Electric Power Systems Research 80 (2010) 886–892

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Three-dimensional power system stabilizer

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A R T I C L E I N F O

Article history:
Received 18 March 2009
Received in revised form 25 August 2009
Accepted 30 December 2009
Available online 2 February 2010

Keywords:
Power system stabilizer
Synchronous generator
Excitation control

A B S T R A C T

Power system stabilizers (PSSs) are used to enhance damping of power system oscillations through excitation control of synchronous generator. The objective of the PSS is to generate a stabilizing signal, which produces a damping torque component on the generator shaft. Conventional PSSs are designed with the phase compensation technique in the frequency domain and include the lead-lag blocks whose parameters are determined according to a linearized power system model. The performance of conventional PSSs (CPSSs) depends upon the generator operating point and the system parameters, but a reasonable level of robustness can be achieved depending on the tuning method. This paper presents a new three-dimensional PSS (3D PSS), which uses rotor speed deviation, rotor acceleration and load angle deviation as input signals. The 3D PSS attempts to return the generator to the state-space origin, based on the generator's trajectory in state-space and the achievement of torque equilibrium. The 3D PSS is robust to system parameters changes. The proposed algorithm was implemented in a digital control system, tested in a laboratory environment on a synchronous generator connected to the power system, and then compared with CPSS. Experimental results show that the proposed PSS achieves better performance than the CPSS in damping oscillations.

1. Introduction

The problem of power system stability is an ongoing one, in fact, it is a problem of electromechanical oscillations of aggregates, electrical power plants and parts of the power system. Electromechanical oscillations are manifested in the fluctuation of state variables of the synchronous generator, e.g., speed, active and reactive power, voltage, load angle, etc. Oscillations can be weakly damped or not damped at all with constant or increasing amplitude; they can also reach a magnitude where the functionality of a power system is at stake [1,2].

Synchronous aggregate oscillations can be classified into one of the following four categories [1]. *Inter-unit mode* oscillation involves two or more synchronous machines at a power plant, in which machines swing against each other, within the frequency range of 1.5–3 Hz. *Local mode* oscillation is associated with synchronous machines at a power plant, swinging together against a comparatively large power system, within the frequency range of 0.7–2 Hz. *Inter-area mode* oscillation is associated with the swinging of many synchronous machines in one part of the power system against machines in another part of the power system, within the frequency range of 0.2–1 Hz. *Torsional mode* oscillation involves relative angular motion between the rotating elements (synchronous machines, turbines and exciter) of a unit, with frequencies of 4 Hz and above.

PSSs are used to enhance the damping of power system oscillations through excitation control of synchronous generator. Fig. 1 shows the structure of voltage control for a synchronous generator, which consists of inner excitation current control loop and outer terminal voltage control loop. A reactive power controller and PSS are used based on the requirements of the power system. The voltage controller is of the proportional-integral (PI) type. It is superior to the excitation current controller, which is of the proportional type. The excitation current controller output is a duty cycle d for a pulse width modulated signal. The PSS output signal is an input signal of the summation point before voltage controller in the excitation control system. The structure of PSS-type PSS1A is shown in Fig. 2[3]. The commonly used inputs of the PSS are rotor speed, active power or terminal frequency [4].

The objective of the PSS is to generate a stabilizing signal, which produces a damping torque component in a transient process. Depending on the type of oscillatory mode of concern, the stabilizer must provide compensation between an input of excitation control system and the electromagnetic torque in the frequency range of interest [5]. CPSSs are designed with the phase compensation technique in the frequency domain. They include lead-lag blocks whose parameters are determined according to a linearized power system model. However, the power system is a nonlinear system with time-changing parameters; CPSSs based on the linearized model of power system do not guarantee satisfactory performance. A

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doi:10.1016/j.epsr.2009.12.014