# DEVELOPMENT AND FIELD TEST RESULT OF KEPCO DISTRIBUTION MANAGEMENT SYSTEM

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## ABSTRACT

*This paper introduces the development of KEPCO DMS(called MiDAS, Microgrid & DER interconnected Active distribution System) and the result of field test. The K-DMS offers new opportunities to improve the efficiency of operating and controlling the distribution systems, as well as Micro Grid, through the accurate information of the real-time situation on the network and various optimization software to handle the circumstance of network efficiently. Now a day, there are many DER source interconnected to distribution network in Korea. Those DER may harm the operation of distribution network such a voltage, bi-direction active power flow as utility knows that. So, the function of K-DMS is focused on the real-time network analysis, to get more accurate information on voltage and load flow, and optimization of voltage and active power by ESS and controllable DER.*

## INTRODUCTION

Recently, the distributed energy resources(DER) and customer information will be steadily increased. Therefore, the system to operate and control the distribution networks are especially important.

Now a day, many reports how to operate and manage the distribution network [1-6] are published, and the distribution management systems(DMS) are developed and tested. In one of the paper, the concept and necessity of network applications and suggested the need for fast simulation and modeling [1] is explained. The other one proposed distribution state estimation and situational awareness [2-3]. Another paper presented the need for real-time analysis of distribution systems, insisting on periodical data measurements of various distribution networks [4], or the concept of an Energy Management System (EMS) and described the role of the control center for distribution systems [5] was introduced.

Overall, the distribution management system has two important common aspects. First, the DMS should have a fast performance and accurate information 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 distribution network, 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.

In this paper, we summarize the development of system architecture and application software for the KEPCO-DMS, and the field test result is introduced.

## K-DMS ARCHITECTURE

The K-DMS is focused on the part of fast performance, accurate information and efficient solution for operation on the power distribution system interconnected DER sources. For this reason, the function of K-DMS is composed with two-parts. First part is the Supervisory Control and Data Acquisition(SCADA) that is consist of the device level for the real-time data acquisition and the sever level for the data processing and middleware. In the K-DMS, numerous data related to the voltage, current, faults, power quality and load profiles of the network are gathered using a standardized communication method. Second part is the application to generate the accurate information of the power system at every minutes(or at least 5 second) and to make a solution for handling the circumstance of power system such an voltage(over or under), active and reactive power flow control or system fault. Fig1. Illustrates the function of K-DMS.

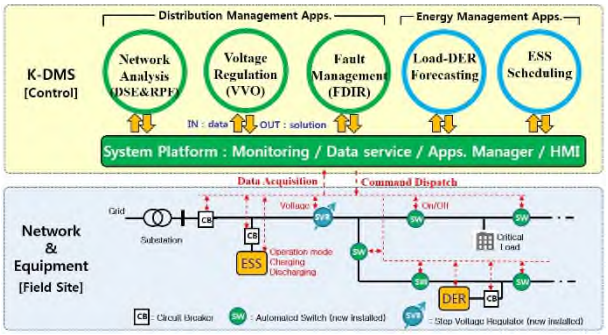



Fig1. Overview for K-DMS Function

### System Platform of K-DMS

For the network application, the synchronized real-time data has to be gathered for real-time analysis. For case of fault or the abnormal circumstance in the distribution network, the fault data and event data can be gathered promptly. After that, to use the abnormal or fault data, a

few network application be able to make the solution how to handle the fault and abnormal case using the controllable network equipment. Also, the interface to show up the gathered field data and the result of the network application to operator should be made up. For these requirements, the software architecture of K-DMS is presented in Fig2. Those modulated software are expendable structure depend on the requirement of operator.

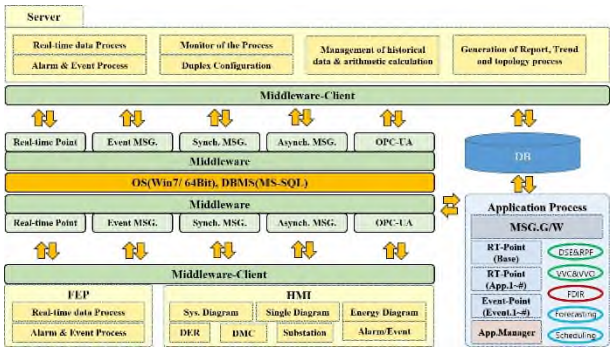


Fig2. Overview for K-DMS Software

## Application of K-DMS

In this section, the design of the network application in K-DMS is presented. Above mentioned, the object of K-DMS is to provide the accurate real-time situation information and predictive operational solution. K-DMS application solutions are divided into three categories, which are shown in Table 1.

Table 1. Categories of application solutions for K-DMS

| No | Type | Execution /Periodic /Execution Time | Object | Appl. |
|---|---|---|---|---|
| 1 | Event Driven Mode | Automatic /Irregular /≤ few sec | Fault clearing, restoration | NP[1)], FD[2)], SR[3)] |
| 2 | Real Time Mode | Automatic /Periodic /≤ few minute | Recognition of current network conditions, control recommendation | NCP[4)] LM[5)], DSE[6)], RPF[7)], VVC[8)] |
| 3 | Study Mode | Manual /Irregular /≤ few minute | Examination of future network conditions | ESC[9)], SPF[10)], ONR[11)], GLF[12)] |

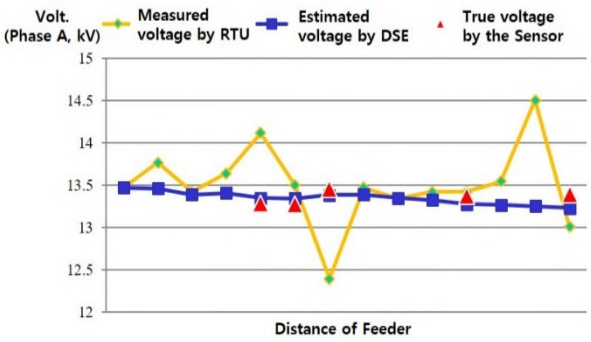
*Note that [1)]NP: network protection, [2)]FD: Fault Diagnosis, [3)]SR: service restoration, [4)]NCP: network connectivity processing, [5)] LM: load management, [6)] DSE: distribution state estimation, [7)]RPF: real-time power flow, [8)] VVC: voltage/var control, [9)] ESC: ESS Schedule and Control, [10)]SPF: study power flow, [11)]ONR: optimal network reconfiguration, [12)]GLF: generation & load short-term forecasting

The objects of each mode are as follows.

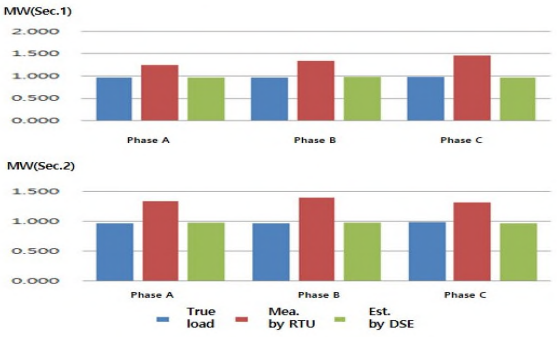
1) Event driven mode treats the fault in the distribution network and service restoration for the un-faulted sections.
2) Real-time mode provides the periodic solutions of network condition and voltage control for operators.
3) If a solution in real-time mode is not satisfied or operator need the pre-operational solution for controllable equipment such ESS and SVR, operators examine the case in study mode. They can examine the case using other application, after which the network conditions (analog/digital status and devices) can be modified.

## FIELD TEST RESULT OF K-DMS

We have done the several field test of K-DMS in domestic area and Canada. The field test in domestic area had been done for 1-year in two sites, one is in south part of Korea, called Sinan region, the other site is also south part of Korea, called Gasa island.
In Sinan, there are several feeder lines, connected the other feeders responsible for other branch office, and almost 20MW DER source are installed. For control of voltage and active power, a step-voltage-regulator(SVR) and ESS are installed additionally. The test is two aspects. First one is the accuracy of estimated voltage and load quantity by real-time mode application. The input data was used the measured voltage and current data from remote terminal unit and the measured active/reactive power from ESS and DER. And, to check the accuracy of the estimated result by the application, the high accurate extra-sensors were installed. The summary of test result is following fig. 3.

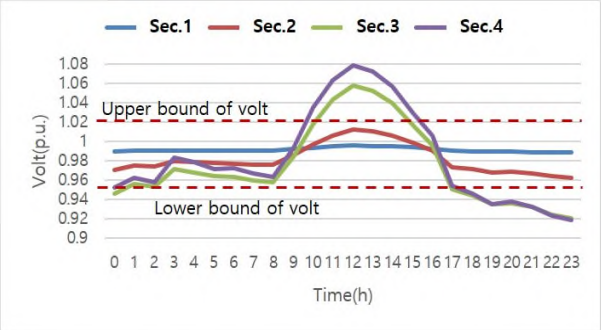


(a) Estimation of voltage

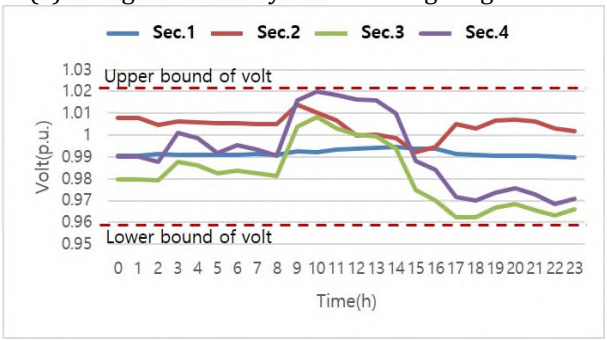


(b) Estimation of load quantity at each line section
Fig. 3. Estimation Result of Voltage and Load

In Fig 3 (a)., the yellow line stands for the measured voltage by RTU and the red triangle stands for the voltage by extra-high accurate sensors. The blue line stands for the estimated voltage by the application. As we can see the result in Fig3(a)., the error between the voltage by the application and the voltage by the extra-sensor is approximately less than 2%. And also, as Fig3(b)., the estimation result of line section load is less than 3%. To use this result, we had controlled the voltage by SVR and reactive power by DER and ESS for voltage regulation. In Fig4., the result of voltage regulation is presented.




(a)Voltage for one day before voltage regulation




(b)Voltage for one day after voltage regulation
Fig4. The result of voltage regulation

The red-bar line stands for upper and lower limits. As we can see in Fig4., the abnormal voltage could control within the limits. The other field test in Sinan was the event mode application. During the field test, the line to ground fault were unfortunately occurred at two-times. In Fig5., the one of result for event mode application is showed.

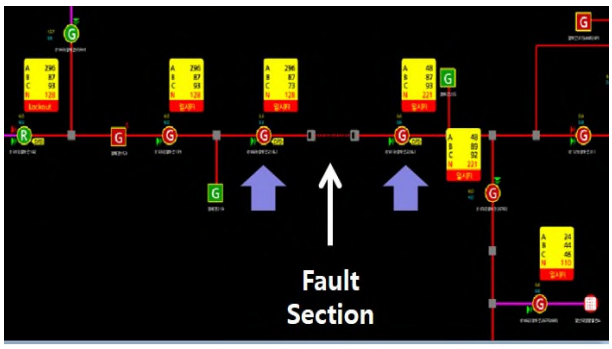



Fig. 5. The result of event mode application

By the event mode application, we were able to find out the sector fault occurred, even though the DER was installed in the line and the one of fault indicate data was missed. In Gasa island, we had done the test for study mode application, especially ESC for maintaining the energy of ESS to control the operational power capacity depending on the output of DER. The following figure is showed the result of ESC for control of operational power capacity in one-day.

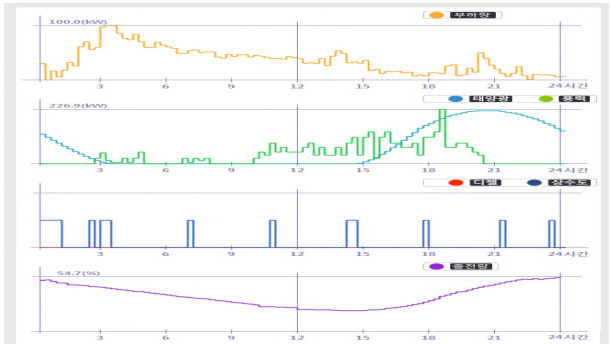


Fig. 6. The result of ESC

As the result of ESC in Fig 6, we were able to get some benefit that the rate of DER capacity limited by operation capacity could be increased, as ESS capacity, by the control of ESS.
In the other field test in Canada, we had tested the new ESC application to make ESS operation schedule considering the Canadian electricity market price. The field test had been conducted for 6 months, and we were able to get the positive result to decrease the purchasing price the customer paid for electricity. The result of new ESC is presented in Fig 7.


Fig. 7. The result of ESC applied in Canada

## FUTURE PLAN

After all of field test, we were able to get the functional reliability of K-DMS. So, KEPCO has made a decision to install the K-DMS in 41 domestic distribution control centers until the end of this year. Actually, the KEPCO has run the distribution automation system, self-developed and has been operated since 1993.

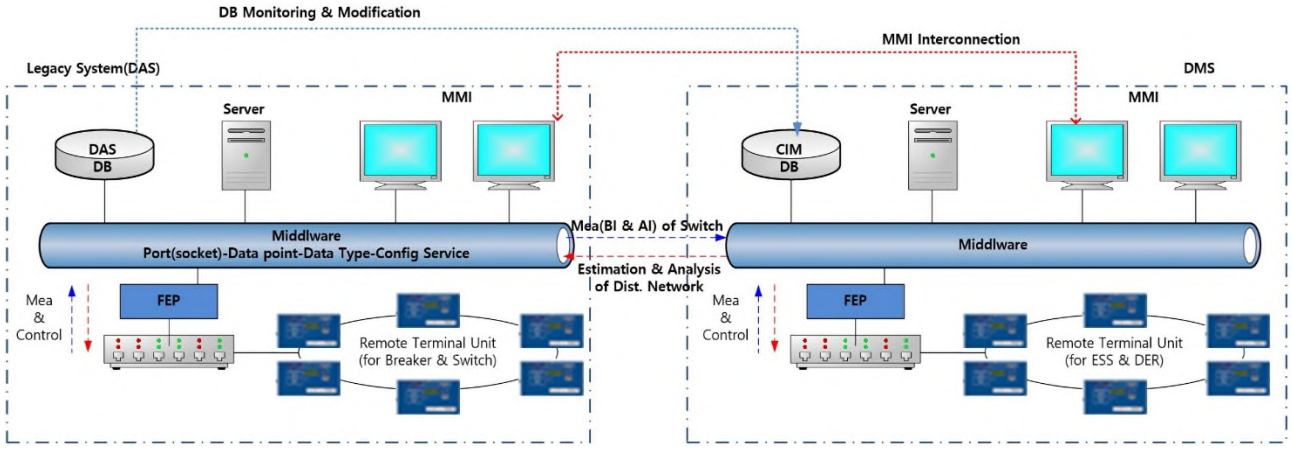



**Fig. 8. The concept of parallel operation between DAS and K-DMS**

Until now, the DAS has been installed in all 194 branch offices, and around 35% of total 127,000 line switches have been automated. The major functions of the DAS are to monitor distribution feeders, clear the faults, and restore un-faulted sections. Because of the long running period of the DAS, there are so many additional function not only operation, but also other work for operator. So, it would be irreplaceable system for KEPCO. However, the DAS doesn't have the function of DMS like a analysis application. So, we made a decision to operate the DAS with K-DMS as a parallel operation. The concept of parallel operation is presented in Fig 8.

## CONCLUSIONS

In this paper, we summarize the system architecture and application software of the K-DMS and the result of field test. The point of the summarization is the object of K-DMS would be designed to generate the accurate network information and operation solution for supporting the operator who has an experience such an abnormal network situation by DER or another reason. For this reason, K-DMS has been developed to handle the real-time data and the periodic diagnosis of various application programs. For this, system architecture is designed to similar with a small EMS. For the architectural designs of K-DMS, we propose various application programs for the periodic analysis of a network. The proposed architecture and application software of the K-DMS will be installed and operated in distribution control centers.

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