DEVELOPMENT AND FIELD EVALUATION OF SMART DISTRIBUTION MANAGEMENT SYSTEM FOR EFFICIENT DISTRIBUION NEWTORK OPERATION

Seongchul KWON Sang-yun YUN Jeong-heon KIM Won-wook Jeong Cheol-min Choo
KEPCO(Korea Electric Power COporation), South Korea
mindall@kepco.co.kr drk9034@kepco.co.kr jaykim@kepco.co.kr wwjung@kepco.co.kr cmchu79@kepco.co.kr

ABSTRACT

This paper presents the summary and the result on the field test of Smart Distribution Management System(S-DMS). And more than this, the main equipment for field test is described. For the field test, the test site is located in the south-western area of South Korea, and the controllable equipment such a Battery Energy Storage System(BESS), STATCOM is installed for network operation to control the active and reactive power. The purpose of SDMS is to conduct the watch, control, operation of power distribution network connected the renewable energy source for stable and efficient power service. For operation of the active network which is connected the energy source, KEPCO has developed the main function of S-DMS in 2009. Now, the field test has been progressed in the test site on main function of S-DMS.

INTRODUCTION

Recently, the management system on power distribution network connected Distributed Energy Resources(DER) including distributed generator, renewable source and BESS is very interest part in point of efficient and stable energy supply service. As the reason that DER is unstable and uncontrollable source, Distribution Management System(DMS) for operation of the network is necessary. In general, DMS is a decision support system that is intended to assist the distribution system operators in monitoring, controlling, and optimizing the performance of the electric distribution system. From 2009, KEPCO has developed Smart-DMS for the operation of active distribution networks with DER. In the function of DMS, the applications that assist the decision of operators' action for improved performance in active distribution networks are one of the key distinguishing factors of the DMS. In distribution network with high penetration of DERs, the network operator has difficulties to handle the voltage regulation. So they put the limit on the capacity of DER interconnection and operate in the fit & forget way. But active voltage control with DERs and control devices can make the voltage profile stable and increase the hosting capacity of DERs in distribution networks. By the network analysis application, the smart-DMS can solve the current technical issues, more than voltage, by the DER. The applications based on the requirements of the operators conduct the function such the monitoring of the network state through real-time analysis & controlling the power flow at the point of common connection of DERs and the controllable Micro Grid(MG), economic & dynamic network operation by control of ESS. In this paper, the summary of system concept and function on S-DMS and the field test site is described

ARCHITECTURE OF S-DMS

As far as mentioned in Intro, the DMS is the decision support system for power distribution network operator. So that, the base function of DMS is to get the measured data from the network and control the field equipment with DER. More than this, the application can be run on schedule. In basic function of DMS, the distinguishable point of S-DMS is Application Server(App. Server). In Fig1, the purpose of App. Server is that the advanced DMS function can be established independently from the SCADA system. Even though there is other SCADA system not to be S-DMS, the App. Server can interconnect with any other SCADA system just only to match the data point map between CIM and ACM.

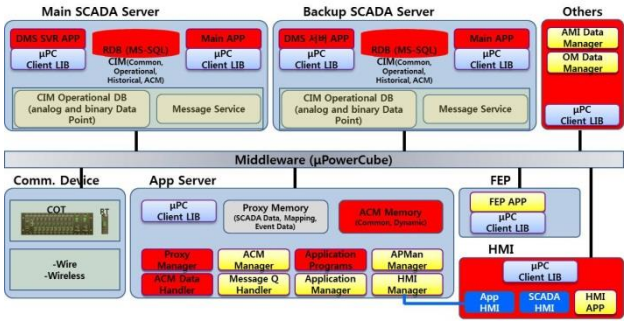

Fig1. Conceptual Structure of S-DMS

The function of SCADA is to measure the state information such a voltage and current from auto-switch gear installed in the network and the output power of DER and to control the equipment with controllable DER. The database of SCADA system is based on the CIM.
The function of App. Server is to support the operator when they make decision for the issue by network state and DER. The App. Server handles 14 applications such a real time network analysis for monitoring the network and making the solution, a plan for network configuration and protection. More than this, the applications for forecasting the load and generation, and scheduling the controllable generator similar with Unit Commitment (UC) for the microgrid are developed and tested.

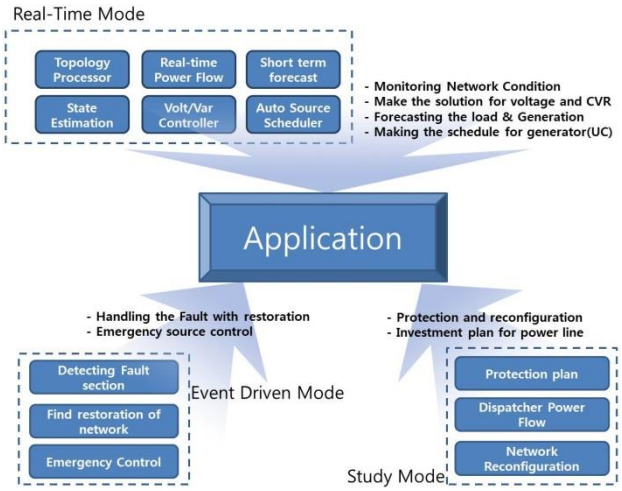

Fig.2 Summery of function about application

Using the measured and estimated information, the solution for the issue of network is suggested to the operator by HMI. The HMI is consisted of several screens such a single line diagram, network diagram, a dash board for application and so on.

Fig.3 HMI on dash-board of application

Fig.4 HMI on network diagram

SUMMARY OF TEST SITE

In order to field test for KEPCO's S-DMS, the project, call Micro grid & Distribution Advanced System(MiDAS), is launched in 2012. The final goal of this project is to test and evaluate the function of S-DMS in active network and micro grid connecting the DER. The test site is located in the south-western area of South Korea, call Shin-An Province. In this test site for active distribution and grid-interconnected micro grid, the customer load is 21MW as peak load, and total installed capacity of Renewable Energy Sources(RES) is over 21MW including 3MW Wind Turbine and 18MW Photovoltaic generator. To control the active and reactive power, 1.5MW BESS and 1MVA STATCOM is installed to control voltage profiles in distribution lines, mitigate the effect of RES on distribution operation and to enhance the service restoration. Moreover, low-voltage grid-connected micro grid is also installed for energy independent operation

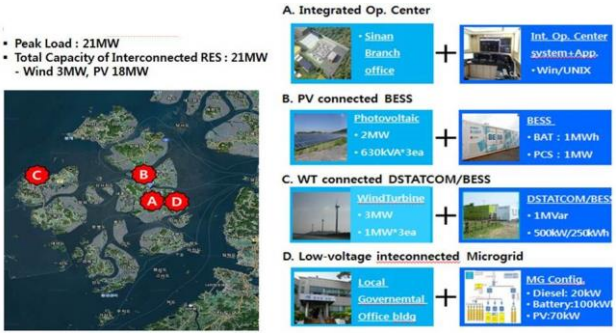

Fig.5 Components in test site for S-DMS

In this test site, three small micro grids interconnected with distribution network are installed include each components. The BESS has two major functions. First function is to stabilize the renewable source(PV) for improving power quality. Another is to supply the electric service for customer whenever the MG with BESS connects or disconnects with the network. The STATCOM also has two major functions. First function is same with BESS, and the other one is the reactive power source to control the voltage profile. The building micro grid installed in low-voltage side, especially office building, has the purpose that there is non-interrupted power supply on the building. In the MG site, small size of energy storage and PV system are installed in the building. Furthermore, using those components(BESS, STATCOM, small scale MG), S-DMS can control the voltage profile on distribution network to expend the interconnected capacity of DER, and operate the dynamic island by occurring the line fault.

RESULT OF FIELD TEST

The result of field test is divided into 3 categories as following below.

① Monitoring the network state such voltage and load

② Controlling the voltage for the service quality and reduction of active power(CVR)

③ Operating the dynamic island(like MG) by BESS

To look out over the network, the automation switch with the sensor is installed in the network. However, it is not enough to watch the state, and also, the accuracy of the sensor is very low. To solve that problem, there is an application of S-DMS such the state estimation. Using the measured value, the application estimates the network state such a voltage, section load. The result of voltage estimation is less than 1% error as following below fig.6. And also, the estimated result error on section load is within 1.5%.

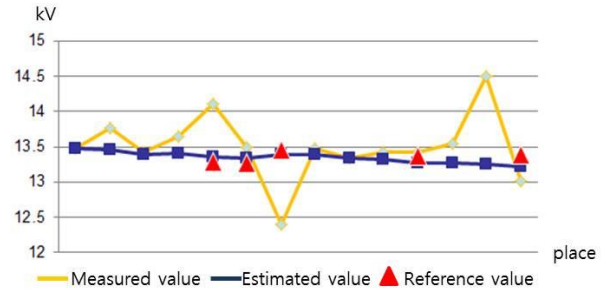

Fig.6 Result of the state estimation

To control the voltage for CVR function, the application, called Volt/Var Optimization(VVO), make result on the tap step of transformer such a SVR(static voltage regulator), OLTC(on-load tap changer) and reactive power of DER. The VVO make solutions for the issues such a voltage violation, power loss and CVR using the voltage control equipment such a DER, SVR, OLTC. Even though DER is not enough to control for the entire feeder, it is possible to control the each section of feeder using DERs' reactive power. After that, to control the tap step of SVR or OLTC for the feeder voltage, the effect of voltage control is efficient.

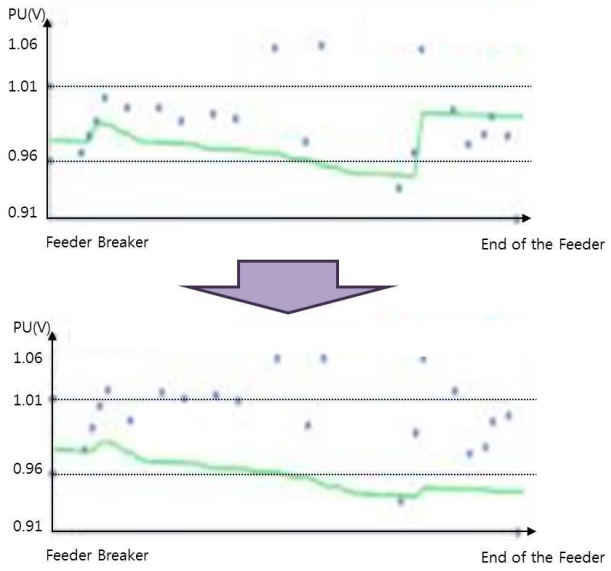

Fig.7 Result of the voltage control for CVR

The fig.7 describes the result of VVO. In this figure, the dote stands for measurement value, and the green line is the result of voltage control for reducing the active power of the feeder. This test is conducted in Bi-Geum D/L, one of feeder in test site. In this feeder, two SVR and STATCOM are installed as voltage controllable equipment.

In general, the dynamic island is the network operated by BESS without the energy supply of the utility. At that time, the key point is how much stable operation is possible when the island is connected and disconnected form distribution network. To conduct the test, the system configuration of the BESS site is presented in fig. 8.

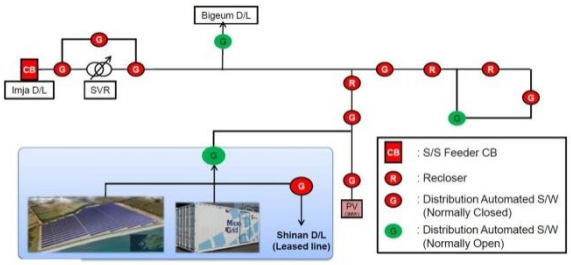

Fig.8 BESS interconnect with the network

The result of dynamic island operation using BESS, installed Im-Ja D/L one of feeder in test site, is that BESS makes stable to the island within 25msecond, when the island disconnected from the network.

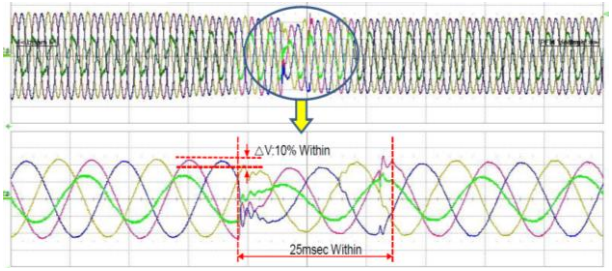

Fig.8 Result of the dynamic island by BESS
(Waveforms of Uninterruptible supply)

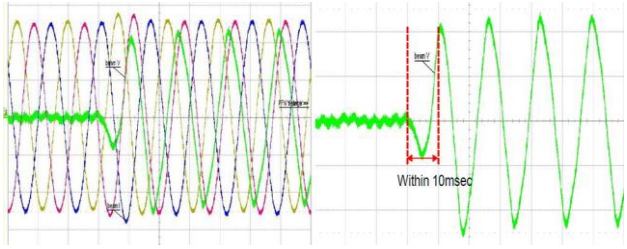

Fig.9 Result of Response time test

Additionally, the result of small scale MG installed in low-voltage side is presented. In 19th December, 2014, and 4th January, 2015, the instantaneous interruptions were occurred by the line fault. After the MG site was disconnected to the network, the ESS supplied the

electric service automatically. The fig. 9 and 10 illustrate the circumstance of the interruption.

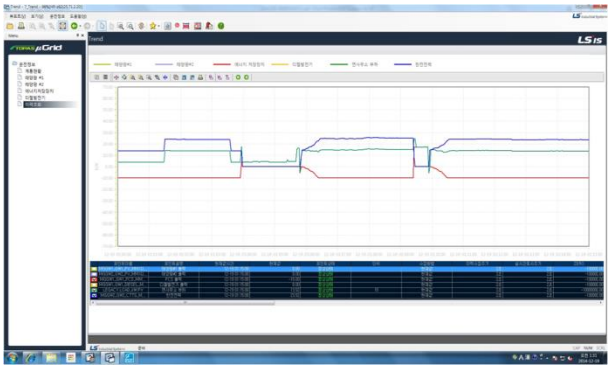

Fig.9 Case-1 of islanding operation in the MG site (Twice instantaneous interruptions were occurred in 19th December, 2014)

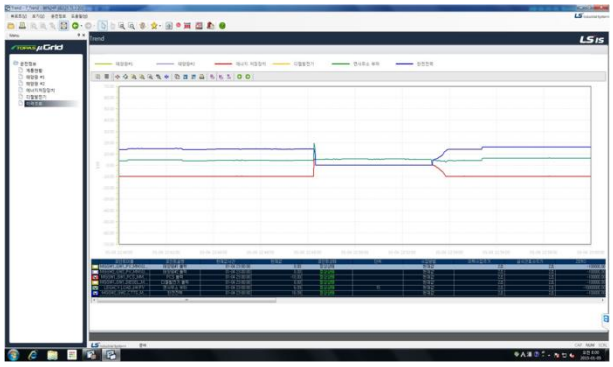

Fig.10 Case-2 of islanding operation in the MG site (An instantaneous interruption was occurred in 1th January, 2015)

CONCLUSION

The field test is still conducted. The field test item for function of S-DMS is more than 600, and the rate of test progress is approximately 70% on total test items. Until now, the test progress is successfully conducted. The state estimation programme, one of application for monitoring the network, can estimate the voltage and current within 1% error, and the voltage control test such control of reactive power and CVR is successfully done. After this, to use the BESS, there is a test plan for peak load shaving and the dynamic island operation. Now, KEPCO has a plan for making the reliable technology of S-DMS to conduct the more field test with Canadian electric power corporation.

Acknowledgments

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