IEC 61850: ROLE OF CONFORMANCE TESTING IN SUCCESSFUL INTEGRATION

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ABSTRACT

The IEC Standard 61850, Communications Networks and Systems in Substations*, is an internationally recognized data communications suite of protocols for substation and system-wide protective relaying, integration, control, monitoring, metering, and testing. With multivendor installations, developers and users recognize the risk of varying interpretations of such a complex standard. Standard conformance testing and certification by test laboratories, carried out with standardized procedures and tools by experts who are not the designers of the equipment under test, can remove much of the risk and can bring a common understanding of how to implement the communications so that all products work together.*

This paper, focuses on the evolutionary nature of the testing program established by the UCA International Users' Group (UCAIUG) and what the tests can and cannot accomplish. The results from the test activities will be explained. We present a roadmap on how to use the certification process to improve the end-user integration experience. The paper describes additional measures, such as interoperability and functional testing, to traverse this roadmap to interoperable substation installations.

INTRODUCTION

The IEC 61850 Standard, *Communications Networks and Systems in Substations* [1] and its predecessor UCA for Substation Control were conceived by pioneering utility and vendor relaying and substation control engineers who wanted a single standard solution for communications integration. They wanted technical capabilities that were unavailable or unused in existing protocols. The most important technical objectives were:

1. Use self-description and object modeling technology to simplify the integration and configuration process for the user.
2. Dramatically increase the functional capabilities, sophistication and complexity of the integration to meet users' ultimate relaying, control, and enterprise data integration needs.
3. Incorporate robust, very high-speed control communications messaging that can operate among relays and other IEDs to eliminate panel wiring and controls.
4. Map substation functionality to base communications stack layers that are in widespread use, notably in the IT and industrial control world.
5. Focus on substation-oriented communications object development effort that rests on top of a standard application layer.
6. Standardize the protocol for the utility industry worldwide. In this way, users can select products from different vendors and interconnect their communications ports. The products would all exchange the information and control messages as required without creative protocol translation or interfacing by the user.
7. Allow product manufacturers to focus their full efforts on implementing this one protocol suite, rather than supporting several choices.

On the fourth objective, the most vigorous development of IEC 61850 capable products is based on IEC 61850-8-1, which maps the standard object modeling (message format definition) process to the application layer protocol called Machine Messaging Specification (MMS) and from there to message packets on Ethernet networks.

On the sixth objective, note that IEC 61850 is a massive 10-part document comprising detailed statements of what sorts of messages are supported and how they are to be formatted and exchanged among server and client devices in substation protection and control systems. The standard is over 1,700 pages and still growing rapidly, so the probability that two different implementers read every single requirement in the same way is close to zero. It is normal that two separately developed products may work well individually but show interoperating problems when connected together. Therefore, system development must include effective and complete testing and debugging to assure that communications work right when installed in the field.

For IEC 61850, the industry needs an effective process for validating these communications interfaces in structured, fair, neutral test beds with an effective diagnostic capability and a complete script of features and functions for testing. If this process works, then the user will have a much easier time when commissioning individual substations.

TYPES OF COMMUNICATIONS TESTING

In the next section, we will describe an established industry testing program for conformance of products to the IEC 61850 communications standard. The goal of the standardized laboratory testing program is to increase the likelihood that when different types of tested and certified equipment from different manufacturers are connected together, they all interoperate as expected, and the overall system performs as needed.

To have a successful testing program, we need a clear picture of what we are trying to show with each test step, what is possible to accomplish in the end, and what can still go wrong with product communications performance.

In this section we discuss three major categories of communications protocol testing:

- Conformance testing – does the tested device communicate as the standard specifies?
- Interoperability testing – do two or more devices work together on the LAN as expected when they exchange standard IEC 61850 messages?
- Performance or stress testing – does the networked group of devices perform the functions as accurately, reliably, and quickly as the user needs? We evaluate device or system performance specifications, often to establish boundaries of capabilities; results are not specified in the IEC 61850 Standard.

Conformance Testing

The objective of conformance testing is to determine if a relay or IED under test (device under test or DUT) conforms to the specifications of the standard. We do this by exchanging messages between a test system and the DUT. The test system sends a carefully selected array of test messages to the DUT and records the responses of the DUT. Messages are selected to exercise all the features of the DUT communications that the manufacturer claims to offer. The approach for this particular type of IEC 61850 testing is thoroughly specified in IEC 61850 Part 10, Conformance Testing.

From the DUT perspective, the test system acts like the ensemble of devices on a typical LAN to which the DUT might be connected in field service. If the DUT is a server (such as a relay), then the test system behaves as though it is a networked combination of clients (like a substation data concentrator or historian) and other peer servers (like other relays on the LAN).

To run a conformance test, the tester first reviews the design information on the DUT. Along with the product itself and its instruction literature, IEC 61850 specifies the format for the following product feature descriptions:

Protocol Implementation Conformance Statement (PICS) – Summarizes the communication capabilities of the system or device to be tested, as a subset of all that IEC 61850 offers.

Model Implementation Conformance Statement (MICS) – Details the standard data object model elements supported by the system or device.

Protocol Implementation eXtra Information for Testing (PIXIT) – This optional document contains specific information on the communication capabilities that are outside the scope of the IEC 61850 Standard, which the test laboratory needs to know to carry out the test.

The tester creates a test script for the included services and objects, including positive tests (correct messaging behavior and response) and negative tests (behavior in the face of faulty messaging).

We emphasize that it is not practical to test every variation of every message type that could ever be exchanged for the services and objects under test. The possible combinations are nearly infinite. The practical approach is to script a large sample of behavior that has a very high probability of showing any problems. Highly probable does not mean certain—it is always possible to have an implementation bug for some combination of messages and data that does not get tested.

When the test is successfully completed, the laboratory issues a certificate of conformance to the vendor, stating:

- Specific product(s) tested
- Specific services verified
- Date of test version used if the test procedure itself evolves over time.

Note that the certificate just gives the facts of the test. It makes no statement about other similar products from that vendor, product design revisions newer or older than the one tested, or services not tested in an otherwise conformant product. We say more on this critical point in the "Limitations of Testing and Certification" section below.

Interoperability Testing

For interoperability testing, we connect two or more relays and/or IEDs to a LAN and stimulate them to exchange IEC 61850 messages and exercise their interactive behavior.

In theory, if the standard is clear in every detail and all the IEDs have been conformance tested for all relevant services, then we expect the IEDs to interoperate flawlessly, and this testing seems superfluous. If all the IEDs are from the same development team, the interoperation will likely be fine. However, if the test combines IEDs from different manufacturers, or even different development locations of a single manufacturer, there is a chance that some standard specification interpretation differences will arise, especially if the industry conformance testing program is in its early stages or if the standard is vague or silent on some necessary technical issues. As the conformance-testing program matures, it adds checks for issues that have been identified from earlier interoperation test failures or field problems. Also, the interaction may be corrupted by design variables that have not been specified in IEC 61850, such as certain network timing issues. The testing program participants then discover that standard requirements may need to be added for these variables that were initially missed.

Interoperability testing in the laboratory environment is vastly superior to and easier than debugging in the field. The lab testing program focuses on exercising the full range of interactions by a structured testing plan. If interoperating problems are found, the specific cause is much easier to identify using the data capture, diagnostic tools, and test repetition capability available in the lab. The designers of the IEDs will have time to make modifications that correct the interaction problem and maintain conformance to IEC 61850.

While IEC 61850-10 specifies the approach for conformance testing, there is at this time no standard for interoperation testing, nor is there an industry program for interoperability testing like the one we describe for performance testing in the following section “Industry Testing Program for IEC 61850.” Typically, a utility initiating a major IEC 61850 substation project with a new interconnection of IEDs from multiple vendors will commission or request interoperability tests in-house or at an independent laboratory.

Performance or Stress Testing

Beyond the specified interactions, vendors or potential users may need to explore the limits and capabilities of either individual IEDs or interconnected systems to know how much safety margin exists in a demanding new application. For example, IEEE C37.115-2003 describes methods for testing IEC 61850 LAN environments in data storm situations [7]. Consider the simulation of a fault that evolves to include multiple zones of protection in a station, along with breaker failures. Testing can show if the LAN can handle the heavy bursts of GOOSE messages in this stress situation, with all the IED functions and interactions still taking place as necessary.

Performance testing might also evaluate the time needed for a critical control message (such as a GOOSE backup trip command sent across the LAN to several relays) from the initiating event to trip outputs from the subscriber relays.

The IEC 61850 Standard contains no separate performance testing section. However, note that for certain critical behavior parameters, Part 10 does require that this performance parameter be tested. For example, an IED supporting the GOOSE or GSSE subscriber service must be tested for time latency from receipt of the GOOSE message to the physical control action output. The same is true for latency in implementing client control object requests. Part 10 describes methodology for checking accuracy of time synchronization using the SNTP time synchronization service specified in IEC 61850, if this service is supported in the DUT.

LIMITATIONS OF TESTING AND CERTIFICATION

To support creation of a practical and effective industry testing program based on IEC 61850-10, UCAIUG commissioned a Testing Subcommittee that oversees the conformance testing activities. This includes product certification definitions and approach, certification of test laboratories that are qualified to conduct the tests, and handling the first-tier resolution of problems in the testing process or with interpretation of the IEC 61850 standard.

Gap Between Conformance and Interoperability Test Results

In describing the types of tests, we explained that the goal of conformance testing and certification is to assure interoperability. As a practical matter, the industry testing program can claim that it is close to this objective now, but can only approach it asymptotically. We stated that interoperability problems still show up between products that have conformance certificates. It is critical that these problems are reported to the UCAIUG help desk, or by other channels into the process of handling TISSUES. Then, the GoE digs to determine exactly how the conformance test failed to find the interoperability problem. Ultimately, they solve this problem with green (resolved) TISSUES, updates to the standard, and/or changes to the conformance test script. As these TISSUES are resolved, the standard and the conformance test process both grow continuously stronger. As time passes and we accumulate this experience, the conformance test gets closer to the ideal of assuring interoperability.

Meaning of a Conformance Test

We stated that the certificate lists only the facts of the test, the exact product tested, for which IEC 61850 services, on a particular date. When a user later purchases a product, it is likely that the delivered product is somehow a little different from the one that was certified. Does this invalidate the test result? It helps to view the certificate as a point on a graph with axes of time of the test (test version), products from across a line of products from that manufacturer, and product feature variations or enhancements as compared to the tested product. If we can’t have a new test for every point on the graph, we visualize a sphere around a successful conformance test. If another product from the same vendor is within the sphere of the one that has a test certificate, the user should look at specific differences and decide if the product being purchased is close enough to be presumed conformant.

RESULTS FROM CONFORMANCE TESTING SO FAR

After being accredited by the UCAIUG KEMA started its IEC 61850 certification program in 2005. Before accreditation a pilot test had to show the applicability of the test procedures and the test tools. The results were reviewed and accepted by the testing subcommittee of the UCAIUG. Until now KEMA issued over 25 certificates from 8 manufacturers, most European.

The certification effort resulted in the generation of several Technical Issues (TISSUES) to the UCAIUG to solve ambiguities in the standard. Not only the standard itself and the IEC 61850 implementations under test were improved, but also the conformance test procedures. This quality cycle is important for the evolution of the standard and its related procedures.

The time to perform a complete conformance test run on all available IEC 61850 functions has been reduced to 4 days because the test tools have been improved and less discussion items are left. Further automation of the test simulator will further reduce the cost of conformance testing.

An important issue raised in this first phase of IEC 61850 testing was the handling of "device platforms" i.e. devices with different functionality but using the same software platform including the IEC 61850 communication software. Some vendors argued that since the communication software was tested not all devices should be object to a separate conformance test. The UCAIUG testing subcommittee decided however that every device can only get a certificate when the device itself and the specific IEC 61850 configuration (ICD file) are used for the test. The certificate should also identify the ICD file used and end-users should have access to this file in order to check which configuration was tested.

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