DEVELOPMENT AND TEST OF SMART DISTRIBUTION MANAGEMENT SYSTEM

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ABSTRACT

In this paper, we summarize the development and test for the Korean Smart Distribution Management System (KSDMS). To overcome the challenges faced by the Korean distribution automation system (KDAS), we propose three types solutions-real time, study and event-driven mode. For the architectural designs of KSDMS, we propose a communication system using the IEC 61850 and DNP3 protocols, feeder IEDs, and CIM-based middleware and server systems. We propose a database model that all KSDMS application programs will commonly use. The functions of FRTU and FIED are tested, and the test results of base platform are monitored through various HMIs. Through the integration test in Gochang power test center (PTC) between the base platform and the application program, we verify the performance of KSDMS.

INTRODUCTION

The Development of smart grids allows network operators to optimize the use of dispersed generation resources and enables real time communication between customers and utility service providers to allow optimization and balancing of energyusage. The Korean Smart Distribution Management System (KSDMS) project was started in 2009 to achieve advanced distribution operation for smartgrid circumstance in Korea.

In recent years, many reports relating to smart distribution management systems have been published [1-8]. Overall, the studies above identify important common elements for smart distribution management system. First, operators of smart distribution systems should have fast and accurate access to the current network situation. This requires periodic and fast simulation of the distribution network security, as well as collecting variety of real time information for each network component. Second, changes in the topology of the distribution system and the role of the distribution control center must be considered. In a smart distribution grid, the grid topology is not only radial; looped and meshed networks will also be introduced under normal operation conditions. Therefore, the role of the control center can no longer be that of merely indicating faults in the distribution network. The concept of the control center must change for EMSs.

CONVENTIONAL KDAS

Development of the Korean distribution automation system (KDAS) begun in 1993, and KDAS has been operating since 1998. Until now, KDAS has been installed in all 190 branch offices, and around 35% of total 127,000 line switches have been automated. Several types of communication media such as optical fiber (68%), telephone wires (15%), trunked radio systems (TRS, 8%), mobile data (8%) and CBMA (1%) are used for KDAS.

The major functions of KDAS are to monitor distribution feeders, clear the faults, and restore unfaulted sections. For this purpose, KDAS has application programs such as those for fault location, isolation and restoration (FLISR); load balancing and loss minimization; and relay coordination. The major challenges of KDAS in smart grid circumstance are the interconnection of numerous dispersed generations (DGs), changes in the topology of distribution network, and the utilization of newly added information.

KSDMS ARCHITECTURE

KSDMS Characteristics

The characteristics of KSDMS are summarized as follows

1)The dependence of application program in KSDMS operation is more increased compared with the conventional KDAS. The results of application are used for the ancillary information with the operator's intuition.

2)The platform (server, telecommunications, middle ware, etc.) architecture is changed for the support of application operation.

3)The standardized structures are applied. For this, the IEC 61970, IEC 61968, IEC 61850 standards are applied for the database modelling, interface with the other systems, and telecommunication between devices (server, RTU), respectively.

The outcomes of KSDMS are shown in Table 1.

Table 1. Outcomes of KSDMS

No	Items	Performance
1	SDMS Application S/W	Total 12 applications, including the DSE, VVO, DFD
2	SDMS Main Platform	Server architecture, Middleware, On/Offline DB
3	SDMS Devices	Telecommunication devices, 6 types of feeder IDEs (including the IEDs for substation, feeder, DG)

KSDMS Applications

The KSDMS application solutions are divided into three categories, which are shown in Table 2.

Table 2. Types of application solutions for KSDMS

No	Mode	Object	Application
1	Event Driven	Fault detection and restoration	DFD1), DSR2)
2	Real Time	Recognition of accurate network conditions and appropriate control	NCP3), DSE4), RPF5), VVO6), DLP7), PCE8)
3	Study	Examination of other network conditions	DNR9), SCA10)

*Note that 1)DFD: distribution fault detection, 2)DSR: distribution service restoration, 3)NCP: network connectivity processing, 4)DSE: state estimator, 5)RPF: real time power flow, 6)VVO: voltage VAr optimization, 7)DLP: distribution load pattern, 8)PCE: protective coordination estimation, 9)DNR: distribution network reconfiguration, 10)SCA: short circuit analysis

As shown in Table 2, solution extraction procedures of KSDMS are shaped as EMS. It differs from conventional KDAS in that the object is to monitor and clear events for each feeder. The operators of KSDMS can recognize problems and anticipate potential risks for the entire distribution network for each branch office using various application solutions.

1)Voltage control of interconnected DGs: In real-time mode, operators receive periodic solutions for network voltage control strategies using the RPF and VVC. If a solution in real time mode is not satisfied, operators examine the case in study mode. They can examine the case using other application (DPF, ONR), after which the network conditions (analog/digital status and devices) can be modified.
2)Looped network: In real time mode, NCP is periodically executed and informs the operators of the topology of the entire network. For any topological conditions, SE, RPF or VVC can be executed.
3)Usage of additional information: Distribution SE can be performed using accurate data for each load point, and the conditions of the entire network can be recognized. LM&F and GF use additional data and can offer pseudo loadsand generation MW/MVArs for current and future networks.

KSDMS Server Architecture

Fig. 1 shows the system architecture of the KSDMS servers and the interconnections among the components through middleware. Data from field devices such as FIED are connected and exchanged with the server via data communication processing (DCP) server. Other system components include HCIs (human computer interface), engineering stations for DB, and schematic editing, the application server and DBMS server are also connected to each component via middleware.

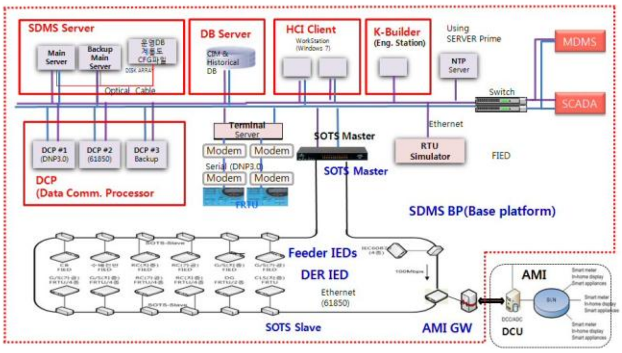


Fig. 1. Server system architecture of KSDMS.

The main function of the server can be summarized as follows:
1)Monitoring the health and failure of the network, system resources and applications
2)Automatic redundancy control for high availability
3)Real-time computation and data processing
4)Handling network analysis programs
5)Storage of historic data such as measures and events
6)Providing middleware API services
7)Converting the CIM model to exchange data with external system such as the meter data management system (MDMS)
8)Providing supporting data for analysis and decision making
9)Handling alarm events and TLQ

For exchanging CIM data with external systems, the server uses generic data access (GDA) for request/reply oriented service for access of complex data structures and generic eventing and subscription (GES) for a general purpose capabilities to publish and subscribe to events and alarms defined in IEC 61970/61968.

KSDMS Data Communications Architecture

The main component in the data communication processing of KSDMS is the DCP. It processes data from field devices using IEC61850 as well as DNP3 protocol. It analyzes the data frames from field devices such as smart FIED (feeder intelligent electronic devices) and FRTU (feeder remote terminal unit) and converts these events to measurement and control data which are then adapted to CIM (common information model) database. Using SNMP (simple network management protocol), the DCP also provides the capabilities of configuring and monitoring the communication networks and devices. It can also manage time synchronization between field devices using SNTP (simple network time protocol). It uses redundancy control to achieve high availability. IEC 61850 is considered as the proto col for field communication. To satisfy the requirement of a communication network for using IEC 61850, three design factors such as network management, automatic communication link transfer and architecture of communication stack are considered for the communication network and devices. Fig. 2 shows the hierarchy of the communication networks of KSDMS.

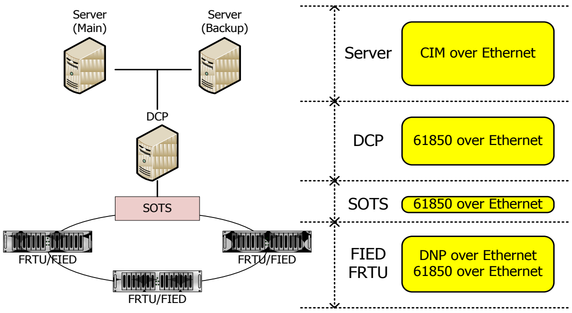


Fig. 2. Feeder intelligent electronic device.

Feeder Devices

In KSDMS, an IEC 61850 based FIED for KSDMS is developed. Fig. 3 shows the 6 types IEDs developed in KSDMS. 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. In addition, IEC 61850 services are also modified and redesigned to apply to FIED.


(a) Feeder IED


(b) Multi-Circuit Feeder IED


(c) Substation IED


(d) Multi Circuit CB IED


(e) Recloser IED


(f) Telecom. Device (SOTS)

Fig. 3. Smart IEDs of KSDMS.

KSDMS TESTS

Integration Test

The performance of the platform (server system, middleware, etc.) and the applications of KSDMS are tested for a JeJu island network, which has 7 S/S and 65 D/L. Fig. 4 shows the network diagram of the JeJu island.

Fig. 4. Network diagram of JeJu island.

A summary of the test system is shown in the Table 3.

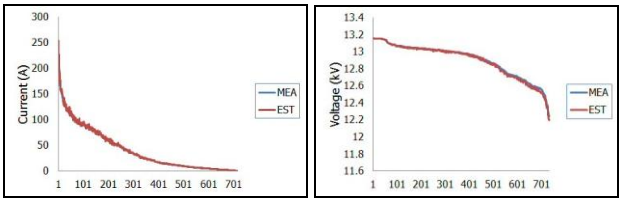
Table 3. Summary of the test system

No	Type	Number
1	Substation	7
2	Power Transformer	17
3	Distribution Line (D/L)	65
4	Overhead S/W	1350
5	Recloser	164
6	Multi-Circuit S/W	542
7	Multi-Circuit CB	2
8	Pole Type Transformer	10
9	Pad Type Transformer	435
10	ALTS	24

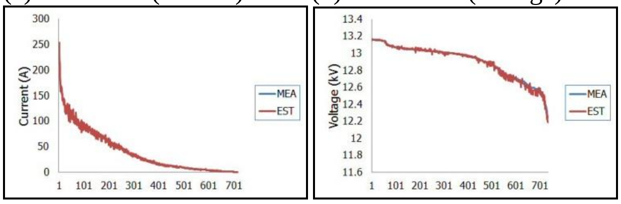
The integration test set for FRTU/FIED is shown in Fig. 5.

Fig. 5. Integration test set for FRTU/FIED.

The test results of distribution state estimator (DSE) are shown in Fig. 6. These are the results of the random noise injected for all measurement data (voltage, current, and angle) of the automatic switches.



(a)10% noise (current) (b)10% noise (voltage)



(c)20% noise (current) (d)20% noise (voltage)

Fig. 6. Integration test results for DSE.

Field Test

For the test of adaptability in the field environment, we select the GoChang power testing center (PTC) of KEPCO. The network diagram of GoChang PTC is shown in Fig.7.

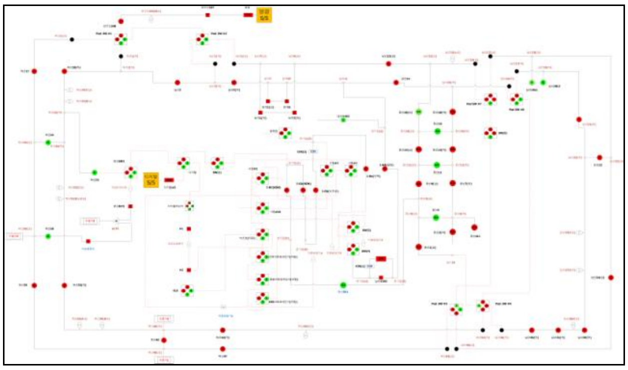


Fig. 7. Oneline diagram of GoChang PTC

Fig. 8 shows the control center for KSDMS field test and the artificial fault generator for devices test.

(a)control center (b)AFG device

Fig. 8. Facilities of GoChang PTC

Fig. 9 shows the field test result for the function of KSDMS self healing. KSDMS self healing function is composed with the several sub functions.

1)Smart alarm processor : Fault identification, FI(fault indicator) data processing
2)DFD(fault location detection) : Fault section (between S/Ws) detection using FI and fault current. Fault isolation and protective devices close.
3)DSR(service restoration) : Output of S/Ws sequence for the restoration of unfaulted sections.

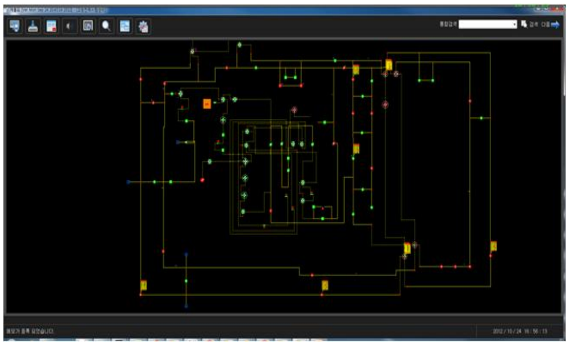


Fig. 9. Test result for KSDMS self healing function

CONCLUSION

In this paper, we present the development and test for the KSDMS. Using the integration test between the base platform and the application program, we verify that the performance of 12 applications is excellent. KSDMS will be installed on an actual distribution network in 2013.

Acknowledgments

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