



BSI Standards Publication

Communication networks and systems for power utility automation

Part 10-3: Functional testing of IEC 61850 systems

National foreword

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TECHNICAL REPORT



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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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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.....	

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 XCBB LN – Scenario 1 – simplified	64
Figure 40 – Unit test of XCBB LN – Scenario 1	66
Figure 41 – Unit test of XCBB LN – Scenario 2 – simplified	67
Figure 42 – Unit test of XCBB LN – Scenario 2	68
Figure 43 – Interface test of CSWI – XCBB 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

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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.

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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.

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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 process

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.

4.2.2 Simulation based testing in substations under normal operation

Simulation in the context of IEC 61850 is the capability of a test device to send messages with a "simulation" flag activated in parallel to the real message to support the distinction between the actual messages from the equipment in the live substation and the messages from devices used for testing purposes. It is NOT related to a generic simulation of the process. It is also the ability of the subscribing device to process simulated messages.

At the IED¹ level the option to set the logical node LPHD data attribute Sim.stVal to TRUE or FALSE allows the IED to select the multicast signals that will be processed. In order to test an IED, Sim.stVal is set to TEST. The test device shall inject GOOSE and/or SV messages with the simulation flag in the header set to TRUE.

Figure 1 shows IED1 receiving simultaneously two similar GOOSE messages (GOOSE 1). The GOOSE message from the test simulation device has its message header simulation bit set to TRUE while the other GOOSE 1 message coming from the configured nominal source has its simulation bit set to FALSE. The IED1 with its physical device logical node LPHD1 data Sim.stVal also set to TRUE will listen for messages from the test devices with the Simulation bit set to TRUE and will process only these GOOSE 1 message after the first such message is received from the test device. If the data Sim.stVal is set to FALSE it will process the GOOSE 1 message from the actual device that has the simulation bit set to FALSE.

While LPHD1 data Sim.stVal remains TRUE, two other GOOSE messages from actual devices, GOOSE 2 and GOOSE 3, with simulation bits FALSE will still be processed according to IEC 61850 as shown in Figure 1 as there are no other GOOSE 2 or GOOSE 3 messages on the network that have the simulation bit set to TRUE. As soon as there is a GOOSE 2 or GOOSE 3 that has the simulation bit set to TRUE, the device will subscribe to this/these GOOSE.

NOTE 1 Data flow of signals using client/server communication channels to the IED are not affected by the simulation option bit of LPHD.

NOTE 2 Simulation status is not propagated to the output of the function using simulated streams, i.e. downstream treatment will not have any means to discriminate between a simulated output and a normal one.

NOTE 3 If LSVS.SimSt is true, subscribed SV messages with the simulation bit set are being received and accepted.

NOTE 4 If LGOS.SimSt is true, subscribed GOOSE messages with the simulation bit set are being received and accepted.

The simulation is thus not completely equivalent to the use of a "test handle" diverting all input data associated to a conventional IED since not all input signals systematically come from the test tool. Also, when designing the test cases and scenarios, the effects of GOOSE coming from the system under operation shall be taken into account. Depending on the test aim, it might be preferable to combine the use of LPHD.Sim and the test mode.

¹ In this subclause an IED refers to a LD including a LPHD LN, i.e it will affect also all children LDs in case of nested LDs to the concerned LD.

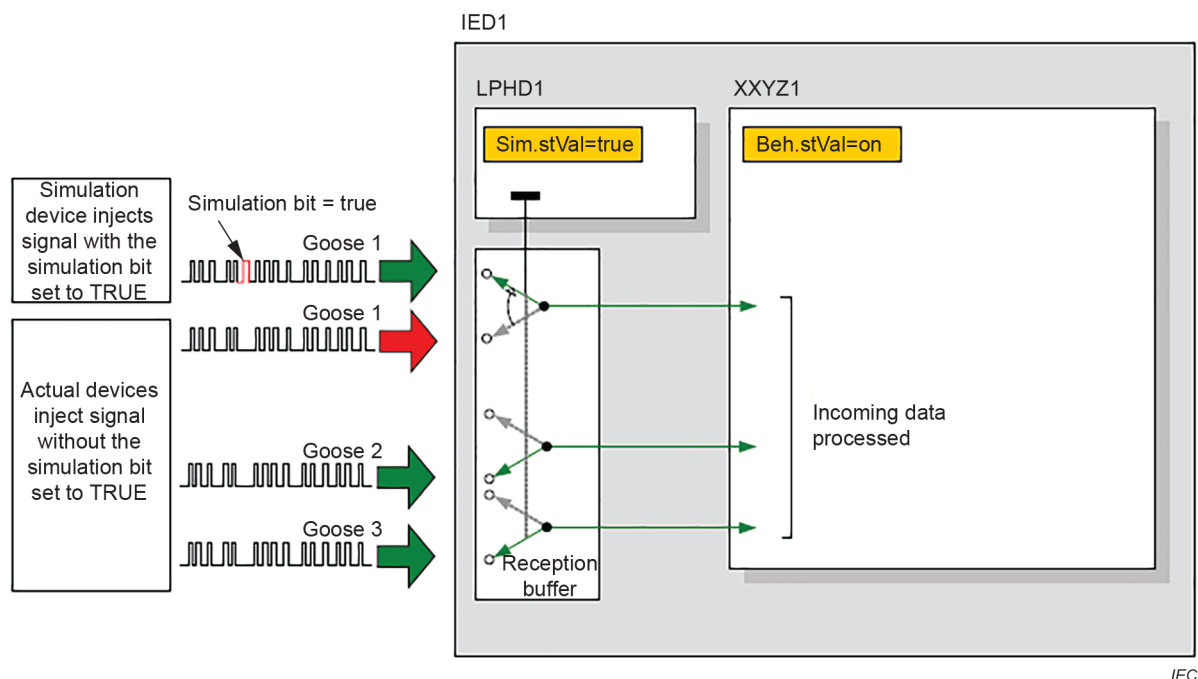


Figure 1 – Data used for receiving simulation signals (IEC 61850-7-1 Fig. 40)

Simulation is applicable in the LPHD at the level of the Physical Device and defines the processing of the data by the communication processor of the LD(s) "connected to²" the Physical Device. There shall be one subscription per later simulation stream. If different logical devices need to process different simulated streams (for example of 1 1/2 breaker) then more than one subscription may be required to allow the later independent testing using simulation.

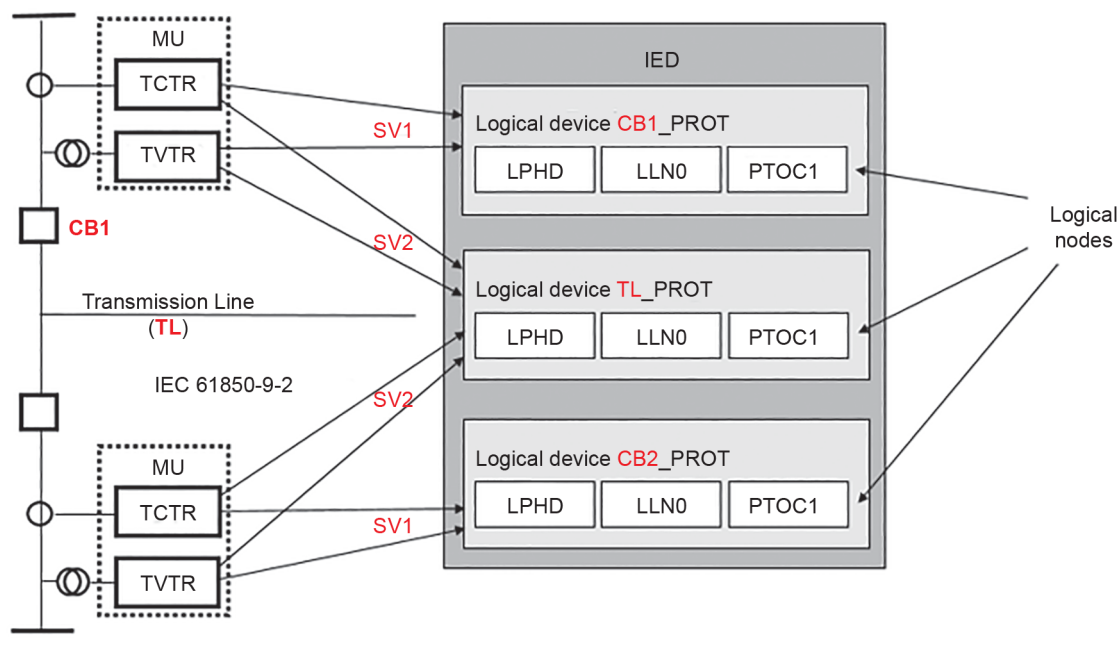


Figure 2 – IED with multiple process interfaces

² LDs may be nested and refer to a « root » LD hosting the LPHD as explained in 4.2.3.

Figure 2 gives an example of the use of multifunctional IED for the transmission line protection in a double breaker configuration, but also applies to breaker-and-a-half or ring bus.

In this case, a single IED requires separate interfaces with the merging units on each of the individual breakers (CB1 and CB2). If we are to test for example a PTOC function element protecting CB1, we will need only sampled values simulation for CB1.

If we are to test a PTOC function element protecting CB2, we will need only sampled values simulation for CB2.

Remember that the processing of simulated values starts only after receiving the first message with the Simulation parameter set to TRUE.

In order to use the simulation flag, LPHD.Sim of the receiving Physical Device must adopt the value "TRUE" **and** the simulation bit in the message received from the test device also must be "TRUE".

However, the mixing of sampled values coming from the actual process (the MU of CB2) and from a test device simulating sampled values from the MU of CB1 creates a problem from the testing point of view due to the fact that this is not a fully controlled test environment. Because of that in case of maintenance testing in an energized substation all logical nodes that are using sampled values from both CB1 and CB2 merging units should be in test mode before the start of the simulation. This can be solved by CB1.MU and CB2.MU sending two streams (SV1 and SV2) of sampled values each. Thus CB1.MU stream SV1 can be simulated for LDevice CB1, while TL is using the real value of CB1.MU stream SV2.

4.2.3 Mode and behavior of functions

In IEC 61850, each function, represented by a Logical Node or a Logical Device, can adopt one of five different modes resulting in five different functional and communicational behaviors (cf. IEC 61850-7-4:2010, Annex A):

on, blocked, test, test/blocked, off

If the LN behavior is reported as 'on', the application of a function is operative, all communicating features are in service.

If the LN behavior is reported as 'blocked', the LN behavior is almost identical to 'on' with only one difference depicted below:

The featured difference between the 'on' and the 'blocked' can only be used by functions which have a direct interaction with the process (i.e. no other intermediate LN). For these boundary Logical Nodes the outputs through contacts or analogue ports can be blocked. This means that these outputs are not changed for the duration of the blocking. All communicating features are in service.

Testing shall not impact other functions in normal operation. Therefore a function which is set to 'test' is operative, but propagates the testing information downstream by formally indicating information as being produced under test conditions. Details are provided further in the document.

The output to the process of a function in 'test' can be blocked in a similar way to 'blocked' using the 'test/blocked' behavior, blocking the outputs contacts or analogue ports. The application indicates information as being produced under test conditions and it reacts on control commands with a test flag set.

A function can be set to 'off', which disables its application. As the application does not work, it neither processes inputs nor produces physical outputs, communication output is provided with data quality 'invalid', except Mod, Beh and Health. Control commands from a client are rejected with negative responses, except Mod, in case it is controllable.

The behaviour of a function is controlled jointly by its superior hierarchical level as well as through its controllable object 'Mod'. To reach a definite behavior among of these two access variants, the states are ordered by priority, where 'off' has priority over 'test' which has priority over 'on' (cf. Table 1, Example: If the superior Logical Device is set to 'test', Logical Nodes or nested Logical Devices on a lower hierarchical level may only be varied into 'test/blocked' behavior or switched 'off', never be set to 'on'.

Table 1 – LD/LN Mode/Beh inheritance

LNMode or nested LDMode XXXX.Mod	LDMode LLN0.Mod	LNBeh (read only) XXXX.Beh
on	on	on
on	blocked	blocked
on	test	test
on	test/blocked	test/blocked
on	off	off
blocked	on	blocked
blocked	blocked	blocked
blocked	test	test/blocked
blocked	test/blocked	test/blocked
blocked	off	off
test	on	test
test	blocked	test/blocked
test	test	test
test	test/blocked	test/blocked
test	off	off
test/blocked	on	test/blocked
test/blocked	blocked	test/blocked
test/blocked	test	test/blocked
test/blocked	test/blocked	test/blocked
test/blocked	off	off
off	on	off
off	blocked	off
off	test	off
off	test/blocked	off
off	off	off

Regardless of the status of a LN, the communication service to control its behavior through its Mod is always in service, even in 'off' status.

For testing purposes, Mod shall be set to TEST; to allow "processing as valid" of a control service command with a test service parameter set to TRUE or a GOOSE data signal with q.test service parameter value of TRUE as shown in Figure 3. Subclause 4.2.4 provides an insight into the processing of information specific for the states of a function.

A command with test service parameter value of FALSE will not be processed if the receiving element is in test mode. When Mod is set to test-blocked it will behave as in TEST but the result of the processed reactions will not be issued as output data to the process. IEC 61850-7-4:2010, Annex A, cf. Table 2 provides a detailed explanation of the behavior for various settings of the data object Mod.

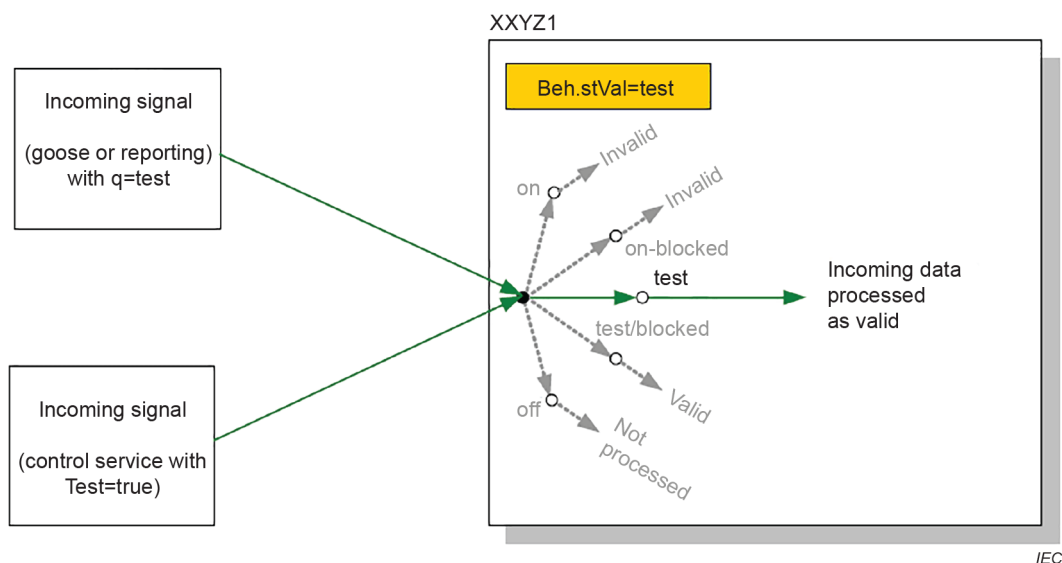


Figure 3 – Processing of test signals (Part 7-1, Figure 42)

4.2.4 Logical devices management hierarchy

The management of logical nodes according to Edition 2 of IEC 61850 is based on the functional hierarchy represented by the nesting of logical devices. Logical devices which offer ways of grouping functions may be used to represent a group of typical automation, protection or other functions. The functions generally rely on sets of function elements represented by logical nodes in the IEC 61850 object model. The logical nodes are contained and managed in logical devices.

It is important to note that LDs offer more than grouping functions, they also offer ways to manage general common properties (such as the control authority) and behaviours (as explained above through Mod/Beh). Nesting LDs offers then ways to "propagate" these common properties and behavior down to all elements of the hierarchy.

The following text illustrates how this can be used in a concrete example.

In a multifunctional protection IED we typically have several main function types:

- Protection
- Automation
- Control
- Measurements
- Recording
- Condition monitoring
- Other

In this example, we assume that specialized LD are used to reflect these function types, i.e. one LD will be used for each of this function types, offering ways to share some common properties and behavior, as if they were in different physical entities.

Depending on the type of protection IED, each function may contain several sub-function types. For example, in a distribution feeder protection IED we may have:

- Overcurrent protection
- Overvoltage protection
- Underfrequency protection

Then we assume that specialized LD are used to reflect these sub-function types, i.e. one LD will be used for each of this sub-function types, offering ways to share some common properties and behavior. Nesting these with the root LN PROT enables dispatching common properties and behavior set at the root level down to each of these LDs.

Figure 4 shows such an example of a protection logical device PROT which contains a nested logical device ocp, representing the overcurrent protection sub-function. PROT is called the "root" logical device. The overcurrent LD (LD ocp) is even further broken down into two more logical devices – gnd and phs, which accordingly represent the ground and phase overcurrent protection sub-functions.

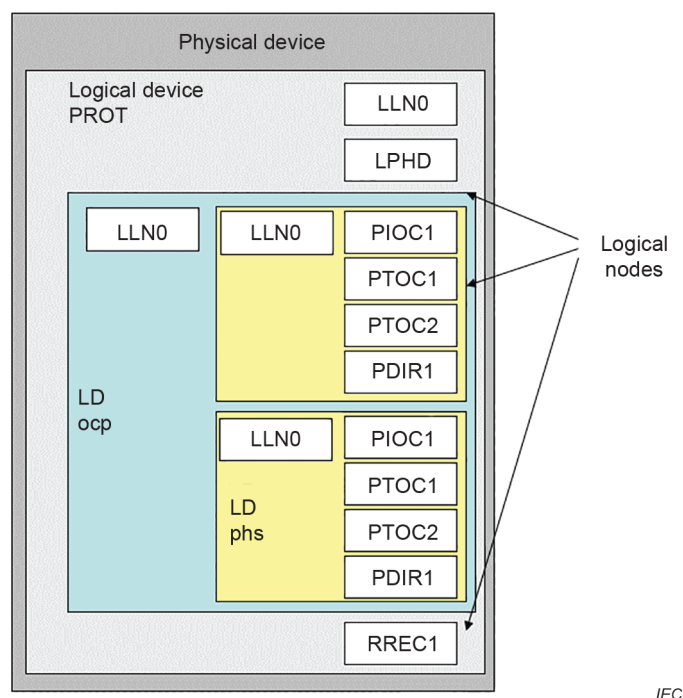


Figure 4 – Nesting of logical devices representing the functional hierarchy

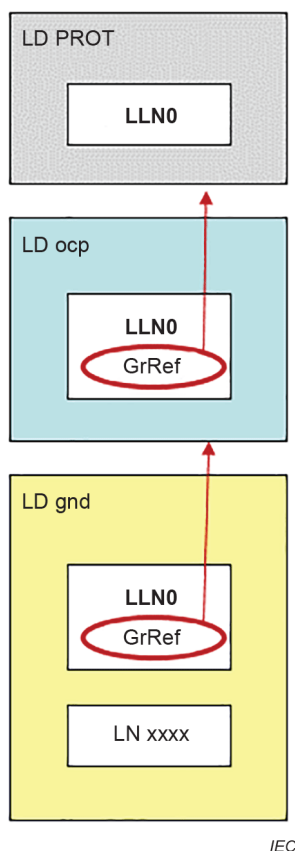


Figure 5 – Use of GrRef in the modelling of nested logical devices

LLN0 of the logical device LD ocp contains a setting data named GrRef whose common data class is ORG ("object reference setting group"). The referenced value of GrRef in LD ocp is PROT, meaning that the logical device function refers to the functional group represented by the logical device PROT.

Likewise, LLN0 of LD gnd refers to the functional group represented by the logical device LD ocp. In other words, LNs in LD gnd are sub-functions of LD ocp.

The use of the object reference GrRef is shown in Figure 5.

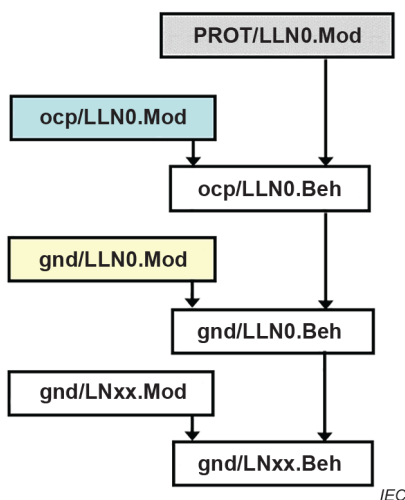


Figure 6 – Management hierarchy of nested logical devices

The management of the behavior within a logical device is based on the Mod setting of its LLN0, which contains common information for the LD like health, mode, behavior and name plate.

The hierarchy determines how the mode (e.g. on, off, test) of these functions and sub-functions is managed (cf. 4.2.3).

The referenced value of GrRef is PROT, meaning that the logical device function refers to the functional group represented by the logical device PROT.

The hierarchical management of the mode and behavior is shown in Figure 6.

In Figure 6, the mode of the LNs in LD gnd may be changed individually or globally by means of LLN0 of LD gnd.

Their mode may also be changed either by means of LLN0 of LD ocp or by means of LLN0 of LD PROT. For example, if the mode of the functional group LD ocp is set to "Off", it not only set the behavior of all logical nodes in LD ocp to "Off" but also the behavior of all logical nodes in LD gnd. Switching the mode of LD PROT will affect the behavior of all logical devices and logical nodes belonging to the functional group LD PROT, i.e. all logical nodes in LD PROT, LD ocp, and LD gnd and LD phs.

Such hierarchical management of the mode and behavior allows a very efficient control of the different functions and sub-functions implemented in a multifunctional IED. This is designed in particular to enable testing at different levels.

The above described inheritance of mode does not apply to the inheritance of the "on" mode as shown in Table 1. "on" is configured at the logical node and logical device level, thus specifying which logical nodes and logical devices are to be used. The reason is that after performing a test when mode has been set to "test" which is inherited as a behavior by all logical devices and logical nodes with mode setting of "on", when we return the mode setting to "on" we do not want all nested logical devices and logical nodes to switch to "on".

4.2.5 Processing of information

Information is transmitted between a publishing function and a subscribing function. The publishing function is expected to convey additional information, such as data quality, etc. This information of the value is necessary for the correct understanding and processing of the value by the subscribing function. Different data attributes can be used as the inputs for the subscribing function which define how to handle the value in an application specific way.

If the test bit in the quality attribute of a data object is different from the testing behavior (Beh) of the subscribing function, the application deals with the input in a way which reflects the definitions in Table 2.

As a matter of interoperability, functions must be provided with an implementation of the data quality processing rules as defined in IEC 61850-7-4. Only if all functions participating in a scheme are processing data quality with the same understanding, an effective isolation and testing of a function can be reached. The processing of data quality is illustrated in Figure 7.

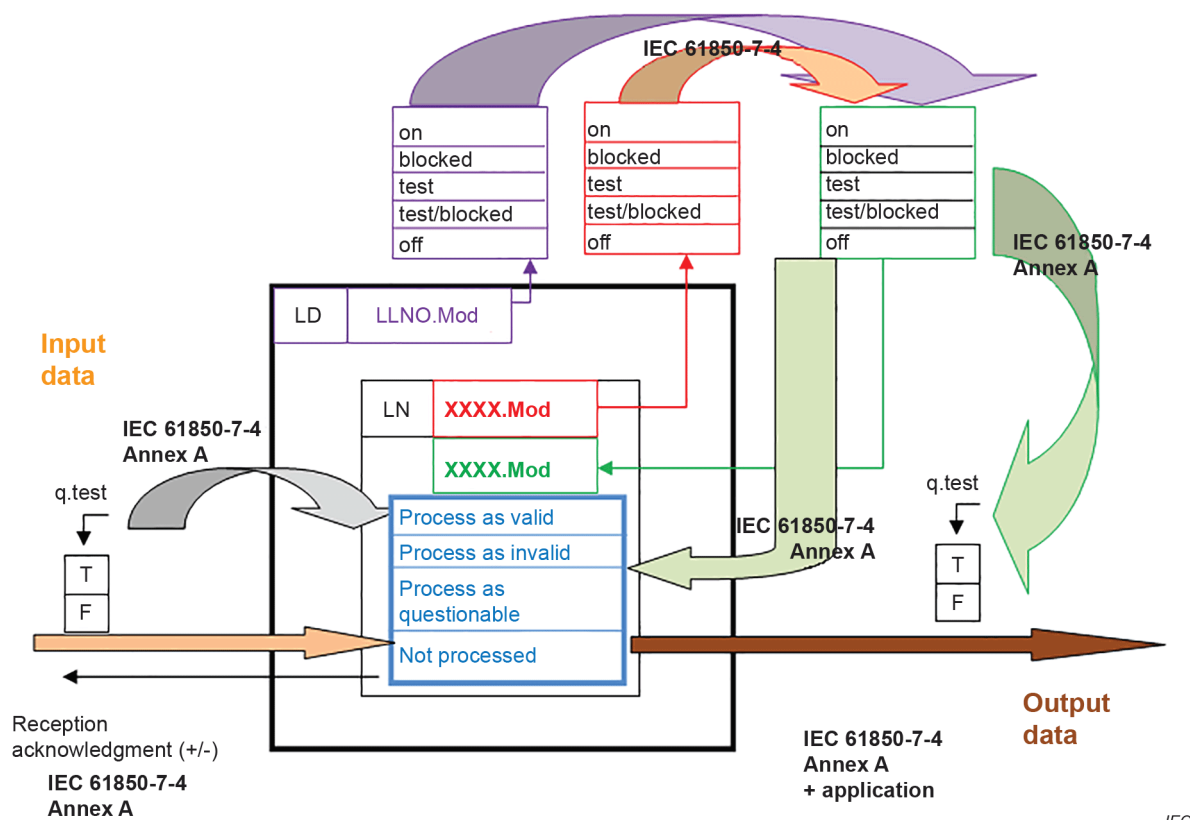


Figure 7 – Processing of the data by a LN depending on the LN behaviour and the quality attribute of input data

For a function which is 'on' or 'blocked', the user expects that its processing is not affected by information published by another function under test. Commands marked as 'test' are not considered for processing by functions operating normally. Therefore, a function in 'on' or 'blocked' state must be configured to react properly when an input data with q.test set to TRUE.

Properly can mean:

- use instead a defaulted good value
- ignore that value (keep last value)
- block the function.

Logical Nodes publishing states of physical inputs can also be in test mode. This can be used by the operators to indicate that tests are performed

- with a test set representing the primary equipment,
- on the primary equipment itself,
- on the secondary equipment.

Since the test bit (e.g. XCBR.Pos.q.test) will be set to TRUE for these tests, these inputs have to be processed accordingly.

A function which is set to 'test' or to 'test/blocked' processes "as valid" messages with q.test = FALSE and messages with q.test = TRUE (cf. Table 2), q.validity = GOOD assumed. This characteristic has an important impact on the test methodology. Table 2 summarizes the processing principles expressed in various chapters of the standard. These principles are needed to secure the interoperability of functions in the way the user expects applications to work.

The 'invalid' indication is typically known in conjunction with measurement values, but not limited to. Stronger than with an indication 'questionable' where a processing of the value is conceivable (depending on the configuration of the dedicated input processing for an application), 'invalid' unambiguously indicates that a value is not to be used. In the subscribing function, the communication services takes note that information was received, but the application does not consider the value for its processing. For a better understanding why a value is ranked 'invalid' or 'questionable', detailed quality identifiers are provided. Overflow, Out of Range, Bad Reference, Oscillatory and Failure lead to an indication 'invalid', Out of Range, Bad Reference, Oscillatory, Old data, Inconsistent and Inaccurate lead to an indication 'questionable'. The subscribing function can evaluate the detailed quality identifiers to derive the most appropriate way of processing of the information. The behaviour of the subscribing functions upon reception of invalid or questionable data should be included in the test scope.

**Table 2 – Table A.2 of IEC 61850-7-4:2010/AMD1:2020,
Annex A summarizes the processing principles**

MODE/BEHAVIOUR	On	Blocked	Test	Test/blocked	Off
Function behind LN	ON	ON	ON	ON	OFF
Output to the Process (Switchgear) via a non-IEC 61850 link for example wire (typical for X..., Y... and GGIO LNs)	YES	NO	YES	NO	NO
Output of FC ST, MX (issued independently from Beh)	Value is relevant q is relevant	Value is relevant q is relevant	Value is relevant q.test=true	Value is relevant q.test=true	Value is relevant q.validity=invalid
Response to (Normal) Command from Client (a+ / a- acknowledgement)	a+ pos. ack.	a+ pos. ack.	a- neg. ack.	a- neg. ack.	a- neg. ack.
Response to TEST Command from Client (a+ / a- acknowledgement)	a- neg. ack.	a- neg. ack.	a+ pos. ack.	a+ pos. ack.	a- neg. ack.
Incoming data with validity=good AND test=false AND operatorBlocked=false	Processed as valid	Processed as valid	Processed as valid	Processed as valid	Not processed
Incoming data with validity=questionable AND test=false AND operatorBlocked=true	Processed as questionable	Processed as questionable	Processed as questionable	Processed as questionable	Not processed
Incoming data with validity=good AND test=true AND operatorBlocked=false	Processed as invalid	Processed as invalid	Processed as valid	Processed as valid	Not processed
Incoming data with validity=questionable AND test=true AND operatorBlocked=true	Processed as invalid	Processed as invalid	Processed as questionable	Processed as questionable	Not processed
Incoming data with validity=invalid AND test=don't care AND operatorBlocked=don't care	Processed as invalid	Processed as invalid	Processed as invalid	Processed as invalid	Not processed
Non-IEC 61850 binary (relay, contact) inputs and analogue (instrument transformer) inputs	Processed	Processed	Processed	Processed	Not processed

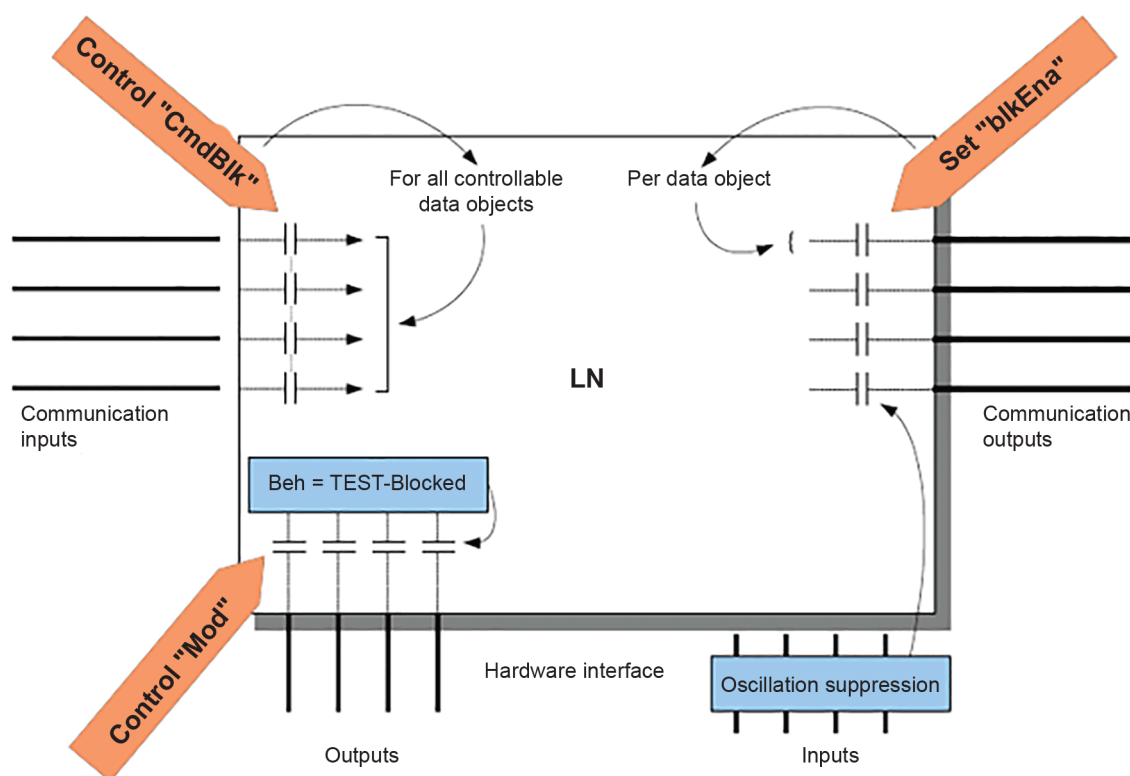
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It is worth noting that more than one quality indication may be set to TRUE at the same time.

A dataset using Functional Constraint Data Attributes (FCDA) should also include the quality information associated to a status value or measurement value. The Function Common Data (FCD) includes this information in their structure.

4.2.6 Blocking of information

NOTE This subclause does not treat potential blocking of data change or commands for operation reasons (such as the local/remote control authority or block open or block close of breakers).



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**Figure 8 – Data used for logical node inputs/outputs blocking:
IEC 61850-7-1:2011, Figure 39)**

4.2.6.1 General

In Figure 8 the different possibilities to intervene into a given communication scheme of functions are shown. The activation of physical outputs (contacts, analogue ports) of functions which have a direct interaction with the process can be blocked by setting the function to 'blocked' or 'test/blocked' status using the control service on the controllable object 'Mod'. The status evaluation of physical inputs can be influenced by an oscillation suppression feature, if implemented in the application. This feature is defined by the configuration. The updating of a communication output can be blocked by an operator.

4.2.6.2 Blocking of incoming commands

The acceptance of commands may be prohibited by activating 'CmdBlk' (data object optionally present in any controllable LN). This blocking affects all controllable objects (i.e. with CDC of type 'controls' as defined in IEC 61850-7-3:2010, 7.5) of the Logical Node in one, except for the data objects Mod and CmdBlk, which are always accessible. If 'CmdBlk' is activated, control sequences and action triggers of all controllable data objects in this function have been blocked.

In case of effective control blocking the latest valid input is considered for the internal treatment of the LN.

Application example: This feature can be used to prevent from inadvertent triggering of a function (e.g. commanding of a switchgear). The function processes the input data normally and publishes the output data normally.

4.2.6.3 Blocking process outputs

An operator or an application may be able to freeze the further update of a data value. The value shall be the information that was acquired before the blocking by setting the (optional) attribute 'blkEna' of the concerned data to TRUE. This intervention is done on data level, i.e. on the individual information produced by a function. Upon activation of 'blkEna' on a certain data, the issuing of this data is frozen and the indications 'operatorBlocked' and 'oldData' are set to the associated data quality, as the value is no longer updated.

This feature is not to be mixed up with the Logical Node modes 'blocked' or 'test/blocked' which each affect the process outputs of a function, while 'blkEna' has effect on data level.

4.2.7 Changing the information source (input reference) for testing

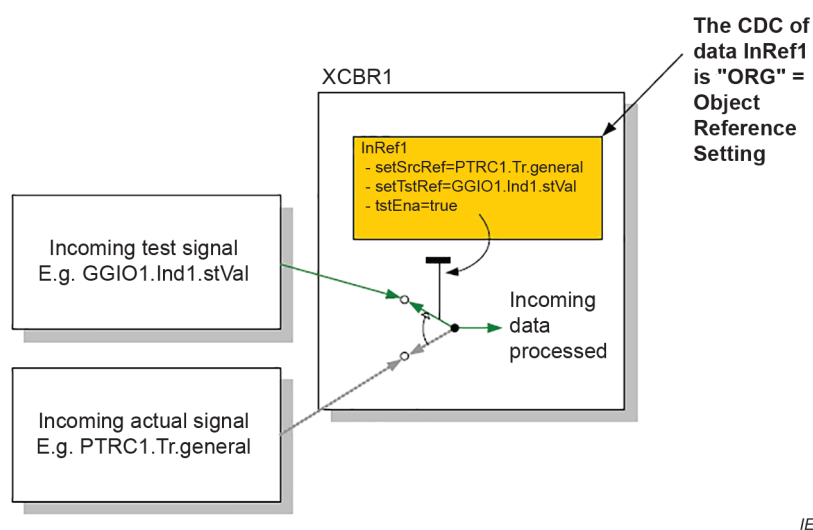


Figure 9 – Example of input signals used for testing (IEC 61850-7-1:2011, Figure 41)

The input signals to a LN may be switched between process signals from other functions and tests signals from functions dedicated for testing (even from testing devices) defined through the data object 'InRef' (an online representation of ExtRef) as shown conceptually in Figure 9. This does not depend on the Behaviour of the Logical Node and the data is processed and published according to the Behaviour.

Data attribute 'setSrcRef' specifies the object reference to the input that is normally used as input while 'setTstRef'³ specifies the reference to data object used for testing. By setting the data attribute 'tstEna' to TRUE, the application will use the test signal referred to by 'setTstRef' instead of the data object referenced by 'setSrcRef' used for normal operation (independently from the LN behavior, even if the LN behavior is not 'test' or 'test/blocked').

The use of this dedicated input as indicated through 'setTstRef' for testing is not automatic when the LN is forced to go in 'test' mode. This shall be individually set, for each of the concerned data.

A function LN can have multiple instances of 'InRef' for multiple inputs.

By means of switching over the input reference from the process signal, which may be not accessible or cannot be modified, to a signal which can be easily modified, an application can be isolated on the input side from the process and fed with test signals (value and data quality information). This feature requires having an extra function at hand which allows a controlled

³ Presence of the attribute 'setTstRef' in the ORG CDC (the one used by 'InRef') is optional.