IEC TR 61850-10-3

Edition 1.0 2022-02

TECHNICAL REPORT

colour inside

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.200

ISBN 978-2-8322-1075-7

Warning! Make sure that you obtained this publication from an authorized distributor.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

FOREWORD 6
INTRODUCTION 8
1 Scope 9
2 Normative references 9
3 Terms, definitions, abbreviated terms and acronyms 10
3.1 Terms and definitions 10
3.1.1 Testing types 10
3.2 Abbreviated terms and acronyms 13
4 Testing-related features in IEC 61850 13
4.1 General 13
4.2 Test features defined in IEC 61850 13
4.2.1 General 13
4.2.2 Simulation based testing in substations under normal operation 14
4.2.3 Mode and behavior of functions 16
4.2.4 Logical devices management hierarchy 18
4.2.5 Processing of information 21
4.2.6 Blocking of information 23
4.2.7 Changing the information source (input reference) for testing 25
4.2.8 Substitution of information 26
4.2.9 Use of testing related features 26
5 Testing of Protection, Automation and Control Devices and Systems 28
5.1 General 28
5.2 Test system requirements 29
6 Test methods, practices and needs 30
6.1 General 30
6.2 Testing requirements for IEC 61850 based systems 30
6.3 The V-Model 31
6.3.1 General 31
6.3.2 Unit testing 31
6.3.3 Integration or subsystem testing 32
6.3.4 System testing 32
7 Testing use cases 32
7.1 General 32
7.2 Distributed Breaker Failure Protection Scheme 33
7.2.1 General 33
7.2.2 Use case description 33
7.2.3 Breaker Failure Protection Scheme Interfaces 37
7.3 Distributed Select Before Operate 38
7.3.1 General 38
7.3.2 Select Before Operate Scheme Components 38
7.3.3 Select Before Operate Scheme Interfaces 41
7.3.4 Select Before Operate Scheme Behavior 42
7.3.5 Single line diagram 44
8 Test sequences for the use cases 46
8.1 Breaker failure protection testing 46
8.1.1 General 46

8.1.2 Normal sequence 46
8.1.3 Fault sequence 47
8.1.4 Setting the test mode and the simulation state of the line protection function 48
8.1.5 Setting the test mode and the simulation state of the breaker failure function 49
8.1.6 Setting the test mode and the simulation state of the breaker function 50
8.1.7 Setting the test mode of the bus bar protection function 51
8.1.8 Testing the line protection IED 52
8.1.9 Testing the breaker failure IED A interface 54
8.1.10 Testing the breaker IED A interface 56
8.1.11 Testing the breaker failure function End-to-End 58
8.2 Select Before Operate Scheme Testing 61
8.2.1 General 61
8.2.2 Unit testing 61
8.2.3 Subsystem (Interface) testing 69
8.2.4 System (End-to-End) testing 70
9 Modeling requirements related to testing in IEC 61850 75
10 Object modeling of test systems 75
11 Engineering of the test system 77
12 Impact of the testing system on the substation LAN traffic 77
13 Functional and cyber security considerations 78
14 Remote testing 79
Annex A (informative) Introduction to the used UML notation 80
A.1 General 80
A.2 Component diagram 80
A.3 Sequence diagram 80
Annex B (informative) Requirements for extensions 83
B.1 Requirements for extensions in IEC 61850-7-1 83
B.2 Requirements for extensions in IEC 61850-7-3 83
B.3 Requirements for extensions in IEC 61850-7-4 84

Figure 1 – Data used for receiving simulation signals (IEC 61850-7-1 Fig. 40) 15
Figure 2 – IED with multiple process interfaces 15
Figure 3 – Processing of test signals (Part 7-1, Figure 42) 18
Figure 4 – Nesting of logical devices representing the functional hierarchy 19
Figure 5 – Use of GrRef in the modelling of nested logical devices 20
Figure 6 – Management hierarchy of nested logical devices 20
Figure 7 – Processing of the data by a LN depending on the LN behaviour and the quality attribute of input data 22
Figure 8 – Data used for logical node inputs/outputs blocking: IEC 61850-7-1:2011, Figure 39) 24
Figure 9 – Example of input signals used for testing (IEC 61850-7-1:2011, Figure 41) 25
Figure 10 – Use of InRef for LN test 26
Figure 11 – Quality assurance stages of IEC 61850-4:2011 28
Figure 12 – Testing stages for site acceptance test as defined in IEC 61850-4:2011 29
Figure 13 – V-Model used for system engineering 31

Figure 14 – Single line diagram according to IEC 81346 34
Figure 15 – System components (Static) 36
Figure 16 – System components (Dynamic) 37
Figure 17 – Select Before Operate Scheme 39
Figure 18 – Component decomposition of Select Before Operate Scheme 40
Figure 19 – Allocated interfaces for Select Before Operate Scheme – SLD 41
Figure 20 – Allocated interfaces for Select Before Operate Scheme 42
Figure 21 – Simplified SBO scheme behaviour 44
Figure 22 – Single line diagram 45
Figure 23 – Normal sequence 47
Figure 24 – Fault sequence 48
Figure 25 – Line protection function: Setting the mode and the simulation state 49
Figure 26 – Breaker failure function: Setting the mode and the simulation state 50
Figure 27 – Breaker function: Setting the mode and the simulation state 51
Figure 28 – Bus bar protection function: Setting the mode 51
Figure 29 – Line protection IED A interface testing 53
Figure 30 – Interfaces between test system and tested IED for testing of line protection function 54
Figure 31 – Breaker failure IED A interface testing 55
Figure 32 – Interfaces between test system and tested IED for testing of breaker failure protection function 56
Figure 33 – Breaker IED A interface testing 57
Figure 34 – Interfaces between test system and tested IED for testing of breaker control function 58
Figure 35 – Breaker failure function end to end testing 60
Figure 36 – Interfaces between test system and tested IEDs for End-to-End testing of breaker failure protection scheme 61
Figure 37 – Unit test of TVTR LN – simplified 62
Figure 38 – Unit test of TVTR LN 63
Figure 39 – Unit test of XCBR LN – Scenario 1 – simplified 64
Figure 40 – Unit test of XCBR LN – Scenario 1 66
Figure 41 – Unit test of XCBR LN – Scenario 2 – simplified 67
Figure 42 – Unit test of XCBR LN – Scenario 2 68
Figure 43 – Interface test of CSWI – XCBR LNs 70
Figure 44 – End-to-end test of SBO scheme 72
Figure 45 – End-to-end test (positive) 73
Figure 46 – End to end test (negative #1) 74
Figure 47 – End to end test (negative #2) 74
Figure 48 – End to end test (negative #3) 75
Figure 49 – Simplified object model of test device as an IED Simulator 76
Figure 50 – Simplified object model of test device as generic Simulator 76
Figure 51 – Testing of transformer differential protection 78
Figure 52 – Remote test system 79
Figure A.1 – Example of a component diagram 80

Figure A.2 – Sequence diagram example 81

Table 1 – LD/LN Mode/Beh inheritance 17
Table 2 – Table A.2 of IEC 61850-7-4:2010/AMD1:2020, Annex A summarizes the processing principles 23
Table 3 – Applicable modes for different types of tests 27
Table A.1 – Description of the component diagram UML elements 80
Table A.2 – Description of UML elements in a sequence diagram 82
Table B.1 –Examples of accuracy attributes 84

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 10-3: Functional testing of IEC 61850 systems

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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*