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TECHNICAL REPORT

colour inside

Communication networks and systems for power utility automation – Part 10-3: Functional testing of IEC 61850 systems

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COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 10-3: Functional testing of IEC 61850 systems

FOREWORD

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IEC TR 61850-10-3, which is a Technical Report, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
57/2199/DTR	57/2328/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

A list of all parts in the IEC 61850 series, published under the general title *Communication networks and systems for power utility automation*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

The growing success of the IEC 61850 series calls for guidelines for testing of substations implementing this standard. This Technical Report aims at producing a practical guide for protection, automation and control (PAC) engineers on best practise for testing of the latest amended IEC 61850 based devices and systems.

Since the release of the first edition of the IEC 61850 standard in 2002-2005 thousands of substations have been built making use of the new multi-part standard. Most of those systems are more integrated and complex than the previously deployed, making use of multi-function capable IEDs and the rich feature set of IEC 61850. Especially the sending and receiving of protection trips via GOOSE messaging control commands/indications, monitoring and time synchronisation information over the same shared equipment or network will need to drive changes to existing test methods and practices as many of the traditional test boundaries have changed.

Despite the large number of commissioned IEC 61850 substations, considerable uncertainty among end-users (system integrators and power utilities) regarding the correct testing procedures still exists. Devices implemented according to the first edition of the standard also utilized a limited part of the test related functionality in the standard. Much of the functionality included in IEC 61850 to allow efficient, functional oriented testing has been clarified and extended in the second edition of IEC 61850-6, IEC 61850-7-1 to IEC 61850-7-4, IEC 61850-8-1 and IEC 61850-9-2. Therefore, there is a need to help the industry by describing the methods and principles for testing the IEC 61850 based applications.

This Technical Report provides insight into the changing requirements and practice of testing following the introduction of IEC 61850 based devices and systems. One example is the disappearance of so-called 'hardwired' connections between substation automation devices. These connections are replaced by communication networks and this means that traditional simulation and isolation of signals for the purpose of testing is no longer possible.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 10-3: Functional testing of IEC 61850 systems

1 Scope

This part of IEC 61850, which is a technical report, is applicable to testing of applications within substations. It is intended to give practical guidelines to perform the stages of quality assurance defined in IEC 61850-4:2011. However, while the quality assurance in that document begins with the IED manufacturer development stage and focuses on the role of the system integrator this document focuses on end-user requirement fulfilment.

The report may be useful to users applying IEC 61850 to other domains, however testing of IEC 61850 systems outside the substation domain is not within the scope of this document.

This document describes:

- A methodical approach to the verification and validation of a substation solution
- The use of IEC 61850 resources for testing in Edition 2.1
- Recommended testing practices for different use cases
- Definition of the process for testing of IEC 61850 based devices and systems using communications instead of hard wired system interfaces (ex. GOOSE and SV instead of hardwired interfaces)
- Use cases related to protection and control functions verification and testing

This document does not cover the conformance testing of devices according to IEC 61850-10 or methodologies for testing of abstract device independent functions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61850-4:2011, *Communication networks and systems for power utility automation - Part 4: System and project management*

IEC 61850-6:2009, *Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs*
IEC 61850-6:2009/AMD1:2018
IEC 61850-6:2009/AMD1:2018

IEC 61850-7-1:2011, *Communication networks and systems for power utility automation - Part 7-1: Basic communication structure - Principles and models*
IEC 61850-7-1:2011/AMD1:2020

IEC 61850-7-2:2010, *Communication networks and systems for power utility automation - Part 7-2: Basic information and communication structure - Abstract communication service interface (ACSI)*
IEC 61850-7-2:2010/AMD1:2020

IEC 61850-7-3:2010, *Communication networks and systems for power utility automation - Part 7-3: Basic communication structure - Common data classes*
IEC 61850-7-3:2010/AMD1:2020

IEC 61850-7-4:2010, *Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data object classes*
IEC 61850-7-4:2010/AMD1:2020

IEC 61850-8-1:2011, *Communication networks and systems for power utility automation - Part 8-1: Specific communication service mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3*
IEC 61850-8-1:2011/AMD1:2020

IEC 61850-9-2:2011, *Communication networks and systems for power utility automation - Part 9-2: Specific communication service mapping (SCSM) - Sampled values over ISO/IEC 8802-3*
IEC 61850-9-2:2011/AMD1:2020

IEC 61850-10:2012, *Communication networks and systems for power utility automation - Part 10: Conformance testing*

IEC 81346-2, *Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations - Part 2: Classification of objects and codes for classes*

3 Terms, definitions, abbreviated terms and acronyms

3.1 Terms and definitions

3.1.1 Testing types

3.1.1.1
acceptance tests
tests which serve to verify if an IED or a scheme meets the customer requirements

Note 1 to entry: This could include a specific FAT if it is required by the customer.

3.1.1.2
commissioning tests
test on an item carried out on site, to prove that it is correctly installed and can operate correctly

Note 1 to entry: The commissioning phase is carried out on site (in the substation) when the installation phase is complete. These tests are performed to ensure the safe and reliable operation of the system with associated substation interfaces. The commissioning phase is a global operation which follows the installation and runs until the energization, load tests and adjustments are completed.

[SOURCE: IEC 60050-151:2001, 151-16-24]

3.1.1.3
conformance tests
first of the functional tests of the components of an integrated substation automation system (SAS)

Note 1 to entry: Every IED or Device Under Test (DUT) which belongs to the SAS, is tested. The conformance tests are performed to show that the IED are compliant to requirements relative to environment, data model, communication and functional standards. These tests can be performed by a vendor or by an independent authority who certify test results.

3.1.1.4
Factory Acceptance Tests (FAT) of schemes and systems
customer agreed functional tests of the specifically manufactured system or its parts, using the parameter set for the planned application

Note 1 to entry: This test is typically performed in the factory of the system integrator by the use of process simulating test equipment.

[SOURCE: IEC 61850-4:2011 3.20]

3.1.1.5
installation tests
tests carried out by the contractor after installation in order to verify if the system is ready to be commissioned

3.1.1.6
interoperability tests
tests applied to an assembly of IEDs of the same or different vendors

Note 1 to entry: They shall demonstrate that these IEDs, when interconnected by a proper communication system, may operate together, sharing information and performing their functions in a secure way and with specified level of performance. They should be performed with the customer acceptance during system development and factory acceptance tests.

3.1.1.7
Communication Interface tests:
tests applied to two function elements of a distributed function interfacing over a substation communication interface in order to evaluate the impact of the communications architecture and traffic on the performance of the distributed function or sub function

3.1.1.8
Maintenance Tests
all testing activities which occur after the IED or PAC scheme has been put into service

3.1.1.9
Site Acceptance Tests (SAT)
tests consisting of the verification of each data and control point and the correct functionality inside the automation system and between the automation system and its operating environment at the whole installed plant by use of the final parameter set

Note 1 to entry: The SAT is a precondition for the automation system being put into operation.

[SOURCE: IEC 61850-4:2011 3.21]

3.1.1.10
End-to-End test
End-to-end testing is used to ensure that the integrated components of an application function as expected – from the input from the process to the output to the processTesting Methods

3.1.1.11
black-box testing
testing based upon the requirements with the function or system treated as a "black-box" when the internal workings of the system are unknown

Note 1 to entry: In black-box testing the system is given a stimulus (input) and if the result (output) is what was expected, then the test passes. No consideration is given to how the process was completed.

3.1.1.12
bottom-up testing
testing which starts with the function elements and works upwards

Note 1 to entry: It involves testing the function elements at the lower levels in the hierarchy, and then working up the hierarchy of sub-functions until the final function is tested.

3.1.1.13
closed-loop testing
testing characterized by the fact that the output from the device or system under test is looped back and affects the next stage of the simulation

3.1.1.14
local testing
process where all simulation tasks, the assessment of the tested device performance and the documentation of the results from the test are performed by the tester at the site of the tested devices or system using mobile test equipment

3.1.1.15
manual testing
manual testing is the process where most of the simulation tasks, the assessment of the tested device performance and the documentation of the results from the test are performed manually by the tester.

3.1.1.16
negative testing
testing process where the system validated against the invalid input data

Note 1 to entry: A negative test checks if a application behaves as expected with its negative inputs.

3.1.1.17
positive testing
testing process where the system is validated against the valid input data

Note 1 to entry: In this testing the tester always checks for only valid set of values and checks if an application behaves as expected with its expected inputs. The main intention of this testing is to check whether the software application is not showing an error when not supposed to and showing an error when supposed to.

3.1.1.18
remote testing
process where all simulation tasks, the assessment of the tested device performance and the documentation of the results from the test are performed by the tester from a remote location over a communications link to the site of the tested devices or system using test equipment permanently installed at the site

3.1.1.19
top-down testing
testing method which tests the high levels of a system before testing its detailed functional components

Note 1 to entry: Testing starts with the overall function test and goes down the hierarchy testing sub-functions until the function elements at the bottom of the hierarchy are tested.

3.1.1.20
white-box testing
testing based upon the requirements with the internal workings of the function or system known

Note 1 to entry: In white-box testing the system is given a stimulus (input) and if the result (output) is what was expected, then the test passes, however consideration is also given to how the internal elements of the function worked.

3.2 Abbreviated terms and acronyms

The following abbreviations and acronyms are used in this document:

BFP: Breaker Failure Protection

GOOSE: Generic Object-Oriented Substation Event

IED: Intelligent Electronic Device

PAC: Protection, Automation and Control

PACS: Protection, Automation and Control System

PUAS: Power Utility Automation System

SAS: Substation Automation System

SBO: Select Before Operate

4 Testing-related features in IEC 61850

4.1 General

Functions in Power Utility Automation Systems (PUAS) are not performed by a single function element (Logical Node, LN), but implemented through an interaction of multiple Logical Nodes, each contributing its specific functionality. The different functions may be accommodated in different logical devices, even hosted by different physical devices, which imposes the usage of agreed-upon basics:

- standardized function interfaces content and behavior (from a communicational perspective) through LN,
- evaluation of the information received in a predictable manner,
- exchange of information of a common semantic.

While during normal operation the information flow is defined by the communication configuration, testing requires a user interference into this scheme prior to the test, to avoid inadvertent reactions onto information created during testing. Disconnecting of a device under test is not the appropriate way of doing, moreover as this device may require information from the other components of the system to perform its function.

The above mentioned basics of IEC 61850 are used for testing purposes to functionally isolate a definable structure of functions in a system environment without disturbing the components in normal operation. The following chapters will present the principles of how functional isolation is achieved.

4.2 Test features defined in IEC 61850

4.2.1 General

Some of the features described in this subclause are not mandatory and therefore may not be available in all IEDs which conform to IEC 61850. It is in the responsibility of the user to re-establish operational conditions in the device under test after having finalized the tests.

It shall be well understood which testing-related features defined in IEC 61850 and described in the following clauses are implemented in the devices used in the substation. The user shall develop procedures that will use the testing features for virtual isolation of the different active protection, automation and control devices during the testing in a live substation. This includes resetting of all interventions made onto controllable elements for testing purposes as well as clearing of buffers, logs, counters if applicable. Considering the possibility that the actual operational conditions may include settings which deviate from the as-built status, manipulating a device under test requires careful considerations. The user is welcome to be supported by tools during this task.