DEVELOPMENT OF IEC 61850 BASED FEEDER IEDS FOR SELF-HEALING OPERATION IN DISTRIBUTION NETWORK

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ABSTRACT

Recently, in the context of smart grid, the usage of the IEC61850 communication standard gets broader and broader. Though IEC61850 has been used as communication standard for substation automation, the scope that it is applied becomes wider and wider into area of distributed energy resources including storages, communication between substation and control center, feeder automation and EV charging for smart consumers. In the flow of this IEC61850, KEPCO are carrying out the development of Smart Distribution Management System, and as a part of this R&D project, IEC61850 based Feeder IEDs of distribution switchgear is being developed. In this paper, IEC61850 based data model, software & hardware architecture of Feeder IEDs are presented. In addition, protection coordination and service restoration scheme by using peer to peer communication among FIEDs are also presented for self healing operation of distribution network.

Keywords
Smart DMS (Distribution Management System), IEC 61850, Feeder IEDs (Intelligent Electronic Devices), Distribution Automation

INTRODUCTION

Smart grid became a buzz word as one of major trends and markets in energy field for last 5 years. EU set the target of smart grid as 20:20:20 by 2020, i.e. reduction of GHG emission in 20% below 1990 levels, 20% of energy consumption from renewable sources, 20% reduction in primary energy use by 2020. Korea understands smart grid as green growth platform that can converge the relating industry including power, communication, construction, auto and energy industry for optimal operation of T&D network intelligently for energy efficiency and GHG reduction.

In the flow of smart grid, IEC 61850 becomes core communication protocol for open accessible, interoperable and future proof environment in power automation. Though IEC61850 started as international standard for communication of substation automation, the scope of IEC61850 applied become wider and wider into area of distributed energy resources including storages, communication between substation and control center, feeder automation and EV charging for smart consumers. That's why object oriented data model, high speed data exchange, support of peer to peer communication, interoperability, the support of simple engineering [1].

In recent years, some papers have been published relating to application of IEC61850 in distribution automation. Mohagheghi et.al also proposed the modelling of distribution automation system components using IEC61850 [2]. Palak et.al presents the simulation study for distribution automation systems (DAS) with DERs based on IEC61850 [3]. V. Valeriy et.al presented the distributed fault location, isolation and supply restoration in distribution networks [4].

KEPCO Research Institute is carrying out the development of Smart Distribution Management System (S-DMS), and as a part of this project, IEC61850 based feeder IEDs of distribution switchgear is being developed [5]. In this paper, IEC61850 based data model, software & hardware architecture of Feeder IEDs are presented. In addition, protection coordination and service restoration scheme by using peer to peer communication among FIEDs are also presented for self healing operation of distribution network

SYSTEM ARCHITECTURE OF IEC61850-BASED FEEDER IEDS

Overview

Figure 1 shows the system configuration of Smart DMS (SDMS). Field data from switch and breaker along the distribution lines and distributed generation data also be sent through Feeder IED (Intelligent Electronic devices). Meter data can be sent through AMI gateway to SDMS Server. These devices use IEC61850 as well as DNP3 for data communication. Using these collected data SDMS application carried out the functionality including real time network analysis, distribution network operation and optimization, DER (Distributed Energy Resources) management & control and self healing. This configuration will be extended to energy storage device, electric vehicle and home and building energy management system. In the long run, SDMS will expand its function to virtual power plant including demand response resources.

IEC61850 communication protocol is used in data acquisition from Feeder IEDs and meter data from AMI Gateway station.

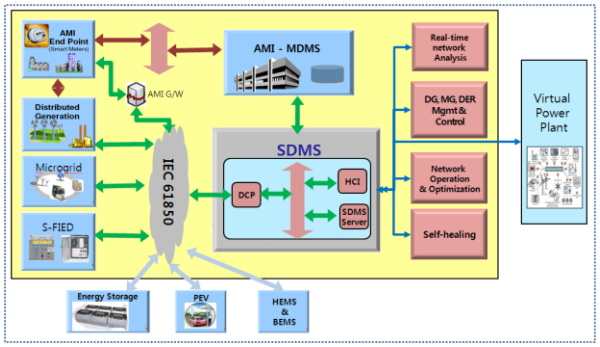

Figure 1 Overview of Smart DMS and its functions

IEC 61850 protocols have major advantages over legacy protocols such as DNP3. It is listed as following:

1) It is more easily extendable.
2) The data (LNs, data objects and attributes) are more self-descriptive.
3) It is more flexible in parameter setting control and gives the user the degree of freedom to define, change and edit the parameters.
4) The user can access the complete information hierarchy of all objects by obtaining the directory.
5) User can select data more flexibly for reporting, enabling /disabling the comm. Control objects and changing report/log behaviours
6) Complete description of device configuration is available in XML format
7) It provides vendor independent engineering tools
8) It is open for future service systems

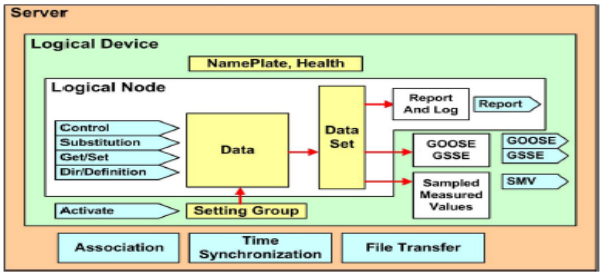

Figure 2 LN, LD and the comm. services

Data Communication Processing in S-DMS

The main component in the data communication processing of the SDMS is the DCP (Data Communication Processor). The DCP processes data from field devices using IEC61850 as well as DNP3. It analyzes data frames from field devices, such as the smart FIEDs (using IEC61850) and FRTUs (using DNP3), and converts these events to measurement and control data. Using the simple network management protocol (SNMP), the DCP also provides capabilities of configuring and monitoring the communication networks and devices. The processor can also manage time synchronization between field devices using the simple network time protocol (SNTP). Redundancy control is used to achieve high availability. Fig. 4 shows the DCP system architecture.

IEC 61850 Data Models for Feeder IEDs

In this section, IEC 61850 data models for the Feeder automation are presented. Logical Devices are divided and modelled into 4 groups including protection, sensing, control, measurements. And suitable logical nodes are selected in each group. To implement the IEC 61850 protocol for distribution devices, we define logical nodes for devices such as recloser, automated switch, multi way circuit breaker, etc. Some logical nodes are reused in FIED whereas some such as cold load pick up, fault indicator and power quality must be created or redefined.

Table 1 Logical Nodes in Feeder IEDs

LN Name	Functions
PTUV	Low voltage, voltage loss,
PTOV	Overvoltage, Live line, swell
PIOC	Instantaneous Trip (High current)
PTOC	Overcurrent Prot. (Fast/delay)
PTRC	Trip
PTUF	Under Frequency
RDIR	Direction of power flow
RREC	Reclosing
RDRE	waveform
RSYNC	Phase Synchronization
RBRF	Failure of Trip
MMXU	Measurement (Src/Load/Fault current, True RMS Mag. Of Sag, swell, interruption)
MSTA	Average Load Current Max Current of Day
MMTR	kWh
MSQI	Unbalance
MHAI	THD
XSWI	Open/Close of Switchgear
XCBR	Open/Close of Breaker
CSWI	Control of Switch/Breaker
ZBAT	Battery status
GGIO	Door Open, Lock/Unlock TD, internal Temperature
GGIO	Fault Indicator (Instant. Permanent)

IEC61950 Service Utilization Schemes

In this section, the strategies of the IEC 61850 service utilization for the provision of the Feeder measurement and status data to the SDMS are proposed. In this paper, 9 types of services are proposed to be used in the Feeder IEDs, among 10 types of services defined in the IEC 61850 Communication services. Sampled Value service is not used. And GOOSE service is used for exchange the event messages (such as detecting fault current) for protection coordination. The definitions and the utilization schemes are described in detail in Table 2.

H/W architecture of Feeder IEDs

An IEC 61850 based Feeder IED for SDMS is developed. Feeder IEDs can be divided into 4 parts such as MCU (Main Control Unit), AIU(Analog Input Unit), PSU(Power Supply Unit), and HMI(Human Machine Interface) Unit. Main control Unit has 2 processors of Main processor and DSP (Digital Signal Processor). Main processor handles the functions of input/output data processing, event monitoring & analysis, communication. DSP take the parts of floating point calculation, real time waveform conversion, data measurement and protection. Figure 3 shows the block diagram of Feeder IEDs.

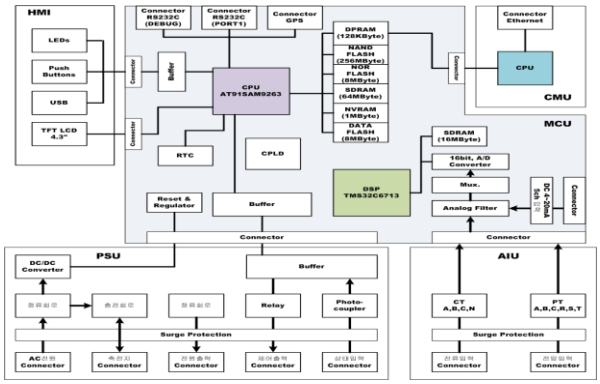

Figure 3 Feeder IED Block diagram

Table 2 IEC 61850 Service utilization strategies

Service model	Definition	Utilization scheme
Basic exchange	Issued for reading and writing data.	To be applied to read distribution feeder data and write the parameters
Data set	Allows grouping various data.	To be used for grouping the similar data set with same priorities, periods, etc.
Substitution	Replaces the process values such as DI, DO and AI by the pre-defined or pre-specified values.	To be used when some problems occur in the acquisition of data from the feeder IED
Setting group	Defines how to switch from one set of setting values to another, and how to edit values of each setting items.	To be used for the client to manage the configuration of the Feeder IEDs
Report	Generates reports to the client. Reports are divided into two categories: buffered reports and unbuffered reports.	To be used for the SGS to send the feeder data to the client, in the form of buffered or unbuffered report.
GOOSE	Provides fast and reliable system-wide distribution of data; peer-to-peer exchange of IED binary status information.	To be used for exchange the event message for protection coordination
Sampled value	Provides fast and reliable transmission of the sampled values of the process data.	Not to be used
Control	Provides the clients with the function to control the devices in the servers.	To be used for control of remote controlled switches and recloser.
Time synchronization	Provides the function of the time synchronization for the IEC 61850 systems.	To be applied to synchronize the time information of the Feeder IEDs with S-DMS Server.
File transfer	Supports the exchange of huge data blocks in the form of files.	To be applied to send the waveform in case of fault and in-rush.

Figure 4 shows a prototype of the Feeder IED. All 4 types of Feeder IEDs are developed for automated switch, recloser, multi way circuit switch/breaker.

Figure 4 Feeder Intelligent Electronic Device (IED)

PROTECTION COORDINATION

In this section, the scheme and algorithm of protection coordination and fault isolation in feeder IEDs are presented briefly. This scheme and algorithms are applied to distribution network with distributed generation.
When reclosers detect the fault and its direction, it starts trip_ready timer and muticast the fault detection events(PFF;Protection Forward Fault/PRF:Protection Reverse Fault) to reclosers in neighbourhood. When the reclosers receive fault event data from other reclosers, it decides whether or not it has to reset its trip_ready timer with the following logical equation 1. If (SELF_PFF and Loadside_ PFF) or (SELF_PRF and Sourceside_PRF) == true, reset Trip_Ready. If recloser did not feel the fault current, it did not take any action. If trip_ready timer is not reset, it is going to trip in specified period.

After recloser (or other breaker) goes open, switch goes to the process of fault isolation. When switches feels the fault and no voltage, it starts sw_ready timer and mutica st the fault detection events (SFF;Switch Forward Fault/ SRF:Switch Reverse Fault) to switch/reclosers in neighb ourhood using GOOSE message. When the switch recei ve fault event data from other switches/reclosers, it deci des whether or not it has to reset its sw_ready timer with the following logical equation 1. If (SELF_SFF and Loa dside_ SFF) or (SELF_SRF and Sourceside_SRF) == tr ue, reset sw_Ready. If switch did not feel the fault curre nt, it did not take any action. If sw_ready timer is not res et, it is going to open in specified period in no voltage c ondition. After switching (to open), it sends the comman ds of OPEN to load side switch(es)(DTO: Direct Transf er OPEN). The switch(es) which receive DTO Comman d from its/their source side switches, it/they switches to OPENif it/they are not OPEN.

CONCLUSION

In this paper, the IEC 61850 based Feeder IEDs are pres ented as a part of the R&D project of "Development of Smart Distribution Management System (SDMS)" whic h is being carried out by KEPCO Research Institute sinc e 2009. The system architecture of IEC61850 based feed er IEDs is depicted briefly with data communication pro cessing in Smart Distribution Management System. IEC 61850 data models and service utilization strategies of f eeder IEDs are also presented. In addition, hardware arc hitecture and prototype of feeder IEDs are showed. Lastl y, protection coordination scheme and fault isolation usi ng peer to peer communication briefly introduced. Conf ormance and functional test are being conducting now.

As a future plan, after functional test and integrated test with SDMS and other components in laboratory, prototy pe of feeder IEDs are modified and get some advanceme nts in protection coordination and fault isolation algorith m. In the third quarter of the year, field test with these fe eder IEDs are planned for self-healing operation.

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