Chapter 10
Stability Enhancement in Multi-Machine Power Systems by Fuzzy-Based Coordinated AVR-PSS

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ABSTRACT

This paper presents performance of intelligent fuzzy-based coordinated control for Automatic Voltage Regulator (AVR) and Power System Stabilizer (PSS), to prevent losing synchronism after major sudden faults and to achieve appropriate post-fault voltage level in multi-machine power systems. The AVR and PSS gains can adaptively change to guarantee the power system stability after faults. For change in AVR and PSS gains, at least one significant generator in each area of a multi-area power system is equipped with fuzzy logic unit. The fuzzy logic unit accepts normalized deviations of terminal voltage and phase difference of synchronous generators as inputs and generates the desirable gains for AVR and PSS. The construction of appropriate fuzzy membership functions and rules for best tuning of gains is described. The proposed fuzzy control methodology is applied to 11-bus 4-generator power system test case. Simulation results illustrate the effectiveness and robustness of the proposed fuzzy-based coordinated control strategy.

1. INTRODUCTION

Multi-machine power systems ever threatened by different disturbances; this problem may cause instability or change in voltage level of the generators (Kundur, Paserba, Ajjarapu, Andersson, Bose, Canizares, Hatziargyriou, Hill, Stankovic, Taylor, Cutsem, & Vittal, 2004). Instability and emergency condition in the Europe and Canada's power system led to a major blackout surround these countries (Andersson,

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Donalek, Farmer, Hatziargyriou, Kamwa, Kundur, Martins, Paserba, Pourbeik, Sanchez-Gasca, Schulz, Stankovic, Taylor, & Vittal, 2005). Early, the generators utilized Automatic Voltage Regulator (AVR) merely. With appearance of frequency and voltage oscillations, power systems equipped with Power System Stabilizers (PSSs) as the second controller to enhance the oscillatory stability. The AVR and PSS are installed on the generators to improve rotor angle stability consisting transient and small signal stability and optimal regulation of terminal voltage (Kundur, Paserba, Ajjarapu, Andersson, Bose, Canizares, Hatziargyriou, Hill, Stankovic, Taylor, Cutsem, & Vittal, 2004; Kundur, 1994).

It is noteworthy that after a fault condition in the power system, while a high-gain fast-response AVR improves the large-signal transient stability, it also has a detrimental effect on oscillation stability and has a converse effect on the PSS operation for the transient stability (Dudgeon, Leithead, Dysko, O'Reilly, & McDonald, 2007). The AVR and PSS controllers are generally designed for the nominal operating point, and for the fault situation it is necessary to have coordination between two controllers.

In the past decades, numerous papers investigated the transient and oscillatory stability enhancement with and without coordinated AVR-PSS (Boules, Peres, Margotin, & Houry, 1998; Law, Hill, & Godfrey, 1994; Bevrani, Hiyama, & Mitani, 2008; Dehghani, & Nikravesh, 2011; Dysko, A., Leithead, & O'Reilly, 2010; Golpıˆra, Bevrani, & Naghshbandy, 2011). To stability improvement and optimal control in power system several papers have changed the conventional structure of the system (Boules, Peres, Margotin, & Houry, 1998; Law, Hill, & Godfrey, 1994). The known frameworks for these changing structures are Internal Model Control (IMC) and Decentralized Four Loops Regulator (DFLR). Multi-machine power systems have complex models that it makes difficult the usage of these methods. With the conventional AVR-PSS and an additional optimal static gain vector, Bevrani, Hiyama, and Mitani, (2008) have attempted to gain robust performance of excitation system. The optimal gain vector has used the feedback signals including terminal voltage, active power and machine speed. In order to optimal tuning of gains, the problem is formulated via an $H\infty$ static output feedback ($H\infty$-SOF) control technique. Adding an extra loop can be troublesome with attention to antiquity of AVR-PSS usage as the only local controllers. A Proportional Integral Differential (PID) controller for power system is designed in (Dehghani, & Nikravesh, 2011). Since, the PID gets feedback from machine speed, it cannot regulate the generator voltage in appropriate level. Bode frequency response with a step-by-step algorithm is addressed in (Dysko, A., Leithead, & O'Reilly, 2010) to create a trade-off between AVR and PSS. The Bode frequency response is suitable for small signal stability analysis. A control algorithm that is employed a new comprehensive criterion for the coordinated AVR-PSS is proposed in (Golpıˆra, Bevrani, & Naghshbandy, 2011), and then a control strategy is designed based on the switching technique and negative feedback.

Recently, modern intelligent methods have been applied for stability enhancement of the power systems (El-Zonkoly, 2006; Selvabala, & Devaraj, 2010; Viveros, Taranto, & Falcao, 2005). The Particle Swarm Optimization (PSO) method in (El-Zonkoly, 2006) and Differential Evolution technique in (Selvabala, & Devaraj, 2010) are used to enhance the stability of Single Machine Infinite Bus (SMIB) power system. These two works considered some constraints on the AVR-PSS coefficients. In other hand, the objective functions that must be minimized include mode damping index, speed error and terminal voltage. Application of these procedures in large-scale power systems with numerous constraints and objective functions are very difficult. Also, the PSO algorithm is used for off-line tuning of PSS parameters in Benghazi North Power Plant (BNPP) by (Tawfiq, 2013). Generally, the off-line tuning for controller parameters gives suitable performance for specified condition and not for all conditions. Genetic Algorithm (GA) method is investigated to enhance the power system stability in (Viveros, Taranto, & Falcao, 2005).