1 – Introduction

A substation automation system is basically composed of elements to protect equipment, to control switches, circuit breakers and transformers, as well as supervision and monitoring of the status from all involved equipment, respecting each equipment features and possible limitations.

There are two typical scenarios when it comes to substation automation: the first relates to new plants, in which the designer can create a concept for the plant automation, define the best network and infrastructure topology, in order to mitigate the risks, get complete information of the electrical system and optimize the system implementation costs; but there is also the second scenario, where existing plants are in production (some for many years) and without dedicated infrastructure to electrical automation. In these plants it is common to find several automation systems for each substation, using usually PLCs, supervisory systems from various vendors with little or no information exchange because, as a rule, there isn’t a central system that manages all substations, making plant control and management to be much harder.

In these days, it’s essential to have an automation system capable of integrating all available information into a single platform, regardless of the model chosen for a particular protection relay or the chosen protocol, and making information available anywhere in the plant so as to facilitate remote operation. Moreover, the possibility of integrating the substation automation system to the process control system enables a single database and complete plant management, both for operation and maintenance.

2 – Electrical Automation Integrated System

2.1 IEC61850 standard

With the evolution of substation equipment, such as IEDs (Intelligent Electronic Devices) and digital meters, and with the advent of IEC 61850, the possibility of having the equipment integration from different vendors in a single system becomes reality. In the case of plants in production, such integration allows several substations with IEDs from different vendors to be grouped into a single system, because they all speak “the same language”. This makes operation and maintenance of the electrical system to be easier, bringing information from the whole plant. This is called interoperability.
IEC 61850 standard can be misunderstood as a communication protocol; however, it goes far beyond that. In order to standardize the complete communication concept in substation automation, the standard is based on three goals: interoperability; freedom of configuration and long-term stability. Interoperability is the ability for IEDs from different vendors to communicate with each other; freedom of configuration is the ability of each vendor to use different methods and philosophies in the internal programming of logic performed by IEDs, as long as the data exchange between them obey the goal of interoperability, and concerns the freedom to allocate functions to one or more IEDs during the substation project by the engineering team; and long-term stability refers to the ability of communication protocols to remain updated in front of technological advances.

For that, the way devices exchange data is standardized, using the concept of Logical Node. According to its definition, a Logical Node is "the smallest part of a function that exchanges data" (IEC 61850-SER ed1.0, 2010). Each substation function is broken into smaller parts, and data exchanged between each part is standardized, without affecting the inner operation of each part. This ensures interoperability and freedom of configuration.

In order to allow information exchange between devices, two communication protocols are defined: one for communication between IED and supervisory system, called MMS; and another for fast communication between IEDs for interlocks and logic selectivity, called GOOSE. MMS protocol (Manufacturing Message Specification) is used for communication between IEDs and supervisory system based on client-server philosophy, i.e., the IED becomes a server for the information available in it and the supervisory system becomes a client for that information; it is used for supervision and operation information, being a non-critical time communication. GOOSE protocol (Generic Object Oriented Substation Events) is used to exchange the critical time information between IEDs inside network for protection, interlocking and logic selectivity purposes; this communication is based on MAC addresses, and allows the transmission of packets in the network as fast as 3 ms. GOOSE protocol is one of the great advantages of IEC 61850, reducing the amount of wiring between cubicles of a substation to perform logic selectivity schemes, greatly reducing installation and maintenance costs.

All communication between the devices is over Ethernet network protocol, globally known in enterprise environments and now also in the industry ones. At this point, it’s important to notice the importance of network configuration on an industrial project. Today it is no longer possible to foresee an industrial scenario without communication possibilities offered by industrial networks. The need for information integration (achieved long ago in IT scenarios) becomes crucial in industrial scenarios, and will become increasingly essential in the near future.

Figure 2 presents a generic topology that addresses the minimal concepts of an electrical automation project. One can see the substation equipment such as circuit breakers, switchgears etc., (given by IPASS Switchgear boxes) as well as measuring instruments like CTs and VTs (MUPX and MUPY boxes), physically connected to the protection and control IEDs (given by boxes Bay Controller, Prot X and Prot Y), which are connected to an Ethernet switch. The switches of each substation are part of a network that is connected to protocols gateways and to human-machine interface equipment (HMI). GPS devices are also commonly used to protocols gateways and to human-machine interface equipment (HMI). GPS

2.2 Advantages for the electrical system

As the intelligence for protection and logic selectivity is distributed to the IEDs (which can now communicate with each other), the DCS can be in charge of power management and other logics that require a higher level system view. Some functions such as load shedding, generator control, turbine management, transformer tap control can be run on the DCS, and some controllers have GOOSE interface, achieving operating times faster than 10 ms, thus reducing selectivity adjust times, taking care of mechanical health of cabling, circuit breakers and machines, without using hardwires.

Another great advantage with the advent of IEC 61850: a trend of all equipment in the electrical system to suit the communication according to IEC 61850, which initially started only in IEDs. Today we already have digital meters, and soon CTs and VTs will emerge in the market with communication drivers, plus circuit breakers and switchgears, i.e., it will be possible to see the system more and more integrated, through a single standard of network connection and the electrical system itself.

3 – Case study: Itabira integrated system

In order to show how the information integration brought by the use of IEC 61850 concepts, especially interoperability, some features of a real system already implemented are here illustrated. This section is about the electrical automation integrated system of Itabira, the iron ore beneficiation plant located in the city of Itabira-MG, Brazil. In this system, six main substations were integrated into a single system, providing information of
high voltage equipment such as 230 kV and 69 kV up to medium voltage as 13.8 kV and 4.16 kV. The six substations are located in different places around the city, separated by distances up to 30 km from the central operating room. The IEDs are from two different vendors, due to the fact that substations retrofits were made at different periods and under different contracts.

The supervisory system is from a third vendor, and it communicates with the IEDs via MMS protocol for system operation and supervision. Moreover, due to the large distance between the substations and the risk of losing communication, it was used a contingency operation solution in each substation, consisting of a human-machine interface touch screen panel and a controller with GOOSE interface, being able to receive data from and send commands to the IEDs, in order to ensure remote operation of circuit breakers and switches. This guarantees the main project concept: to keep the operator away from the electrical cubicle, and consequently from the electrical risk.

Figure 3 illustrates the generic automation system topology used in Itabira. One can see how the two interfaces of the automation system to the IEDs, using both protocols proposed by IEC 61850.

Due to greater amount of information available in the IED network because of digital communication protocols (IEC 61850 network in Figure 3, for better understanding), besides the possibility of communication between IEDs from different vendors located in substations away from each other, it was possible to get an integration level of all the available information in the same system, so the electrical system operation is possible regardless of where the operator is. The information centralization through Ethernet networks also allowed creating a remote operating room, from where there is view of everything that’s happening in the system. Moreover, system maintenance also become easier because the IEDs can be parameterized and configured from anywhere with access to the automation system, and if it’s necessary to go to the failure spot, the technician will be able to get there with more details about what happened.

So the three main project concepts were achieved: remote operation guaranteed; remote maintenance; and integration of information in a single system.

4 – Electrical and Process automation integration on the same system

The adoption of Ethernet-based systems makes open protocols to be used more often, creating more complete automation systems, thus optimizing costs and information availability on the entire plant.

In the past, and in many plants in operation nowadays, there is still a strong separation between the electrical automation system, responsible for power management, and the process automation system, more focused on the production, in a way that there is little or no exchange of information between them. Today one can understand it’s an increasing trend to have a single system managing the entire plant, looking for both Process and Electrical automation with excellent performance and availability through a unique DCS system.

Figure 4 presents a topology that can best show the new model.

Figure 3. Automation System Network Topology, with two interfaces to IEC 61850 devices.

Figure 4. Integrated Topology for Process and Electrical Automation Systems, using IEC 61850.

4.1 Advantages for the process control system

Among the advantages that can be pointed from this integration, cost reduction is the first one, because servers, software and hardware are optimized. Besides that, indirect costs such as training and investment shared between areas. In addition, new features can be implemented from the combination of information.

An example of this possibility is the adoption of medium voltage protection relays for motors control in IEC 61850, in which it’s possible to use all the benefits of GOOSE messages between IEDs without losing the interaction with process equipment, such as instrumentation, valves, and inverters.

A real case for this functionality can be given by a conveyor that handles ore, steel or any other goods.
Usually in these cases, big medium voltage motors are responsible for the operation, and if one of them failures the replacement won’t be immediate, causing damage and loss of production. Using features from substation automation environment, like logic selectivity and interlocks, it’s possible to preserve their health. Here are some pictures that illustrate how these features can be applied.

5 – Conclusion

The availability and the quality of information are assumptions that guide the day-by-day, increasing the level of demand in all areas including the industrial environment, and causing dramatic changes in established practice that are becoming obsolete.

With the advent of IEC 61850, more information is collected from the electrical automation system, due to Ethernet communication and data standardization, enabling interoperability, allowing free choice of IED vendors in order to best suit the substation environment. And with such a wealth of data available in supervisory systems, the information integration between automation systems allows multidisciplinary decisions to be taken by putting together the electrical control with process control needs. This provides more efficiency and bigger production availability, current concerns in the competitive global market. Moreover, applications developed typically for electrical environment can be used in process control system, which can be seen in the examples given.

In this scenario one can assure the advent of IEC 61850 provided a huge evolution in quality, changing the way we think of automation: automation based on the information integration.

6 – References

