name="Mod" type="ENC_67_Mod" /><br><DO name="Beh" type="ENS_55_Beh" /><br><DO name="NamPlt" type="LPL_18_NamPlt" /><br><DO name="GrRef" type="ORG_11_GrRef" /><br></LNodeType><br>The DO Health is not there in the DLNodeType defined!<br>In the related ICD file, the Health is available:<br><br>- <DataTypeTemplates><br>- <LNodeType id="LN0" lnClass="LLN0"><br><DO type="NamPlt-LN0" name="NamPlt"/><br><DO type="Beh_type" name="Beh"/><br><DO type="Health_type" name="Health"/><br><DO type="Mod_type" name="Mod"/><br></LNodeType><br>This is just one example several such issues found! | x | | | | | |

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| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **20** | The issue was detected during the client / server test case between TMW (Client) and the IED L2_PU GE P443 (server).<br>The data model uploaded in the Client from the SCD file (v7) shows 32 Buffered Report CB (brcbA01=>16 and brcbB01=>16). While trying to enable the BRCB “brcbA12”, we got an error response (object non existent).<br>In fact, this report brcbA12 doesn’t exist in the IED. It seems that the SCD, while instancing the RCB, exceeds the GE P443 capabilities :<br>Extract from ICD file :<br><ReportControl name="brcbA" confRev="0" buffered="true" desc="System Logical Device Report Control Block"> (…) **<RptEnabled max="8"/>**<br>Extract from SCD file (HV_V7_Ed2.0)<br><ReportControl name="brcbA" confRev="60000" rptID="L2_PU_GE_P443_Meas" buffered="true" desc="System<br>What is the valid behavior of the device? | x | | | x | | WG10 is suggesting that the configuration should be rejected. |
| **21** | The issue was detected during the client / server test case between TMW (Client) and the IED L2_BCU of Omicron (server).<br>The comparison, in the TMW client, of the data model uploaded from the SCD file (v7), and the online configuration of the IED, shows some differences :<br>Error: **value not equal** on the OptFlds of reports RCB101=>RCB116. The last bit, which corresponds to segmentation, is different (1 in TMW and 0 in the Omicron BCU).<br>In the SCD file, the segmentation value is not displayed, so the default value should be expected.<br>It seems that the Omicron BCU and the TMW client don’t use the same default value for the segmentation bit.<br>In the IEC part 6, we can see that the “segmentation” bit is deprecated, and at value “false” by default. | x | | | | | |

| **SCL Issues** | | **Resolution** | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **22** | A reservation could not be made via SCL for an IED’s report due to the lack of a ConnectedAP associated with the client’s (SEL-3560) AccessPoint.<br>The SEL-3560 ICD file describes its client and server via independent AccessPoint definitions.<br>-6 Ed2 :<br>First paragraph after table 36<br>“Each connected access point optionally has **one server-related address, and additional address**<br>**information for real time communication**-related control blocks such as GSE control and SMV<br>control. If all three are missing, it describes only the Subnetwork connection topology, for<br>example for communication performance studies. For a complete SCD file, either the server<br>address or at least one control block address shall be specified.”<br>9.4.3 Address definition<br>Second paragraph:<br>“The access point address shall be filled with **a unique value at least for server** type access<br>points to get a complete SCD description.”<br>The above citations show a need for clarification of the standard.  The first citation seems to suggest that a ConnectedAP is only applicable to a server.  The second seems to suggest that AccessPoint addresses are required to be unique – preventing a client and server from sharing an IP address. | | | | x | | |

| SCL Issues | | Resolution | | | | | |
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| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **23** | IED had dynamically configurable optFlds:<br><ReportSettings cbName="Conf" datSet="Conf" rptID="Dyn" optFields="Dyn" bufTime="Dyn" trgOps="Dyn" intgPd="Dyn" owner="true" /><br>For this BRCB:<br><ReportControl name="Rpt1" confRev="40000" datSet="dataset3" rptID="TXB_PU2_ABB_670_Prot" buffered="true" intgPd="300000" bufTime="2" desc=""><br><TrgOps dchg="true" qchg="true" period="true" gi="true" /><br><OptFields seqNum="true" timeStamp="true" dataSet="true" reasonCode="true" entryID="true" /><br>But the client was unable to modify the OptFlds to include the data set name in the report (required by client). Cause was unrelated problems in the SCD that forced the ICT to manually configure and fix other settings and the BRCB setting got fixed as well. ICT changed the setting to enable client modification and test was able to pass. | | | | | x | |
| **24** | SCD: IOP_2019_HB_v8beta_ed2.1.scd (and all HV SCDS after V4)<br>IED in the SCD contains access points (S1 and others) with GSE with ldInst = “Prot” and a single GoCB.<br>However, the GoCBs are instantiated only in the ldInst=”Master” and no MAC-Address is provided for GSE where ldInst=”Master”.<br>The Access Points should refer to “Master” not “Prot” for the GSE<br>The posted IID file for this device has IED name = TEMPLATE and no GoCBs in any LDs<br>While this is apparently a “simple” implementation error. | x | | | | | |

| | | | | | | | |
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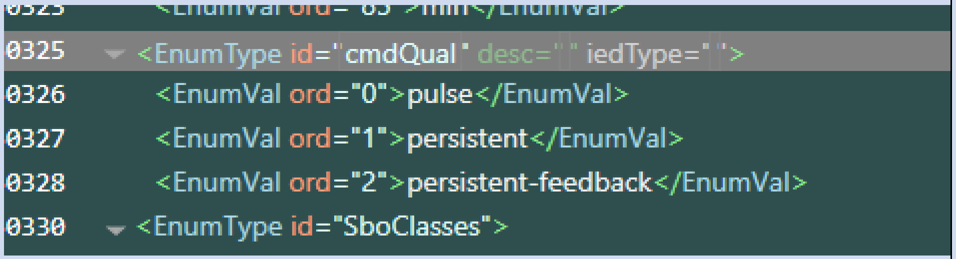
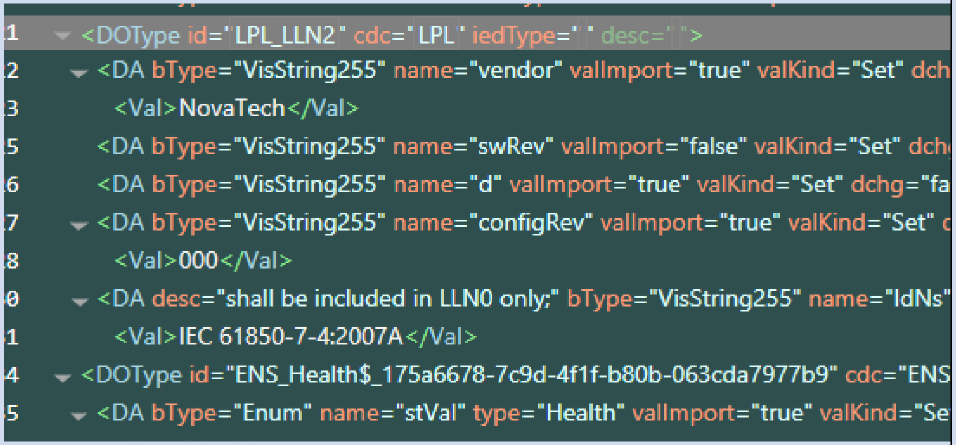
| **25** | In SCD file we find the following enum type:<br><br>`<EnumVal ord="65">min</EnumVal>`<br>`<EnumType id="cmdQual" desc="" iedType="">`<br>`<EnumVal ord="0">pulse</EnumVal>`<br>`<EnumVal ord="1">persistent</EnumVal>`<br>`<EnumVal ord="2">persistent-feedback</EnumVal>`<br>`<EnumType id="SboClasses">`<br>The LD Namespace is declared as:<br><br>`<DOType id="LPL_LLN2" cdc="LPL" iedType="" desc="">`<br>`<DA bType="VisString255" name="vendor" valImport="true" valKind="Set" dch`<br>`<Val>NovaTech</Val>`<br>`<DA bType="VisString255" name="swRev" valImport="false" valKind="Set" dch`<br>`<DA bType="VisString255" name="d" valImport="true" valKind="Set" dchg="fa`<br>`<DA bType="VisString255" name="configRev" valImport="true" valKind="Set" c`<br>`<Val>000</Val>`<br>`<DA desc="shall be included in LLN0 only;" bType="VisString255" name="ldNs"`<br>`<Val>IEC 61850-7-4:2007A</Val>`<br>`<DOType id="ENS_Health$_175a6678-7c9d-4f1f-b80b-063cda7977b9" cdc="ENS`<br>`<DA bType="Enum" name="stVal" type="Health" valImport="true" valKind="Se`<br>There is no LN Namespace configured: | x | | | | | |

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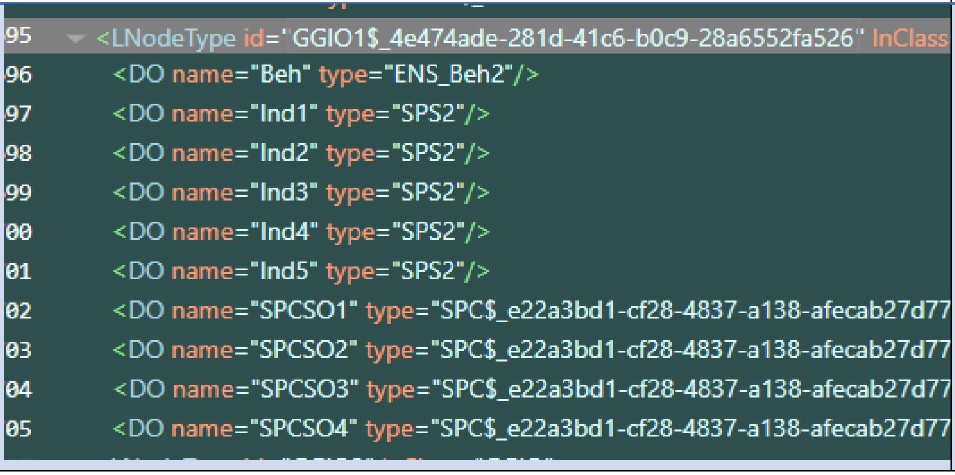
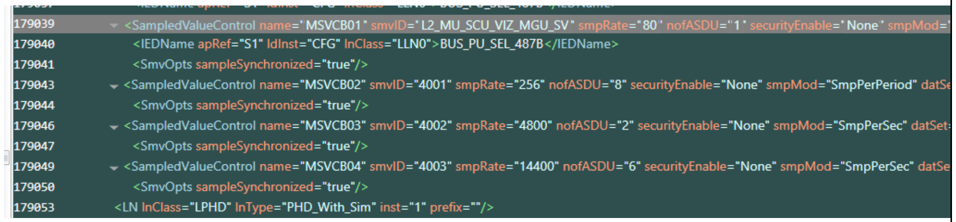
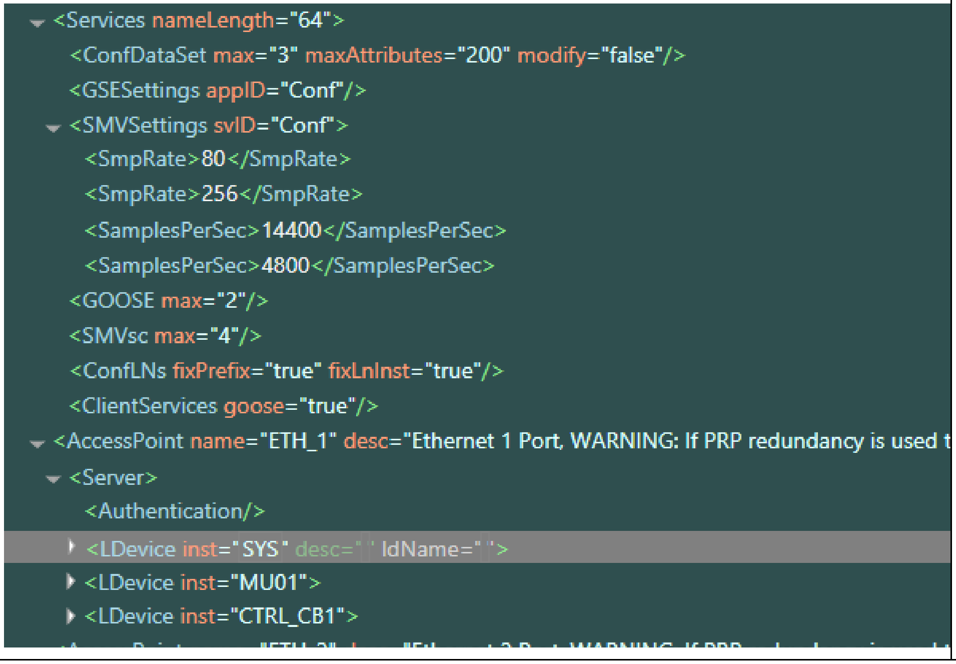
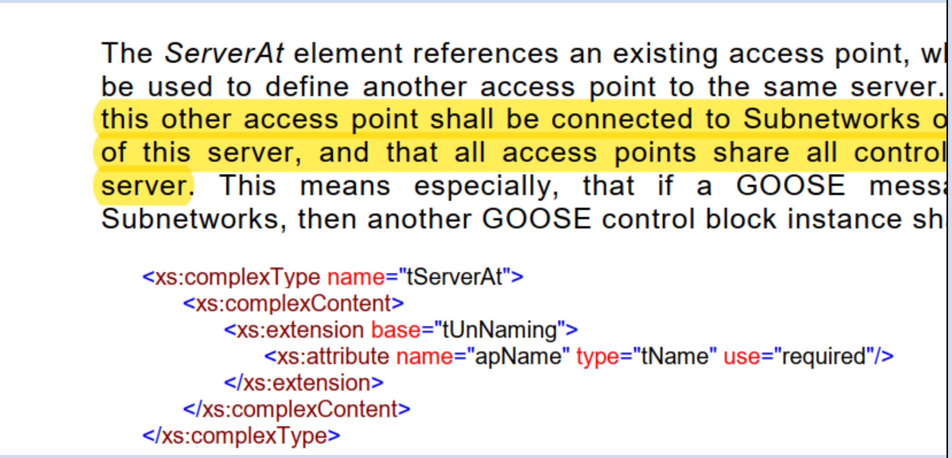
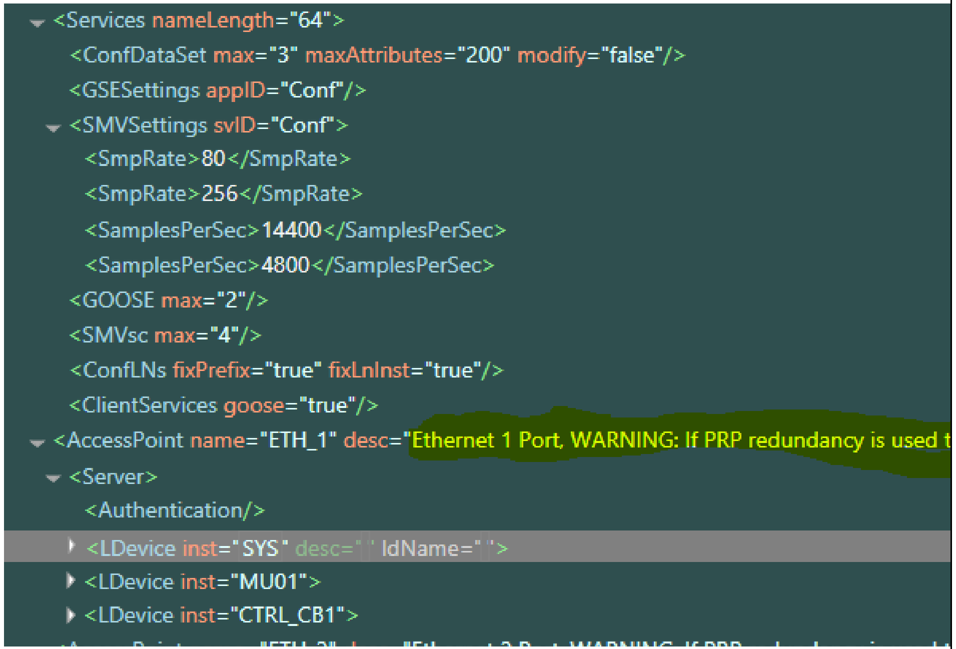
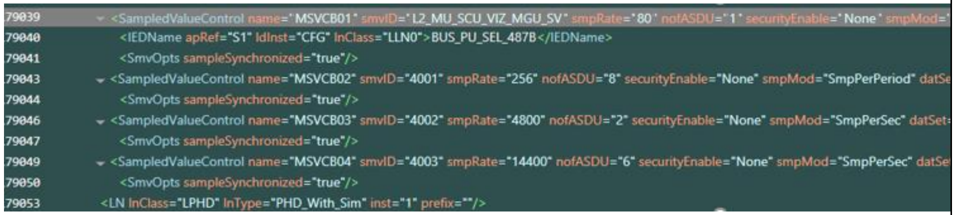
| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| | <br>`<LNodeType id="GGIO1$_4e474ade-281d-41c6-b0c9-28a6552fa526" InClass`<br>`<DO name="Beh" type="ENS_Beh2"/>`<br>`<DO name="Ind1" type="SPS2"/>`<br>`<DO name="Ind2" type="SPS2"/>`<br>`<DO name="Ind3" type="SPS2"/>`<br>`<DO name="Ind4" type="SPS2"/>`<br>`<DO name="Ind5" type="SPS2"/>`<br>`<DO name="SPCSO1" type="SPC$_e22a3bd1-cf28-4837-a138-afecab27d77`<br>`<DO name="SPCSO2" type="SPC$_e22a3bd1-cf28-4837-a138-afecab27d77`<br>`<DO name="SPCSO3" type="SPC$_e22a3bd1-cf28-4837-a138-afecab27d77`<br>`<DO name="SPCSO4" type="SPC$_e22a3bd1-cf28-4837-a138-afecab27d77` | | | | | | |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **26** | It is unclear, how to disable SV control blocks that are not in use.<br>Example of a control block declaration and related service section:<br><br><SampledValueControl name="MSVCB01" smvID="L2_MU_SCU_VIZ_MGU_SV" smpRate="80" nofASDU="1" securityEnable="None" smpMod="<br><IEDName apRef="S1" ldInst="CFG" lnClass="LLN0">BUS_PU_SEL_487B</IEDName><br><SmvOpts sampleSynchronized="true"/><br><SampledValueControl name="MSVCB02" smvID="4001" smpRate="256" nofASDU="8" securityEnable="None" smpMod="SmpPerPeriod" datSe<br><SmvOpts sampleSynchronized="true"/><br><SampledValueControl name="MSVCB03" smvID="4002" smpRate="4800" nofASDU="2" securityEnable="None" smpMod="SmpPerSec" datSet<br><SmvOpts sampleSynchronized="true"/><br><SampledValueControl name="MSVCB04" smvID="4003" smpRate="14400" nofASDU="6" securityEnable="None" smpMod="SmpPerSec" datSe<br><SmvOpts sampleSynchronized="true"/><br><LN lnClass="LPHD" lnType="PHD_With_Sim" inst="1" prefix=""/><br><br><Services nameLength="64"><br><ConfDataSet max="3" maxAttributes="200" modify="false"/><br><GSESettings appID="Conf"/><br><SMVSettings svID="Conf"><br><SmpRate>80</SmpRate><br><SmpRate>256</SmpRate><br><SamplesPerSec>14400</SamplesPerSec><br><SamplesPerSec>4800</SamplesPerSec><br><GOOSE max="2"/><br><SMVsc max="4"/><br><ConfLNs fixPrefix="true" fixLnInst="true"/><br><ClientServices goose="true"/><br><AccessPoint name="ETH_1" desc="Ethernet 1 Port, WARNING: If PRP redundancy is used t<br><Server><br><Authentication/><br><LDevice inst="SYS" desc="" ldName=""><br><LDevice inst="MU01"><br><LDevice inst="CTRL_CB1"> | | | | | x | WG10 has resolved issue by updating standard to specify that the destination address of null shall stop the SV or GOOSE from being transmitted. |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| 27 | Server and ServerAt access points are connected to the same SubNetwork.<br>Reverse engineering of subscription is not possible at SCD import.<br>According to part 6:<br><br>The *ServerAt* element references an existing access point, wl be used to define another access point to the same server. this other access point shall be connected to Subnetworks o of this server, and that all access points share all control server. This means especially, that if a GOOSE mess Subnetworks, then another GOOSE control block instance sh<br>`<xs:complexType name="tServerAt">`<br>`<xs:complexContent>`<br>`<xs:extension base="tUnNaming">`<br>`<xs:attribute name="apName" type="tName" use="required"/>`<br>`</xs:extension>`<br>`</xs:complexContent>`<br>`</xs:complexType>` | | | | | x | Part of the WG10 Subnet discussion |
| 28 | External references are pointing to source references that do not exist:<br>The ExtRef.prefix was set to “”. But there was no LN implemented at the publisher using that prefix. | x | | | | | |
| 29 | ICD file provides later binding External References for value and quality.<br>Example<br>pDA = instMag.i<br>pDA = q<br>The SCT only connects the values External reference and leave the quality external reference unconnected.<br>(See Part 6 Annex H – Use case 2)<br>Observed for SMV and GOOSE later binding inputs SCD HV V8 | x | | | | | |
| 30 | 7UT Sample value supervision LSVS.SvCBRef were not configured.<br>How does a SCT know to configure or not. | | x | | | | Requires system knowledge. |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **31** | BUS_PU_SEL_487B is supposed to:<br>- Receive samples over the process bus<br>- Send GOOSE over the station bus<br>The device only exposes 1 AP but is expected to be connected to the Station Bus and the Process Bus. Configuration in ICT? | | | | x | | It is clear in the configuration that a single access point can only be connected to a single LAN segment. However, the standard must clarify the use of Subnet. The SCL Subnetwork is currently not the same as a LAN Subnetwork. |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **32** | An IED declares the following constraints, that are not machine processable:<br><br>&lt;Services nameLength="64"&gt;<br>&lt;ConfDataSet max="3" maxAttributes="200" modify="false"/&gt;<br>&lt;GSESettings appID="Conf"/&gt;<br>&lt;SMVSettings svID="Conf"&gt;<br>&lt;SmpRate&gt;80&lt;/SmpRate&gt;<br>&lt;SmpRate&gt;256&lt;/SmpRate&gt;<br>&lt;SamplesPerSec&gt;14400&lt;/SamplesPerSec&gt;<br>&lt;SamplesPerSec&gt;4800&lt;/SamplesPerSec&gt;<br>&lt;GOOSE max="2"/&gt;<br>&lt;SMVsc max="4"/&gt;<br>&lt;ConfLNs fixPrefix="true" fixLnInst="true"/&gt;<br>&lt;ClientServices goose="true"/&gt;<br>&lt;AccessPoint name="ETH_1" desc="Ethernet 1 Port, WARNING: If PRP redundancy is used t<br>&lt;Server&gt;<br>&lt;Authentication/&gt;<br>&lt;LDevice inst=" SYS " desc=" " ldName=" "&gt;<br>&lt;LDevice inst="MU01"&gt;<br>&lt;LDevice inst="CTRL_CB1"&gt;<br>&lt;AccessPoint name="ETH_2" desc="Ethernet 2 Port, WARNING: If PRP redundancy is used t<br><br>&lt;SampledValueControl name=" MSVCB01 " smvID=" L2_MU_SCU_VIZ_MGU_SV " smpRate=" 80 " nofASDU=" 1 " securityEnable=" None " smpMod="<br>&lt;IEDName apRef="S1" ldInst="CFG" lnClass="LLN0"&gt;BUS_PU_SEL_487B&lt;/IEDName&gt;<br>&lt;SmvOpts sampleSynchronized="true"/&gt;<br>&lt;SampledValueControl name="MSVCB02" smvID="4001" smpRate="256" nofASDU="8" securityEnable="None" smpMod="SmpPerPeriod" datSe<br>&lt;SmvOpts sampleSynchronized="true"/&gt;<br>&lt;SampledValueControl name="MSVCB03" smvID="4002" smpRate="4800" nofASDU="2" securityEnable="None" smpMod="SmpPerSec" datSet=<br>&lt;SmvOpts sampleSynchronized="true"/&gt;<br>&lt;SampledValueControl name="MSVCB04" smvID="4003" smpRate="14400" nofASDU="6" securityEnable="None" smpMod="SmpPerSec" datSe<br>&lt;SmvOpts sampleSynchronized="true"/&gt;<br>&lt;LN lnClass="LPHD" lnType="PHD_With_Sim" inst="1" prefix=""/&gt;<br>Do we have any better means? | | | | x | | |

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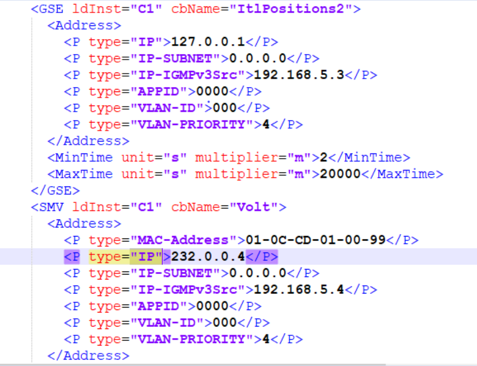
<table>
<tr>
<td><b>33</b></td>
<td>
Several Issues in communication section in SCD file IOP_2019_HV_v7_ed2.1.

In the SCD file IOP_2019_HV_v7_ed2.0 we found the same issue, GCB, SVCB with IP address defined.

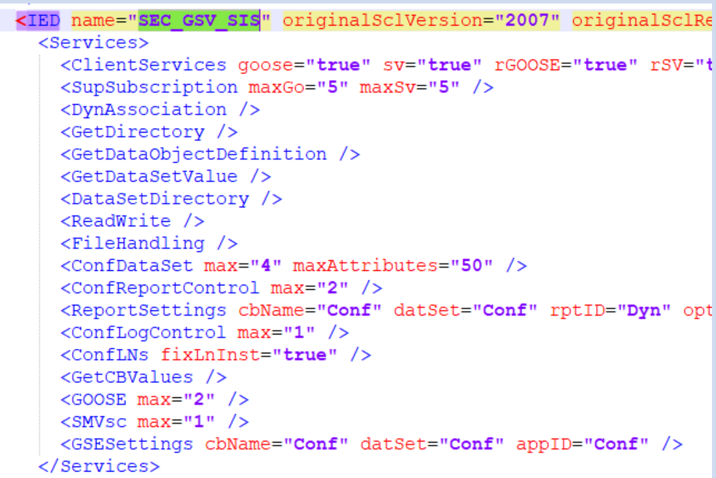
Ed 2.0 is not supporting R-GOOSE, R-SV.

Found  SV Control Block with Dest. Mac and IP Address defined.



<pre>
  <GSE ldInst="C1" cbName="ItlPositions2">
    <Address>
      <P type="IP">127.0.0.1</P>
      <P type="IP-SUBNET">0.0.0.0</P>
      <P type="IP-IGMPv3Src">192.168.5.3</P>
      <P type="APPID">0000</P>
      <P type="VLAN-ID">000</P>
      <P type="VLAN-PRIORITY">4</P>
    </Address>
    <MinTime unit="s" multiplier="m">2</MinTime>
    <MaxTime unit="s" multiplier="m">20000</MaxTime>
  </GSE>
  <SMV ldInst="C1" cbName="Volt">
    <Address>
      <P type="MAC-Address">01-0C-CD-01-00-99</P>
      <P type="IP">232.0.0.4</P>
      <P type="IP-SUBNET">0.0.0.0</P>
      <P type="IP-IGMPv3Src">192.168.5.4</P>
      <P type="APPID">0000</P>
      <P type="VLAN-ID">000</P>
      <P type="VLAN-PRIORITY">4</P>
    </Address>
</pre>

The service section of the related IED tells us the publishing of R-GOOSE and R-SV is not supported:



<pre>
 <IED name="SEC_GSV_SIS" originalSclVersion="2007" originalSclRe
   <Services>
     <ClientServices goose="true" sv="true" rGOOSE="true" rSV="t
     <SupSubscription maxGo="5" maxSv="5" />
     <DynAssociation />
     <GetDirectory />
     <GetDataObjectDefinition />
     <GetDataSetValue />
     <DataSetDirectory />
     <ReadWrite />
     <FileHandling />
     <ConfDataSet max="4" maxAttributes="50" />
     <ConfReportControl max="2" />
     <ReportSettings cbName="Conf" datSet="Conf" rptID="Dyn" opt
     <ConfLogControl max="1" />
     <ConfLNs fixLnInst="true" />
     <GetCBValues />
     <GOOSE max="2" />
     <SMVsc max="1" />
     <GSESettings cbName="Conf" datSet="Conf" appID="Conf" />
   </Services>
</pre>

For R-Goose, R-SV we should have the Protocol element added to the control blocks in the IED section. <Protocol mustUnderstand="true">R-GOOSE</Protocol>?

In the related IED section are no control blocks defined:
</td>
<td>x</td>
<td></td>
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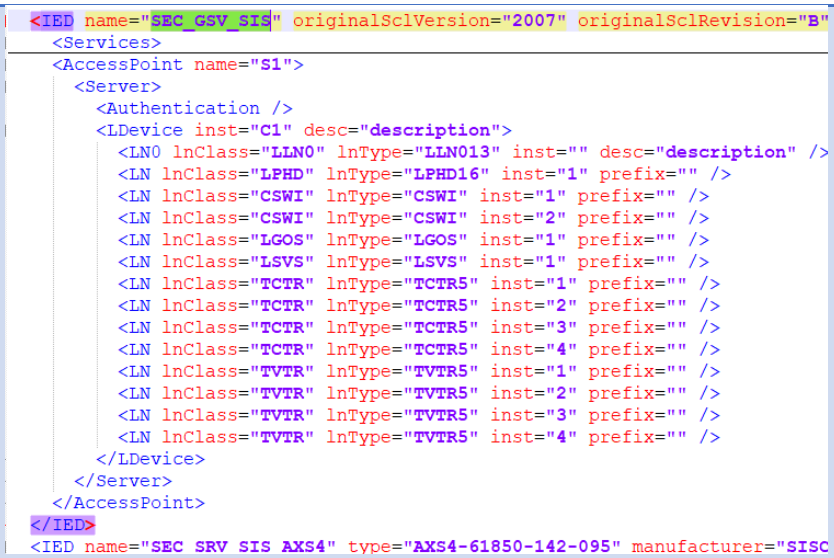
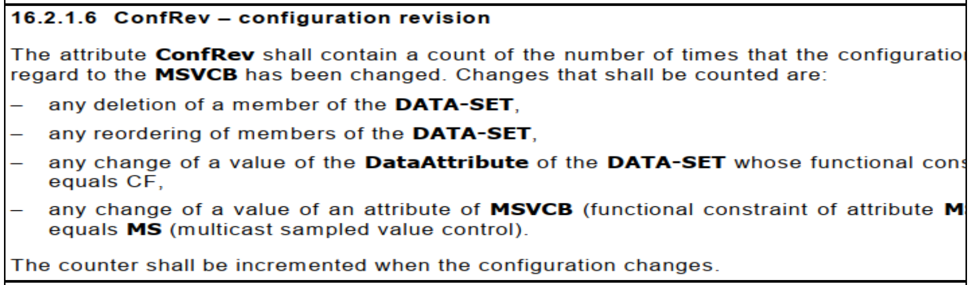
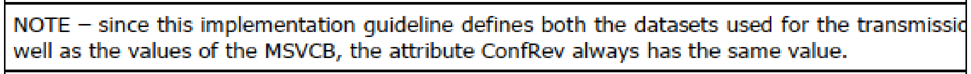
</table>

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| |  | | | | | | |

```
<IED name="SEC_GSV_SIS" originalSclVersion="2007" originalSclRevision="B"
  <Services>
  <AccessPoint name="S1">
    <Server>
      <Authentication />
      <LDevice inst="C1" desc="description">
        <LN0 lnClass="LLN0" lnType="LLN013" inst="" desc="description" />
        <LN lnClass="LPHD" lnType="LPHD16" inst="1" prefix="" />
        <LN lnClass="CSWI" lnType="CSWI" inst="1" prefix="" />
        <LN lnClass="CSWI" lnType="CSWI" inst="2" prefix="" />
        <LN lnClass="LGOS" lnType="LGOS" inst="1" prefix="" />
        <LN lnClass="LSVS" lnType="LSVS" inst="1" prefix="" />
        <LN lnClass="TCTR" lnType="TCTR5" inst="1" prefix="" />
        <LN lnClass="TCTR" lnType="TCTR5" inst="2" prefix="" />
        <LN lnClass="TCTR" lnType="TCTR5" inst="3" prefix="" />
        <LN lnClass="TCTR" lnType="TCTR5" inst="4" prefix="" />
        <LN lnClass="TVTR" lnType="TVTR5" inst="1" prefix="" />
        <LN lnClass="TVTR" lnType="TVTR5" inst="2" prefix="" />
        <LN lnClass="TVTR" lnType="TVTR5" inst="3" prefix="" />
        <LN lnClass="TVTR" lnType="TVTR5" inst="4" prefix="" />
      </LDevice>
    </Server>
  </AccessPoint>
</IED>
<IED name="SEC_SRV_SIS_AXS4" type="AXS4-61850-142-095" manufacturer="SISC
```

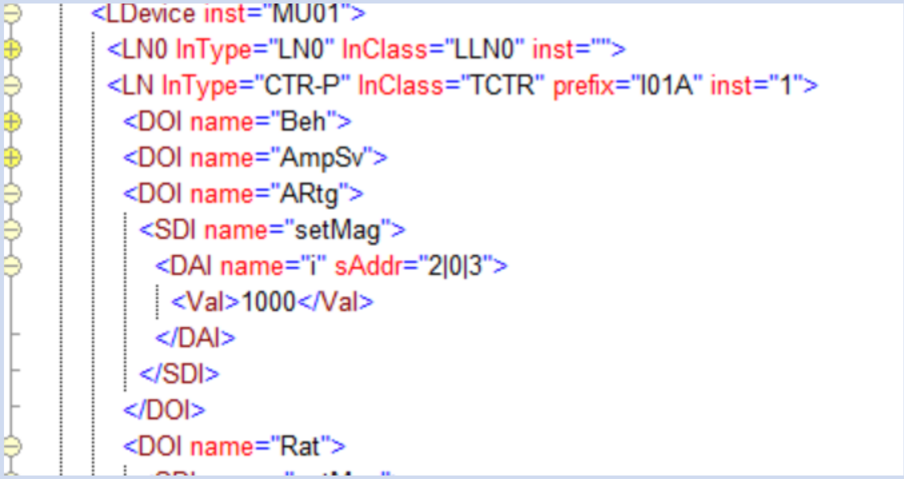
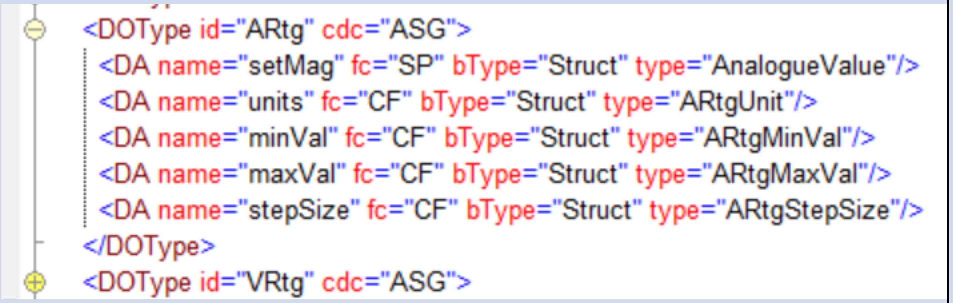
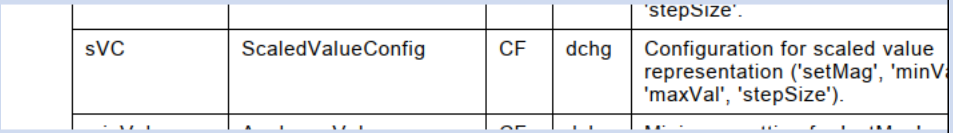
| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **34** | **Issue:** a couple of SCTs are updating the **confRev** of 9-2 LE Sampled Value streams.<br>As per IEC 61850 Ed.1 part 7-2:<br><br>**16.2.1.6 ConfRev – configuration revision**<br>The attribute **ConfRev** shall contain a count of the number of times that the configuratio regard to the **MSVCB** has been changed. Changes that shall be counted are:<br>– any deletion of a member of the **DATA-SET**,<br>– any reordering of members of the **DATA-SET**,<br>– any change of a value of the **DataAttribute** of the **DATA-SET** whose functional cons equals CF,<br>– any change of a value of an attribute of **MSVCB** (functional constraint of attribute **M** equals **MS** (multicast sampled value control).<br>The counter shall be incremented when the configuration changes.<br>As per 9-2LE:<br><br>NOTE – since this implementation guideline defines both the datasets used for the transmissio well as the values of the MSVCB, the attribute ConfRev always has the same value.<br>Hence, the test tools which inject 9-2LE SV streams wouldn't allow the user to modify the **confRev**.<br>But, the IEDs which do a check on the **confRev** of SV stream(s) before accepting the to 9-2LE streams wouldn't subscribe to the SV streams from the test tools as there is a mismatch between the confRev of SV from the test tool (which is 1) and confRev of SV which the IED is expecting (as defind in the SCD).<br>1. The SCTs shouldn't increment the confRev of 9-2LE SVs.<br>2. Suggestion: the IEDs accepting 9-2LE streams should perform a check on the confRev and should declare this in the PIXIT. | x | | | | | |
| **35** | No ldNs declared for the in multiple IED ICDs | x | | | | | |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **36** | [NSD validation] type of DA/BDA “Check” (line= 349175) is not Check<br><DAType id="Oper_16"><br><BDA name="ctlVal" type="Mod" bType="Enum"/><br><BDA name="origin" type="CN_V2.0_Originator_1" bType="Struct"/><br><BDA name="ctlNum" bType="INT8U"/><br><BDA name="T" bType="Timestamp"/><br><BDA name="Test" bType="BOOLEAN"/><br><BDA name="Check" bType="BOOLEAN"/><br></DAType><br>Used by IED : SS_GWY_JPE_GWM<br>NSD 8-1 says :<br><ServiceConstructedAttribute titleID="IEC 61850-8-1:2003.SBOw" name="SBOw" typeKindParameterized="true"><br><SubDataAttribute descID="IEC 61850-8-1:2003.ctlVal" name="ctlVal" typeKind="undefined" presCond="M"/><br><SubDataAttribute descID="IEC 61850-8-1:2003.operTm" name="operTm" typeKind="BASIC" type="Timestamp" presCond="MOoperTm"/><br><SubDataAttribute descID="IEC 61850-8-1:2003.origin" name="origin" typeKind="CONSTRUCTED" type="Originator" presCond="M"/><br><SubDataAttribute descID="IEC 61850-8-1:2003.ctlNum" name="ctlNum" typeKind="BASIC" type="INT8U" presCond="M"/><br><SubDataAttribute descID="IEC 61850-8-1:2003.T" name="T" typeKind="BASIC" type="Timestamp" presCond="M"/><br><SubDataAttribute descID="IEC 61850-8-1:2003.Test" name="Test" typeKind="BASIC" type="BOOLEAN" presCond="M"/><br><SubDataAttribute descID="IEC 61850-8-1:2003.Check" name="Check" typeKind="BASIC" type="Check" presCond="M"/><br></ServiceConstructedAttribute> | x | | | | | |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **37** | 3 errors :<br>[NSD validation] type of DA/BDA “SBO” (line= 340639 + 340673 + 340772) is not VisString129<br><DOType id="ENC_6_Mod" cdc="ENC"><br><DA name="stVal" type="Mod" bType="Enum" fc="ST"/><br><DA name="q" bType="Quality" fc="ST"/><br><DA name="t" bType="Timestamp" fc="ST"/><br><DA name="stSeld" bType="BOOLEAN" fc="ST"/><br><DA name="ctlModel" type="CtlModelKind" bType="Enum" fc="CF"/><br><DA name="sboTimeout" bType="INT32U" fc="CF"/><br><DA name="operTimeout" bType="INT32U" fc="CF"/><br><DA name="SBO" bType="ObjRef" fc="CO"/><br><DA name="SBOw" type="AA1D1Q03Q1LD0.LLN0.Mod.SBOw_1" bType="Struct" fc="CO"/><br><DA name="Oper" type="AA1D1Q03Q1LD0.LLN0.Mod.Oper_1" bType="Struct" fc="CO"/><br><DA name="Cancel" type="AA1D1Q03Q1LD0.LLN0.Mod.Cancel_1" bType="Struct" fc="CO"/> </DOType><br>Used by IED : L2_BCU_OMI_SSC (OMICRON)<br>NSD 8-1 says :<br><ServiceCDC cdc="ENC"><br><ServiceDataAttribute name="SBO" typeKind="BASIC" type="VisString129" fc="CO" presCond="MOsboNormal" descID="IEC 61850-8-1:2003.SBO"/><br><ServiceDataAttribute name="SBOw" typeKind="CONSTRUCTED" type="SBOw" underlyingTypeKind="ENUMERATED" fc="CO" presCond="MOsboEnhanced"/><br><ServiceDataAttribute name="Oper" typeKind="CONSTRUCTED" type="Oper" underlyingTypeKind="ENUMERATED" fc="CO" presCond="MOctrl"/><br><ServiceDataAttribute name="Cancel" typeKind="CONSTRUCTED" type="Cancel" underlyingTypeKind="ENUMERATED" fc="CO" presCond="MOctrl"/><br></ServiceCDC> | x | | | | | |
| **38** | ExtRef not correctly mapped to IED Logical Nodes | x | | | | | |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **39** | [NSD validation] type of DA/BDA “dirGeneral” (line= 340741) is not Enum<br><DOType id="ACD_5_Str" cdc="ACD"><br><DA name="general" bType="BOOLEAN" fc="ST"/><br><DA name="dirGeneral" bType="BOOLEAN" fc="ST"/><br><DA name="q" bType="Quality" fc="ST"/><br><DA name="t" bType="Timestamp" fc="ST"/><br></DOType><br>NSD 8-1 says :<br><CDC name="ACD" titleID="IEC61850_7_3.CDCStatusInfo::ACD.__cl.title"><br><DataAttribute name="general" fc="ST" type="BOOLEAN" dchg="true" descID="IEC61850_7_3.CDCStatusInfo::ACD.general.desc" presCond="M"/><br><DataAttribute name="dirGeneral" fc="ST" type="FaultDirectionKind" typeKind="ENUMERATED" dchg="true" descID="IEC61850_7_3.CDCStatusInfo::ACD.dirGeneral.desc" presCond="M"/> | x | | | | | |
| **40** | The issue was detected during the client / server test cases between: TMW TSP (Client) and the IED CSI 200E and CSC 211 of SIFANG (server).<br>The “compare” tool, in the TMW TSP client (which make a comparison of the data model uploaded from the SCD file, and the online configuration of the IED), gave a failed response when we tried to launch it.<br>The issue was that the TMW TSP client was already connected to the IED (to display the data model), and tried to **open a second TCP connexion with the same IP address**, to do the compare model.<br>The SIFANG IEDs don't accept the second connexion (same @IP, different client port).<br>The issue was solved when disconnecting the first client to do the compare model.<br>Is the behaviour of the server normal? | | x | | | | It is a local implementation issue. |

| SCL Issues | | | Resolution | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **41** | The SCT tool created an invalid ReportControl element for INCB_BCU in the IOP_2019_LV_ED2_0_V9.scd.<br><ReportControl desc="Created by HELINKS STS" datSet="ds_rcb1" name="rcb2" intgPd="0"<br>buffered="true" bufTime="100" confRev="10000" indexed="false"<br>rptID="INCB_BCUCFG/LLN0.rcb2"><br><TrgOps dchg="true" dupd="false" gi="true" period="false" qchg="true"/> <OptFields bufOvfl="true" configRef="true" dataRef="false" dataSet="true" entryID="false" reasonCode="false" seqNum="true" timeStamp="true"/> <RptEnabled max="7"><br></RptEnabled><br></ReportControl><br>Per the standard, a buffered report is limited to one instance. | x | | | | | |
| **42** | The SCT tool deleted reports and datasets, present in INCB_BCU's ICD file, from the IOP_2019_LV_ED2_0_V9.scd. | | | | | x | WG10 indicated that it is OK to delete non-fixed DataSets that are not used. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **43** | Problem with the DataTypeTemplate<br>DOI ARtg is exposing the “i” component of the Analogue Value<br><br>`<LDevice inst="MU01">`<br>`<LN0 lnType="LN0" lnClass="LLN0" inst="">`<br>`<LN lnType="CTR-P" lnClass="TCTR" prefix="I01A" inst="1">`<br>`<DOI name="Beh">`<br>`<DOI name="AmpSv">`<br>`<DOI name="ARtg">`<br>`<SDI name="setMag">`<br>`<DAI name="i" sAddr="2\|0\|3">`<br>`<Val>1000</Val>`<br>`</DAI>`<br>`</SDI>`<br>`</DOI>`<br>`<DOI name="Rat">`<br>However, there are no sVC available in the DataTypeTemplate nor scaled value config values:<br><br>`<DOType id="ARtg" cdc="ASG">`<br>`<DA name="setMag" fc="SP" bType="Struct" type="AnalogueValue"/>`<br>`<DA name="units" fc="CF" bType="Struct" type="ARtgUnit"/>`<br>`<DA name="minVal" fc="CF" bType="Struct" type="ARtgMinVal"/>`<br>`<DA name="maxVal" fc="CF" bType="Struct" type="ARtgMaxVal"/>`<br>`<DA name="stepSize" fc="CF" bType="Struct" type="ARtgStepSize"/>`<br>`</DOType>`<br>`<DOType id="VRtg" cdc="ASG">`<br>7-3 definition mandates sVC as soon as “i” is implemented<br><br>'stepSize'.<br>sVC \| ScaledValueConfig \| CF \| dchg \| Configuration for scaled value representation ('setMag', 'minVa 'maxVal', 'stepSize').<br><br>NOTE: | x | | | | | |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| | device declares ldNs = IEC 61850-7-4:2007B however, the SCL file is SCL edition 2. | | | | | | |
| **44** | Various ICT support different mechanisms where a SCT must connect the ExtRef, including:<br>- A dedicated GGIO LN<br>- A InRef at LN LGOS<br>But icd files do not declare noIctBinding<br>Connecting through an InRef does not seem the right approach.<br>Requiring dedicated places to bind, from Ed 2.1 on requires the declaration of noIctBinding | x | | | | | |
| **45** | ICT requires later binding to a range of binary signals. If a double point DO (e.g. XCBR.Pos.stVal) needs to be connected, SCT is required to either connect the XCBR.Pos.stVal to 2 individual consecutive ExtRef or leave one empty.<br>Also, it requires a private String to indicate if quality shall be included as well. | x | | | | | Extref is only based upon DataTemplate definitions and are not allowed to be anything other than those definition.<br>The mapping of a combination DPS values bits to a single SPS is not allowed in the standard. |
| **46** | Several vendor ICD files contain an empty type="" attribute in their IED element.<br>&lt;IED name="SS_GWY_NV_LXM4" desc="IEC61850 IED" type="" manufacturer="NovaTech LLC" configVersion="1" originalSclVersion="2007" originalSclRevision="B"&gt;<br>The validity/meaning of an empty string as a type should be clarified. | | | | | x | |

| SCL Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **47** | In dataTypeTemplate section, there is a DOType that has the same id than an EnumType.<br>ERROR [SemanticConstraints] Unique child id from DataTypeTemplates (line 315780)<br><DOType id="Mod_1" cdc="ENC" iedType=""><br><DA bType="Enum" name="stVal" type="ModEnum" dchg="true" fc="ST"/><br><DA bType="Quality" name="q" fc="ST" qchg="true"/><br><DA bType="Timestamp" name="t" fc="ST"/><br><DA bType="Enum" name="ctlModel" type="CtlModelKind" dchg="true" fc="CF"/><br></DOType><br><EnumType desc="CB Operating Capability" id="Mod_1"><br><EnumVal ord="1">on</EnumVal><br><EnumVal ord="2">blocked</EnumVal><br><EnumVal ord="3">test</EnumVal><br><EnumVal ord="4">test/blocked</EnumVal><br><EnumVal ord="5">off</EnumVal><br></EnumType><br>SCL XSD 2007B4 says :<br><xs:unique name="uniqueDTT_ID"><br><xs:selector xpath="*"/><br><xs:field xpath="@id"/><br></xs:unique> | x | | | | | |

<table>
<tr><th colspan="2">SCL Issues</th><th colspan="5">Resolution</th><th></th></tr>
<tr><th>Issue Number</th><th>Description</th><th>I</th><th>M</th><th>C</th><th>U</th><th>O</th><th>Comment</th></tr>
<tr><td><b>48</b></td><td>It was observed that in may files originalSclVersion was missing, which would imply 2003A and would be wrong. Is it clear enough who is responsible to mark original SCL Version ICT/SCT?<br>Tissue on this topic are #1398, #1450 and #1485.<br><table>
<tr><th>Test ID</th><th>Test description</th><th>Nu oc</th></tr>
<tr><td>sCnf46</td><td>Verify IED@originalSclVersion and IED@originalSclRevision attributes match corresponding attributes of SCL element (SCL@version and SCL@revision)</td><td>13</td></tr>
</table></td><td>x</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td><b>49</b></td><td>Context: client / server test cases between: TMW TSP (Client) and the IED SEL 487B (server).<br>For test cases purposes, the ICT added some members on the Dataset configured by the SCD.<br>When we display the data model on the client from SCD, the added members are not present. As a result, we cannot perform any action on these. We have to use a discovery mode on the Client, which doesn’t use the SCD file and get the data directly with the IP Address.<br>The question is: should the ICD be allowed to modify the data model compared to the SCD file, and if so, how the clients have to handle the information missing from SCD file?</td><td>x</td><td></td><td></td><td></td><td></td><td>ICTs can modify Data Models and this needs to be provided to the SCT in the form of an IID or ICD.</td></tr>
</table>

| **SCL Issues** | | **Resolution** | | | | | |
|---|---|---|---|---|---|---|---|
| **Issue Number** | **Description** | I | M | C | U | O | Comment |
| **50** | Context: client / server test cases between: TMW TSP (Client) and the IED SEL 487B (server).<br>When we made the test about deadband configuration, we have found that the value of the deadband was 75kV on the server side, and 10 kV on the client side.<br>In the SCD file, we have :<br><DAI name="db" **esel:datasrc="imm:750000"**><br><Val>**10**</Val><br></DAI><br>Is the **esel:datasrc** a correct attribute (does not seem to be in part 6)?<br>It should be an implementation error on the client or on the server side. | x | | | | | SCT issue<br>SCTs need to preserve namespaces. |
| **51** | The SCT tool added an OSI-AE-Qualifier to the ConnectedAP associated with INCB_BCU.<br>No OSI-AE-Qualifier was present in the ICD file.<br>Is an SCT tool allowed to add OSI parameters when they are not present in the ICD's ConnectedAP? | x | | | | | An SCT is responsible for communication configuration. Thus, it may add the parameters in question. |

There were a total of 52 recorded SCL related issues at the IOP. Some of the issues were implementation issues due to mis-understanding. Thus, they were categorized in multiple categories. Therefore, the following chart appears to have more that the recorded number of errors.

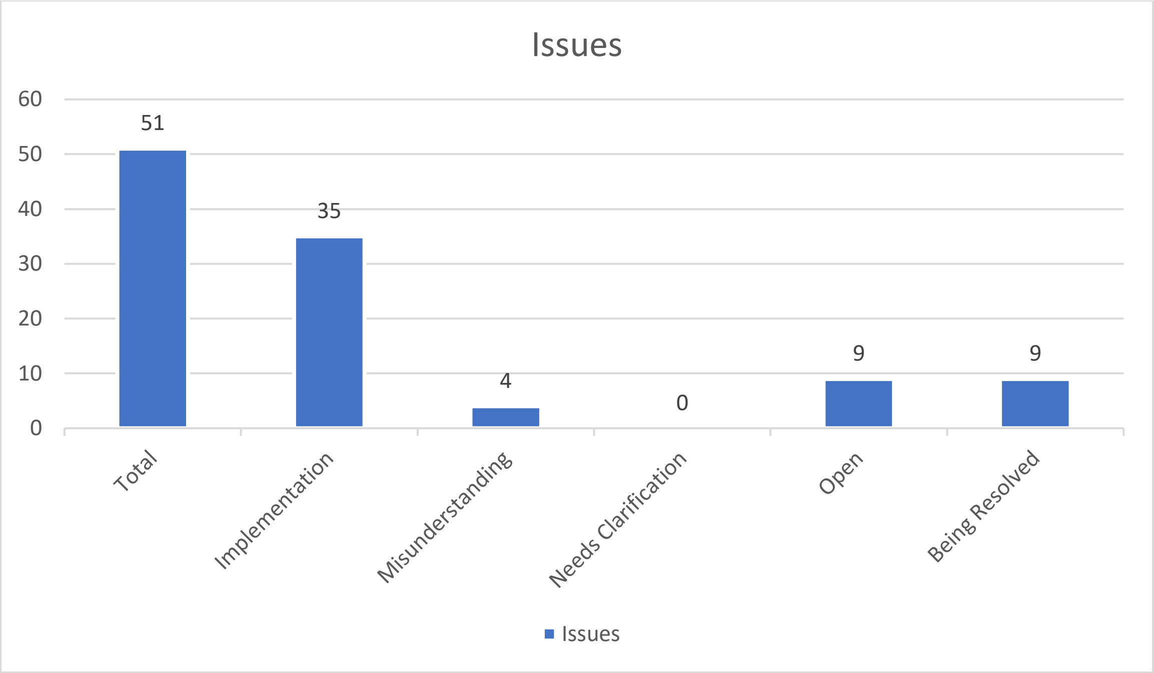


Figure 27: Distribution of SCL Issues

## 1.2 Network

The following table details the issues and the proposed resolution for Network issues that were reported to IEC TC57 WG10 and does not include the implementation issues reported to the vendors.

| Network Related  IOP Issues | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Description | Resolution | | | | | Comment |
| **Issue Number** | | I | M | C | U | O | |
| **1** | IED had PRP implementation that was a  PRP setup bridges PRP LANs. Device acted as root bridge forwarding BPDUs across independent PRP networks. Unknown if other traffic was forwarded as well. This caused the PRP network to crash. | x | | | | | |
| **2** | GOOSE packets on the main trunk port have an extra 6 bytes on the end of them. Probably due to someone connecting a PRP link into a Red Box which adds more PRP bytes and the end point only strips 6 bytes.<br>Not sure if this was only happening on the main monitoring table but it makes the GOOSE message look like an invalid packet because of extra bytes in the packet after decoding.<br>9.2 Should applications reject these packets or ignore the extra bytes?<br>If ignore, what if the extra bytes are not PRP generated? | x | | | | | Investigation showed that the extra bytes are to be treated as Ethernet padding unless expected (e.g. receiver configure for security or PRP extensions).  They are not part of the GOOSE APDU. |

## 9.3 R-GOOSE

The following table details the issues and the proposed resolution for R-GOOSE issues that were reported to IEC TC57 WG10 and does not include the implementation issues reported to the vendors.

No issues recorded.

## 1.3 GOOSE

The following table details the issues and the proposed resolution for GOOSE issues that were reported to IEC TC57 WG10 and does not include the implementation issues reported to the vendors.

No recorded problems.

## 1.4 Sampled Values

The following table details the issues and the proposed resolution for Sampled Values issues that were reported to IEC TC57 WG10 and does not include the implementation issues reported to the vendors.

No recorded problems.

However, there is a relationship with Time Sync issue #3. IEC 61869-9 explicitly states that when merging units/SV publishes sync to a clock, the time adjustment **Shall** jump (e.g. not a ramp). During the testing, all SV publishes appeared to behave properly. However, one of the boundary clocks that was being synchronized with ramped and did not jump when the grandmaster was adjusted. Therefore, the SV publisher followed the ramping boundary clock for synchronization and thus did not jump. IEEE 1588 and IEC 61850-9-3 allows this type of clock behavior, although many clocks have configuration options that facilitate the required jump. Care should be taken into account when designing an SV system that the clocks provide the appropriate jump. This is especially critical for messages being exchanged between multiple time domains where one clock could jump and the other ramps (e.g. Differential Protection).

## 1.5 Client/Server

The following table details the issues and the proposed resolution for Client/Server issues that were reported to IEC TC57 WG10 and does not include the implementation issues reported to the vendors.

| Client/Server IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **1** | The Novatech Orion server rejected an MMS AlternateAccess write to a report control block attribute.<br>Is a server required to support this?<br>Server negotiates that it supports VALT(alternate access). | x | | | | | Yes, if VALT is negotiated then it applies to all MMS NamedVariables. |

## 1.6 Time Sync/PTP

The following table details the issues and the proposed resolution for Time Sync issues that were reported to IEC TC57 WG10 and does not include the implementation issues reported to the vendors. Many of the issues were referred to both IEC and IEEE. Successful negotiation between both

| PTP IOP Issues | | Resolution | | | | | Comment |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | |
| **1** | Toshiba GMU200 did not follow PTP clock, it stayed in local. | x | | | | | |

| PTP IOP Issues | | Resolution | | | | | Comment |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | |
| **2** | GE D60 : Took an inordinate amount of time  re-synced after the Grand Master clock was placed back into service. The device continued LOCAL time Sync. | x | | | | | Originally thought that it did not re-sync. |
| **3** | Merging Unit standard requires MU clock to jump on PTP time jumps. But this cannot work if Boundary clocks exist between the clock source and sink because boundary clocks are not required to perform this jump. | x | | x | | | Unclear if can resolve in the standards but needs to be taken into account in system design and equipment selection.<br>Presented the issue to the IEEE ICAP responsible for PTP testing.  They will be adding a test for clocks in order to test if they can be configured to be compliant with the IEC 61869-9 requirement. |

| PTP IOP Issues | | Resolution | | | | | Comment |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | |
| **4** | During the clock failure test, we can see that the SEL 451 jumped from 17hxx to 14hxx when the GM Clock was disconnected.<br>⇨ Is that behaviour normal?<br>The IED remained on internal clock until the initial GM clock was reconnected. The ordinary clock, whose accuracy was “unknown”, were not used by the device.<br>⇨ Is that behaviour normal? | x | | | | | Further investigation required. |

## 9.4 Security

The following table details the issues and the proposed resolution for Security issues that were reported to IEC TC57 WG15 and does not include the

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **1** | Server did not have a CA certificate, however it did not block an incoming connection from the client.<br>The test case was not clear if authentication and encryption is used.<br>We checked that IEC 62351-3 Ed.1.1 clause 5.6.3 states that the validation shall be bi-directional and both client or server should terminate the connection when the CA certificate is not found AND raised a security event ( test case should add this check). | x | | | | | |
| **2** | RFC 2409 has a statement that says:<br>"Each message should be padded up to the nearest block size using bytes containing 0x00."<br>However, other standards referred to by IEC 62351-9 make statements that the padding is a choice.<br>Discussion, with the implementors needed to make a decision and have proposed that IEC 62351-9 be updated to specify padding to be PKCS7 padding, as there are security and other advantages with this padding technique. | | | | x | | IEC 62351-9 is being revised to take this into account. |
| **3** | The use of a prepended Initialization Vector, prior to the encrypted SA Payloads is unclear if the IV is pre-determined (e.g. the last octets of the previously sent/received message) or sent in the message.  There are conflicting statements in RFC 2409 that could be interpreted either way.<br>The decision was to implement the modern mechanism of sending the IV octets prior to the encrypted payloads. | | | | x | | IEC 62351-9 is being revised to take this into account. |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **4** | IEC 62351-9 does not specify the key length for TripleDES-CBC which can be either 128 or 192 bits.  AES-CBC has such specifications. | | | | x | | IEC 62351-9 is being revised to take this into account. |
| **5** | IEC 62351-9 does not specify the assumed default key length for either Triple DES CBC nor AES-CBC.<br>This means that key lengths must be proposed in the SA Transfer Sets.<br>It is recommended that IEC 62351-9 not specify default values, rather specify the key lengths shall be sent. | | | | x | | IEC 62351-9 is being revised to take this into account. |
| **6** | RFC 8052 has a cut and paste error that will lead to mis-interpretation and interoperability issues.<br> <br>The linked image cannot be displayed.  The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location.<br>The second SA Attr (marked as 2) is the copy and paste error. | | | | x | | IEC 62351-9 is being revised to take this into account. A revision for RFC 8052 will be attempted. |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **7** | Upon deletion of CA certificate from trusted store, SISCO server refuses any new requests for connections authenticated by CA, but does NOT terminate active, previously established sessions.<br>This does not constitute a failure of the test as the requirement only states that connections are refused. It is unknown if this is a violation of IEC 62351.<br>Should servers be required to terminate active connections upon loss of trust to the client? | | | | | x | Standard states that already active connections should not be impacted.  Text being strengthened. |
| **8** | IEC **TS** 62351-4:2007 specifies the MMS authentication  value type CHOICE as EXTERNAL. The presentation-context-definition **shall** include a reference to the abstract syntax used for EXTERNAL<br>IEC 62351-4:2018 retains this specification but contains a footnote that some implementations do not include the indirect reference in the authentication value.<br>MMS clients that include the abstract syntax in the presentation-context-definition, according to the standard, may not be able to establish communication with MMS Server that do not expect the entry in the presentation-context-definition list and that do not expect the indirect reference in the MMS authentication value. | | | | x | | IEC 62351-4 is being revised to have a compatibility Annex. |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **9** | Secure MMS<br>IEC **TS** 62351-4:2007 specifies abstract syntax name as oid 1.0.840.0.1.0.1.1<br>IEC **TS** 62351-4:2007 specifies the mechanism-name as oid 1.0.840.0.1.1.4.1<br>IEC 62351-4:2018 specifies the abstract syntax name as oid 1.0.62351.4.0.31.1<br>IEC 62351-4:2018 specifies the mechanism-name as oid 1.0.62351.4.3.1<br>IEC 62351-4:2018 contains a footnote stating that some implementations use the oid and that this is an illegal oid.<br>MMS clients that include the oid according to the IEC 62351-4 may not be able to establish communication with MMS Servers that expect the oid to be the value from IEC TS 62351-4. | | | | x | | IEC 62351-4 is being revised to have a compatibility Annex |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **10** | IEC **TS** 62351-4:2007 specifies that the time value shall be of the ASN.1 type GeneralizedTime and shall be as accurate as possible. In GeneralizedTime, milliseconds are optional.<br>IEC 62351-4:2018 specifies that the accuracy shall be one second<br>Implementations may include the milliseconds component in the GeneralizedTime component either in the MMS Initiate Request or in the MMS Initiate Response<br>It is not expected that this is going to be an interoperability issue for implementations | x | | | x | | IEC 62351-4 is being revised to have a compatibility Annex |
| **11** | What is the structure for routable GOOSE without encryption and without authentication Hash at the end. Normally the hash is encoded as 04 NN where NN is the length of the hash.<br>Is it ok to:<br>- not to have 04 NN bytes when no authentication hash present<br>- or should it rather be 04 00?<br>The second option sounds better, however it is not clear what to use at this moment. | | | | x | | IEC 62351-6 will include the change. |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **12** | IEC 61850-8-1 is not clear about how to compute the HMAC with encryption.<br>For the CBC/HMAC test, SISCO encrypted the data, and then computed the HMAC. But NR computed the HMAC (on the unencrypted data), and then encrypted the data. The calculated HMAC would never match. We didn't see how other vendors compute HMAC. For interoperability, this really needs to be clear in IEC 61850-8-1.<br>NOTE: After SISCO made "significant" code changes, we were able to communicate, but we still don't know which way is correct. | | | | | x | IEC 61850-8-1 is being revised. |
| **13** | IEC 61850-8-1 is not clear what ASN.1 tag to use before the HMAC or GMAC.<br>SISCO encoded 0x04 (UNIVERSAL OCTETSTRING). But NR encoded 0x85 because IEC 61850-8-1 simply referred to IEC 62351-6 for the MAC. In the "Extension" encoding defined in IEC 62351-6, the tag ends up being 0x85. But IEC 61850-8-1 has no similar "Extension" encoding, so using that tag seems inappropriate.<br>It should be clearer if IEC 61850-8-1 defines exactly what tag to use. | | | | | x | |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **14** | IEC **TS** 62351-4:2007 specifies IMPLICIT for the SignatureCertificate, GeneralizedTime and SignedVlaue<br>IEC 62351-4:2018 no longer specifies IMPLICIT in 11.2.2<br>IEC 62351-4:2018 in Annex 1 specifies IMPLICIT for the module but not for the individual elements<br>IEC 62351-4:2018 does contain a note in 11.2.1 stating that the module specifies the IMPLICIT tag and tagging is assumed where relevant<br>Interoperability issues may result due to the note and the change in the value representation if these are interpreted incorrectly | | | | x | | IEC 62351-4 is being revised to have a compatibility Annex |
| **15** | IEC **TS** 62351-4:2007 specifies the MMS authentication value type CHOICE as EXTERNAL. The presentation-context-definition **shall** include a reference to the abstract syntax used for EXTERNAL<br>IEC 62351-4:2018 retains this specification but contains a footnote that some implementations do not include the indirect reference in the authentication value.<br>MMS clients that include the abstract syntax in the presentation-context-definition, according to the standard, may not be able to establish communication with MMS Server that do not expect the entry in the presentation-context-definition list and that do not expect the indirect reference in the MMS authentication value. | | | | X | | IEC 62351-4 is being revised to have a compatibility Annex |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **16** | IEC **TS** 62351-4:2007 specifies abstract syntax name  as oid 1.0.840.0.1.0.1.1<br>IEC **TS** 62351-4:2007 specifies the mechanism-name as oid 1.0.840.0.1.1.4.1<br>IEC 62351-4:2018 specifies the abstract syntax name as oid 1.0.62351.4.0.31.1<br>IEC 62351-4:2018 specifies the mechanism-name as oid 1.0.62351.4.3.1<br>IEC 62351-4:2018 contains a footnote stating that some implementations use the oid and that this is an illegal oid.<br>MMS clients that include the oid according to the IEC 62351-4 may not be able to establish communication with MMS Servers that expect the oid to be the value from IEC TS 62351-4. | | | | X | | IEC 62351-4 is being revised to have a compatibility Annex |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **17** | IEC **TS** 62351-4:2007 specifies that the time value shall be of the ASN.1 type GeneralizedTime and shall be as accurate as possible. In GeneralizedTime, milliseconds are optional.<br>IEC 62351-4:2018 specifies that the accuracy shall be one second<br>Implementations may include the milliseconds component in the GeneralizedTime component either in the MMS Initiate Request or in the MMS Initiate Response<br>It is not expected that this is going to be an interoperability issue for implementations | | | | X | | IEC 62351-4 is being revised to have a compatibility Annex |
| **18** | IEC **TS** 62351-4:2007 specifies the mandatory cipher suite TLS_DH_DSS_WITH_AES_256_SHA for TLS<br>IEC 62351-4:2018 specifies the mandatory cipher suite TLS_DH_DSS_WITH_AES_256_SHA  for TLS for compatibility mode<br>The OpenSSL versions 1.1.0 and higher no longer have support for this cipher suite.<br>The last OpenSSL version that provides support for this cipher suite is version 1.02<br>OpenSSL Version 1.0.2 will be supported only until 2019-12-31 (LTS). | | | | x | | IEC 62351-4 is being revised to have a compatibility Annex |

| Security IOP Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **19** | IEC **TS** 62351-4:2007 specifies the hashing algorithm for the signedvalue of the mmsauthenticationvalue to be SHA1<br>IEC 62351-4:2018 specifies the hashing algorithm used at the mmsauthenticationvlaue in compatibility mode to be SHA256<br>IEC 62351-4:2018 does not contain a note regarding backwards compatibility to implementations based on IEC TS 62351-4:2007 | | | | x | | IEC 62351-4 is being revised to have a compatibility Annex |

There were a total of 19 recorded Security related issues at the IOP.  Some of the issues were implementation issues due to mis-understanding. Thus, they were categorized in multiple categories.

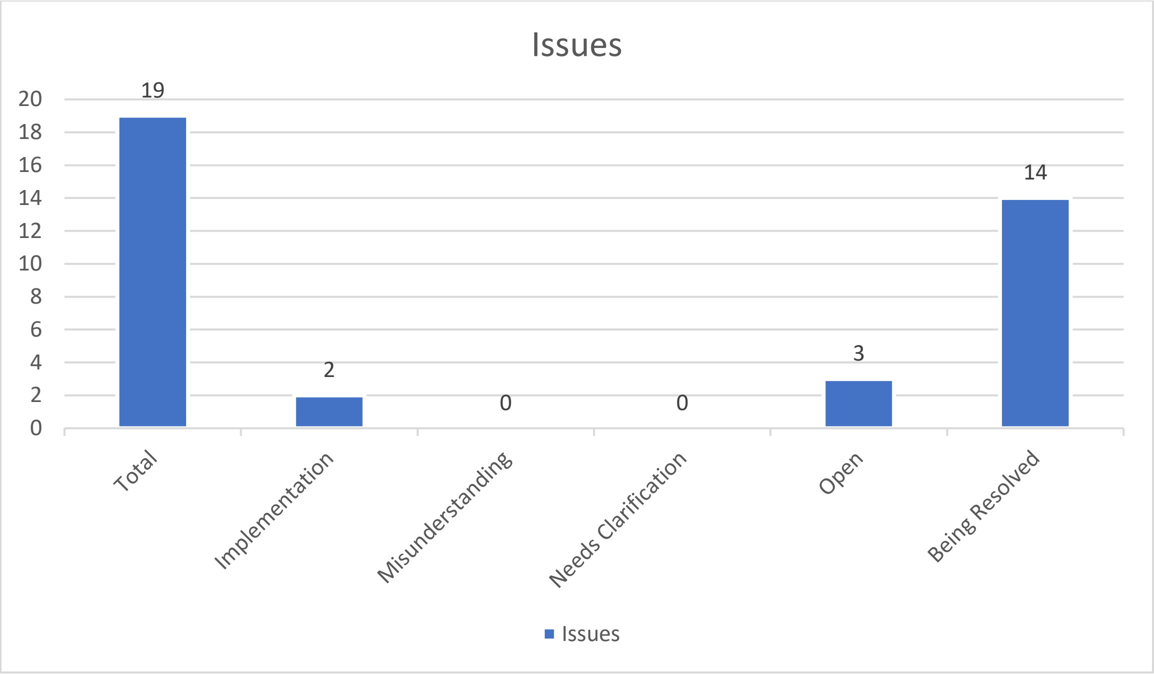


**Figure 28: Analysis of Security Issues by Type**

The following figure shows the distribution of issues based upon standards that will require revision to standards.

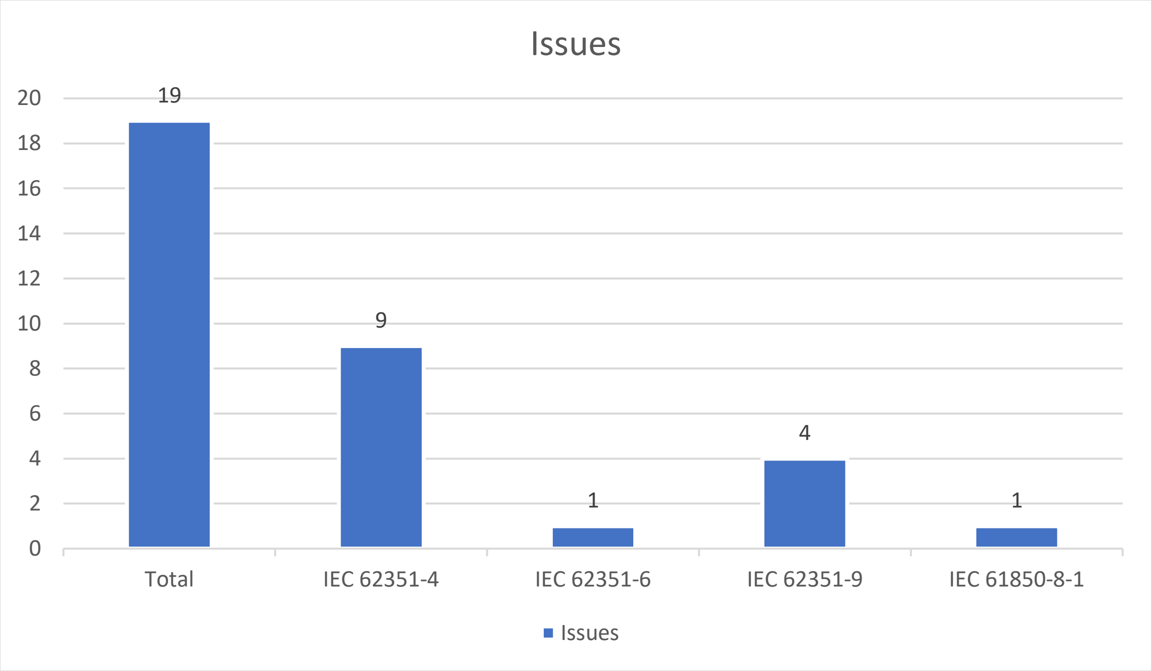


**Figure 29: Distribution of Issues vs Standards Needing Revision**

Of the 19 issues,  9 were logged due to backward compatibility issues introduced due to the recent revision of IEC 62351-4.  An amendment is being created for IEC 62351-4 that provides the needed backward compatibility.  IEC 62351-6 will be revised to resolve the issue once the amendment to IEC 62351-4 is stable.

The 2019 IOP was the first IOP that actually tested interoperability of IEC 62351-9 key distribution and 4 issues were found in the standards specified for IEC 61850 multicast key distribution. The editor of IEC 62351-9 has captured and agreed to issues/solutions proposed by the IOP and IEC 62351-9 is beginning a revision process.

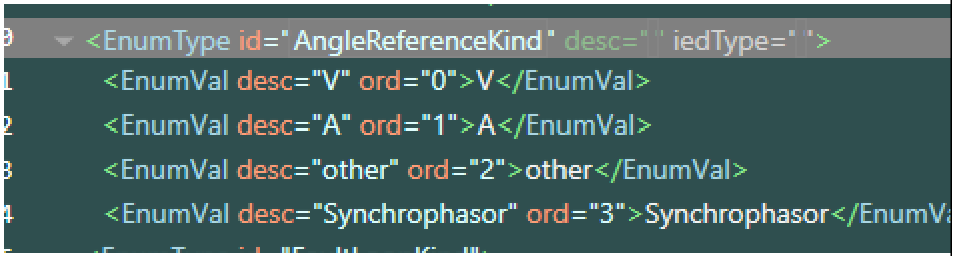
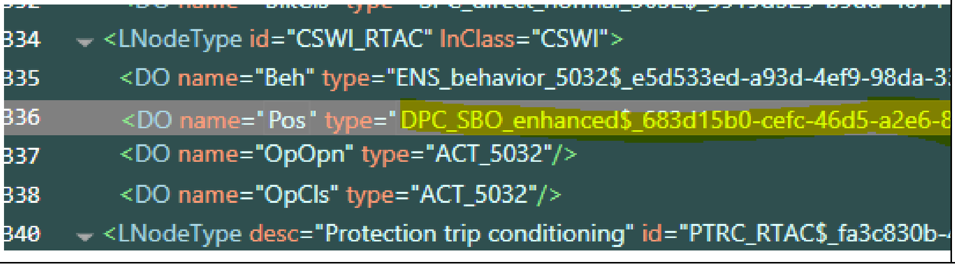
## 9.5 Test Cases

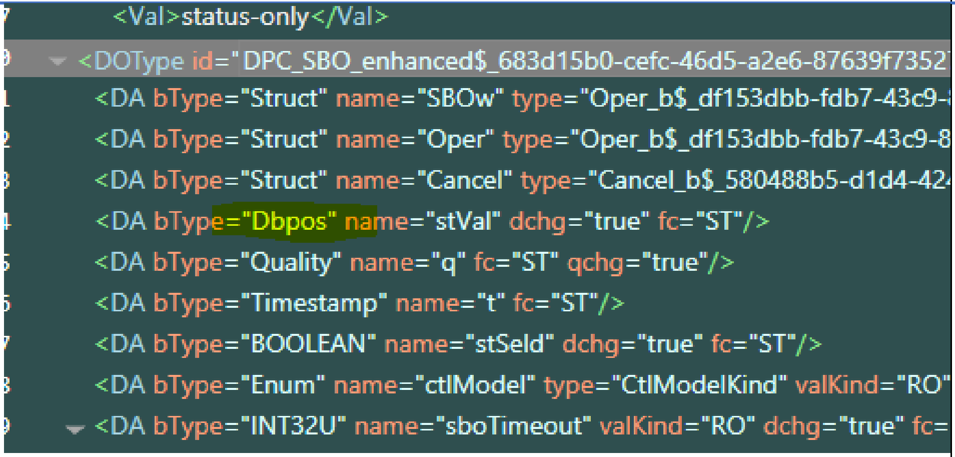
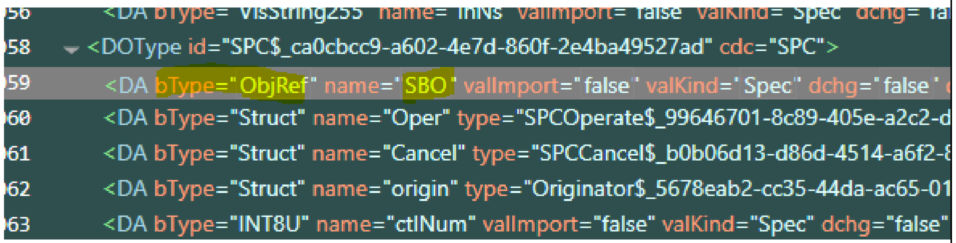
| Test Case Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **1** | Test case 62351-4-9 / NORM-03 lacks details on how to test, the high level name is clear, to make sure a device supports both secure and unsecure connections at the same time.<br>However the detailed steps are missing, so we see steps for a client connecting without security, but it is not clear for the secure part.<br>Should we test the same client with the same server not secure or use a different server?<br>Is this a realistic/valid test, will this ever happen in real life?<br>We tested with 2 connections, one from client to server secure and one from same client to the same server non-secure.<br>However some servers need a different IP address for a new connection, they can only connect to one server with a unique IP-address.<br><br>Underlying issue:<br>Add steps for how to test this test case, how many servers are needed, how many client interfaces are needed? Allocate separate server ip-addresses as not all clients support a connection to the same server with the same IP address<br>(or they need a different AE-qualifier (most servers don't care for the value, so a mismatch will still allow a new connection) | | | | | x | For next IOP. |

| Test Case Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **2** | Any vendor using actual electrical quantities out of test set (as opposed to SV); potentially as an input to a Merging Unit<br>During testing, unexpected results were seen on the output of a Merging Unit (sampled values) sourced from a test set (in this case, Omicron to ABB). Without tools to verify the output of the test set, the time to troubleshoot the problem was extended as the output of the test set was wired to an alternate MU that had to be reconfigured, etc.<br>For future Interops, the participants should arrange in advance to bring a few basic analog testing tools to the interop. This could include a multimeter that can measure voltages and currents, and some type of device that can measure phase angles to verify phasing. This could also be a relay with metering/event report capabilities (or a metering screen).<br>We would only need one or two devices (w test leads) for the entire Interop; this could be a shared test device. At least some of the issues encountered may be as simple as flopped leads or circuit continuity; basic testing tools could probably have caught this quickly. | | | | | | |
| **3** | Unable to access device data due to ServicesSupportedCalling not set properly by the server in Initiate Response. Server responds by performing a logical AND of the client and server ServicesSupported CBB resulting in the server stating that all services not supported by the client are not supported. This is non-conformant.<br>Client changed configuration parameter to ignore services supported CBB to be able to read data from device.<br>Conformance testing procedures may need to be updated. | | | | | x | |

| Test Case Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **4** | In test case ABN-SV-01, when the test set that is publishing simulated SV messages is unplugged from the network, the test case expects St=False and SimSt=True.<br>However, we observed that St =True and SimSt = False.<br>The definition of the St in the Standard says that it is the "Status of a subscription (True=active, False= not active)". By that definition, St should be True because the publishing IED is still actively publishing to the Subscriber.<br>Also, since simulated messages are no longer being published to the device, the subscriber will not process them. Hence, SimSt should be False. | | | | x | | Next IOP |

| Test Case Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **5** | ICD files delivered by vendors did not match requirements.<br>The icd file delivered for the initial configuration had a generic (out of the box) data model. The SCT was not able to map all required information into the IED – multiple iterations were required until the ICD file was finally reflecting the requirements.<br>Sometimes, that was just the data model as such (i.e., the control of a switch (CSWI.Pos) was preconfigured as status-only and could not be changed by the tool as the data model did not provide the structure for control) – the system design engineer had to communicate verbally with the IED what is needed and got a new file back with the modifications in the IED tool.<br>Sometimes, GOOSE messages could not be configured. Again – through verbal interaction, the system design engineer told the IED design engineer what he needs as signals and the IED engineer configured the dataset for the GOOSE control block accordingly, such that it could then support the requirements. This required additional iterations.<br>The process needs to be clarified! According the standard, an icd file is a – if needed pre-configured – file that matches the requirements from the substation. The less flexibility an IED tool provides regarding configurability by the system tool, the more preconfiguration is needed. That requires the essential design work to be done in multiple tools.<br>To avoid this, the standard should enforce flexibility of the IED tools with regard to engineering capabilities through the system tool. | | | | x | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **6** | SCD file inherits errors from the icd file that the tool is not allowed to fix. A few example:<br><br>`<EnumType id="AngleReferenceKind" desc="" iedType="">`<br>`<EnumVal desc="V" ord="0">V</EnumVal>`<br>`<EnumVal desc="A" ord="1">A</EnumVal>`<br>`<EnumVal desc="other" ord="2">other</EnumVal>`<br>`<EnumVal desc="Synchrophasor" ord="3">Synchrophasor</EnumV`<br>That type is used e.g. at a DO MMXU.A.phsA; enum type is not correct for angle reference of a phsA<br><br>Or a wrong CDC:<br><br>`<LNodeType id="CSWI_RTAC" lnClass="CSWI">`<br>`<DO name="Beh" type="ENS_behavior_5032$_e5d533ed-a93d-4ef9-98da-3`<br>`<DO name="Pos" type="DPC_SBO_enhanced$_683d15b0-cefc-46d5-a2e6-8`<br>`<DO name="OpOpn" type="ACT_5032"/>`<br>`<DO name="OpCls" type="ACT_5032"/>`<br>`<LNodeType desc="Protection trip conditioning" id="PTRC_RTAC$_fa3c830b-` | | | | | x | Conformance testing of icd files needs to be improved. |

| Test Case Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| | <br>`<Val>status-only</Val>`<br>`<DOType id="DPC_SBO_enhanced$_683d15b0-cefc-46d5-a2e6-87639f7352`<br>`<DA bType="Struct" name="SBOw" type="Oper_b$_df153dbb-fdb7-43c9-`<br>`<DA bType="Struct" name="Oper" type="Oper_b$_df153dbb-fdb7-43c9-8`<br>`<DA bType="Struct" name="Cancel" type="Cancel_b$_580488b5-d1d4-42`<br>`<DA bType="Dbpos" name="stVal" dchg="true" fc="ST"/>`<br>`<DA bType="Quality" name="q" fc="ST" qchg="true"/>`<br>`<DA bType="Timestamp" name="t" fc="ST"/>`<br>`<DA bType="BOOLEAN" name="stSeld" dchg="true" fc="ST"/>`<br>`<DA bType="Enum" name="ctlModel" type="CtlModelKind" valKind="RO"`<br>`<DA bType="INT32U" name="sboTimeout" valKind="RO" dchg="true" fc=`<br><br>Or wrong bType:<br><br>`<DA bType="VisString255" name="lnNs" valImport="false" valKind="Spec" dchg="fa`<br>`<DOType id="SPC$_ca0cbcc9-a602-4e7d-860f-2e4ba49527ad" cdc="SPC">`<br>`<DA bType="ObjRef" name="SBO" valImport="false" valKind="Spec" dchg="false"`<br>`<DA bType="Struct" name="Oper" type="SPCOperate$_99646701-8c89-405e-a2c2-d`<br>`<DA bType="Struct" name="Cancel" type="SPCCancel$_b0b06d13-d86d-4514-a6f2-`<br>`<DA bType="Struct" name="origin" type="Originator$_5678eab2-cc35-44da-ac65-01`<br>`<DA bType="INT8U" name="ctlNum" valImport="false" valKind="Spec" dchg="false"` | | | | | | |

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| Test Case Issues | | Resolution | | | | | |
|---|---|---|---|---|---|---|---|
| Issue Number | Description | I | M | C | U | O | Comment |
| **7** | Client was unable to enable a report in the server since it wrote less than the full length of Optflds. | | | | | x | High-priority: add UCAIug test to verify OptFlds and TrgOps bitstring writes specify the correct length (10 and 6 bits)<br>Low-priority: consider adding a test to verify ANY malformed objects in a write request are rejected at the time of write (very low priority because there is a semi-infinite number of ways to specify a malformed object). |

# 10 Thoughts for Next IOP

The following are thoughts for the 2021 IOP.

- The Integrated Application will continue to be the lens through which other tests are executed.

- The 2019 IOP saw many more implementations regarding cyber security. However, some of the standards related to monitoring for cyber events were not tested. It would be hoped that this could be possible in 2021 (e.g. Syslog and SNMP MIBS).

- It is hoped that through SCL conformance checking of ICDs that the quality of the SCL process will be greatly improved.

- The standard for HMI configuration exchange should be published by the 2021 IOP. It would be hoped that such exchanges could be tested.

- Other suggestions should be submitted to UCAIug.

The next IOP will be in 2021. Already offers for hosting the event have been received from France and India. The site determination will be made mid-2020.