Impact Mitigation of Wind Farms in the Jeju Island Power System with BESS

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Abstract. This paper presents analysis of impact mitigation of wind farms with BESS(Battery Energy Storage System) in the Jeju Island power system, which is composed of several wind farms, thermal power plants. To analyze the impact of irregularly fluctuation of wind power generation output in the Jeju power system, three kinds of major components are modeled: a total of 202 MW wind farms, thermal power plants and 372MW Jeju power system load. And simulation has been carried out for two case studies by using PSCAD/EMTDC program. One is for the steady-state operation under variable speed wind, and the other is for transient-state operation when 108MW wind farms are disconnected suddenly from the Jeju power grid due to the electric trouble. These comparative studies have been effective in analyzing the impact mitigation of wind power generation on the Jeju power system.

Keywords: BESS, Wind farm, Thermal power plant , PSCAD/EMTDC

1 Introduction

The Korean government selected Jeju Island in Korea on June 2009 as the location for smart grid test-bed and 10 consortiums in five areas which are smart power grid, smart renewables, smart green homes, smart power market and smart transportation have been participated in testing technologies and developing business models between 2009 and 2013. Especially, wind power, the most plentiful renewable energy in Jeju, is considerably installed and developed for the smart renewable project. However, because of irregularly variable speed wind in Jeju, it is difficult to apply the wind power generation output as stable electric source. To solve this problem, two kinds of studies are being popular in many countries, one is to add control algorithms in each wind turbines, and the other is to install additional hardware for example, ESS (Energy Storage System).

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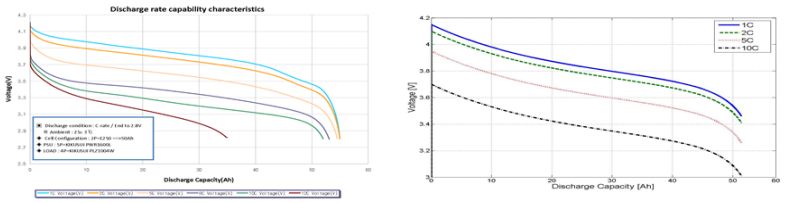
In this paper, two kinds of simulations are carried out for the analysis of the impact mitigation of wind farms by using the PSCAD/EMTDC program. One is the steady-state operation under the rated wind speed, and the other is the transient-state operation when 108MW among total wind farm capacity in the island are disconnected suddenly from the Jeju power grid due to the grid trouble under the variable speed wind. With the simulation results, it is very useful to analyze power quality under the steady and transient state to understand the impact mitigation of wind power generation with BESS in Jeju Island power system.

2 Modeling and Simulation

2.1 Modeling of BESS



(a) Discharge curve of the Li-ion Battery (b) Discharge curve of the modelled Li-ion Battery

Fig 1. Comparison of discharge curves

$$f_{bat(it)} = E_0 - k\frac{Q}{Q-it} \cdot it + Aexp(-B \cdot it) \quad (1)$$

BESSs are modeled by Shepherd nonlinear battery model as demonstrated by (1). The applied model is based on Li-ion battery whose rated voltage is 3.6V and capacity is 50Ah. Fig. 1 shows two discharging curves, (a) is applied and (b) is modeled and they have similar characteristics each other. With the model battery, it is applied to all of wind farms in the Jeju Island.

2.2 BESS control

When the wind farm is dropped from the grid due to internal or external trouble, thermal power plants immediately have need to cover the loss of wind power generation. The drop rate of power generation in Jeju Island power system should be limited within 10MW per minute according to grid code which is the maximum incremental power of the power system. Therefore, the minimum capacity of BESS for the stabilization when the wind farm is disconnected, C_{bat_min}, is

$$C_{bat\_min} = \frac{P_{wf} * T_{op}}{2} \quad (2)$$

where, P_{wf} is the rated power of wind farm, T_{op} is the time to retain the slope 10MW/min from the rated power in the wind farm to zero, i.e. T_{op} is

$$T_{op} = \frac{P_{wf}/10}{60} \tag{3}$$

Substituting (3) into (2) yields

$$C_{bat\_min} = \frac{P_{wf}^2}{1200} \tag{4}$$

2.3 Modeling of Jeju Island Power System

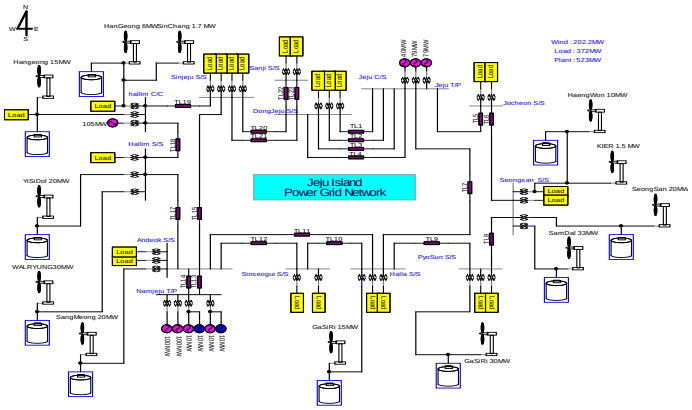


Fig 2. Virtual power grid network of Jeju Island in 2014

TABLE 1. PARAMETERS OF POWER PLANTS

		Ju_40MW	Ju_79MW	NJ1_100MW NJ2_100MW
Type		Diesel turbine	Steam turbine	Steam turbine
Power rating [MW]		40	79	100
H [MW*sec/MVA]		6.71	6.90	5.93
Open circuit Time constant [sec]	$T_{do}^{'}$	7.60	2.75	10.30
	$T_{do}^{''}$	0.087	0.047	0.046
	$T_{qo}^{'}$	0.067	0.127	0.093

Fig. 2 shows the PSCAD/EMTDC model of Jeju Island power system. There are four types of components: thermal power plants, wind farms, transmission lines and the loads. On the assumption of 372 MW base load in Jeju Island, the supply of electric power is from three kinds of power generation systems: thermal power plant composed of a 40 MW diesel engine, one 79 MW and two 100 MW steam turbine generation systems, and wind farms located in several different sites supplying power

up to the maximum of 202 MW under variable wind speed. The system parameters for thermal plants are listed in Table 1.

2.4 Simulation Results

To verify the effectiveness of proposed modeling system, two kinds of wind speed are applied to the wind farms located in the east side of Jeju Island with and without BESS. One is constant wind speed, and the other is variable speed wind, respectively. Fig. 3 shows simulation results under the simulation conditions. To analyze the transient characteristics of power output and grid frequency in Jeju Island power system, wind farms, 108MW, were shut down at 10 sec immediately. Fig.3(a) and (b) show the transient-state during 10-20sec in the grid frequency without BESS even though constant wind speed and variable speed wind. But there is no transient-state in Fig.3(c) and (d) with BESS in the same wind speed situation because BESS discharged during this time.

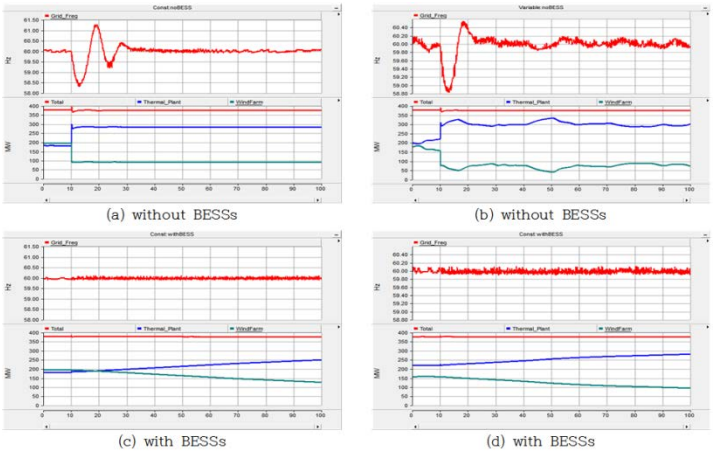


Fig 3. Simulation results
(a),(b) Power output and grid frequency without BESS
(c),(d) Powr output and grid frequency with BESS

3 Conclusion

Modeling and analysis of impact mitigation of wind farms in the Jeju Island power system, consisting of thermal power plants, power load, and several wind farms with BESS, have been performed under constant and variable wind speed by using the PSCAD/EMTDC program. In the simulation study, it has been shown that the variable power generation of intermittent wind farms without BESS has effects on the grid frequency and power generation of thermal power plants in steady-state. In transient-state when the wind farms were shut down due to the trouble, the BESS was

able to pick up the power lost from the wind farms, and yet not affecting the grid frequency. Therefore we can be expected that the proposed schemes and method are very useful for installing and operating the BESS for strengthen the power system stability.

Acknowledgments

This work was supported by the Human Resources Development of the Korea Insitute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Knowledge Economy. (NO.2009402020002)

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