Abstract

This paper investigates the enhancement of power system stability via coordinated design of Power System Stabilizers (PSSs), Thyristor Controlled Series Capacitor (TCSC)-based stabilizer, and Static Var Compensator (SVC)-based stabilizer in a multi-machine power system. The design problem of the proposed stabilizers is formulated as an optimization problem. Using the developed linearized power system model, the particle swarm optimization (PSO) algorithm is employed to search for optimal stabilizer settings that maximize the minimum damping ratio of all system oscillating modes. The proposed stabilizers are evaluated on a two-area weakly-connected multi-machine power system with unstable interarea oscillation mode. The nonlinear simulation results and eigenvalue analysis show the effectiveness of the proposed coordinated stabilizers in damping low frequency power system oscillations and enhancing the system stability.

Keywords: FACTS, Low Frequency Oscillations, Particle Swarm Optimization (PSO), Power Oscillation Damping (POD), PSS, SVC, TCSC

Introduction

Power systems are experiencing low frequency oscillations due to disturbances. These oscillations may sustain and grow to cause system separation if no adequate damping is available (Yu, 1983). In order to damp power system oscillation and increase system oscillation stability, the installation of power system stabilizer (PSS) is both economical and effective (Abido & Magid, 2007; Tse & Tso, 1993).

To date, most major power system plants in many countries are equipped with PSSs. However, PSSs suffer a drawback of being liable to cause great variations in the voltage profile and they may even result in leading power factor operation and losing system stability under severe disturbances. Although a control scheme...
using PSS has been successfully developed for damping inter-area oscillations in some real power systems like Argentina and Australia electric systems (Cigre Report, 1999). PSSs are not usually effective in damping interarea mode of oscillations and use of other means of solution may be necessary (Feliachi & Yang, 1994).

Recently, FACTS-based stabilizers such as Static Var Compensator (SVC), Thyristor controlled Series Compensation (TCSC), and Thyristor Controlled Phase Shifter (TCPS) offer an alternative way in damping power system oscillations. Although, the damping duty of a FACTS controller often is not its primary function, the capability of FACTS-based stabilizers to increase power system damping characteristics has been extensively investigated. Analysis and identification of the most effective parameter of FACTS controller has been investigated (Abido, 2005). A comparative analysis with minimum singular value, direct component of torque and residue has been presented for finding the most appropriate control input parameters of unified power flow controller for POD (Pandey & Singh, 2009). On the other hand, a dynamic phasor modeling of SVC has been introduced for system transient stability enhancement (Zhijun et al., 2009).

Several approaches based on modern control theory have been applied to TCSC and SVC controller design. The effectiveness of the series compensation devices on stability enhancement has been presented (Bamasak & Abido, 2004; Chen et al., 1995) presented a state feedback controller for TCSC by using a pole placement technique. (Chang & Chow, 1997) developed a time optimal control strategy for the TCSC where a performance index of time was minimized. A fuzzy logic controller for a TCSC was proposed (Lie et al., 1995). Heuristic optimization techniques have been implemented to search for the optimal TCSC based stabilizer parameters for the purpose of enhancing SMIB system stability (Wang et al., 2002). The power damping enhancement by application of SVC has been analyzed. (Wang & Swift, 1996) used damping torque coefficients approach to investigate the SVC damping control of a SMIB system on the basis of Phillips-Heffron model. It was shown that the SVC damping control provides the power system with negative damping when it operates at a lower load condition than the dead point, the point at which SVC control produces zero damping effect. Robust SVC controllers based on $H_\infty$ also has been presented to enhance system damping (Wang & Tsai, 1998). (Noroozian, 1995, 1994) examined the enhancement of multi-machine power system stability by use FACTS. It was concluded that the SVC is more effective for controlling power swings at higher levels of power transfer. However, unlike SVC, TCSC is not sensitive to the load characteristic and when it is designed to damp the inter-area modes; it does not excite the local modes. In some real power systems like the North-South interconnection in the Brazilian system a solution based on FACTS was successfully implemented to solve inter-area oscillations (Gama, et al., 1998).

Some work has been devoted in the literature to study the coordination control of excitation and FACTS stabilizers. (Hiyama et al., 1995) presented a coordinated fuzzy logic-based scheme for PSS and switched series capacitor modules to enhance overall power system stability. Robust coordinated design of excitation and TCSC-based stabilizers using genetic algorithm in a SMIB system was presented (Magid & Abido, 2004). Pourbeik and Gibbard (1998) presented a two-stage method for the simultaneous coordination of PSSs and FACTS-based lead-lag controllers in multi-machine power systems by using the concept of induced damping and synchronizing torque coefficients.

In this paper, a comprehensive assessment of the effectiveness of the individual and coordinated design approach of PSSs, TCSC and SVC-based stabilizers on power system stability enhancement has been carried out in a two-area weakly-connected multi-machine power system. The stabilizer design problem is transformed into an optimization problem where PSO is employed to search for the optimal settings of the proposed stabilizer parameters. The locations of PSSs have been investigated.
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