System Frequency and Tie-line Power Flow Control by Coordination of Batteries and Heat Pump Based Water Heaters on Customer Side in Power Systems with a Large Penetration of Wind Power Generation

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Abstract

Nowadays, due to rising environmental concerns, greenhouse gas reduction and energy conservation gain much attention. Therefore, it is expected to interconnect a large amount of generation from renewable energy such as wind power generation in the near future. However, a large penetration of wind power generation causes some problems to the power system, e.g. frequency fluctuation, because of its power output fluctuation. Installation of battery energy storage systems (BESS) is one of the effective solutions to this problem. Control methods of BESS have been studied in many researches, while it is desirable to keep the capacity of BESS as small as possible due to the high cost of BESS.

In this research, a number of heat pump based water heaters (HPWH), one of the energy efficient-use customer equipment, as well as BESS, are considered as controllable equipment for regulating the frequency. The HPWH are conceived as controllable loads because the transition of energy consumption can be changed if the water is already heated. The utilization of customer equipment such as HPWH for power system control, e.g. the frequency regulation and the emergency control, while considering customers' convenience, is one of the key elements in the concepts of a Ubiquitous Power Grid, our research group has proposed. To realize the Ubiquitous Power Grid, it is essential to establish a control method of controllable loads in order to alleviate uncertainty caused by increasing renewable energy sources such as wind power generation and photovoltaic generation. A coordinated control method of the BESS and the HPWH to suppress frequency fluctuation and the tie-line power flow fluctuation is introduced. The proposed method is considered as a centralized control one. According to their response speed and capacity, the central load dispatching control center provides Load Frequency Control (LFC) signals into three parts, LFC generators, BESS, and HPWH.

The effectiveness of the proposed method is manifested by numerical examples conducted on IEEJ 30-machine system, which is an interconnected two-area system model. The frequency of the larger area is controlled by Flat Frequency Control (FFC) and that of the smaller area is controlled by Tie-line Bias Control (TBC). It is made clear that the system frequency is improved and the tie-line power flow fluctuation is suppressed. It is found that it is more effective to control BESS and HPWH coordinately than to control only BESS. Moreover, the result shows that the proposed method can reduce the BESS capacity.