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A Frequency Recovery Effect by Operating Battery Energy Storage System in Transient State in the Power System

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Abstract: The purpose of this study is operating the Battery Energy Storage System (BESS) to securing the reactive power. The BESS has been maintained power voltage value to rapidly response speed for steady state in the power system. The power system has been used the BESS for the frequency recovery in transient state. This study was analyzed by operating the BESS in the power system. The BESS was installed that the power quality necessary of high level for the Governor Free Control (GFC) and Automatic Generation Control (AGC) operation in the power system. The BESS was evaluated to compare the real power system with simulation power system in fault state (outage of large scale power capacity). It would be stable operation by load fluctuation in the power system. The simulation result, it should be used for expended application of the BESS in the power system as stable power supply and low load fluctuation.

Key words: GFC operation, AGC operation, reserve power, energy storage system, study, state

INTRODUCTION

Recently, the fossil fuel should be required alternative fuels due to critical of global warming and fuel shortage. The power system has been connecting the various power devices (fossil fuel and renewable energy, etc.) by development of technology. The renewable energy was introduced into the power system as alternative energy sources (Lee *et al*., 2017; Kenfack *et al*., 2009; Evans *et al*., 2009).

However, the power system was connected unstable power supply by increasing the ratio of the renewable power. The renewable power (solar and wind power) was changed generation power by changing nature energy. It would be effected risk element as supplied unstable power in the power system. So, the BESS is operated for the stable power supply in the power system (KCPL., 2015; Zhang *et al*., 2004; TVA., 2004). The BESS was achieved by unexpected power supply and demand unbalance that stabilizing the power system. It could be enhanced the power transmission line and smoothing supply the renewable power source. This study was studied that was cooperated unwired power supply area to enable efficient self-sustained operation by energy optimization and quality control through storage and discharge.

MATERIALS AND METHODS

Frequency control by using the bess: The Energy Storage System (ESS) should be characterized and installed for applying the power system. The power ancillary services were classified by frequency usage and operating time (IEC., 2011; Kumar and Saravanan, 2016) in Fig. 1 and 2. The ESS for frequency adjustment is in charge of power quality and primary regulation. It would be performed to reduce frequency fluctuation of the power system.

The ESS could be stabilize the power voltage fluctuation by increasing the ratio of renewable generation power in the large scale power system. In

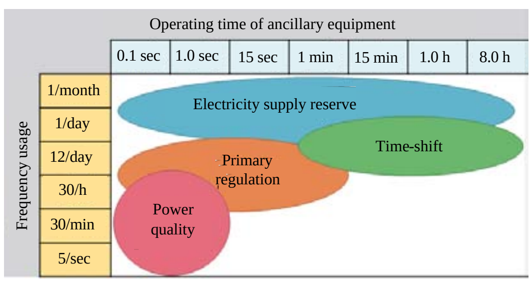

Fig. 1: Power ancillary service by frequency usage and operating time in the power system

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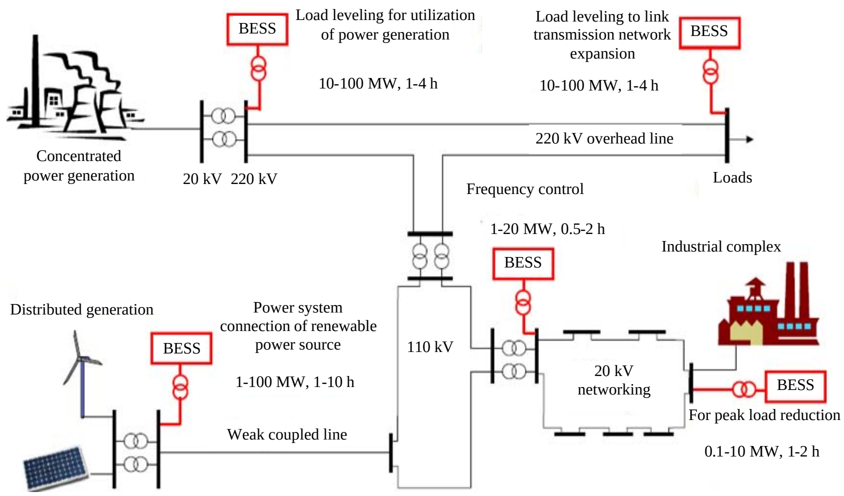

Fig. 2: ESS application position for stabilizing the voltage in the power system

Table 1: Battery demonstration project for frequency adjustment and power quality in the world

Uses	Project	Location	Rated power/Capacity
Freq regulation	GVEA BESS Ni-Cad Project Altairnano-PJM	Fairbanks, Ak	27 MW/75 MWh
	Li-ion battery ancillary services demo BEWAG	Phiadelphia, USA	1.0 MW/250 kWh
	Battery facility (Pb.Acid)	Berlin, Germany	8.5 MW/8.5 MWh
	Hawaii electric light company VRLA battery project	Keahole Generating Station	17 MW/5.7 MWh
	SUBARU project (VRB flow battery)		10 MW/15 MWh (3 h rate)
	Puerto Rico Electric Power Authority (PREPA) battery	Hokkaido, Japan	4 MW/6 MWh (6MW×30's pulse power)
	System (Lead Acid, Flooded Cell)	Puerto Rico	20 MW/14 MWh
	Metlakatla lead acid battery project	Metlakatla AK	1.0 MW/1.4 MWh
Power quality	Arizona lead acid battery project	Phoenix, AZ	10 MW/4.17 MWh
	PQ2000 installation at Brockway Standard	Geogia,USA	2 MW/55 kWh
	Lithography plant in Hornerville (lead acid)		

Table 2: ESS devices for frequency adjustment type in Korea

		Battery		PCS		Control	
Site	Facility cap (MW)	MWh	Supply	MW	Supply	Product	Supply
SAS (GFC type)	16	5.4	KoKam	16	LS IS	GE R×3i (USA)	Nexchal
	12	6.16	LG Chem	12	WooJin IS	Beckhoff (Germany)	Power21
SYI (AGC type)	16	11.76	Samsung SDI	16	EN Tech.	GE R×3i (USA)	NeoPis
	8	5.9	Samsung SDI	8	LG CNS	GE R×3i (USA)	Zenith Tek

addition, it was reinforced the power system and smoothing of the renewable power source by storing energy to prepare for unrespecting power supply and demand unbalances. It was able to optimize energy and control quality through saving and discharging power in cooperation the ESS with renewable energy in the site in the unconnected power system. Therefore, it could be efficient independent operation by using ESS.

Recently, the BESS was studied on frequency adjustment and power quality improvement in the power system 9 as shown in Table 1.

Demonstration test of the ESS: The ESS was installed the power system by operating the GFC type and the AGC type in Korea. The ESS capacity has been operating the 28 MW (11.56 MWh) and 24 MW (17.66 MWh) with the battery, Power Conversion System (PCS) and controller in the SAS and SYI location as shown in Table 2.

The frequency control was classified to steady state, transient state and steady-transient switching state control methods. The steady state control has been generated the output by proportional the frequency error and the power system parameters. The transient state control was fully discharged by operating the ESS when started the rate of change frequency is >-0.0306 Hz/sec and stopped operation when frequency is 59.9 Hz. The frequency has been recovered to linear slop for 0-10 sec from the transient state to the steady state. The BESS was automatically operated frequency recovery according to rapidly dropping the power system frequency due to failure of nuclear power generator in Fig. 3.

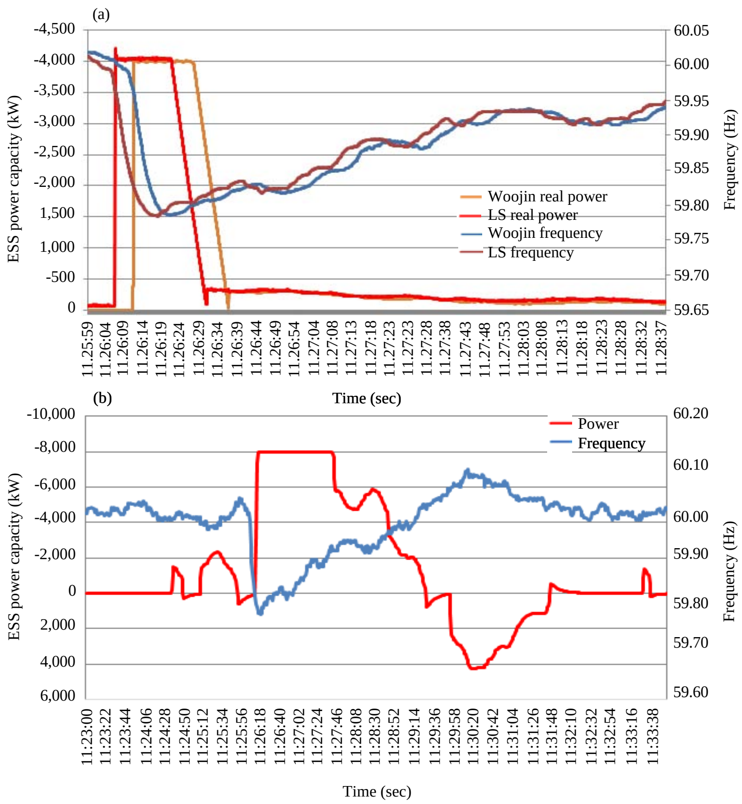

Fig. 3: ESS operation characteristics in case outage of the Nuclear power generator: a) The GFC operating result for recovering the power frequency in the SAS substation and b) The AGC operating result for recovering the power frequency in the SYI substation

RESULTS AND DISCUSSION

Periodic analysis by operating the ESS: The power system was analyzed the frequency characteristics by operating BESS in Fig. 4. The GFC mode was operation in the SAS substation, the response distribution of the load fluctuation was concentrated the operation the extremely restricted region with only 8 MW capacity according to the dead-band and small ESS capacity. In spite of those condition, the SYI substation was shown controlled some quantity of frequency fluctuation bandwidth in the power system.

The load distribution was analyzed data of load variation by the representing day the power system of the Spring, Summer and Winter in Fig. 5. A result, the fluctuation of the GFC mode operating time was shown the greatest load variation on the peak load. The load fluctuation was larger in Summer and Winter than in Spring.

Dynamic analysis for recovery frequency of the ESS: It was simulated the frequency response characteristics

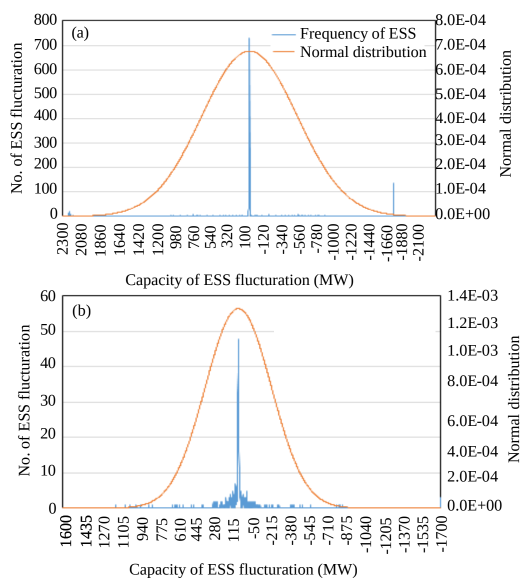

Fig. 4: Operating characteristic of BESS by failure the nuclear power; a) The GFC response result by operating the BESS in the SAS substation and b) The AGC response result by operating the BESS in the SYI substation

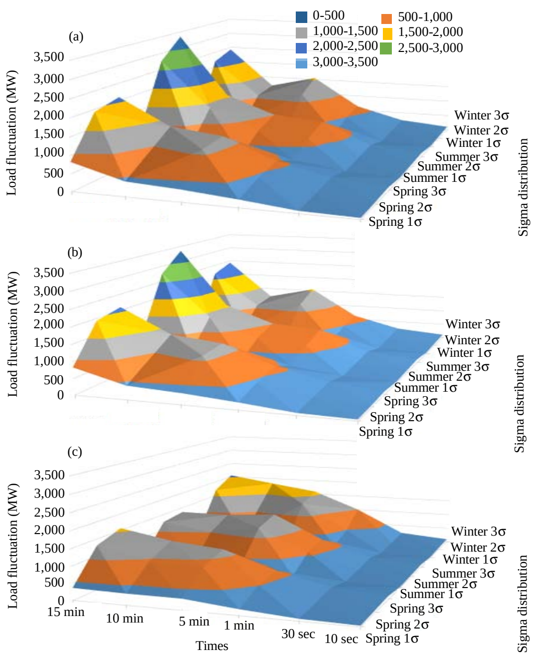

Fig. 5: The probability of sigma distribution according to load variation over time: a) Load fluctuation distribution of the off-peak load daily data in domestic power syste; b) Load fluctuation distribution of the mid-peak load daily data in domestic power system and c) Load fluctuation distribution of the peak load daily data in domestic power system

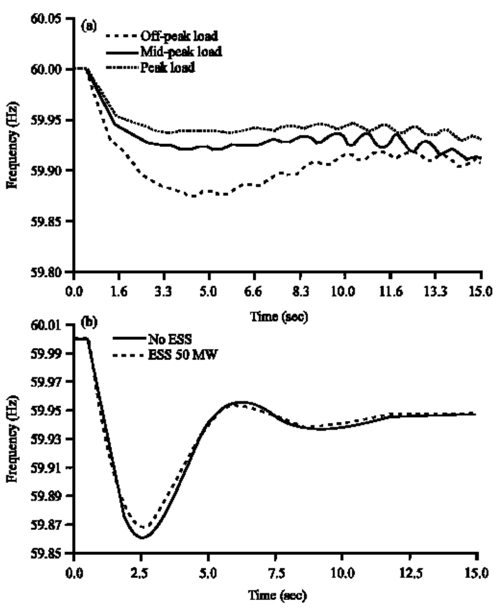

Fig. 6: Compared frequency fluctuation the simulation data: a) The curve of failure the nuclear power generator according to load level and b) The curve by whether or not the ESS

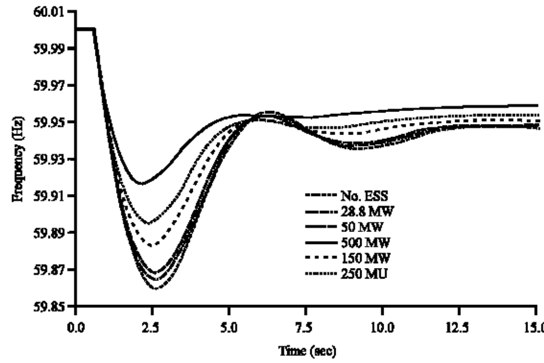

Fig. 7: Frequency characteristics by changing the ESS capacity in the power system

of the nuclear power generator for each load level (off-peak, mid-peak and peak loads) in the power system in Fig. 6.

It was compared the measured and simulated result using PSS/E program in order to examine the frequency characteristics in failure of the nuclear power generator. And it was observed the improvement effect while increasing the ESS input capacity. Case of not installed the ESS, the frequency has been shown the drop of -0.13 Hz in the off-peak power system.

The frequency variation characteristic has been simulated through load fluctuation of increasing the interval between 50 MW in the ESS capacity in Fig. 7. It was not necessary to add the ESS to maintain the frequency tolerance (±0.2 Hz) but 500 MW ESS was required to meet the frequency target (±0.1 Hz) of the power electricity company.

CONCLUSION

To determine the BESS capacity required for frequency adjustment for large power system, the frequency response characteristics for load and power fluctuations were obtained by recording the simulation. The required capacity of BESS for high frequency stabilization was calculated. The main points were as follows.

- First; the load fluctuation is 795 MW at the time of frequency adjustment which is smaller than the dropout capacity of the nuclear power plant
- Second; the introduction of BESS for frequency adjustment at the time deviation range. However, it is necessary to achieve the target frequency
- Third; the BESS capacity required to achieve the target frequency (±0.1 Hz) was simulated at 500 MW

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