

**From conventional protection technology  
to the process bus  
A new dimension in power grid  
reliability and efficiency**

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**ABSTRACT**

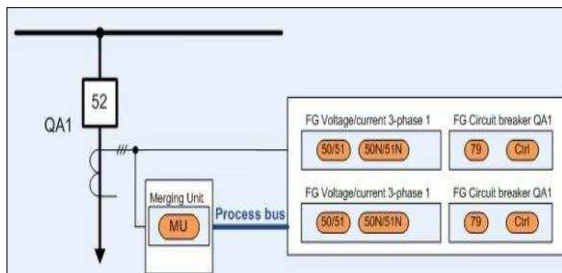
New technologies such as the process bus require an evaluation phase. Various layouts and work processes are tested in this phase. The test results are used to develop optimal strategies for a specific application case. A systematic approach is the key in this context as it progressively adapts the individual functions of the conventional substation to the process bus technology. Before each step, it should be defined which findings are desired in order to design reproducible and sustainable configurations and processes. To limit complexity, the evaluation phase should be restricted to the secondary technology. Major interventions in the substation architecture of the secondary technology, such as introducing the process bus technology, require carefully planning. It is therefore advisable to collect experiences using simple substation structures first before testing more complex configurations. Modern protection devices are flexible in use and can be tailored to the respective circumstances of different facilities.

**PHASES OF INTRODUCING A PROCESS BUS SOLUTION**

The introduction of the process bus requires hands-on experience in the new technology. For this reason, the new technology should be used selectively during a pilot phase in a stepwise approach and the results should be analyzed subsequently.

**Phase 1: Protecting a feeder in parallel operation**

The first configuration to test the process bus can be a simple feeder protection. Modern protection devices have a modular expandable design. For instance an overcurrent protection device can be fitted with process bus inputs, providing for cost-efficient pilot operation (Figure 1).



**FIGURE 1: To test the process bus, a simple protection can be used for a feeder.**

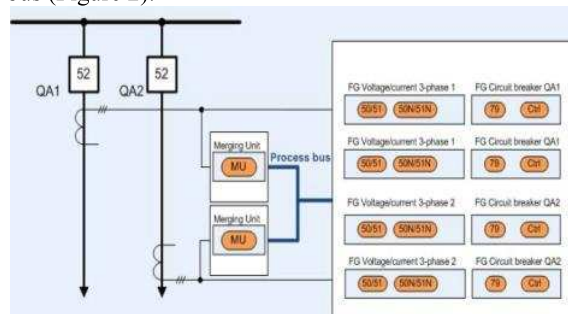
As another benefit, state-of-the-art protection devices are capable of efficiently protecting more than one object. One protection device, for example, could be sufficient to protect up to seven feeders. These two characteristics along with the fact that the process bus only requires the measured current values of one merging unit allow parallel operation with the process bus to be implemented when protecting a system with fewer than seven feeders.

For this purpose, the device is fitted with a process bus input module and the feeder current is simultaneously measured in a merging unit. The current measured by the merging unit is subsequently connected to the protection device via the process bus. The protection device thus receives the measured current values twice: its own measured values on the one hand and the values transferred through the process bus on the other. The protection function is instantiated two times so that the protection device protects the same feeder via the conventional setting and via the process bus. This allows the process bus and the direct measurement to be compared with each other.

Since all values of the protection function are measured by a merging unit, no synchronization is required in this layout. That is another advantage of the solution because it additionally reduces complexity

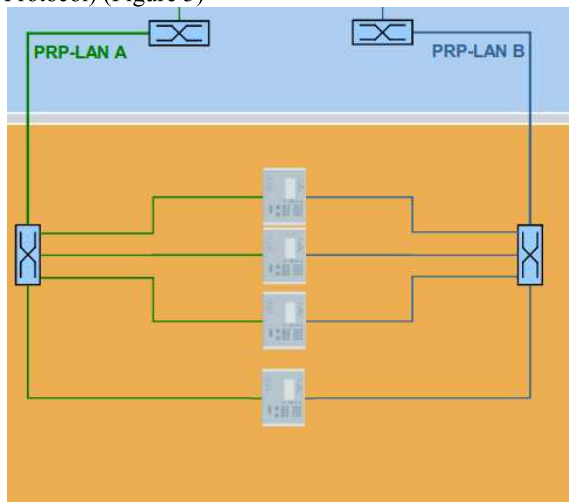
**Phase 2: Setting up a communication bus**

The next step in launching a process bus is to install multiple merging units and to set up a communication bus (Figure 2).



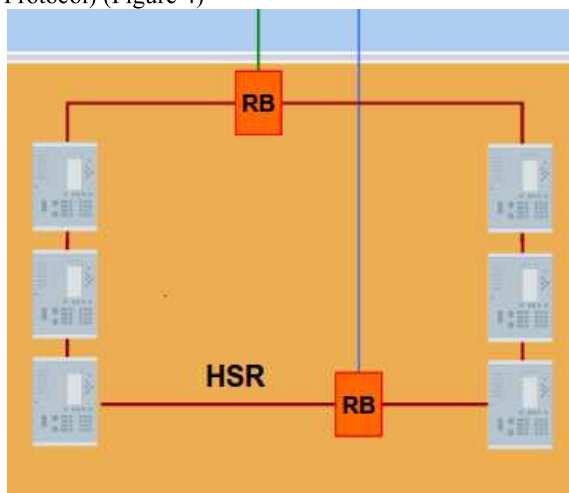
**FIGURE 2: Install multiple merging units and set up a communication bus**

Since modern protection devices are capable of protecting several feeders with just one device, the concept from phase 1 can be continued. The focus in this phase is on testing the communication technology. New technologies such as PRP (Parallel Redundancy Protocol) (Figure 3)



**FIGURE 3 : Example for a PRP configuration**

and HSR (High Availability Seamless Redundancy Protocol) (Figure 4)



**FIGURE 4 : Example for a HSR configuration**

enable seamless redundancy. Sampled measured values can thus be transferred reliably over an Ethernet data bus. Both technologies can be tested in this configuration. The use of HSR in particular enables quick set-up requiring little effort. The favorable ring structure does not require any additional switches in the process bus qualifying it for communication networks in the process bus.

This configuration, too, does not require a time synchronization mechanism: No protection function uses measured values from multiple merging units.

### Phase 3: Synchronization for multiple merging units

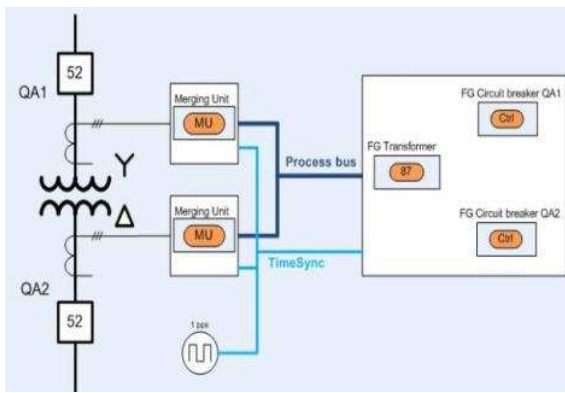
More complex protection functions require measured values from multiple merging units. This calls for the merging units to be synchronized so that the measured values of different units can be

compared with each other.

The mechanism should be added in the next phase. Synchronization has to satisfy the high requirements of the process bus. To meet the required synchronization accuracy of  $\pm 1 \mu\text{s}$ , additional effort is needed. There are two approaches to synchronize merging units. It is obvious to want to use the existing communication infrastructure between the protection devices and the merging units also for synchronization. Since the process bus is based on Ethernet, the Precision Time Protocol (PTP) according to IEEE 1588 is a viable option. This protocol describes mechanisms that enable synchronizing different network components with ultra-high precision while permitting various implementation options. For this reason, different work groups define profiles for their application area which limit the implementation of PTP in their domain to make it interoperable. At present, there is no PTP profile in energy automation that satisfies the process bus's requirements for reliability, interoperability and accuracy. Until synchronization via Ethernet meets the requirements of the process bus, it is easier to use a separate time signal. This solution does not require additional infrastructure, but the method is proved and tested, reliable and easy to install. Various synchronization methods have proved to be reliable in other energy automation applications that place equally high demands on accuracy. The line differential protection and the phasor measurement unit (PMU) are classical applications that require exact synchronization. The PMU needs a precise synchronization both of the devices among themselves and with the current time. This is usually implemented using (IRIG-B1). The line differential protection provides several possibilities to synchronize multiple devices. If the delay over the communication network between the two line differential protection devices is constant and identical in both directions, the devices can be synchronized directly. If that is not the case, external synchronization is necessary. Since the differential protection only requires relative synchronization – the absolute time is not relevant – the pulse-per-second method (PPS) is employed here in addition to IRIG-B. Besides IRIG-B and PPS, the PMU and the line differential protection can both integrate GPS receivers for synchronization.

Just like the differential protection, the process bus only requires relative synchronization. Therefore, all three options (PPS, IRIG-B, GPS) are viable for the process bus. Below we will look at the simplest method, namely PPS: This version is also recommended in the UCA profile for using IEC 61850-9-2.

The transformer differential protection serves as sample configuration for an arrangement requiring synchronized values of multiple merging units (Figure 3). Compared to the line differential protection, this protection function has the advantage of being implementable in a single device. The line differential protection would require at least two devices as well as communication between these two units.



**FIGURE 5 : Transformer differential protection as sample configuration for an arrangement requiring time synchronized values of multiple merging units**

A timer generates the PPS. This pulse is transmitted to all merging units via direct links. The merging units synchronize their measured data stream to the PPS. This procedure ensures that the differential protection compares measured values at the same point in time. It is also advantageous to connect the synchronization signal to the protection device as it allows the protection device to check the measured data stream, for example, whether or not the delay requirements for the process bus are observed. Once this phase has been completed successfully, the process bus can be introduced. All relevant techniques and methods were set up, tested and their results analyzed. The process bus can be integrated into the substation.

## References

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