# Communication Module for Numerical Protection Relay – A Smart Grid Element

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***Abstract—***Smart grid is a system that manages power demand in a reliable, sustainable, and economic manner, which is built on high-tech infrastructure and integrates all the parameters involved. The existing conventional substation automation protocols and relay architectures provide basic functionality for power system automation, but lack in designing with respect to networking technology. In recent times, there has been a vast improvement in networking technology, like Ethernet, TCP/IP, high-speed WANs, which provide the capabilities that could barely be imagined when earlier protocols were designed. This paper presents Communication Module for a Numerical Protection Relay, by referring to IEC61850, an important new international standard for substation automation. This is a part of the IEC's Technical Committee 57 (TC57) architecture dedicated for electric power systems. The model driven approach of the IEC61850, is very innovative, that requires a new way of thinking about substation automation which can result in a significant improvement in performance of electric power systems along with cost reduction.

***Keywords—****smart grid; substation automation; protection relays; networking; communication;*

## I. INTRODUCTION

One of the significant challenges that substation engineers are facing is, justifying substation automation investments. Automation impacts positively on power quality, operating costs, and reduced outage response. But little attention is paid on the use of a communication standard and its impact on operation of the substation. Communication always performs a crucial role in the real-time operation of any power system. Fig.1 shows typical substation automation architecture[1].

Legacy communication protocols were developed with the objective of providing the necessary functions required by the power systems as well as reducing the number of bytes used by the protocol, due to severe bandwidth limitations. Eventually, as advanced networking protocols like TCP/IP became widespread, the existing protocols were accustomed to run over TCP/IP-Ethernet. This approach gave the advantages of advanced networking technologies to the substation, but it has a fundamental flaw. The protocols are unable to take advantage of the enormous increase in bandwidth that modern technologies deliver by giving a higher functionality level which can significantly bring down the operational and implementation costs of substation automation[1][2].

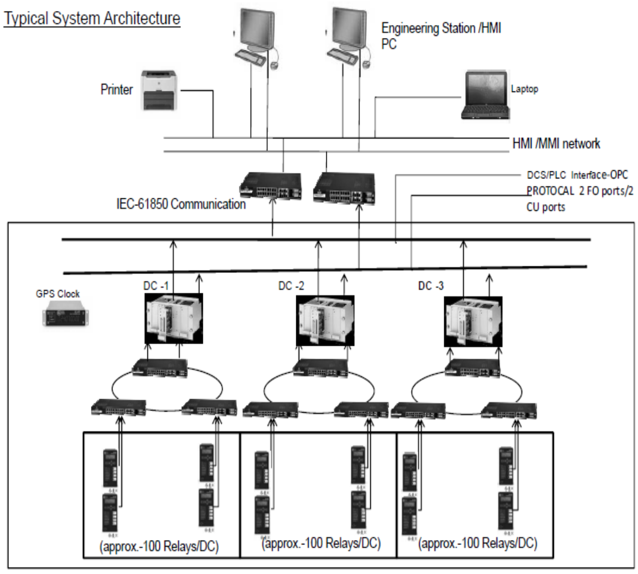


Fig. 1. Typical Substation Automation Architecture

This paper discusses on providing a framework for substation engineers to identify the benefits of using IEC 61850 technology for numerical protection relays.

## II. LITERATURE SURVEY

As we move into the digital age, hundreds of analog and digital data pickup points are present in a relay and communication bandwidth is now, no longer a inhibiting factor. Substation to master communication data lines operating at 64 kb/s is now very common with an aim to achieve much higher rates. The key requirements of a communication system are[1][2][4]:

- Networkability throughout the utility enterprise
- Guaranteed delivery times
- Standards based
- Multi-vendor interoperability and integration

- Support for Voltage and Current samples data
- Support for File Transfer
- Auto-configurable
- Support for security

Given these requirements, work on next generation communication architecture began with the development of Utility Communication Architecture in 1988. This architecture gave rise to definition of a "profile" of protocols, data representations, and some service definitions, and this was then, known as UCA. The concepts and paramount work done in UCA became the base for the work done in the IEC TC 57, Working Group 10, resulting in the International Standard, "IEC 61850"[4].

## III. MODELING APPROACH

### A. *Outline and Scope of IEC 61850*

The scope of IEC 61850 was stated for communication within the substation. The numerous aspects of the substation communication network divided in 10 major sections can be seen in the Table.

TABLE I. STRUCTURE OF THE IEC 61850 STANDARD

| Part # | Title |
|---|---|
| 1 | Introduction |
| 2 | Glossary |
| 3 | General Requirements |
| 4 | System and Project Management |
| 5 | Communication Requirements for Device Modeling |
| 6 | Configuration Description Language for Communication i Substations Related to Relay Architectures |
| 7 | Basic Communication Structure for Substation |
| 7.1 | Principles and Models |
| 7.2 | Abstract Communication Service Interface (ACSI) |
| 7.3 | Common Data Classes (CDC) |
| 7.4 | Compatible logical node classes and data classes |
| 8 | Specific Communication Service Mapping (SCSM) |
| 8.1 | Mappings to MMS(ISO/IEC 9506 – Part 1 and Part 2) and t ISO/IEC 8802-3 |
| 9 | Specific Communication Service Mapping (SCSM) |
| 9.1 | Sampled Values over Serial Unidirectional Multidrop Point-tc Point Link |
| 9.2 | Sampled Values over ISO/IEC 8802-3 |
| 10 | Conformance Testing |

The parts 3, 4, and 5 of the standard, analyze the general and specific requirements for communication in a substation, which are then used as forcing functions to assist in the description of the services and data representations needed, the protocol required, and the underlying layers that should meet the overall requisites[5].

The unique construct that 61850 adopts is, "abstracting" the definition of the data items and the services, i.e., creating data items and services which are independent of any protocol. These abstract definitions permit "mapping" of the data objects and services to any other protocol which can meet the data and service requisites. Part 7.2 of the standard defines the abstract services and Part 7.4 defines abstraction of the data objects (Logical Nodes). Almost all of the data objects are made up of similar pieces like Status, Control, Measurement, Substitution. Hence, a concept of "Common Data Classes" or "CDC" was developed which defined basic building blocks to create larger data objects. These elements are defined in Part 7.3 of the standard.

After having the data and services abstract definitions, the concluding step is the "mapping" the abstract services into an actual protocol. Part 8.1 of the standard defines the mapping of the abstract data objects and services onto the MMS, the Manufacturing Messaging Specification and the Parts 9.1 and 9.2 define the mapping of Sample Measured Values onto an Ethernet data frame. Part 9.2 of the standard defines the Process Bus[5].

From a system perspective, a significant amount of configuration is required in order to combine all the pieces together and have them in working condition. To expedite this process and to eradicate the human error component, an XML based Substation Configuration Language (SCL) has been defined in Part 6. It gives a description of the relation between substation and the substation automation system. At the application level, the substation topology itself and the relation of the substation structure to the logical nodes configured on the relay architecture can be described. Each device must possess an SCL file describing its configuration. Finally, Part 10 defines a test plan in order to determine conformance with the numerous protocol definitions and constraints[5].

IEC 61850 has been designed to operate over modern networking technologies and delivers a remarkable amount of functionality which is not available in the existing communications protocols. These above mentioned characteristics of IEC 61850 have a large impact on the cost to design, build, install, commission, and operate substation automation systems[1][5].

### B. *Hardware Designing*

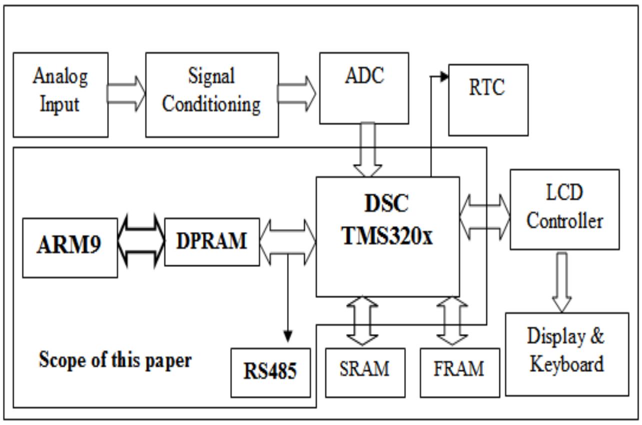


Fig. 2. Block Diagram of Numerical Protection Relay

The main components of the protection circuitry are the energizing inputs, analog to digital converter and a digital signal processor including the memory circuits. Further, a device contains a power supply unit, display/keyboard and communication module interface mainly for IEC protocols. The scope of this paper is the highlighted part shown in the block diagram[7].

The analog input (current or voltage) is step-downed, isolated, signal conditioned and applied to the ADC. The equivalent signals in digital form are further processed by the Digital Signal Processor according to the protection relaying algorithm which has been developed in the software. The RTC is used for time stamping the occurrence of any important event, and the memories are crucial as they store the fault records and the disturbance records[5][6].

As discussed earlier, the IED needs to communicate with the outside world. So, a half duplex RS485 communication is provided from the DSP. But, requirement of an Ethernet port is mandatory in these types of devices, which is required for MODBUS on TCP/IP, IEC61850, and IEC60870-103 on TCP/IP types of protocol. But, DSP does not have any Ethernet (MAC) port, also it is dedicated for signal and application processing purposes and hence, it does not possess the power for Ethernet communication.

An ARM processor is therefore incorporated in the design, which has a 32-bit ARM926EJ-S™ RISC core and operates at, upto 456 MHz. It can perform 32-bit or 16-bit instructions and is capable of processing 32-bit, 16-bit, or 8-bit data[11]. The core implements a pipelining mechanism, that enables all parts of the processor and memory system to operate continuously. This will communicate raw data from the DSP and will convert the data into required format for communication. Since the ARM core works at very high speed also it is easy to port operating system within the device, the preferable operating system here, is Linux as it is universally used and easily portable. Also, developing the IEC61850 protocol is easy using Linux operating system. Another advantage of using Linux OS is that future requirements like implementing web server within the device are easily possible.

Since we are using separate processor for communication, a separate mechanism has to be developed for communicating with the DSP. So, a Dual Port RAM (DPRAM) has been used. As the name implies it is a standard SRAM with 2-ports for each memory location. The DPRAM from Cypress semiconductors has true dual-ported memory cells which enable simultaneous access of the same memory location and provides high speed access of around 20 - 25 ns.

The device has two ports for same memory location. One port is connected to the ARM processor, and the other to the DSP. The arbitration mechanism is handled by the device. Here both the processors have to manage the timing according to the busy signal available from the device. The ARM processor operates at 456 MHz and the peripherals operate at 150 MHz.

The ARM 9 processor is interfaced with the DPRAM to exchange data from the DSP in real-time. It also handles all the communication related activities like handling Ethernet interface, IEC 61850 stack, interface of real-time data with IEC 61850 server stack, and time synchronization using SNTP client, etc. Since the operating system involved for this processor is Linux, a DDRAM, NAND Flash and RTC are also required. The actual Linux kernel & file system reside in the NAND Flash and during the runtime, DDRAM is used for processing.

## IV. SUBSTATION MODELING

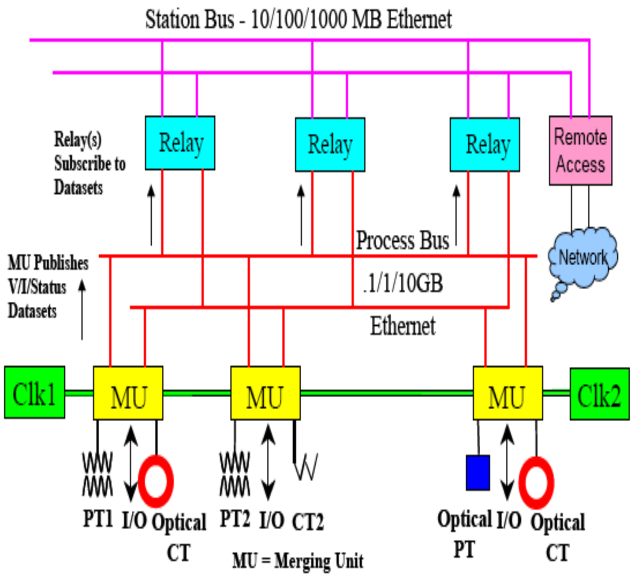


Fig. 3. IEC 61850 Substation Architecture

The substation architecture, as a whole is shown in Fig. 3. Initially, data from Voltage and Current Transformers, and status of digital inputs will be collected and digitized by the Merging Units. This will be collected through 100MB fiber optic Ethernet connections. The data collection centres are redundant Ethernet switches that facilitate Virtual LAN, which allows the Ethernet switch to deliver datasets to switch only those relays that have been subscribed to the data.

A synchronized clock architecture is also to be addressed in this case. If a failure of Clock 1 is detected, Clock 2 automatically comes on line and further handles sampling synchronization. At the substation level, a Station Bus, based on 10MB Ethernet exists which will surely progress to 100MB Ethernet. This bus provides communications between the various Logical Nodes, which in turn provide the numerous station monitoring, control, protection, and recording functions. The communication is either connection oriented or a connection-less, known as GOOSE - IEC Generic Object Oriented Substation Event. Again, an redundant communication architecture is usually recommended, as the application of inter-relay data transmission draws the communication system on the critical path in faulty situations, or in case of system failure.

Finally, the architecture supports remote network access for all types of data read-writes. As all the communication is network enabled, multiple remote clients desire access to the wide variety of available information. The remote access point is a logical location to implement network and data security functionalities like encryption and authentication. This implementation reduces the load on the individual protection relays to perform encryption on internal data transfers but still provides security on all external transactions.

## V. CONCLUSION

IEC 61850 has been now released to the industry which addresses most of the issues that entail to migration to the digital world, especially, data names standardization, creating all-inclusive set of services, and implementing over standardized protocols and hardware. The IEC 61850 substation architectures are providing significant benefits in the power sector. The key feature is the flexibility to accomplish new objectives that were too costly or almost impossible using the legacy protocols. Multi-vendor interoperability has been manifested and compliance certification process is being established with the existing relay architectures. Discussions are underway to implement edition 2 for IEC 61850 protocol, to be known as IEC 61850-9-2 Process Bus, and the library providers are also updating their libraries for the same. Thus, the IEC 61850 protocol is bound to become the protocol of prime preference in terms of providing network solutions for the substation automation systems.

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