CHAPTER 7

CONCLUSION AND SCOPE FOR FUTURE WORK

7.1 GENERAL

The present chapter aims at reviewing the significant contribution made during the course of the present research and suggesting the scope for future work. Before proceeding with the review of work done, the objectives of the thesis stated earlier are recalled.

The main aim of the thesis is to propose a methodology to determine the optimal location of FACTS controllers in the grid system.

In this context, a methodology has been developed to determine the location of TCSC for secured power flow in the grid system using multiple sensitivity indices formulated on the basis of the factors deciding the realistic power flow in the grid. Subsequently, a methodology has been suggested to locate the FACTS controllers in the transmission system to minimize the SOL of the system and the voltage control under contingencies using an index called OVI along with CSI with a minimum number of FACTS controllers. These methodologies are tested in a practical Indian utility network.

In addition to the above, the various aspects of Transmission system planning in India are reviewed and suggestions for incorporating the FACTS controllers in strategic locations in the grid system during system expansion planning have been proposed.
7.2 REVIEW OF THE WORK DONE

After presenting the literature review on FACTS controllers’ placement and transmission system expansion planning in Chapter 1, the core work has been done in three phases as follows,

i) Three different sensitivity indices namely $S_{ISD}$, $S_{IGM}$ and $S_{IREI}$ have been formulated and applied to determine the optimal location of FACTS controllers for secured power flow in an Indian utility network through the simulation studies in phase 1.

ii) In phase 2, formulation of an index, OVI, ranking of branches using OVI along with CSI for placement of FACTS controllers to minimize the SOL of the system and voltage control under contingencies, with a minimum number of FACTS controllers when compared to CSI based ranking are done.

iii) The multi-faceted TEP in India has been reviewed and it has been suggested that the FACTS controllers be placed in strategic locations of the grid during system expansion planning in third phase.

7.2.1 Phase 1- Formulation and Application of Sensitivity Indices for the Placement of FACTS controllers

In this phase, the factors influencing the transmission line loading are studied from the context of the Indian power system. By using these factors, three different sensitivity indices namely $S_{ISD}$, $S_{IGM}$ and $S_{IREI}$ are formulated by developing a realistic generation mix schedules and taking relevant demand conditions. Simulation has been carried out using these
sensitivity indices to determine the location of TCSCs in a practical Indian Utility Network. This phase is explained in two chapters.

In Chapter 2, the importance of the factors influencing the line loading such as ABT, Integration of RE, power purchase, TOD tariff, daily peak and off-peak demand, varying seasonal demand, accommodating open access customers, future projected demand for the plan period and change in the capacity of the generation and transmission system configuration are discussed in detail. Different realistic generation mix schedules are formulated and used with the different demand conditions for formulating the sensitivity indices namely $SI_{SD}$, $SI_{GM}$ and $SI_{REI}$.

In Chapter 3, the sensitivity indices formulated in chapter 2 are utilized for optimal placement of FACTS controllers. Hence a methodology to find sensitivity indices is presented in this chapter. Based on the values of the sensitivity indices, the branches are ranked for placement of FACTS controllers, followed by the discussion on achieving the settings of FACTS controllers through CF-PSO algorithm. The proposed methodology has been tested on Chennai metro city network to place TCSCs. The results revealed the effectiveness of the proposed methodology.

7.2.2 Phase 2- Formulation and Application of an OVI for Placement of FACTS controllers

In phase 2, an Index OVI has been formulated. The ranking of branches has been done based on OVI and CSI together so as to decide the optimal location of FACTS controllers. The main objective of reducing the SOL with the minimum number of FACTS controllers compared to CSI based ranking has been achieved. This work has been detailed in the Chapters 4 and 5.
In Chapter 4, the CSI has been explained. The investigation of the CSI based ranking of lines under contingency condition with under loaded branches during base case has then been carried out. It is observed that the CSI based ranking alone cannot be relied upon to assess the security margin of the system, since the CSI is based on the base case study, it may not reflect the actual overloading and SOL in the system.

In Chapter 5, the OVI formulated in the previous chapter is used with the CSI for the ranking of the branches to place FACTS controllers under contingencies. Upon ranking of branches, the setting of FACTS controllers is obtained through CF-PSO with the objective of minimizing SOL with voltage control under contingencies. Afterwards, the simulation studies are conducted to place TCSCs and UPFCs on different test systems on IEEE 6 Bus system, IEEE 30 Bus system and practical Indian utility network feeding Chennai metro city. The results show the advantages of the proposed CSI and OVI based ranking over CSI based ranking.

7.2.3 Phase 3- Reviewing of TEP in India and Suggestion for Placement of FACTS controllers at Strategic Locations during System Expansion Planning

In phase 3, the multi-faceted TEP in India are reviewed and it has been suggested to place FACTS controllers in strategic locations of the grid during system expansion planning. This is presented in the Chapter 6.

In Chapter 6, the fundamental care approach explains the important basic issues to be considered for developing the transmission expansion planning. The components of TEP, issues of power evacuation planning, network expansion planning, congestion alleviation management, reactive power management and uncertainty management from the perspective of application of FACTS controllers in strategic locations are discussed.
7.3 CONTRIBUTION OF THE RESEARCH

The main contributions of the present research are summarized below:

- The realistic power flow in the grid system depends on many vital factors. Based on these factors three different sensitivity indices namely $SI_{SD}$, $SI_{GM}$ and $SI_{REI}$ are formulated.

- A methodology has been proposed to determine the location of FACTS controllers for secured power flow in the grid system using the sensitivity indices $SI_{SD}$, $SI_{GM}$ and $SI_{REI}$. The proposed methodology is tested on a practical Indian utility network by conducting simulation studies.

- The drawback in using CSI based ranking of branches to place FACTS controllers for the reduction of SOL of the system under contingencies has been identified.

- Subsequently, a methodology has been proposed to optimally locate the FACTS controllers to minimize the SOL of the system and voltage control under contingencies using an Index called OVI with CSI thereby achieving maximum reduction of SOL with minimum number of FACTS controllers.

- The methodology developed using CSI and OVI based ranking is tested on IEEE 6 bus system, IEEE 30 bus system and practical Indian utility network for placement of TCSCs and UPFCs. The results proved that the maximum reduction of SOL under contingencies with minimum number of
FACTS controllers is achieved by the proposed methodology when compared to CSI based ranking.

- The various aspects of TEP in India are reviewed and the application and advantages of FACTS controllers at strategic location during the TEP evolving process itself has been explored.

7.4 SCOPE FOR THE FUTURE WORK

Since the proposed sensitivity index based approach has explored all the possible combinations of generation mix and load patterns, it would give a more appropriate solution for identifying the network branch to optimally place the FACTS controllers. The proposed methodology could be tested for voltage profile improvement using different types of FACTS controllers in practical power systems.

Also, this approach could be beneficially used for designing wind power evacuation system aiming for optimum utilization of the EHV corridors even during off-wind seasons and critical contingency conditions.