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An Optimal Virtual Inertia Controller to Support Frequency Regulation in Autonomous Diesel Power Systems with High Penetration of Renewables

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Abstract. This paper addresses the problem of frequency control in autonomous diesel-based power system with high penetration of renewables. Usually, small power systems with high penetration of renewable energies are supplied by one or two small diesel generators, resulting in a system with a relatively low moment of inertia, and which can be susceptible to significant frequency variations. However, frequency regulation can be supported by modifying the inertial response of the system in an artificial way, i.e., by adding a virtual inertia. The latter can be performed by controlling the power electronics interface of a distributed generator or an energy storage unit. In this work, a controller is designed to provide the optimal virtual inertia which minimizes, according to the proposed performance index, variations in the fundamental frequency as well as in the power flow through the energy storage system. The optimal controller is compared by simulations with other virtual inertia control strategies.

Keywords

frequency regulation, virtual inertia, optimal control, energy storage, hybrid power system.

1. Introduction

Diesel generators (gensets) are very popular as main power source in stand-alone power systems. For instance, in autonomous wind-diesel power systems (AWDPS) [1], the power grid is established by a diesel generator—which is a controllable source of energy—and a wind generator (WG) is used to complement power production when the wind turbine reaches a specific speed. With an appropriate control strategy fuel consumption can be reduced, lowering the cost of the energy produced. However, aside from reducing fuel consumption, there also exists the necessity of controlling the frequency of the voltage being supplied to the load. The latter is specially important in small power systems (10-200kW) with high penetration of renewable energies [2], [3]. Usually, this kind of grids are supplied by one or two small gensets, resulting in a system with a relatively low moment of inertia, and which can be susceptible to significant frequency variations due to sudden variations in load demand and/or in the output power of a renewable energy source.

Virtual synchronous machine/generator (VSM, VISMA, VSG) is a novel concept and it has been proposed as a control strategy to tackle stability issues in power systems with a large fraction of inertia-less distributed generators [4]–[9]. The main idea is to control the power electronics interface (PEI) of a distributed generator, or energy storage unit, in order to behave as a conventional rotating generator, which consists of a prime mover and a synchronous machine [10]. Virtual inertia control is a particular case of a VSM implementation, where only the action of the prime mover is emulated to support frequency control.

A. Interest of the work

Since the fundamental concept of VSMs was formally introduced, it has been subject of several publications. Most of the research deals with specific issues on the implementation of VSMs such as: the necessary requirements of the PEI to perform a VSM [11], selection of the storage media [12], and laboratory prototypes for experimental tests [13]. The most recent literature related to VSMs found on the IEEE database has been reviewed and, to the best of our knowledge, no research work has been reported concerning optimal control.

B. Objectives

1) Main objective. Design an optimal controller for the ESS in order to emulate a virtual inertia to support frequency control in a diesel based power system.

2) Secondary objectives. *i)* Model main components of the system, *ii)* Compare the performance of the optimal controller versus other virtual inertia controllers, and *iii)* analyze the effects on the ESS of using the optimal controller.

C. Main contribution

The optimization of the virtual inertia controller with the performance index being the integrated sum of the weighted quadratic regulating errors (QRE) of the power frequency and the power flow through the ESS.

2. System overview and modeling

The system of this study is an autonomous power system based on a diesel generator and a wind generator connected in parallel (see Fig. 1). It also has an energy storage system which is interfaced to the ac-bus by a bidirectional power electronics interface. The active