FUNCTION AND OPERATION PLAN FOR STABLE OFF-GRID MICROGRID

Bo-Gun Jin
Hyosung Corp.
Republic of Korea
sinato@hyosung.com

Dae-Hee Choi
Hyosung Corp.
Republic of Korea
craptor@hyosung.com

Jin-Ho Lee
Hyosung Corp.
Republic of Korea
easyknow@hyosung.com

Woo-Kyu Chae
KEPRI
Republic of Korea
microgrid@kepco.co.kr

ABSTRACT

The interest in renewable energy sources and microgrid is increasing around the world, and the island grid based on the conventional diesel generator, is changed into off-grid microgrid using renewable energy resources. This paper presents the necessary functions and strategies for construction and operation of off-grid microgrid.

INTRODUCTION

A microgrid is defined as a system that supplies and manages electric energy independently. Microgrids can be classified to two different types. One is the grid-connected microgrid which can be connected or disconnected to the main grid. Other is the off-grid microgrid. The off-grid microgrid is completely separated from main grid.

For the configuration of the off-grid microgrid, it is necessary to analyze the characteristics of the load and decide appropriate renewable energy sources and its capacity. Then the capacity of ESS is determined to complement intermittency of renewable energy source. After that, the strategy for the operation of microgrid is established.

Currently, the off-grid systems uses mainly diesel generators supply electric power. The cost of generation is higher than inland grid, environmental problems such as carbon emissions and air pollution are occurring. Therefore, many of projects using renewable energy sources and ESS are in progress.

In these projects, the capacity of renewable energy sources is designed to be larger than the load. It may cause problems in microgrid due to variability of renewable energy sources. By using ESS as primary source in microgrid, these problems can be solved, and the grid operates in stable [1-7].

There are cases where the installed renewable energy is controllable and impossible so that the management method of SOC is different. The independent island must be able to cope with all situations that occur as loads must be driven only by a 24 hour renewable generator and ESS.

In order to support this, more functions are requested than the PCS used in cooperation type, and EMS is required for proper management in multiple situations.

In this paper, we will talk about the functions necessary for operating a standalone micro grid and the way of operating the system and investigate the operation of Gapa and Gasa Island.

OFF-GRID MICROGRID FEATURES

Most of small capacity off-grid microgrids have diesel generators to supply power to loads. And renewable energy sources are added, ESS is installed and operated to assist intermittency of renewable energy.

This paper is targeted at the off-grid microgrid consist of diesel generators, renewable energy sources, ESS.

The configuration and operation strategy of off-grid microgrid depends on the characteristic and structure of the system. It is important to establish the strategy of operation based on the structure and characteristic of grid.

SYSTEM CONFIGURATION

Load

Unlike the system that operates only for a specific time, the off-grid microgrid needs to supply power to the load for 24 hours, so it is necessary to grasp the load characteristics for 24 hours and form a supply strategy accordingly. At this time, the capacity of renewable energy source needs to be considered by reflecting the daily load characteristics (including weekday and weekend) and monthly load characteristics.

Renewable Energy

The capacity of renewable energy source is calculated according to the diesel power generation reduction target. If the reduction target is 100%, renewable energy sources are designed according to the largest load in year. In this case, it will result in lower utilization of renewable energy when the load is lower than the largest load.

ESS

The load and the power generation are examined to determine the capacity of the PCS and the battery of the ESS. Also, the duration for load supply without renewable energy should be considered.

OPERATION OF OFF-GRID MICROGRID

The basic consideration for the operation is that the ESS mainly maintains the voltage and frequency of microgrid, and covers the output of renewable energy and the load. If the output of renewable energy is more than the load, the ESS will charge. In the opposite case, it will discharge.

It is necessary to change the configuration according to the situation on the off-grid microgrid.

Of course, special circumstances that are difficult to operate with only the following operation strategies and modes may occur. So the specific functions corresponding to the characteristics of the off-grid microgrid can be individually required.

Diesel Standalone operation

The diesel standalone operation is necessary to maintain the microgrid during ESS failure or system check. Also, at the start of the grid, the black start will proceed by using diesel generator.

Diesel, ESS Linked operation

This operation is used to connect ESS during the diesel standalone operation or to supply required energy from diesel generators at the shortage of renewable generation and insufficient SOC during the ESS standalone operation.

ESS Standalone operation

If the system is normal and operates in the ESS standalone operation, it stably supply power to the load and cover the output of renewable energy.

OPERATION MODE OF PCS

The operation modes of the PCS for operating off-grid microgrid are as follows.

CVCF Diesel Mode

The CVCF Diesel mode is necessary for ESS synchronized connection when the diesel generator is operating as the primary source. In this operation mode, the PCS detects the phase of the system and traces the same phase.

CVCF Ready Mode

It is the standby mode for backup in case of PCS failure, and starts CVCF operation with uninterruptible power supply when PCS fails. In this operation mode, it is necessary to detect failure of the Main PCS and to maintain the voltage and frequency in the same phase within 8 [ms].

CVCF Mode

It is a function to maintain the voltage and frequency using ESS as the primary source of the system, and when power failure occurs in the off-grid microgrid, execute Ramp control for Black start

PQ Mode

The constant power operation mode controls active power and reactive power when diesel generator or main PCS operates as the primary source so that it can operate a stable system.

SYSTEM-SPECIFIC OPERATING STRATEGY

The operation status of microgrid is divided into the change of the system and normal status. The change of the system means replacement of the main transformer, the maintenance situation of the system. In this case due to the characteristics of PCS, there is a possibility of trip during the transient period, so, the diesel standalone operation is used. Under normal status, since the ratio of renewable energy source is high, it is difficult to cover the output fluctuation with the diesel generator as the primary source. It may occur voltage/frequency problems during operation. Therefore, The ESS maintains the voltage and frequency of the system maintaining through CVCF (Constant Voltage Constant Frequency) operation, and cope with the output of renewable energy sources. Through SOC (State of Charging) management operation, the off-grid microgrid is maintained in stable.

Normal

Normal status of SOC means that SOC of ESS is higher than SOC Min and lower than SOC Max(SOC Min <SOC <SOC Max), and no special control is performed.

Warning

Warning is the status that SOC is lower than SOC Min(SOC<SOC Min). In this situation, it controls to reduce power consumption or increase power generation when the power generation of renewable energy sources is equal to or less than the load power consumption.

Emergency

This is the case when a system fault occurred or a problem occurred in the ESS. If there is a backup, it is a backup operation, otherwise use a diesel generator to operate the system.

EXAMPLE

The operational example of off-grid microgrids in Gapa Island and Gasa Island, Korea is as follows.

Gapa Island

Gapa Island is located in the south of Jeju Island, where 126 households live. For the purpose of the carbon free island, renewable energy resources such as wind, solar power has been installed as well as ESS. The ESS has been installed in three stages, and the final construction has completed in 2016.

Figure 1 EMS in Gapa Island

The above picture is the gapa island EMS, and the optimal control is performed by judging the current state of the system.

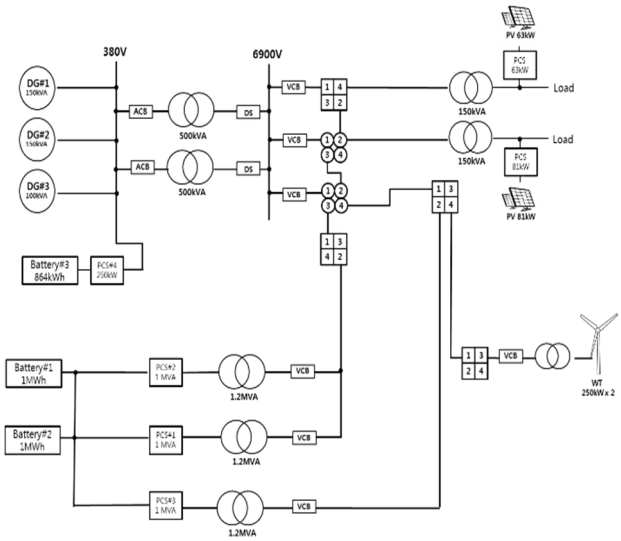

Figure 2 Gapa Island Single Line Diagram

Table 1 Gapa Island Configuration

	Before	After
Load(Average)	110[kW]	120[kW]
Diesel	150[kW] * 3	150[kW] * 3
PV	-	142[kW] (3[kW] * 47)
WT	-	500[kW] (250[kW] * 2)
ESS (PCS)	-	1[MW]*3, 250[kW]*1
ESS (Battery)	-	3[MWh], 864[kWh]

The average elecrical load is 120 kW and three diesel generators of 150 kW each was installed. The rooftop PV capacity is 144 kW (3 kW * 48), and the WT capacity is 500 kW (250 kW * 2). The ESS capacity is 3 MW / 3 MWh (1 MW * 3).

The wind power system is not an inverter type, so in order to increase the stability in the small power system, PCS3 is installed as back-to-back through the wind power. If that PCS3 is out of order, the wind power system can be connected to the main power system.

Two battery systems were installed in different time, so they have different characteristics. If problems occurs due to different characteristics, two batteries can be worked with no interference with DS.

In general, the PCS1 mainly supplies power to control load demand, PCS2 is ready for backup, and PCS3 charges the batteries from the wind turbines.

Operation

Basically, ESS is operated by CVCF mode for standalone operation. When the battery SOC is insufficient, the diesel generator is connected to the grid. And the overcharge of the battery is prevented by controlling the power generation of wind turbines.

In order to prevent problems in grid caused by intermittency of the photovoltaic power generation during diesel standalone operation, the ESS is charged a constant amount of power with photovoltaic power generation.

Wind turbines is not capable of output control, solar power generation is also installed 3 kW each at home, control is impossible and the SOC exceeds the maximum, the wind power generator manage through omission of. And PCS 1 and 2 are impossible to drive, absorbing photovoltaic power generation through PCS 4 control during diesel sole operation.

Gasa Island

Gasa island is located in Jindo, South Korea, and 164 households are inhabited. Since 2014, wind power, solar power, and ESS have been installed with the aim of ensuring energy self-reliance.

Figure 3 Gasa Island EMS

The above picture is the picture of the EMS of the Gasa island and it controls the system such as the renewable energy source and the load control according to the situation to enable stable operation.

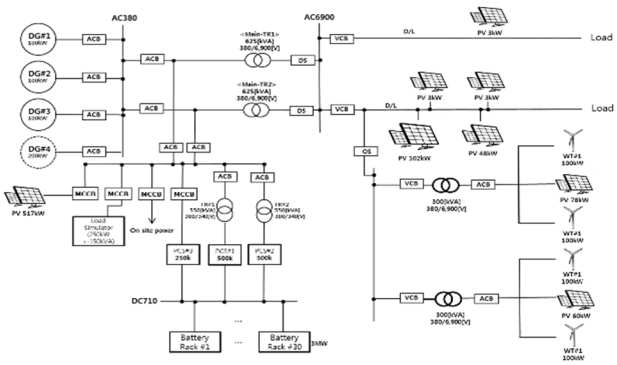

Figure 4 Gasa Island Single Line Diagram

Table 2 Gasa Island Configuration

	Before	After
Load(Average)	95[kW]	110[kW]
Diesel	100[kW] * 3	100[kW] * 3
PV	-	314[kW]
WT		400[kW]
ESS(PCS)	-	500[kW]*2, 250[kW]*1
ESS(Battery)	-	3[MWh]

In Gasa Island, the average load capacity is 100kW and three diesel generators (100kW each) are installed. In addition, the power grid has total 341kW solar systems, four wind turbines(100kW * 4) and ESS system(500kW * 2 + 250kW / 3MWh).

In general, PCS1 mainly supplies power to control load demand, PCS3 is ready for support PCS1 when generated power is over 500[kW], and PCS2 is backup to PCS1. Battery were installed 3 [MWh] parallel to 30 racks (100[kWh]). Test D / L was installed to test the new regenerative linkage and independent operation so that system operation was not influenced during system test.

The renewable energy of the lyrics can be restricted for all outputs, and when the amount of power generation is large via the power generation forecast, the output is limited and the vehicle is operated.

Operation

Operating the system based on the SOC If the SOC is less than the Minimum, if the load is reduced by reducing the load through the load control and the load is larger than the generated amount, through the cooperation of the diesel generators It supplies necessary energy. When the SOC becomes larger than the Maxmum If the SOC becomes larger than the Maxmum and it can not be solved by activating the startable load, operate so as not to exceed the load through the regeneration power generation control.

CONCLUSION

It presents the necessary operation modes and operation methods when renewable energy source and ESS installed on the small independent island are installed and operates and explained through the two independent island examples to which the operation mode and the plan were applied , It is currently being driven steadily.

REFERENCES

[1] L. Freris, and D. Infield, “Renewable Energy in Power Systems”, WILEY, 2007.

[2] R. Teodorescu, M. Liserre, and P. Rodriguez, “Grid Converters for Photovoltaic and Wind Power Systems”, WILEY, 2010.

[3] Z. Lubosny, “Wind Turbine Operation in Electric Power Systems”, Springer, 2003.

[4] M. R. Patel, “Wind and Solar Power Systems–Design, Analysis, and Operation–Second Edition”, Taylor & Francis, 2005.

[5] M. G. Simoes, and F. A. Farret, “Renewable Energy Systems–Design and Analysis with Induction Generators”, CRC Press, 2004.

[6] F. P. Sioshansi, “Smart Grid - Integrating Renewable, Distributed, & Efficient Energy”, Academic Press, 2011.

[7] A. Yazdani, and R. Iravani, “Voltage-Sourced Converters in Power Systems–Modeling, Control, and Applications”, WILEY/IEEE Press, 2009.