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DYNAMIC PERFORMANCE ENHANCEMENT OF WIND PENETRATED POWER SYSTEM USING SMES AS VIRTUAL SYNCHRONOUS GENERATOR

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Abstract

This paper analyses the impact of superconducting magnetic energy storage (SMES) as a virtual synchronous generator (VSG) on the transient stability of the wind-penetrated power system. A modified 18-machine, 70-bus, 5-area power system is simulated in MATLAB/Simulink environment. Power command for the SMES-VSG unit is generated from frequency deviation and rate of change of frequency deviation for controlling the duty cycle of SMES chopper. System performance is assessed for two different types of disturbances: a step wind perturbation and a three-phase fault in the New England Test System (NETS) and the New York Power System (NYPS). The simulation results show that both frequency deviation and rate of change of frequency deviation (ROCOF) are minimized with SMES as VSG. The transient stability measured in terms of critical clearing time (CCT) verifies that CCT is comprehensively increased compared to other topologies of SMES.

Key Words

Virtual synchronous generator, superconducting magnetic energy storage, frequency, faults, wind disturbance, critical clearing time

1. Introduction

The penetration of renewable energy sources is growing rapidly due to the depletion of fossil fuels, increase in cost of fuels, increase in power demand, etc. For example, China has an installed wind energy capacity of 221 GW and is the leader in wind energy followed by the USA with 96.1 GW. In other countries like Germany, India and Spain, a significant amount of power from renewable energy sources is planned to be connected to their power systems for the next two decades.

Wind and photovoltaic (PV) power are the most commonly used renewable energies. Renewable energy has experienced fast technology growth, which contributes to their availability at considerably low cost [1]. The synchronous generators regulate frequency instability events due to inherent rotor inertia and damping characteristic, as well as voltage control [2], [3]. Suppose the power from the wind farm has to be integrated into the power system. As the wind turbine is decoupled from the grid frequency due to the asynchronous generator, the system only gains power with no inertia and no damping properties. This makes the system prone to frequency deviations [4]. This results in a system prone to large frequency deviations. The concept of virtual synchronous generator (VSG) aims to emulate the behaviour of synchronous generator (SG) to stabilize the power system [5], [6]. VSG consists of the combination of energy storage, inverter and control mechanism. Energy storage can be ultrabattery, supercapacitor, flywheel, superconducting magnetic energy storage (SMES) or battery. Among these, SMES is a fast-acting storage device with almost zero power loss. SMES has a high efficiency and a large number of charge and discharge cycles [7].

The reference output power command of SMES-VSG is given as follows:

$$P_{VSG} = k_I \frac{d\Delta\omega}{dt} + k_D \Delta\omega + k_C (I_{sm}^0 - I_{sm}) \qquad (1)$$

where $\Delta\omega = \omega - \omega_0$ and ω_0 is the nominal frequency of the system.

The first term in (1) emulates the power that is absorbed/released by the positive or negative frequency deviation rate ($\frac{d\Delta\omega}{dt}$) [8]. K_I is the inertia emulating coefficient and determines the response to a high rate of change of frequency deviation (ROCOF) values. Power will be exchanged only during transients because the change in frequency is zero in steady state. After disturbance, if the

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