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Coordinated design of probabilistic PSS and SVC damping controllers

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ABSTRACT

This paper presents an application of probabilistic theory to the coordinated design of power system stabilizers (PSSs) and FACTS controllers, taking static VAr system (SVC) as an example. The aim is to enhance the damping of multi electro-mechanical modes in a multimachine system over a large and pre-specified set of operating conditions. In this work, conventional eigenvalue analysis is extended to the probabilistic environment in which the statistical nature of eigenvalues corresponding to different operating conditions is described by their expectations and variances. Probabilistic sensitivity indices (PSIs) are used for robust damping controller site selection and for optimization objective functions. A probabilistic eigenvalue-based objective function is employed for coordinated design of PSS and SVC controller parameters. The effectiveness of the proposed controllers is demonstrated on an 8-machine system.

1. Introduction

Under economic and environmental pressures, electric power system becomes more heavily loaded and system damping is weakened. Electromechanical oscillations occur more often than before, and insufficient damping of these oscillations will limit the capability to transmit power. Application of power system stabilizers (PSSs) has become the first measure to enhance the system damping. In some cases, if the use of PSS cannot provide sufficient damping for inter-area power swing, FACTS damping controllers are alternative effective solutions. The most commonly used FACTS devices are thyristor-controlled series capacitor (TCSC) and static Var system (SVC). The basic principle of these FACTS devices is to modulate the voltage and reactance. In addition, the system damping can be improved by incorporating additional damping controller.

FACTS devices and PSS are all fast acting power system devices, and they have the potentials of interaction with each other and deterioration of expected performance. To improve overall system performance, many researches were made on the coordination between PSSs and FACTS controllers [1–3]. However, most all of these methods are based on linearized power system around certain specified operating points (i.e. deterministic). As the operating environment varies with loading, the controller settings, which stabilize the system in certain operating conditions, may be unsatisfactory in another. Although many approaches based on different real time tuning techniques [4] and adaptive methods [5] have been proposed, an extension of the conventional eigenvalue analysis to develop a coordinated PSS and SVC design to cover a wide range of operating conditions is much desired by utilities.

Choice of SVC location/signal and its controller design by probabilistic method had been discussed [6,7]. This paper extends the probabilistic approach [8] to the coordinated design of PSS and SVC controller and a systematic approach to analyze probabilistic eigenvalues is introduced. Firstly, two types of indicators to measure stability robustness are derived from expectation and standard deviation of the probabilistic distribution. Based on the second-order eigenvalue sensitivity of the distribution, second-order probabilistic sensitivities are developed for PSS/SVC location selection, initial settings design, and coordinated PSS/SVC settings design. A more advanced optimization-based tuning algorithm is proposed to optimize the total system performance by means of the steepest descent (SD) approach and quasi-Newton (QN) technique. The effectiveness of the proposed method is illustrated based on an 8-machine test system.

2. Multimachine system modeling technique

The Plug-in Modeling Technique (PMT) [9] is suitable for modeling standard power system components, and the entire system is exclusively represented by two types of blocks with five types of parameters in Fig. 1.

The outstanding feature of PMT is that system matrix $\boldsymbol{A}$ is an explicit function of every parameter x and $\partial \boldsymbol{A}/\partial x$ are very simple

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