Design of an IEC 61850 Based Communication System for DER Management

Taein Hwang, Yoonsik Yoo, Shinyuk Kang, Ilwoo Lee
Electronics and Telecommunications Research Institute
tihwang@etri.re.kr, midasyoo@etri.re.kr, ameba@etri.re.kr, ilwoo@etri.re.kr

ABSTRACT

We design an IEC 61850 based communication system for DER management through a CTTS controller to be able to gather vibration, noise, and temperature values from environment sensors placed around distributed energy resources. The designed system performs a function to transfer DER-related data obtained by the CTTS controller to a DER management server based on IEC 61850 MMS protocols after converting the data into IEC 61850-compliant data. In this paper, we define a functional architecture of the proposed system and describe its operation in detail.

KEYWORDS

Distributed Energy Resources, CTTS, Smart Grid, IEC 61850, Micro Grid, Backup Generator

1 INTRODUCTION

To fulfill rapidly increasing electric power demand, many countries have made an effort to construct nuclear power plants that is the most economical way to produce electric power. However, people's concerns on radioactive contamination and high voltage transmission make construction plans delayed or canceled. This results in power shortage in case of rapidly increased power consumption in summer or winter season, which makes some countries or big cities around the world plunge into the risk of a large scale blackout.

Photovoltaic and wind are considered to be alternative energy resources to fill a shortage of electricity coming from the main grid. However, power generation systems using the renewable energy resources are not rapidly deployed as their return on interest rate is still low without government subsidies. The systems need lots of money for initial investment. Due to characteristics of the system resources easily influenced by weather condition, it is difficult to ensure their power quality without an energy storage system and to cope with national energy crisis efficiently. It could be an alternative way to reduce the amount of power that micro grids require from the main grid or transmit surplus power to the grid by utilization of emergency generators.

Public establishments, commercial buildings, apartments, and industrial buildings have a power generator for emergency use to supply electric power to their vital facilities such as lighting or elevator system. The remodeled generator can produce electricity for a long time using gas supplied through pipelines. Buildings with such type of power generator can reduce their power consumption just by turning it on. Its surplus electricity can be aggregated into a bulk capacity of power. The aggregated bulk power can be transmitted into the main grid. According to power quality from the main grid, the emergency power generator can be operable with the grid in an interconnected or islanded mode through an electrical switch such as Automatic Transfer Switch (ATS) and Closed Transition Transfer Switch (CTTS). In this paper, we describe a functional architecture of an IEC 61850 communication system and its operation for management of backup generators through CTTS controllers.

2 RELATED STANDARDS AND WORKS

We give an overview of IEC 61850-7-420 that specifies the information model for Distributed

Energy Resources (DER) in this section. This standard is a basis of the designed system. In addition, we mention IEC 61850-8-1 that specifies the mapping of IEC 61850 abstract data objects to Manufacturing Message Specification (MMS) objects.

The IEC 61850 series provides interoperability between the Intelligent Electronic Devices (IED) from different suppliers or, more precisely, between functions to be performed by systems for power utility automation. The information exchange mechanisms rely primarily on well-defined information models. These information models and the modelling methods are at the core of the IEC 61850 series. The IEC 61850 virtualizes actual devices and functions into hierarchical data structures by information modeling, and performs certain functions by data exchange with the Abstract Communication Service Interface (ACSI) between different communication entities. Mapping between different communication protocols is implemented through Specific Communication Service Mapping (SCSM), achieving maximum compatibility and avoiding impacts imposed by the development of communication protocol stacks [1].

IEC 61850-7-4 specifies the information model of devices and functions generally related to common use regarding applications in systems for power utility automation. In particular, it specifies the compatible logical node names and data object names for communication between IED. This includes the relationship between logical nodes and data objects. IEC 61850-7-420 defines the IEC 61850 information models to be used in the exchange of information with DER, which comprise dispersed generation devices and dispersed storage devices, including reciprocating engines, fuel cells, micro turbines, photovoltaics, combined heat and power, and energy storage. This standard utilizes existing IEC 61850-7-4 logical nodes where possible, but also defines DER-specific logical nodes where needed [2-3].

IEC 61850-8-1 specifies the mapping of the objects and services of the ACSI to MMS and ISO/IEC 8802-3 frames. 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 [4].

Due to the complexity of the MMS, most of the current manufacturers achieve the mapping of the communication services by SISCO MMS-EASE LITE tool package in the development of IEC 61850 product. Model mapping and protocol conversion research between the IEC 61850 standard and MMS has being focused on nowadays. The research on the model mapping between Modbus and IEC 61850 standard is less. The Modbus protocol defines a simple Protocol Data Unit (PDU) independent of the underlying communication layers. The mapping of Modbus protocol on specific buses or network can introduce some additional fields on the Application Data Unit (ADU). A realization method of conversion method between Modbus and IEC61850 was proposed in [5-7].

3 IEC 61850 Based Communication System for DER Management

This section describes core components of an IEC 61850 communication system and their operation as depicted in Figure 1.

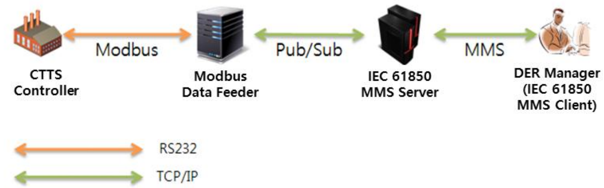

Figure 1. Core Components of an IEC 61850 Communication System for DER Management

The designed system consists of the following core components: CTTS controller, Modbus data feeder, and MMS server and client. The CTTS controller is to control a CTTS that switches a load between DER and a utility source. It controls DER to be operated in a grid-connected or an isolated mode. It also gathers

ISBN: 978-1-941968-02-4

vibration, noise, and temperature values measured by environment sensors placed around DER. The Modbus data feeder provides a function to get DER related raw data from a CTTS controller through a serial communication port such as RS-232c or RS-485, and sends the obtained Modbus data to a MMS server. The MMS server is capable of converting the Modbus data into IEC 61850 data objects and mapping the objects to specific MMS objects. The data objects are transferred to a MMS client by MMS read and write services.

Publish/subscribe services are used for communication between the Modbus data feeder and the MMS server. In this model, the Modbus data feeder acts as a publisher, and the MMS server as a subscriber. These services provide an effective way to periodically multicast data and the opportunity for better scalability than traditional client-server.

3.1 Obtaining Data from CTTS Controller

The information model for DER management can be customized by defining additional information such as values measured by environment sensors or unique DER characteristics on the basis of the IEC 61850-7-420 information model. The Modbus data feeder obtains DER-related information through a serial port such as RS-232C or RS-485 from a CTTS controller according to the Modbus serial communication protocol. The protocol is one of popular protocols for use with industrial applications. With the master-slave technique of the protocol, the CTTS controller and the Modbus data feeder communicate with each other. The Modbus data feeder as a master can initiate transactions. The CTTS controller as a slave responds the requested data to the master, or takes requested actions. The Modbus data feeder can address the CTTS controller and other environment sensors, or initiate a broadcast message to all slave devices. Slaves return a message to queries that are addressed to them individually. The CTTS controller and the Modbus data feeder should support RS-232c, RS-485, or Ethernet port in physical level. Through the ports, they are connected to each other, and can transmit data using the Modbus protocol. The Modbus data feeder puts the data in a hash table whenever receiving them from the CTTS controller. The hash map is a data structure that can map keys to values, and distribute key/value pairs across an array of slots. Given a key, the hash map function computes an index that suggests where the key/value pairs can be found. Upon on receiving data, the Modbus data feeder calculates a key required for searching a slot to store them, and stores the key and the received data together in the slot indicated by the key.

3.2 Transmitting DER-Related Data to MMS Server

The Modbus data feeder performs a function to obtain DER-related data from the CTTS controller and environment sensors. The MMS server receives the data after subscribing to the data channels of the feeder. The MMS server retransmits the Modbus data to requesting MMS clients after converting the Modbus data into MMS data.

ZeroMQ Pub-Sub pattern for state distribution and monitoring is used for communication between the Modbus data feeder and the MMS server as shown in Figure 2. The former is set to a publisher, and the latter to a subscriber. This mechanism unlike request/reply services provides one way communication services from a publisher to a subscriber after completing a subscription process between them. This communication model gives an effective way for the MMS server to collect all of the data coming from several DER and many individual electric devices around them.

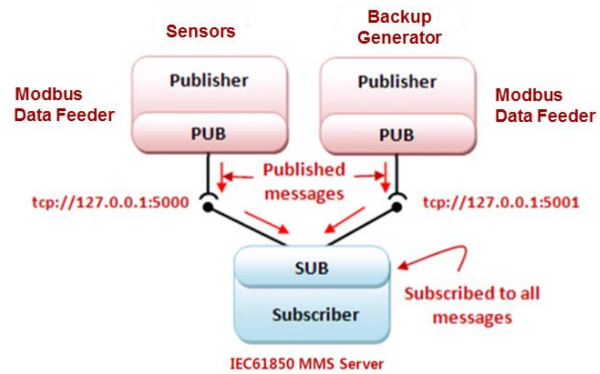

Figure 2. ZeroMQ Pub-Sub Pattern Between MMS Server and Modbus Data Feeder

3.3 Message Flows between CTTS Controller and MMS Server

DER-related data obtained from a CTTS controller are transferred to an IEC 61850 MMS client via a Modbus data feeder and an IEC 61850 MMS server. Communication between the CTTS controller and the Modbus data feeder is based on the Modbus protocols. Figure 3 shows the message flow between them. A Modbus data feeder connects to a CTTS controller after completing COM port configuration. Upon on establishing the connection between them, the data feeder requests the content stored in a specific input register of the CTTS controller. After receiving the response data from the CTTS controller, it calculates a key required for searching a slot to store the data. Finally, the data feeder stores the data in its hash table.

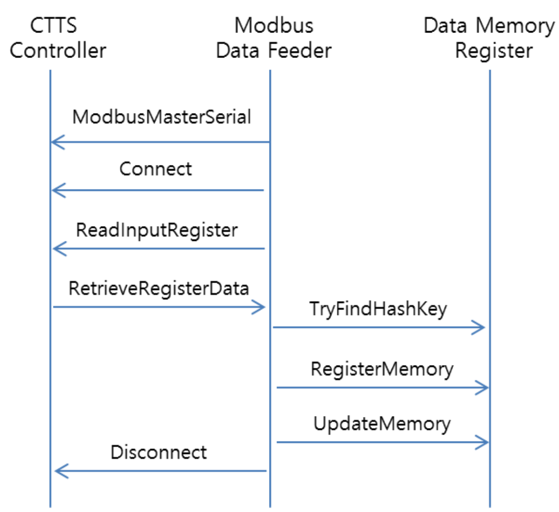

Figure 3. Mesasage flow between CTTS Controller and Modbus Data Feeder

Communication between the Modbus data feeder and the MMS server is based on the ZeroMQ Pub-Sub pattern. Figure 4 shows the message flow between them. The Modbus data feeder publishes the data stored in its data memory register after converting them to ZeroMQ packets. The MMS server receives the packets after subscribing to them, maps the receiving data to specific MMS objects, and transmits the data objects to a MMS client.

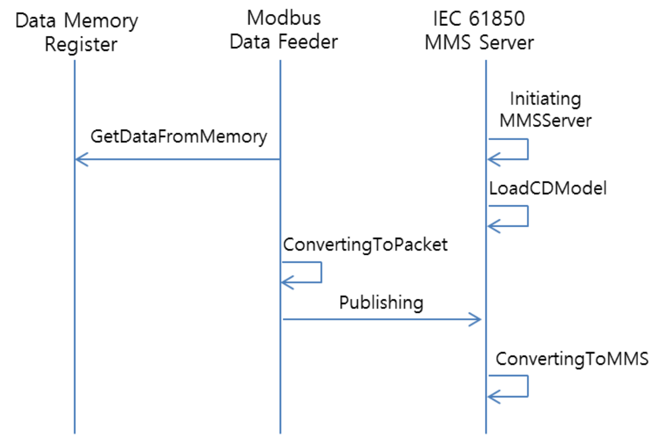

Figure 4. Message flow between Modbus Data Feeder and MMS Server

4 CONCLUSIONS

We designed an IEC 61850 based communication system for management of DER that transmit surplus power to the utility grid or act as an energy resource for demand response in case of national energy crisis. Core components of the designed system and its operation were explained in detail. Finally, we described the message flows from a CTTS controller to a MMS server. The designed system can be used as a communication system for Virtual Power Plant (VPP) management or demand response services.

5. ACKNOWLEDGEMENT

This work was supported in part by the R&D program of Ministry of Science, ICT and Future

Planning, Republic of Korea, under Grant of no. 2014044001001, development of technology for integrated energy management service of building and community and their energy trading.

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