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Robust coordinated design of multiple and multi-type damping controller using differential evolution algorithm

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ABSTRACT

A robust coordination scheme to improve the stability of a power system by optimal design of multiple and multi-type damping controllers is presented in this paper. The controllers considered are power system stabilizer (PSS) and static synchronous series compensator (SSSC)-based controller. Local measurements are provided as input signals to all the controllers. The coordinated design problem is formulated as an optimization problem and differential evolution (DE) algorithm is employed to search for the optimal controller parameters. The performance of the proposed controllers is evaluated for both single-machine infinite-bus power system and multi-machine power system. Nonlinear simulation results are presented over a wide range of loading conditions and system configurations to show the effectiveness and robustness of the proposed coordinated design approach. It is observed that the proposed controllers provide efficient damping to power system oscillations under a wide range of operating conditions and under various disturbances. Further, simulation results show that, in a multi-machine power system, the modal oscillations are effectively damped by the proposed approach.

1. Introduction

When large power systems are interconnected by relatively weak tie lines, low frequency oscillations are observed. These oscillations may sustain and grow to cause system separation if no adequate damping is available [1]. Power system stabilizers (PSSs) are now routinely used in the industry to damp out power system oscillations [2,3]. However, during some operating conditions, these devices may not produce adequate damping, and other effective alternatives are needed in addition to PSS. Recent development of power electronics introduces the use of flexible AC transmission system (FACTS) controllers in power systems. FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the stability of a power system [4]. Static synchronous series compensator (SSSC) is one of the important members of FACTS family which can be installed in series in the transmission lines. SSSC is very effective in controlling power flow in a transmission line with the capability to change its reactance characteristic from capacitive to inductive [5,6]. An auxiliary stabilizing signal can also be superimposed on the power flow control function of the SSSC so as to improve power system stability [7]. The application of SSSC for power oscillation damping, stability enhancement and frequency stabilization can be found in several Refs. [8–12]. The influence of degree of compensation and mode of operation of SSSC on small disturbance and transient stability is also reported in the literature [13–15].

The interaction among PSSs and SSSC-based controller may enhance or degrade the damping of certain modes of rotor's oscillating modes. To improve overall system performance, many researches were made on the coordination between PSSs and FACTS power oscillation damping controllers [16–21]. For the design of an efficient and effective damping controller, selection of the appropriate input signal is a primary issue. Input signal must give correct control actions when a disturbance occurs in the power system and it should preferably be locally measurable to avoid extra costs associated with communication.

In recent years, one of the most promising research field has been "Heuristics from Nature", an area utilizing analogies with nature or social systems. These techniques are finding popularity within research community as design tools and problem solvers because of their versatility and ability to optimize in complex multimodal search spaces applied to non-differentiable objective functions. In recent years, some evolutionary methods such as genetic algorithm (GA) and particle swarm optimization (PSO) have been applied to the power system problems [22,23]. As the performance of PSO is affected significantly by the selection of the control parameters, it might suffer from the problem of convergence stagnation when the optimization model is very complex. Differential evolution (DE) is a branch of evolutionary algorithms developed by Rainer Stron and Kenneth Price in 1995 [24] is an improved

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