CHAPTER 9

CONCLUSIONS

9.1 THE INITIATIVE

The stability problem of a power system can be summarized as being whether or not the synchronous generators in the system can be successfully controlled, i.e., maintained in synchronism following major upsets to the system. Classical and modern control techniques using mathematical system theory, which deals with the analysis and synthesis of dynamical systems, have served remarkably well. However these techniques are inadequate when one is confronted with the control of complex systems characterized by poor models, high dimensionality of the decision space, multiple performance criteria, time–varying parameter values, nonlinearities, disturbances, and failing component parts. As the system to be controlled becomes more complex, so does the complexity associated with the computation of the control law and the task of implementing the control in a timely fashion.

The research reported in this thesis was motivated by the fact that stability problems exist in any given power system and its control is a challenging task to engineers due to its increased complexity. Fixed parameter control systems that are designed using linear control theory may not perform satisfactorily when the system experiences severe transients, since power systems are highly nonlinear.

This thesis has addressed a single issue in the category of power system stability control, that is, stability enhancement through supplementary excitation control accomplished with power system stabilizers(PSSs). The research on, and practice of, this technology has progressed from fixed parameter conventional PSSs, adaptive PSSs to intelligent control systems. The latter is at its early stage of application. An intelligent control system is one that can sense the environmental changes, process the sensor data, generate and execute a timely control action that guides the system from an initial state to a terminal state satisfying the various constraints and objectives imposed. Since intelligent control, defined as a combination of control theory, operations research and artificial intelligence, offers fast and robust control, it is emerging as one of the most popular new technologies in the industrial and manufacturing worlds. This has put an urgency to utility companies where new technology evolution is slow due to the fact that implementation of unproved new technology is a risk to both the customer and the utility. On the other hand, utilities want to improve their facilities and technology to better serve the customer.

9.2 REALIZATION

This thesis has presented a non–conventional control strategy consisting of an hybrid neural fuzzy–logic modeling technique, to meet the diverse demands of supplementary excitation control to enhance power system stability. Two ANN–FL PSSs have been designed for a two–machine infinite–bus power system and extensive simulation studies were performed using the Transient Stability Simulation Package(TSSP) implemented under SIMULINK. The following points summarize the observations from the work.

1. Steady–state stability studies have shown that the two–machine infinite–bus power system exhibits two oscillation modes. The local mode of the test machine is $1.7Hz$. The inter–area mode is $0.8Hz$. A study of the frequency response of the system was carried out to confirm the obtained results.
2. Transient simulation studies have shown that the multimachine power system is insufficiently damped and highly oscillatory without supplementary excitation control. This condition is designed for the purpose of testing any PSS to see whether it can stabilize the system.
3. When the test machine experiences a 4% step increase of its reference terminal voltage, the operating point of the machine has to change. The transient of this change has been simulated with different control schemes. It is shown that the system is oscillatory without PSS, and stable with

either the CPSS or the speed ANN–FL PSS. The latter provides marginally better performance.

4. When the test machine experiences a 0.25% step increase of its input mechanical power, both the CPSS and the speed ANN–FL PSS can stabilize the system. The latter provides instant control action(as it has no dynamic itself) and moderately more damping to the local mode.
5. When the system experiences severe disturbances such as three–phase to ground faults under different operating conditions, the ANN–FL PSSs exhibit much improved performance over the CPSS.
6. In Chapter 5, an ANN–FL controller is designed for speed–tracking control of a DC motor. It has been shown that the ANN–FL controller outperforms an optimally–tuned PID controller under various transients.

9.3 SIGNIFICANCE OF THE WORK

The results presented in this thesis have contributed to the innovation of design techniques for supplementary excitation control of synchronous generators. The hybrid neural fuzzy–logic modeling methodology combines the power of artificial neural networks(ANNs) and fuzzy–logic(FL) to form a control system that can learn, generalize and adapt. At the same time it can store knowledge of the system behavior as a structured database for later use. The significance of this research work can be summarized as follows:

1. This thesis has presented an innovative modeling technique referred to as ANN–FL modeling for designing supplementary excitation control systems to enhance the stability of multimachine power systems. Two ANN–FL PSSs, one using speed deviation as input, the other using accelerating power, are designed. Simulation studies have shown that this ANN–FL algorithm is fast in responding to state variable changes and immune to changes in the operating conditions.
2. An ANN–FL controller is designed for speed–tracking control of a DC motor. Its performance is compared with that of a PID controller. It is shown that the ANN–FL controller provides perfect speed–tracking control.
3. Simulation studies have shown that an ANN–FL controller designed for one machine can be utilized on another. This means that fast and economic intelligent controllers for both motor drives and generator control can be developed without customized design.
4. Handling of generator saliencies has been a challenge and an iterative procedure has been utilized in transient stability studies[9–1]. An innovative simulation algorithm overcoming this difficulty has been developed in this research.
5. A highly productive simulation environment has been developed as part of this research, based on the Transient Stability Simulation Package(TSSP) under the platform of SIMULINK. A device library has been created for

power system apparatuses and network equations. In this environment, advanced control systems can be easily designed, prototyped and simulated.

9.4 FUTURE WORK

Simulation studies have shown promising performance of the newly–designed ANN–FL controller for DC motor control and ANN–FL power system stabilizers for synchronous generator control. There are a few areas where further research work can be carried out.

1. Investigate whether there exist torsional oscillatory modes with an ANN–FL PSS using speed deviation as input. If such oscillatory modes exist, accelerating power may be utilized as input signal, since the integral of accelerating power is free of torsional modes[9–2].
2. Investigate whether coordinated operation[9–3] of ANN–FL PSSs in a multimachine power system is beneficial to the damping of local and inter–area modes where synchronous generators can be divided into coherent generating groups[9–4].
3. Implement in laboratory the ANN–FL controller for DC motor control and the ANN–FL PSSs for synchronous generator control.
4. Investigate the applicability of the proposed ANN–FL algorithm in (a) steam temperature control on the boiler side in a generation station and (b) governor and combined governor and AVR control.