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A novel excitation controller to damp subsynchronous oscillations

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ABSTRACT

A novel supplementary subsynchronous damping controller (SSDC) is proposed for the generator excitation system which is capable of damping out subsynchronous oscillations in power systems with series compensated transmission lines. It is shown that the controller is able to stabilize all unstable modes for all compensation ratios. Eigenvalue analysis and transient simulations of detailed nonlinear system are considered to investigate the performance of the controller. Robustness of the controller has been analyzed by facing the system with disturbances leading to significant changes in generator operating point. The IEEE Second Benchmark Model is considered as the system under study. All the simulations are carried out in MATLAB/SIMULINK environment.

1. Introduction

Series capacitors have been used extensively since 1950 as a very effective means of increasing the power transfer capability of a power system that has long (150 miles or more) transmission lines. Series capacitors significantly increase transient and steady-state stability limits, in addition to being a near perfect means of VAR and voltage control. Until about 1971, it was generally believed that up to 70% series compensation could be used in any transmission line with little or no concern. However, when in 1970, and again in 1971, a 750 MW cross compound Mohave turbine-generator in southern Nevada experienced shaft damage it is learned that series capacitors can create an adverse interaction between the series compensated electrical system and the spring-mass mechanical system of the turbine-generators. This effect is called subsynchronous resonance (SSR) since it is the result of a resonant condition, which has a natural frequency below the fundamental frequency of the power system [1].

Numerous papers have been published about damping the SSR phenomenon however, in general most of the papers fall into two different categories: the first is using Flexible AC Transmission Systems (FACTS) and the second is using generator excitation system and power system stabilizer (PSS). Among the two categories the second one has some advantages over the first one. FACTS devices have been available for several years, but have still not been widely accepted by all grid operators for several reasons [2]. Implementing such devices with a high level of reliability imposes some considerable extra costs. To cover the damping for the all series compensation ratios, wide area measurements containing generator speed deviation, rotor angle and etc. are needed [3]; therefore, the cost and complexity increases further. In addition, the measured remote signals must not contain delays larger than some predetermined values. On the other hand since the generator excitation system and PSS locate on the low voltage part of the generator and the all needed signals can be measured easily, the cost of such devices are much less than using FACTS devices. The other advantage of the excitation system over FACTS devices is that in contrast with the FACTS devices it will not change the compensation ratio of the transmission line that can decrease the power transfer efficiency [4]. Shunt reactor controller and SMES are used to damp torsional modes in [5,6], respectively. PID controller with a feedback from generator rotor speed deviation has been used in both of the papers. In [7] a SSDC is designed and added to STATCOM to enhance the torsional mode damping of the system. The SSDC in [7] uses the Thevenin voltage signal to modulate the reactive current reference of STATCOM.

The investigation on the damping of subsynchronous oscillations using excitation controllers dated back to as early as 1975 [8]. Excitation system damper is used in Navajo power plant for the first time [9]. Field tests [10] have demonstrated that the excitation system damper is very effective in controlling torsional interaction and operating experience has been satisfactory. Since then, a lot of papers have been published about excitation system dampers [11–17]. Most of these control schemes failed to stabilize all the torsional modes for the all series compensation ratios. For example, only one mode can be controlled in Fouad and Khu's work [11]. In an attempt to control all the SSR modes pole assignment method is applied [12–14]. Yu et al. [12] employed the method

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