Chapter-6
Chapter 6

Conclusion

6.1 General Conclusion

Problems related to optimal operation of power systems are of prime importance in electric systems. The choice of optimal criteria is always a subjective one as one has to first decide as what shall have to be minimized or maximized, how many objectives are to be considered and what are the relations among the objectives. The problem becomes challenging because of mainly two facts; one, the unit characteristics may be highly nonlinear and two, the objectives may be of conflicting nature. Two types of problems of optimal operation in power systems are addressed in this thesis works: (1) Single objective problems that deal with the minimization of total cost of production of all generating units, usually called Economic load dispatch (ELD). The complexity in solving this type of problem arises because of the highly non-convex cost curves of generating units; (2) Multi-objective problems in power systems as generally called combined economic emission dispatch (CEED). Solution of these types of problems are more challenging as because of their conflicting nature of objectives and high nonlinearity of the objective functions.

Algorithms based on floating point GA (GAF), self-adaptive CEP, PSO, PSO-CEP, CEP-PSO and CEP-PSO' were developed in Chapter-2 and their performances were tested on two test cases of non-convex economic load dispatch problem with valve point loading effects; one comparatively smaller system of 15 units and the other moderately large one with 40 units. Results show that all
6.1. General Conclusion

the hybridized algorithms are more competent to individual algorithms. There is not much significant difference in performance between CEP-PSO and PSO-CEP while the former appears to have slight improvement over the latter. Amongst the hybrid algorithms, CEP-PSO' appears to be the most efficient in achieving better quality solutions at faster convergence rate. Solutions with different random trials also proved higher efficiency of the CEP-PSO' technique. Hence, CEP-PSO' technique can be considered as a very fast and reliable algorithm to solve non-convex economic load dispatch problems.

Also, because of reported better performance of IFEP amongst the EPs, it was felt to hybridize PSO and IFEP. Accordingly algorithms based on CEP-PSO' and IFEP-PSO' were developed and their performances were tested on a test case of non-convex economic load dispatch problem with valve point loading effects. Results reveal that IFEP-PSO' appears to be more efficient in achieving better quality solutions at faster convergence rate. Solutions with different random trials also proved better performance of IFEP-PSO' technique over CEP-PSO' in finding quality solutions. Hence, IFEP-PSO' technique can be considered as a very fast and reliable algorithm to solve highly nonlinear non-convex economic load dispatch problems.

In Chapter-4, multiobjective problems like CEED in power system are dealt with. The reported impressive performance of NSGA-II on benchmark mathematical problems induced us to use NSGA-II for solving CEED problems in power system. Some modifications were proposed to improve the efficiency of creating more number of nondominated solutions spread over entire Pareto front. Programs based on modified NSGA-II algorithm with adaptive threshold value for crowding distance are developed in Matlab command line and their performances are tested on two test cases of optimum combined economic emission dispatch problems. Test case-I is comparatively smaller and simpler i.e. cost functions do not consider the valve point loading effects although the emission curves for both $SO_2$ and $NO_x$ are of cubic type. The number of objectives considered is three. Test case-II is moderately larger having comparatively more complex functions because of the effects of valve point loadings in addition to having the cubic emission functions for both $SO_2$ and $NO_x$. The results demonstrate that the algorithm based on
modified NSGA-II is well competent and efficient in solving multiobjective optimization problems like combined economic emission dispatch (CEED), as in test case-I, specifically when more than two conflicting objective functions are to be optimized. It is equally well competent in solving CEED problems even when there are more than two objective functions and all the functions are of highly nonlinear nature as in test case-II.

Chapter-5 proposes to develop an algorithm for the solution of complex and nonlinear CEED problems based on modified NSDE to exploit the reported better performance of DE algorithm on benchmark problems. Programs based on modified NSDE with adaptive value for crowding distance algorithm are developed in Matlab command line and their performances are tested on the same two test cases of optimum combined economic emission dispatch problems as in chapter 4. Test case-I is comparatively smaller and simpler i.e. cost functions do not consider the valve point loading effects although the emission curves for both $SO_2$ and $NO_x$ are of cubic type. The number of objectives considered here is three. Test case-II is moderately larger and also comparatively more complex with the cost functions with the effects of valve point loadings in addition to having the cubic emission functions for both $SO_2$ and $NO_x$. The results demonstrate that the algorithm based on modified NSDE with adaptive value for crowding distance is very well competent and efficient in solving multiobjective optimization problems like combined economic emission dispatch (CEED), specifically when more than two conflicting objective functions are to be optimized. It is equally well competent in solving CEED problems even when there are more than two objective functions and all the functions are of highly nonlinear nature like in test case-II. The results obtained by modified NSDE are superior to that obtained by modified NSGA-II. Hence, modified NSDE may be recommended for solving highly nonlinear multiobjective CEED problems.
6.2 Limitations

Though the proposed algorithms, hybrid PSO and EP based algorithm for solving ELD problems, modified NSGA-II and modified NSDE algorithms for solving CEED problems, are demonstrated to be efficient in solving the problems, they do have the limitations. That means there are ample scopes for further improvement. The followings are the limitations in the developed algorithms:

6.2.1 Limitations of Hybrid PSO-EP Techniques

(i) Both PSO and EP require the evaluation of individuals more than twice which may make the algorithm cost in efforts and time.

(ii) There is no explicit rules for optimum choice of multiplier used in adaptation of strategy parameter and tuning of the parameter requires a number of trial which takes time.

(iii) Also, the adaptation of strategy parameter using log-normal formula often lead to premature convergence.

(iv) The quadratic and dynamic penalty function used in this work assumes that constraint violation incur independent penalties and as a result there is no interaction between constraints. Intuitively, this seems to be a possibly erroneous assumption as one could make a case for a penalty which increases more than linearly with the number of constraints violated.

6.2.2 Limitations of modified NSGA-II Method

(i) Both the crossover and mutation functions used in NSGA-II give rather more stress randomization than any heuristic, which may limit the search capability of the algorithm specifically the convergence rate.

(ii) Tuning of the parameters is a prerequisite before finding a final solution requiring repeated trial runs of the algorithm, which may take time.

(iii) The used selection function in NSGA-II based on nondominated sorting does not have much self-adaptability to cater automatically different types of
6.3 Scopes For Future Works:

multiobjective problems.

6.2.3 Limitations of modified NSDE Method

(i) In the single objective implementation of the Differential Evolution, if the new candidate is evaluated and found to be better than the current individual, then the current individual is replaced with the new individual. In the multi-objective implementation this is not possible because we don't know which individual is better until all candidates are sorted together and assigned to a non-domination level.

(ii) Though modified NSDE uses the self-correlating step sizes of Differential Evolution under Scheme DE1 of mutation, the scheme do not have much greediness as in Scheme DE2 of mutation. As such the convergence rate and efficiency of the algorithm will be affected.

(iii) The control parameter used for amplification of differential variation in mutation operation is assumed constant, which may also have to be tuned. This requires time and efforts. Also, as the amplification required is not same for all the parameter and during the whole evolution period, use of constant parameter may reduce the efficiency of the algorithm.

6.3 Scopes For Future Works:

It has been demonstrated that hybrid algorithms based on PSO and EP are very efficient in finding the optimum solutions of ELD problems in power systems with valve point loadings. But the efficiency of these techniques can be improved further if their limitations are solved with the incorporation of further intelligence in the techniques. The multiplier used in strategy parameter may be made adaptive based on some intelligence like fuzzy logic etc. The penalty functions considered in this work are quadratic and dynamic type. They are not adaptive to the ongoing process of the search and can not guide the search to particularly attractive regions or away from unattractive regions based on what has already been observed. Completely adaptive penalty function which requires no user specified constraints
and also the development of improved adaptive operators to leverage the information gained during evolution process to improve both effectiveness and efficiency of the penalty function method and in turn the algorithm. Another idea may be to consider multiple constraints to be linearly combined to yield an appropriate penalty function. Also, one could make a case for a penalty which increases more than linearly with the number of constraints violated.

As the randomized features of crossover and mutation in NSGA-II limit the performance of NSGA-II, a method with inherent adaptive tuning of parameters of GA will prove to be very enhancing the performance of the algorithm. The non-dominated sorting technique may be improved through incorporation of adaptive features to create more nondominated solutions over the entire region of Pareto front and for different types of multiobjective problems.

The scheme DE1 mutation under DE is used in multiobjective problems which does not have much greediness as compared to that under scheme DE2. This is because in the multi-objective problems, finding of better solutions is problematic because we don't know which one is better till all the individuals are sorted together and assigned a nondomination level. An intelligent technique may be developed using the scheme DE2 to add more greediness to the algorithm. As the assumption of constant control parameter for amplification of differential variation in mutation operation do affect the performance of the algorithm, the parameter may be made adaptive during the evolution process.