A NEW APPROCH FOR TEST IN SUBSTATION WITH ENTIRE APPLICATION OF IEC 61850 INCLUDING THE PROCESS BUS

*Pereira Junior P. S., Martins C.M., Rosa R. R. (Conprove Industria e Comercio, Brazil)
Pereira P. S., Lourenço G. E. (Conprove Engenharia, Brazil)

Summary

The IEC 61850 standard is day by day present in substations all over the world. It brings significant advantages to interoperability and enable a lot of cable cost saving. However its adoption has created new challenges and procedures.

This paper aims to discuss the tests requirements that imposed thought paradigms rupture, which are occurring on substations projects due to application of IEC 61850.

It will be traced the main needs and changes that exists for the IEC 61850 fully conforms and no conforms substations and will be pointed out the requirements of new tool to execute the tests.

Keywords

IEC 61850, Tests, Process Bus, Sampled Values, IEC 61869, Relay, IED, Test Set, New Approach

1. Introduction

The IEC 61850 standard was first published by the 2003 year, and its effects are very presented nowadays in substations automation projects. The standard is not a simple communication protocol, but instead of it is an interoperability solution. It has been considered a key to the implementation of Smart Grids networks.

Two main contributions of the Standard were the patterning of Data Models and Communication Services, theses allow data exchanges between IED´s of different manufacturers.

About data exchanges for automation systems the IEC 61850 Standard has proposed three types of communications: the client-server (that has no critical times requirement), the GOOSE (Generic Object Oriented Substation Event) and the SMV (Sampled Measured Values also named SV Sampled Value), which both have high speed and critical times requirements.

The main in the IEC 61850 Standard is the interoperability between devices that are shared all over the three levels of the SAS: the station level, the bay level and process level. The data exchange occurs through two digital buses: Station Bus and Process Bus. The implementation of the Standard brings several changes to the data transfer procedure at substation equipments, such as:

* psjunior@conprove.com.br

a) Data exchange on the vertical direction going from IED´s to the station computer / SCADA, using the named “Client - Server” services.

b) Data exchanges between IED´S that traditionally were made by copper wire (I/O) to perform interlocking and others logics types can now be done by using GOOSE messages.

c) Traditional techniques using analog current and voltages from CT´s and VT´s secondary are changed by the use of Sample Values (SV 9-2). These messages (SV 9-2) can be generated either by electronic transformers or by Merging Units.

As GOOSE and SV are fast messages, this affects the tests procedures, so they will be deeply addressed in this paper.

As a basic concept the SV can be thought as the changing of position of the A/D converter from the IED inputs, to the station yard. In this way the analog digitalized signal will travel by Ethernet Network up to the IED in the control room.

One of the greatest benefits of the Process Bus is the cable cost saving, since one optical fiber will substitute four current and four voltages cables that are necessary to take the analog information from the station yard up to the IED.

As already been mentioned the data exchanges inside the substation occurs by using two buses: the Station Bus and the Process Bus.

The station bus makes the interface between the station´s level and bays level. This bus allows the traffic of GOOSE messages (for interlocking and logics) and the traffic of Client-Server messages. These messages go through the interfaces IF1, IF3, IF6, IF8 and IF9 (defined on Part 5 of IEC 61850 - Interfaces for Substation Automation Systems).

In another way the traffic of GOOSE TRIP and Sampled Values (SV) messages are made using the Process Bus. The Sampled Values that emerges from CT´s ad VT´s by a Merging Unit or by electronic transformers goes through interface number 4, IF4, and the GOOSE trip messages by IF5 interface (definitions of part 5 of IEC 61850 - interfaces for substation automation systems). The figure 1, illustrates theses arrangements.

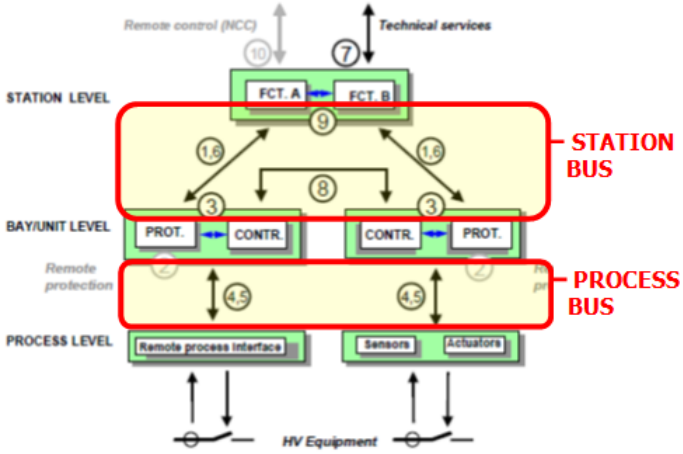

FIGURE 1- Logical Interfaces and Levels

The process bus can be considered the greatest challenge of the IEC 61850 Standard, once by this bus, the Sampled Values flows to the IED´s and the trip messages comes out of the IED´s to operate the breakers at the station yard.

The Merging Unit provides the sampled values messages that travels by the Ethernet LAN up to the protection IED flowing usually by a switch. This switch should be

compartmentalized by using Virtual-LAN techniques to avoid overloading of the net. It is also important to remember that Ethernet LAN has statistical switching process that can produce delays on the transmission of packets. The standard IEC 61850 on part 5, defines transmissions delays for protection performance class P2/P3 with a maximum delay´s time of 3 ms.

On part 9-2 of the IEC 61850 standard some definitions to implement SV were left open. This has generated the need of definitions, and the "UCA - IMPLEMENTATION GUIDELINES FOR DIGITAL INTERFACE TO INSTRUMENT TRANSFORMERS USING IEC 61850-9-2" has proposed and also called Light Edition (LE), which was published on 2004. This guide will be adopted in this paper.

The technical aspect to implement the process bus is out of this paper purpose, however the interested reader can always refer to the bibliography [4], [5] and [6].

With all these modern concepts including data travelling on the network, the traditional tests procedures and test sets used to tests legacy instruments no more can be used, and new tools and procedures had to be adopted.

2. Current Methods of Testing

The commissioning of IED´s and protections devices has been made in two steps: FAT (Factory Acceptance Tests) and SAT (Site Acceptance Tests).

Depending upon the IED installation and location requirements, such as the voltage level, system point, importance of the equipment where it will be connected and the user philosophy, the adopted test routine can diverge.

Some of the more common tests practices in use are: Characteristics Searching, Shots Faults Simulations and Transients Reproduction.

Characteristics Searching: It looks for the relay characteristic tolerance / border. The test is made by injecting tests points outside the characteristic and changing it up to the relay trip. It will be repeated all over the relay characteristics in order to check it fully.

Shots Points Simulations: (Simulations of one or more fault condition): This test is made by injecting simple RMS conditions of current and voltage, representing faults inside or outside the protection operating zone in order to evaluate the relay behavior under particular conditions defined by users.

Transients Reproduction: These tests are carried out by using transient programs (such as ATP), reproduction of COMTRADE files or by test sets which provides some software that the system can be modeled and the faults signal can be generated.

In the last years we have been contemplating a partial implementation of the IEC 61850 where GOOSE messages have been used to exchange messages through the Station Bus. This by itself imposes changes to the traditional test sets by requiring GOOSE simulation and subscribe. However after the IEC 61850 be fully applied using SMV and the Process Bus, there will be greater changes requiring new tools and tests procedures.

The sampled value is something new to the Power Engineer / Protection Professional and there is a huge challenge and expectation around it.

These new tests procedures and tools to perform the tests will be described below.

2.1. The Test´s Importance

IED´s works based on an internal software named firmware. When the manufacturer provides the firmware update the devices can be considered as a new one, and the historical of the devices behavior has to be reset, requiring that new tests should be made. For example there are cases that the firmware update changed the Ibias equation of a differential relay.

Some IED´s provides facility so that the user can do the test bypassing the A/D converter and signal conditioning circuitry and injecting bits to the relay microprocessor. This however does not substitute the complete test once it leaves part of the device without checking.

Others IED´s manufacturers supply small tests routines inside their products. It should, however, be considered that these tests are not complete tests and do not check some problems such as the analog input defects or not calibrated, and does not verify the frequency response, etc.

Tests on IEC 61850 IED´s entirely conformed devices, got to integrate SMV and GOOSE messages and it has to be done with the same performance level requirements used for the legacy devices, of course with special attention to the new device technology. Otherwise if a fault on the system occurs, and there is a problem left in the device, the damage will be even greater.

3. Options to Convert Analog Current and Voltage to Sampled Values - (IEC 61850 Process Bus)

According with IEC 61869-9 there are several options to provide Sampled Values. Depending upon the used technique there will be different tests requirements. The table below presents some options. Schema

	Schema	**Observation**
A	CT+MU	Merging Unit is incorporated to the Instrument transformer
B	CT-DIG-SAMU	A SAMU is a device that is separated from the instrument transformer and has digital inputs
C	CT-AN-SAMU	A SAMU is a device that is separate from the instrument transformer and has analog inputs

SAMU = Stand Alone Merging Unit DIG = Digital Connection AN = Analog Connection

It is worth saying that all Merging Units techniques got to provide Sampled Values outputs with the same frame format in accordance with the IEC 61850-9-2 LE.

To check the main aspects of data flowing to and from a Process Bus (SV 9-2), it is important to test the following:

- Digitalization time (1PPS – Time of SC=0)
- Check if the Sample Count order was addressed correctly.
- Check if there are messages losses occurring.
- Check if there are delays occurring.

In the progress of this paper it will be assumed the use of (CT-AN-SAMU), scenario C, since it represent the easier solution for retrofits in installations.

4. Requirements of the New Test Sets:

Considering the IED by itself, working with Sampled Values and GOOSE messages, the reader may think that the test can be fully made by using only digitalized signals (bits), and the traditional tests instruments used in the past, which generates analog current and voltage signals with hundreds of watts, will no longer be required. However it has to be realized that the CT´S, VT´s and SAMU, test´s from now on will define the needs for generation of the analog signals with a considerable power.

The generation of high analog current and voltage signals composing with the capacity of interact with Sampled Value and GOOSE messages, and also new project procedures, are dictating that new tests tools and new tests process will have to be adopted.

By comparing the traditional copper wired tests method that injects analog signal with the Process Bus method, the figure 2 and 3 illustrate the main blocks of these schemes.

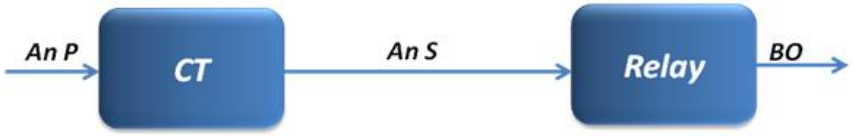

FIGURE 2 - Classical Method with Copper hard wire connections

FIGURE 3 - Process bus /Sampled Values

In the classical method referred in figure 2 the primary analog (An P) signal is converted to the analog secondary signal (An S) by the IT´s and its output goes to the relay, that provides or not, the trip signal using Binary Output signal (BO).

On the Process Bus method in figure 3, the CT secondary output is connected to the SAMU. The Merging Unit converts the CT secondary signal to sampled values in accordance with IEC 61850-9-2 format. The frame generated by SAMU, goes through Ethernet LAN to the IED, where the decision of trip will comes like a GOOSE message.
Regarding the chain with CT, SAMU and IED, another test´s requirement are necessary, figure 4 divides the process in some parts that allows identifying the test needs and possibilities.

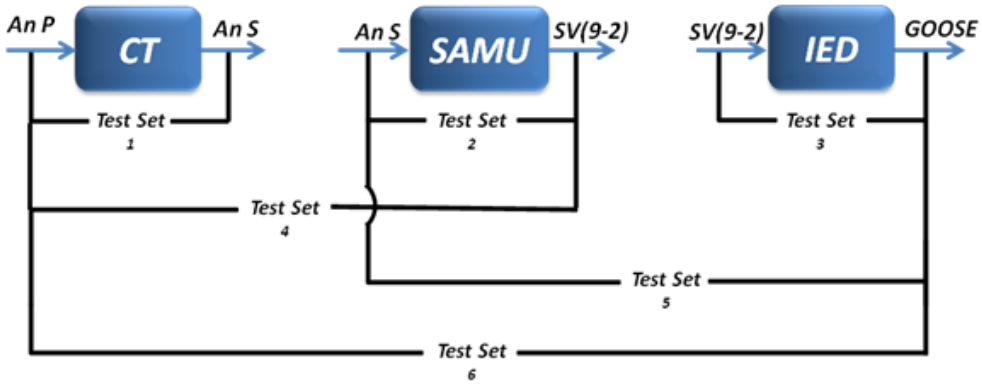

FIGURE 4 – Splitting the Process Bus scheme to display the tests requirements

In each part of the whole scheme, the requirements for input and output have to be analyzed, considering their specific needs.

For the proposed scheme there are six tests options, and for each option one object or group was evaluated. To achieve these requirements the test set instrument got to be capable to generate and measure analog (primary and secondary amplitude), digital (frame) and timer signals.

	Object Under Test	**Inject**	**Measure**
1	CT	Primary Current	Secondary Current
2	SAMU	Several secondary currents and voltages	SV (9-2)
3	IED	SV (9-2)	GOOSE
4	CT + SAMU	Primary Current	SV (9-2)
5	SAMU + IED	Several secondary currents and voltages	GOOSE
6	CT+ SAMU + IED	Primary Current	GOOSE

It however has to be mentioned, that depending on the tests objectives, the arrangement can be made including one or more blocks.

4.1. The New Standard IEC 61869

This is a standard dedicated to Instrument Transformers, it has 15 parts that define all requisites for CT´s and VT´s and in its Part 9 the reader will found the description of the digital interfaces for Instruments Transformers.

The IEC 61869-9 is still in draft format and its end version is expected for the second half of the 2013 year. It is coming to substitute and upgrade the IEC 60044-8 Standard that was previously used as reference guide to the Sampled Values dataset structure. In this way, the IEC 61869 Standard will be an IEC 61850 standard complementary. The IEC 61869-9 has a strong correlation with the Guide for Implementation of UCA (Light Edition). It brings to its body several definitions that were there, trying to keep the compatibility with what has been adopted up to nowadays.

In the section 7, of the IEC 61869-9 , there was discussed some tests orientation, to be carried out in the new instrumentations, but due the Standard is still open for comments and has not reached the final version, several items may will receive more details. The more relevant tests are:

- Frequency Response Test
- Max delay Time – Digitalization
-Loss of synchronization test
- Synchronism signal -1 PPS TEST
- Accuracy test

4.2. Distributed Functions

The logical nodes concept permits to implement distributed functions, sharing part of a function in different physical devices interchanging data to each other.

One of the main advantages of the IEC 61850 is the information minimization, by logical nodes, data and data attributes. The logical node is the smaller part of a function which makes data exchange. As an example taken from the standard, the function F2 is composed of logical nodes LN3, LN5 and LN6. The LN3, is located in the Physical Device PD1, the

logical node LN5 is located in the Physical Device PD 2, and the Logical Node LN 6 is located in the Physical Device PD3. All logical nodes are in different physical devices, and are all exchanging information.

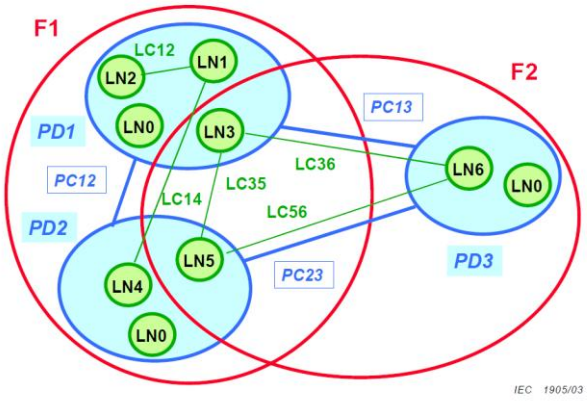

FIGURE 5 – Distributed Function example

The modern test set will have to perform tests over protection systems working with distributed functions. For such a thing it will have to get facilities to verify and measure values which are exchanged by several logical nodes located in different physical devices. A tool prepared to evaluate information exchanged of different nodes has to be used to test.

4.3. Link Redundancy

Nowadays the protocol RSTP (Rapid Spanning Tree Protocols) it´s been used. It works considering that the data transmitted will find the destiny by two connections, however only one input connection is transferring data all the time. Only when the system detects the link is broken then the paths are switched and the data flows by the other input. This is done by the LAN reconfiguration method and the time spent to do this can cause some packet lost.

The IEC 61850 on the second edition included the link redundancy concept. This new technology may avoid losses and delays for sampled values that occur during the reconfigurations of the RSTP protocol.

The link redundancy concept works considering that a source sends two messages, uses different ways, and it is a receiver job to filter out the message that comes sooner. Both messages should arrive in the receiver all the time.

If one of the links is broken the message will travel by other way to reach the intended. In this technique there is no reconfiguration time. The standard IEC 62439-3 presents the High Availability Networks using two methods: HSR (High Availability Seamless Ring) which realizes the redundancy at the IED, and the PRP (Parallel Redundancy Protocols) that performs the redundancy at the switch.

The new test set requirements to perform tests with Sampled Values Systems like SAMU will have to test the link redundancy considering that one of the ways link is opened to check if there is lost packets.

This test will have to be done to check if the link is working properly. This is a new concept, a new test procedure and a new test tolls requirements. The test set system has to be prepared to perform all these requirements already discussed.

5. The New Test Set Instrument Structure Proposed

The instrument shall allow all IEC 61850 tests.

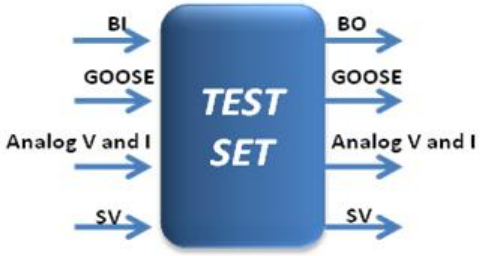

FIGURE 6 - New test set structure for IEC 61850 full tests with inputs and outputs

An instrument, capable to make the full IEC-61850 tests as mentioned in the above text, got to be capable to generate and measure/evaluate: Binary I/O signals, GOOSE messages (including analog GOOSE), Current (from mA up to KA) and Voltage (from mV up to KV) analog signal, and SV.

6. Conclusion:

As anticipated in this paper, all the old tools do not fully attend the overall needs and requirements dictated by the fully application of the IEC 61850 Standard. The standalone instruments available nowadays got partial testing facilities, and new developments will have to be introduced in order to attend the overall requirements.

With emerge of these new challenges it creates a demand for new "weapons" (instruments). Therefore it is necessary to use new test tools to wholly interact to the IEC 61850 environment.

We can not forget the protection/automation professional that do the tests in this new scenery, since he will have to be trained in the new system process reality, and with the new tools which he will learn to operate.

As the IEC 61850 instruments have been gradually installed and the standard has not reached the full level of application maturity, it is expected that new conceptions may still arrive creating possibilities for innovations on this field.

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