A feasibility study on HTS SMES applications for power quality enhancement through both software simulations and hardware-based experiments

Abstract

SMES system provides higher efficiency and faster response of charging and discharging energy. Thus it can be utilized as a power quality enhancement device especially in connection with renewable energy sources. In this report, a software simulation and an experiment result aiming at power quality enhancement are described. The study was performed using PSCAD/EMTDC and power-hardware-in-the-loop simulation scheme.

1. Power network configuration

The number of charging and discharging cycles of SMES is not limited [1–3]. Because of these advantages, various scales of HTS SMES projects have been carried out around the world [4, 5]. The model power network includes five generators as shown in Fig. 1. All generators were operated in governor free mode and the speed droop values were referred to IEEE Std. 1207™-2004. The type of WPGS is a 600 kW squirrel cage induction generator (SCIG).

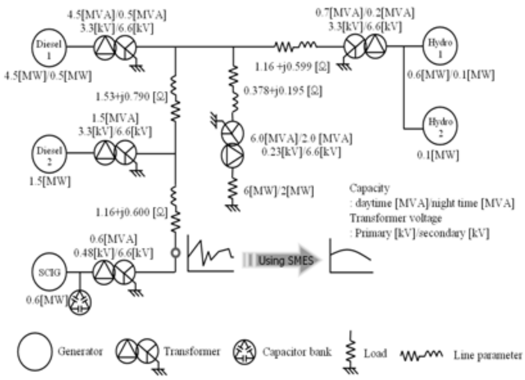

Fig. 1. Schematic diagram of the model power network including WPGS

2. PSCAD/EMTDC simulation

A software based simulation of the model power network including SMES was performed using PSCAD/EMTDC. Fig. 2 describes the control block diagram of the SMES system connected to the terminal of WPGS with DC/AC converter and DC/DC chopper. The SMES system is represented as an inductor in the simulation circuit.

At night, the capacity of the WPGS occupies about 21% of the total capacity of the generator and wind velocity varies between 7 m/s and 12 m/s on average. Consequently, the frequency fluctuation of the system violates its allowed limits, 60 ± 0.2 Hz. The energy capacity of the SMES was selected as 1 MJ and 2.5 MJ, and rated current was 450 A and 944 A, respectively. Fig. 3 represents the stabilization results for the utility frequency. It is clearly seen that the 2.5 MJ SMES can suppress the frequency fluctuations within the allowed limits.

3. Power-hardware-in-the-loop simulation

During the software simulation, the SMES is represented as only an inductor with operating current. To monitor not only the temperature variations but also

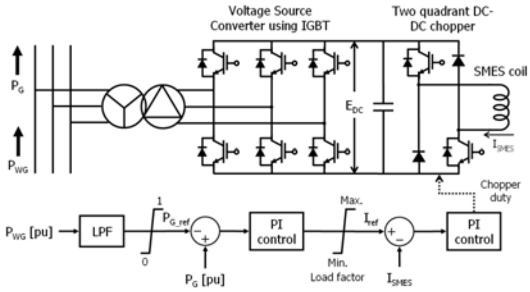

Fig. 2. Simulation circuit in PSCAD/EMTDC: Control diagram of DC/DC chopper for SMES system

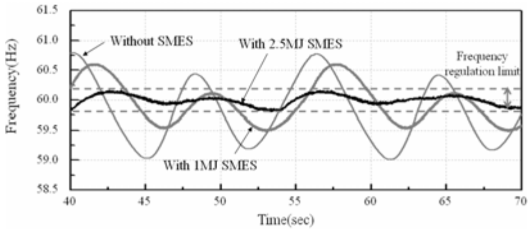

Fig. 3. Comparison of load side frequency stabilized by 1 MJ and 2.5 MJ SMES systems

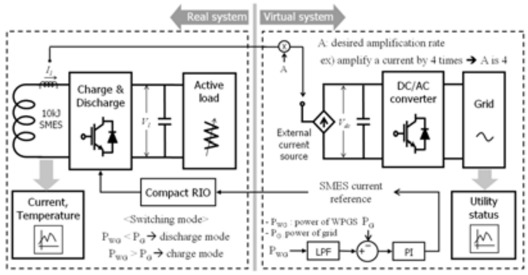

Fig. 4. Conceptual diagram of PHILS with RTDS and a real HTS SMES

operational characteristics of the SMES, PHILS was implemented. Fig. 4 shows a conceptual diagram of PHILS using RTDS and a real SMES [6].

The model power network was simulated using RTDS with the manufactured 10 kJ toroid-type HTS SMES and it was amplified as 2.5 MJ SMES in this simulation circuit. Fig. 5 depicts the hardware system which consists of a toroid-type HTS SMES, a DC/DC chopper. The toroid-type HTS SMES consists of a cryocooler for conduction cooling, metal current leads of brass between room temperature and cryogenic temperature condition, and HTS current leads made of coated conductor [6, 7].

Fig. 6 shows the utility frequency stabilized by the SMES system. The 10 kJ toroid-type HTS SMES was initially charged to 150 A, and consequently 2.5 MJ SMES in RTDS was initially charged to 600 A in RTDS. During the PHILS, the variations of the temperature of 10 kJ toroid-type HTS SMES were monitored in real time as shown in Fig. 7. The temperature varied according to the current charge and discharge, and the maximum temperature of one of the double pancake coils increased up to 9.2 K.

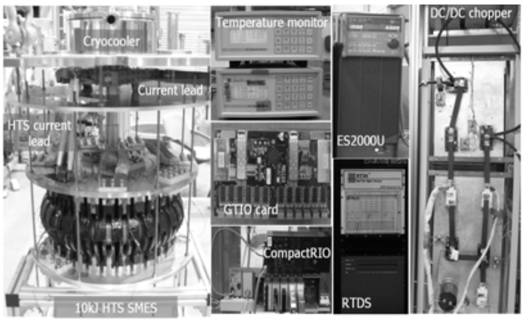

Fig. 5. 10kJ toroid-type HTS SMES and DC/DC chopper

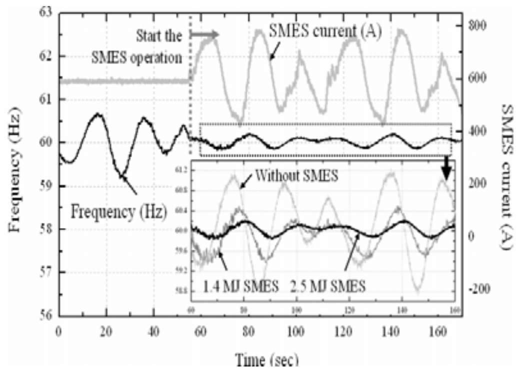

Fig. 6. Utility frequency stabilized by the SMES system and the variation in the current of the SMES using PHILS technology

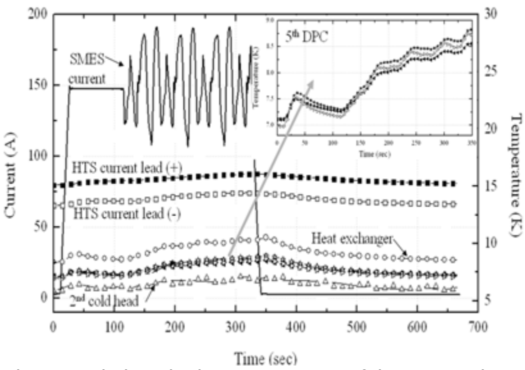

Fig. 7. Variations in the temperature of the SMES due to the operating current variations during compensating the fluctuation of utility frequency

4. Discussions

In this paper, software-based simulation and experiments aiming for power quality enhancement were performed to demonstrate the feasibility of the SMES system. According to the software-based simulation results, it is concluded that the 2.5 MJ SMES can be utilized to the model power network for frequency stabilization. Through the PHILS results, it is possible to monitor both power network status and operating conditions of the SMES system at the same time. Both results confirmed that a SMES system can possibly be utilized to enhance power quality in connection with renewable energy sources.

At present, a 2.5 MJ toroid-type HTS SMES is being manufactured in Korea. Using the current variation as shown in Fig.6, the losses such as eddy current loss and magnetization loss of the 2.5 MJ SMES can be calculated when it will be used for frequency stabilization. Furthermore, operational characteristics of not only 2.5 MJ toroid-type HTS SMES but also all types of SMES will be able to be predicted with higher reliable results through both software simulations and hardware-based experiments.

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Keywords

Power quality, Real time digital simulator; Superconducting magnetic energy storage

Contact to

In-Keun Yu
Changwon National University, Changwon , 641-773, Korea
E-mail: yuik@changwon.ac.kr