Fully Utilizing the Intelligent Electronic Device Capability to Reduce Wiring in Industrial Electric Distribution Substations

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Abstract **-- Each wired termination in a substation represents a cost associated with engineering, installing and testing that wired point. These costs include the obvious financial labor costs, but also include intangible costs such as installation and commissioning time, potential for human error, panel space, increased resistive burden in circuits, and larger raceways. Additionally, each wired termination represents stranded engineering time that is used design these terminations rather than allowing the engineering staff to solve problems.**

Most industrial electric distribution wiring design practices are taken for granted without thought as to the true cost and reliability of the practice and whether or not the function can be implemented with less wiring. Some standard Industrial electric distribution practices have evolved that seek to minimize wiring. An example of this practice is the use of multifunction microprocessor based relays that can logically develop a trip bus from protective elements rather than having to wire individual elements to create the same trip bus.

This paper seeks to expose some of the hidden financial costs and reliability costs associated with copper process wiring. Additionally this paper will discuss ways in which modern Intelligent Electronic Devices (IEDs) can be fully implemented to further reduce wiring. The cost and reliability benefits associated with the reduced wiring will be discussed and quantified. Some of the solutions to be addressed include the use of breaker IEDs as an interface for breaker control, IED to DCS communications, IEC 61850 IED to IED communications, internal lockout Relays, IED pushbutton control, and process bus. Each of these solutions are currently available in today's market place and have varying degrees of acceptance within the industry. The benefits and liabilities of each solution using traditional IED implementation versus maximized IED implementation shall be discussed.

I. INTRODUCTION

The benefits of reducing wiring are so great that reduction of wiring is not a new concept. As protection and control designs have evolved, several methods of reducing wiring have also evolved. The most notable example is the use of trip functions developed in logic inside a microprocessor based IED verses a wired trip bus with discrete electromechanical relays as shown in Figure 1. In Figure 1, the wired trip bus on the right represents traditional wiring where protection and control logic was performed discretely by wiring components. Parallel components represent "OR" gates and series components representing "AND" gates. The logical trip bus on the left of Figure 1 accomplishes the same functionality in digital logic as the wired trip bus performs using wiring.

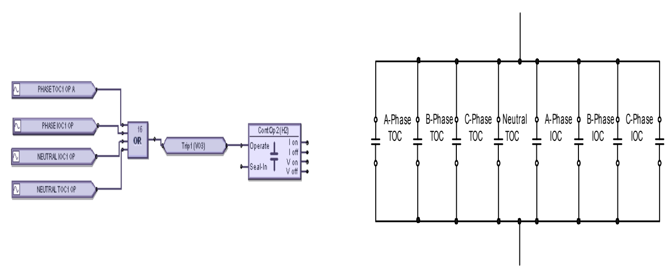

Figure 1: Trip Logic verses wired Trip Bus

The title of this paper might draw the reader to conclude that the industry has a problem with wiring. There is in fact, no problem with wiring. Protection and control wiring has been successfully used for about one hundred years. The problem actually lies with the labor and the time needed to design and install the wiring and the business environment of the Industrial electric distribution industry. The current Industrial electric distribution environment will see a loss of qualified engineers and construction personnel at a time when the electrical infrastructure needs a major overhaul. Funding for future projects as well as time to implement those projects will continue to be condensed. The decisions engineers make in design affect the cost and the time to implement protection and control projects. In the quest to lower costs and time to implement, most of the "low hanging fruit"

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(SCADA to IED communications, IED to IED communications and IED as breaker control) is well documented and has varying degrees of acceptance within the industry.

Newer designs, which eliminate wiring, must be evaluated to insure that the solution is reliable, secure, and cost effective. In evaluating the cost effectiveness of a solution the true costs of the solution must be quantifiably measured against the true costs of the current design. Additionally, several questions must be considered, included among those questions are: How and why is this saving cost? Does this solution save cost in one category, but cause other cost to increase? Does this solution trade one problem for another and cause hidden costs? Is the cost savings solution based on open standards and protocols, which will continue to be supported at the end of life of the IEDs?

In order to answer the questions above, a thorough knowledge of the true costs of wired terminations must be understood. The majority of the costs associated with wired terminations center around the labor needed to install the termination rather than the material being installed. Based on this cost breakdown, it is easy to understand that the greatest potential for cost savings on protection and control projects come from reducing the labor necessary to implement the project. The actual labor to implement the project centers around three categories: engineering, installation, and commissioning.

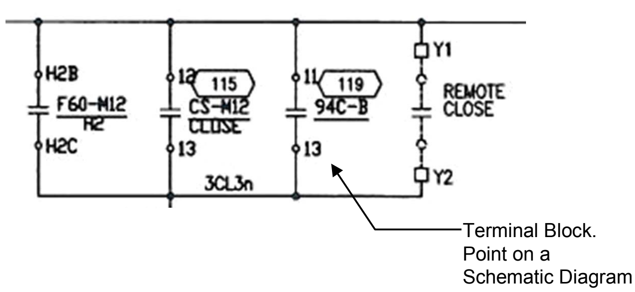

Figure 2 Typical Points on a Schematic Diagram

During the engineering phase of a traditional protection and control project, each wired termination starts its life as a "point" on a schematic or elementary drawing as shown on Figure 2. Each point on each schematic must in some way communicate to the installing wireman how this "point" will physically connect terminations with wires. This is typically done with wiring diagrams that are developed from the elementary diagrams. These wiring diagrams must show how equipment is physically wired internal to a piece of equipment or panel and must also show all of the wired interface cables that piece of equipment has with the outside world. Those results in the designer developing drawings for the equipment that has hundreds if not thousands of terminations. Wiring is typically shown in a point-to-point method where one terminal end shows the opposite terminal end device and terminal designation. A significant amount of time is spent designing and then drafting each termination.

The more time spent with a particular drawing and the higher the information density on the drawing, the more likely the drawing will have errors. In the design-build process, the earlier an error is made and the longer it persists through the process, the more costly the consequences of and correction for the error. This causes the designer to insure every precaution is taken to reduce human error. The quest to reduce error introduces a check or peer review process, in which an individual, untainted with the design process to date, checks the complete design. The checker must review each point of the elementary diagrams, each termination on the wiring diagrams, and then verify the correctness of each letter and line on the drawing. Errors discovered by the checker, then go back to the designer and the design goes back through the design, draft, and check process. The design process is further complicated because the design, draft, and check process is carried out by different individuals. As each individual "hands-off" his work package, it must go into the next individuals work queue, which slows down the flow of the process.

The following discussion describes typical protection and control wiring practices and how those practices can be optimized to reduce the number of wired terminations in the design. Five case studies will be analyzed: a medium voltage switchgear where relay pushbuttons, internal lockouts, and SCADA communications are used to simplify the trip and close circuits, a breaker where IED to SCADA communications, a control IED, and IED pushbuttons are used to optimize the design, a transformer alarm circuit where a control IED is used as an alarm aggregator, and a process bus solution used to eliminate copper process wiring between the IEDs and primary substation equipment

II. MEDIUM VOLTAGE SWITCHGEAR

The trip circuit of a typical medium voltage switchgear breaker is shown in Figure 3. The IED associated with this switchgear is underutilized and there are several areas where the trip circuit can be simplified by using IED logic and communications. The IED actual trips a lockout relay that then trips the switchgear. There are six lockout relays, a DCS (SCADA) contact, and a control switch that trip the breaker. The control switch and the lockout relays can be eliminated with the use of IED logic, communications and pushbuttons.

Most IEDs can now be optioned with control pushbuttons on the IED. These pushbuttons allow the elimination of discrete control switches on the relay panel. This saves cost by simple material reduction, as well as eliminating the need to install and wire the switches, and from freeing up panel space.

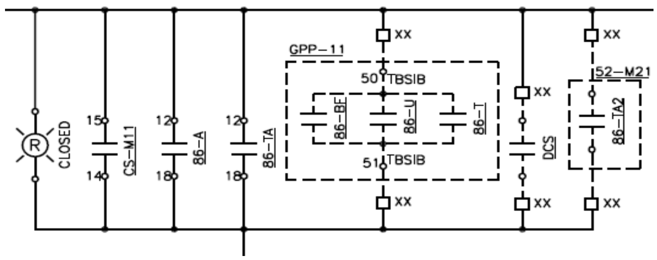

Figure 3: Switchgear Trip Circuit

Figure 3 shows a trip circuit that can be simplified if IED pushbutton control is used with internal lockout relays. IEDs can be optioned with non-volatile latches and mechanically latching output contacts that allow these lockout relays to be created inside relay logic. Non-volatile latches provide a permanent logical flag inside the IED that is safely stored and will not reset upon reboot of the IED. The non-volatile latch may be used inside of IED logic such that devices that would normally trip a lockout relay set the latch. The latch set operand can then be paralleled with other trip functions to create a common logical trip bus. Mechanically latching output contacts are output contacts that are mechanically bi-stable and controlled by two separate coils (open and close). Mechanically latching output contacts retain their state even when the IED is not powered.

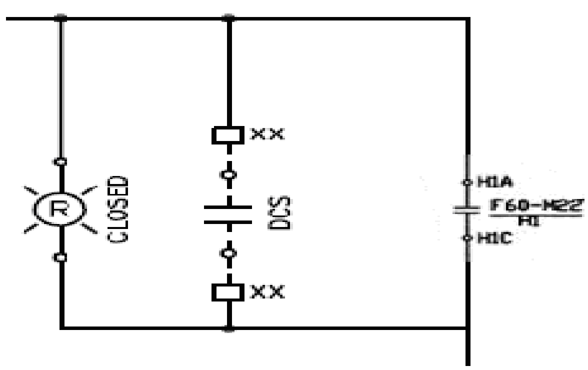

Figure 4: Simplified Switchgear Trip Circuit

The combinations of the control pushbutton and the internal lockout relays can reduce the trip circuit from eight parallel contacts to the one IED contact output and one DCS contact as shown in Figure 4. The IED contact has to be driven by the control pushbutton and the latches that create the internal lockout relays. Several of the lockout relays used in this trip circuit, such as the transformer lockout 86-TA and the unit lockout 86-U, are tripped by protective elements in adjacent protective zones, not the switchgear IED. Since the protective functions for these lockouts are in adjacent IEDs it becomes necessary for those IEDs to communicate to the switchgear IEDs that those protective functions have operated and the associated latches should be set. Several vendor specific communications protocols exist that can perform this type of messaging. However, since this information is required by multiple IEDs from multiple vendors the message must be an open protocol, multi-cast message. The protocol that most easily meets this requirement is IEC 61850 GOOSE messaging. In the IED logic of, the logical trip circuit has been designed to receive GOOSE messages from adjacent IEDs and to latch elements to create logical trip functions.

A. SWITCHGEAR CLOSE CIRCUIT

Lockout relays are used to not only trip equipment, but also prevent re-energization of the equipment until operational requirements are met, and the lockout relay is reset. When the protective zones interlock with several other protective zones the lockout contacts in the close string can become cumbersome as seen in the medium voltage metal-clad switchgear circuit of Figure 5. A transformer lockout, a switchgear main lockout, a breaker failure lockout, a tie breaker lockout, and a unit lockout are wired in series to prevent close until each of these lockouts is reset.

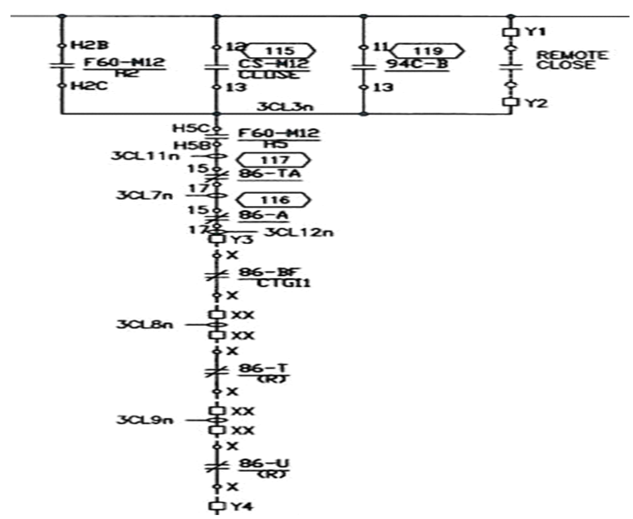

Figure 5: Close Circuit with multiple lock-out relays

This close circuit uses contacts from five lockout relays wired in series with an IED contact that closes when the sources on either side of the switchgear meet synchronous conditions. This permissive string of contacts is then wired to a parallel string of close contacts that actually serve to close the breaker. This close circuit has been recreated with relay logic in Figure 6. In this logic diagram, each of the discrete contacts that cause close have been replaced with relay operands and “or-ed” together in the upper left corner of the diagram. Non-volatile latches are used for each of the lockout functions and the negative logic of the latch (not) is “and-ed” with the IED synchronism operand and the close functions to create the close supervision. The logic of Figure 6 replaces the wired contacts of Figure 5 with one output contact. The wired contacts string requires forty-two wired terminations to build the circuit while the single contact required for Figure 4 requires two terminations. The installation cost savings are obvious due to the reduced number of wires, but this configuration also has the ability to reduce the engineering labor. The relay logic can be documented by the relay setup software and eliminate the need to document this information on schematic diagrams as well as wiring diagrams. Most IEDs are capable of being configured with graphical based logic diagrams like Figure 6 and once the relay is configured the logic can be printed to serve as the document of record of the configuration.

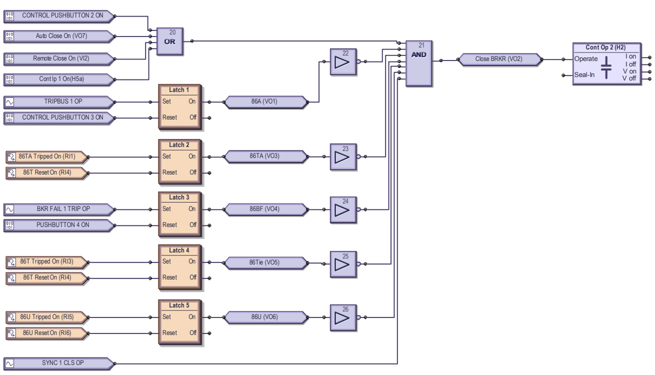

Figure 6: Internal Lockout Relays used to block close

B. SWITCHGEAR DCS/SCADA COMMUNICATIONS

The simplified trip circuit of Figure 4 can be further simplified with IED communications to the DCS control. The DCS output contact can be incorporated into relay logic. This further reduces the trip circuit to only one IED contact output. The original trip circuit had eight parallel contacts and has now been reduced to one contact with the use of communications, IED pushbuttons, and IED logic. This has the benefit of simplifying the control circuit design and wiring, which can reduce engineering and installation time. Additionally the physical control circuit can be identical for all applications. Only the logic needs to be changing for different applications. If future revision is necessary, only changes to logic are required, rather than wiring changes. Commissioning the simplified circuit can be optimized, since commissioning the IED can be performed through bench testing the IED logic and communications. This reduces the amount of commissioning time required in the field after installation.

C. OPTIMIZATION BENEFITS AND DETRIMENTS

The optimizations techniques discussed above have obvious benefits, including reduction in wiring and design time, reduced commissioning time, and repeatability. However, there are some potential drawbacks to consider. In the case of using IED to IED communications, or IEDs to DCS communications, a communications infrastructure is necessary. This will require additional equipment to be purchased, designed, and installed, resulting in additional costs. These costs should be fully understood and recognized as part of the overall protection and control system design. There are also several operational considerations that must be addressed when using IED pushbuttons and internal lockout relays. Most operations personnel are accustomed to operating with discrete devices. The operational procedures associated with these devices are well understood and accepted. Utilization of IED logic to accomplish these functions will require thoroughly training operations personnel in the correct use of the functions, and may require rewriting operational procedures. The effort necessary to train and rewrite must be weighed against the benefits of the simplified control circuit. Tying DCS communications directly to IEDs for status and control simplifies physical wiring design, and also reduces the size and cost of the RTU or communications gateway. There are some potential drawbacks in terms of operations and organization issues. Typically the protection and control design groups and the DCS groups have operated independent of one another with different procedures and practices. If DCS communications are used to control the switchgear, any changes to DCS are now changes to the protection and control design and must be managed as changes to the design. This means that protection and control practices that deal with design review, implementation, and configuration control will now apply to DCS changes, which historically has not been the case. The DCS group will have to be organized such that it can accommodate those changes and the efforts to organize the group must be compared with the benefits perceived from the changes.

III. BREAKER

Before methods of reducing wiring for the breaker can be analyzed, it is necessary to understand what must be wired and how it is typically wired. If the feeder is protected, by redundant protective relaying, the process information necessary for one breaker would be AC currents, breaker status, and alarms to the Relays, SCADA and DFR. Process control to the breaker would include Trip and Close from the Relays, from SCADA, and to the DFR (status only). These process inputs can reach a total of sixty wires for one breaker.

Most process inputs have multiple process destinations where the information is needed. Consider the breaker status contact 52a. This contact needs to pass information to each IED, and SCADA for a total of six wires for this one contact. Historically, the need for current transformer inputs was accomplished by wiring SCADA transducers in series with the IEDs. It has become well accepted within the utility industry to eliminate the current transducers and allow the SCADA master to poll the relay for these analog process values. This same method can be applied to the digital inputs and digital output of the process information to reduce the total number of wires. The SCADA master can read the breaker status and alarms from the IEDs and can write control points for trip and close to the IED using the same communications cables that the IED uses to read analog values from the IED. Utilizing the communications between SCADA and the IED has reduced the number of wires from sixty-two wires per breaker to forty-eight wires per breaker. Since each wire has a termination on each end, this reduces the number of terminations per breaker from one hundred twenty four to ninety-six. When discrete digital process values, are needed, by multiple devices, the value of wiring those signals once and communicating them to the rest of the devices increases as the number of devices increases.

A. BREAKER CONTROLLED IED

IED to IED communications protection schemes enable IED controller schemes where one IED or set of IEDs act as a protective IEDs and a separate IED acts as a controller. The protective IED may be placed in relay panels inside the control house while the control IED is mounted either inside the switchgear or in close proximity to the switchgear. This scheme allows the protective IEDs to pass protection and control outputs to the control IED via communications, which can reduce the amount of cable that is routed from the control house to the switchgear. A cost benefit is derived from routing less cable due to the obvious cost of the cable, but also because the cable raceway may be reduced in size. Additionally, the control IED may be mounted and wired by the breaker manufacture, meaning that the breaker and controller will arrive to the job-site pre-wired and tested, saving the time it would normally take to wire and test these function on-site.

The control IED, located at the switchgear, is tasked with control functions of the breaker as well as passing status and alarm indication from the breaker to the protective IEDs or the SCADA Master. A typical breaker will be required to have control functions of trip

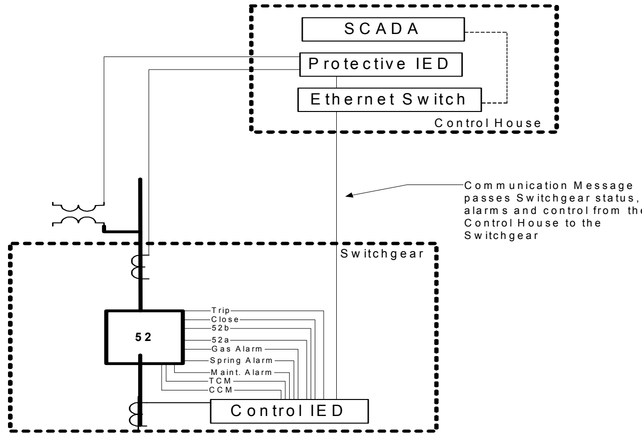

Figure 7: Control IED used for Breaker Controller

control and close control and will be required to send status for breaker status, spring alarm, breaker gas alarm, maintenance mode alarm, trip coil monitor, and close coil monitor. If this is applied to the breaker, additional wires and wired terminations can be eliminated with the assumption that all discrete inputs and outputs will be passed to the protective IEDs via communications, except the trip circuits, which will still be hardwired. The total wired reduction, using communications for discrete inputs and outputs to SCADA and the Control IED, has reduced the total number of terminations to be performed on-site by more than a half.

B. IED PUSHBUTTONS

Typical control functions that would normally control the IED are: reclose enabled/disabled, local/remote, breaker maintenance, breaker trip, and breaker close. Each of these control functions have the ability to reduce two wired terminations at the control switch and two more at either a terminal block for the trip and close functions or at the IED in the case of the IED control functions. Table below shows the potential savings associated with utilizing the control pushbuttons of the IED. In Table 1, fourteen wires have been eliminated which eliminates twenty-eight wired terminations. For the breaker the combination of SCADA communications, an IED controller and pushbuttons on the IED have eliminated eighty-six wired terminations per breaker.

The real estate benefit of IED pushbuttons is realized by comparing the number of relays that can be accommodated onto a relay panel. External discrete control switches can take as much panel space as the relay itself. This means that incorporating the control switches into the relay allows twice as many relays to be accommodated onto the same panel, meaning that half as many panels are needed and also meaning the physical size of the control building must accommodate half as many panels. A smaller control building is cheaper because it lowers cost of material, labor, and transportation and creates a smaller footprint on the site.

Table 1: Control Wiring

Control Function	Wires Req. to Hardwire	Wires Req. with pushbutton control
Trip	2	0
Close	2	0
Reclose Enabled	2	0
Reclose Disabled	2	0
Local Mode	2	0
Remote Mode	2	0
Breaker Maintenance	2	0
Total	**14**	**0**

IV. TRANSFORMER ALARM AGGREGATOR

Control IEDs are not limited to breaker control. They may also be used as alarm and data aggregators for primary equipment such as transformers. In this scenario, the IED is placed at the primary equipment and communicates messages back to protective IEDs or the SCADA master. Typically, discrete alarms for a transformer are: winding high temperature alarm, winding temperature trip, oil temperature alarm, oil temperature trip, low oil level alarm, low oil level trip, sudden pressure alarm, loss of cooling, and Buckholtz alarm. If each of these alarms requires two wires, this has the potential to eliminate an eighteen-conductor cable that would normally be routed from the control house to the transformer. The control IED could also be optioned with RTD inputs that could be wired to transformer RTDs. Typical temperature inputs that are measured by SCADA are: winding temperature, oil temperature, and ambient temperature. The SCADA master poll these temperatures from the IED. The control IED could also serve as an aggregator to other transformer IEDs such as on-line dissolved gas monitors, with alarms or analog inputs wired to the control IED rather than running cables back to the control house. Twenty-seven wires can be eliminated causing fifty-four wired terminations to be eliminated.

The IED controller scheme also adds benefit in that the controller can be mounted by either the transformer manufacturer or switchgear manufacturer and wired by that manufacturer. This eliminates the construction time necessary for wireman to wire these functions in the field. Since it can be commissioned at the manufacturer's facility, it eliminates the need to commission these functions in the field. In essence the only work required when the controller arrives with the primary equipment is to connect the communications cables to the controller and functionally test the communications. This has the potential to create a large labor savings and outage-time savings.

The major challenge to implementing the IED controller scheme is in the utilities interpretation of NERC CIP critical cyber asset identification. Currently NERC CIP identifies a critical cyber assets as a device that communicates via a routable protocol. This paper has proposed that communication from control IEDs be carried out via IEC 61850 GOOSE messaging, which by definition is a layer two protocol and is non-routable. IED communicating with this protocol would not be classified as a critical cyber asset. However, if the industrial electric distribution has taken a more conservative interpretation of NERC CIP, use of this scheme will be either limited or unavailable.

V. IED WITH ETHERNET MODULS

This paper makes the recommendation that communications, such as IEC 61850 GOOSE messaging, and internal relay logic, be used to replace control logic performed with copper wiring and auxiliary devices. The logic behind this recommendation is to simplify the physical design of the protection and control system, thereby speeding up overall design, installation, and commissioning time. Replacing contact logic with communications does not necessarily lead to a reduction in material costs. Copper wiring is replaced with communications equipment, including Ethernet switches and routers. However, the communications network between devices can use the same communications network as SCADA or DCS systems. Like all wiring, careful design of the communications network is necessary to ensure operational reliability in a cost-effective manner.

As communications is fully utilized inside an industrial electric distribution protection and control design, the communications wiring may become congested, especially if a redundant Ethernet topology is used with central switches located in the control house. An optimization method must be addressed which simplifies the communications design of the control schemes. Using IEDs that are optioned with Ethernet switches inside the IED can eliminate a large portion of the communications cabling and simplify the routing of communication cables. This topology along with the traditional communication topology is shown in Figure 8 below. If the IEDs house Ethernet switches, a complete ring topology can be created by simply connected each IED to the IED below it in the panel and IEDs at the top and bottom of the panels can be connected to the IEDs in adjacent panels. This topology reduces the communications cabling because external Ethernet switches are no longer necessary and the cable routing to these switches is also not necessary. As seen in Figure 8 the traditional communications scheme requires two Ethernet cables to be routed from each IED to the Ethernet switches. The length of each of these cables must reach from the IED to the Ethernet switch. The switch module communications still requires two Ethernet cables per

IED, but since the cables are routed to switch modules in adjacent IEDs the cable runs are much shorter.

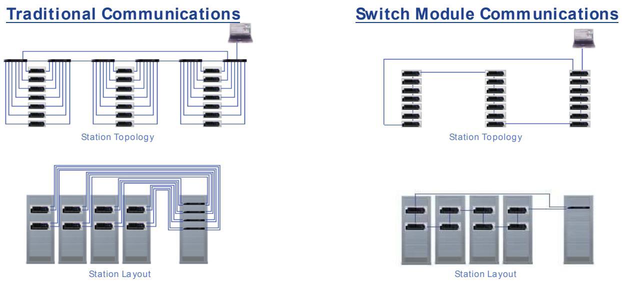

Figure 8: Traditional Communications verses IED Switch Module Communications

VI. PROCESS BUS

The protection and control system is actually a process control system. Process measurements such as equipment status, current, and voltage, are connected to process controllers, specifically protective relays. Protective relays analyze these quantities, and take control actions, such as opening circuit breakers to isolate faulted pieces of the power system. The process measurement system includes all the wiring between primary equipment in the switchyard and protective relays (and other IEDs) in the control house. Process bus is nothing more than the concept of using a digital communications architecture to replace the copper wiring between primary station equipment and the control house.

The solutions described in this paper focus on improving the design of the protection and control system by fully utilizing the power of microprocessor-based relays and communications. Communications and programmable logic replace contact logic and auxiliary devices. This results in great savings in design and installation time, and increases the reliability of the system. However, these solutions do not address the large number of copper wires, and resulting copper terminations, to transmit data across the switchyard.

The IEC 61850 communications standard provides the framework for actual, practical process bus solutions. IEC 61850-9-2 describes the data formats necessary to send analog sampled values between an interface device in the substation (known as a "merging unit") and protective relays in the control house. Functionally, this moves analog-to-digital conversion, and analog data sampling, from protective relays to the merging unit. IEC 61850 GOOSE messages can be transmitted between relays and contact I/O devices in the switchyard for control and status information.

Consider the circuit breaker of Figure 9. It is typical to pull 11 multi-conductor copper cables between the control house and the circuit breaker. There are 67 copper wiring terminations to make, by hand, in the field, once the circuit breaker arrives on site. These same copper wires must be terminated in the control house as well. With process bus, it is possible to have the circuit breaker manufacturer install Process Interface Units (PIUs) during their manufacturing process. A PIU consists of merging units to acquire currents and voltages, and contact inputs and outputs to provide equipment status and equipment control. Each PIU is wired to acquire signals from 2 sets of CTs, and all necessary status and control points. The installation process on site then becomes connecting fiber optic cable to the PIUs. The only field terminations necessary for the breaker are then those for DC and AC power.

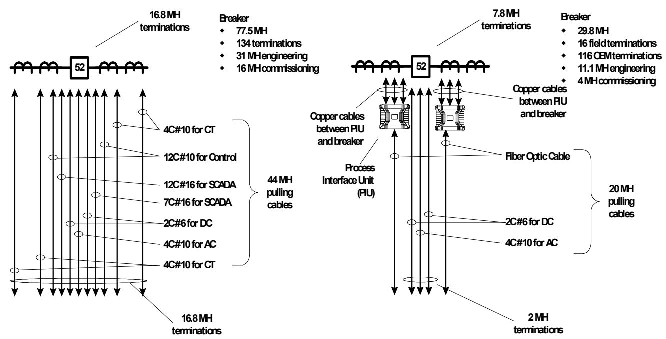

Figure 9: Process bus savings

With process bus, the physical interface for protective relays is always the same: a PIU connected to a fiber optic cable. The reductions in design and installation time for protection and control systems can therefore be immense. In this specific example, process bus provides a 60% reduction in design, installation, and commissioning of the copper wiring across the switchyard, with some additional equipment cost.

The IEC 61850 standard describes data message formats for transmitting data in the substation, including analog sampled values. However, IEC 61850 does not describe architectures for communications networks. The communications network architecture is an especial challenge for process bus. The architecture should be such that the system is robust, reliable, flexible, and scalable. Most importantly, it must be intuitive to design, install, and operate. There are commercially available process bus solutions available in the marketplace. These systems, to date, have chosen to use a star (point-to-point) topology. This allows for a simple, intuitive design, very similar to today's copper wiring. Also, such as topology is very flexible and scalable, is straightforward to install, supports zones of protection as the industry understands them, and allows simple isolation of equipment for testing, maintenance, and operational reasons. Similar to the breaker controller IED discussed previously, process bus installations may be considered a critical cyber asset, and may require additional cyber security protection.

VII. FUTURE DIRECTIONS

Microprocessor relaying and digital communications have lowered total installation costs and operational costs for protection and control systems, while increasing the overall reliability. Multiple functions, including protection, control, communication, metering, and oscillography have been converged in to the microprocessor relays. The practical limit to further convergence has been the physical limitations of connecting copper wiring to each protective relaying. Process bus allows protective relays to be divorced from the physical limitations of copper wiring.

One future direction that protective relaying can take is that of providing multiple zones of protection inside of one microprocessor device. Multiple input feeder protection and transformer protection relays already exist. Their practical application with copper wiring is limited, due to physical wiring challenges. However, with process bus the installation becomes simple and cost effective, as in Figure 10.

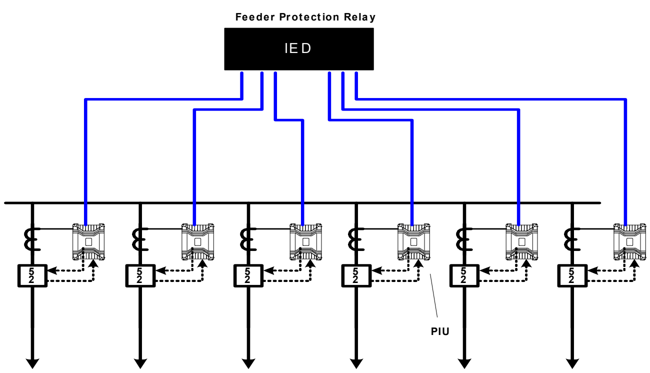

Figure 10: Multiple feeder protection with process bus

However, this is only the first step. It is simple to envision a device that provides all zones of protection and control necessary for a complete distribution substation or small transmission substation. Physical design then becomes the matter of designing the process bus system. All control functions are carried out inside this "substation in a box". Design then becomes a matter of selecting the right pieces, and configuration.

VIII.CONCLUSION

Each step in the processes discussed above has sought to further reduce wiring to as few locations as possible. Since some contacts must be wired, it would be impossible to totally eliminate the copper wire for process signals from a substation. It does leads to a protection and control rule of thumb of: "wire a process value once and only once". When this rule is obeyed, all other locations that need the process value for protection or reporting purposes can receive the information from IED communications. This will speed engineering, construction, and commissioning. The second rule of thumb is: "if a function does not have to be wired, then don't". In the case of alarm and status points these rules cause the status and alarm points to be wired to the IED and passed via communication to the other devices that need these process values. The "if a function does not have to be wired, then don't" rule leads to the use of pushbuttons for control, internal lockout relays, and process bus.

Every application described in this paper is possible today. The solutions recommended here are non-proprietary, commercially, available, and technically proven. The important message to take away from this paper is this: there is no better time to leverage the power of microprocessor relays and digital communications than right now. The challenges facing the Industrial electric distribution industry are well known: increasing load, aging facilities, and an aging technical workforce. The solutions recommended here are all simple suggestions that can increase the productivity of the technical workforce at little or no cost. For your specific utility, it is important to look past the *tradition* of designing protection and control system, and to at these solutions from a *business* perspective. Do these solutions really require less time to design and install? What will it take to implement them? Are they really cost effective? It is, of course, vital to ensure any solution will maintain or increase the reliability of the system. But the goal is to break system design to the most basic level. Spend your time designing the protection and control system to meet specific application requirements, not designing wiring schedules and copper terminations.

References

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