The Advantages of IEC 61850 Process Bus Over Copper-Based Protection and Control Installations

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1. Introduction

This paper reviews key aspects of the process of implementing traditional hard-wired solutions utilizing integrated multi-function relays and compares them with implementing the equivalent system using an IEC 61850-9-2 [1] process bus solution [2]. The various benefits as they relate to the engineering, construction, commissioning, and routine maintenance from transitioning from traditional Protection and Control (P&C) systems to a process bus solution are reviewed.

Typically benefits are translated into specific cost savings on a project. Recognizing differences in absolute cost and relative costs of materials and labour, as well as other factors such as accounting for constraints resulting from labour regulations, relative currency differences and so on, specific financial costs savings are difficult to predict in a general case. However, by deploying practical IEC 61850 process bus-based P&C systems, it is estimated that total labour savings approaching 50% or more are realizable over the life of the system, particularly in green-field installations.

Not all benefits can directly be translated into specific monetary savings. A number of benefits relate to the ability to better optimize the utilization and deployment of resources, improving the overall efficiency in using both capital and operating & maintenance budgets. This paper presents evidence as to these assertions.

2. The Traditional Protection & Control System

The traditional P&C system uses individual copper wires to transmit signals from the switchyard to protective relays in the control house. Each copper wire for an individual signal is terminated at the primary apparatus in the switchyard, pulled through cable trenches to a termination block in the control house, then is terminated numerous times within the control house through terminal blocks, test switches and various relay terminals. The signal is then returned from the relay to the primary apparatus through even more terminations. One complete copper signal path typically requires 8 or 10 terminations.

During the design phase, these numerous copper connections result in large amounts of variability in engineering design. Each design and application will be unique, based on the individual site location, designer and design requirements. Design changes require significant manual labour to implement the changes in the copper connectivity. Each change usually requires a skilled draftsperson revising a large number of drawings manually. Materials are procured and installed as individual components in the system, and the number and type of materials vary between zones, again due to all of the variability introduced by the copper wiring.

On-site construction, commissioning and maintenance also expend a great deal of effort, and consequently carry a high cost, dealing with copper wiring. Each wire and termination is made by hand in the field, one wire at a time, using expensive, skilled labour. The integrity of each copper signal path needs to be verified during commissioning, and errors require troubleshooting and rework to correct. High-energy signals from primary equipment are brought to the control house and therefore test switches are required during maintenance procedures to isolate these signals for both personnel and equipment safety. Isolating and restoration of individual signals using test switches during maintenance carry a risk of human error and misoperation of protection, as all of the correct test switches must be opened to start maintenance safely, and then correctly restored for proper system operation after restoration.

Project management is difficult, as there are large requirements for skilled labour, and many handoffs between engineering, drafting, construction, and maintenance groups in the utility. All of these handoffs must be accounted for in the project schedule, and a delay in one group handing their output to the next group can have significant impact to the project in terms of both delays and cost overruns.

3. A Practical Process Bus System

One example of a practical IEC 61850 process bus system is the HardFiber system from GE shown in Figure 1. This system is made up of a small number of standardized components, almost completely connectorized for fast installations and easy replacement. The system itself is naturally scalable, supporting the addition of new zones and modifications to existing zone in a straightforward and low-risk manner.

4. The Benefits of IEC 61850 Process Bus

Benefits of a particular process bus system, the HardFiber System [3], 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.

4.1 Materials

With the HardFiber system, materials become a finite set of standard components, with a small number of each type, across all zones and stations. Regardless of the physical construction or vintage of the associated primary apparatus and the nature of the project (new construction versus retrofit), the interface to the primary power system is always exactly the same. Even the order code for the associated protective relay is reduced to a relay with a single IEC 61850 Process Card for virtually every application.

Control buildings and cable trenches can be greatly reduced in size due to elimination of most of the bulky copper cables, terminal racks and AC and DC test switches on relay panels.

4.2 Engineering

The interface between the protection and control system and the power system is always presented exactly the same, regardless of the actual physicals of the substation – the interface is always a Brick located in the switchyard at the end of a fiber optic communications channel. There is only minor physical variability in mapping Bricks to specific relays, based on the topology of the switchyard as mirrored in the provisioning of specific protection & control zones. All of the variability with respect to the mapping of specific power system signals is transferred completely into the specific configuration of each relay involved in protection and control, as opposed to the mapping and connection of specific physical signals via copper wiring.

The HardFiber system is based on the well-proven Universal Relay (UR) family of protection and control relays, covering a wide range of protection applications and zones. The use of a known relay product line, coupled with the fact that the fundamental operation of the relay algorithms remains unchanged, greatly reduces the risk and amount of type testing necessary to adopt, adapt and deploy the HardFiber system.

4.3 Drafting

The only documentation required for copper connections in the switchyard is in the interface wiring between the primary apparatus and the corresponding Brick I/O. These documents can be standardized to each primary equipment vendor and type. The documentation for the installation of the Bricks in the primary apparatus may be specified as deliverable as part of purchase of apparatus.

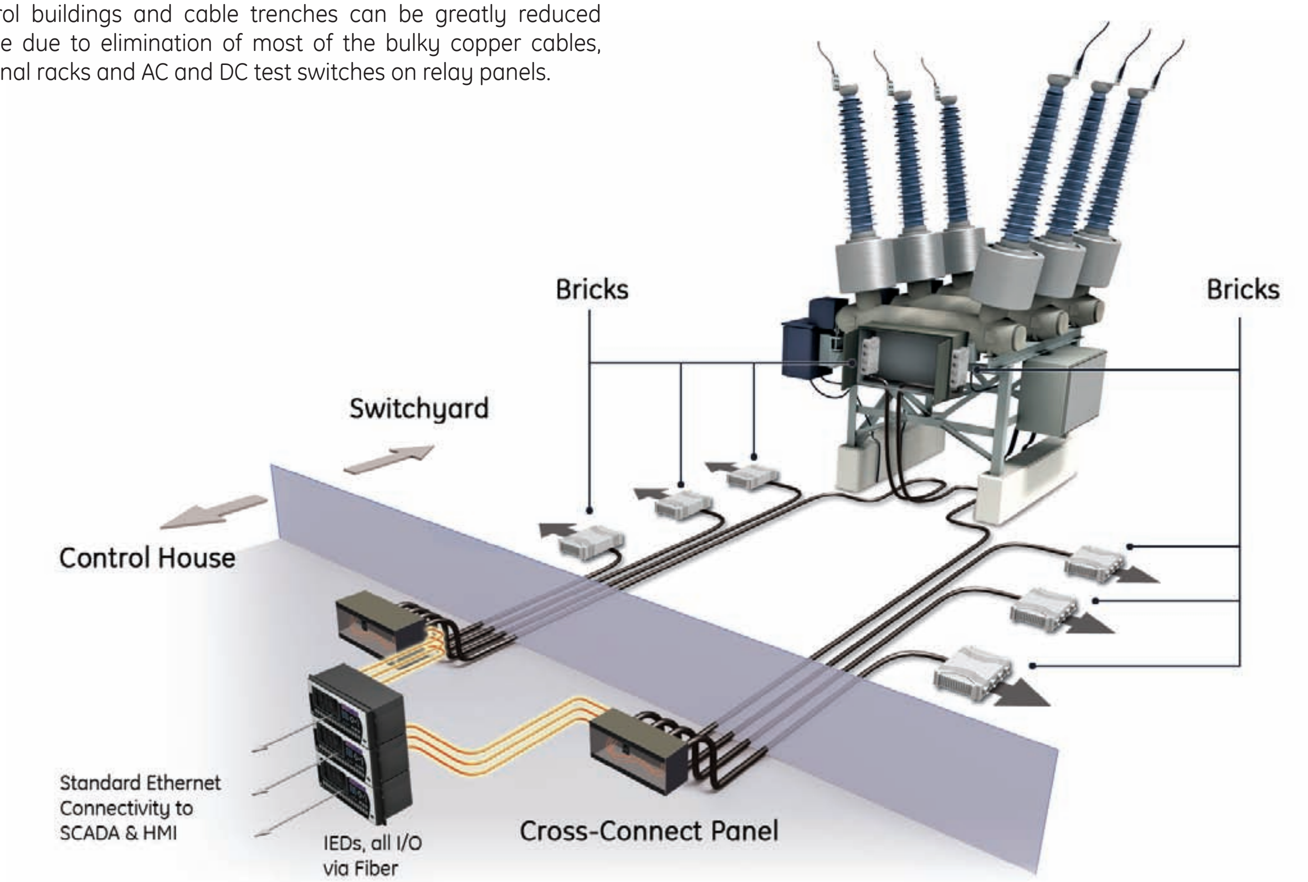

Figure 1.
HardFiber process bus architecture

Within the control house, the amount of documentation for the connectivity is vastly reduced and simplified to single point-to-point fiber connections. These connections can be summarized in tabular form as opposed to drawings, and may even be automatically generated by software to create system and connection documentation.

4.4 Construction

The construction effort needed to make on-site copper connections, and is virtually eliminated when the apparatus manufacturer installs Bricks in the primary apparatus prior to delivery to site. The chance for errors is vastly reduced by eliminating the majority of copper terminations and by standardising the physical connectivity between the primary apparatus and the Bricks.

The simplified interface point to the switchyard offered by the Cross Connect Panel provides faster on-site installation for P&C systems, particularly where turn-key control buildings are used with primary apparatus pre-wired with Bricks.

4.5 Commissioning and Maintenance

Continuous monitoring of the architecture and equipment reduces protection misoperations from incorrect isolation or restoration during protection testing [4]. Construction errors are limited to provisioning of communication between origin and destination of information. No high-energy signals (AC or DC) are present in the control building for greater personnel safety when working on protection and control systems.

By providing the opportunity to use fully duplicated field measurement hardware (Bricks), along with continuous self-monitoring of all hardware and communications allows maintenance to be condition-based (event-driven, e.g. run-to-fail) as opposed to calendar-based periodic maintenance. This reduces the costs associated with maintenance over the entire life of the P&C system, and reduces the opportunity for power system interruptions to occur due to human error during isolation and restoration of a P&C system during routine maintenance.

4.6 System Modifications & Switchyard Additions

The HardFiber system's point-to-point architecture allows for the same degree of scalability that traditional hardwired P&C systems provide. Each zone can be conveniently engineered, installed and commissioned individually without impacting adjacent zones. For retrofit applications, the HardFiber system can be deployed for a single zone only, for example the addition of a new capacitor bank on an existing station, without disturbing the existing in-service protection nor requiring the entire station protection be converted to a process bus-based solution.

Similarly, existing process bus-based protection zones may be expanded to incorporate new power system elements by tapping to the newly added Brick. The dedicated point-to-point architecture of the HardFiber system allows new zones and new equipment to be added and integrated without concerns regarding isolation for existing protection and control applications or adverse system performance from increased network traffic.

4.7 Project Management

Procurement, engineering, and construction are greatly standardized, and fewer handoffs with less labour effort required at each stage increase productivity and helps control and reduce project cycle times. Up-front decisions regarding material planning are simplified, so engineers and draftpersons can be engaged earlier on detailed design work, without needing the complete physical details of the installation.

Another advantage is the execution of work on-site is almost completely decoupled from the presence of large components like breakers and a control at the substation. Outdoor fiber optic cables for the Bricks can be run at convenient time when labour is available, even if the Bricks have not been installed yet. Turn-key control houses can be assembled in a controlled environment and completely tested to the demarcation point (Cross Connect Panel) prior to delivery to the substation site. Bricks can be installed in the primary apparatus, and even tested in-situ to ensure the correctness of the copper interface wiring. Ideally, new breakers or refurbished breakers will have the Bricks installed and tested in the controlled environment of the breaker shop. The on-site installation then becomes the simple task of making fiber optic connections between the pre-tested relays in the control house and pre-tested Bricks in the switchyard – a truly "plug-in" substation project.

4.8 Operations

The high degree continuous self-monitoring and optional duplicated measurement hardware allows the hardware implementing protection and control to detect spontaneous failures and go into a fail-safe state, thereby preventing certain protection maloperations and the corresponding unexpected outage of the primary power system. The Brick, with its connectorized cabling and no internal settings or firmware facilitate fast replacement of hardware without requiring long outages to re-commission protection and control systems in the event of a hardware failure.

4.9 Cyber Security

The dedicated, point-to-point architecture of the HardFiber system does not contain any active network switching or routing hardware, and therefore does not require any external access for monitoring or configuration purposes. Due to its completely isolated nature, the HardFiber system as designed is implicitly secure from external cyber security threats and by design complies with cyber security requirements.

5. Conclusions

In this paper, some of the advantages have been presented that are realized by deploying an IEC 61850 process bus solution like the HardFiber System to implement power system protection & control systems.

Copper-based signalling is the central question in the IEC 61850-9-2 process bus discussion. Copper wiring is a source of physical variability that not only generates the majority of the labour cost, but also prevents transition of the industry from a "workshop" mode of production to a factory mode: with less assembly done in-situ by hand and more physical elements pre-tested and shipped with a manufacturer's warranty. This optimization of labour is going to become a key consideration in the electricity sector for many years to come [5].

Utilities should strategically look at the adoption of a low-risk process bus solution like the one presented in this paper and take advantage of all of the tangible business benefits such as project cost reduction, faster facility construction, lower maintenance costs and improved reliability that this exciting new technology offers.

6. References

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[3] B.Kasztenny, D.McGinn, S.Hodder, D.Ma, J.Mazereeuw, M.Goraj, "A Practical IEC61850-9-2 Process Bus Architecture Driven by Topology of the Primary Equipment" (42 CIGRE Session, Paris, August 24-29, 2008, paper B5-105).

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