IEC61850 9-2 PROCESS BUS: OPERATIONAL EXPERIENCES IN A REAL ENVIRONMENT

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ABSTRACT

New IEC61850 based pilot substations are being deployed all over the world, but few attempts have been made so far to use the process bus to directly communicate with the switchgear and measuring equipment of an electrical substation. This means that the IEC 61850-9-2 process bus has not yet been tested thoroughly in a real environment. In Spain, one utility, a group of protection, control and communication equipment manufacturers and one measurement transformer manufacturer are building a testing scenario in a real distribution substation in order to test the feasibility of a multivendor IEC61850-9-2 process bus based substation.The work presented in this paper reflects the actual development of a pilot installation in an existing high voltage substation and the Operational Experience after one year of operation of the first stage of the Project. The main goal of the project is to review the state-of-the-art process bus technology and evaluate it for practical use, including actual interoperability between different manufacturers, degree of maturity, robustness, and possible benefits. Next stages (with several vendors) will be tested and evaluated in the same way as the first one.

EXPERIENCE AND EXPECTATIONS FROM FIRST PILOT PROJECT IN SPAIN

The pilot installation of IEC 61850 Process Bus architecture presented in this paper is at Iberdrola's 132kV station in Benavente, Spain. This is a conventional installation and the process bus system is installed in parallel with the existing P&C system that is still in use. The new system operates as a shadow system and actually is not being executing any switchgear operation. Its application is limited to measurement and protection, issuing control commands but without physical connection to physical beaker trip/coils. The system is recording historical data of all the external faults as well as internal diagnostics. The data captured during fault conditions by Process Bus system has been compared to data existing conventional system. The internal diagnostic logs in the merging units can record internal temperatures, the receive and transmit optical signal levels along with various diagnostic conditions such as DC power loss, processor reboot, ADC circuitry problems, output driving circuits problems, contact input wetting supply problems and any possible communication failures. Single line diagram of the application has been depicted at Figure 1.

The First Stage of the project comprises the installation of a shadow P&C system for one 132kV line and one power transformer on an existing substation, and the installation of several merging units from one manufacturer.

The selected substation (located in Benavente, Spain) was built in the 70's and is still in service. It has been chosen due to the high number of faults experienced on its connected overhead lines, especially in the summer season owing to the frequent occurrence of storms.

The application consists of a protection of one 132kV line and transformer protection. At first stage one distance relay, one transformer relay and one bay controller from the same vendor is being used (GE). The second stage of the project will include installation of two identical cabinets manufactured by two other P&C vendors in order to prove the concept of IEC 61850 interoperability.

MERGING UNITS (MUS)

One of the main elements in the project is the Process Interface Unit (PIU), which is a process bus merging unit as per IEC 61850 9-2, combined with contact inputs and outputs to form a complete protection and control interface to primary equipment in the switchyard. This PIU is a rugged device designed for outdoor mounting in a switchyard. This unit uses connectorized cables (for copper cables to interface with equipment, and fiber optic cables for communications) to allow simple installation, removal, and replacement. The MUs prototypes has been tested in the most hard environments as we can see in the figures 2 & 3. MUs used in the project are commercial ones. The PIU contains 4 merging units using the same data to provide a star connection to 4 different devices.

The purpose of this design is to have the same physical interface both for the protection and control systems, a PIU connected to a fiber optic cable, for all applications and zones of protection. The only variability in design is where to place the PIUs, and how to lay out the fiber optic cables. The use of a standard, rugged PIU, with connectorized cables, provides many benefits: there is a small list of standard components (PIU, copper cables, fiber optic cable) for the installation, the system can be designed by engineers and installed by field personnel with no high-level training required, the system is successfully commissioned using standard testing tools and methods.

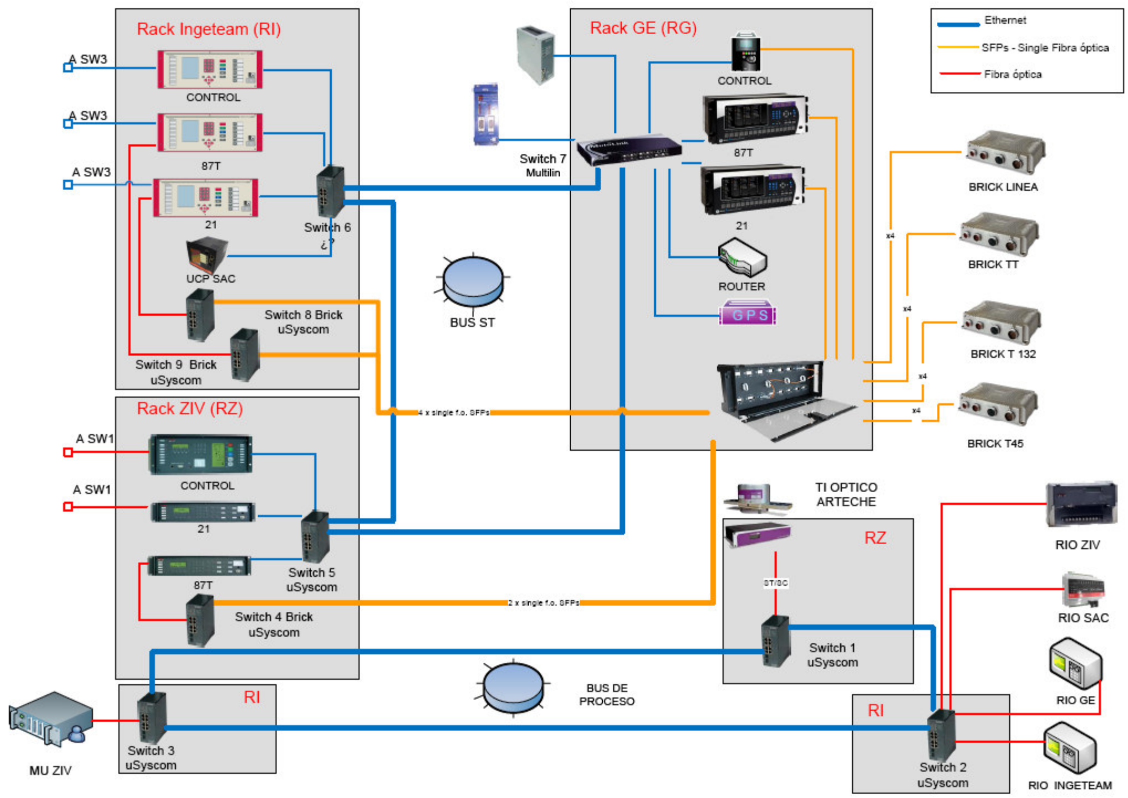

Figure 1: General scheme of Benavente process bus project

Additionally, operation, maintenance, and life cycle costs should be considerably less than with conventional installations and replacement, refurbishment, repair, or upgrade to the system requires only replacing individual components using only simple hand tools.

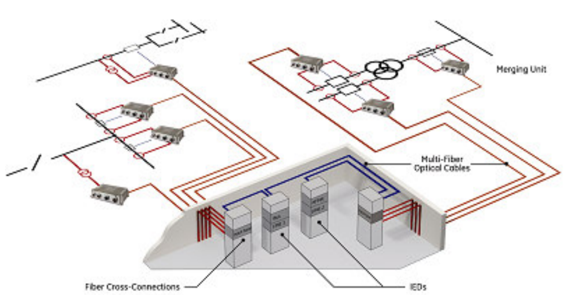

Figure 2 – Point-to-point Process Bus architecture

MUs to be connected only to conventional CTs and VTs, without contact inputs and outputs, are also planned to be tested.

The installation consists of 4 Merging Units to be installed outdoor at the switchyard

PROJECT EXECUTION

Benefits of a practical, point-to-point process bus architecture can be found at every step of the design, installation, and maintenance of P&C systems. Standardized components, copper terminations that end at merging units installed at primary apparatus in the switchyard, and purpose-driven, straightforward architecture simplify procurement, engineering, drafting, construction, commissioning, maintenance, and operations. The execution of this pilot installation illustrates these benefits clearly. The first part of the project was executed in few simple steps listed below.

Site survey

A site survey was performed to determine the physical locations of the merging units and to measure the physical lengths for the pre-fabricated and connectorized fiber and copper cables. Merging units and relays were selected according to application needs and cables were ordered as per the site survey results..

Configuring the System

This process bus based P&C system is very simple to configure. In fact it is no different than the current practices of setting the relays except the additional step of mapping the I/O to their respective merging units. Each merging unit is mapped using its serial number, digital core number and order code. This process is very intuitive and straightforward and there is really no need for specific knowledge of IEC61850 process bus to do this. Setting the rest of the functions of different relays remains exactly same as it is done today. More importantly there is no need for any special software tools to configure this process bus system; the existing IED software tool itself is used.

Factory Acceptance Testing (FAT)

The P&C system presented here promotes the shift from Site Acceptance Testing (SAT) to Factory Acceptance Testing (FAT). The process bus system consisting of pre-connected cables, merging units and pre-configured relay panels, is shipped as a completely tested entity. This transfers the maximum amount of design and construction to a controlled environment rather than on-site. Whole of the process bus system was assembled at factory in the way it would be installed at site and tested thoroughly.

Installation and Commissioning

The installation and commissioning phase of the pilot project was done in September 2009, involved the following tasks:

- Mounting the merging units out in the switchyard in pre-determined locations
- Making and verifying the copper interfaces to the primary apparatus using the pre-connected cables
- Routing and connecting the outdoor fiber cables between the merging units and control house
- Powering up the whole system and verifying that the relays and the merging units do not report any errors.
- Placing the whole system in service and verifying that the measurements reported by the process bus system are consistent with the conventional system

It is worth noting that mounting of merging units and making the copper interfaces have to be done for this pilot installation, as it is a retrofit. However, for Greenfield or fresh installations the merging unit can be made part of the primary apparatus. This means the merging units will come mounted and pre-wired in the primary apparatus, significantly reducing site work.

OPERATIONAL EXPERIENCE

The process bus system has been operating without any anomalies for more nearly two years and has remained operationally consistent with the conventional system.
There have been many external fault conditions and the process bus system has captured the fault conditions very close to the way the conventional system has done. The rugged merging units mounted outdoors on the switchyard structures have performed well serving under varying environmental and electromagnetic field conditions. The diagnostics logs in the merging units recorded internal temperatures, the receive and transmit optical signal levels along with various diagnostic conditions such as DC power loss, processor reboot, ADC circuitry problems, output driving circuits problems, contact input wetting supply problems and various communication failures.

Environment

Benavente substation has more than 20 years of service and has been chosen on purpose for the pilot Process Bus installation because it is characterized by the large number of faults on the 132 kV lines connected to it, especially in the summer season due to frequent occurrence of electrical storms and large concentration of birds (storks) that build their nests on many HV towers along the transmission lines.

Short circuits and other events

Since September 2009 until July 2010 the 145 kV Vilecha line has experienced a total of 10 faults being 9 phase-to-ground and 1 phase-phase-ground. In all the faults the protection has performed correctly.

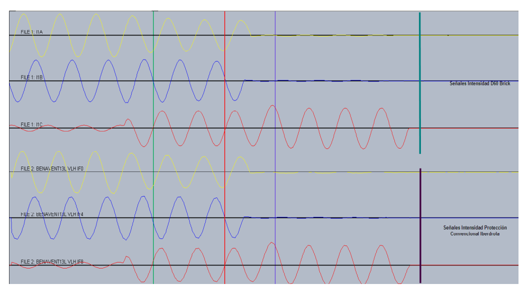

Fig. 3 Fault currents during a phase-to-ground fault on phase C. The three upper currents correspond to the Process Bus Relay and the other three to a conventional numerical relay.

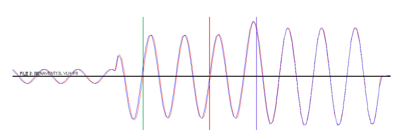

Figure 4. Comparing current signals between process bus (Red) and conventional (Blue) systems for the fault of Figure 3.

The response of the transformer protection relay was also correct. No false trip was observed during more than 15 external faults registered by the relay.

CONCLUSIONS

The paper describes a novel approach for implementation of IEC 61850-9-2 process bus, which permits deployment of this technology without being forced to modify the design of primary equipment and reports on a pilot installation for a 132kV transmission line and transformer application.

Introducing a point-to-point communication architecture for process bus helps solving key technical challenges like data sharing and sampling synchronization for analogue signals. On dedicated fiber optic links the Ethernet traffic is fully deterministic. Second and third stages of the project will comprise the connection of Ethernet switches, in order to compare the performance with the point-to-point architecture.

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The benefit from interfacing protection and control IEDs by fiber optic only is the elimination of conventional I/O boards from IEDs and huge reduction in copper wiring in relay cabinets. Instead of several I/O boards with dozens of copper connections the new generation of IEDs contain just one communication card with few fiber optic ports. Apart from cost reduction at design, manufacturing, installation and commissioning stage it also provides advantages for IEDs maintenance. With this concept the relay cabinets in control building would not need thousands of copper wires and thousands of connection terminals. These connections can be replaced by few fiber optic cables and by software configuration of digital signal mappings.

The paper presents robust process bus architecture for distributed protection, metering and control. In particular the solution:

- Targets copper wiring as a major cost, labour and time factor, and replaces copper wiring for protection and control purposes in the switchyard and the control room with fiber-based communication.
- Introduces rugged merging units that solve practical problems such as outdoor fiber cabling and connectivity in harsh conditions, weatherproofing, commissioning, maintenance, and expandability.
- Uses merging units designed to interface all process interface measuring and control points at a given switchyard location using a common device and working with a standard I/O structure: status inputs, binary output commands, transducers and sensors, and instrument transformers.
- Increases reliability by a novel concept of redundancy and optimized communication architecture.
- Eliminates cyber security concerns by using a non-routed communication scheme.
- Eliminates the need for extra software tools for setting up the process bus data.
- Provides long-term maintenance benefits by elimination of hundreds of copper wires traditionally run in secondary cable ducts across the switchyard and replacing them by few robust fiber cables, with prefabricated military grade connectors.

The work presented in this paper reflects the actual development of a complete system encompassing all major protection application types. The main goal at the design stage was developing a system that could provide a real benefit for the end user in terms of cost reduction, project duration decrease and simplification of the system architecture.

A future work on the presented system could include implementation of interface to the Non-Conventional Instrument Transformers (NCIT's) once market acceptance grows for NCIT's and more new installations are delivered with this technology. The next steps of the project involves also the connection of the "bricks" with relays from other manufacturers and the development of Remote Digital Inputs/Outputs (RIO´s) devices with the purpose to interface individually with the switchgear devices (Isolator switches, CB´s) and to send the information to the control room through fiber optic.

The authors believe that the presented system offers special opportunities for application in High Voltage substations. This is due to its native extremely robust design suitable for the most extreme environmental conditions like direct exposure to dust, sun, high temperature, vibrations and electromagnetic shocks. Ruggedized Merging units that are electronic devices aimed for signal acquisition can be seen as part of primary equipment.

REFERENCES

[1] IEC International Standard "Communication networks and systems in substations - Part 9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3", *(IEC Reference number IEC/TR 61850-9-2:2004(E), IEC, Geneva, Switzerland).*

[2] M.Adamiak, B.Kasztenny, J. Mazereeuw, D. McGinn, S. Hodder "Considerations for Process Bus deployment in real-world protection and control systems: a business analysis" *presented at 42 CIGRE Session, Paris, August 24-29, 2008, paper B5-102*.