Process Bus

A Practical Approach

Process bus is generically defined as the digital transmission of process measurements between the substation switchyard and digital protective relays in the control house. The IEC 61850 standard addresses process bus through Part 9-2 “Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3”, by providing data mapping to transmit analog sampled values directly into the Ethernet Data Link layer.

The adoption of process bus by utilities has lagged behind the adoption of the bay level device-to-device communications of station bus. This is due in part because, until now, there has not been a practical process bus solution available in the marketplace.

The original vision of IEC 61850 process bus was defined in Part 9-1 “Specific Communication Service Mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link” as applying to electronic current and voltage transformers with a digital output via a merging unit, for use with electronic measuring instruments and electronic protective devices.

Biographical Sketch

Rich Hunt began his 20 year professional career in system protection at a utility, before moving to protective relay manufacturers after graduate school. He received his BSEE from Virginia Tech in 1986. Rich concentrated on power systems while studying for his BSEE to avoid taking microprocessor design classes.

After spending a decade at a utility, Rich went back to Virginia Tech to learn about the application of microprocessors to protective relaying, earning his MSEE. Since then, Rich has worked on the supplier side. Presently, he is an Application Engineer for GE Digital Energy - Multilin.

Rich is presently a subcommittee chair in the IEEE Power Systems Relaying Committee, and an active member of the IEEE Industrial Applications Society. He is a professional engineer and author of numerous technical papers on applications of protective relays.
For some, the vision has changed over time to that of replacing the hard-wired copper connections of the protection and control system in the substation with a digital communications network. The belief is that the IEC 61850 process bus solution will have more flexibility in design and application, tighter integration between devices, “plug-and-play” capabilities to facilitate design, replacement, and expansion, leading to reduced design costs, installation costs, and operating costs. Much work has been done towards developing products and tools that solve the technical problems of station bus and process bus as defined in the IEC 61850 standards documents. The products and tools that have been developed to date are practical technical solutions, in that they work, and meet the business objectives of a utility to be practical. Utility business objectives can be defined as improving financial performance, meeting market demands, and increasing workforce utilization. The second objective is that any process bus solution must be aligned with present day protection and control practices. This minimizes the amount of learning and design changes needed, increases the adoption rate, and accomplishes high reliability at the start. The third objective is that process bus must be “fit-for-purpose”. The solution should be based on industry standards (primarily IEC 61850) to be open and non-proprietary. It should also have a robust architecture ready to use. Each process measurement piece requires a large amount of skilled labor. There are numerous hard-wired connections between the typical protection and control system. The background business environment is one that requires process measurement requirements for a merging unit.
electric utilities to change their approach to construction projects. To be able to afford the capital costs on infrastructure renewal and expansion, a utility must leverage highly integrated IEDs for significant savings from reduced wiring costs and number of devices, while reducing the amount of labor, and the skills required. And in today’s economic environment, projects must be completed faster to maximize the use of capital. In addition, utilities are facing changing market demands beyond increased load growth. Customers are also increasingly sensitive to service interruptions and the losses they may absorb from service interruptions, requiring more reliability, and faster completion of infrastructure projects. Also, due to the constraints of operating the loaded transmission system, the permission to have equipment outages is more difficult to get, and the length of the obtainable outage window is getting shorter. Possibly the most important business objective for utilities, especially in light of the aging technical workforce, is efficient utilization of skilled labor. Previous advancements in technology, such as microprocessor relays, have not fully addressed workforce efficiency. Protection and control systems are still constructed using the same on-site labor techniques of 30 years ago. This method is not sustainable when faced with the coming large turnover in skilled employees. Also, beyond the need of replacing an aging workforce, there is also the challenge of recruiting new workers to the industry from a shrinking pool of technical talent.

A practical process bus solution must support these business objectives. The biggest benefit process bus can supply is reducing the amount of time to design and install the process measurement network, and lessening the skills needed to design, and especially install, this network. By solving this problem, process bus also helps utilities meet their financial objectives (build more, build faster, build more cost-effectively) while meeting new market demands. 

**Process bus must be a practical business solution.**

**Design considerations for a process bus architecture**

The process measurement system in today’s substation uses hard-wired copper connections in an established architecture. This architecture is defined around the protective relay and relay application. Using microprocessor relays, the engineer process is to design the process measurement system for a specific relay application, and then configure the relay for protection, control, and other ancillary functions. The process measurement system is zone-based: the wiring necessary to acquire process measurements is installed as new lines, transformers, or circuit breakers are installed. These wires, and the associated protective relays, are dedicated to a specific zone of protection. Existing process measurement uses a point-to-point communications topology, by sending AC and DC signals over copper wiring. Point-to-point wiring is straightforward to design and install, is installed to support a specific zone of protection, and is easily shared by connecting additional relays or meters in series with or parallel to existing devices. Reliability is addressed by having two independent point-to-point connections per zone, operating in parallel. The existing process measurement system is also a purpose-driven design. The architecture is robust, allowing each zone of protection to be reliable, flexible, and scalable. This design is also cost-effective within the limits of traditional technology. Each zone and associated devices are separate from the process measurements and associated devices of other zones of protection, though they may interconnect at primary power system equipment.

The benefits of this architecture are many. Process measurement systems using copper wiring are highly reliable, with the wiring and equipment known to last 50 years. It is flexible and scalable. New wiring and devices are added only as needed during construction, while existing process measurement wiring is not disturbed when adding new primary equipment. The present architecture is also deterministic, in that operating times and performance can be designed for, and tested for. Adding new bays or protection zones, or replacing equipment in existing zones, won’t impact the performance or require re-commissioning of other protection zones. This architecture also supports interoperability with clear segregation of design functions. End users design the process measurement system to meet specific application requirements, with the interface to protective relay designed by industry standards. Equipment suppliers design products that meet these interface standards, such as, nominal secondary CTs, and 125V DC battery systems.

Process bus is not limited to this zone-based architecture. In fact, Part 9-2 explicitly defines the data sets for transmitting sampled values via Ethernet communications, but only suggests possible architectures in Annex B. The design envisioned as the IEC 61850 standard developed is one of the process bus network as some form of a local area network. This design allows the modern substation to leverage the commercial off-the-shelf solutions of information technology. Also, the local area network design allows all process measurements to be used by all devices in the substation. The tradeoff is this solution introduces additional equipment, such as Ethernet switches and substation master clocks, and requires information technology skills 

**The driving goal of this design is to reduce the labor to design and install protection and control systems by over 50% over the traditional design.**

The process bus also supports faster completion of infrastructure projects. Also, due to the constraints of operating the loaded transmission system, the permission to have equipment outages is more difficult to get, and the length of the obtainable outage window is getting shorter. Possibly the most important business objective for utilities, especially in light of the aging technical workforce, is efficient utilization of skilled labor. Previous advancements in technology, such as microprocessor relays, have not fully addressed workforce efficiency. Protection and control systems are still constructed using the same on-site labor techniques of 30 years ago. This method is not sustainable when faced with the coming large turnover in skilled employees. Also, beyond the need of replacing an aging workforce, there is also the challenge of recruiting new workers to the industry from a shrinking pool of technical talent.

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include AC currents and voltages required for a zone of protection, and relays (Figure 1). Cables, and fiber patch panels for apparatus, the relay, pre-terminated mounted directly at the primary into an IEC 61850 Part 9-2 frame (that convert analog signals components that includes merging set of standard, interchangeable design. This system uses a finite protection and control systems to and mimic of the traditional designed as a direct replacement in the marketplace. This system is practical process bus system available to conventional solutions, and will limit the need to learn new skills. One practical process bus system This article describes one practical process bus system available in the marketplace. This system is designed as a direct replacement to and mimic of the traditional zone-based, point-to-point hardwired copper system, using an IEC 61850 Part 9-2 frame to transmit process measurements. The process bus solution design is based on: The variability of the physical design ends at the fiber patch panels in the control house. Fiber cables from each merging unit, and fiber cables from each relay, land at the patch panel. Connections between merging units and relays are made by simple fiber patch cord connections. Since the cables are multi-fiber cables, a patch cord connection connects one fiber from the state of the power system and primary switchyard are transmitted over secure, high-bandwidth fiber optic communication channels using an IEC 61850 Part 9-2 frame. Therefore, the physical interface of the protection and control system in the switchyard is always the same: a merging unit connected to a fiber optic cable. The variability of the physical design is simply where to place the merging units, and how to locate the fiber optic cables across the switchyard. The process bus system design is based on:

- Traditional protection and control schemes. The installation can be carried using the commonly known and available skills and tools found in any electric utility.

3 Process bus installation project

The system is scalable enough to accommodate any size station.

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a merging unit to one fiber from a relay. Therefore, a single relay can connect to several merging units through dedicated point-to-point connections at a patch panel. It is important to note that the patch panel is not an Ethernet switching device. It is simply a physical rack or cable mounting device designed to be the interconnection point between the switchyard and the control house.

The use of point-to-point fiber optic connections provides a deterministic time delay for signal transmission between the relay and the merging unit. This allows the relay to control the sampling rate, as well as to synchronize all merging units connected to it. Therefore, no master synchronizing clock is required.

Good protection and control practices for high voltage substations use redundant measurement paths from instrument transformers to redundant protective relays. This practical process bus implementation accommodates redundant merging units installed at every measurement point. Each merging unit uses a separate fiber optic cable that can be installed in different trenches across the switchyard, and the redundant fiber optic cables can be landed at different fiber optic patch panels for complete diversity.

This process bus solution is practical for many reasons. For design and engineering, the complexity of the system is in the design of the merging unit and protective relay. For the utility engineer, this complexity is “under the hood”, and hidden. Instead, all that is required is the physical design around the intuitive zone-based, point-to-point architecture. Design time is reduced by developing standard connection drawings for a specific model of circuit breaker or other primary equipment. Configuring the system is “relay-centric”: all configuration, takes place in a protective relay. And this configuration requires no more steps or complication than is presently required to configure a microprocessor-based relay.

This system has great benefits during construction of protection and control systems. The number of copper terminations in a switchyard is greatly reduced. Fewer terminations speeds up construction, frees skilled labor, and reduces the number of errors. Equipment suppliers can make many of these terminations by installing the merging units as part of their manufacturing process. This system can be used to develop “plug-in” control houses, with only fiber optic connections to the control house, reduces the size of protective relay panels, and allows the use of smaller pre-cast cable trenches or duct banks. Construction errors are more reduced, as the connectorized cables are designed to limit the possibility of connecting cables incorrectly.

The advantages described here illustrate how this specific process bus system reduces cost of installation and cost of ownership, by reducing the amount of labor over conventional systems. For illustration, consider a new substation installation. Equipment manufacturers install merging units and make copper terminations as part of the manufacturing process for circuit breakers and transformers, so skilled labor is not required to design, document, or install copper terminations. Fiber optic cables are pulled from the control house to equipment pads, and the fiber cables are connected by hand to the merging units as the equipment is installed. Only simple skills, with
The key objective is lowering the total cost of installation by reducing the amount of labor and the skill sets required.

Merging unit installation

The Process bus system’s architecture needs to be fit-for-purpose, using equipment and designs that will provide reliable protection and control.

The Process Bus

system in reducing labor and wiring. The solution in this case was to locate merging units at the live tank circuit breaker, the freestanding CT marshalling cabinet, and each line VT marshalling cabinet.

To ensure reliability, redundant merging units were installed at each process measurement location. The outdoor fiber cables from pairs of merging units land at different fiber patch panels in the control house.

This system has a unique feature related to redundancy and reliability. The relay can connect to multiple merging units, including two merging units that are measuring data from the same location. It has the ability to crosscheck measurements against each other sample-by-sample. If the measurements vary greatly from each other, indicating a problem with one of the measurement paths, the relay blocks all protection functions and alarms. If communications is lost to one merging unit, the relay can use data from the second merging unit, or block all protection functions, a choice made during relay configuration. Therefore, the system maintains the standard of using redundant relays with redundant measurement paths, adding the capability of having one relay with two measurement paths.

Utility personnel performed all commissioning of the system. Figure 6 shows one of the merging units mounted at a circuit breaker with pre-connectorized cables. The cables, from left to right, are the fiber optic cable, the copper cable for contact outputs, the copper cable for contact inputs, and the copper cable for AC measurements. The copper cables run only a few feet into the breaker control cabinet. The fiber cable runs several hundred feet across the switchyard, part direct buried, part in a pre-cast cable trench and part in a duct bank.

This project illustrates why this specific process bus system is so practical. It is scalable enough to accommodate any size station, and

no special tools or knowledge sets, are required to install the fiber optic cables. Relays are configured using the same process, and same steps. Every one of these steps optimizes the use of skilled labor on the part of a utility, and reduces the amount of skilled labor to design, document, and install the process bus system.

Actual process bus installation

An illustration of the advantages of a specific process bus solution is an actual installation at a major North American utility. This was a retrofit project, installing the process bus system on the 345 kV breaker-and-a-half line bay configuration of Figure 3, in parallel to an existing traditional system. It was installed and commissioned by utility personnel. No special knowledge, training, and tools were required for the installation, so no assistance was needed from the process bus system supplier.

The relays used are line distance relays for each line, and a breaker failure relay for the Center breaker. The first engineering decision is where to apply merging units. The merging units come in two standard versions, one with two sets of current inputs, and one with both current and voltage inputs. This is in addition to a number of contact inputs and contact outputs. The decision was to mount merging units on all existing primary equipment structures where key process measurements must be acquired. Copper interconnections are made in the equipment control cabinets, without any need to provide trenches or conduits for the copper wiring. Merging units with two sets of CTs are located at both dead tank circuit breakers.

The live tank circuit breaker, the freestanding CT, and the line VTs require more consideration. It is possible to locate a merging unit at a circuit breaker, for example, and pull copper wire across the yard from a line VT location to this merging unit. However, this method doesn’t optimize the use of the process bus.