The Study on the Construction of the Smart Grid Test Plant and the Integration of the Heterogeneous Systems

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Abstract: - In this paper, the development of the smart power grid management system (SPG) will be introduced. The purpose of the system is the integration of the separate R&D systems in the power IT project. The intelligent distribution automation system(IDAS), the substation automation system (SAS), intelligent transmission system and active telemetrics are considered at present. For this, each system is first briefly introduced, following with the introduction on the development of the smart power grid management system.

Key-Words: - Smart Grid, Smart Grid Test Plant, SG Test Plant, Smart Power Grid, SPG Test Plant

1 Introduction

According to the announcement of the 1st Smart Grid basic plan recently announced by the government, the Smart Grid is a next generation power system that enables intelligent demand side management, electric vehicle charging, renewable energy integration, etc. by integrating the information communication technology into the existing grid for a mutual exchange of real-time, two-way information between the providers and consumers [1]. Through this concept, the country can respond to climate change by achieving the national greenhouse gas reduction targets and building a low-carbon green growth infrastructure, achieve the national goal of energy efficiency improvement and the necessary energy efficiency improvements for the transition to low energy consumption for sustainable growth and create new growth engines for not only power but also for communications, consumer, construction, automobiles, energy etc. through the smart grid industry.

In this regard, 5 projects are currently underway as a part of the Jeju Smart Grid demonstration project. The first project which is based on a two-way communication is the intelligent consumer project that induces the consumer's reasonable power consumption through an automated energy management system (Smart Place, SP) and the second project is the intelligent transport project to build a charging infrastructure to allow the charging of EVs anytime and anywhere. The third project is the intelligent renewable energy project for enabling reliable connection of the renewable energy to the grid (Smart Renewable, SR) and the fourth project is the smart power grid project to ensure the stability of the existing power grid when new components such as renewable energy and electric cars are connected as well as improving the efficiency of the grid. The last project is the intelligent power service project that focuses on developing new services by activating consumer demand response, power transactions, etc. through a variety of tariffs such as real-time pricing.

Fig.1. PR Center in the SG Test Plant, Jeju island

Korea Electric Power Corporation (KEPCO) is participating in all smart grid projects in response to the government's policy and this paper focuses on the Jeju Demonstration Complex development status approached from the perspective of the provider and the smart power grid and the and discusses about the required operating technologies for the mutual integration of the heterogeneous systems. Fig. 1 shows the Smart Grid PR Center located in Jeju island, Gujwa-eup.

2 Establishment of Smart Grid Demonstration complex

The transmission, substation and distribution systems are being widely accommodated by the Smart Power Grid (SPG). In this section, the status of the on-site installation in the vicinity of Jeju Gujwa-eup and the intelligent power distribution system, digital substation system, power system reactive power management system and active telemarketing metrics integrated into a unit system is being examined.

2.1 Establishment of the intelligent power distribution system

The intelligent power distribution system is established for the efficient operation of the distribution system by real-time remote sensing of various distribution equipments such as switches and reclosers, minimizing the fault section whenever required through control schemes when faults occur and through distribution system applications such as loss minimization, load balancing etc [2].

Table 1. The list of devices installed in the field for DAS

Classification	Installation History		Remark
	Q'ty	Contents	
Main device	2set	1set for operation 1set for demonstration	Operation center
Intelligent device	17	7 terminal devices 10 Switchgear	Distribution lines in demonstration complex
Lightning monitoring device	20	Lightning prone areas	

The intelligent power distribution system applied in the demonstration complex has 4 targeted distribution lines and a total of 20 intelligent terminals and distribution equipments, 20 lightning and arrester monitoring device, 5 ground transformers and an intelligent power distribution system main device, for the remote management of the above devices, being installed.

This way, the power quality issues such as voltage drop or rise, momentary outages, lightning, etc. in the distribution system within the demonstration complex can be monitored in real-time and the impact on the system when renewable energy is being connected to the distribution system. Especially, real system operation information and field data is acquired and managed through the intelligent power distribution system main device thereby allowing the analysis of various forms. Fig. 2 shows the installation status of the intelligent power distribution system within the demonstration complex.

Fig.2. Deployment in the Intelligent Distribution System

2.2 Establishment of digital substation system

The digital substation system is a system that automates the substation automation by acquiring field data in a digital form on a single network which was previously acquired in a one-to-one manner in an analog form. The individual features such as measurement and control, monitoring, diagnosis and protection of the power equipment within the substation are based on the IEC 61850 international standard which are interconnected into a single structure. The components of the digital substation system include the IED (Intelligent Electronic Devices) and digital operating systems, communications infrastructure etc [3].

The digital substation system is applied on the Seong-san substation within the demonstration complex where 4 154kV transmission line protection IEDs, 4 170kV GIS Bay Controller IEDs, 5 154kV main transformer protection and bay controller IEDs, 13 25.8kV GIS Bay Controller and a digital substation operating system are installed.

Table 2. The list of devices installed in the field for the SA

Classification	Installation History		Remark
	Q'ty	Contents	
154kV T/L LED	4	T/L protection (main/backup)	Main transformer and line monitoring and protection IED
170kV LED	4	2 GIS BC	
154kV LED	5	1 M. Tr. 4 BC	
25.8kV LED	13	D/L Monitoring	
Operating system	1	HMI, G/W	Operation server

Through this system, not only the real system operation information and demonstration data acquisition and analysis according to the substation HMI in the demonstration complex is enabled but also grid connection modules and distribution automation connection algorithm functionality check, substation equipment interconnection functionality and performance analysis through intelligent electronic devices (IEDs) and performance verification through the correlation of the substation equipment state monitoring system (transformers, GIS) is made possible. Fig. 3 shows the installation status of the digital substation system HMI and G/W and the 154kV transmission line protection IED.

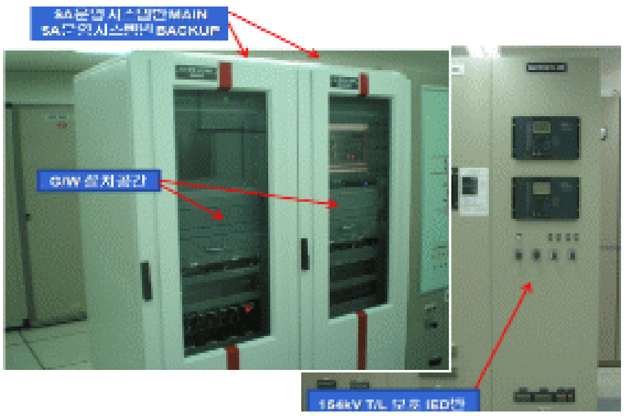

Fig.3. Deployment of the Server and Devices in the Substation Automation System

2.3 Power system reactive power management system

The power system reactive power management system calculates the reactive power by utilizing the voltage management system central control unit and reactive power distributor and on-site information acquisition device to measure the system data in real-time and performs the functionality of reactive power management by adjusting the power plant AVR and StatCon by using the above results [4]. The power system reactive power management system applied in the demonstration complex acquires the real-time Jeju power system data from the voltage management central control unit in Jeju Power Exchange, 2 Jeju area power plant reactive power distributor and the on-site information acquisition device in Jeju convertor station and provides the information on the calculated result of reactive power.

Table 3. The list of devices installed in the field for the VMS

Classification	Installation History		Remark
	Q'ty	Contents	
Voltage management system central control unit	1	Server, HMI	Jeju area installation operation
Reactive power distributor	2	Reactive power distribution (Jeju power plant)	
Field information acquisition device	1	Field information acquisiton (Jeju converter station)	

Through this system, by measuring the power system data in real time, not only monitoring reactive power of the Jeju area power system in real time is made possible but also the management of reactive power by utilizing the data by controlling the power plant AVR or the substation StatCon depending on the needs of the system is enabled. Also, the client functionality is provided so that monitoring is available at all times even for areas outside the area where the server is installed. Fig. 4 shows the schematic diagram of the power system reactive power management system within the demonstration complex.

Fig.4. System Diagram in the Voltage Management

2.4 Active telemetrics

Active telemetrics is a system that remotely monitors and diagnoses the transmission line's status and is comprised of ball sensors for monitoring the transmission lines which consists various sensor capabilities and a main device which includes a sensor network. The transmission line ball sensors measures the wind direction and speed, temperature, current and inclination and the main device monitors the transmission line operating conditions and dip, lateral movement and vibration, wildfires and tree approach [5]. The active telemetrics applied in the demonstration complex is configured of the active telemetrics main device, 2 ball sensors on the targeted transmission line and the data relay device for transmitting data from the ball sensors on the transmission lines.

Table 4. The list of devices installed in the field for the Active Telemetrics

Classification	Installation History		Remark
	Q'ty	Contents	
Active telemetrics main device	1	Server, HMI	Operating center
Ball Sensor	2	Jeju T/L	154kV T/L
Data relay device	1	T/L near the substation	

In this way, the on-site measured data of the transmission line to be monitored such as wind direction and speed, temperature, tilt, on-site video information can be measured and transmitted through the sensor network to the main device located at a remote location where not only the transmission line operating conditions and dip, lateral movement and vibration, wildfires and tree approach can be monitored but also the calculation of the transmission line dip can be calculated by synthesizing the transmission line tilt, tension and temperature data. Fig. 5 shows the on-site installation status of the active telemetrics ball sensor and data relay device.

Fig.5. Deployment of the Sensor and the LNB in the Active Telemetrics

3 Smart Grid Demonstration Complex Integration

For deploying the demonstration complex, the integration of the system is built not to replace the existing system but rather to maintain the existing system roles and functions at the lower system level while performing the function of mutual linkage of the required data as well as enabling a intuitive grasp of the system conditions within the demonstration complex through the integrated HMI at the higher system level. Therefore, the smart grid demonstration system integration of the intelligent power distribution system, digital substation system, power system reactive power management system and active telemetrics system been introduced previously can be integrated at the level of the HMI or at the level of data integration. Integration at the level of HMI is the development of the design of the screen in an integrated form of the individual HMIs and integration at the level of data is the integrated management of the individual data.

3.1 Overview of demonstration system integration main device development

The demonstration system integration main device configures the database and HMI centered on the intelligent power distribution system and the intelligent transmission and active telemetrics data is added to the intelligent power distribution system database which is utilized as the database for the main device while an additional HMI is included in the intelligent power distribution system by utilizing this added data.

A data type is developed based on the CIM (Common Information Model) in order to seamlessly send and receive data between the subsystem including the digital substation system and the upper level main device and the upper system in a corresponding way receives the data and the data is managed by converting it to the intelligent power distribution system database form in the saving process. As shown in Fig. 6, the database utilized by the main device is configured by adding the intelligent transmission and active telemetrics data to the intelligent power distribution system database and the main device HMI also is developed based on the database being additionally configured.

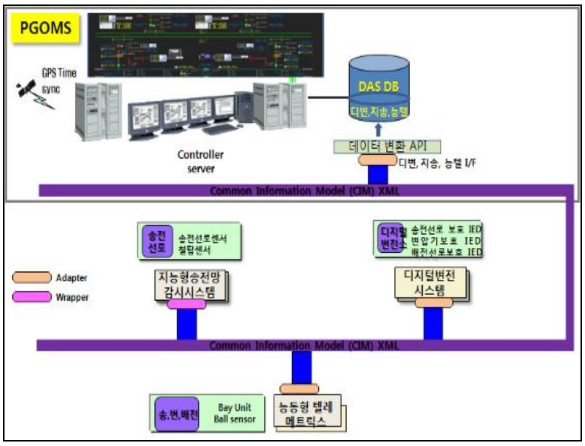

Fig.6. System Architecture for Smart Grid Test-bed

3.2 DB development for integrated main device

The database for the demonstration system integrated main device consists of the common definition and point part, application part, logging part configured in the form of a table. The common definition part consists of a table that stores information that is used in other areas, and the point part stores the point information in the database. The application part pre-stores the information to be collected when it runs periodically according to the schedule and the logging part is configured by a table which stores the alarm history information.

The table that corresponds to the common definition part consists of tables which manage the eight outputs for priority information according to the alarm level, state point and state name used in the device and input status, unit designation, scale factor information used in analog points, user account, type of communication etc. Table 5 shows the corresponding table.

Table 5. The Management table for the Common Definition Function

	Main function	Table name
Common definition part	Priority	S_ALARM_PRIORITY
	State name	S_STATE_NAME
	State calculation	S_STATE_CALCULATOR
	Unit name	S_UNIT_NAME
	Scale	S_SCALE_FACTOR
	Account	account
	communication	comm_type

The table that corresponds to the point part consist of tables which manage station and status points information, analog point information, accumulated points information, analog points definition, station point definition, state point definition, group defined for mapping, mapping point information etc. Table 6 shows the corresponding table.

Table 6. The Management table for the Point Data

	Main function	Table name
Point part	Station	S_STATION_S
	Status point	S_STATUS_S
	Analog Point	S_ANALOG_S
	Accumulate point	S_ACCUMULATOR_S
	Analog definition	d_analog
	Station definition	d_station
	Status definition	d_status
	Mapping point group	ItemGroup
	Mapping point	ServerItems

Table 7. The Management table for the Application and Logging Functions

	Main function	Table name
Application part	Calculation formula	S_CALC_S
	Trend	S_TREND_S
	Report	S_REPORT_S
Logging part	Alarm history	alarm_log

The table that corresponds to the application part consist of tables which manage the calculation and trend information, the report information etc. and the table that corresponds to the logging part consist of a table which manages the alarm history. Table 7 shows the corresponding table. These tables can be used independently of each other and if necessary, also be used interdependently. Figure 7 shows the relationships between the tables used in the integrated main device.

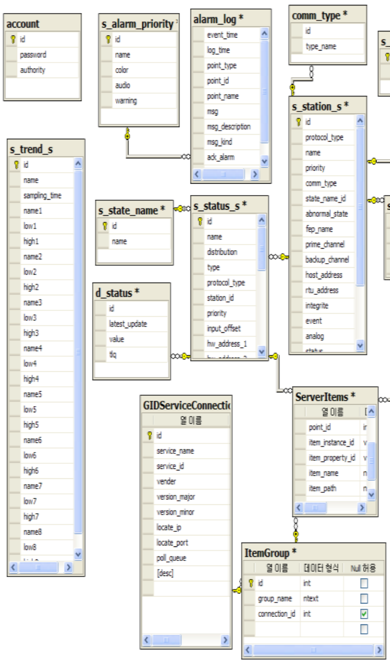

Fig.7. DB Diagram for the Main Server in the SG Test-bed

3.3 Development of integrated main device HMI

In the integrated main device HMI of the demonstration system, the point information of the intelligent distribution system, digital substation, reactive power management system and the active metrics and the interface functionality of the real-time events and information, history search etc. are served to the users. In Fig. 8, the demonstration system integrated main device which is installed and operated is shown.

Fig.8. HMI in the Smart Power Grid

3.3.1 HMI integrated intelligent power distribution system

The intelligent distribution system to be included in the demonstration system integrated main device ranges to the distribution lines in the demonstration complex and the HMI is configured so that the information of the intelligent equipments including the intelligent distribution main device and the intelligent FRTU, the lightning/arrester monitoring device information, the real-time monitoring point information of the ground transformer load monitoring devices etc. are checked on the screen. In figure 9, the real-time monitoring point information and the screen configuration of the distribution lines in the demonstration complex are shown.

Fig.9. HMI in the Intelligent Distribution System

3.3.2 Digital substation integrated HMI

The digital substation to be included in the demonstration system integrated main device is intended for the Seong-San substation and the HMI is organized to check the real-time monitoring point information of 170kV, 154kV, and 25.8kV on the screen accordingly. In Fig. 10, the real-time monitoring point information and the screen configuration of the Seong-San substation are shown.

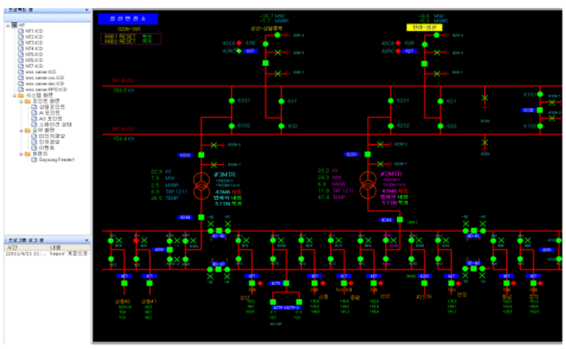

Fig.10. HMI in the Substation Automation System

3.3.3 Reactive power management system integrated HMI

The reactive power management system to be included in the SPG integrated main device utilizes the voltage management central control unit and reactive power distributor to measure real-time system data and configures the HMI to show the reactive power information calculated by the measured information on the screen. Fig. 11 shows the screen configuration of the real-time system information obtained and information on the calculated reactive power.

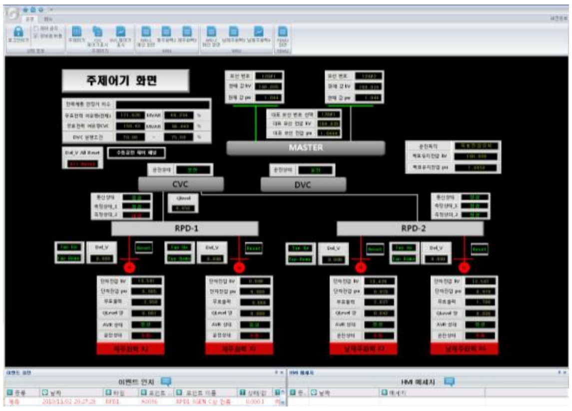

Fig.11. HMI in the Voltage Management System

3.3.4 Active telemetrics integrated HMI

The active telemarketing metrics to be included in the SPG integrated main device is composed of the monitoring ball sensor on the transmission line and the sensor network including the main device. The HMI is configured to check the wind direction and wind speed, current, inclination etc. measured by the ball sensor on the transmission line on the screen. In Fig. 12, the real-time surveillance point information and the screen configuration of the active telemetrics are shown.

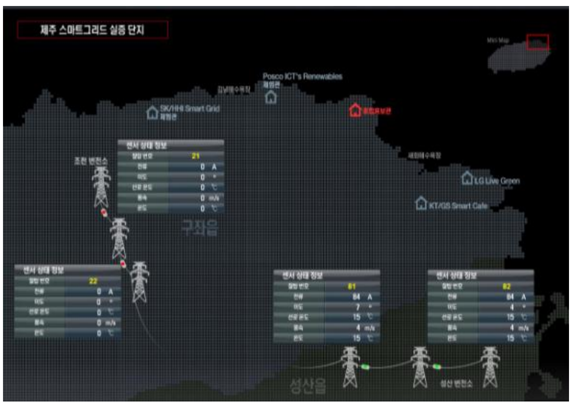

Fig.12. HMI in the Active Telemetrics

4 Conclusion

In this paper, the progress status and development content of the Jeju Demonstration Complex performed by KEPCO has been intensively examined in regard to Smart Grid growing interest all over the world in the power industry. In particular, when the unit systems are integrated, the integration was focused from the perspective of the data and HMI and the common information model of IEC 61970 and IEC 61968 has been utilized for the data model for linking, and for the systems based on IEC 61850 such as the digital substation system a separate gateway is developed so that a correlation with the integrated main device is formed. Also, the external interface required for inter-operation with not only SPG but also other Smart Grid systems including SP, ST, SR, SES has been developed and provided.

For future work, the improvements through the trial operation of the system are examined and emphasis are placed on the field of study to discover various Smart Grid services.

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