



PS3 – S7-05



Testing in IEC 61850 Edition 2

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1 INTRODUCTION

The IEC 61850 edition 2 introduces new features in the substation automation world in order to increase the interoperability aspects of IEC61850 systems. One major enhancement has been achieved in the functional and performance testing domains. In comparison, the IEC 61850 edition 1 had defined essential methods for testing systems, with basic support for system interoperability. The first experiences in projects have shown that there was a need for additional testing features and their implementation in products. As a consequence, some of those additional features have been explained in amended descriptions.

The following test features are now specified and standardized in the IEC 61850 edition 2:

- Use the Data object **Behavior** “Beh” regarding to its values “test” and “test/blocked”.
- For the **monitoring of the result of control services**, new Data attributes “opRcvd”, “opOk”, “tOpOk” in all controllable CDC (Common Data Classes) have been introduced.
- For the functional testing, new Data Objects for referencing the incoming data flow and additionally new Data Attributes “tstEna”, “setSrcRef” and “setTstRef” for input references.
- Introduction of a Data field **Simulation bit** in the SV and Goose messages acc. 61850-8-1 and 9-2.
- The **Quality Bit** “q” with value ”Test” for the evaluation or selective processing of testing results in an interoperable way.
- Use the **Service parameter** “Test” in control commands in an interoperable way.
- Diagnosis and logging functionalities with the Logical Node **Tracking** “LTRK” for logging any service requested to an IED.
- Diagnosis functionality for subscriptions of GOOSE and SV with the definition of the Logical Nodes **LGOS/LSVS**.

2 USE OF TEST FEATURES IN IEC 61850 EDITION 2

2.1 Basic configuration

In the following the test features will be explained by practical examples. The basic configuration (figure 1) has been retained to develop the different testing features.

The figure shows a simplified configuration with conventional process interface. Intelligent process bus devices are not considered here. The IED1 represents the device under test (DUT). It communicates with clients by use of client-server reporting services- Its controllable data can be operated by control services. Data exchange with other IED on bay level is based on peer-to-peer GOOSE communication.

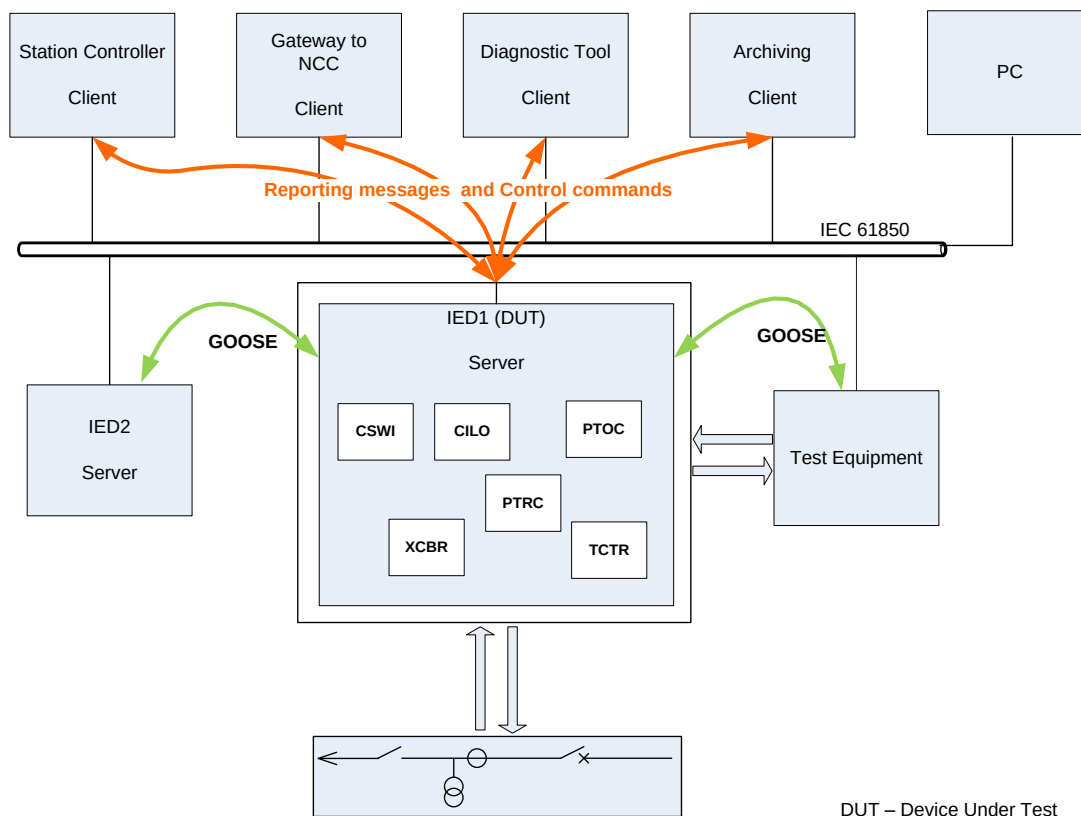


Fig. 1: Basic configuration of the test system

The test equipment is connected in order to carry out different test cases. The DUT acquires measurements (currents) by conventional parallel wiring to the transformer- The trip signal to the CB coils are transmitted by parallel wiring as well.

2.2 Data Object “Beh” (behavior) of Logical Nodes

The data object “Beh” (behavior) of a Logical node represents the communication behavior regarding changes of its inputs, outputs, internal states, settings and communication services.

“Beh” can be changed by manipulation of the data object “Mod” (Mode). Mode is a controllable enumerated data (ENC).

The data object “Beh” is an enumerated data (CDC ENS) with possible values: *on*, *on-blocked*, *test*, *test/blocked*, and *off* (see IEC61850-7-4). For testing, the behavior states *on*, *test* and *test/blocked* are relevant.

- **on** – The LN is running in a normal mode, i.e. all communication services are running and getting updated values by the application represented by this LN. The application rejects all incoming data / incoming requests with *quality bit = test*.
- **test** – The application represented by this LN is running. The communication services are running and getting updated values. All data objects issued by this LN will be added with *quality bit = test*. Only control commands with *quality bit = test* will be accepted, all others will be rejected (negative response with an additional cause indicating *Blocked-by-Mode*).
- **test/blocked** – The application represented by this LN is running, but if the LN is a so-called “boarder LN” (physical interface to the process), no output will be sent to the process (e.g. output relays will not be activated). All communication services are running and getting updated values. All data issued by this LN will be added with *quality bit = test*. Only control commands with *quality bit = test* will be accepted, all others will be rejected (negative response with *addCause = Blocked-by-Mode*). It is important to remember that a logical node whose

behavior is test blocked will not sent the command to the process. Therefore all control sequences will be negatively acknowledged with an *addCause* “blocked-by-mode” (no reaction of the process level). However, the logical node noticed that the command would have been issued if its *Beh* had allowed it to forward the command to the process level. This conditional distinction will be displayed later by the use of the Data Attributes *opOk* and *tOpOk*.

The data object *Beh* of a Logical Node is the result of its own *Mod* and of the *Mod* of the logical device where it resides.

The data object behavior is mandatory for all logical nodes, whereas the controllable data object *Mod* is optional except for *LLN0*. The presence of *Mod* in a given logical node is only to provide the granularity/possibility of setting a specific function to a specific state. In case the *Mod* is not available in a logical node, then its value is considered as “on” for determining of the logical node behavior.

2.3 Monitoring of results of control services

In all common data classes *CDC* (IEC61850-7-3) with controllable data attributes, three optional data attributes have been additionally defined:

- ***opRcvd*** (operate command received), (Boolean)
- ***opOk*** (operate command evaluated and accepted)(Boolean) and
- ***tOpOk*** (timestamp of data attribute *opOk*).

They are used for monitoring control commands if the control command is received by the IED. The command service can either be a control service or a GOOSE message that conveys a data object that is interpreted as an operate request on the controllable object. The data attributes *opRcvd*, *opOk* and *tOpOk* are relevant to verify the correct control function in case the logical node behavior is in “test/blocked”.

The concept is shown in the figure 2.

The data attribute *opRcvd* (TRUE) shows if the control request has been received by the controllable, i.e. all tests in the control state machine acc. 7-2 will be performed.

The data attribute *opOk* (TRUE) and it’s timestamp *tOpOk* show if the command has been accepted (i.e. all tests have been performed successfully) and has performed (behaviour of the host logical node is not “test/blocked”) or would perform a change (behaviour of the host logical node is “test/blocked”) of the output wired to the process.

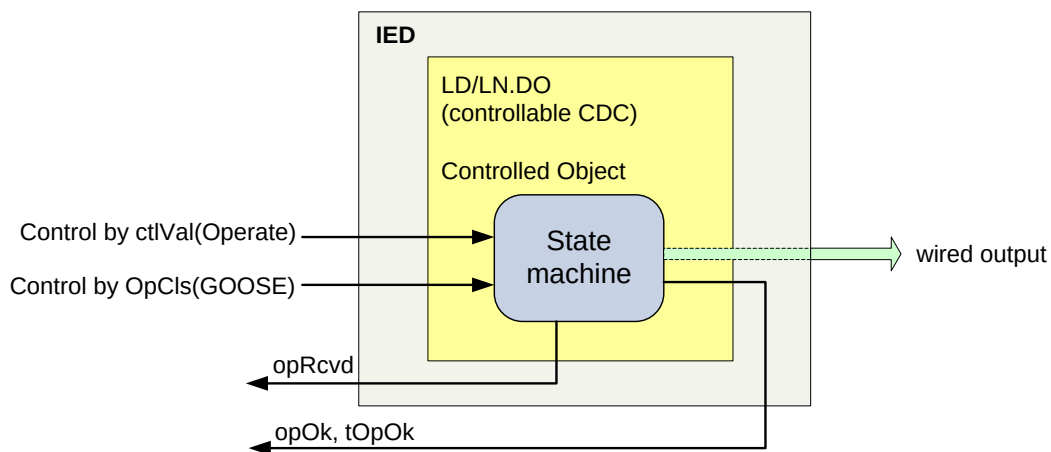


Fig. 2: Concept of monitoring of the result of control service

2.4 Data attributes *tstEna*, *setSrcRef* and *setTstRef* for functional testing

The common data class *ORG* contains between others the following data attributes:

- ***setSrcRef*** (set source reference)
- ***setTstRef*** (set test reference)
- ***tstEna*** (enable test)(Boolean)

The concept of using these attributes is shown in figure 3.

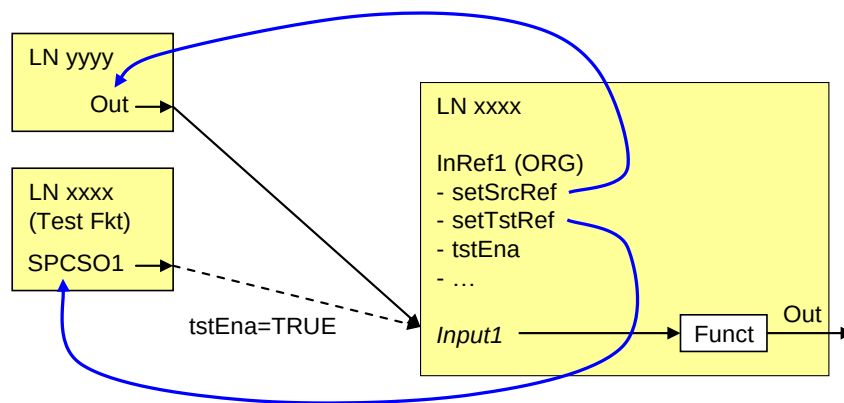


Fig. 3: Use of attributes in CDC ORG providing functional test

The data attribute *InRef1.setSrcRef* specifies the bonded/referenced data object of information in normal operation, i.e. the relationship between the source (output of a LN) and the sink (input of a LN) of the information. This bonded information can be located within the same logical device, within the same IED or even within another IED. By setting the *setTstRef* and enabling the test configuration by setting *tstEna* to TRUE a special data source can be switched on. By this means the source data can be "re-wired". The purpose of the "re-wiring" is of practical interest when the output value of the newly referenced data object can be modified and therefore provides new stimuli for the logical node (function) under test.

As a use case for functional testing, interlocking conditions could be taken. In the basic configuration (figure 1) the Logical Node CILO in the DUT gets the information from other IEDs including position and operating status of the switches by GOOSE in order to check if an enable-open signal (*EnaOpn*) could be created and sent to the switch controller (CSWI). In a test sequence the relationship between the original sources could be switch over a test equipment (test signal generator), which alternatively may send the data. The interlocking function will process the information and calculate the interlocking results. In addition a test control command could be initiated by the substation controller. If the border LN XCBR is in test/blocked mode, the high-voltage switch is protected. By using the attributes *opOk* and *opRecvd*, the correct function of the control sequence could be verified. If all involved LN sent their information with the *quality bit "test"*, a special test log can be produced by filtering this value.

2.5 Monitoring of subscription of SV and GOOSE messages

Edition 1 did not provide any standardized way to facilitate the commissioning of GOOSE subscription. The PIXIT specified how to test/verify the behavior of an IED in case of failed GOOSE subscription.

The SV subscription was treated equally in the previous version of the standard.

Here again, the first experience projects have shown that a standardized diagnosis functionality for the subscription in general was required. IEC 61850-7-4 now defines the logical nodes LGOS (GOOSE subscription) and LSVS (sampled value subscription). For IED that support the GOOSE resp. Sampled Value diagnosis, there will be a single instance of the logical node per subscription. The setting data object *GoCRef* resp. *SvCRef* specifies the control block reference of the published telegram that is being surveyed by the diagnosis function.

The following status data object, among others, will facilitate the commissioning of a system:

- **St** – when set to true, it indicated that the subscription is active, i.e. incoming GOOSE telegram are present.
- **SimSt** – when set to true, it indicates that the subscription is receiving messages for simulation purposes, i.e. messages that have been issued by a message simulator for testing purpose. The when and how to simulate will be explained in the next paragraph.

A client commissioning application could consist in monitoring these logical nodes. After having imported the system configuration file (SCD), and identified the multicast associations

between IEDs, the client commissioning application may connect to the subscribers, verify the number and validity of the logical nodes LGOS, cross check the *ConfigRevNum* information, and indicates herewith which IED has commissioning issues for which multicast association.

2.6 Testing and simulation of real-time messages like SV and GOOSE

As introduced earlier, the IEC 61850 edition 2 has defined a simulation features for real-time messages. The simulation concept resides in the use case that a real publisher and a simulator simultaneously publish on the network the same telegram with the exception of the simulation property. Figure 4 illustrates the use case, where a Merging Unit sends its samples both to Power Quality Device and a Protection Device. When testing the Protection Device with simulated sampled values, there might be a need for feeding the Power Quality Device with the real samples.

The subscriber itself will ignore the simulated telegram as long as it has not been controlled to receive them. The changing of state *occur* at IED basis, and its switch is available at the controllable data object *Sim* located in the LPHD logical node (logical node for the physical device information).

Having the IED SIMU and PROT in test, the simulation is in service. This includes that the IED PROT processes the sampled values sent by the IED MU. However, the IED Circuit Breaker remain on, so that any rip that will be received during the protection test will not trigger the breaker, since it will not process the incoming trip flag as test.

The simulation feature exclusively serve at multicast association since the publisher is not aware of all the connections, the subscribers operate independently and all receive the same message. There is no need for such an approach in case of unicast association, since it only concerns a single server and a single client.

The concept of simulation can be combined with the *Mod* concept and *Beh* interaction presented previously. These concepts are independent of each other. However, a real use case in a process bus environment will determine the *Mod* to switch in which device.

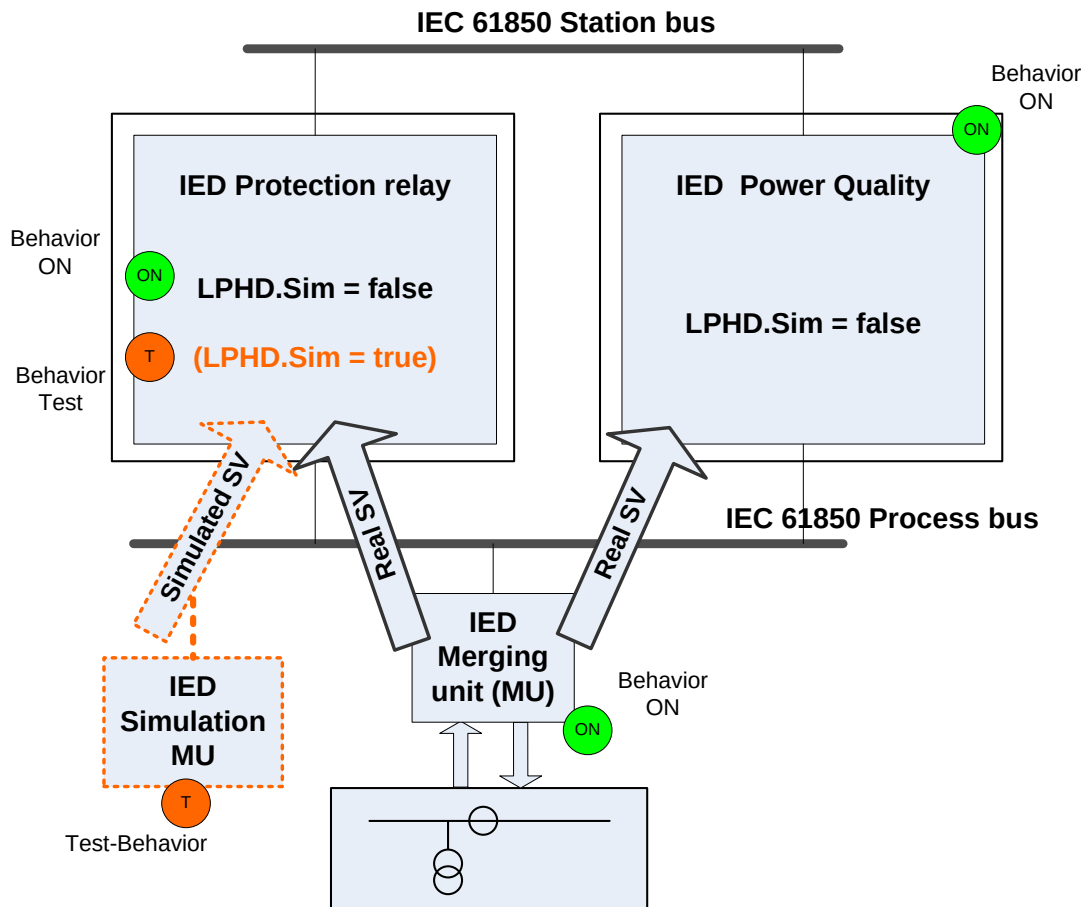


Fig. 4: Normal (green behavior, black SV) and simulation (orange) operation in case of multicast associations

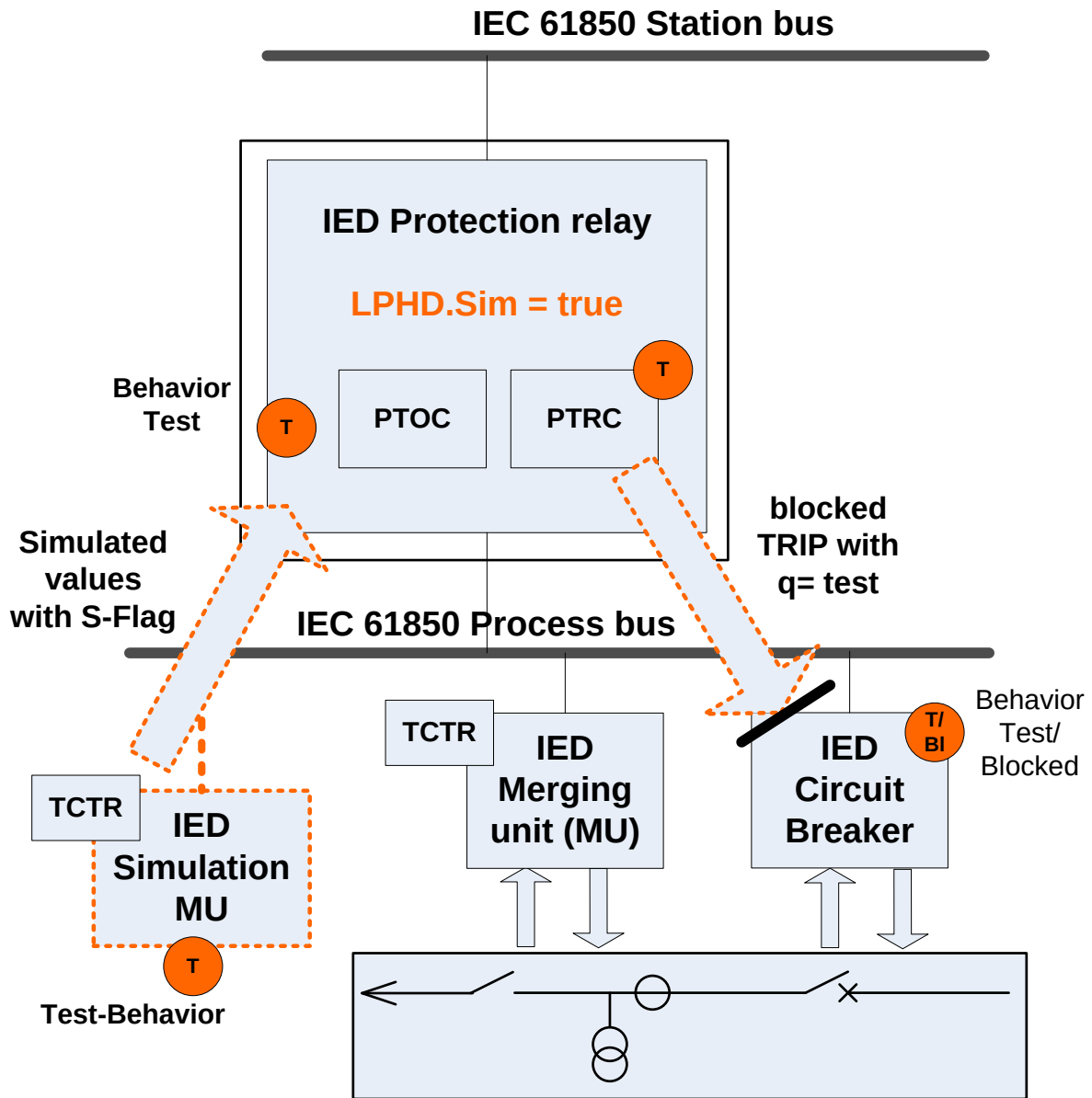


Fig. 5: Use of Mod in a simulation environment

3 TESTING OF PROTECTION FUNCTIONS

In this use case the testing of a protection function including its parameter settings is described. The DUT is fully connected to the operating system except to control direction of the primary equipment. Compared to the previous discussed process bus configuration in which the simulation flag, the behavior *Test/Blocked* and the filtering of the quality bit are used for testing, in the conventional configuration the disconnection of the primary process is required (see figure 6). For disconnection test plugs are typically used.

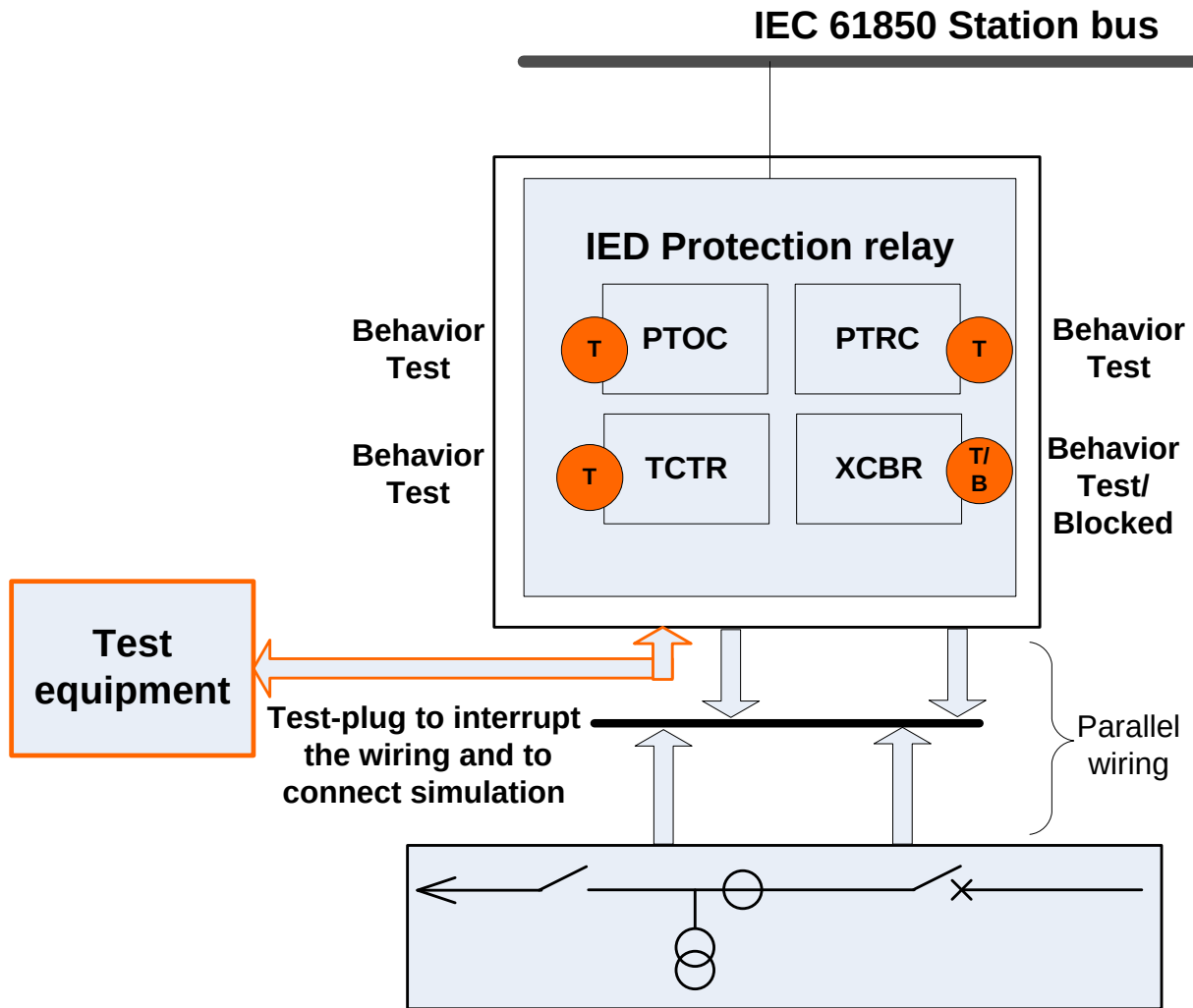


Fig. 6: Testing of protection functions and parameter settings in conventional configurations

Guideline for test scenario:

- The protection relay is switched in a TEST mode, i.e. all LN of this test configuration should be in Test switched by Mode (additionally the XCBR could be in a stronger comparing to TEST mode: TEST/BLOCKED).
- In order to block the primary equipment from relay's TRIP signals and to decouple the analogue signal inputs of the relay from the field CTs and VTs, a test plug is installed.
- The test equipment for the simulation of the analogue signals is switched on.
- Now the test can be started by initiating the injection of the current through the test equipment.
- The protection function should send the information about the start (*PTOC.Str*) and operate (*PTOC.Op*) to the LN PTRC (Trip Conditioning).
- The PTRC generates a TRIP signal and the LN for the circuit breaker would activate a TRIP signal to the terminals of the relay if the LN XCBR would not be in *Beh=TEST/BLOCKED*.
- Additionally the test plug decouples the relay from the primary equipment (circuit breaker), preventing the test TRIP to result in primary equipment interaction..
- All data about the test protection case could be reported to the client. The client may filter out the data flagged by the *quality=TEST* and store them in a special log about this test case. With the help of the data *opRcvd*, *opOk*, *tOpOk* the result of the trip of the circuit breaker could be also logged.

- The final order of the disconnection of the test configuration will be done:
 - first decouple the test equipment,
 - continue with extracting the test-plug and
 - finally changing the LN of the protection relay in the behavior normal *ON* mode.

To sum up, in this use case is the following test facilities are used:

Behavior *TEST* and *TEST/Blocked*, the *quality bit* = *TEST* and the data of the *XCBR.Pos.opRcvd*, *XCBR.OpOk/tOpOk*. Additional a test-plug should be installed in order to facilitate the decoupling from DUT and primary equipment.

4 CONCLUSION

The standard IEC 61850 edition 2 provides enhanced features for functional and performance testing. These methods allow an interoperable testing, as well as enhancing the commissioning and testing of a substation automation system. The new features have been added to the standard as response to technical issues and to experience in interoperability testing projects. Soon after the publication of the second edition, new generations of certified devices will be available supporting the new functionalities. After having convinced with its major concepts including engineering, the edition 2 continues the evolution in substation automation offering new benefits in the way of testing a substation automation system.

REFERENCES

- [1] IEC 61850: "Communication networks and systems in substations", Edition 1, 2004.
- [2] IEC 61850: "Communication networks and systems for power utility automation", Edition 2, 2011.