ADVANCED SIMULATION OF IEDS

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ABSTRACT

IEC 61850 is the established standard for substation communication. Since the standard describes different stages of lifecycle of Substation Automation Systems (SAS) the demands for specification, testing, and especially simulation differ. The approach described in this papers can be used in the different stages and fulfil practical requirements. The paper describes the requirements for simulation and proposes an implementation applicable. If a single Intelligent Electronic Device (IED) and its data model to be simulated in technical investigation phase is sufficient at Factory Acceptance Testing (FAT) and Site Acceptance Testing (SAT) multiple IEDs and utilized services as GOOSE and Reports will be needed. Additionally, the methods described for indicating test mode/behavior and simulation indication become important. The simulation has to be embedded in testing environment and interact with tools to be used for visualization of changes in IED's data model. Advanced services in IEC 61850 like setting groups control, switching device control and file transfer have to be added. The requirements will be discussed from utility's perspective taking into account experiences in IEC 61850 projects. The method described can be extended for routine testing and maintenance testing e.g. after firmware upgrades. An outlook develops a vision to be utilized for automation and control testing.

INTRODUCTION

IEC 61850 [1] is not the "new standard" for substation communication anymore. Being introduced almost 13 years ago, it became the preferred choice for communication in our industry at all over the world.
IEC 61850 is mature, at the latest with the publication of Edition 2 and 2.1 of the standard being finalized in the last years. The standard extended the scope and changes the title- from substation communication to "Communication networks and systems for power utility automation". So, we are leaving out of the substation to other substations, control centers and distributed energy resources (DER). IEC 61850 is the core-standard for communication in the "smart grid".
IEC 61850 is not "just a protocol"- it describes the communication between IEDs and SCADA systems utilizing point-to-point-connection (Client-Server) as well as the transmission of real time values utilizing

GOOSE and Sampled Values. This has an impact on testing technology used.

TESTING

As described in [2] testing is a main issue and the standard describes several possibilities how to implement and to perform. This paper also contains new approach how to perform protection testing. Some of the proposals made there will be used later in this paper.

PHASES IN LIFECYCLE

The standard [3] in general is not focusing on testing, but describes the lifecycle of SAS projects. The terms FAT (factory acceptance test) and SAT (site acceptance test) are introduced and define different phases with different needs e.g. for simulation. As FIGURE 1 illustrates the need for simulation is bigger at the beginning of a project and decreases during commissioning phase. Nevertheless, even commissioned substations might need simulation. A typical example is the security patch of an IED in a live substation. To test for instance interlocking conditions, automation components simulating certain conditions and/or IED status might be required.

FIGURE 1   Lifecycle of SAS

INDICATING TESTING

Some users expect a single test bit what is not defined in the standard in that manner. The reason is obvious. In IEC 61850 are several possibilities to communicate. We distinguish between client-server-communication used for SCADA purposes and real-time communication utilizing GOOSE and Sampled Values. Additionally, the data model as defined in the standard is complex and multilayered- additional possibilities need to be found. The classes for Logical Nodes (LNs) are defined in IEC 61850-7-4 [4]. Every Logical Devices (LD) consists of at least 2 LNs. Every LN got its own Mode (Mod). This mode can be as follows:

- on
- on-blocked (name in edition 1: "blocked")
- test
- test/blocked
- off

In addition to Mod/Beh for every information available a quality (q) is defined. The encoding is explained in part 8-1 [5] , here we learn that bit string of 13 is currently used (Bit 0....Bit 12; Bit 11 is a Boolean attribute with the name "quality").
Testing and simulation units must be capable to handle and visualize this information.

DIFFERENTIATE BETWEEN REAL AND SIMULATED SIGNALS

To distinguish between simulated values and values from process the "simulate" indication is most welcome and used [2]. This allows an easy detection or distinction e.g. by a subscribing IED (FIGURE 2). The mechanism is explained in FIGURE 2. The entire physical device (!) can be set with a control in the LN describing the physical device (LPHD) to receive simulated GOOSE or simulated Sampled Values instead of real.
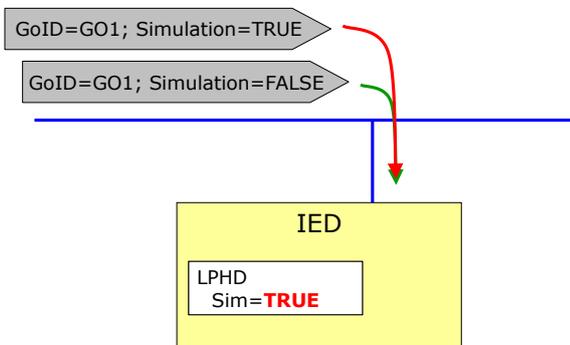

FIGURE 2   Network with simulated and real GOOSE message [2]

Testing and simulation units must be capable to enclose simulation information.

SIMULATING GOOSE

Testing solutions visualizing and simulating GOOSE are available for a long time already [6]. **Error! Reference source not found.** shows an implementation example in protection testing software. All IDs and the multicast addressee must be set properly. The source MAC addressee must not be considered by the subscribing IED! The figure also shows Configuration Revision to be set. This is important since several IEDs accept only GOOSE with the configured revision.

FIGURE 3   Simulated GOOSE

Simulation of GOOSE makes testing of interlocking schemes possible. The GOOSE is used between the bay devices and contains position indications. Also, intertripping and remedial action schemes (RAS) are utilizing GOOSE. For such applications state sequencers are utilized and are making complex tests possible. Test sets configured as shown in FIGURE 3 can be operated with application based or system based test software.
Starting GOOSE simulation should be used carefully. Especially if the simulation indication is not used the same GOOSE occurs twice on the network (only different source MAC addresses). Such a "GOOSE race" is an undefined condition of SAS and might cause trouble and unexpected behaviour!
Simulation under real time requirements demands a test set to be used. Since most of SCADA applications are none- real time simulation is also possible from computers.
To publish the GOOSE an SCL file is loaded and the simulation can be enabled (FIGURE 4). Additionally, the simulation indication described already can be activated.

FIGURE 4   GOOSE simulation with software

SIMULATING THE SERVER

For most of the applications GOOSE simulation only is not sufficient. The entire server needs to be simulated. This contains:

- Data model
- SCADA services
  - o Report
  - o Control
- File Transfer
- Setting Groups

Typical applications for simulation of IEDs in SAS are

- Missing IEDs during commissioning
- Simulation if real IED in live substation must continue working
- Check of operation after firmware upgrade
- ,,,,,

Since SCADA services operate on TCP/IP level at least here an IP configuration must be applied. Simulated on a PC the system can have different IPs and even the loopback (127.0.0.1) can be applied. The software should listen on all IPs of the computer (FIGURE 5).
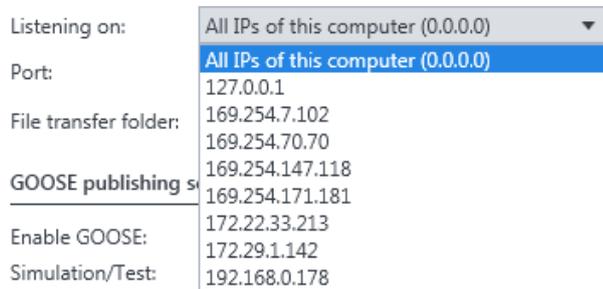
FIGURE 5   Listening on IP

MMS communication is used for SCADA communication in IEC 61850 [5]. Like every communication, a port is used- in that case 102. If the port is blocked by other applications (which might occur in case of some protection setting software) an alternative must be chosen (FIGURE 6).

FIGURE 6   Communication port

In case of other ports the connected client must be adapted accordingly.

CHANGES IN DATA MODEL

Every IED consists of a data model summarizing LDs, LNs with data objects (DO) and their attributes (DA). **Error! Reference source not found.** shows an example of protection IED. Setting of values should be simulated must be possible on DO and DA level.
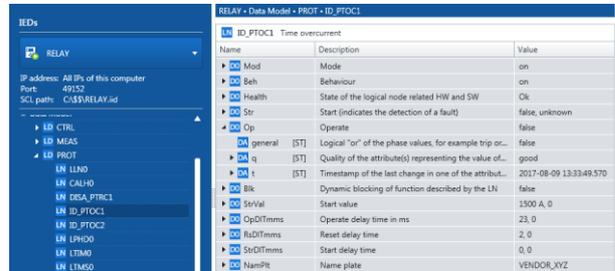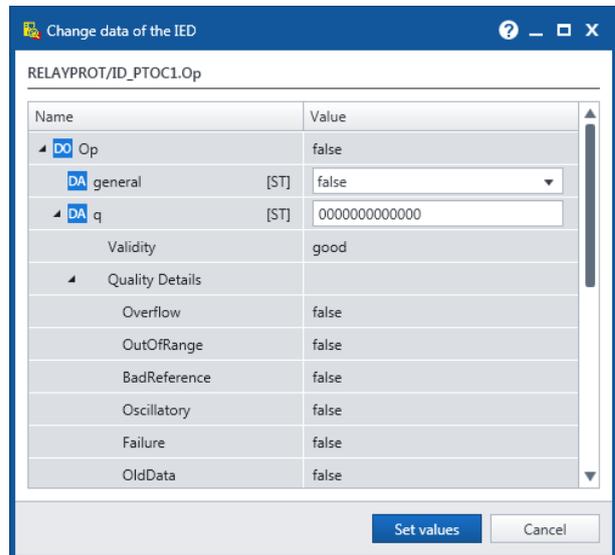

FIGURE 7   IED's data model

FIGURE 8   Change data of the IED

WORKING WITH SERVICES

Changing a single or chain of attributes influences the reaction of IEC 61850 services. A good example is the Report used for SCADA communication. Every Report is triggered by a certain option for instance data change.
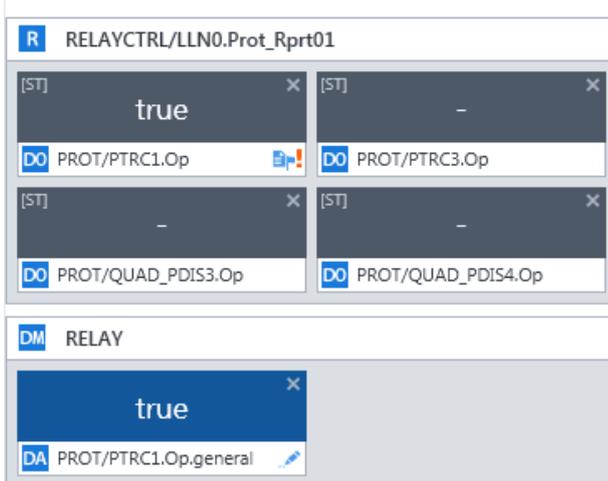
FIGURE 9   Report with data changed

So, the report (FIGURE 9, top) is issued if the single attribute is set (FIGURE 9, down).
Now the SCADA communication can be simulated and tested.

CONTROL

Switching devices as well as the modes described above is performed with IEC 61850 control services. FIGURE 10 shows the control of simulated IED.
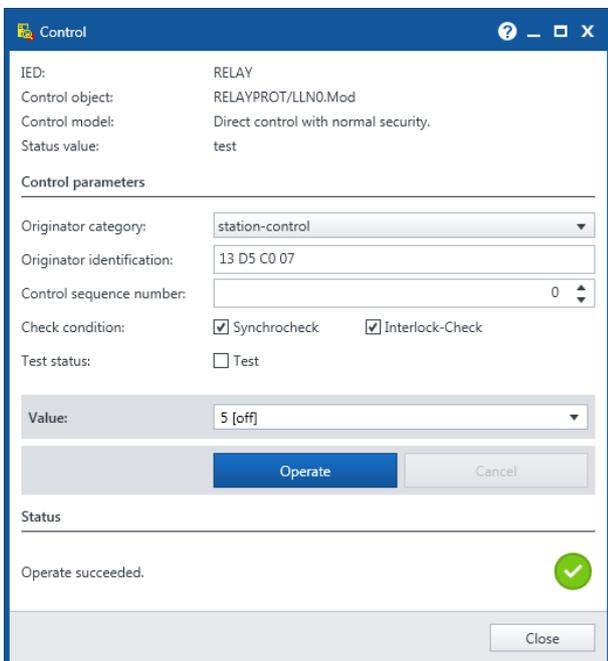

FIGURE 10   Control

FILE TRANSFER

IEC 61850 provides file transfer for instance of disturbance records from IEDs. For simulation, this feature needs to be enabled and a file location must be defined.
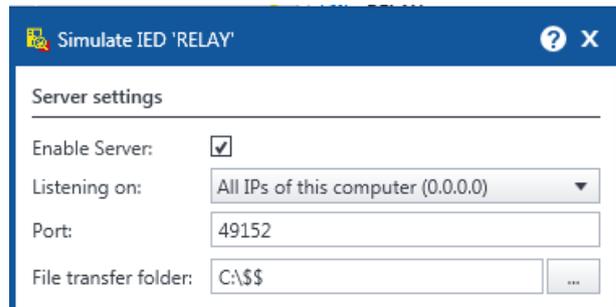
FIGURE 11   File transfer- location

Now also the file transfer is simulated and the COMTRADE file stored can be accessed (FIGURE 12).
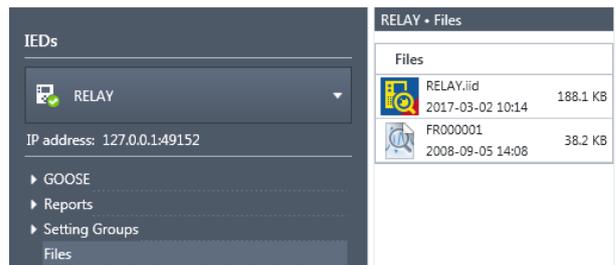
FIGURE 12   File transfer- files

This method allows direct access to disturbance records stored as well as IED's configuration.

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SETTING GROUPS

Setting groups in IEC 61850 offer new possibilities and are described in detail in [7]. IEC 61850 extends the setting group approach with the predefined data sets. Setting groups can be activated and even edited. The details are described in Setting Group Control Blocks (SGCB) of the IED affected.

The (SGCB) allows the modification of multiple data attributes (DA) to predefined states. An SGCB can only modify the DAs with the functional constraint "SG" and "SE" of the CDCs defined for setting group usage (e.g. ASG, ING, ...). An SGCB contains lists of values for every DA controlled by the SGCB (FIGURE 13)

FIGURE 13   Setting Group Control Block

Even IEDs with setting groups can be simulated and tested. The client connected needs to be aware of the active SG and should have the possibility selecting another one (FIGURE 14).

When supported also changing of parameters is possible (FIGURE 15).

FIGURE 14   Setting Groups: Choose

FIGURE 15   Setting Groups: Edit parameters

EXTENSION

The methods proposed can be used in utilities to simulate IEDs during design, FAT, SAT and commissioning.

For application in all phases of lifecycle of SAS extensions are necessary and will be implemented. An automated test set as shown in FIGURE 16 is proposed. This solves the problem of multiple IED simulation with different IP addresses and makes access easy.
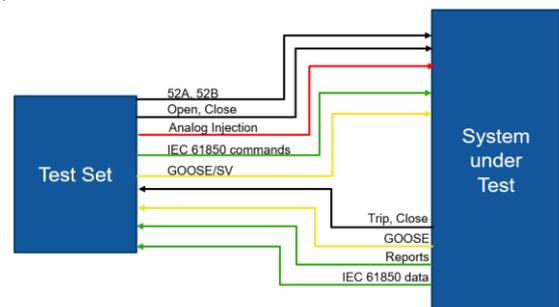

FIGURE 16   Test set

FIGURE 17 shows a test plan ready for re-usage at another phase of SAS project.
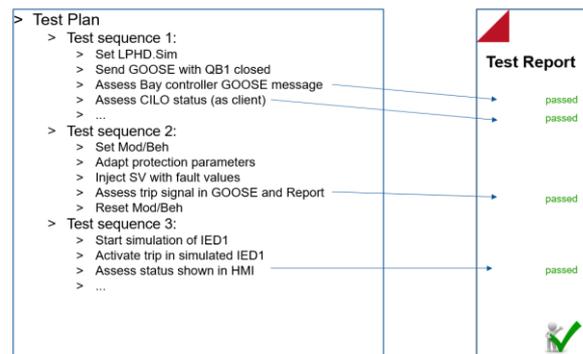

FIGURE 17   Test report

CONCLUSIONS

The paper describes the need for testing and simulation in different phases of SAS life cycle and shows implementation proposals. Advanced simulation offers new possibilities and increases the efficiency of testing and contributes to the reliability of the grid.

REFERENCES

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[4] IEC 61850-7-4 Ed. 2: 2010 Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data object classes

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ABOUT THE AUTHOR

Thomas Schossig was born in Gotha (Germany) in 1970. He studied electrical engineering and power systems at the Technical University of Ilmenau, and received his master degree (Dipl.-Ing.) in 1998. After this he worked as SCADA engineer at VA TECH SAT GmbH in Waltershausen (Germany) and took the team protection. In 2006 he changed to OMICRON electronics GmbH in Klaus (Austria). As a product manager in power utility communication (PUC) he is a member of the standardization group and author of many papers covering IEC 61850 and protection testing.