# MICROGIRD'S STRATEGIC PLANNING IN KEPCO

Dae-young KIM
KEPCO-Seoul, Korea
zeuss@kepco.co.kr

Jung-sung PARK
KEPCO-Seoul, Korea
jindulpa@kepco.co.kr

Dong-hoon JEON
KEPCO-Seoul, Korea
dhjeon@kepco.co.kr

Sung-man KIM
KEPCO-Seoul, Korea
kisma@kepco.co.kr

Young-jin WON
KEPCO-Seoul, Korea
Wonyji@kepco.co.kr

## *ABSTRACT*

*The microgrid system is small power supply system that consists of loads and DERs(Distributed Energy Resources), such as renewable sources and co-generation, energy storage system. Because the microgrid system has not only loads but DERs, it is necessary for interconnection guidelines and control coordination. Therefore we must provide new rate system to be complicated for generation and consumption of electricity but not existing uniform rate system. In this paper, we provide the technical and financial management planning for distribution network of KEPCO before the smart grid will become more common.*

## INTRODUCTION

Environmental issue is one of the key factors to industry area using fossil fuels, because it accelerates the global warming. This issue is especially for the power industry. During the 1970s, increases in the price of oil and natural gas and concerns about the finite nature of reserves, coupled with increasing awareness of the environmental damage caused by the burning of fossil fuels, stimulated interest in alternative, renewable sources of energy. As a result, many kinds of research and development to enlarge the use of renewable energy resources which can be able to replace fossil fuels are accelerated in the power industry. Consequently, it is supposed to reduce greenhouse gases around the developed nations of the world at times go. However, there are still technical issues to apply DERs (Distributed Energy Resources), including renewable energy resources, to the conventional power system. Especially, because of intermittent power output and difficulty of control, there are many problems to be solved regarding the spread of renewable energy resources such as wind turbine and photovoltaic. In addition, DERs are not economically practical yet. Under this background, the microgrid system that consists of DER systems, such as natural power system (wind turbine, photovoltaic) and fuel-cell, cogeneration, also known as CHP (Combined heat and power) generation, has been developed greatly during the last 10 years. The microgrids are small power supply system located on-site that can supply both the electricity and the heat simultaneously. In this paper, we discuss the distribution network management with the microgird system in KEPCO.

## MAIN CONTENTS

### 1. Definition and Organization of a Microgrid

#### 1.1 Definition

The microgrid concept assumes a cluster of loads and microsources operating as a single controllable system that provides a new paradigm for defining the operation of distributed generation. To the smart grid the microgrid can be thought of as a controlled cell of the power system. For example this cell could be controlled as a single dispatchable load, which can respond in seconds to meet the needs of the transmission system. To the customer the microgrid can be designed to meet their special need; such as, enhance local reliability, reduce feeder losses, support local voltages, provide increased efficiency through use waste heat, voltage sag correction or provide uninterruptible power supply functions to name but a few.

#### 1.2 Microgird Engineering for Construction

The microgird offers opportunities for optimizing DERs through CHP, which is currently the most important means of improving energy efficiency. It usually consists of a cluster of distributed generators, energy storage systems and loads, and can operate in the grid-connected mode and the islanded mode.

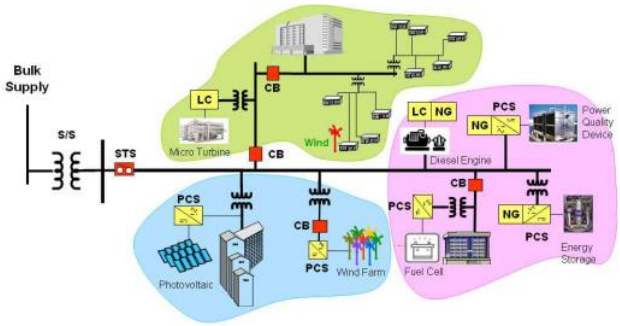


*Figure 1. Microgrid concept*

#### 1.2.1 Optimal Planning Model

The optimal planning is applied to select DERs providing optimal fuel mix and economic dispatch schedule. Due to the nature of the optimal planning, the objectives are minimizing the fixed cost and variable cost. The objective function is subject to various operating constraints such as energy balance equations and generation functions.

The operation cost of microgrid depends largely on the planning and operational policies which are fuel cost, FIT (Feed-In Tariff) and RPS (Renewable Portfolio Standards)

in advance of construction on power market. Because of its strategic planning, the variable cost of the objective function can be more complex.
Unlike the conventional power system such as CHP (Combined Heat and Power) and gas directly fired unit, its constraints are balanced for electricity and heat energy.

### 1.3 Microgrid Control for Strategic Operation

As mentioned earlier, some DERs like wind turbine are adversely affecting the power system. With the number of DERs increasing rapidly and the trend of developing microgird, it is possible to control DERs to provide constant power (good citizen) to the power system. It means that the microgrid can be used for their immense benefits, for example, improve power quality and reliability, defer or avoid system expansion. Moreover, for the ISO, the microgirds have the potential to provide the ancillary services, such as AGC services. To the customer the microgrids can be designed to meet their special need, such as, enhance local reliability. To offer special services, the central controller, Energy Management System, is necessary.

#### 1.3.1 Energy Management System (EMS)

The microgrid EMS is not different from the conventional EMS, for bulk grid. However, its control cycle is more frequently performed than the conventional EMS because load of microgrids fluctuate very widely and its generators have small inertia.

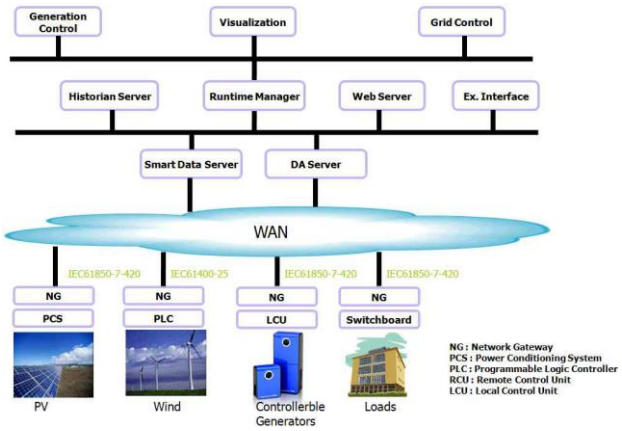


*Figure 2. Microgrid EMS*

Generation control is most important portion of EMS in the microgrid. Unlike the conventional EMS that control generators from few minutes to more time, the microgrid EMS have to control generators from few seconds to few minutes with automatic generation control (AGC).

## 2. KEPCO's Microgrid Test-Bed Case Study

### 2.1 Project Outline

KEPCO's microgrid test-bed is in KEPCO research institute, Daejeon, South Korea. KEPCO research institute is leading the electric power industry with the best research engineers and technologies in Korea.

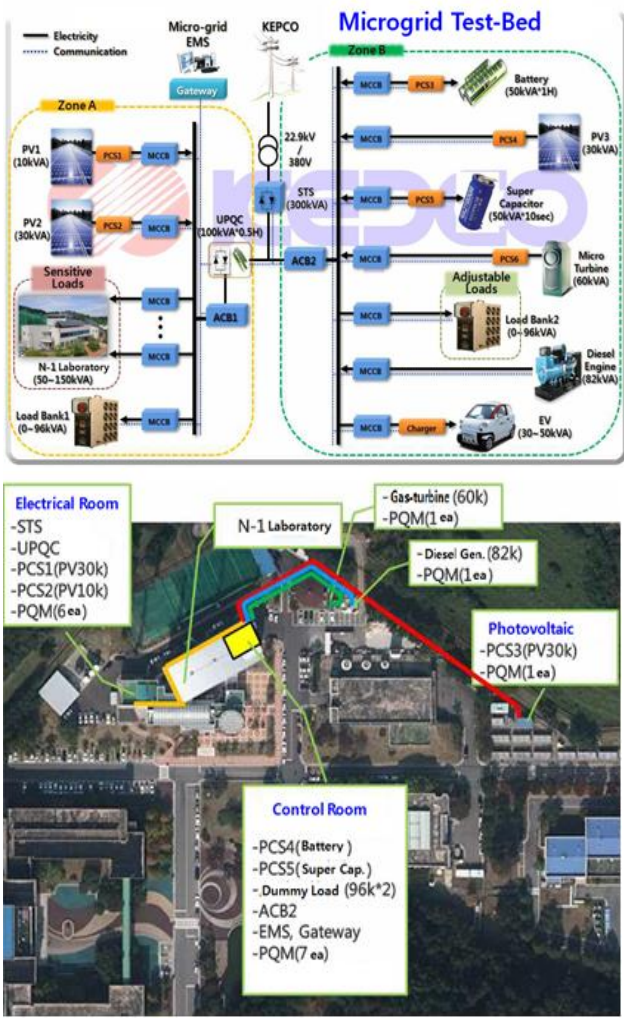


*Figure 3. Microgrid Test-Bed component*

Microgrid is a new power supply system that is capable of supplying power and heat independently through small-scale distributed generator such as renewable energy source, etc.; it can improve power quality and power reliability by controlling power output and power flow depending on the various requirements of customers. This microgrid is usually operated in gridconnected operation mode, but it shifts to islanded operation mode to supply power if an event occurs, such as power system failure in the upper tier system. In addition, frequency and voltage are balanced at a constant level even after it is converted to operation mode, thereby increasing power reliability. Thus, the microgrid requires the energy management system, which monitors the status of the system and provides adequate control capability. In this study, EMS was designed and developed to ensure the optimal operation of the microgrid. Testing was conducted to validate the performance of EMS under various operation

scenarios for the 200kW-class test-bet system.

*Figure 4. Microgrid Test-Bed whole view & Control room*

### 2.2 Grid-Connected Mode

Supply and demand balance is automatically maintained by the upper tier system in grid-connected operation mode. Therefore, the microgrid power is operated such that the biggest technical and economic benefit is realized for customers or microgrid operators. In other words, the power output generated using renewable energy source such as wind power, photovoltaic power, etc. Renewable energy sources are always maintained at the maximum possible level; controllable power sources such as micro turbine, fuel cell, diesel, etc., are used to ensure the most efficient operation of the microgrid. To establish a plan for optimal power generation, EMS maps out the daily power generation plan on the very day of load dispatch based on the load of the previous day and the forecast data of renewable energy power generation. The final set point of the individual power generator is transmitted through power control at the point of common coupling after economic dispatch is carried out for several minutes based on the start/stop plan for the very day of load dispatch.


*Figure 5. Microgrid EMS*

### 2.3 Island-Mode

System voltage and frequency must be balanced within a constant range through supply and demand balance if the microgrid shifts to islanded operation mode due to failure in the upper tier power system or occurrence of event. In islanded operation mode, the renewable energy source is uncontrollable. Thus, the supply and demand imbalance arising from the variation in output and load fluctuation of the renewable energy source is resolved by controllable sources and energy storage system. The non-critical load must be intercepted appropriately if the load exceeds the power output. If the mode shifts to islanded operation mode, EMS checks the supply reserve, activates additional power generator, and carries out economic dispatch for several minutes. The final set point of the individual power generator is transmitted through the primary frequency control power backup generation (secondary control) as a result of the fluctuation of load during the economic dispatch. Following recovery from failure, operation can start by reconnecting to the upper tier system. Synchronization with the upper tier system is necessary for reconnection; at this time, the voltage and frequency of the microgrid must be maintained within a constant range.

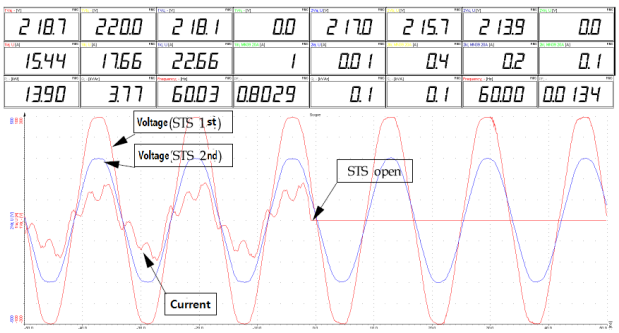


*Figure 6. Grid-Connected Mode -> Island Mode*

## 3. Microgrid Operating Strategy with Electric Rate Policy

KEPCO has implemented a standardized electric rate policy by contract classification in Korea at the present

moment. In other words, the rate table is divided into receiving voltage, capacity, client type and time period. More elaborate rate system is necessary because it is difficult to active respond to electricity use of customer. Thus the microgrid will must necessary to lead the active demand response, but not single DERs (distributed energy resources).

### 3.1 Electricity Contract Capacity Reduction and Economic Operation with another Energy

#### 3.1.1 Contract Capacity Reduction

Electric rate can be subdivided into two major sections in Korea, basic cost and usage cost. Of these, basic cost which is contract capacity cost is calculated on energy receiving capacity of customer except residential. The residential adopt usage cost only. In other case, if the customers reduce their energy receiving capacity (kW), they can cut down their basic cost. The microgrid can significantly reduce energy receiving capacity because the microgrid consists of DERs and demands. That is, if its energy cost compared to the self generation cost and energy receiving cost for contract capacity appropriately, energy cost can be reduced much.

| Division | | Basic cost (₩/kW) | Energy cost (₩/kWh) | | |
|---|---|---|---|---|---|
| | | | summer (7~8) | Spring/fall (3~6,9~10) | winter (11~2) |
| Low volt. | | 5,280 | 93.50 | 58.30 | 74.70 |
| High volt. A | Selection I | 5,790 | 98.10 | 61.20 | 77.60 |
| | Selection II | 6,660 | 94.70 | 57.70 | 73.60 |
| High volt. B | Selection I | 5,790 | 96.30 | 60.20 | 75.80 |
| | Selection II | 6,660 | 91.90 | 55.80 | 71.40 |

*Figure 7. Sample of Electric Rate Table in Korea*

#### 3.1.2 Strategic Operation with another Energy

Most generators using fossil fuels to less than 50% efficiency, conventional electric generators get a lot of waste of the end use energy compared to the fuel input. Can raise the generation efficiency is the best way, to produce electrical energy as the heat generated to use. Using this technique, the actual efficiency of CHP (Combined Heat and Power) is more than 90%. However, large-scale CHP plants cost a lot of money to build the heat pipe infrastructure and difficult to be built at complex urban. If the microgird can solve such a problem properly. The microgrid is a system that can accommodate various small-scale DERs such as wind power, photovoltaic generator, micro gas-turbine (micro CHP). In other words, the microgird has an appropriate scale to supply heat and electricity at load pocket unlike conventional CHP primarily supplying heat. If using these microgrid system that supply electricity and heat to customer at proper ratio will be possible strategic economic operation.

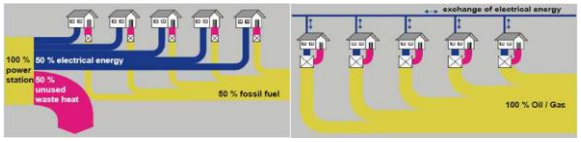


*Figure 8. Compare of Centralized power supply & Distributed power and heat supply of Mocirgrid*

### 3.2 Incentive Inducement by Active Demand Response

Unlike other industries, the electric industry has very inelastic market. So it is difficult to follow planning and strategic use of electricity for the customers who use general pattern of electric usage. But the Smart grid environment have been made throughout the world in technology development lately, it is possible to use the electricity actively. In other words, according to various rate information of usage patterns and information technology equipments that suggest the strategic use, the electric usage can lead to a more aggressive response. In this regard, the microgrid is a very useful system that can accommodate active demand response. Because the microgrid EMS can gather real-time information of each loads and generators, the electric power supply and demand and price of bulk gird, it can perform the active demand response ideally. Thus, the microgird can derive incentive from demand response and lead a new demand response market.

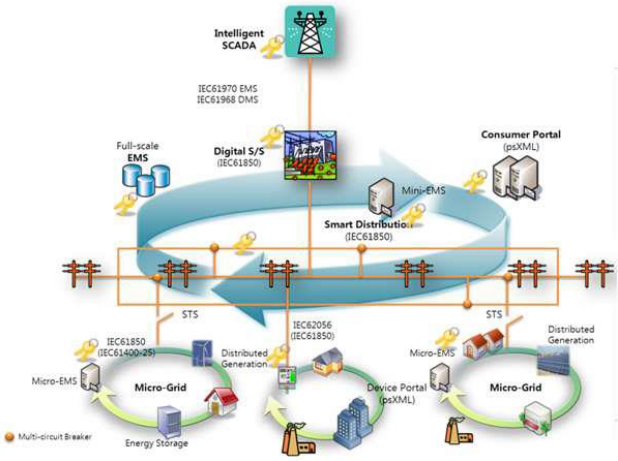


*Figure 9. Mocirgrids of Smart Grid Environment*

### 3.3 Power Producer with Large Scale (MW-Class) Microgrid

Currently, the energy operators can sell electricity and heat separately in Korea. But, at the same time small-scale heat and electricity can be sold by the single seller who is called an operator of Community Energy Supply (CES). These operators supply the electricity and heat in their business area. If there is not enough electricity to sell, they purchase the electricity from KEPCO and resell it. However, these operators take precedence over heat supply to the

electricity supply, so the operators will be affected seasonal factors or the cost of producing heat and electricity for supply. Due to this structure, affordable electricity from KEPCO was resold to costumers not their effort. The generation business using the microgrid has a lot of difference between the CES business. The microgrid having various DERs can be optimized from stage of the engineering to meet various local conditions. As a result, the microgird can make the maximum effect by adequate supply of electricity and heat. Thus, the energy supply using the microgrid can create a variety of rate structures.

**3.4 Differential Rate by Uninterruptable Power Supply**

Because electrical energy is currently essential to human life such as water, there are various fields which wish to be sure uninterrupted power supply. For example, at hospitals, data centers, military bases and radar station, reliable electricity supply must be made. At this point, even if the failure occurs on bulk grid, the microgrid that can supply uninterrupted power has received a lot of interest. Actually, the microgrids are being deployed as important facility for security in the U.S military. As such, new rate system depending on the power quality can be created.


*Figure 10. U.S Military Microgrid Concept*

## CONCLUSION

Because the microgrid system has not only loads but DERs, it is necessary for interconnection guidelines and control coordination. Therefore we must provide new rate system to be complicated for generation and consumption of electricity but not existing uniform rate system. In this paper, we provide the technical and financial management planning for distribution network of KEPCO before the smart grid will become more common. Besides existing interconnection guidelines for DERs, KEPCO prepare the technical issues for the microgird will increase rapidly. KEPCO would like to plan the new rate system for the future distribution network rationally. In the near future, the distribution network environment will have complexity in technological and financial aspect. Without the support of utility, it will be very difficult to spread the commercial microgrid system services. To promote the green and high efficiency energy system actively, we have to prepare thoroughly in advance. This paper presents the strategic planning of KEPCO to promote the microgrid system.

## REFERENCES

[1] Yongwen Yang, 2005, "Optimal Model of Distributed Energy System by Using GAMS and Case Study", SCADE LBNL-61117, November 30

[2] T. Funabashi, R. Yokoyama, "Microgrid Field Test Experiences in Japan", IEEE PES General Meeting, Jun., 2006.

[3] C. Marnay, 2007, "Optimal Technology Selection and Operation of Commercial Building MicroGrids", IEEE Trans. on Power Sys., TPWRS-00549-2007.R1

[4] Tetsushi Tanaka, 2007, "Activities toward Microgrid Technologies", MEIDEN Review Series No.140, pp.1-3

[5] Jungsung Park, 2008, "Economic Feasibility of MicroGrid on the Environmental Cost and Operation Type",
KIEE Trans. on Power Sys.,vol. 57, 1738-1743

[6] Hakju Lee, 2009, "Microgrid Technical Report of KEPRI (Phase2) ", KETEP

[7] Keeyoung Nam, 2009, "Establishment of a pilot plant for KERI microgird system based on power IT development program in Korea", IEEE Conferences.,TD-ASIA.2009. 5356840

[8] Hakju Lee, 2010, "Microgrid Technical Report of KEPRI", KETEP

[9] Jungsung Park, 2011, "Engineering and Operation of Micorgrids with Optimal Planning and Control on Smart Grid", ICEE 2011