Chapter 10
Hybrid Adaptive NeuroFuzzy Bspline Based SSSC Damping Control Paradigm:
Power System Dynamic Stability Enhancement Using Online System Identification

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ABSTRACT

This work explores the potential of Bspline based Adaptive NeuroFuzzy Wavelet control to damp low frequency power system oscillations using Static Synchronous Series Compensator (SSSC). A comparison of direct and indirect adaptive control based on Hybrid Adaptive Bspline Wavelet Control (ABSWC) is presented by introducing the online identification block. ABSWC with Identification (ABSWCI) provides the sensitivity information of the plant to control system. The parameters of the control and identification block are updated online using gradient descent based back propagation algorithm. The robustness of the proposed control algorithm has been evaluated for local and inter-area modes of oscillations using different faults. The nonlinear time domain simulation results have been analyzed on the basis of different performance indices and time-frequency representation showing that ABSWC effectively damps low frequency oscillations and incorporation of online identification optimizes the control system performance in terms of control effort which reduces the switching losses of the converter.

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INTRODUCTION

The demand of continuous and good quality power supply for large infrastructures, like communication and transportation systems, in addition to the consumption of electricity for daily life highlights the importance of stable, secure and reliable operation of a power system. The geographical enhancements and technological advancement of power consuming systems demand the structural expansion of power systems and power transmission over long distances. But the structural expansion of existing power systems is restricted due to environmental and economical factors, which makes the system to operate close to its maximum limit and hence the system works in a highly stressed condition. In case of a fault event, like loss of load or generating unit, three phase to ground fault, and so forth, transient stability can become a transmission limiting factor due to increased loading of long transmission lines (Varma, 2011).

Transient stability is the stability associated with rotor angle oscillations. Power system stability can be defined as the ability of regaining its state of equilibrium after the occurrence of a physical disturbance. Depending upon the devices, resulting modes, nature of fault, fault duration and method of stability assessment, it can mainly be divided into following categories (Singh, 2011);

- Rotor angle stability
- Frequency stability
- Voltage stability

The rotor angle stability can further be divided into small-signal stability and large-signal or transient stability. The transient stability is the ability of power system to maintain its synchronism when subjected to large disturbances. In steady-state, all the generating units connected in a large power system operate at the same speed known as synchronous speed. However, a speed imbalance occurs when the steady-state of the system is perturbed. This may cause a machine or group of machines to accelerate in one area of a power network and decelerate in the other, resulting in Low Frequency ElectroMechanical Oscillations (LFEMOs) (Badar and Khan, 2012a,b,c).

These LFEMOs, arising due to lack of damping torque, are a consistent threat to the stable operation of power system as they may grow indefinitely if not damped out properly which eventually leads to partial or full system outage. Major blackouts have been reported in literature due to these LFEMOs (Pal & Chaudhuri, 2005). The installation of Automatic Voltage Regulators (AVRs) and Power System Stabilizers (PSSs) is a cost-effective remedy to restore the system stability (Eslami, Shareef, & Mohamed, 2010a, b; 2011a, b). However, these devices are simple and linear in nature and are locally installed with generating units, exhibit poor damping performance due to lack of information about global behavior of the system.

In their quest of secure power transmission over long distances, avoiding the expansion of existing systems, researchers found that the power flow on a line can be controlled by changing magnitude and phase of voltage and impedance of the transmission line which eventually lead to the emergence of Flexible AC Transmission Systems (FACTS). The idea of FACTS was first proposed by Gyuayi and Hingorani in 1980s (Hingorani, 1993; Hingorani & Gyugyi, 1999). There are two generations of FACTS introduced so far.

The first generation of FACTS controllers are based on phase controlled thyristors/diodes. They include Static Var Compensator (SVC), Thyristor Controlled Series Compensator (TCSC), and Thyristor Controlled Phase Shifter (TCPS) (Mathur & Varma, 2002). The second generation of FACTS controllers evolved from switch-mode voltage source converter configurations with energy storage unit, such as DC capacitors. The STATic Synchronous COMpensator (STATCOM) (Hingorani & Gyugyi, 1999; Song & Johns, 1999), Static Synchronous Series Compensator

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