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A novel use of the hybrid energy storage system for primary frequency control in a microgrid

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Abstract

High penetration of renewable energy causes fluctuations of power flow and results in system frequency fluctuation, which significantly affects the power system operation. The situation in microgrid (MG) is worse because of the low inertia and small time constant of the system. This paper present a novel use of the superconducting magnetic energy storage (SMES) and battery hybrid energy storage system with the function of frequency control in the MG. A hybrid power management strategy for the SMES and the battery is used to achieve, firstly, a faster primary frequency control and secondly, an improvement of battery service time.

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Keywords: Battery, Frequency control; Hybrid energy storage system (HESS); Lifetime extension; Microgrid (MG); Superconducting magnetic energy storage (SMES).

1. Introduction

Microgrid is defined as a low voltage power system which has a cluster of loads and generators and is able to provide electricity to its local area [1]. The distribution generations using renewable recourse can be integrated into a microgrid efficiently [2]. However, due to variable nature of renewable sources and fluctuating load profiles, the power supply in the MG sometimes cannot match the load demand. The unbalance between generation and load will result in system frequency fluctuation and the situation in MG

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is worse because of the low inertia and small time constant of the system [3]. Therefore, frequency control is a critical in the island MG.

Battery energy storage systems which have high efficiency and large energy density [4] are believed as effective solution for power balancing in an island MG. Many works have been done to study batteries using in off-grid MG: shave peak demand and store the surplus renewable energy in [5, 6], improve power quality [5] and frequency control [3, 7]. However, the limited service lifetime and the relative low power density are mainly two disadvantages that limit the usage of battery [8, 9].

Many previous works have introduced SMES/battery HESS in different applications: improving overall system efficiency in wind applications [8], compensating fluctuating loads in railway system [10], extending battery lifetime in electrical buses [11], etc. However to the authors' best knowledge, there is no published work using the SMES/battery HESS in the MG with the frequency control function. The improvement of battery lifetime in a battery and SMES HESS has already been proved by many previous works [10, 12], but few article does quantitative analysis of the extension of battery lifetime. In this paper, a battery and SMES hybrid energy storage system used in MG is designed and tested in simulation achieving, firstly, the frequency control function and secondly, an extension of battery lifetime. The battery lifetime in the HESS is quantitatively increased based on a battery lifetime model.

2. System configuration and modelling

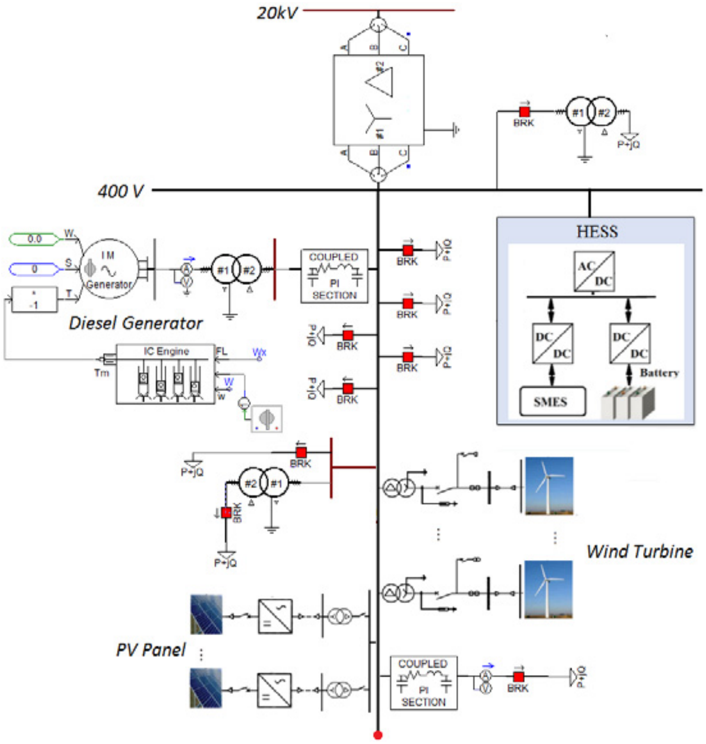

Fig. 1 Single line configuration of the MG system.

A dynamic MG system based on the benchmark system [13] with renewable powers and the SMES/battery HESS has been established in the PSCAD/EMTDC software. The single line topology of the MG is shown in Fig. 1. A 400V distribution system connects to a 20 kV final station via the transformer. The battery and SMES HESS is interfaced with the 400 V bus by the AC/DC converter. The SMES and battery are modelled and sized using the methods described in [11, 14]. The diesel generator (DG) with rated voltage of 400 V is build based on the IEEE standard AC1A. The wind turbine (24 kW) and the solar panel (15 kW) in this study are modelled based on the previous work described in [3].