CHAPTER 6

CONCLUSION

6.1 INTRODUCTION

The purpose of this chapter is to review the significant results obtained during the present work and to make suggestions for future research. Before proceeding with the review of the work done, the objectives of the thesis stated in the first chapter are recalled.

The primary objective of this thesis is to propose a common evolutionary programming methodology that can be applied to all types of power dispatch problems viz. economic dispatch of generators with prohibited operating zones, economic dispatch of generators with multiple fuel options, combined environmental / economic dispatch with conflicting objectives and multi-area economic dispatch with tie-line constraints.

6.2 REVIEW OF WORK DONE

An evolutionary programming approach has been developed which is adaptable for any kind of power system economic dispatch problem, which involves optimization of an objective function with non-linearities and discontinuities. The approach developed accounts for several practical operating constraints. These constraints include the power balance equality constraint and
inequality constraints such as unit generation limits, reserve constraints, ramp rate limits and tie-line flow constraints.

In the introductory chapter, a brief survey of the optimization techniques available in the literature for solving power system economic dispatch problems is included. This survey covers both conventional and the recent unconventional search techniques. The motivation for the present work is also brought out in this chapter.

Based on the objective, a common evolutionary programming methodology has been developed to solve the different kinds of economic dispatch problems with several constraints. The major difficulty faced in this approach was to account for the different constraints associated with each kind of economic dispatch problem. The investigations made to test the applicability of this new approach and the results obtained are summarized as follows:

i. **Economic dispatch of units with prohibited operating zones**

The traditional method of solving power system economic dispatch problems requires a continuous, smooth, convex cost function. The presence of prohibited operating zones divides the operating region between the generation limits into disjoint convex sub-regions. As a result the economic dispatch problem becomes a non-convex optimization problem. This non-convex nature of the problem has been dealt with by the developed evolutionary programming approach without any extra computation or complexity as required in the traditional methods.
An innovative procedure for initialization and for tackling constraint violations are adopted. In the initialization procedure itself, the chosen unit power generations were confined only to the operating sub-regions.

During mutation, the constraint violation of power generation falling in a prohibited zone is corrected by assigning each violating generation level, a boundary value which depends upon the unit generation's magnitude with respect to the mid-point of the prohibited zone.

ii. Economic dispatch of units with multiple fuel options

Since the proposed evolutionary programming approach imposes no restrictions on the shape of the function to be optimized, the piecewise quadratic cost function associated with economic dispatch of units with multiple fuel options has been solved successfully using the new method.

The developed evolutionary programming approach is found to be direct, simple and easy to implement, as there is no need for additional computations to deal with piecewise quadratic cost curves.

In this approach, during initialization, each component of a trial parent individual is generated at random, which is uniformly distributed within its feasible range between the upper and lower generation limits.

This approach is successfully tested on a system of ten generating units, each with two or three fuel options and the results obtained are compared with those obtained by adaptive Hopfield neural network method and the solutions are found to be identical.
The approach developed in this work has faster convergence property in finding the optimal solutions and hence is a more powerful and practical tool for optimizing piecewise quadratic cost functions associated with economic dispatch problems.

iii. Combined environmental/economic dispatch

A bi-objective power dispatch problem is solved using the evolutionary programming approach. The approach has been used to solve a six generator example system with transmission losses accounted using B-coefficients. The example system has been solved for pure economic dispatch, pure environmental dispatch and combined environmental / economic dispatch. All these dispatch strategies include the power balance and generation limits constraints. The comparison of the results obtained using the proposed method with those of fuzzy logic controlled genetic algorithms shows that evolutionary programming approach always leads to global or near global optimum solutions.

A trade-off curve between fuel cost and emission level for a specific value of load demand has been plotted. This curve is generated by increasing the value of the weighting coefficient $\omega$ from 0 to 1 in steps of 0.1. For each value of weighing coefficient the combined environmental/economic dispatch problem has been solved for minimum cost. Such a trade-off curve will be useful for power system dispatcher depending on the utility's priority between minimum fuel cost and minimum emission levels.

This proved that the evolutionary programming approach developed in the present study can be utilized to solve a single objective as well as conflicting multi-objective power dispatch problems.
iv. Multi-area economic dispatch with tie-line constraints.

The new approach presented in this thesis has also been applied for complex multi-area economic dispatch problem which includes tie-line constraints. The tie-line constraint is enforced by introducing the tie-line flow in either direction as decision variable and the inclusion of this constraint does not complicate the approach. A single variable is used to represent the tie-line flow in either direction as against using two variables and hence the number of iterations required for convergence has been drastically reduced. This approach has been tested on two, four and fourteen area sample systems with one, six and seventeen tie-lines respectively.

In the four area sample system there are sixteen units and six tie-lines. In addition to fuel cost, transmission cost is also minimized by including it as part of the objective function. The transmission costs are considered as linear functions of the power transfer. Its results are compared with those of the incremental network flow programming algorithm. The percentage difference between the optimal cost of the evolutionary programming approach and the incremental network flow programming algorithm is a negligible 0.08%.

In the fourteen area seventeen tie-line example system, in addition to tie-line constraints, tie-line losses are also accounted for. The tie-line losses are assumed to be linear function of the power transfer. The results of applying the evolutionary programming method are compared with those of spatial dynamic programming method. The percentage difference between the optimal values of cost of the developed approach and spatial dynamic programming method is only 0.011% which is negligible.

These errors can be reduced with additional iterations, if desired, at the cost of computing time. The flexibility of the evolutionary programming approach
in accommodating the tie-line constraints shows that this approach is a powerful tool for solving multi-area economic dispatch problems.

The developed evolutionary programming approach provides better solutions with less computational effort and has the ability to account for all types of constraints with improved reliability and wider applicability. Several system studies prove that the convergence to the optimum is very fast.

6.3 RECOMMENDATIONS FOR FURTHER RESEARCH

The hill climbing algorithm and iterative gradient methods get trapped in local minima but have faster convergence. Evolutionary algorithms have global search characteristics and robustness that prevent them from getting trapped in local optima. Hence evolutionary algorithms can be applied in the initial stages of the solution for global search and the hill climbing algorithms can be applied in the later stages for fine local search. This hybrid evolutionary search may be able to combine the advantages of both the approaches and find optimal solutions more rapidly compared to using a single search technique throughout. This has to be examined for solving different kinds of economic dispatch problems.

The conventional evolutionary programming for economic dispatch problem have used Gaussian mutations to generate new offsprings. Using a variety of mutation operators like Cauchy mutations the potential for producing better solutions with less computational effort and solution time have to be investigated.

For solving large scale practical multi-area economic dispatch problems with tie-line constraints, there is scope for developing further the evolutionary programming approach to improve the computing speed. Hence the present
approach and the results presented in this work will encourage further research in this field.

6.4 SUMMARY

The evolutionary programming approach developed in this thesis will be extremely useful for electric power utilities in enhancing the economy and security of operation in their systems.