Communication Interconnection Network Architecture and Logical Devices Application

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Abstract

Recently launched a communication standard, communication architecture for network protocol design technique, defined by International Electrotechnical Commission (IEC), the need is to implement communication interconnection network architecture with logical devices, it’s a challenging task. The choice of logical device is to attain the critical time requirement of data transmission for Protective Relaying of 3ms without complicating the real-time implementation, processing power and data interconnection requirement. We are confirmed that the speed is only depends on the interconnection architecture design so as to prove the effectiveness of network design.

Keywords: Interconnection Network Architecture, Logical Devices, Protocol Design

1. Introduction

In general, an electrical substation is a subsidiary station of an electrical generation, transmission and distribution system where high-power voltage is transformed from high to low using the transformers. In the meanwhile, substations are generally equipped with transformers, circuit breakers, switchgears, voltage regulators, power factor correction capacitors, surge protection, metering, controls, grounding systems.

International Electrotechnical Commission (IEC), which is standard of communication protocol and policy maker, their one of the recent protocol product, logical devices are microprocessor-based controllers which can receive data from sensors and power equipment and can issue control commands of power system equipment. We called this is an Intelligent Electronic Devices (IED) and the purpose of these IEDs is to maintain the output of power system equipment at desired level they can have some protection function, self monitoring and communication capabilities.

Consequently, these protocols for communication interconnection network can be mapped over TCP/IP networks and/or substation Local Area Networks using high speed switched Ethernet. The high speed requirement for the standard is to achieve response time of less than four milli-seconds of protective relaying.

Emerging technology has made it possible to implement the Smart-grid concept that can predict and heal the problems. Smart-grid will have the capability to allow plug-and-play interconnection of both intelligent distributed generations (DG) sources, including energy storage technologies, and intelligent loads; so available power at any point in time is delivered to the prioritized critical loads during that same instant in time. Development of the smart control architecture for an electric power distribution network that allows plug-and-play interconnection of a diverse range of distributed generation technologies, energy storage
equipment, and the critical loads that are served into a readily scalable and deployable smart-grid depends on its networked system.

Standardization from IEC has made it possible to integrate IED’s on the high speed network communication. This paper organizes the detail and methods required for communication protocol for transmitting on logical devices. Starting with the network architecture design, we have briefly explained the standard protocol in Section-III and application layer protocol (ACSI) in Section-IV. Section-V discusses the middleware with Section-VI explaining in detail of results and Section-VIII describes the protocols.

2. Network Architecture Design

Algorithmic and mathematical underpinnings and look-ahead capability of an intelligent smart-grid needs to result in a self-healing grid. It uses logical devices, IED’s and controllers which have the Ethernet connectivity along with the Network switches.

![System Architecture for Interconnection Network Model](image)

Figure 1: System Architecture for Interconnection Network Model

A logical device, IED is used to monitor and control the each distributed energy source. The IEDs are Intelligent Transformers, Switches, circuit Breaker, protection Devices, meter etc. Thousands of analog and digital data points can be available in a single Intelligent Electronic Device (IED). Controllers are used to establish control loops, acquire data and perform some actuation process in IEDs.

At the same time, controllers establish communication with multiple controllers. Human Machine Interface (HMI) is for the operators to monitor and observe the status of the system. Smart-grid requires high degree of coordination and knowledge of each Smart-grid attributes and the capability of energy exchange among various domains in real time. Web based agents can provide coordination through internet. Power generation, supplying, storage and conversion units are managed centrally by the Energy Management System (EMS) controller. EMS make sure the all time power availability by coordinating multiple generation sources and dispatches power according to the demand and fuel availability.

These data names are determined by the standard, XCBR logical node models a circuit breaker. Inside LN, Each element of data conforms to the specification of a common data class (CDC) per IEC 61850-7-3.
3. Communication Model

Time constraint is one of the critical issues for the transmission of sampled values. The communication model provides transmission of sampled values in an organized and time controlled way so that the combined jitter of sampling and transmission is reduced to a degree that an unambiguous allocation of the samples, times and sequence is provided. The communication model applies to the exchange of values received from multiple Intelligent Electronic Device’s (IED’s) after A/D conversion. A transmission-reception buffer structure is defined for the transmission of the sampled values.

![Figure 2: Physical and Logical Device](image)

![Figure 3: Communication Model for Sampled Value Data](image)

The communication procedure is based on a publisher/subscriber mechanism. First of all, publisher shall use the time stamp mechanism to attach time stamp for data synchronization. After that, publisher will send the time stamped data to transmit buffer. The sampled value control block in the publisher is used to control the overall communication procedure. The
sampled values from the transmit buffer are send via high speed Ethernet to subscriber. The subscriber will receive the sampled values in a receive buffer. After that sampled value data is send to time stamp check mechanism to confirm the time synchronization of the received data. After that data is send to the control and monitoring section for further data analysis.

4. Results and Discussion

The fact that protection responses rely on the successful and timely exchange of messages requires very strict performance requirements, such as the need for a worst case 4ms application-to-application delivery delay requirement [5]. This implies that the total delivery delay between the communicating devices, which not just includes the delay on the wire but also the delay message encounters while travelling through protocol stack from the application layer all the way to the hardware, should not exceed 3ms. However the important message such as trip signal, the transmission time is required to be less than 3 ms [6].

MMS and XML can utilize object models completely, over any lower Layer network protocol. XML does not specify the Communication services (when to send, trigger by what etc). So an underlying service capability must be added most of which do not handle some of the powerful services like data sets. This implies that existing technologies must be modified for real-time implementation of IEC protocol and communication.

The PC0 is responsibility as a controller. It receives sample values, processes, and measures the delay time. The PC1 is responsibility as a station. It includes ten logic nodes. Two logic nodes, LPHD and LLN0, respond to description the station itself as standard defined in IEC 61850. Station includes four current transformers and four voltage transformers. Station (simulated by PC1) and controller (simulated by PC0) connect to a switch to transfer data.

![Figure 4: Tested Configuration](image)

PC1 simulate the operation of a station by continuously send IEC 61850 message reporting status of transformers to Controller on PC0. The Controller on PC0 use C-language library WinPcap to capture data from PC1. The message delay is calculated and report in Fig. 4. That graph report delay of thirty IEC messages. As shown in the figure, the delay time is distributed from 1.9ms to 2.9ms. These delays conform to requirement in IEC 61850 standard.
5. Conclusions

The issue involves the choice of suitable architecture and a number of communication techniques. Some of the specific requirements for real time substation applications such as the need for a time synchronization mechanism also need to be discussed and solution proposed. The advantages of IEC61850-9-2, Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3, as listed in section discussed.

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