"**IEC61850 in Practice**"

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Abstract-- Legacy substation automation protocols and architectures typically provided basic functionality for power system automation and were designed to accommodate the technical limitations of the networking technology available for implementation. There has recently been a vast improvement in networking technology that has changed dramatically what is now feasible for power system automation in the substation. Technologies such as switched Ethernet, TCP/IP, high-speed wide area networks, and high-performance low-cost computers are providing capabilities that could barely be imagined when most legacy substation automation protocols were designed.

IEC61850 is an important new international standard for substation automation that will have a very significant impact on how electric power systems are designed and built for many years to come. IEC61850 is a part of the International Electro technical Commission's (IEC) Technical Committee 57 (TC57) architecture for electric power systems. The model driven approach of the TC57 standards, including IEC61850, is an innovative approach that requires a new way of thinking about substation automation that will result in very significant improvements in both costs and performance of electric power systems.

It is not sufficient to develop systems that only produce, transmit, or distribute electric power. Fully automated – remotely supervised – systems that require little or no human intervention seem to be ideal. Technologies bundled into the power system, therefore, have to include protection and control equipment, as well as interfaces to supervisory control and data acquisition (SCADA) of control centers.

Introduction:

Electric utilities, all over the world continuously encounter the challenge of providing reliable power to the end-users at competitive prices. Due to several reasons such as equipment failures, lightning strikes, accidents and natural catastrophes, power disturbances and outages in substations occur and often result in long service interruptions. Thus, the substations should be properly controlled and monitored in order to take the necessary precautions accurately and timely. In this respect, substation automation, which is the creation of a highly reliable, self healing power system that rapidly responds to real time events with appropriate actions, ensures to maintain uninterrupted power services to the end users.

The IEC 61850 standard covers a wide range of substation applications. At the process level the IEC 61850-9-1 standard defines a unidirectional serial communication interface connecting current (CT) and voltage transducers (VT) with digital output to electrical metering and protection devices. This allows the exchange of synchronized phasor measurements using GPS signals for synchronization. The GOOSE (Generic Object Oriented System Event) that defines the transmission of high priority information like trip commands or interlocking information meets another real-time requirement. Additional applications that are necessary for a complete system may include: metering, protection and control, remote monitoring and fault diagnosis, automated dispatch and control, data retrieval, site optimization of electrical/thermal outputs, asset management, as well as condition monitoring and diagnosis.

Globally, utility deregulation is expanding and requiring demands to integrate, consolidate and disseminate real-time information quickly and accurately within all kinds of utility automation systems – from power plants to customer interfaces. Utilities and vendors spend an ever-increasing amount for real-time information exchange; costs for data integration and maintenance are exploding. Vendors of power systems have – because of the fast growing market or market deregulation – very limited resources to implement and apply hundreds of proprietary communication systems. In response to this situation, the IEC (International Electro-technical Commission) and IEEE have developed and published a suite of (draft) international communication standards and a technical report.

The Impact of IEC 61850 on Substation Automation:

The basic functionality of Substation Automation is given by its tasks and will not be changed by IEC 61850. On a first look, also the system architecture is not so much changed. Nevertheless, communication is the backbone of SA and, therefore, IEC 61850 the most important key for designing systems. A lot of inherent features in IEC 61850 like the use of object oriented data model, the selection of mainstream communication technology allow responding very dedicated to requirements stated in customer specifications not by chance but based on standardized rules. Therefore, these features support designing optimized systems. Optimization includes not only functional performance but also economic aspects like investment, availability, expandability and maintainability, i.e. all life cycle costs. For specification, design and engineering, the most important feature of IEC 61850 is its support to strong formal description of the substation and its automation system. The use of this strong description facility will be mentioned in all steps below if applicable. If the customer is not providing this formal specification, this task is left for the system integrator or provider to use its power for the SA system design.

The future electricity systems will – thank to the seamless real-time communication systems – be smart at the top but smarter at the bottom, self-regulated by millions of communicating devices connected to form feedback loops, and permanently aware of the world around them. The benefactors of the results of open device data integration span the entire industry and include all of the stakeholders in this industry. With the standard IEC 61850 intelligent protection relays and other real-time devices are becoming more common. Utilities could take advantage of these new developments, and make the power systems safer than before – taking into account that all critical information (status and measurements) is available (at any time and any where) when making control decisions.

Communication System Needs:

Communication has always played a critical role in the real-time operation of the power system. In the beginning, the telephone was used to communicate line loading back to the control center as well as to dispatch operators to perform switching operations at substations.

As we move into the digital age, literally thousands of analog and digital data points are available in a single Intelligent Electronic Device (IED) and communication bandwidth is no longer a limiting factor. Substation to master communication data paths operating at 64,000 bits per second is now common place with an obvious migration path to a much higher rates. With this migration in technology, the "cost" component of a data acquisition system has now become the configuration and documentation component. Consequently, a key component of a communication system is the ability to describe themselves from both data and services (communication functions that an IED performs) perspective. Other "key" requirements include:

· High-speed IED to IED communication
· Networkable throughout of the utility enterprise
· High-availability
· Guaranteed delivery times
· Standards based
· Multi-vendor interoperability
· Support for V and C samples data
· Support for File Transfer
· Auto-configurable / configuration support
· Support for security

Given these requirements, work on"next generation" communication architecture began with the development of the Utility Communication Architecture (UCA) in 1988. The result of this work was a profile of "recommended" protocols for the various layers of the International Standards Organization (ISO) Open System Interconnect (OSI) communication system model. This architecture resulted in the definition of a "profile" of protocols, data models, and abstract service definitions that became known as UCA. The concepts and fundamental work done in UCA became the foundation for the work done in the IEC Technical Committee Number 57 (TC57) Working Group 10 (WG10) which resulted in the International Standard – IEC 61850 – Communication Networks and Systems in Substations.

Example of Modeling a Substation Using IEC 61850 Concepts:

General:

As an example, part of a single line diagram (SLD) of a substation with two transformer bays is shown in Figure 1. The minimal needed automation of this substation part and the intended operating procedures already contain implicitly a big part of the functional specification. The SLD shows all power equipment to be controlled and protected, and defines how this shall be done from the operator's point of view.

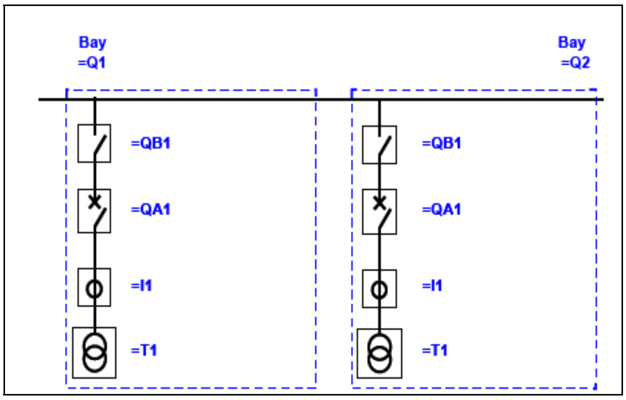

Figure: - 1 Part of a substation Single line diagram with equipment Designations

The topology, how the power equipment is electrically connected, gives further information needed e.g. for interlocking and synchro-check functionality. The equipment designation [1] in the SLD gives further inputs for detail engineering of the SA systems. The SLD as part of the specification is currently drawn on paper. The XML based Substation Configuration description Language (SCL) of IEC 61850 [2] offers a formal way to describe the SLD. Passing the SLD in this form as file reduces misunderstandings and enables automatic processing of it without new data entry.

Specification method

The functionality as given by the SLD has to be, however, further refined. All requested functionality should be specified without reference to any implementation to allow optimizing the solution. Only by this approach, the system design can exploit all benefits of state-of-the-art technology. Up to now, the most formal and simple way is to add the Device Function Numbers according to IEEE [3] if applicable. IEC 61850 offers the concept of logical nodes (LN) for formally defining functions. The LN is the smallest part of a function, which communicates with other LNs and which may be implemented in a separate IED. The LN is an object, which comprises at least all related mandatory data and attributes and all extensions according to the rules of IEC 61850. It defines also the standardized access to its data. Therefore, LNs allow defining functional requirements in a standardized way. The resulting LN names (see section 3.3.2) may be used in the SLD (see Figure 2) is representing the requested functionality.

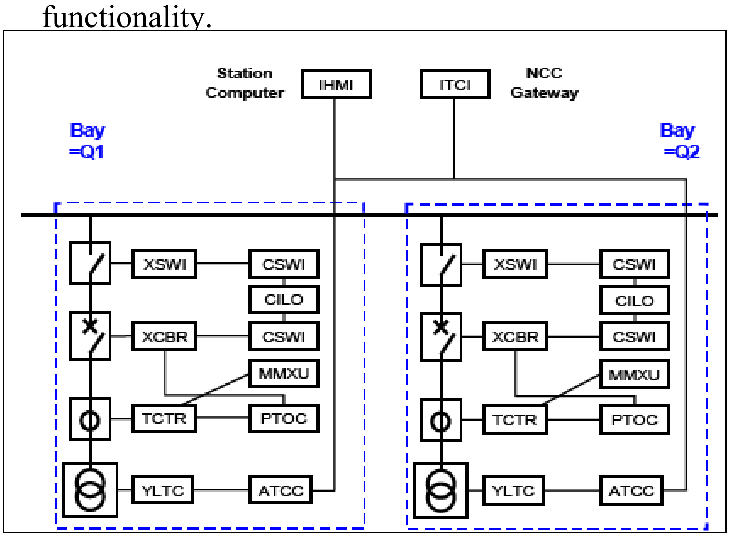

Figure 2 - Part of a substation single line (example) with function allocation by LN names

By adding the data objects used by the LNs as LN type definitions, this specification will contain also the data as described by the well-known signal lists. At this level of design, no allocation of functions to IEDs is done. To give signals, functions and connections the proper meaning, we have to know which power equipment and bay within the switchyard refers to what function or reverse. This may be done with help of SCL. The resulting file is called System Specification Description (SSD) file. However, this SSD file does not define specific details of function implementation and function interaction. These must be described as today with text blocks and diagrams. The SSD file allows however including short text parts or references to files containing additional information into the objects of the SLD as well as into the LN definitions. With these features the degree of understandability is enhanced quite a lot compared to current verbal specification, and supports automated consistency checks of quotations against specifications.

LNs used in the example

For better understandability of the figures, the LN class definitions according to IEC 61850 are given. XCBR Circuit breaker, XSWI Isolator or earthing switch, TCTR Instrument transformer/transducer for current, YLTC Power transformer, CSWI Switch control, CILO Interlocking, MMXU Measuring unit, PTOC Time over-current protection, ATCC Automatic tap changer control, ITCI Tele-control interface or gateway, IHMI Human machine interface, operators place.

Performance

Performance comprises a wide range of topics such as response time, safety and reliability. These requirements guide the allocation of LNs and their related functions to devices, and strongly influence the structure of the communication system. Response time requirements can be subdivided into average response time requirements, which are not process critical, and absolute worst case requirements, whose deviation might lead to dangerous process states. If the performance requirements are safety related or not, depends on the function using this data. Therefore, they should be specified per function. For safety it might be sufficient to specify the degree of safety to be met as a safety probability per function.

It is up to the system designer selecting IEDs, communication configurations and function implementations which match these response times and failure modes additionally to the needed availability. Some considerations in the context of IEC 61850 can be found in [4], [5] and [6]. This approach is, however, only possible if the communication system is not already fixed. In this case the communication system designer has the responsibility for the safety of distributed functions. Safety and availability are normally specified as probability values, together with some general rules like “no single failure shall endanger the safety" or "... shall lead to functional loss”, etc. The probability numbers can either be derived by comparison with conventional systems offering sufficient safety and availability, or by considering the costs of failures. Some explanations on availability calculations and an example to the last case can be found in [7]. The question has to be addressed also what kind of redundancy results from the reliability requirements.

Constraints

The constraints include some boundary conditions like the geographical extension and topology of the substation, the existence of building structures, switchyard kiosks, shielded rooms for the station HMI, etc. All these conditions influence the SA system architecture regarding possible IED locations and the resulting communication links. Other boundary conditions are the interfaces to auxiliary power supply system, the switchgear and to network control centers. Especially, the type of process interface (parallel wired or serially linked) can vary as boundary for a system provider depending how the delivery is organized and allocated to different providers. Devices already existing or prescribed by the customer may be also constraints in the specification, but are neglected in the context of this paper. The performance requirements together with the given constraints define the final physical architecture.

Typical Architectures of IEC 61850 based SAS Systems:

The introduction of numerical relays and communication technology some 15 years ago has led to system architectures similar to what is shown in Fig. 3. The same architecture can also be used with IEC61850.

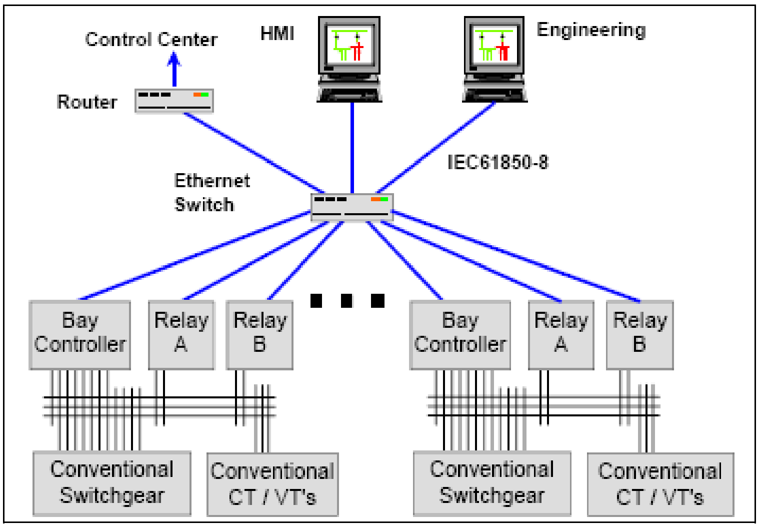

Fig 3: **Station bus and conventional wiring to the process**

Non-conventional instrument transformers will in a first 3 step be connected through serial point-to-point connections according to IEC61850-9 to the relays. This results in the architecture as shown in Fig. 4.

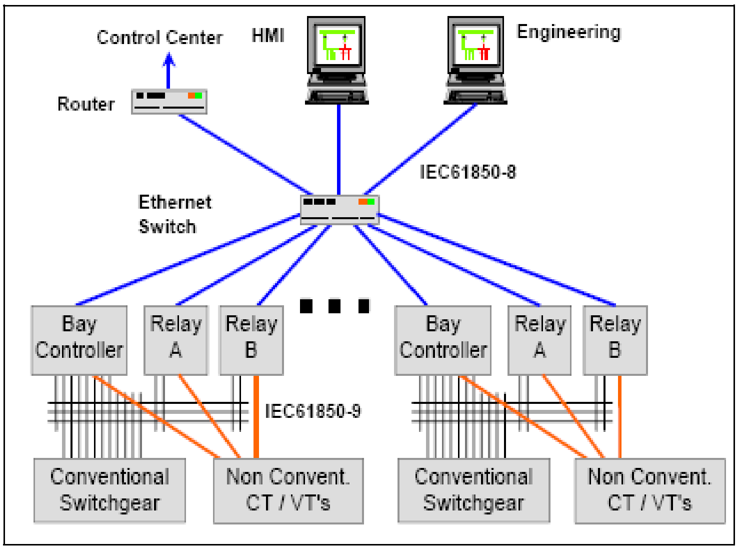

Fig. 4: **IEC61850-8 station bus and IEC61850-9 links to non-conventional instrument transformers**

The next step, where the drives of the switchgear are equipped with a communication interface may result in the architecture as shown in Fig. 5. A bus-like communication between the bay level functions and the process close equipment will further reduce copper wiring and will simplify the connection topology.

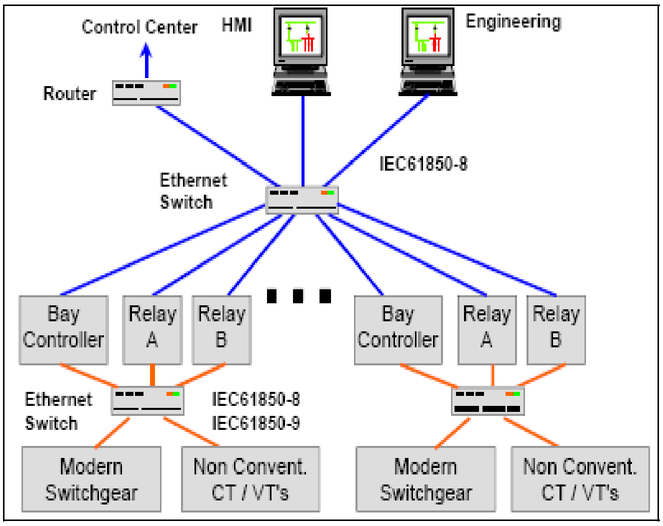

Fig. 5: **Hierarchical communication networks with IEC61850-8 as station bus and a process bus using both IEC 61850-8 and IEC61850-9**

Since IEC61850 uses the same communication technology for the station bus and the process bus, the final system architecture may be as shown in Fig. 6. This will allow a Seamless data access within the substation. Also architectures based on a ring topology are possible.

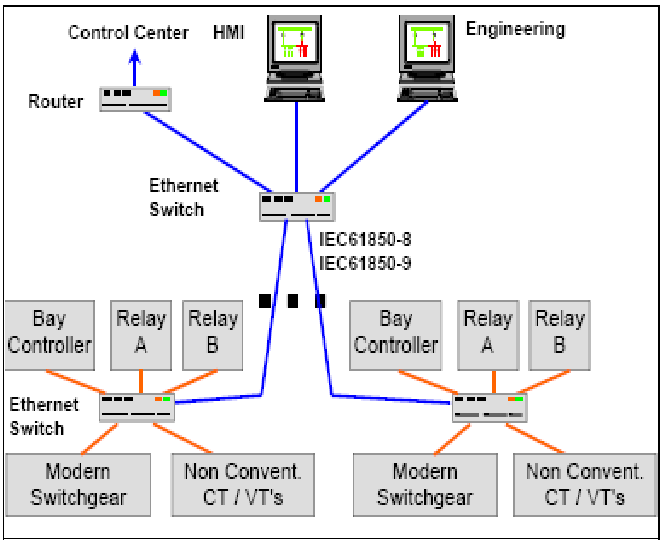

Fig. 6: **One single, station wide communication network using both IEC61850-8 and IEC61850-9**

Conclusion:

The new process close technology and the new standard IEC61850 offer several benefits for the design of a substation. The number of copper wires will be significantly reduced. This will also reduce the amount of manual work involved in assembling and testing these wires. The number of non-supervised functions will be reduced to almost zero. This reduces the time until an error will be detected and increases the availability of the system. With the introduction of the new technology, a true redundancy is possible at reasonable cost for all functions of the substation. Initially, on the path towards the intelligent switchgear, more physical devices are introduced in the system and may affect the overall system reliability. However, with each step of function integration, there is a reduction of the number of physical devices that consequently will improve the overall system reliability.

The communication system has been proven to be scalable supporting the requested availability. The free allocation of functions has been used in a very conservative way only. More freedom based both on state-of-the-art in technology and acceptance by the utilities will improve the optimization supported by IEC 61850, but ever-existing constraints will always control the process.

ABOUT THE AUTHOR

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Dy.Manager-Technology,Automation Business in Easun Reyrolle Limited . He has more than 5 Years of experience in design and development of Communication products and protocols in Power Automation field. He is currently in charge of Technology Department and also conducting Training Programs for Internal and External Customers on Communication medium and protocols for Substation Automation.

REFERENCES

[1] IEC 61850 Standards – Communication Networks and Systems in Substations;

[2] Manufacturing Messaging Specification; ISO 9506-1&2:2003; Part 1 – Service Definition: Part 2 – Protocol Specification