Review on compensation of power fluctuation in large scale wind farm using hybrid energy storage system

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Abstract: This paper proposes an application of superconducting flywheel energy storages (SFESs) to compensate the power fluctuation of the large scale wind farm. Based on the global interest against global warming, the power capacity of the renewable generation, especially wind generation, has been increased steeply. However, since wind generations depend on the natural wind speed completely, the power output cannot be controlled. The power fluctuation caused by the non-controllable output characteristic may create voltage problem for local system and frequency problem for whole power system. To solve those problems, the hybrid application of the large-capacity battery energy storage system (BESS) and the high-speed superconducting flywheel energy storage system (SFES) are considered for wind farm. Through the case studies based on the site-measured output data, the optimal power and energy capacity of the BESSs and SFES are figured out.

I. Introduction

Due to the increasing interest in the smart grid which focuses on greenhouse reductions, many efforts have been made to establish the smart grid on a national scale including from the domestic industries and academia. Increasing the utilization of renewable energy is being implemented for the reduction of greenhouse gases where the wind power is being considered as the appropriate renewable energy sources in terms of efficiency and economical aspects. The scale of wind farms have been increasing and large-scale wind farms have already been constructed and under operation and additional sites is planned. However, wind power has intermittent output characteristics, which makes it difficult to maintain stable outputs, thereby requiring many issues to be addressed when the large scale wind farms are linked to the system. Since the fundamental problem caused by the connection of wind power is the intermittence in the power output, technology developed for stabilizing the wind power output will be beneficial for the dissemination of wind power. Measures to suppress the effects on the grid owing to the output change are being studied from various aspects, out of which utilizing the energy storage technology is available. The flywheel, the object of the study in this paper, is an energy storage device that stores mechanical energy utilizing the rotational inertia of the rotor, where superconducting bearings are being applied to eliminate the thermal losses due to the friction in the pivot bearings. The main advantage of these flywheel storage devices is that the response rate and efficiency is relatively high. In terms of electrical characteristics, the SFES (Superconductor Flywheel Energy Storage), depending on the design of the rotor, has an advantage of implementing a high storage capacity since the rotating mass can be increased for the same mass, but also has the disadvantage that the instantaneous output is not very high since it utilizes devices with permanent magnet in the rotor to eliminate the loss due to the magnetic coupling in the device. This paper proposes a measure to compensate the output of wind farm by utilizing a super- conducting flywheel, which has a quick response and low power capacity, and a battery energy storage system, which has a comparatively lower response capability and high power capacity when compared to the flywheel.

II. STORAGE SYSTEM MODEL

BESS (Battery Energy Storage System) and SFES are being utilized in this paper in order to compensate the wind farm's output variability. Generally, since BESS has slower response characteristics and a larger capacity when compared to SFES, BESS can compensate large fluctuations whereas the SFES can respond to rapid fluctuations. This paper proposes a hybrid compensation method that combines the advantages of each storage device to effectively compensate the intermittent wind power output.

A. *BESS*

In spite of the low response capability, BESS is an energy storage devices can ensure a high reliability of energy supply and achieve a high storage capacity with a relatively low installation cost. As shown in Fig. 1, the battery is connected to the system through an AC-DC inverter and a DC-DC converter for flexible charging/discharging characteristics. The AC-DC inverter plays the role of the active rectifier, whereas the DC-DC operates as the charger.

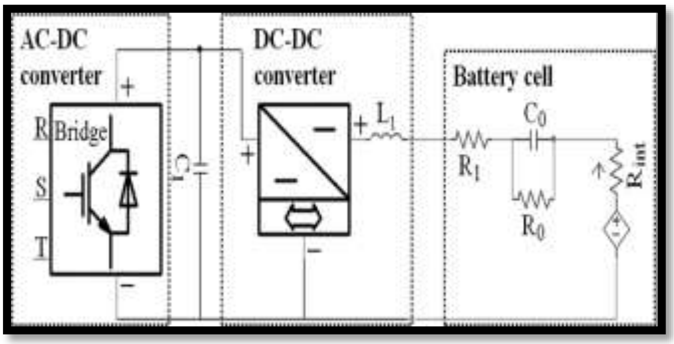

Fig. 1 Battery model and controller set

B. *SFES*

The superconducting flywheel utilizes the permanent magnet synchronous motor/generator. As mentioned earlier, due to the usage of superconducting bearings, the PMSM/G model, which has a friction torque of 0, should be utilized instead of the general synchronous machine which generates heat due to the magnetic coupling of the rotor and stator. Fig. 2 shows the grid connection diagram of the 900 kW PMSM/G model.

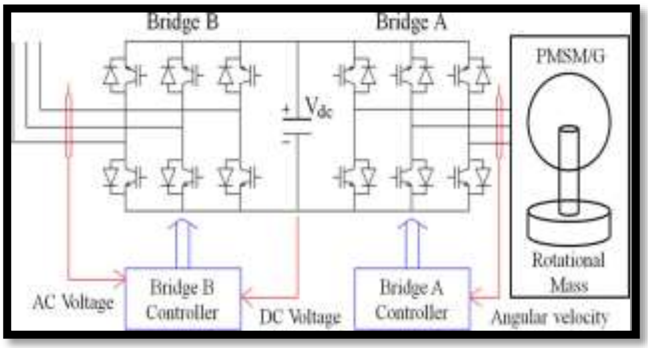

Fig. 2 Grid connection diagram of 900 kW PMSM/G

III. Proposed Work

The intermittent nature of wind is the biggest problem associated with wind power. Therefore, we use BESS to reduce the power fluctuations. Fig. 3 illustrates that the BESS is used to compensate for the intermittent output power of the wind turbine. As shown in Fig. 3, the DFIG is driven by a wind turbine and a gearbox. The mechanical power output of the wind turbine as a function of wind speed and blade pitch angle is described in the wind turbine model.

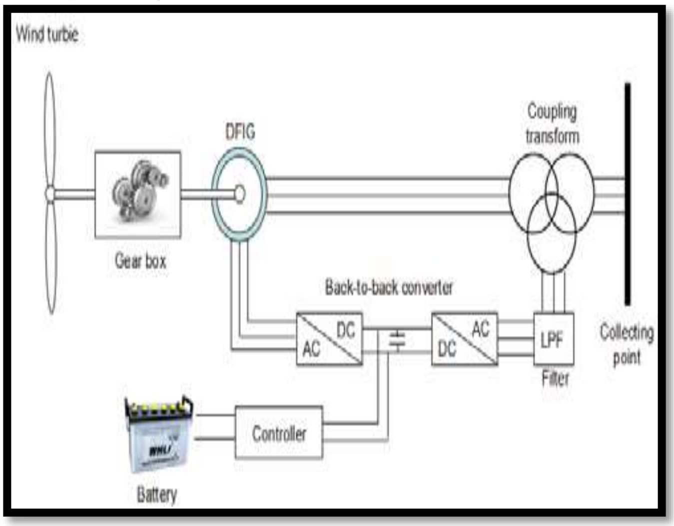

Fig. 3 BESS integration with wind energy conversion system

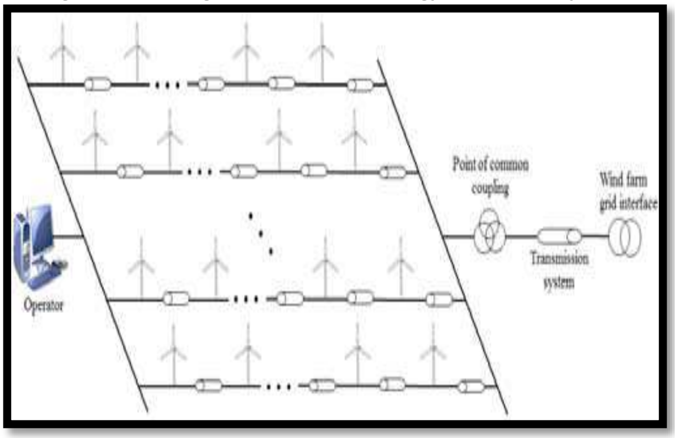

Fig. 4 The network layout of the wind farm

The wind farm consists of several wind turbines that BESS are integrated into wind turbines to smooth the output power of wind farm. The power reference of wind farm is distributed to each wind turbine by operator. Then each wind turbine tracks the power reference of each wind turbine by BESS. The BESS is connected into the wind turbine between the DC/AC converter and AC/DC converter. Also, the BESS can be charged/discharged to smooth the output power.

IV. Modelling and Results of Wind System

The Matlab modelling of PMSG type wind power plant is shown in the fig 5 below. The Excitation system and Wind turbine section is provided with synchronous generator. The simulation results shows the output voltage of wind turbine and also shows the different parameters output like stator voltage, excitation voltage and other mechanical parameters also.

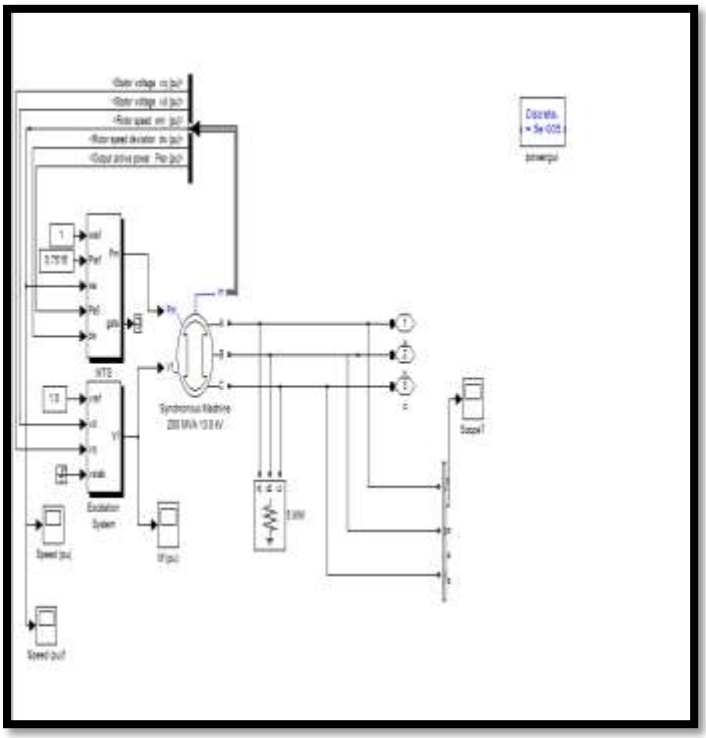

Fig 5-Wind Power Plant Simulation Circuit

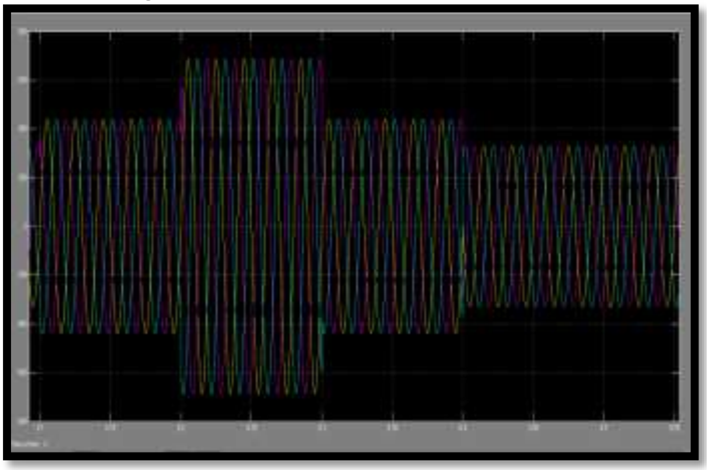

Fig 6- three phase output voltage of wind power plant

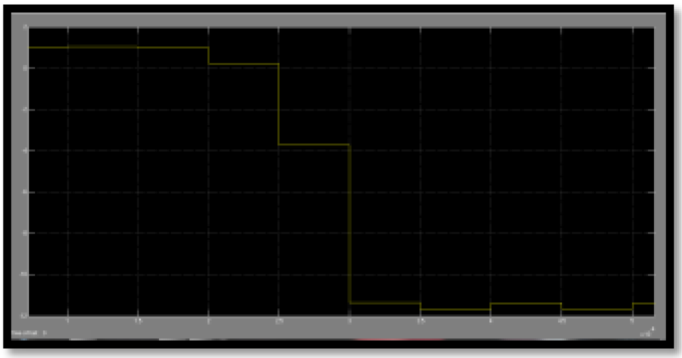

Fig 7- Excitation voltage in p.u for wind power plant

V. CONCLUSION

In this paper, the wind farm output stabilization measures were simulated by utilizing the energy storage characteristics of SFES and BESS. In order to stabilize the wind farm output, a hybrid storage device scheme has been proposed where the energy storage device capacity and response rate has been considered to combine the high capacity battery and flywheel device. Simulation results show that instead of only using BESS, adequately mixing SFES with BESS is a more efficient and effective method for stabilizing the output of wind farms. However, above a certain level, increasing the SFES capacity didn't show much improvement in the compensation. Therefore, future studies will be required from an economic point of view for the calculation of the SFES capacity and the optimal combination of the energy storage devices.

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