6.1 CONCLUSION

A concept of Knowledge Domain States Mapping for intelligent power flow control in multi-area system has been proposed in present work. It has been demonstrated that as operating condition varies due to dynamical change observed in power network, retuning of respective control parameters from knowledge domain certainly enhances oscillation damping in overall system, and therefore system becomes relatively stable and secure as well. The thesis reports an intelligent multi-area power control with dynamic knowledge domain inference concept. This includes a new concept of updating control parameters, which is linked with operational shift, initially in offline mode with building respective knowledge domain that fits into the framework of changing situations, to ensure states regulation. The concept of control shifting/ sharing has also been proposed and adequately analyzed by introducing FACTS controllers in the system when PSS approaches to the onset of unacceptable system behavior at certain system operating conditions.

Chapter 1 presents the motivation of research work along with various literatures reported on power oscillations arising due to dynamic changes and recovery methodology of power network. The design of Power System Stabilizers (PSSs) and FACTS devices employing various methods from conventional to the new heuristic optimization techniques have been attempted by researchers to damp out electromechanical oscillations of power network. In order to ensure adequate power oscillation damping, coordination concept for different PSSs and FACTS devices has also been proposed. Based on existing trend of controller functioning, it has been found that the Knowledge Domain States Mapping Concept for intelligent power flow control may be an effective way to have better system performance which can ensure overall system stability along with security and reliability. The objectives of research work are detailed along with contribution in operational behavior.

Chapter 2 presents the concept of Smart Power Flow Control for multi-area system. The system regulation has been addressed with intelligent power control concept which deploys controller structure depending upon the system requirements, such as operational shift. Since the operational shift is observed with many external effects such as loading patterns, inadequate transmission capacity of interconnected tie line and also imprecise controller parameters (due to design limitation) for a given controller structure, apart from the different rating of generating units which might cause local mode oscillations, and if not addressed by PSSs may transfer in form of inter-area oscillations unnoticeably for another operational point slight change. Thus controller induction and parametric tuning, at plant and transmission level as well, is required which has been viewed and proposed as concept of smart power flow control with knowledge domain states mapping for intelligent power oscillation damping as dynamical operational shift occurs in system.

To develop any control concept, accurate system modeling is very essential. **Chapter 3** presents a modular mathematical model of multi-area power system comprising of detailed dynamics of each subsystem and controllers as well. The proposed model can be extended for any number of generators along with multi-areas power system utilizing the beauty of block matrix formulation. The system representation for each machine along with Power System Stabilizers (PSSs) has been derived and interfaced with FACTS devices (STATCOM, SSSC and UPFC) in state space framework. The model derived is general enough and can accommodate other supplementary controllers with suitable interface variables (like LQR Controller, POD Controller, Multi-Stage LQR (MSLQR) Controller (based on State Predominant

Concept) and proposed Integrated MSLQR-POD controller and modified MSLQR controller) for improved system stability.

Chapter 4 presents heuristic approach for controllers' tuning. Intelligent heuristic optimization techniques (PSO, FA and GSA) have been discussed in this chapter for development of knowledge domain structure of all the controllers connected in the system. The parameters of controllers have been tuned with various heuristic approaches and compared which results in better performance.

In **Chapter 5**, system studies have been extensively carried out for various operational shifts. The model developed has been effectively used to simulate all possible conditions which demonstrate the effectiveness of the proposed concept of knowledge domain states mapping for intelligent power flow control. A rigorous system study has been done under variety of dynamical changes, the controller tuning by all heuristic approaches mentioned in Chapter 4 has been done and results demonstrate the best system response and also appropriate tuning method. The overall system considered has been subjected to an on-going perturbation along with associated control strategy such as PSS alone and also coordination of PSS with FACTS devices. Results with such a controller structure demonstrate the concept of intelligent power control concept under variety of operational conditions. The concept of intelligent power controller (hierarchical control structure) augmentation such as parametric range extension along with controller sharing and shifting has been extensively studied for large interconnected sample Test system.

Following are the main outcome of Thesis:

- Development of complete hierarchical control structure for quick power oscillation damping-both local mode and inter-area oscillations as operational shift occurs in the system.
- Damping of power oscillation with proper design of controllers within the acceptable time frame (like PSS, FACTS devices (STATCOM, SSSC and UPFC) and Multi-Stage LQR controller).
- Development of Knowledge Domain Structure with well-known heuristic optimization techniques covering broad spectrum of operating conditions.
- Development of **Intelligent Controller Tuning and Controller Switching Concept** for quick oscillation damping.
- In situations of inadequate capacity of existing controllers for system stabilization within desired limits, another auxiliary controller supplements over and above existing controller based on intelligent approach-**Control Shifting/Sharing Concept.**

Particle swarm optimization (PSO) technique, Firefly algorithm (FA) and Gravitational search algorithm (GSA) optimization techniques have been used to develop the knowledge domain inference mechanism for PSS controller parameters by minimizing cost function J (J=ITAE performance indices).

Sample Two Area Four Machine test system, Six Area test systems and Ten Area 50 Machine test system have been considered with FACTS devices and PSS to all the generators. Time constants (T1 and T2) of lead-lag compensation block and gain (Kc) are used as the control parameters for PSS, and modulation ratio and phase angles are used as input control parameters of FACTS devices. State variables deviations have been studied at different system operating condition with proposed concept for different test systems. Integrated MSLQR-POD FACTS Controller and Modified MSLQR controller have been designed, and results show the better response as compared to previously reported FACTS Controller.

6.2 FUTURE SCOPE

During the course of research work, some important points have been noticed and are listed as possible areas of future research work:

- The proposed concept of retuning of controllers' parameters in real time framework can be done with multi-agent control environment which may help the system operator to detect variation in system operating conditions and also integrate suitable control injection as quick as possible. This may be an upcoming area of ancillary services in power network for effective oscillations damping and adding security of entire power network of interest. The hardware and software compatibility may be another area of research to ensure real time delivery.
- A Hybrid- Heuristic Optimization (HHO) technique may be developed utilizing the proposed knowledge domain structure for more accurate tuning and parametric extension of existing controllers/upcoming controllers in network quickest damping in overall power network.