About the usage of clients for protection testing

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Abstract

IEC 61850 is the established standard for power utility communication in substations and beyond. The topic “testing” was a main concern in the standardization from the beginning and is quite important in the field. This papers describes a new approach with new possibilities. The solution requires a client in the test software.

1 Introduction

IEC 61850 was published for the first time in the early 2000s and became the widely accepted solution for substation automation systems (SAS) around the world. Thousands of installations illustrate this success story. The topic of “how to test” was discussed from the beginning. Edition 1 of the standard described several possibilities, however, these were not well accepted in the industry because they were so numerous and were not supported by detailed explanations. When Edition 2 of the standard [1] came out, advanced possibilities and detailed explanations became available.

2 About testing

The demand for testing is accepted since substations are in operation [2]. To interrupt tripping circuits, infeed analog values and receive startup and trip signals test plugs are widely used. [2].

3 Testing in IEC 61850

3.1 Test bits

Some users expect a single “test-bit”, but the standard does not use this definition. The reason is obvious, as in IEC 61850 there are several possibilities to communicate. We distinguish between client-server-communication used for SCADA purposes and real-time communication utilizing GOOSE and Sampled Values. Additionally, the data model – as defined in the standard – is complex and multilayered, and therefore, additional possibilities need to be found. Sometimes the latter mentioned indication "test" in GOOSE (according to [3]) is also called "test-bit".

3.2 Test mode

The classes for Logical Nodes (LNs) are defined in IEC 61850-7-4 [4]. Every Logical Device (LD) consists of at least 3 LNs. Every LN has its own Mode (Mod). This mode can be as follows:

- on
- on-blocked (name in edition 1: "blocked")
- test
- test/blocked
- off

The setup for the entire LD and LNs contained result in the “behavior” (Beh). Appendix A2 in part 7-4 of the standard [4] contains a table describing the expected behavior in case of any mode. To switch between the modes, the control service of IEC 61850 is issued by the client.

3.3 Test as Quality

In addition to the Mod/Beh for all available information, a quality (q) is also defined. The encoding is explained in 8-1[3]. Here we learn that bit string of 13 is currently used (Bit 0....Bit 12; Bit 11 is a Boolean attribute with the name "quality").

3.4 Test Indication in GOOSE

As already mentioned in part 8-1 [3], for the GOOSE, a parameter "test" is also defined. It is transmitted in the GOOSE-PDU and can be used to decide whether or not the GOOSE is published by an IED in test mode. According to edition 1 of the standard, this was rarely implemented by the vendors in IEDs. Such an indication was not defined for Sampled Values.

In edition 2, a new indication was introduced for GOOSE and Sampled Values, called “Simulation” (S). . This indication shows that the GOOSE or Sampled Values come from a test set and not from a configured IED. Switching to “Simulation” is done for the entire physical device (LPHD logical node) and makes it similar to conventional test switches (Figure 1).

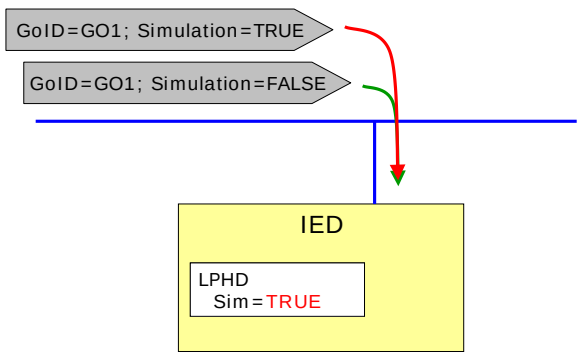

Figure 1 Simulation of a GOOSE message

3.5 Testing scenario

Figure 2 shows the testing scenario. The protection IED is switched to mode “test”. The circuit breaker is operated by an extra IED so this is in mode “test/blocked”. Sampled Values are published by the Merging Unit or test set. In this case, with simulation indication Sim= True.

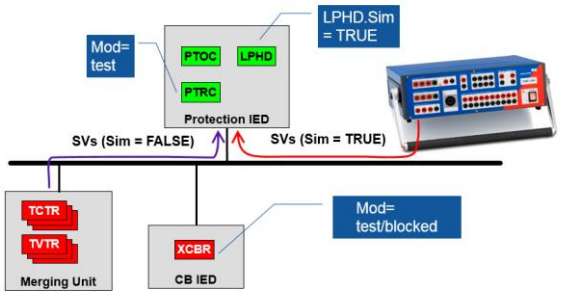

Figure 2 Testing scenario

4 Communication methods

To understand testing we have to distinguish between different communication methods in IEC 61850. For non-time-critical SCADA communication, point to point communication on IP level is used. Time critical information such as GOOSE and Sampled Values is published as multicast (Figure 3).

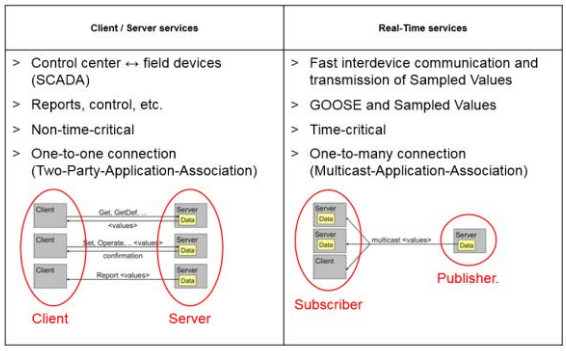

Figure 3 Communication

5 Testing equipment

There are different communication demands for different testing equipment (Figure 4). IEDs of different vendors communicate together. SCADA systems is connected. Between the IEDs, IEC 61850 GOOSE is used. The IED publishes its information (protection, position indicators) to many receivers. A connected test set will also receive this information, which makes protection testing quite easy.

The communication to the SCADA system is realized as point to point connection. The IEDs send out the information (“server”), the connected SCADA system is the IEC 61850n client. To test this traffic, test clients (such as OMICRON IEDScout) can be used.

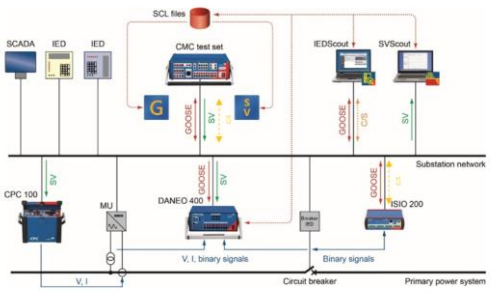

Figure 4 Test equipment

6 Functional Testing

CIGRE Work Group B5.32 presented their report "FUNCTIONAL TESTING OF IEC 61850 BASED SYSTEMS" in 2009 [6]. This report described new ways to test performance and functionality of IEC 61850 Substation automation Systems (SAS). The brochure contains a structured method to specify functional tests on systems based on this standard. An object oriented approach was proposed, using UML, text and XML formats. Conformance and interoperability tests are not treated, being already standardized. This document is a good base for further discussions how to test dedicated protection functions or how to embed this into existing protection testing routines.

The IEC working group WG 10 is responsible for IEC 61850, and is currently discussing associated issues (task force functional testing). The approach in Germany (mentioned below) provides input to this working group.

IEC 61850, its impact on substation automation and protection have already been under discussion in Germany for a long time. First user recommendations [7] [8] gave hints for testing. With the new release of [7], which was published in 2013 [9], it was obvious that further definitions and recommendations would be needed. The results are described in testing recommendations which are to be published in English at the end of 2016. To developing this approach users and vendors discussed the future of protection testing. Figure 5 shows an example of a test sequence for distance protection.

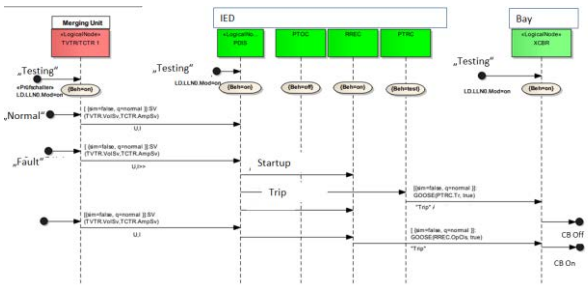

Figure 5 Test sequence

It illustrates the different steps, and that different logical nodes in the device will be set to "test" during the test. After the test the nodes needs to be switched back to the original mode. This will be "on" in normal case. Nevertheless, the auto recloser should be "off". It is obvious that such a sequence and changing the modes could not be done manually during protection testing. This should be embedded into protection testing and requires a client in the testing software.

7 Client in protection testing

7.1 Introduction

As discussed, to switch the modes a client is essential. Bringing such a client into test software offers new opportunities which should be explained (Figure 6).

The client communicates with the IEC 61850 server utilizing point to point connection (IP). The client should be embedded into protection testing software. Its configuration will be done with engineering files of IEC 61850 - most likely the SCD file (substation configuration description). This file contains the data model as well as the description of the IEC 61850 Report used for protection testing (Figure 7).

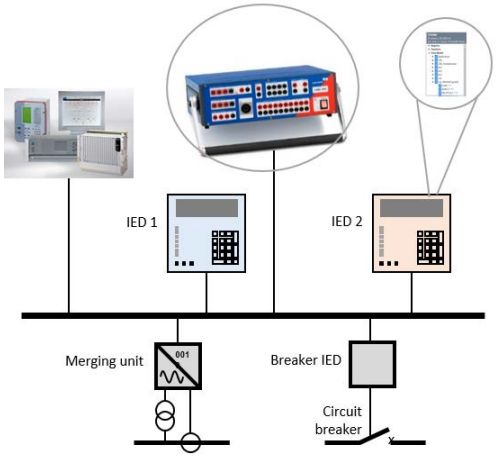

Figure 6 Client in protection testing

Within the module, the modes of logical nodes and/ or devices can be set ("Set") and Reports to SCADA system have to be enabled or disabled.

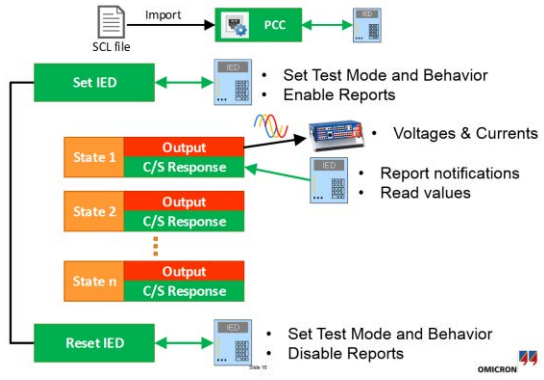

Figure 7 Test sequence

When real-time is not important for that kind of testing, some parts of testing can be done outside the test set, in the Test Universe PC software. The test set is only needed for calculating and injecting the fault values (Figure 8).

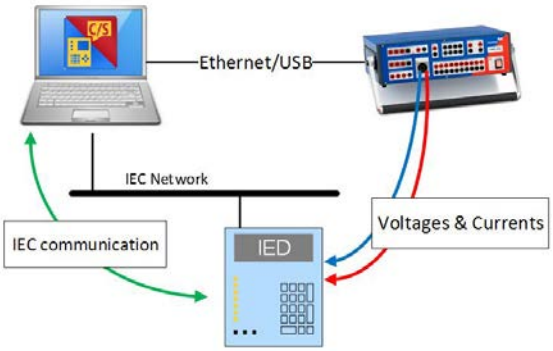

Figure 8 Clients in communication

7.2 Test module IEC 61850 Client/ Server

The steps of testing are collected in a separate test module. Figure 9 shows the usage in Test Universe with its test view, starting with "Set" and enabling the IEC 61850 Reports.

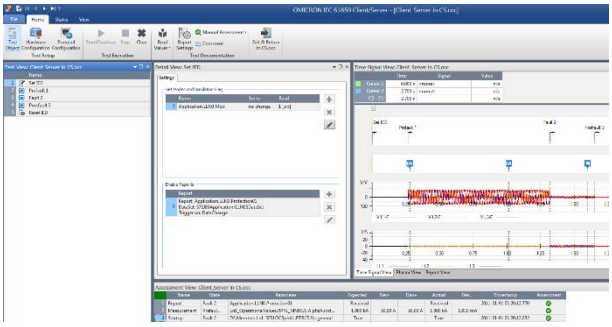

Figure 9 IEC 61850 Client/Server in Test Universe

The next steps are as in conventional protection testing (pre-fault, fault, post fault) - Figure 10.

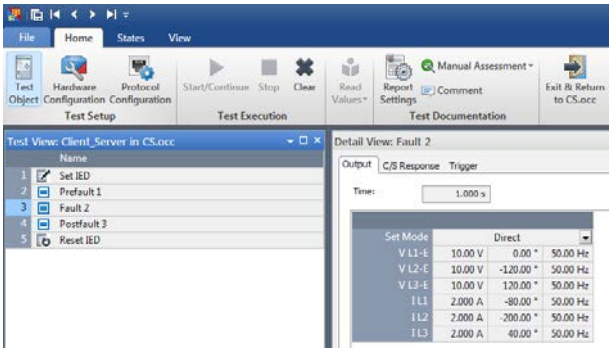

Figure 10 Fault values

In every step the data model, single attributes, entire DataSets and Reports can be accessed and used for assessment (Figure 11).

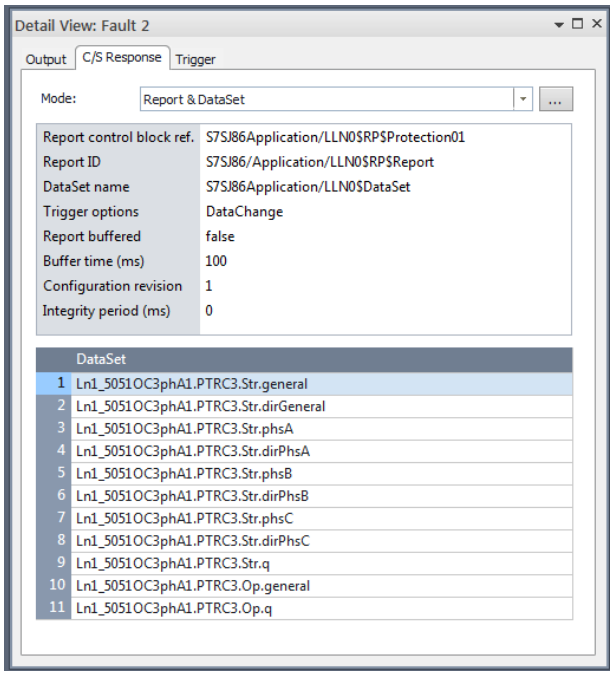

Figure 11 Client/Server response

Figure 12 shows the data model of an IED with a lot of interesting details to be used in protection testing.

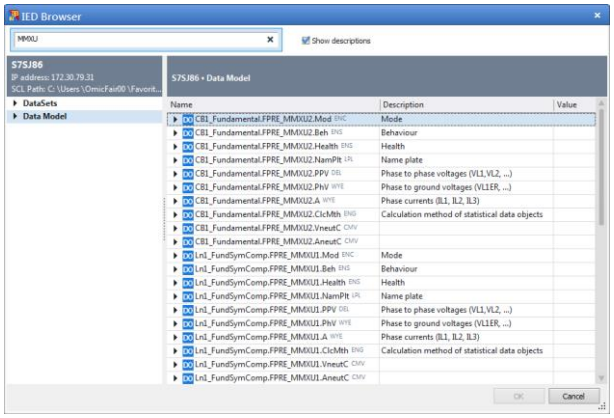

Figure 12 Accessing the data model

The received report can be used for further testing and assessment (Figure 13). This allows the entire chain to be tested, from the process to the SCADA systems. It also allows automated testing of SCADA communication during protection testing.

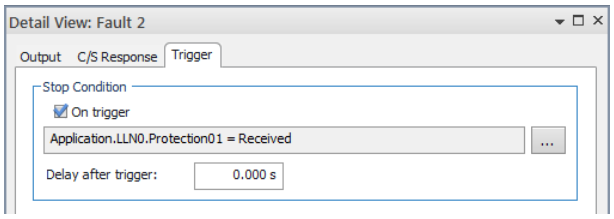

Figure 13 Trigger Report received

Every single operation, every set in the IED will be recorded in a dedicated monitor (Figure 14).

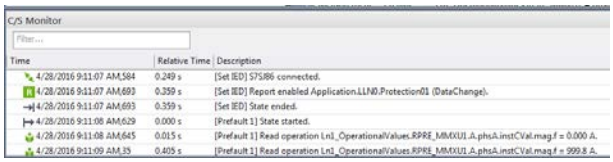

Figure 14 Client/Server monitor

On request, every detail will be recorded in test report of the module and can be embedded in the OCC-file (Figure 15).

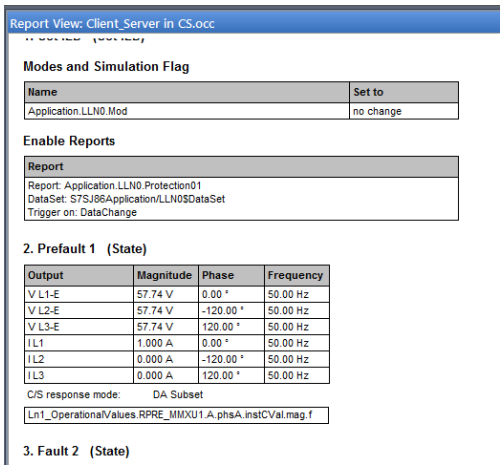

Figure 15 Test report

For any assessment, the content of the IEC 61850 Report can be used (Figure 16).

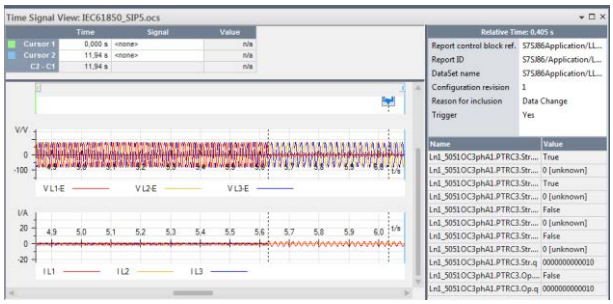

Figure 16 IEC 61850 Report's content

When test is finished, resetting logical nodes and devices is essential. The value used for resetting can be read at the beginning of test. The reset will be documented safely and delivers confidence and safety for utilities and testers (Figure 17).

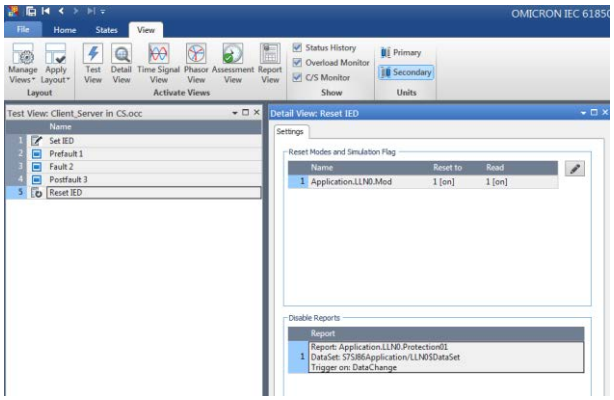

Figure 17 Reset

7.3 New possibilities

The innovative approach presented offers new possibilities for protection testers. Since the IED'S data model contains all information, this could be used for protection testing. Examples:

- Measurement values (Figure 18)
- Binary inputs and outputs (Figure 19)
- Startups
- Trips
- Directions (Figure 20)

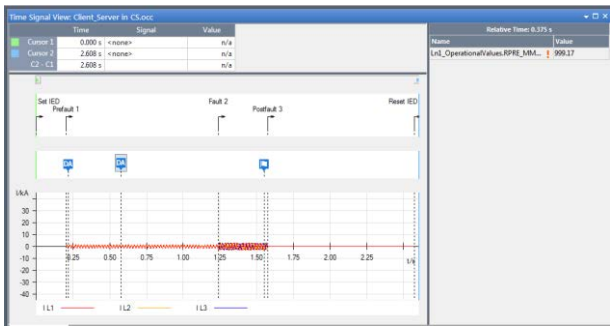

Figure 18 Measurement values

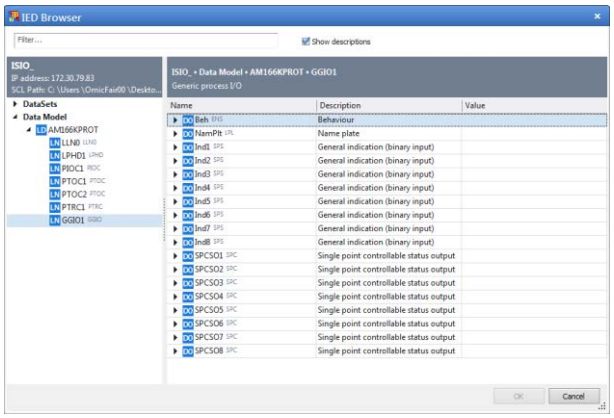

Figure 19 Binary inputs and outputs

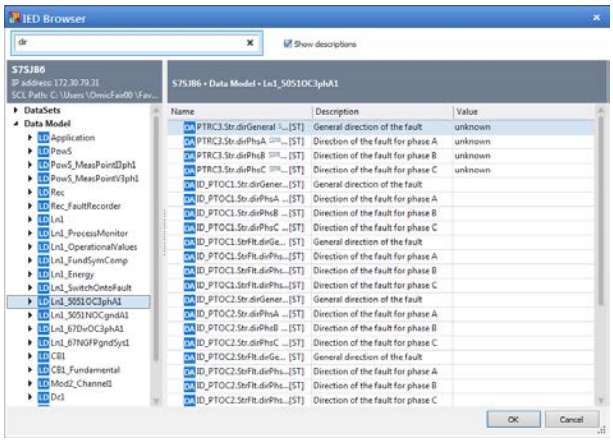

Figure 20 Protection information

Every signal can be used for assessment (Figure 21).

The green check mark indicates successful testing. This allows even those protection testers who are not familiar with IEC 61850 to perform and assess such tests.

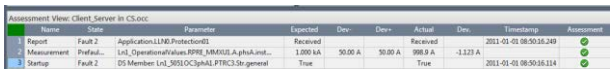

Figure 21 Assessment

8 For the future

IEC 61850 offers the opportunity to handle protection parameters in data model. Even if not every senior protection engineer will like the idea of SCADA guys accessing the protection parameters, this offers new opportunities. Adaptive protection schemes become possible [10] and test-able. New opportunities for supervision, set-actual comparison and setting groups are currently under discussion [11].

Literature

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About the Author

Thomas Schossig was born in Gotha (Germany) in 1970. He studied electrical engineering and power systems at Technical University of Ilmenau and received his master degree (Dipl.-Ing.) in 1998. After this he worked as SCADA engineer at VA TECH SAT GmbH in Waltershausen (Germany) and took the team protection. In 2006 he changed to OMICRON electronics GmbH in Klaus (Austria). As a product manager in power utility communication (PUC) he is a member of standardization group and author of many papers covering IEC 61850 and protection testing.

OMICRON is an international company serving the electrical power industry with innovative testing and diagnostic solutions. The application of OMICRON products allows users to assess the condition of the primary and secondary equipment on their systems with complete confidence. Services offered in the area of consulting, commissioning, testing, diagnosis and training make the product range complete.

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