CHAPTER 6
CONCLUSION AND SCOPE FOR FUTURE RESEARCH

6.1 CONCLUSION

This chapter covers a review of the contributions made during the course of this work and suggests some new ideas for future work. Reactive power must be sufficiently available whenever and wherever required to ensure constant voltage profile through the transmission and distribution networks. Otherwise, voltage instability occurs leading to system blackout. Therefore, reactive power compensation is important in power systems.

In this thesis, FACTS devices like SVC are employed for reactive power compensation in WFs to examine the possibility of providing reactive power support to the grid. A simulink model has been developed using MATLAB / SIMULINK and simulated for various wind speeds and pitch angles. It is also observed that the voltage profile is maintained usually within ±5% of the nominal voltage through the usage of SVC, even though voltage variations are caused due to wind speed fluctuations. This can be achieved by the injection of reactive power using three TSCs in SVC controller module for higher values of pitch angles.

Then the optimum cost of reactive power is estimated by two different ways namely

1. Sensitivity Analysis
2. Load Tracing

In the first method, reactive power support can be segregated into two components namely the utilized component of reactive power and its effective
reserve. For the calculation of these components, MAIS is adopted considering both the static and dynamic variables of the system. MAIS is applied to a case study of practical 75-bus Indian system WFs and found that the sensitivity analysis done using MAIS ignores the line losses and is found to be less accurate. Since Newton Raphson load flow is performed for the calculation of sensitivity factor, the number of iterations is large and requires more computational time.

In the second method, the drawbacks in sensitivity analysis have been overcome and the optimum cost of reactive power is estimated by employing a hybrid algorithm (HIOPFE-LTMSA) namely an IOPFE with a novel load tracing using Meta-heuristic search algorithm. Tabu Search (TS) is the selected Meta-heuristic Search Algorithm which prepares the tabu list for load tracing. If SVC used for reactive power compensation in wind farms seems to be insufficient, it may combine the diesel generator. Therefore, the objective function is framed consisting of the cost of system loss components, reactive power support cost of SVC and production cost of diesel generator. The proposed hybrid algorithm has been applied to IEEE 14-bus, IEEE 26-bus, IEEE 30-bus and IEEE 57-bus and the results are compared with other evolutionary algorithms like BX-CACO, ACO\textsubscript{R}, EP and GA. It is observed that even for IEEE 57-bus system, the proposed algorithm converges faster than BX-CACO for 50 minutes, ACO\textsubscript{R} for 85 minutes and EP,GA for an average of 80 minutes after the ant colony algorithms. Further, this proposed hybrid algorithm is compared with other tracing algorithms like Bialek’s and Kirschen’s tracing for solution optimality. After finding out the efficiency of this hybrid algorithm, it is applied to a case study of practical 75-bus Indian system WFs for reactive power cost estimation.

Finally for the same case study, Load Tracing using Monkey Tree Search Algorithm (LT_M TSA) is also adopted which makes smart and intelligence decisions in a shorter running time. The convergence time is very much reduced due to the application of greedy factor of monkeys compared to HIOPFE-LTMSA.
From the Table 6.1, the reactive power cost calculated for practical 75-bus Indian system using LT_MTSA is lesser compared to the hybrid algorithm, HIOPFE-LTMSA which implies that LT_MTSA algorithm produces a near optimal cost of reactive power. The computation time of reactive power cost is calculated for the entire set of wind speed data ranging from 3 m/s to 15 m/s.

**Table 6.1 Comparison of various methods**

<table>
<thead>
<tr>
<th>Methods</th>
<th>Total Cost (Rs./MVAr)</th>
<th>Computation time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSO</td>
<td>1,25,240.03</td>
<td>40.12</td>
</tr>
<tr>
<td>HPSO</td>
<td>1,48,346.45</td>
<td>35.12</td>
</tr>
<tr>
<td>Conventional Value Based Approach [47]</td>
<td>96,133.39</td>
<td>30.00</td>
</tr>
<tr>
<td>MAIS</td>
<td>95,678.02</td>
<td>26.16</td>
</tr>
<tr>
<td>Load Tracing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIOPFE-LTMSA</td>
<td>1,18,547.50</td>
<td>105.36</td>
</tr>
<tr>
<td>LT_MTSA</td>
<td>1,07,184.00</td>
<td>85.24</td>
</tr>
</tbody>
</table>

The cost of reactive power computed by PSO and HPSO are 30.28% and 54.31% higher compared to conventional value based approach [47], but MAIS produces 0.47% lesser cost compared to the conventional value based approach [47]. The computation time for PSO and HPSO are 33.73% and 17.07% respectively higher compared to conventional value based approach [47]. But MAIS requires 12.8% computation time which is lesser compared to the conventional value based approach [47].

The proposed methodologies of reactive power pricing based on load tracing makes the pricing stable and can serve as a system index related to the system voltage support and provides an incentive to improve the load power factor and reduce the reactive power demand. The proposed algorithms in spite of providing near optimum and efficient solution, also provides a potential tool to help the power system operators in the on-line environment. Compared to the two proposed load tracing algorithms, it is observed that LT_MTSA provides
a reduced cost, faster convergence to near optimal solution and helps the power system operators for optimal reactive power cost estimation in wind farms. Therefore, LT_MTSA can also be applied to solve non-linear, non-differentiable and high dimensionality optimization problems because of its effectiveness of computation with a faster convergence rate.

6.2 SUMMARY

- Reactive power cost management is accomplished by reactive power compensation and reactive power pricing. Optimum reactive power cost allocation is performed using both sensitivity analysis and load tracing by incorporating SVC for reactive power compensation.
- A case study of practical 75-bus Indian system WF is considered for reactive power cost allocation.
- For sensitivity analysis, a novel Meta-heuristic search algorithm like MAIS is adopted and found that it takes a computation time 50% lesser than HPSO and 60% lesser than PSO.
- For load tracing, novel Meta-heuristic search algorithms like HIOPFE-LTMSA and LT_MTSA are adopted and the results are compared with other conventional evolutionary algorithms and it is also inferred that LT_MTSA has 9.5% lesser cost compared to HIOPFE-LTMSA.

It can be observed that for the same electrical network configuration both sensitivity and tracing methods are proved almost better. But those methods are not so much comparatively competitive for the reactive power cost allocation in the ancillary service environment in the restructured market by the way that is:

- For achieving better accuracy, the tracing method is proved comparatively better since it considers the line losses of the electrical network. Among the two tracing methods like HIOPFE-LTMSA and
LT_MTSA, the latter provides a near optimum cost of reactive power for lossy electrical network.

- For increased speed of response or execution, sensitivity analysis is proved comparatively better since reconfiguring of the electrical network is not required. Among the population based algorithms like PSO, HPSO, conventional value based approach and MAIS, the latter provides a near optimum cost of reactive power for lossless electrical network.

### 6.3 SCOPE FOR FUTURE RESEARCH

- FACTS Devices like STATCOM and UPFC can also be employed for reactive power compensation in wind farms and their best optimal location in wind farms can also be calculated using sensitivity analysis.
- Case Study of higher bus systems can also be selected for reactive power pricing.
- Other Meta-heuristic Search Algorithms like Improved Sheep Flock Heredity Algorithm and Mean-Variance Mapping Optimization (MVMO) can also be adopted for load tracing for obtaining optimum reactive power cost.
- Reduction of Computational time can be achieved by combining two meta-heuristic methods like GA and PSO with a classical method SQP (Sequential Quadratic Programming)
- Multiobjective functions can also be formulated for Reactive Power Planning by subcategorizing the problem into evolution based and swarm intelligence.
- A hybrid model comprising wind and thermal generation can be developed and optimized using a new evolutionary hybrid algorithm and the results can be compared with PSO to prove its effectiveness.