



# Virtual Isolation of IEDs for Testing in IEC 61850 Based Substation Protection Systems

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# Standard Questions by Alex

- ✓ *What are we testing?*
- ✓ *Why are we testing?*
- ✓ *What should be tested?*
- ✓ *How it should be tested?*

# IEC 61850 Testing

## **Requires good understanding of:**

- The functional hierarchy of the IEC 61850 system
- The local and distributed functions
- Existing testing tools
- The purpose of the test:
  - Conformance / Acceptance
  - Interoperability / Integration
  - Factory Acceptance Test / Site Acceptance Test
  - Commissioning / Maintenance

# Requirements for Isolation

Depend mainly on 1) what is being tested and 2) the purpose of the test.

If we consider that the methodology for testing changes with the scope of the system, then we can propose the following order of system component tests:

- Functional testing of individual IEDs used in the scheme, or
- Functional testing of distributed functions within a substation.

In the following table we will highlight in which cases the test should be performed using a normal operating configuration and when we should use a different operating mode that supports virtual isolation.

# Testing Purpose

| <b>Purpose</b>   | <b>Initial Test Method</b> | <b>Opt. Test Method</b> | <b>Subset of:</b> | <b>Isolation Method</b> |
|------------------|----------------------------|-------------------------|-------------------|-------------------------|
| Acceptance       | Bottom-Up                  | Dynamic                 | Conformance       | Both Normal & Virtual   |
| Interoperability | System                     | Network Simulation      | Application Spec  | Both Normal & Virtual   |
| Integration      | System / EndtoEnd          | Network Simulation      | Application Spec  | Normal                  |
| FAT              | Top Down Black Box         | White Box               | Acceptance        | None                    |
| SAT              | Top Down Black Box         | White Box               | Acceptance FAT    | Virtual if Req'd        |
| Commissioning    | Bottom-Up                  | System                  | Acceptance        | None                    |
| Maintenance      | System                     | Dynamic                 | Commission        | Both Normal & Virtual   |

# Maintenance Testing Reasons

## ***Scheduled Maintenance Tests (Periodic Testing)***

### ***Maintenance Testing in Case of Incorrect Protection System Operation***

- if the system does not operate when it has to and
- if it operates when it should not.

### ***Virtual Isolation During Maintenance Testing of IEC 61850***

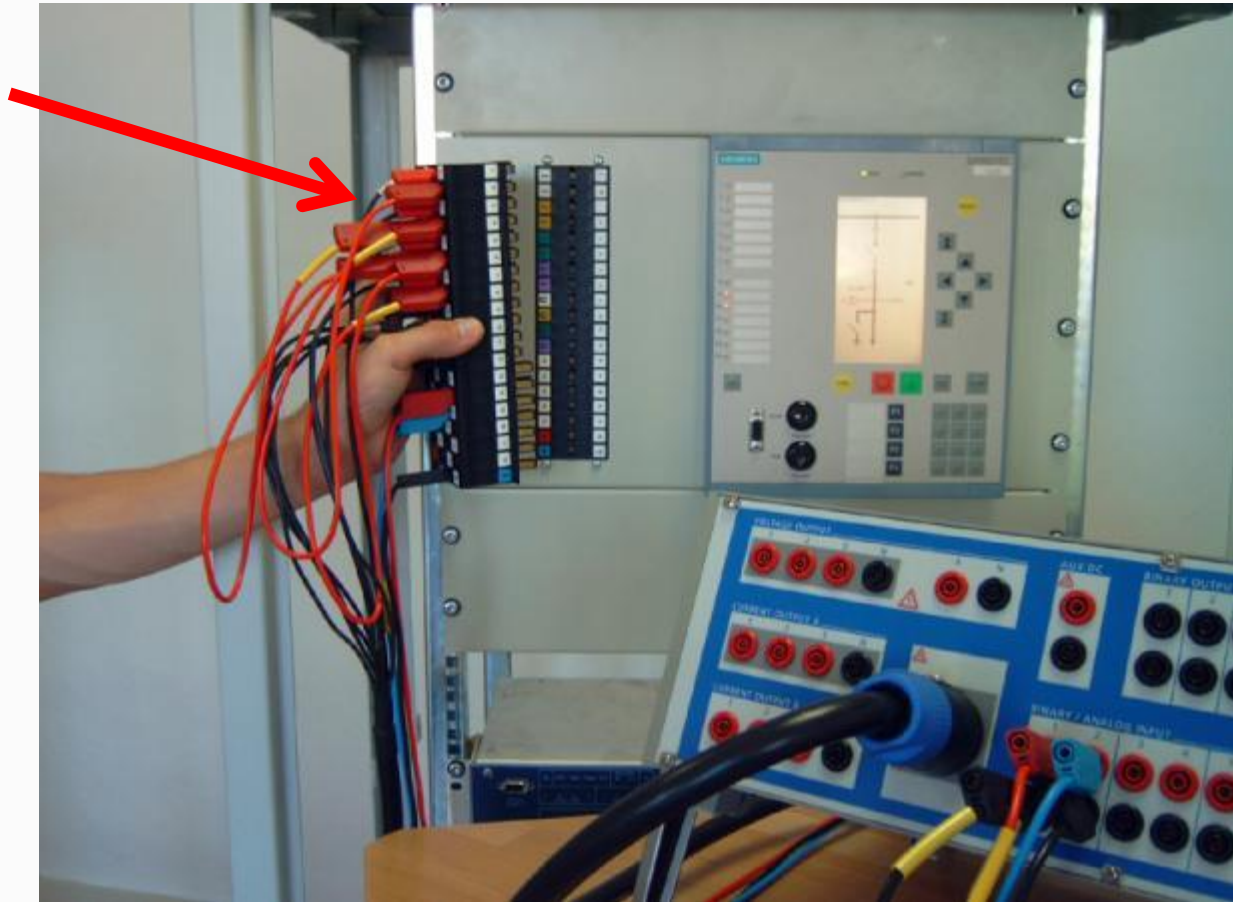
Maintenance testing is the main use case for virtual isolation because it involves testing of different functions or functional elements in an energized substation.

The following virtual isolation options may be considered:

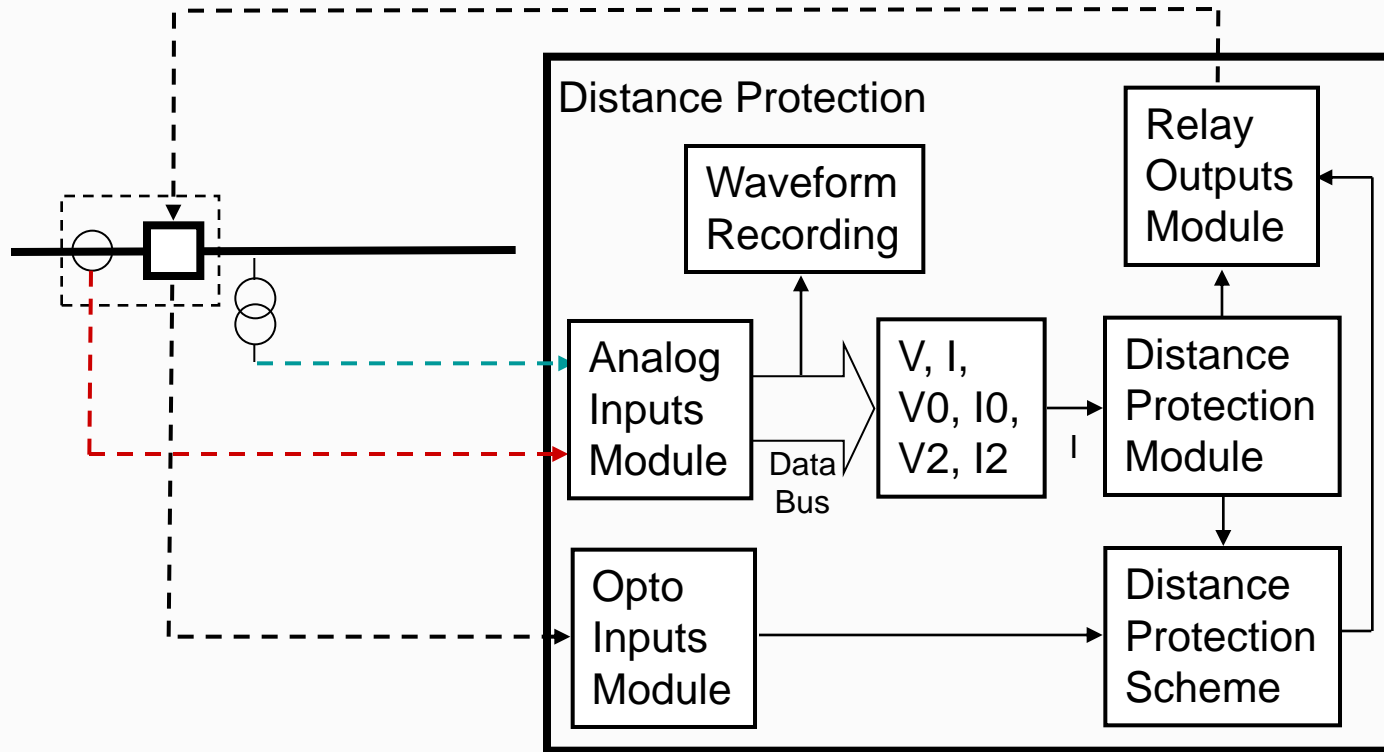
- Isolation of a function element for testing
- Isolation of a sub-function or function for testing
- Isolation of the complete IED for testing

IEC 61850 allows the control of the mode and behavior of different functional elements, something that is not possible in conventional IEDs.

# Conventional Isolation Method

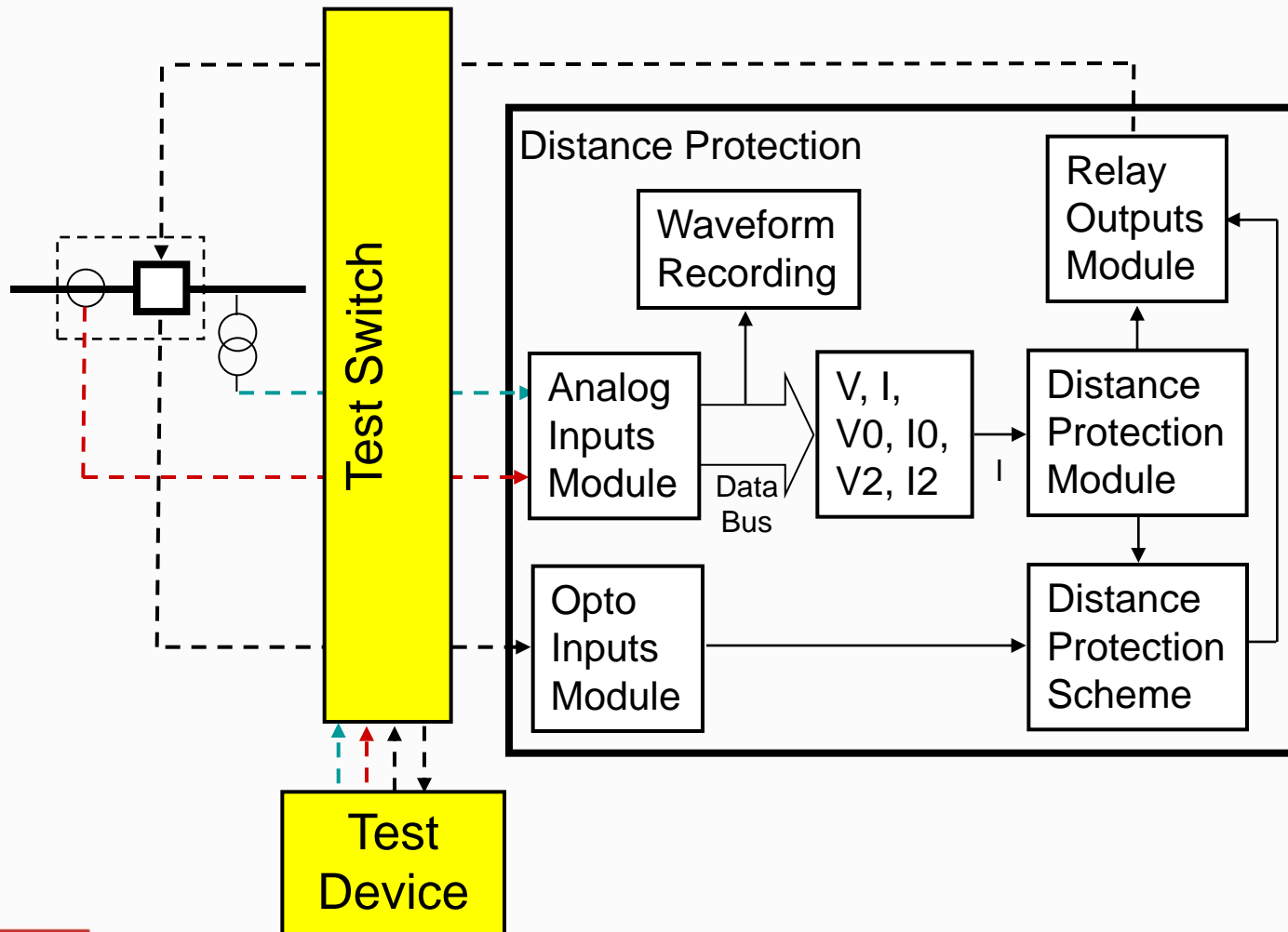


# Typical Distance Protection





# Distance Protection Testing



# IEC 61850 Ed. 1 Testing

In order to support the testing of IEC 61850 system components in energized substations, Edition 1 of the standard had many different features that could be used for testing.

- The possibility to put a function or a functional element (logical nodes or logical devices) in a test mode
- The possibility to characterize a GOOSE message as a message being sent for test purpose
- The possibility to characterize a service of the control model as being sent for test purpose
- The possibility to flag any value sent from a server in the quality as a value for test purpose

However, Edition 1 was not very specific on how to use these features.

# IEC 61850 Ed. 2 Testing

1) A logical node or a logical device can be put in test mode using the data object **Mod** of the LN or of LLN0, either by command or a GOOSE message.

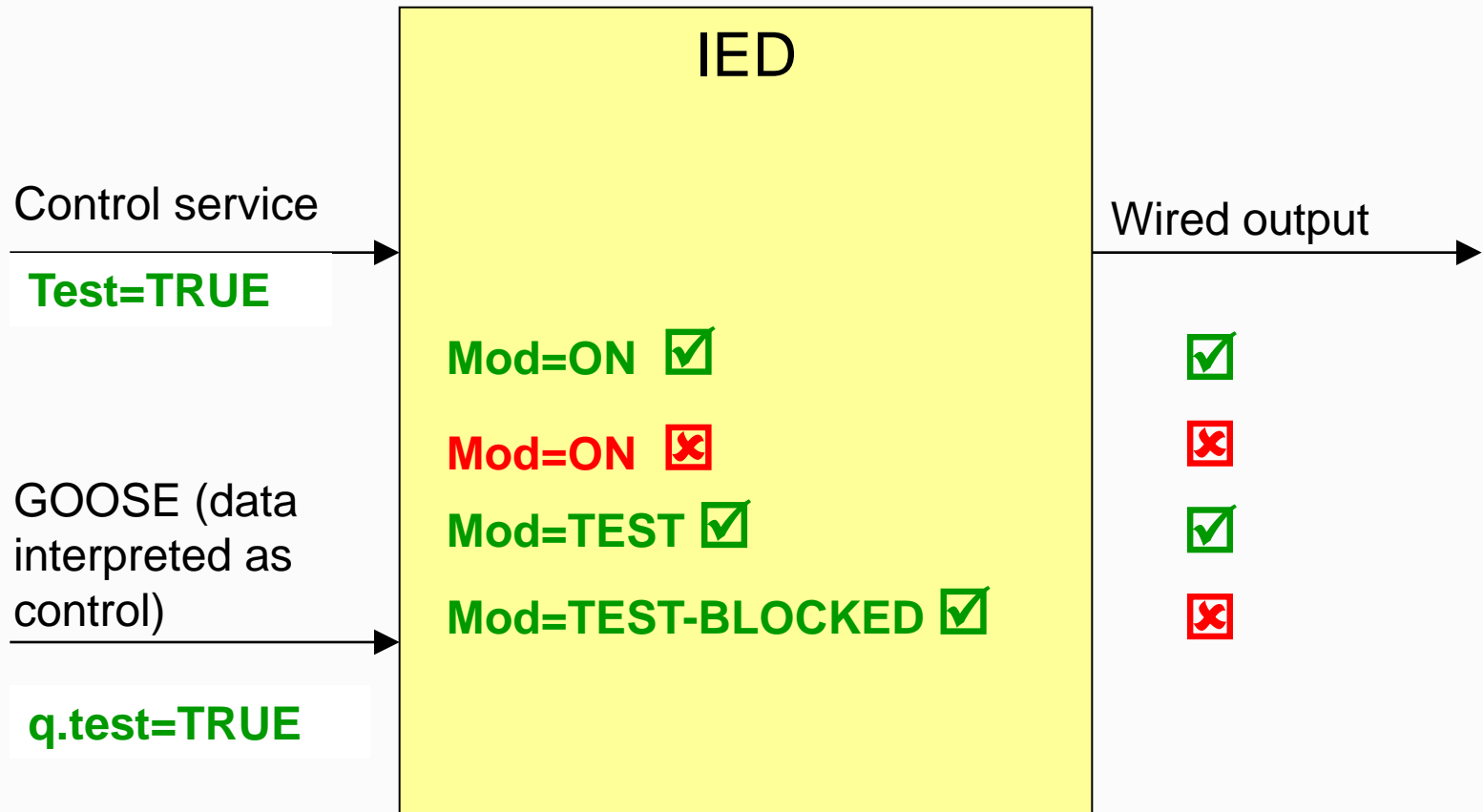
Conditions:

- A. The test flag is set to FALSE; and MOD=ON, Output is executed.
- B. The test flag is set to FALSE; and MOD=TEST, Output Not executed.
- C. The test flag is set to TRUE; and MOD=ON, Output Not executed.
- D. The test flag is set to TRUE; and MOD=TEST, Output is executed.
- E. The test flag is set to TRUE; and MOD=TEST-BLOCKED, Output Not Executed

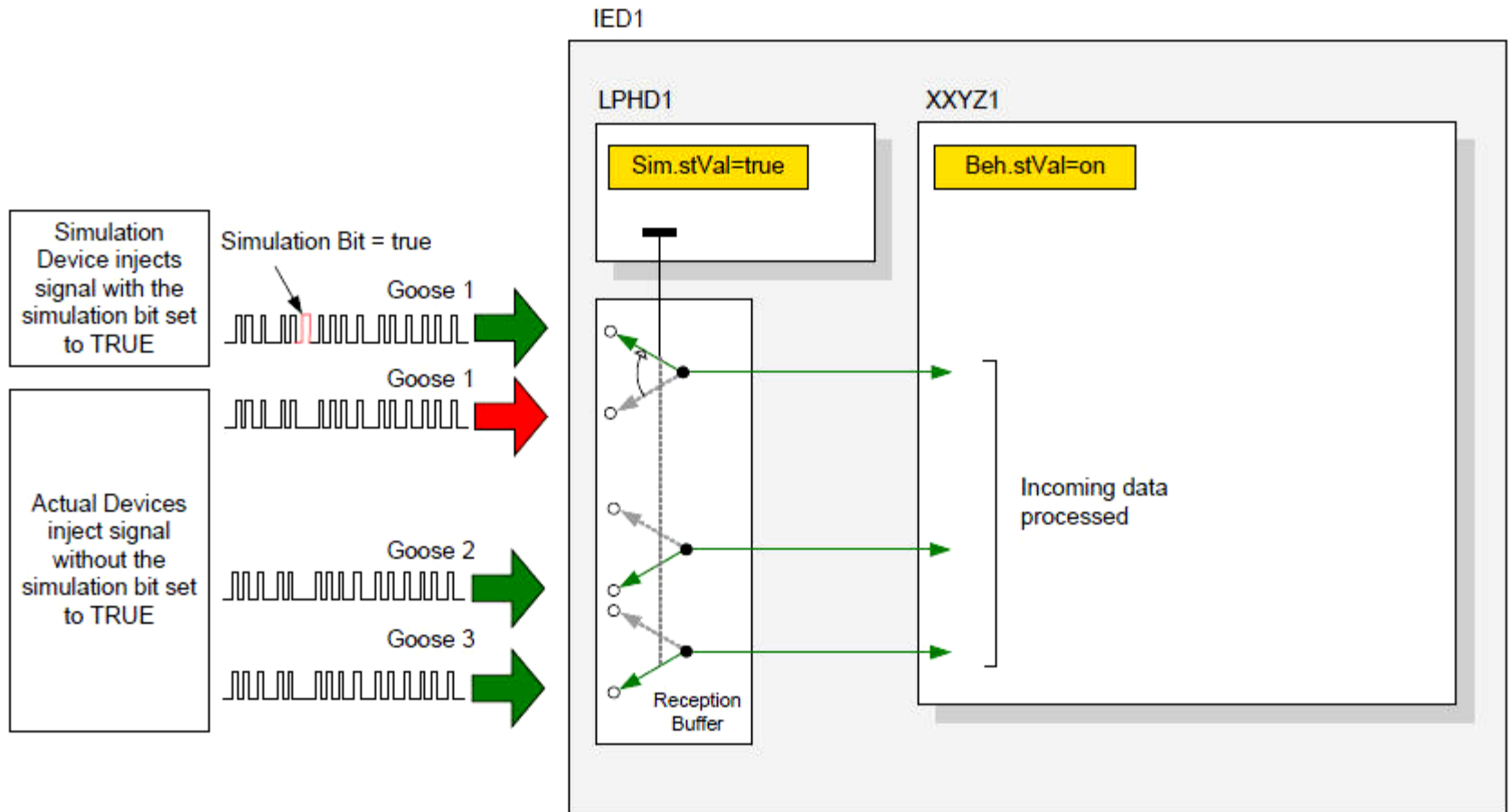
2) An IED can subscribe to GOOSE messages or sampled value messages from simulation or test equipment. The IED has in the logical node **LPHD** a data object defining, if the IED shall receive the original GOOSE or SV messages or simulated ones. (**Sim=TRUE/FALSE**)

This can only be set for entire IED.

# Ed. 2 Testing of an IED



# Simulation Bit



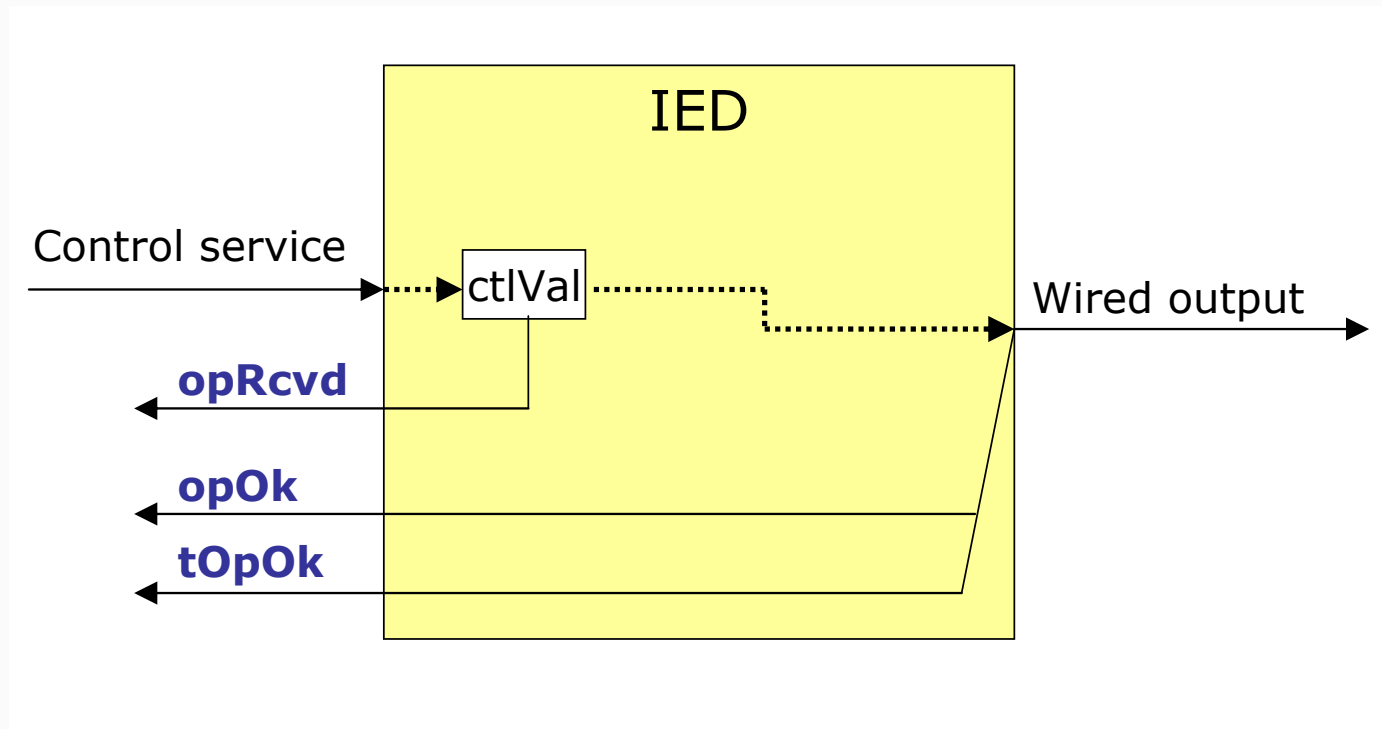
# IEC 61850 Ed. 2 Testing

3) Another feature that has been added is the “Mirroring of Control Information”. This supports the possibility, to test and measure the performance of a control operation while the device is connected to the system.

Conditions:

- A. Command is sent to a controllable Data Object (DO)
- B. Response is to set the Data Attribute “**opRcvd**”
- C. If Command accepted, then the Data Attribute “**opOk**” is set with same timing (and pulse length) as the wired output.
- D. Then the Data Attribute “**tOpOk**” has same time stamp as wired output and “**opOk**”.
- E. The attributes are produced independent of the wired output (on or off)
- F. Wired Output is Not produced if **MOD=TEST-BLOCKED**.

# Ed. 2 Mirroring Control Info



# IEC 61850 Ed. 2 Testing

4) Combining the mechanisms described in the previous sections, it is possible to test a device that is connected to the system.

Example:

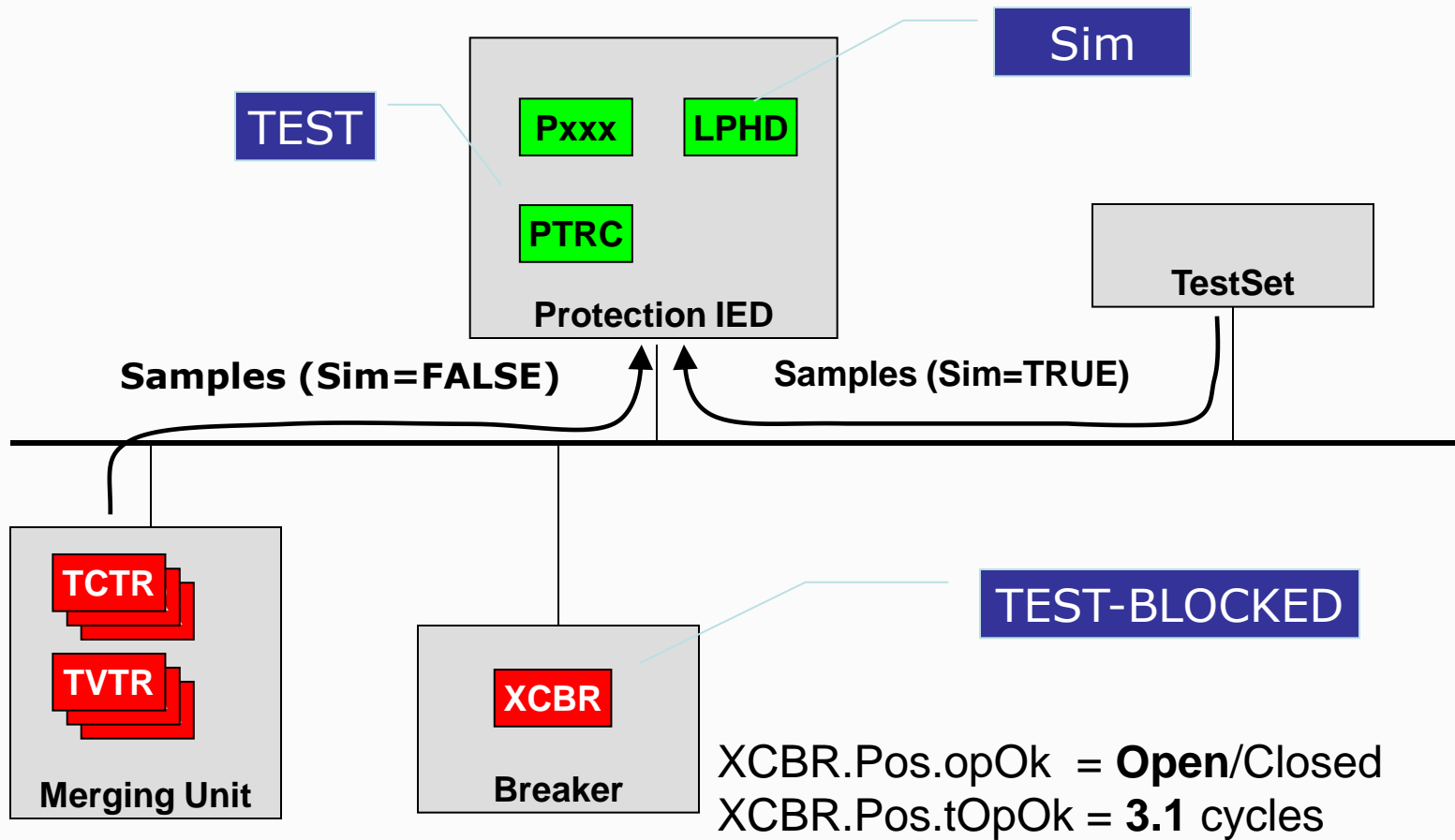
Assume we want to test the performance of a “main 1 protection” that receives sampled values from a merging unit. In the LN **LPHD** of the main 1 protection IED, the data object **Sim** shall be set to “TRUE”, the logical device for the protection function shall be set to the mode “**MOD=TEST**” and the logical node **XCBR** as interface to the circuit breaker shall be set to the mode “**MOD=TEST-BLOCKED**”. A test device shall send sampled values with the same identification as the ones normally received by the protection relay but with the Simulation flag set to “**SIM=TRUE**”.

Result:

The IED will initiate TRIP; the XCBR will accept the command but no output generated. However, the attributes **XCBR.Pos.opOk** and **XCBR.Pos.tOpOk** can be used to verify the operation.



# Isolation and test



# IEC 61850 Ed. 2 Testing

5) Advanced Simulation Capability – through defining “References “ to inputs of a logical node (LN) which has been added to Ed. 2.

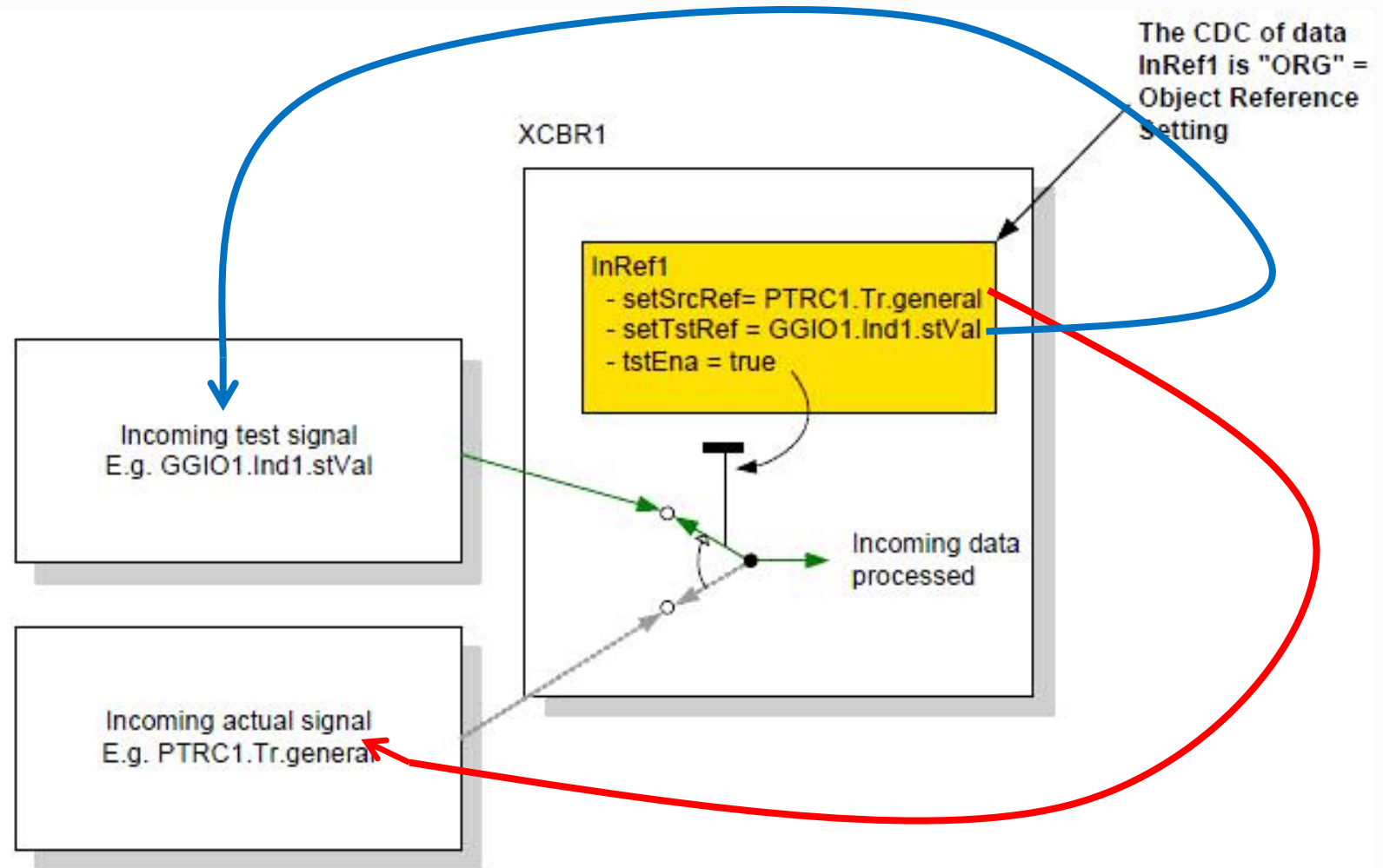
This is done through multiple instances of data objects **InRef** of the CDC ORG. That data object (DO) has two data attributes (DA) providing object references: one as a reference to the object normally used as input; the other one as a reference to a data object used for testing. By activating the data attribute **tstEna**, the defined function in the LN shall use the data object referred to by the test reference as input instead of the data object used for normal operation.

Example:

A test application can now easily modify the different data objects of the LN **GGIO** to simulate the test patterns that shall be verified. That logical node can be external (the data objects being received through GOOSE messages) or it can be implemented in the IED itself for testing support.

(Not suitable for Performance Testing as inputs are individually switched.)

# Input Reference



# IEC 61850 Ed. 2 Testing

6) Last is the addition of Service Tracking - a data object instance has been defined for each kind of service, which mirrors the values of the service parameters. That data object can be included in a dataset for logging or reporting.

So now, both Application Process and Communication Process can be logged and reported.

# Conclusions

- Conventional PAC systems are hard wired and use test switches for isolation
- There are no physical test switches for communication links in substations based on IEC 61850
- Devices supporting Edition 2 will provide new advanced methods of functional isolation.
- **Virtual isolation is possible using features from Edition 1 but advanced features in Edition 2 provide for many new testing methods not possible in conventional IEDs.**