CHAPTER 6

CONCLUSIONS

6.1 INTRODUCTION

This chapter summarizes the impact of the research for minimizing the fuel cost of electric power generation expenses, the findings obtained from the work carried out and the suggestion for future research. The main objectives of the thesis as stated earlier in the introductory chapter are recollected before proceeding with the review of the contributions of this research. The main objective of EDP is to allocate the generation among the committed units in such a way that the total cost of utilized fuel is minimized satisfying all necessary constraints.

The ultimate aim of this research is to formulate a more accurate EDP. In traditional EDP, fuel-cost function of generating units will be formulated as a quadratic function and it is solved using derivative based optimization techniques. But in reality this assumption may lead to infeasible solution because of non-linear characteristics in practical generating units. These non-linear characteristics of a generator include valve point effect, prohibited operating zones, ramp rate limits, multiple fuel option and etc.

For a unit with prohibited operating zones, its operating region will be broken into several isolated sub-regions. It can only be dispatched to one of the isolated sub-regions in practical operation. The isolated sub-regions will form multiple decision spaces and result in a very challenging task for
determining the optimal economic dispatch. Generators with multivalve steam turbines produce ripples like effect on their smooth fuel cost curves. This effect known as valve point effect makes the generator cost function discontinuous and non-convex.

For accurate modeling of the cost function, the valve point effect is considered by superimposing it with the basic quadratic cost function. The EDP is modelled with the above practical features of generating units transforms the EDP to a complex optimization problem containing nonconvex characteristics, with multiple solutions. This makes the traditional derivative based optimization techniques difficult to search the global optimum. As an alternative to the conventional mathematical approaches, several derivative-free optimization methods were applied to solve the EDP and DED problems. Here in this research, it is proposed more efficient solution techniques using DE and validated using numerical test case simulations. The performances of the proposed methods are compared and validated with the result of other techniques from the literature.

6.2 SUMMARY OF CONTRIBUTIONS

EDP and DED are the essential and vital step in power system operational planning. Accurate modelling of EDP & DED with the inclusion of valve-point loading effects makes the solution space of these problems, non-convex with many local minima. Therefore, DED becomes a highly non-linear and non-convex optimization problem, which cannot be solved by traditional techniques. To overcome, a new algorithm inspired by the DE algorithm is proposed in this thesis.

This thesis starts by reviewing the state-of-the-art survey of both the EDP and DED problems and the hybrid algorithm applications. A clear consensus is presently tending towards the non-classical optimization
techniques over traditional optimization techniques. This research is based on many research articles published in last 40 years and periodic bibliographic updates on this topic will be useful as the electrical industry continues to evolve. Thus in this research work an attempt is made to solve the non-smooth EDP and DED problems using several variants of the DE algorithm. Thus, to solve the EDP, DE with variable neighbourhood search (DE-VNS) method, DE with random scale factor (DE-RSF) and DE with neighbourhood search operation are used. However, to solve the DED problem, DE with neighborhood based mutation is used.

The development of a new approach to solve EDP with non-smooth cost function using differential evolution technique is proposed. The DE technique is combined with VNS to improve the quality of the solution and convergence speed. DE is first introduced to find the locality of the solution and then VNS is applied to tune the solution. The efficiency of the proposed technique is examined with four test systems of 3, 10, 15 and 40 generating unit system. Results obtained from the proposed DE-VNS method after simulation show that the total production costs is less expensive compared with other traditional methods. In addition to the DE-VNS method, DE with random scale factor is also developed to solve the ELD problem with non-smooth cost function. Here an additional unit with a few constraints are included in the problem formulation of EDP. In order to verify the effectiveness of the proposed method, four test systems with 3, 13, 15 and 40 units are considered. After simulation with standard test systems, results obtained for the proposed technique implies better results compared with the existing.

Subsequently, a differential evolution technique enhanced with neighbourhood search operation is implemented to solve the ED problem. The neighborhood search operation based DE method incorporates DE as the main
optimizer and neighborhood search operator as a local optimizer. A neighborhood search operation is equipped with linearly increasing weight factor is considered in an attempt to balance the effects of both exploration and exploitation capability of differential evolution. An extensive performance comparison with other strategies of DE indicated that the proposed approaches enhance DE capability to produce solutions in the search space. The significant modifications are mainly focused on preventing premature convergence of DE for dealing with the complicated constraints of the non-smooth economic load dispatch problem. A more realistic EDP is formulated by considering non-linear generator characteristics such as valve point effect, ramp rate limits, prohibited operating zones and spinning reserve. The performance of the proposed method is validated using five case studies derived from three test systems are considered. The three test systems considered are 10-unit, 13-unit and 15-unit systems. Each case study differs from the other by the test system considered and the constraints handled. The case studies with different type of practical constraints such as Spinning Reserve, multiple fuels, prohibited operating zones and valve point loading effects were considered in solving a non-smooth economic load dispatch by the proposed method. The robustness and effectiveness of the proposed technique is compared with other variants of DE based on the quality of the final solution obtained. The proposed method was also tested for a real time Indian utility system. Simulation results clearly shows the results obtained for incremental load demands by the proposed method is minimum and is compared with those obtained from various methods.

This research also discusses the application of differential evolution with neighborhood based mutation) technique for solving dynamic economic dispatch (DED) problem with valve point effects and multiple fuel options. The performance of the proposed method is tested on a standard ten unit and a real public Indian utility system with nineteen generating units. Both the test
systems are illustrated under different load patterns. Two case studies are studied using the proposed method. The fuel cost functions of the two systems are non-convex considering valve point effect and multiple fuel option in its fuel cost. Three different load patterns are applied for both these systems to demonstrate the robustness of the proposed solution technique as well as to show the effectiveness in scheduling for different load patterns. The simulation horizon for all the three load patterns is taken as 24 Hour with a dispatch interval of 1 hr. The results show that the proposed method is efficient in handling the constraints and it is applicable to larger systems. The search ability of the proposed method is improved by striking proper balance between exploration and exploitation process. The final schedule and cost obtained using the proposed method is compared with available data in the board. The simulation results shows that the proposed method is capable of producing solutions which are near optimal and has stable converging characteristics.

6.3 SCOPE FOR FUTURE RESEARCH AND SUMMARY

Optimization of power generation problem formulation considered in this research confines to the system, which is to be solved for both EDP and DED problems. It is recommended that, the problem formulation can be extended in future by considering systems with higher order polynomial cost function, incorporating the line constraints such as voltage profile improvement index, line loading capability, reactive power dispatch and environmental constraints such as emission dispatch. In future it can be extended by considering and hybridization of non-conventional energy sources like wind, solar and micro turbine power generation systems in the conventional power systems so as to minimize the total production cost subjected to the above constraints. The constraints considered in the new EDP and DED problem formulations are sufficient to validate the outcomes of the
solution techniques and this is claimed from the publications resulted out of this research. Even then it is suggested that, there are several other constraints left to be addressed. The constraints considered in this research work not only increase the accuracy of the problem formulation but also improve the feasibility and reliability of the solution techniques for real-time cases.

The contributions of the thesis may be extended for future research in the following areas

- Differential Evolution with Neighborhood Search Operation algorithm can be utilized to solve other electric power system optimization problems such as Unit Commitment and Optimal Power flow.

- The DED problem solved by using Differential Evolution with Neighborhood Mutation can be subjected to additional constraints or objective functions. The current system can be incorporated with renewable energy sources so as to minimize the total production cost.

- Incorporating distributed generation for the above system by including the concept of sitting and sizing of distributed generation makes the problem more complex.

- Dynamic Economic Dispatch problem considered in this research can be extended to solve for emission constrained optimization problem. By including various gas emissions such as NO\textsubscript{x}, CO\textsubscript{x} and SO\textsubscript{x} in the problem formulation it can be formulated as a multi-objective optimization problem.
This research presented various issues in developing effective solution techniques for a reasonable power generation problem considering the multiple fuel options and spinning reserve in addition with other constraints, for economic and effective power system operation. Since the future scenario fully focuses on economic power system operation to meet the electric power crisis, it can be understood that this research is not confined to a small research group and the results presented here will be of immense use and will serve the purpose of stimulating interest among future researchers.