Chapter 7

Conclusions and Scope for Future Work

7.1 Contributions and Conclusions

In electric- power generation, disturbances caused by load fluctuations will cause changes in the desired frequency value and tie-line loadings. Load frequency control is thus very important in power system operation for supplying sufficient and reliable electrical power of good quality. There are essentially two objectives of load frequency control. Firstly, the system frequency is to be maintained at or, very close to specified nominal value. Secondly, tie-line deviations must also be made zero as fast as possible.

Many types of control strategies have been implemented by researchers so far in order to achieve the objectives of load frequency control which is also known as automatic generation control. A comprehensive literature review on load frequency control problem is presented in chapter 2 and different control techniques i.e. conventional techniques as well as intelligent techniques are thoroughly discussed.

In this thesis, essentially, two area and three area systems are analysed. Mathematical models with transfer functions of two area and three area interconnected systems are developed in chapter 3. The transfer functions are derived for the purpose of reliable solution for one of the major problem of power system control i.e. LFC. Generation rate constraint as a non-linearity is considered for all non-linear studies. Two area systems are modeled with combinations of non-reheat turbines, reheat turbines, non-reheat turbines with non-linearity as generation rate constraint, reheat turbines with generation rate constraint, one non-reheat and one hydro turbine and lastly one reheat and one hydro turbine are considered for dynamic performance analysis when any one area is subjected to step load disturbance. In the next step, mathematical model for two area system is modified to include the effect of HVDC link which results not only in reduction of peakovershoot but also the faster stabilization of system frequency. While three area system is modeled for all three non-reheat turbines, reheat turbines and combinations of two non-reheat with one hydro and one non-reheat, one reheat and one hydro turbine. The step load disturbance is applied in any one area or any two areas in dynamic performance study of three area system.

Further control techniques are developed in chapter 4 for obtaining the system responses in terms of settling time and peakovershoot on sudden changes in load. Two control strategies:

- Linear quadratic regulator (LQR) technique
- Fuzzy logic based integral controller

are implemented in this thesis. Linear quadratic regulator design is only implemented in two area system while the fuzzy based integral controller is employed in three area system also. Initially, LQR optimal controller results are analysed and found to be impractical for the implementation because of the following reasons;

- The optimal control is a function of all the states of the system. In practice all the states may not be available. The inaccessible states or missing states are required to be estimated.
- It may not be economical to transfer all the information over long distances.
- The controller output, which is a function of the system states in turn, is dependent on the load demand. Accurate prediction of load demand may be essential for realizing optimal controller.

- The optimal control is also dependent on the weighing matrices and is not unique.

The above mentioned constraints restricted the use of LQR technique to three area system. Fuzzy logic based integral controller with different types of membership functions such as triangular, Gaussian and trapezoidal in different numbers (3, 5 and 7) is used in the control strategy. The efficient and reliable results obtained using this for two area and three area systems are presented in chapter 5 and chapter 6 respectively. The fuzzy logic controller used in the analysis is fed with two input signals i.e. Area control error and Rate of change of Area control error which results in output as integral gain.

Chapter 5 is dedicated to results obtained for two area system with different combinations as discussed in the beginning. The proposed fuzzy based integral controller gives good results as compared with other researcher's work. For non-reheat two area interconnected system, proposed controller gives 17 % lesser settling time and 26 % lesser peakovershoot as compared to latest Cam's study [96] for the same system parameters and same system model. Robustness is also achieved by means of varying operating input parameters to ± 30 % to their nominal values i.e. power system time constant, tie-line constant and frequency bias coefficient and achieving dynamic system responses within tolerable limits. Similarly, non-reheat with GRC is compared with different neural network approaches and found better in terms of settling time by 51 % as 3.54 seconds by proposed controller to 6.81 seconds by dynamic neural network technique [81] but peakovershoot is noted 25 % less in neural network approaches. The results are summarized in table 5.1 and table 5.2. Various other cases such as non-reheat and hydro combination and reheat and hydro combination of two area system are employed with proposed fuzzy logic controller and responses are compared with other research works.

System responses of two area power system equipped with parallel HVDC link are also given and on comparison with similar research works [119, 120] found better in terms of frequency stabilization and tie-line power deviation. Under same system conditions of both areas equipped with reheat turbines, the settling time is found to be 4.33 seconds to 16.85 seconds and peakovershoot -0.115 Hz to -0.0246 Hz. In this study, the proposed two area interconnected power system via a HVDC link model is also using fuzzy logic integral controller. Simulation study reveals that the designed controller with parallel HVDC link is very effective in suppressing the frequency oscillations caused by sudden load disturbances.

In order to have validity of control scheme proposed for load frequency control of interconnected electrical power system, the proposed controller is also implemented on three area interconnected power system with various possible combinations as mentioned earlier. The results presented in chapter 6 justify the implementation of proposed fuzzy based control strategy when results are compared with work of other researchers. For same system conditions as given in [94], settling time with proposed controller is 8.23 seconds to 9.0 seconds of [94]. Results of three area system are better compared to fixed gain integral controller and PI controller results [112]. The controller is also robust as it gives good responses even when operating parameters are varied. Three area system is also tested with combination of a non-reheat, a reheat and one hydro turbine which is not even discussed in literature as yet.

The performance of proposed fuzzy based integral gain controller has been thoroughly investigated for load frequency control of two area and three area interconnected power systems. It has been shown that the proposed control algorithm is effective in terms of lesser settling time and peak overshoot and provides significant improvement in system dynamic performance. In addition the proposed controller is very simple and easy to implement since it does not require any information about system parameters. The validity of the control technique is verified through extensive simulations for two area and three area systems with non reheat, reheat and hydro turbines, taking into account a number of practical aspects such as parameter variations and generation rate constraints. Therefore, this controller is recommended for generating good quality and reliable electric energy.

7.2 Scope for Future Work

There are tremendous scopes for work in this area since load frequency control problem is still a big challenge in front of power engineers. Some of the important aspects and issues that need to be addressed in this area are the following:

- The HVDC link connection in parallel to AC line can further be studied with considering non-linearity in HVDC connection for much better control of frequency and tie-line power.
- More practical transfer function for HVDC link may be evolved and implemented for system dynamic performance study.
- The controller can further be implemented on four area system with different combinations of turbines.
- The design and implementation of fuzzy logic based such type of intelligent controller and its practical application to present day power industries will be extremely useful.