Chapter 7

Conclusions

7.1 General

As a consequence of deregulation of electrical power systems, there is growing interest about the transfer capabilities of transmission lines with increased wheeling transactions. But due to the economical, environmental and political reasons it is very difficult to build new transmission lines. So there is an interest in optimal utilization of the existing transmission systems by installing new FACTS device like TCSC. TCSC is popularly used FACTs device which offers many advantages. But due to many reasons, it is very important to optimally locate it to obtain its full benefits. This thesis has mainly addressed the issues of optimal placement and setting of TCSC considering different types of objectives, such as maximization of Total Transfer Capability (TTC), minimization of total real power losses, maximization of social welfare, minimization of total generation cost and minimization of installation cost of TCSC. The effect of optimally placed TCSC on spot prices, wheeling charges and secure bilateral transactions has been investigated also. Lastly, the most fundamental and highest priority transmission management problem i.e congestion management has been solved. The main contributions of the thesis include:

- A comprehensive review on the background research work on optimal location of FACTS devices, TTC maximization, social welfare maximization, pricing of transactions and congestion management has been presented. In chapter 2, review of applications of Particle Swarm Optimization in power system has been presented..

- Development of PSO based algorithm for finding the optimal location and setting of TCSC for maximizing Total Transfer Capability and minimizing transmission losses of the deregulated power system which consists of bilateral and multilateral transactions as reported in chapter 3.
- To develop PSO based algorithm for finding the optimal location and setting of TCSC to maximize social welfare, minimize total generation cost and installation cost of TCSC while satisfying various constraints, reported in chapter 4.
- To investigate the impact of optimally placed TCSC on transmission pricing (Spot prices), active power and reactive power wheeling charges and secure bilateral transactions, reported in chapter 5.
- To develop simple and efficient method for selecting number of participating generators for managing congestion. So, theory of reactive power generator sensitivity factor has been developed and implemented for selecting the participating generators. In addition, PSO based algorithm has been suggested to minimize active power and reactive power rescheduling costs of participating generators considering voltage stability and voltage profile improvement criteria, as reported in chapter 6.

The aim of this chapter is to highlight the main findings of the work carried out in this thesis and to make few suggestions for the further research work.

7.2 Summary of Important Findings

The main focus of chapter 2 was to survey and summarize the applications of Particle Swarm Optimization (PSO) for solving various power system optimization problems like Economic load dispatch, Reactive power management, Optimal power flow, Power system controller design, Neural network training, Price forecasting, Load forecasting, and other areas of power system. From the literature survey it was revealed that there were some additional unexplored areas where it could be further employed like protection, restoration, renewable energy sources etc. The advantages and disadvantages of PSO based approaches have been also discussed. This chapter would be very much useful to the researchers for finding out relevant references as well as previous work done in the field of power system optimization, so that further research work could be carried out.

In chapter 3, one of the most challenging issues i.e enhancement of Total Transfer Capability (TTC) of the deregulated power system was solved. To facilitate the deregulated electricity market operation, control and trading, sufficient transmission capability should be provided to satisfy increasing demand of power transactions reliably. The conflict of this requirement and the restrictions on the transmission expansion in the deregulated electricity market has motivated the development of methodology to enhance the TTC of the existing transmission grid. FACTS device like TCSC could be the best alternative to increase TTC. But due to many reasons, it is necessary to "optimally" place it to get its full benefits. So, this chapter has proposed Particle Swarm Optimization (PSO) based algorithm to find optimal location and setting of TCSC for maximizing TTC and minimizing total real power losses of the competitive electricity markets which consisted of bilateral and multilateral transactions. Simulations were performed on IEEE 30-bus and practical UPSEB 75-bus systems. Results of the two systems revealed the following:

1. Test results indicated that optimally placed TCSC by PSO could significantly increased TTC, reduced real power losses and reactive power losses under normal and contingency conditions.

2. PSO exhibited robust convergence characteristic so it could be used to effectively calculate TTC. PSO obtained sub-optimal solution within 40 iterations, so the proposed method could be used to evaluate TTC in online TTC measurement system.

Chapter 4 has suggested PSO based algorithm to find the best location and setting of TCSC to maximize social welfare, minimize total generation cost and installation cost of TCSC while satisfying various constraints. Simulations were performed on IEEE 6-bus, IEEE 30-bus and practical UPSEB 75-bus systems. Results of the three systems revealed the following:

1. Different simulation results obtained showed a remarkable rise in social welfare of various market participants like producer surplus and consumer surplus and decrease in total generation cost.

2. Optimally placed TCSC decreased merchandize surplus (congestion rent) because it decreased line losses.

3. Optimally placed TCSC enhanced voltage profile of various load buses. The results of the proposed method were compared with those of classical method (Nonlinear programming method) and Evolutionary Programming (EP) methods. The simulation results also revealed that the proposed PSO based algorithm outperformed Non-linear programming method and Evolutionary Programming (EP) methods in terms of quality of solution.

Chapter 5 has investigated the impact of optimally placed TCSC on transmission pricing (Spot prices), active and reactive power wheeling charges and secure bilateral transactions. The simulations were carried out on IEEE 6-bus, IEEE 30-bus and practical UPSEB 75-bus systems. Results of the three systems revealed the following:

1. Optimally placed TCSC could significantly increased active power spot prices and reactive power spot prices at the generator buses and decreased them at the load buses. Reactive power spot price is negligible as compared to active power spot price but reactive power wheeling charge is comparable with active power wheeling charge.

2. TCSC remarkably decreased active and reactive power wheeling charges of various bilateral transactions. So, it is concluded that optimal placement of TCSC is very much beneficial to the GENCOs and DISCOs because they have to pay less charges to the transmission owner for the usage of transmission infrastructure.

3. The pattern of secure bilateral transaction matrix has been obtained without and with optimally placed TCSC. It is seen that the pattern of secure bilateral transactions is different for without and with TCSC due to different power flow through the transmission lines. The obtained transaction matrix will enable Independent System Operator (ISO) to obtain better dispatch results to meet bilateral demands and reserving the bilateral transactions within the available transfer capability for increasing the operational efficiency of the deregulated electricity market.

In chapter 6, the top priority problem i.e. Congestion management has been solved by PSO. A sensitivity based method has been used for selecting number of generators which took part in managing congestion. Then PSO based algorithm has been suggested for minimizing active power rescheduling cost and reactive power rescheduling cost of selected generators to alleviate congestion in IEEE 30-bus and UPSEB 75-bus test systems, considering voltage stability (L-index) and voltage profile improvement criteria. The results obtained by the proposed method have been compared with those of [108] and [85]. The contribution of this chapter can be summarized as follows:

1. Instead of using all generators for managing congestion, only a few generators may be used to manage congestion and the generators which take part in congestion management may be selected based upon their sensitivities to the congested lines.

2. The effect of reactive power of generators should be considered in managing congestion. Rescheduling of reactive power of generators along with their active power rescheduling reduced overall rescheduling cost to manage congestion.

3. Reactive power rescheduling helped in improving voltage profile of the load buses and it enhanced voltage stability of the system in the post-rescheduling state.

4. Losses obtained by the proposed method were significantly lower than those of other reported methods. So, the proposed algorithm improved performance of the system in the post-rescheduling state. Thus, experiment showed encouraging results, suggesting that the proposed approach was capable of efficiently determining higher quality solutions addressing congestion management.

7.3 Scope for future research

Consequent to investigations carried out in this thesis, the following aspects are being suggested as future research work to be carried out.

1. In chapter 3, a PSO based method has been suggested for maximizing TTC and minimizing transmission line losses with and without using TCSC. In order to improve effectiveness of the proposed method, Transmission Reliability Margin (TRM) and Capacity Benefit Margin (CBM) may be included in OPF model. The proposed method may be used for TTC calculation in Day Ahead Market. Placement of TCSC has

been done from static point of view. Its dynamic consideration may be included in the proposed method.

2. In chapter 4, only TCSC was considered for social welfare maximization. Other FACTS devices like UPFC, SSSC and TCPAR may be used for maximizing social welfare. In addition, Installation cost of TCSC has been minimized. In future, investment recovery of TCSC may be included in OPF model so benefits offered by TCSC can be quantified in terms of monetary values.

3. In chapter 5, active power and reactive power spot prices have been found out. In future, sensitivities of the spot prices with respect to load demand, generator cost parameters and voltage bounds may be included in the OPF model. The proposed method can be extended to include reactive power transaction allocation.

4. In chapter 6, the bids from generators have been utilized for congestion management. In some deregulated markets, interruptible loads are also used. So bids from such loads can be incorporated for congestion management. Also, the same algorithm may be extended to solve dynamic congestion management problem. In recent years, the usage of renewable energy sources like wind energy and solar energy has increased drastically. So, their cost functions and constraints may be included in the OPF model to simulate congestion management.