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Frequency Control for Island Operation of Bornholm Power System

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Abstract

This paper presents a coordinated control strategy of a battery energy storage system (BESS) and distributed generation (DG) units for the island operation of the Danish island of Bornholm. The Bornholm power system is able to transit from the grid connected operation with the Nordic power system to the isolated island operation. In order to ensure the secure island operation, the coordinated control of the BESS and the DG has been proposed to stabilize the frequency of the system after the transition to the island operation. In the proposed coordinate control scheme, the BESS is used to provide the primary frequency control and the DG units are used to provide the secondary frequency control. As such, the proposed control scheme can strike a balance of the frequency control speed and the energy used from the BESS for the frequency control support. The real-time model of the Bornholm power system was used to carry out case studies using real time digital simulator (RTDS) to illustrate the performance of the coordinated control strategy. Case study results show that the proposed control strategy can efficiently help stabilize the frequency under different conditions.

Keywords: Battery energy storage system (BESS), distributed generation (DG), island operation, load frequency control (LFC), real-time digital simulator (RTDS)

1. Introduction

Denmark has a very pro-active energy policy. As it can be seen in the future energy outlook and policy of Denmark, more renewable energy integration is planned in the near future. The Danish parliament has entered a new energy agreement and set a target of 50% penetration of wind power in 2020, 100% renewable energy penetration in the electricity and heating sectors in 2035, and 100% independent of fossil fuel in 2050 [1]. In relation to the planning and operation of the future power system and smart grid technology development, the Bornholm Island is of great interest due to the characteristics of the

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Bornholm power system. The Bornholm power system has a high share of electricity supplied by renewable energy sources (RES) and can represent a future power system to a great extent in the island operation mode. The power generation on Bornholm consists of 1 steam unit, 1 combined heat and power (CHP) unit, two biomass generation units, 14 diesel units, and a large share of wind power generation supplying 30% of the total electricity consumption with an additional 20MW estimated to be installed in the near future. The future scenario of wind power installation will certainly create serious challenges to the power system operation and control. Additional power balancing is required for dealing with the intermittent characteristics of the wind power.

The Bornholm power system is connected through a long submarine cable to the Swedish power system. The sea cable can be disconnected to test a restricted area with a very high share of renewables. During these periods, frequency control of the system becomes fairly difficult. Several projects in Denmark have been carried out by Energinet.dk, the transmission system operator (TSO) [2-4]. Since the wind power generation is intermittent, they cannot guarantee the constant power supply required by loads. Furthermore, the DG units with relatively slow response have insufficient dynamic performance in terms of load tracking [5]. To deal with the frequency control challenges, energy storage systems (ESS) are considered to be an effective solution. The Battery energy storage system (BESS) is the most efficient technologies because of its fast response and relatively large capacity. It is used to improve the power system operation and control with high renewable energy penetration. Quite many studies have been reported on the use of BESS [6–10].

This paper is to develop a coordinated control strategy of a BESS and distributed generation (DG) units for the island operation of the Danish island of Bornholm. In the proposed coordinate control scheme, the BESS is used to provide the primary frequency control and the DG units are used to provide the secondary frequency control. As such, the proposed control scheme can strike a balance of the frequency control speed and the energy used from the BESS for the frequency control support.

The paper is organized as follows. The control strategy of BESS and DGs is presented in Section II. The Bornholm power system and BESS model are described in Section III. The case study results are presented in Section IV and the conclusions are drawn in Section V.

2. Control Strategy

The main concept of the control strategy is the coordination between the BESS and several distributed generation units, as shown in Fig. 1.

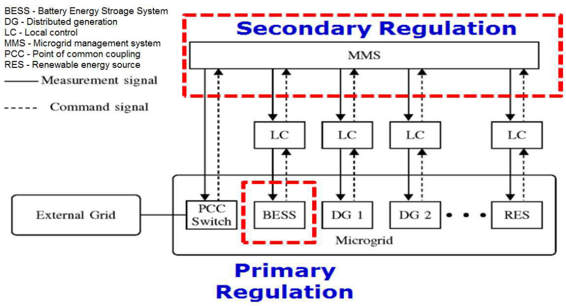

Fig. 1. hierarchical control structure

The power generated by RESs varies faster than conventional power generation. If there is no BESS, the power balance between the generated power and the existing loads does not always match due to the renewable energy fluctuations. As a result, the frequency and the voltage of the grid will fluctuate. This must be properly solved or it can lead to grid instability. Once the island situation is detected, the BESS is activated. Clearly, the BESS can provide fast response by proper power balancing as other DGs or