Real Power Control Design for SSSC via Fuzzy Neural Network based on Genetic Algorithms

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Abstract—The static synchronous series compensator (SSSC) is a series controller of Flexible AC Transmission Systems (FACTS). It can be controlled by thyristors, it also has the ability of fast control adjustments and high frequency operation. Through impedance compensation, it is able to control the magnitude and directions of the real power flow in the transmission system. In order to achieve a fast and steady response for real power control in power systems, this paper proposed a unified intelligent controller, which consists of Fuzzy Neural Network (FNN) and Genetic Algorithms (GA) for the SSSC to provide better control features for real power control in the dynamic operations of power systems. Finally, the simulation results of the proposed controllers are compared with the conventional proportional plus integral (PI) controllers to demonstrate the superiority and effectiveness of the unified intelligent controller.

I. Introduction

The Flexible AC transmission Systems (FACTS) devices are solid state, power electronics based devices designed for controlling certain electrical parameters [1]. FACTS devices can be used to increase the limiting capability of long-line transmission systems and provide additional damping for power system dynamic characteristics improvement. Basically, there are various definitions of FACTS given by power engineers and researchers working in this field; however, it can be broadly defined as a power transmission system where high-capacity power electronic devices, advanced control technologies and communication technologies are utilized to improve its transmission reliability, controllability, and efficiency [2].

In recent years, Voltage sourced converter (VSC) based series connected FACTS controller known as the new FACTS generation, can inject a voltage with controllable magnitude and phase angle at the line frequency and found to be more capable of handling power flow control, improvement of transient stability margin and improve damping of transient.

The static synchronous series compensator (SSSC) uses a voltage source converter to inject a controllable voltage in quadrature with the transmission line current of a power system. It is able to rapidly provide both capacitive and inductive impedance compensation independent of the line current [3]. By coupling an additional energy storage system to the dc terminal, the SSSC can also provide simultaneous active power compensation, which further enhances the capability in power flow control, power oscillation damping and transient stability.

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In most papers published in recent years, conventional linear control techniques have been used to design the internal controllers for the SSSC. In such approaches the linear PI controllers are designed to control the SSSC around a specific operating point where the nonlinear system equations are linearized. However, at other operating points the PI controller performance degrades. Nonlinear controllers can provide good control capability over a wide operating range, but they have more sophisticated structures and are more difficult to implement compared to the linear controllers.

In the paper, a number of conventional controllers have been proposed for the SSSC to perform the power control functions; however, most of them are linear controllers designed on a linearized model of the power system. To achieve robust control effects and better control performances some advanced controllers with adaptive features and somewhat with the ability of learning will be required.

It is well known that adaptive control is able to improve the control of a nonlinear system with fast changing dynamics, such as the power system. This is as a result of the dynamics of the controlled system being continually identified by a model. In this aspect, the fuzzy neural networks (FNN) are very suitable for multivariable applications especially for the system with unclear and complex dynamics since they can easily identify the interactions between the system's inputs and outputs [4-5]. In addition, the ability to learn and store information about system nonlinearities allows neural networks to be used for modeling and designing intelligent controllers for power systems [6-7]. Thus, they offer potential alternatives to those applications where the traditional linear controllers are not working adequately.

Advantages of the FNN based controllers over the conventional controllers are that they can adapt to the changes in system operating conditions automatically unlike the conventional controllers whose performances degrade for such changes and are required to be retuned to give the desired performance. But the FNN initial values of learning rate are normally difficult. Therefore, this paper proposed the application of Genetic Algorithm (GA) to search the optimal values of these parameters. GA is a global search technique. They can search several possible solutions simultaneously and they do not require any prior knowledge or special properties of the objective function. Moreover, they always produce high quality solutions and, therefore, they are excellent methods for searching optimal solution in a complex problem [8-9].

This paper presents the design of conventional PI controllers with on-line gain-tuning using the FNN based on GA for a SSSC to improve the overall control performance of a power system. Basically, the FNN uses either single neuron or multi-neuron architecture and the parameters can be dynamically adjusted using an error surface derived from deviations of the controlled parameters. In fact, the FNN is a