GE
Grid Solutions

Top Five Reasons to Implement Distributed Bus Protection

White Paper

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imagination at work

1. Abstract

Power systems have evolved in the past few decades due to factors such as the addition of sources like distributed energy resources to various parts of the electric grid (e.g., distribution) and the increasing need to design the system around economic considerations rather than simplifying protection schemes. Busbar schemes of power systems thus became much larger and more complex, with reconfiguration a requirement. As a result, bus protection schemes have had to evolve to ensure all bus configurations can be covered safely during all power system conditions, including during the reconfiguration of the bus system.

This paper will discuss this evolution of bus protection, focusing on distributed bus protection schemes and five key considerations in implementing IEC® 61850 process bus distributed bus protection schemes in modern power systems.

2. Introduction

Power systems used to have simple busbars with dedicated current transformers (CTs) and unidirectional current flow during load and fault conditions. These buses traditionally were protected by the high-impedance principle – a fast and reliable scheme with decades of dependable and secure field experience.

Until the late 1990s, digital busbar and breaker failure protection schemes for medium-size and large busbars were not attractive, and the high-impedance approach was preferred. Low-impedance schemes available on the market were expensive, difficult to apply, considerably slower as compared with the high-impedance protection schemes, and were perceived to be less secure.

New power systems and substations are often designed to satisfy economic requirements rather than to keep protection schemes simple. At the distribution level, the addition of new power generation such as distributed energy resources (DER) complicates historically simple busbar arrangements and exposes existing CTs to saturation due to increased fault current levels which becomes bi-directional. This results in complex busbar arrangements, hence the need for the evolution of bus protection.

High-impedance busbar protection schemes face major problems when applied to complex busbar arrangements. Quite often, the protection zones are required to adjust their boundaries based on changing busbar configuration, (such as the double-bus single breaker arrangements in Figure 1). This requires the switching of secondary CT currents, an unsafe and dangerous operation which should be avoided whenever possible. Open circuited CTs under load saturate and induce lethally dangerous high secondary voltages.

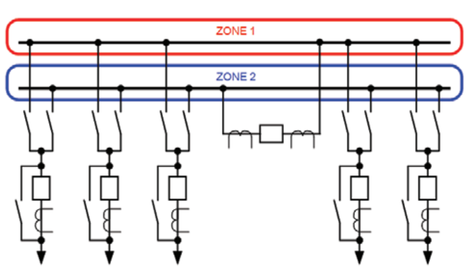

Figure 1: Example of a double-bus single breaker with bus coupler and breaker bypass scheme.

With the development of digital low-impedance busbar protection schemes, the capability to protect and manage complex busbars without CT current switching was introduced. Dynamic bus replica (ensuring the bus comprises all circuits dynamically connected to it) is done by switching currents in software to be included or excluded from the bus zone. This is achieved by adding all connected circuit currents to the appropriate zone of protection based on isolator positions, for each zone configured, while keeping physical currents uninterrupted.

Modern digital relays are much faster, use better algorithms for security, and became affordable after their introduction in the early 1980s. Other benefits of these devices include integrated breaker fail protection, back-up protection such as overcurrent functions, the ability to use and share different CT ratios and classes with other devices, communications, oscillography/waveform capture, sequence of events recording, multiple setting groups, and other benefits of the digital generation of protective relays.

In late 2001, phase-segregated microprocessor-based busbar relaying schemes were introduced. These schemes focus on a phase-segregated centralized approach (central unit (CU)) where one "box" is required per phase to manage all the analog signals required for medium-sized and large buses. Additional boxes are required to manage the large number of digital inputs/outputs (DI/O), and up to five boxes are required for a large configurable bus scheme with embedded breaker failure. Programing of these schemes, including managing the flow of all signals between boxes and creating of distributed logic, can be very complex; it is recommended this programming be performed by engineers specializing in busbar scheme design and configuration.

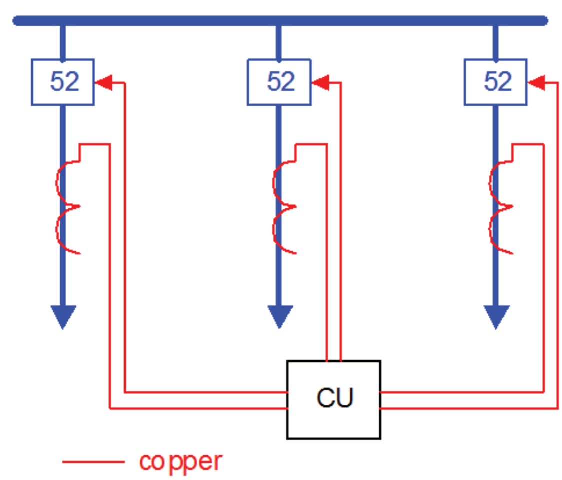

Figure 2: Typical centralized bus differential scheme architecture.

Distributed busbar schemes had been emerging since the early 1990s; however, these schemes focused on using one CU with several bay units or data acquisition units (DAU). Each unit (CU and each DAU) had to be programmed separately. One DAU is installed for each bay to sample and process all analog and digital signals, and provide this information via fiber-optic communications to the CU. The communications connection between the DAUs and the CU is a point-to-point connection using a proprietary protocol.

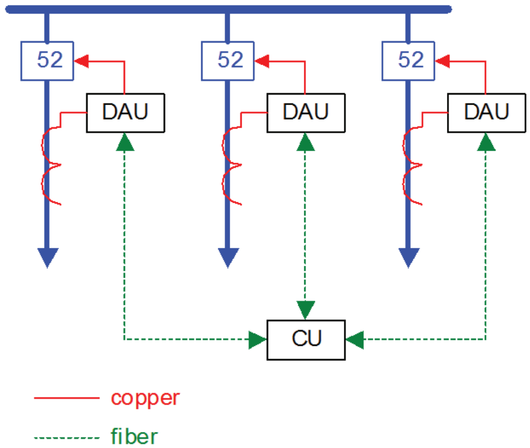

Figure 3: Typical distributed bus protection scheme architecture.

With the development of IEC 61850 came the realization that distributed bus protection is nothing more than process bus: Data is collected at the primary equipment (breakers DI/O, CTs and voltage transformers (VTs)), and transmitted to a central unit for processing/control. From 2009 to 2012, the first IEC 61850 process bus distributed bus protection schemes were introduced. These schemes use process interface units (PIU) as the bay unit or DAU (Multilin™ HardFiber Brick) and the Multilin B30 or B95^{Plus} as the CU. The PIU is a combination of analog inputs (voltages and currents) and digital inputs/outputs (DI/O). Each PIU is directly connected to the CU, as per the following system architecture:

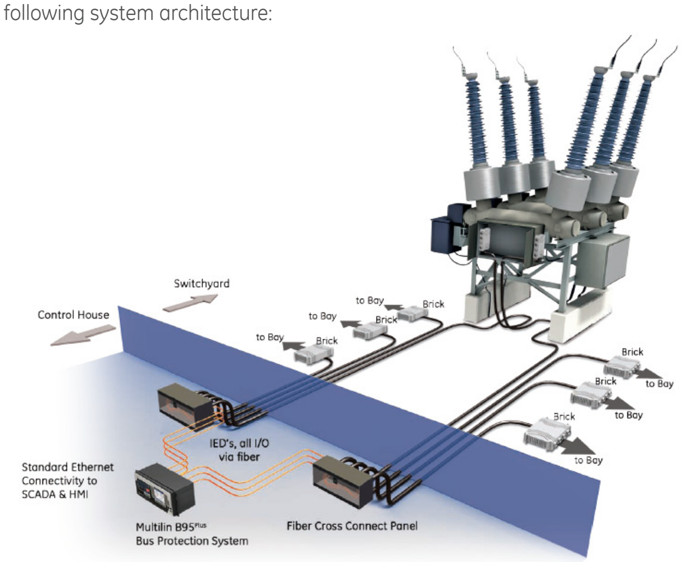

Figure 4: The HardFiber system can easily be incrementally scaled to include new equipment as stations evolve. Duplicated Bricks in the switchyard provide a dramatic improvement in reliability and security over today's technology.

This architecture is point-to-point in nature. Hence each PIU is directly connected to the CU via fiber, where the CU processes all data, sampling synchronization. The CU is the only unit to be programmed. With process bus, the scheme simply moves from proprietary to standard for the communications.

3. Top Five Reasons for Using IEC 61850 Process Bus Distributed Bus Protection Schemes

3.1 Simplifies field wiring

Bus protection schemes, especially for large buses, can be very complex. Multiple analog and digital signals must be wired from primary equipment located at various locations within the station to the central protection and control (P&C) house where the bus protection relaying scheme is located. Some of these breaker, CT and VT locations can be more than 500 m (1,600 feet) from the CU or relay location, meaning copper cables and routing must be designed, implemented and sometimes duplicated for multiple protection schemes. This contributes to a larger burden on CTs with a higher risk of CT saturation. It also exposes the AC signals, digital inputs and outputs wiring to more radio frequency interferences (RFI) during system switching and fault events, impacting protective relay performance. As a result, simpler and shorter wiring arrangements are desired to ensure reliable and secure protection schemes operation.

The true cost value of distributed bus protection is in simplifying field wiring, which is the only practical way to implement bus protection schemes for large bus configurations. This allows for a simple and standardized bus protection panel arrangement and design.

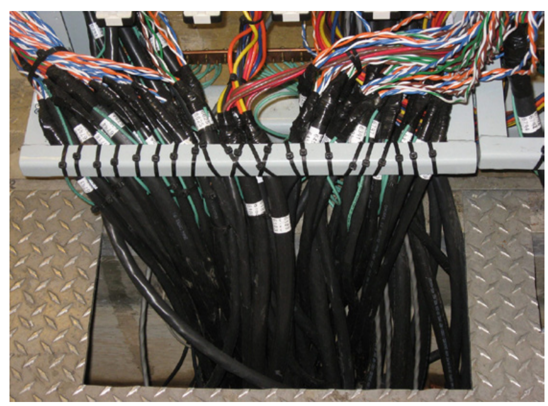

Figure 5: Copper panel wiring.

Figure 6: Process bus wiring with fiber optic cables.

3.2 Reduce material/engineering/commissioning/ maintenance costs

Traditional and centralized bus protection schemes require all copper wiring to be designed, implemented and commissioned from primary equipment (breakers, CTs and VTs), through cable trenches to the bus protection location, normally located inside the P&C house.

This approach requires significant design work and copper wiring to be used and tested during commissioning and trouble shooting. Utilities and industries worldwide are under pressure to reduce costs in protection systems implementation, upgrades and expansion as budgets and the skilled P&C workforce continue to shrink.

Distributed bus protection schemes, with substation and environmentally hardened PIUs, only need copper wiring to the PIU which is located at the primary equipment rather than to the P&C house. Each PIU is connected to the CU in the P&C house via fiber; hence far fewer copper cables are required in the design, implementation, commissioning and testing phases, resulting in much lower initial and running costs.

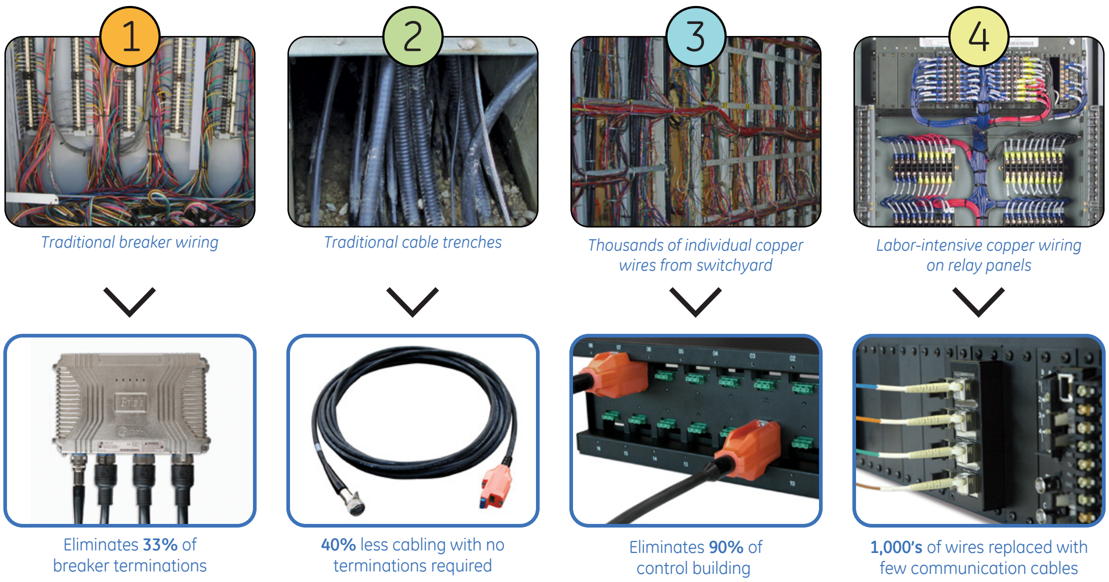

Figure 7: Evolution from conventional to distributed bus protection components.

3.3 Ease of use and implementation

Design and configuration of traditional centralized bus protection schemes, especially for large buses with breaker failure, can be very complex. Each "box" of the scheme's phase segregated centralized scheme must be configured. The distributed logic has to be planned and implemented (i.e., the isolator monitoring) including communications between all boxes ensuring the phase boxes have the correct bus replica logic (or isolator) information. To a lesser degree, this also applies to distributed bus protection schemes where each bay unit needs to be programmed separately. The design and programming of a large and complex centralized bus protection scheme with breaker failure should be performed by experienced experts.

By contrast, the design of a process bus distributed bus protection scheme requires programming and configuration of only the CU. Additionally, it is greatly simplified with the aid of a graphical user interface such as that in the B95^{Plus}, as follows:

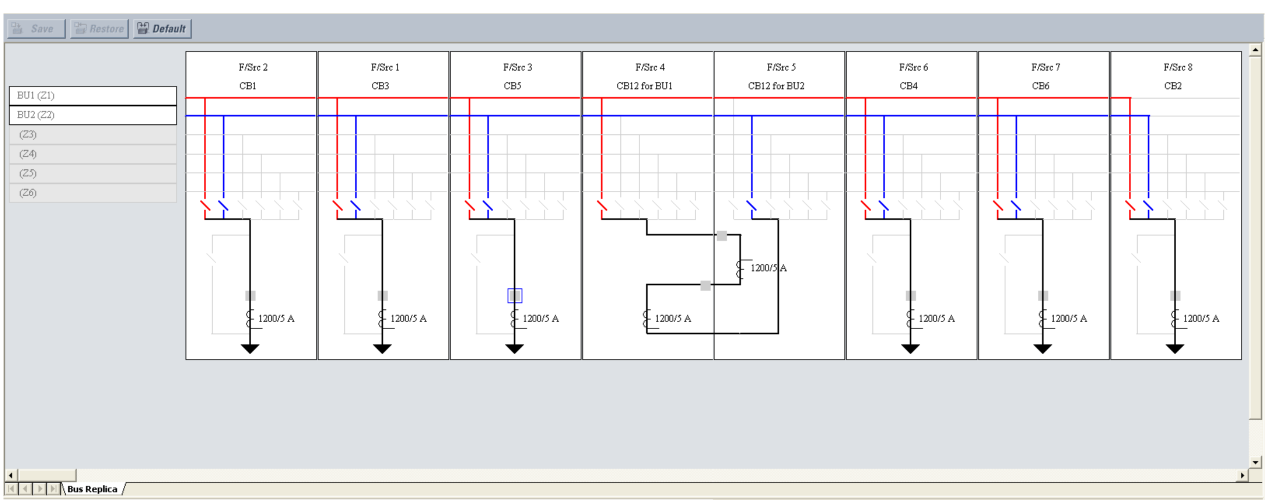

Figure 8: The graphical user interface of the Multilin B95^{Plus} is easy to learn and use, reducing training time and cost.

The dynamic bus replica (assigning isolators of each feeder to appropriate buses) can easily be configured by source or circuit (one at a time) until the scheme contains all sources and zones, for up to six zones.

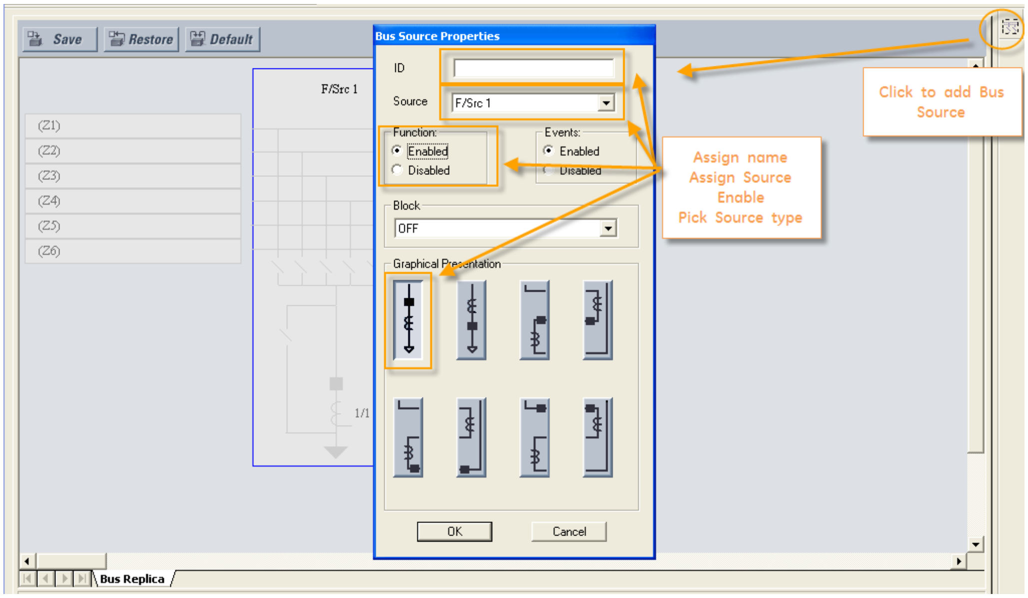

Figure 9: Interface for assigning bus source properties.

Each source is configured as follows by assigning the following properties:

1. Source ID
2. Source where the measured currents are metered from (i.e., bay unit)
3. Function (Enabled or Disabled)
4. Events (Enabled or Disabled)
5. Graphical representation of the bus configuration

Each bus is then enabled if used, and the bus replica (isolators connecting to bus assignment), breaker contacts and CT ratios are configured as follows:

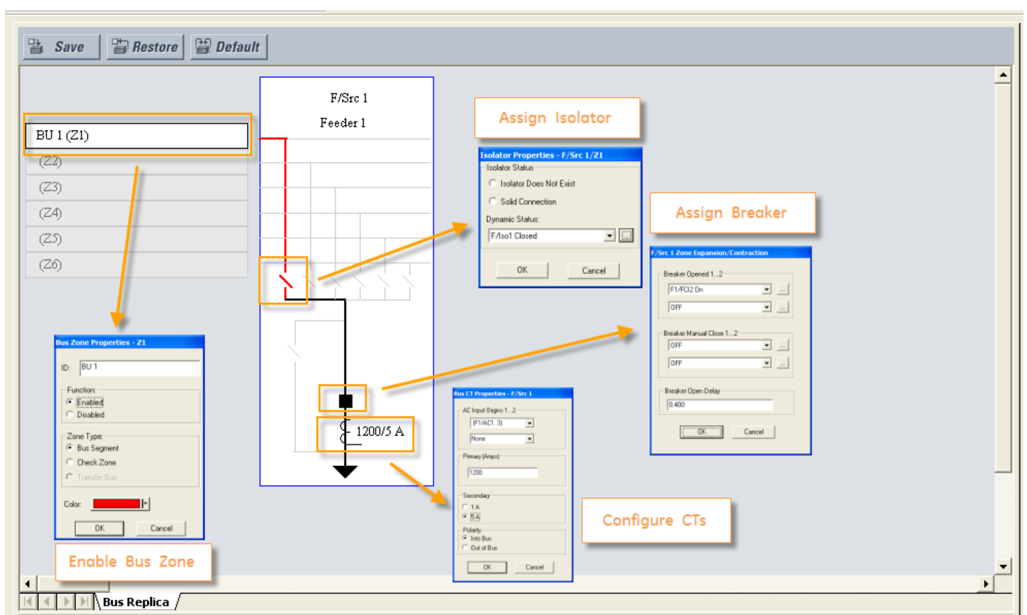

Figure 10: The bus replica, breaker contacts and CT ratios can all be configured in this easy-to-use interface.

This is a much simpler solution to implementing a large bus protection scheme, allowing designers familiar with bus protection and dynamic bus replica to quickly and seamlessly complete a large bus protection scheme with supervision (i.e., check zones with undervoltage supervision) without the need for in-depth product knowledge.

3.4 Support of simple to complex bus arrangements

Bus sources allow each circuit or source to be connected to one or multiple buses; hence they can be applied to a range of applications, from simple single bus schemes up to complex double bus with transfer bus with bus sections and check zone configurations, for up to six bus zones. Each bus source consists of a 3-phase CT bank, breaker, bus isolators and bypass isolator as follows:

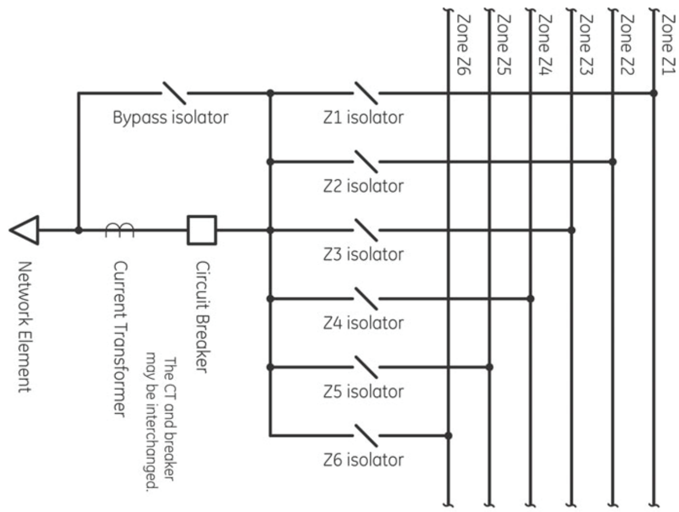

Figure 11: Example of a bus source.

Each bus source provides current for bus protection as well as other protection functions such as breaker failure, phase overcurrent and end-fault protection.

With all sources and buses connected together, the total bus zone can be created:

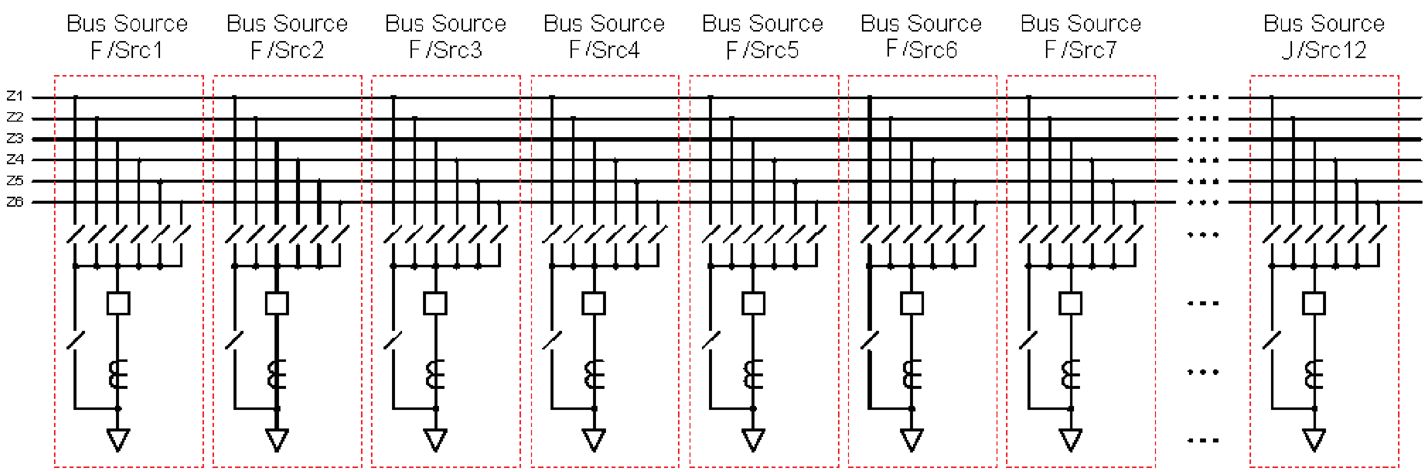

Figure 12: The complete bus zone is created when all sources and buses are connected together.

The power system buses are then mapped to bus zones. Each zone has independent bus differential protection comparators for each phase of a bus segment, and each zone has a specific trip bus based on the bus replica (sources connected to the zone) and the other protection functions as mentioned. This allows for bus configurations from a very simple single bus up to multiple buses with transfer buses, bus sections, check zones including multiple buses and other supervision functions such as undervoltage protection.

This is a great advantage for distributed bus protection; bus sources can't be applied in a phase-segregated centralized bus protection scheme since each phase current must be connected to a different box. Hence all CT and PT wiring must be consistent with the A, B and C-phase boxes to allow the use of equivalent configuration settings. Each phase box must be programmed and treated separately; whereas in a process bus distributed bus protection scheme, this is done only once and with the aid of graphical user interface programming for the control unit only.

The advantage of a bus replica and its ease of use is simply illustrated through a complex system consisting of two double buses tied together with bus sections, 20 feeders and bus couplers. This system can be covered by one bus protection scheme as follows:

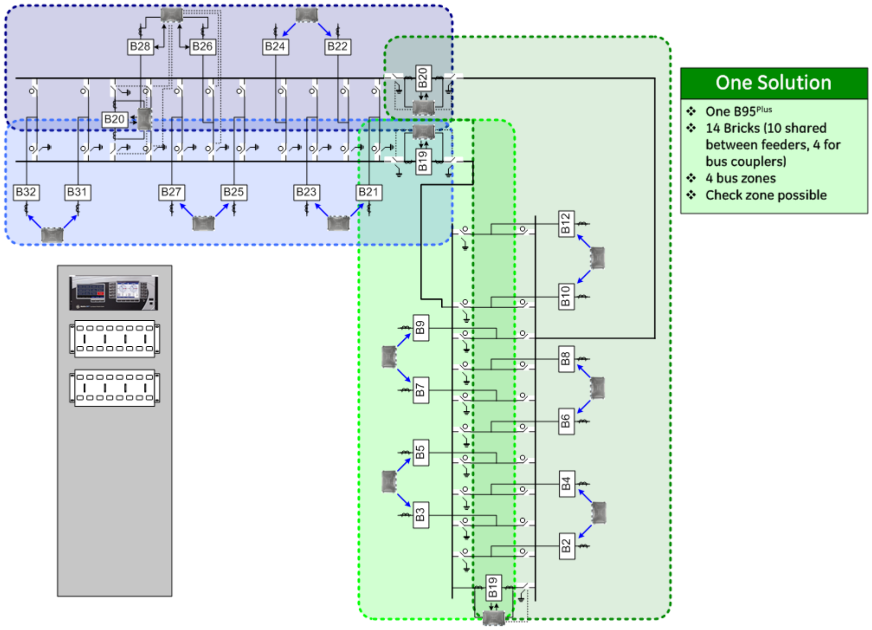

Figure 13: A single bus protection scheme can cover a complex system such as this.

3.5 Supports expandability of bus and other protection schemes

Distributed bus protection schemes can easily be expanded in the event that a new source or circuit is added to the bus scheme. This can be done by simply adding another PIU, wired to the added breaker and CTs, PTs; and providing an additional fiber connection from the PIU to the existing CU. Minimal configuration changes are required in the CU: Simply add this PIU as another bus source and assign this bus source to digital zones as appropriate.

With IEC 61850 process bus distributed bus protection schemes, the PIU can be used for expansion of more than just the bus protection scheme since the PIU has the capability to provide data to up to four different protection schemes:

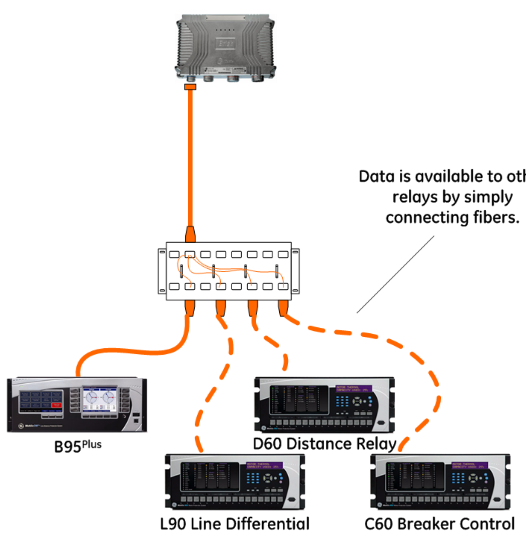

Figure 14: The bay unit can provide data to up to 4 different protection schemes simply by connecting the fibers.

In the following example, source F6 is added to the local system (and thus to the bus protection scheme as well) but also needs additional line differential protection (L90). In this case, the bay unit is a process interface unit or Brick:

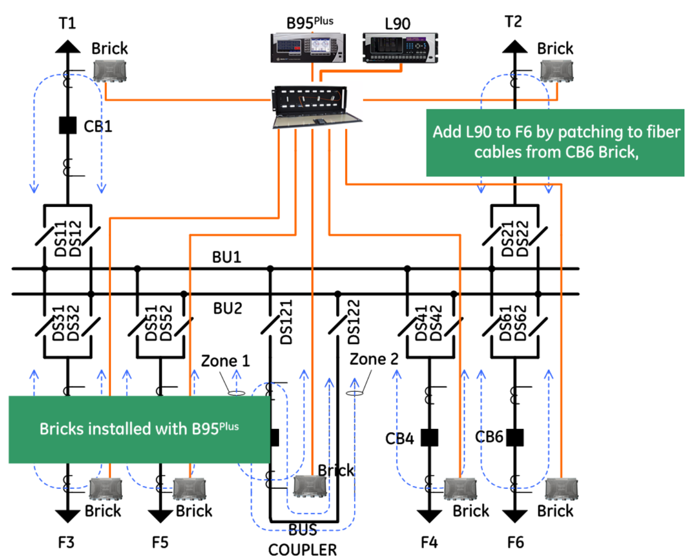

Figure 15: Distributed bus protection schemes can easily be expanded if a new source or circuit is added to the bus scheme.

The long term value of a process bus-based bay unit system is that the distributed bus protection scheme, together with other protection schemes, can be expanded with minimal effort.

4. Conclusion and Recommendations

As power systems have evolved, their associated busbar schemes have become much larger and more complex. Reconfigurable buses are essential, and low impedance bus protection schemes have had to evolve to ensure all bus configurations can be covered.

Today's process bus-based distributed bus protection schemes offer a range of advantages including:

- Simplified field wiring
- Reduced cost from design, commissioning to maintenance
- Ease of use and implementation
- Support for simple to complex bus arrangements
- Support for the expansion of bus and other protection schemes

These advantages make distributed bus protection a better choice than centralized bus protection schemes, especially when considering long-term system upgradability and maintainability on ever-evolving power systems.

Implementation of distributed bus protection schemes are generally recommended for greenfield (new) installations, where the process bus PIU can be installed and wired on the primary equipment during manufacturing. Brownfield (protection retrofit) applications can also benefit from a process bus system. In this case, to realize or capitalize on the benefits of a fiber-based distributed bus protection scheme listed above, PIUs might need to be installed at existing cabling demarcation points, which might be in the P&C house.

Process bus distributed bus protection schemes offer simplicity, flexibility and are much easier to design, implement, commission, maintain, expand and upgrade compared to centralized phase segregated bus protection schemes (especially with the aid of a graphical user interface). As such, this approach is recommended for large and complex bus schemes.

5. References

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