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DSTATCOM with Flywheel Energy Storage System for wind energy applications: Control design and simulation

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ABSTRACT

In this work, the use of a Distribution Static Synchronous Compensator (DSTATCOM) coupled with a Flywheel Energy Storage System (FESS) is proposed to mitigate problems introduced by wind generation in the electric system. A dynamic model of the DSTATCOM/FESS device is introduced and a multi-level control technique is proposed. This control technique presents one control mode for active power and two control modes for reactive power, power factor correction, and voltage control. Tests of dynamic response of the device are conducted, and performance characteristics are studied taking into consideration variations of power references. Moreover, the behaviour of the device is analyzed when combined with wind generation in the electric system. The results obtained demonstrate a good performance of the model developed and of the control technique proposed as well as a high effectiveness of the device to mitigate problems introduced by wind generation.

1. Introduction

Wind power generation is considered the most economic viable alternative within the portfolio of renewable energy resources. Among its main advantages are the large number of potential sites for plant installation and a rapidly evolving technology. However, the lack of controllability over the wind and the type of generation system used cause problems to the electric systems. Among such problems are those produced by wind power short-term fluctuations, e.g., in the power quality and in the dynamics of the system [1–5]. In addition, the reduced cost of power electronic devices as well as the breakthrough of new technologies in the field of electric energy storage makes it possible to incorporate this storage with electronic control into power systems [6–9]. These devices allow a dynamic control to be made of both voltage and flows of active and reactive power. Therefore, they offer a great potential in their use to mitigate problems introduced by wind generation.

Based on the results obtained by analyzing different selection criteria, a Distribution Static Synchronous Compensator (DSTATCOM) coupled with a Flywheel Energy Storage System (FESS) has been proposed as the most appropriate system for contributing to the smoothing of wind power short-term fluctuations [10]. A DSTATCOM is a fast-response, solid-state power controller that provides flexible voltage control at the point of connection to the utility distribution feeder for power quality improvements [11]. This device can exchange both active and reactive power if an energy storage system is included into the DC bus. FESSs store kinetic energy in a rotating mass, and they have been used as short-term energy storage devices. FESSs can be classified as low-speed flywheel (LS-FESS) and high-speed flywheel (HS-FESS). HS-FESSs are a newer technology and they provide better speeds of response, cycling characteristics and electric efficiencies than LS-FESS [9,12,13]. All these characteristics enable the HS-FESS (FESS from now on), working with a DSTATCOM device, to mitigate voltage fluctuations and to correct power fluctuations of a wind power system. With these aspects in mind, it turns necessary to ponder the information stemming from models that simulate the dynamic interaction between the DSTATCOM/FESS device and power systems with wind generation. Such models allow performing the necessary preliminary studies before connecting the DSTATCOM/FESS to the grid. Many solutions are proposed and studied in the literature to compensate wind power fluctuations using a flywheel energy storage device [14–17]. These solutions have been proposed mainly using LS-FESS and with simplified models of the device. The control design to interact with wind power generation is not explained in detail in the analyzed literature.

The aim of this paper is to present a detailed model and a multi-level control of a DSTATCOM controller coupled with FESS to improve the integration of wind generators (WGs) into a power system. A model of a DSTATCOM/FESS device is proposed with all its components represented in detail. The results obtained from the simulations of this model are compared with characteristic data of manufactures. Moreover, the complete control design for

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