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Minimization of shaft oscillations by fuzzy controlled SMES considering time delay

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ABSTRACT

This paper analyzes the effect of fuzzy logic-controlled superconductive magnetic energy storage (SMES) on minimizing shaft torsional oscillations of synchronous generators in a multi-machine power system. The proposed fuzzy logic controller has been designed in a very simple way considering only one input variable and one output variable. The time derivative of the total kinetic energy deviation (TKED) of the synchronous generators is used as the global input to the fuzzy controller for SMES switching. The influence of time delay associated with the global input calculation of the fuzzy controller on minimizing shaft torsional oscillations is investigated. Global positioning system (GPS) is proposed for the practical implementation of the calculation of the global input to the fuzzy controller. Simulation results of a balanced fault at different points in a multi-machine power system show that the proposed SMES can minimize the shaft torsional oscillations of synchronous generators well. Moreover, the time delay has an influence on the performance of fuzzy controlled SMES to minimize shaft torsional oscillations. However, even though the performance of fuzzy controlled SMES is somewhat effected by the communication delay, it is clear from the simulation responses that the fuzzy logic-controlled SMES considering typical communication delays can minimize the shaft torsional oscillations of synchronous generators well.

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1. Introduction

Usually in the analysis of power system dynamic performance, the rotor of a turbine–generator is assumed to be made of a single mass. However, in reality, a turbine–generator rotor has a very complex mechanical structure consisting of several predominant masses (such as rotors of turbine sections, generator rotor, couplings, and exciter rotor) connected by shafts of finite stiffness. Therefore, when the generator is perturbed, torsional oscillations result between different sections of the turbine–generator rotor. The torsional oscillations in the subsynchronous range could, under certain conditions, interact with the electrical system in an adverse manner [1]. Conversely, certain electrical system disturbances can impose torque oscillations on the shaft and reduce the life expectancy of turbine shafts. Therefore, sufficient damping is needed to reduce turbine shaft torsional oscillations.

Intensive progress in power electronics and superconductivity has provided the power transmission and distribution industry with superconducting magnetic energy storage (SMES) units. SMES is a large superconducting coil capable of storing electric energy in the magnetic field generated by DC current flowing through it. The real power as well as the reactive power can be absorbed (charging) by or released (discharging) from the SMES coil according to system power requirements. Since the successful commissioning test of the BPA 30 MJ unit [2], SMES systems have received much attention in power system applications, such as, diurnal load demand leveling, frequency control, automatic generation control, uninterruptible power supplies. SMES can also be used to damp torsional oscillations of synchronous generator shafts [3–8]. However, in all of the results [3–8], the analysis of damping shaft torsional oscillations by SMES was carried out in the case of a single machine power system only.

This paper analyzes the effect of the SMES on minimizing shaft torsional oscillations of synchronous generators in a large multi-machine power system. The control scheme of SMES is based on fuzzy logic. It is important to note here that the fuzzy logic system [9,10] for the SMES control is used only based on the fact that it can be designed more easily in comparison to other alternative systems. The time derivative of the total kinetic energy deviation (TKED) of the synchronous generators is used as the input to the fuzzy controller for SMES switching in this work. In real systems, a time delay is introduced in online calculation of the total kinetic energy as well as the time derivative of TKED, which may fatally affect the control system, and consequently the torsional oscillations of

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