Study Committee B5

SC B5 – Protection and Automation

Paper ID10922

Process bus distributed protection development

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Motivation

When approaching the development of a new distributed Busbar Differential Protection System, in this solution a fundamental requirement was the possibility of having interoperability with other manufacturers, being this an increasingly common requirement among electrical companies. The best way to achieve this, is to use the set of communication protocols provided by the IEC 61850 standard for the exchange of necessary information between the different IEDs that makes up the solution. For this reason, the solution was developed using IEC 61850 process bus. Other benefits in adopting this solution are, for example, avoiding the necessity of using proprietary protocols, the use of standard redundancy for communications (PRP/HSR), the use of standard IEEE 1588 synchronization protocol to sync all the IEDs within the solution or the use of standard communications analysers.

This paper describes the solution developed, the challenges faced during the development process and the standardization requirements to achieve future interoperability between manufacturers.

Method/Approach

In a distributed busbar differential protection solution, 2 types of IEDs are involved and to be designed:

○ Bay Control Units (BCUs) that collect the needed information of analog channels and digital signals of each substation bay (feeder, bus coupler, etc.) and publish them via process bus. Available station bus protection IEDs with Bay Control Unit capabilities had to be adapted as follows to work as BCUs:
  - IEC 61850 Process bus communication ports. It was necessary to increase the Ethernet port bandwidth up to 1Gb/s.
  - IEC 61869-9 Sampled Values published directly by BCU. No additional Mergin Unit required
  - Distributed Busbar Differential specific protection functions (50 BF and 87 B trip supervision functions) had to be implemented in the BCUs

○ Central unit (CU) which subscribes to all the information published by the BCUs, performs the protection algorithms in real time and issues the corresponding trip commands to BCUs:
  - Bus differential protection (87B) as Circuit Breaker (50BF) protection scheme of all substation bays
  - As a receiver of Sampled Values from the BCUs, CU acquires the currents from all the substation bays (feeders, bus couplers, etc.) allowing communication with a maximum of 24 BCUs within the substation.
  - The CU has been designed with a capacity to subscribe to up to 64 GOOSE messages
  - Process bus communication ports. It was necessary to increase the Ethernet port bandwidth up to 1Gb/s.

Objects of investigation

Substation communication topology proposed is as follows:

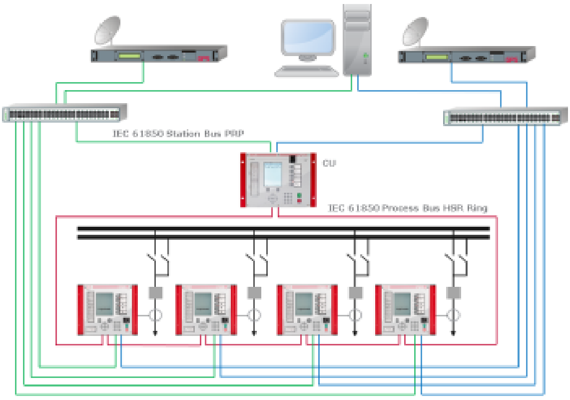

Figure 1

In the first deployment, HSR (see Fig 1) redundancy was chosen over PRP as Process bus topology. The main reasons were:

○ More cost effective due to not needing additional Process Bus switches.

○ More simple. No need to configure switches and allow an easier data stream analysis

The HSR redundancy solution had an additional requirement: The latency in data stream flow (mainly Sampled Values) between IEDs / BCUs had to be low enough to ensure an adequate flow of data for the measurement and protection algorithms

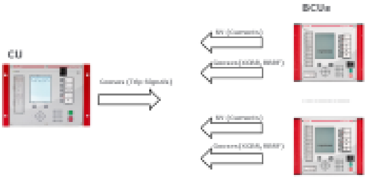

Figure 2 shows the details of the exchange of information between IEDs through Process Bus.

Standardize GOOSE & SV exchanged is fundamental to allow interoperability between different IED manufactures

Standard IEEE 1588 synchronization protocol is used to synchronize all the IEDs of the solution with an accuracy of microseconds. in the event of loss of the substation GPS, the CU takes on the role of master clock and guarantees that the busbar differential system can continue to operate correctly.

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Experimental setup & test results

To test the full solution, several test scenarios have been taken into account, focused on fully testing all the characteristics of the IEDs, but with special emphasis on two critical points: The reliability of the process bus communications in all kinds of situations and the correct behaviour of the busbar differential protection function during all type of disturbances (internal and external faults, extreme current saturation, transformer energization) including appropriate response times.
A complete busbar substation laboratory test model was created to allow simulating a complete set of busbar configurations (single busbar, sectionalized single busbar, double busbar, sectionalized double busbar, etc.).

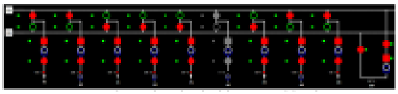

Figure 3. Busbar substation laboratory model scada

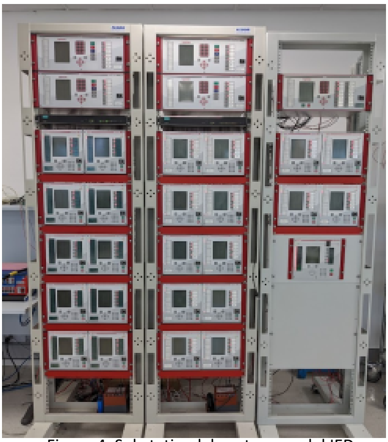

Figure 4. Substation laboratory model IEDs

The substation laboratory test model was composed by a CU and 24 BCUs, as well as auxiliary equipment that simulates the usual operations of breakers and disconnectors. Two communication topologies were tested, one corresponding to an HSR redundancy process bus and the other a PRP redundancy station bus for all the IEDs. IEEE 1588 synchronization was provided by a GPS connected to the bus station.
Among other tests, it was verified that in case GOOSE message avalanche, the measurements collected in the CU met the required times to avoid a malfunction of the busbar differential protection.

To test the correct operation of the busbar differential protection function in all types of disturbances, several sets of HIL (Hardware In the Loop) tests have been created to simulate the response using a Real Time Digital Simulator

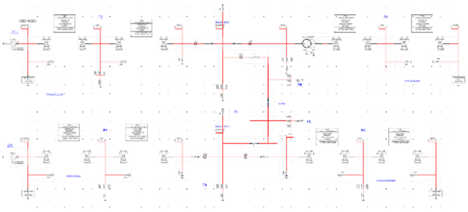

Figure 5. RTDS test model

In the tests that were carried out, a correct behaviour of the system has been verified in all types of scenarios. It has been verified that the final trip times for instantaneous faults, measured from the beginning of the fault to the final trip made by the BCUs, are less than one cycle.

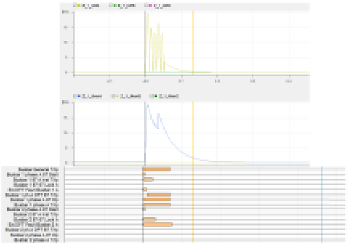

Figure 6. Busbar internal fault protection´s response

One of the main challenges of the solution development has been the complexity of the simultaneous treatment of the measurement information and digital signals of the substation. The correct dimensioning of the bandwidth of the process bus network, the low latency in the passage of packets and the correct IEEE 1588 synchronization of the IEDs have been essential for the solution to operate correctly.

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Discussion

As result of the tests carried out. It can be said that the busbar differential solution based on the IEC 61850 standards is fully functional.

There are two principal advantages:

- The use of standard protocols allows easy monitoring of the process bus communication. LSVS and LGOS node are available to check communication status
- Enables future interoperability between different manufacturers

For a complete interchangeability of devices from different vendors will be necessary to advance in different aspects that are not so necessary when a single-manufacturer solution is supplied:

- Verification that the Sampled Values publishers fully comply with the IEC-61869 transient's standard. In these type of protection schemes, in which the currents supplied by the Sampled Values publishers (BCUs) are being compared, a small difference in response can cause malfunction of differential busbar protection.
- Due to the previous point it is necessary to have a robust algorithm and a set of tests to validate BCUs from different manufacturers.
- It is completely necessary to standardize the digital signals to be shared between CU and BCUs through GOOSE messages (trip and lock signals, breaker and disconnectors' status, etc.). Thus, criteria have been defined with an electric company (reference costumer) to standardize the communications in the process bus in order to allow multivendor IEDs both in CU and BCUs

Conclusion

A fully functional IEC 61850 process bus based distributed busbar differential protection solution has been implemented, requiring the development of a powerful new HW platform that may be the basis of future centralized protection and control platforms in substation environments.
The study summarizes many of the advantages of using a modular design with communications based on standard protocols regarding configuration, interoperability, monitoring, redundancy capabilities and troubleshooting.