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Implementation of Substation Automation Systems using IEC 61850

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ABSTRACT

Electric power system substations are being modernized to better serve user requirements for more efficient communication and more comprehensive protection and to facilitate future expansion by installing and applying higher-performance IEDs. There is a demand for a substation automation system (SAS) that is simple to integrate and provides high performance and flexibility. IEC 61850 capacities provide interoperability and advanced communications capabilities in substation protection, coordination, control, monitoring, metering, and testing. IEC 61850 is the result of the efforts of IEC Technical Committee 57 (TC57) to produce an open standard for substation modeling and communications. Substation configuration description language (SCL) is used in IEC61850-based substations to create substation configuration description files that contain full information about the substation. The main purpose of this format is to ensure that IED capability and substation descriptions are exchanged in a compatible way between the IEDs.

Keywords— *IEC 61850, Substation Automation*

1. INTRODUCTION

IEC 61850 emerges as the promising protocol for the future smart grid. It was designed to ensure interoperability of the communication between Intelligent Electronic Devices (IEDs) in substation automation systems. An IED is the microprocessor-based device that performs several protective, control, and similar functions. The main idea of IEC 61850 to break down the functions of IEDs into core functions called Logical Nodes (LNs). Several logical nodes can be grouped into a Logical Device (LD) which provides communication access point of IEDs. By standardizing the common information model for each LN and the associated services, IEC 61850 provides the interoperability among IEDs of different manufacturers in substation automation systems. [1][5]

2. PROBLEM STATEMENT

- No existing standard for serial communication in substation automation
- Proprietary standards having local/narrow functional scope
- Fast technology changes
- Proprietary standards usually define communication on physical and link layers which are sensitive to changes
- High reliability
- Interoperability issues and testing

3. OBJECTIVES

- Designing a communication network topology for substation automation
- Modeling substation electrical components
- Applying IEC 61850 services for SAS

4. STANDARDIZED APPROACH

IEC 61850 provides a huge variety of communication functions which allow tele control, tele protection, supervision and monitoring between different IEDs in an electric power system.

The standardization approach of the IEC 61850 series as mentioned in IEC 61850-part 1 is to blend the strength of three methods:

- Functional decomposition: is used to understand the logical relationship between components of a distributed function which is decomposed and represented as Logical Nodes (LNs)
- Data flow modeling: is used to understand the communication interfaces that must support the exchange of information between distributed functional components and the functional performance requirements.
- Information modeling: is used to define the abstract syntax and semantics of the information exchanged

In short, IEC 61850 decomposes and standardizes the functions as logical nodes, classified the communication interfaces between different functional levels and models the information exchange in term of data objects, data attributes, and abstract communication services.

5. CONTENT OF IEC 61850

Part 1: Introduction and Overview
Part 2: Glossary
Part 3: General Requirements
Part 4: System and Project Management

Part 5: Comm. Requirements for Functions and Device Models

Configuration:
Part 6: Configuration description language for communication in electrical Substations related devices

Abstract Communication Services:
Part 7-1: Principles and Models
Part 7-2: Abstract Communication Services Interface (ACSI)

Data Models:
Part 7-3: Common Data Classes
Part 7-4: Compatible Logical Node Classes and Data Classes

Mapping to Real Communication Networks (SCSM):
Part 8-1: Mapping to MMS and to ISO/IEC 8802-3
Part 9-1: Sampled Values over Serial Unidirectional Multidrop Point-to-Point link
Part 9-2: Sampled values over ISO 8802-3

Testing:
Part 10: Conformance Testing

6. ACSI (ABSTRACT COMMUNICATION SERVICE INTERFACE)

6.1 Introduction

A significant advantage of IEC 61850 is the split between the communication and application as illustrated in Figure 3.1 by specifying a set of abstract services and objects, IEC 61850 allows the user to design different applications without relying on the specific protocols. As a consequence, the data models defined in IEC 61850 can be used on the diversity of communication solutions.

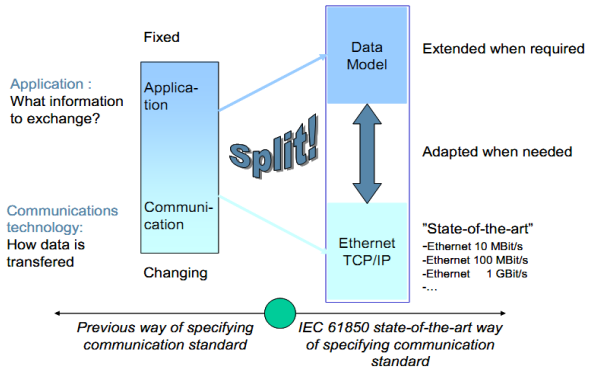

Fig. 1: Abstract communication service interface

6.2 ASCI Services

Besides standardizing the data format in an object-oriented manner, IEC 61850 also defines a set of abstract services for exchanging information among components of a Power Utility Automation System. These services are described in details in part 7-2 of the standard

The categories of services are as follows:
Retrieving the self-description of a device, fast and reliable peer-to-peer exchange of status information (tripping or blocking of functions or devices),

1. Reporting of any set of data (data attributes), Sequence of Event SoE – cyclic and event triggered,
2. Logging and retrieving of any set of data (data attributes) – cyclic and event,
3. Handling and setting of parameter setting groups,
4. Transmission of sampled values from sensors,
5. Time synchronization,
6. File transfer,
7. Control devices (operate service),
8. Online configuration

The complete Abstract Communication Service Interface – ACSI services are shown below:

- **Data Set**– Permit grouping of data objects and data attributes
- **Substitution**– Support replacement of a process value by another value
- **Setting group control**– Defines how to switch from one set of setting values to another one and how to edit setting groups
- **Report control and logging**– Defines conditions for generating report and log. There are two classes of report control: Buffered Report Control Block (BRCB) and Unbuffered Report Control Block (URCB). For BRCB the internal events that trigger the report will be buffered so that it will not be lost due to transport flow control constraints or loss of connection. For URCB internal events issue immediate sending of reports on a "best effort" basis i.e. if no association exists, or if the transport data flow is not fast enough, events may be lost.
- **Control blocks for Generic Substation Event (GSE)** – supports a fast and reliable system-wide distribution of input or output data values; peer-to-peer exchange of IED binary status information, for example, a trip signal.
- **Control block for transmission of sampled values**– fast and cyclic transfer of samples, for example, of instrument transformers.
- **Control**– describes the services to control, for example, a device.
- **Time and time synchronization**– provides the time base for the device and system.
- **File system**– defines the exchange of large data blocks such as programs.

For implementation, the abstract services will be mapped on different protocol profiles; the selection of an appropriate mapping depends on the functional and performance requirements and will be described in the next section.

7. COMMUNICATION SERVICE MAPPINGS

Due to the different requirements for transfer time of different functions inside the substation, IEC 61850 classifies the messages exchanged between the devices to several types:

1. Type 1 (Fast messages)
2. Type 1A (Trip)
3. Type 2 (Medium speed messages)
4. Type 3 (Low-speed messages)
5. Type 4 (Raw data messages)
6. Type 5 (File transfer functions)
7. Type 6 (Time synchronization messages)

The required transfer times rely upon the requirements of the function, for example, the "trip" message to open the circuit breaker for protection is very time critical (3 ms) in order to prevent damage to the system; however, the transfer time for file transfer functions to transfer a large amount of data is non-time-critical (can be 10000 ms).

The figure provides the mapping of these messages to different protocol profiles. Messages of type 1, 1A, and type 4 which are time-critical are mapped directly on Ethernet. Messages of type 2, 3 and 5 which are used for automation, auto-control functions, transmission of event records, reading and changing set-points…etc. require message-oriented services. The Manufacturing Message Specification – MMS provides exactly the information modeling methods and services required by the

ACSI. MMS services and protocol can operate over the full OSI and TCP/IP compliant communication profiles. This is also the only protocol that easily supports the complex naming and services models of IEC 61850. This protocol also includes the exchange of real-time data, indications, control operations, and report notifications. This mapping of ACSI to MMS defines how the concepts, objects, and services of the ACSI are to be implemented using MMS concepts, objects, and services. This mapping allows interoperability across functions implemented by different manufacturers.

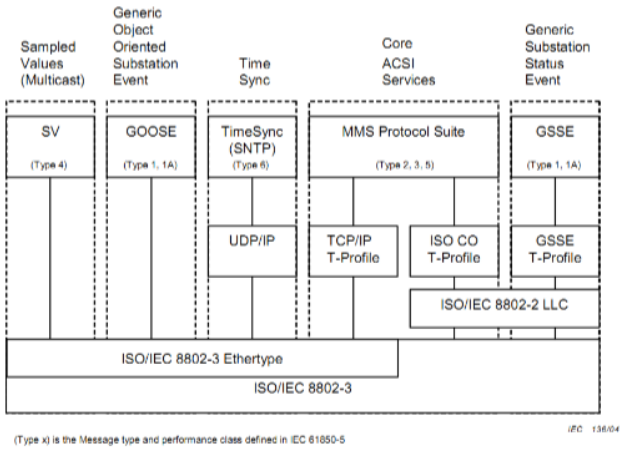

Fig. 2: Message type and performance class

Manufacturing Message Specification – MMS

MMS is a client/server communication model. MMS defines the difference between the entity that establishes the application association and the entity that accepted the application association. The entity that establishes the association is the client and the one that accepts the association is the server.

GOOSE services communication profile

The Generic Object Oriented Substation Events – GOOSE provides fast and reliable system-wide distribution of data, based on a publisher-subscriber mechanism (Generic Substation Event – GSE management). GOOSE is one of the two control classes within the GSE control model (the other is Generic Substation State Events – GSSE).

GOOSE uses Data-set to group the data to be published. The use of Data-set allows grouping many different data and data attributes.

Sampled Value

Sampled Value or Samples of Measured Values (SMV) is the protocol for transmission of digitized analog measurement from sensors (temperature, current transformer, voltage transformer). Sampled value messages are exchanged in a peer-to-peer publisher/subscriber mechanism like GOOSE messages. However, GOOSE uses the multicast model while SMV can be unicast or multicast. Figure 2.6 sketches the comparison between GOOSE and SMV communication models.

8. IEC 61850 DATA MODELLING PRINCIPLE

8.1 IEC 61850 data modeling concept

The main idea of IEC 61850 is to break down a physical device into logical devices each of which will be further broken down into logical nodes, data objects, and data attributes.

The Logical Device hosts communication access point of IEDs and related communication services and is hosted by a single IED. However, there's no rule on how to arrange Logical Devices into a physical device which brings a great flexibility to the user.

Logical Nodes are the smallest entities which are derived from the application functions. Logical nodes are the building blocks of the standard since they represent the smallest functions of the device. The scope of this project is about microgrids control and asset management which is very different from the scope of substation automation systems; therefore, many new functions must be modeled. The next clause will describe how to model a new function as IEC 61850 Logical Nodes. [5]

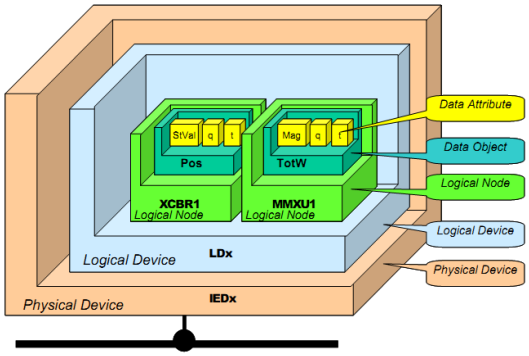

Fig. 3: IEC 61850 data modeling

Figure 3 illustrates the principle of IEC 61850 data modeling. In this case, a physical device IEDx is composed of a logical device LDx in which there are two different logical nodes XCBR and MMXU. XCBR1 and MMXU1 are the two instances of the logical node class XCBR and MMXU which represent the circuit breaker and the measurement unit respectively.

The intended purpose of the XML based Substation Configuration description language (SCL) as defined in IEC 61850 is the interoperable exchange of engineering data for a distributed substation automation (SA) system between engineering tools of different manufacturers at well-defined stages in a general engineering process.

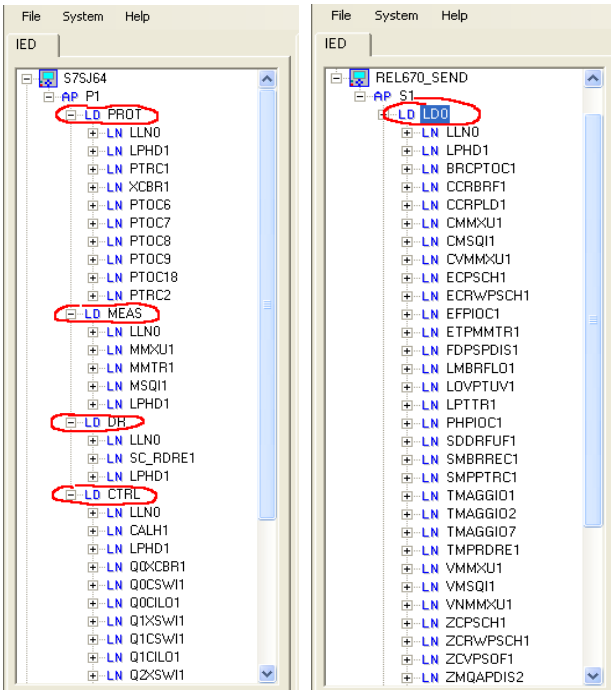

Fig. 4: ABB IED SCL file, SIEMENS IED SCL file

It is possible to "structure" the Logical Nodes, and group them under different Logical Devices.

The "rules" of this structure are described in the XML file.

8.2 Types of SCL

Depending on the information they carry, there are different types of SCL files:

- ICD (IED Capability Description)
- CID (Configured IED Description)
- SCD (Substation Configuration Description)
- SSD (System Specification Description)

Fig. 5: Typical SCL file in XML format

9. CONCLUSION

IEC 61850 has become a widely accepted standard in a SAS. In this SAS modernization, IEDs are seamlessly integrated to exchange control data between relays, automation controllers, the HMI, and other equipment. IEC 61850 international standard for substation communication enables the development of a range of conventional and new types based on Client/Server a high-speed peer –to- peer communication. The IEC 61850 based comprehensive information model of the communication network and its description in substation configuration description language (SCL) files are proposed to have the standard, correct and convenient configuration of the communication network. The proposed information model not only enables the standard, reliable an high efficient configurations of a communication network, but also potential to be utilized for online monitoring and management of communication networks based on IEC 61850 to achieve one standard in substation automation.

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