CHAPTER 6

CONCLUSION

6.1 GENERAL

This chapter reviews the significant contributions made during the course of this research work and presents a few suggestions for the future work. Before proceeding with the review of the work done, the objectives of this thesis stated earlier are recalled.

- It is proposed to find a method for the selection of optimal location of PSSs in a multi-machine power system in order to achieve the best possible damping of critical swing modes and also to reduce the interaction effects among various PSSs.

- It is proposed to evolve systematic method for the effective stabilization of the multi-machine power system with an emphasis on optimal tuning of the parameters of the PSS using optimization technique.

- It is proposed to design a robust PSS using Fuzzy Neural Network in enhancing the small signal stability of multi-machine power systems. The proposed PSS is robust for wide varying operating conditions and for different system parameters which gives the best damping of all the critical modes of the system.
6.2 REVIEW OF THE WORK DONE

A methodology is developed to identify the optimum locations of PSSs in a multi-machine power system to achieve the best possible damping of critical electro mechanical modes using Relative Gain Array (RGA) and Genetic Algorithm (GA). The RGA is calculated on the basis of the transfer functions between the selected inputs and outputs. The Relative Gain Array is used to find out the best possible input-output pair which has good control to damp the critical swing modes and which results in lesser interaction effects with the other loops. The RGA is a matrix of numbers each of which represents the relative influence of a given input on a defined output, is manipulated by moving complete rows and columns, until it most closely approximate to ideal solution, represented by identity matrix. For small systems such manipulations are straightforward. However as systems become larger, such manipulations become complex and also time consuming. Hence the Genetic algorithm search technique is used to rearrange the RGA matrix in such a way that this RGA matrix is closer to the identity matrix. The genetic algorithm used is very effective for large scale power systems. In this study, the RGA matrix is calculated by taking the stabilizing signal of PSS ($\Delta V_s$) in the columns of the matrix and the generator speed deviation ($\Delta \omega$) in the rows of the matrix that is suitable for connecting the Delta Omega PSS.

The proposed approach is applied to two-area five-machine eight-bus test system. An efficient computer-programming package for analyzing the dynamic stability of power systems has been developed in Matlab for the multi-machine power system. The machine is represented by the two-axis model with 4-states, and the static type of fast acting exciter has been used. The simulation results are presented and discussed. The improvement in the damping ratios of the critical electro mechanical modes of the test system before and after the placement of the PSS is discussed. The dynamic
responses of the test system for the 10% step change in mechanical torque as the disturbance has been studied before and after the locations of PSSs in the machines as per the proposed approach. The simulation results demonstrate that all the critical modes are effectively damped.

The second problem taken up in this thesis concerns the design of an effective stabilizing system for a multi-machine power system. In this work, the critical modes are identified for different operating conditions from the linearized model and a set of dominant critical modes among them are chosen and ranked based on the damping ratio. For each one of the selected dominant critical modes, the best location of PSS is identified based on RGA method. For the identified PSSs, the parameters are optimally tuned using non linear optimization technique using Sequential Quadratic Programming Technique. The proposed approach is applied to the 10 machine, 39 bus New England test system. Simulation results carried out by considering different operating conditions in order to demonstrate the robustness and the responses of the test system show the good damping performance

An attempt has been made in this work to develop a robust PSS with particular emphasis on achieving a stable closed loop performance over a wide range of operating conditions and different system parameters. The proposed PSS has the ANFIS structure. The dynamic performance requirements of the PSS have been decided and this performance has been achieved using Fuzzy Neural Network approach.

The proposed RFNNPSS (Robust Fuzzy Neural Network based PSS) consists of an ANFIS (Adaptive Network based Fuzzy Inference System) structure. The input signals to this network are speed deviation ($\Delta\omega$) and its derivative ($\dot{\Delta}\omega$). The proposed adaptive network is trained by hybrid learning algorithm, which is based on error back propagation and least
squares estimate techniques. To design the proposed PSS, two parameters are chosen for tuning.

(1) Width ‘b’ of the triangular fuzzy set (premise parameter).
(2) Output of the rule table ‘r’ (consequence parameters).

To test the performance of the proposed RFNNPSS, simulation studies were performed on two systems: a single machine infinite bus system and a two-area, 5-machine 8-bus multi-machine power system. Extensive simulation results have been presented for a wide range of operating conditions and different system parameters in a single machine infinite bus system and a multi-machine power system to establish the efficiency of the proposed stabilization technique.

Simulation studies have been performed with the proposed RFNNPSS for the SMIB system for the following five different cases with the disturbance of 10% step change in mechanical power. The proposed RFNNPSS has better damping with less peak overshoot and quicker response with less settling time compared to the performance of CPSS & FPSS for all the different operating conditions.

Simulation studies have been performed with the proposed RFNNPSS for a two-area 5-machine 8-bus multi-machine power system for the following three operating conditions.

a. Full load operating condition.
b. Full load operating condition with loading increased by 25%.
c. Full load operating condition with one of the two tie lines between buses 6 and 7 is removed.

The system responses of this multi-machine system for the disturbance of 10% change in mechanical power and also for the above
operating conditions show that the proposed RFNNPSS is better in damping than the other two PSSs.

Performance evaluation of PSSs on single and multi-machine power systems shows that the robust fuzzy neural network based power system stabilizers are indeed a viable solution to the problem of low frequency electro mechanical oscillations. Furthermore, robust performance of the proposed PSS over widely operating conditions shows its superiority over other PSSs.

6.3 SCOPE FOR THE FUTURE WORK

- The RGA is a measure that can be used in order to decide a suitable Input-Output pairing for the location of the PSSs in the Multi-machine Power System. But this measure provides the limited knowledge about when to use multivariable controllers and gives no indication of how to choose multivariable control structures. A new method, which can be an alternative to RGA, is Hankel interaction index array.

- This tuning algorithm can be extended to include different modeling types for generators, exciters. Governors can also be included in the modeling of the test system. We can extend this work by selecting another objective function including the effect of the interactions among PSS and other damping controllers such as FACTS devices.

- In the design of the proposed PSS, the ANFIS network uses the linear triangular membership function. Non-linear membership functions can also be used and its effectiveness in improving the dynamic stability can be investigated.