CHAPTER-6
CONCLUSION

To address the environmental concerns, the share of renewable energy sources has increased considerably over the years. Therefore, to achieve the objective of economic and secure power system operation in the integrated environment has introduced some newer problems. The present work intends to solve a similar problem in a test power system assuming some of the smaller generating resources as DFIG based WECS units. Formulated in the OPF framework, the objective of the problem is to obtain the optimal scheduling of wind and thermal units, so that the generation schedule not only provides minimum cost but also a secure operation, even during stressed system operation. During the problem formulation, suitable cost components which quantify the nature of intermittency of wind, many operational penalties for limit violations of quantities related to the thermal & wind units and the system in general, are added to the total generation cost. The voltage and current limits of GSC imposes a restriction on the reactive powder capacity of DFIG units. Due to the restricted $Q$-support capability at the connected bus, particularly during the $UE$ scenario, they reduce the system operating bus voltages. The problem is addressed in this work in a proposed method of $Q$-restricted power flow solution for the DFIG buses. Two different operating scenarios of $Q$ violation at the DFIG buses are checked for their performance, considering local $Q$-support at the same location. The formulated problem is solved using a modified version of BFA, termed as MBFA. The results when compared with GA solutions gave more economic and secure system operation. To further improve the reactive power capabilities of the system a STATCOM is connected at the weakest bus in the system. Reformulating the additional costs for STATCOM, the OPF problem is solved with MBFA and ACO to obtain an optimum generation schedule and compare their relative optimized costs and system operation. Like the previous case, the MBFA not only depicts
optimization superiority in terms of optimized value of cost but also more secure schedules compared to ACO. In this case the system operation with $Q$-support available only from STATCOM is found to be more economic and efficient during stressed system operation. Local support at the DFIG buses is found to degrade the bus voltages when STATCOM is operating. Apart from the effects of $UE$, which are seen in the first two chapters, the operation of the integrated system under the $OE$ condition has also been studied in the subsequent chapter. For some fundamental understanding, the need and utilization of reserve power of the system is investigated at the outset.

Optimum utilization of available wind power can contribute to reduction of emission from thermal generating units by reducing their load demand. This issue has been designed and modelled properly in environmental optimal power flow (EOPF) framework considering the total generating cost and emission cost as two objectives. The most promising solutions obtained are demonstrated in Pareto optimal front. This problem of multi objective optimization finally chooses the most non compromising solution using a fuzzy rule. In this problem the supremacy of MBFA is found with respect to the PSO and HA, which integrates the GA philosophy into BFA.

Finally, to reduce the burden on thermal power generating units for utilizing their reserve capacity during the $OE$ scenario, hydro power units are integrated with Wind-Thermal generation system. The model and constraints of hydro-thermal-wind powered units are suitably formulated and integrated in the OPF formulation. Different objective functions are proposed for this hybrid system with a suitable power flow that takes care of the voltage violations. The constrained objective function is solved using different optimization techniques namely GA, HA, and MBFA. From system operational point of view it is found that for a smaller wind penetration upto 20%, the wind-thermal system behaves similar to hydro-thermal-wind system. But when the wind penetration is enhanced up to 45%,
considerable improvement in the system voltage is observed for wind-thermal system as compared to hydro-thermal-wind system.

Some concluding points for the entire work are summarized below.

i) The error of real power estimation may involve operating costs and therefore should not be neglected in modelling.

ii) Due to the limited reactive power capacities of DFIG based WECS, the practical Q limits of GSC should not be avoided for an accurate analysis. That is, during the process of power flow solution of wind generator buses, the solution should be iteratively solved within the changing Q limits of the GSC.

iii) The need of additional reactive power support by external sources can be met both by connecting static shunt switched capacitors at the DFIG buses, SVC or STATCOM at suitable location. But, in a preliminary study, the results of STATCOM operating alone have given better system voltages compared to a combined operation of STATCOM and local Q-support at the DFIG buses.

iv) During the OE conditions, the additional utilization of reserve power of thermal units can be optimized so that apart from the generation cost and system operational costs, it can also include an environmental cost.

v) Instead of using thermal reserve capacity, hydro reservoir based systems can be a better alternative to reduce pollution. However, from the system voltage profile point of view, the integration of hydro systems is beneficial only up to 20% of wind power penetration. If the wind penetration level grows beyond 45%, the hydro system connection is not beneficial.

vi) In all the problems of optimization done in this work, the results of the modified algorithm, i.e., MBFA, has shown it superiority over many other algorithms. It has not only minimized the respective objective function but also done so using less
computational time. The performance of all the optimized schedules have given better and more voltage secure system operation even during N-1 contingencies, compared to the results with other algorithms.

**Extension of the work for Future Work**

1. Though this work mainly concentrates on the steady state operational aspects like generation cost, loss and voltage security, the dynamic aspects of operation and constraints may also be incorporated into the multi-objective optimization problem and may be taken up as future work.

2. This work has considered a penalty factor based objective function. Though an approximate approach of Pareto front is tried in Chapter-4, a non dominating solution based multi objective optimization tool like the NSGA, NPGA or any of their improved versions of algorithms may give a better compromising solution in all the problems which can operate the system in even more secure manner.

3. More practical system constraints specific to the three different types of generation systems may be included in the optimization problem. Moreover, the inclusion of Solar and Gas turbine based generation system will complete the entire family of different renewable resources.