CHAPTER 1

INTRODUCTION

1.1 GENERAL

Optimization in general refers to the action of making the best or the most effective use of a resource. All the engineering optimization problems carry complex issues with many practical constraints. They are categorized as non linear programming sections. In the field of Power System Optimization, Economic Load Dispatch (ELD) is a major issue. ELD is a phenomenon where an ideal combination of units to accomplish the ‘best’ plan with respect to an arrangement of organized criteria or limitations. These incorporate expanding elements, for example profitability, quality, dependability, life span, effectiveness and usage. In real time, energy generating units are chosen in order to limit the aggregate fuel cost while fulfilling the load demand and several operational constraints. In a deregulated electricity market, the optimization of economic dispatch is of utmost economic importance to the network operator.

The principle target of ELD problem is to limit the operation cost by fulfilling the different operational imperatives all together in order to meet the load demand. Many traditional algorithms are framed to optimize ELD problems, however in these strategies it is expected that the incremental cost curves of the units are monotonically expanding piecewise linear functions, but the practical systems are nonlinear. Many methods such as Quadratic Programming (QP), Linear Programming (LP), Dynamic Programming (DP), Gradient Methods (GM) and Lagrangian Series (LS) were employed to solve various problems related to ELD. Furthermore current meta-heuristic strategies such as Simulated Annealing (SA), Genetic Algorithm (GA), Tabu Search (TS) and Particle Swarm Optimization (PSO) were framed for getting the ideal answer.
for the curved and non-arched issues. The process of determining the best optimum solution gets stuck in many optimization techniques, which is mainly due to the premature convergence.

A newly developed Power Search Algorithm (PSA) is proposed in this thesis for solving various ELD problems. This algorithm proves its efficiency and robustness by providing the best optimum solution in terms of fuel cost, emission and transmission loss when compared to many optimization techniques. The computational time also gets reduced when compared to other algorithms discussed in the literature.

1.2 ECONOMIC LOAD DISPATCH (ELD) PROBLEM

The ELD is a significant problem in the operation of power generating station. It is considered as an optimization problem and is characterized for minimizing the total generation cost, subjected to different linear and non-linear constraints with a specific goal of meeting the power demand. The ELD problem is classified into two distinctive courses as convex ELD problem and non-convex ELD problem. The convex ELD problem is modelled by considering the objective function as minimizing the generator cost functions with linear constraints. The non-convex ELD problem considers the non-linear constraints in addition to the linear constraints while minimizing the cost function. The linear constraints, that is the generation capacity and power balance leads the ELD problem as approximate, simplified problem and the characteristics curve is assumed to be piecewise linear. An additional precise and accurate problem is modelled by having the non-linear constraints such as ramp rate limits, Valve Point Loading (VPL) effects and prohibited operating zones (POZ).
1.3 LITERATURE SURVEY

1.3.1 ELD Problems Considering VPL Effects

Walters & Sheble (1993) suggested GA to solve ELD problems considering VPL effects. This algorithm uses the payoff information of the possible solutions to evaluate the optimality. The efficiency of the algorithm has been tested on a 3 machine system and the obtained results prove the efficiency of the algorithm.

Bhagwan Das & Patvardhan (1999) presented the design and the application of real coded Hybrid Stochastic Search (HSS) for obtaining the reduced fuel cost. This algorithm uses a genetic operator referred as blend crossover for better search capability. The algorithm has been tested on three different IEEE test systems and the result obtained proves the efficiency in terms of faster convergence with better solution when compared with other algorithms.

Khamsawang et. al. (2002) formulated the Tabu Search (TS) Algorithm for obtaining the optimum solution to ELD problems along with non-smooth fuel cost function. The major advantage of this algorithm is that it escapes from the entrapment in local optimum and continues to the search criteria for providing the near global optimum solution. Three different test systems have been chosen for proving the potentiality of the algorithm.

Sinha et. al. (2003) presented the evolutionary based techniques for solving the ELD problems. The investigation has been carried out in two different ways for various systems considering VPL effects. The initial stage involves the modifications in the basic technique and the latter involves adaptation that denies on the empirical learning rate. From the results obtained, it is observed that the IFEP performs better than the basic EPs comparatively with less computational time and better convergence.
Victoire & Jeyakumar (2004) presented an efficient method for solving the economic dispatch problem by integrating the PSO and sequential quadratic programming (SQP) technique. Here the PSO acts as optimizer and SQP is used for tuning the results of PSO after each run. The effectiveness of this hybrid method has been validated on three different systems along with incremental fuel cost function and VPL effects.

Coelho & Mariani (2006) formulated the Differential Evolution (DE) and SQP for solving the economic dispatch problems with VPL effects. The DE acts as global optimizer and the SQP is used for fine-tuning the results of DE. Two standard systems have been chosen for proving the effectiveness of the algorithm. The results obtained with the help of this method outperform the other optimization algorithms.

Park et al. (2006) designed the Improved Particle Swarm Optimization (IPSO) for solving the economic dispatch problem incorporating the VPL effects. The IPSO is the integration of PSO and chaotic sequences. This efficient strategy includes the chaotic sequences, various constraints and formation of the initial point. In addition, this algorithm improves the global search capability in order to escape from the local minima. The effectiveness of the approach has been carried out for two different systems. The results obtained with the help of this approach are promising.

Wang et al. (2007) formulated the self-tuning hybrid differential evolution (self-tuning HDE) for obtaining the optimal solution for the non-convex problems along with various generator constraints. For the purpose of accelerating the global optimum search, this algorithm uses the 1/5 success rule of evolution strategies. The algorithm has been tested on various test systems and numerical results indicate the overall performance in terms of minimum fuel cost and computational complexity.
Coelho & Lee (2008) devised the combination of PSO and Gaussian probability distribution functions and/or chaotic sequences for solving the ELD problems considering ramp-rate limits and POZ. In this algorithm, the random numbers are initially developed with the help of Gaussian probability distribution and the implementation of chaotic sequences in PSO helps in escaping from the local optima. The effectiveness of the algorithm has been proved by validating with 15 and 20 thermal generating units.

Rajesh Kumar (2009) developed the Bee Optimization Algorithm (BeeOA) for solving the economic power dispatch problems based on the working of honey bee. The honey bees combine together for a decision making process. As a result of decision making process, a new cite is chosen. This is referred as “collective intelligence” perspective. Based on this concept, the BeeOA is devised. The effectiveness of the algorithm has been proved by demonstrating on 6 and 13 unit system.

Khamsawang & Jiriwibhakorn (2009) jointly developed a novel PSO for solving the economic dispatch problems considering various constraints. For improving the diversity exploration of PSO, the DE’s mutation operator plays a major role. The approach is referred as PSO with mutation operators (PSOM). The major advantage of this algorithm is the mutation operators are activated only when the velocity values of PSO is nearly equal to zero or it is violated. The algorithm has been validated on 6 unit system considering losses.

Sailaja Kumari & Sydulu (2009) formulated a Fast Genetic Algorithm (FGA) for the purpose of solving ELD problems. In general, the GA performs global search in a powerful manner, but the long computational time limits the search when solving large scale problems. To overcome this limitation, the FGA is devised, where the search starts with the random solution in the overall space. Since the search is limited to a very small space, the algorithm works very faster. The robustness of the algorithm is tested on the 3, 6, 20 and 38 generator systems.
Bhattacharya & Chattopadhyay (2010) presented the Biogeography-Based Optimization (BBO) algorithm for solving the convex and non-convex load dispatch problems considering necessary constraints. Arising of the species, its migration to another habitat and wiping out is explained by the designed mathematical model. The process of migration and mutation takes place in this algorithm for finding the optimal solution. The application of BBO to various IEEE test systems shows the effectiveness of this algorithm.

Park et. al. (2010) implemented the Improved PSO (IPSO) for solving the ELD problems along with non-convex cost functions. This method eliminates the drawback of getting trapped at local optimal solution which happens due to premature convergence and incapability of finding the nearby extreme points. For handling the equality and inequality constraints, a new framework has been developed. Along with basic ELD problems, this method has been applied to Korean large scale power system. The obtained results were compared with the state-of-the-art methods.

Chen et. al. (2011) developed the combination of Direct Search Method (DSM) and PSO for solving the ELD problems considering VPL effects. The search capability is maximized in this method by intruding the inertia weight mechanism, where it increases the probability of obtaining the global optimum solution. The DSM algorithm is used as a fine tuner for the determination of global optimum solution with less computational time.

Nezamabadi Pour et. al. (2011) presented the Fuzzy Adaptive Genetic Algorithm (FAGA) for solving the ELD problems considering the non-smooth cost functions. This approach deals with the issue of controlling the exploration and exploitation capabilities which results in obtaining the optimum solutions. The real version of the GA uses the Fuzzy Logic Controller (FLC) which effectively explores and exploits the solutions.
Duvvuru & Swarup (2011) demonstrated the hybrid algorithm that combines the Interior Point Method (IPM) and Differential Evolution (DE) for solving the ELD with VPL effects. This algorithm works in two different stages: the initial stage uses IPM for minimizing the cost function without VPL effects and the latter stage involves the DE for minimizing the cost function with VPL effects. The population for DE is generated in a narrow range of $2\pi/f$ with help of the solutions obtained in the initial stage.

Ciornel & Kyriakides (2012) developed a heuristic method for solving the non-convex economic dispatch problems. In this algorithm the overall search capability of two algorithms are combined together for obtaining the better optimal solution. The downhill behaviour of API and the spreading space of GA helps in finding the optimal solution by escaping from getting trapped in the local optima. The robustness of the algorithm has been tested on various complex systems considering different sizes and complexities.

Vishwakarma et. al. (2012) presented the Simulated Annealing (SA) approach that depends up on the annealing process in thermodynamics. This is a stochastic technique that relies on the crystallization process. The detailed analogy is presented which provides the frame work for optimization. As it does not need a large memory for computation process, even at the presence of large number of local minima, obtaining global minima for a multidimensional function is very simple. The robustness of the algorithm is tested with four different test systems.

Hosseini et. al. (2012) developed the hybrid method referred as Hybrid Immune Genetic Algorithm (HIGA) that has very good convergence property. The developed algorithm easily handles the VPL effects, POZ, ramp-rate constraints and transmission losses. Here the crossover operator of GA helps in propagating the attributes of high quality solutions and this process is carried
out in clonal selection. Due to the reproduction of each solution in the search space, the solution obtained is of very high quality and challenging.

Srinivasa Reddy & Vaisakh (2013) developed the Shuffled Differential Evolution (SDE) algorithm which combines the advantages of shuffled frog leap algorithm and DE. A specifically designed differential mutation operator has been methodologically applied for solving the problems effectively. The developed algorithm has been applied to three different test systems which also includes the large scale economic dispatch problem. The efficiency of the algorithm is proven by comparing with other settled nature inspired solution algorithm.

Khandualo et. al. (2014) suggested the Gravitational Search Algorithm (GSA) based on the law of gravity and mass interactions for solving the ELD problems. Based on the physical law of gravity and the law of motion, the GSA is developed. The agents are referred by objects and their performances are measured by masses. Due to the gravitational forces, all the objects with heavier masses are attracted towards each other. The force of attraction causes the global movement of the objects. The algorithm has been tested on various IEEE test systems for obtaining the optimal solutions.

Bulbul et. al. (2016) developed the Opposition-based Krill Herd Algorithm (OKHA) for minimizing the production cost in ELD problems. The basic Krill Herd Algorithm (KHA) is combined with Opposition Based Learning (OBL) for improving the speed and accuracy of the basic KHA. High degree of convergence, less iteration time and higher efficiency with respect to CPU time are the advantages of OKHA. This algorithm has been implemented for various IEEE standard test systems.

Elsayed et. al. (2016) developed the Modified Social Spider Algorithm (MSSA) for solving ELD problems. The MSSA has been derived
from the basic Social Spider Algorithm (SSA), where it involves the mutation process for selecting the iteration values for generating new solutions. With only two parameters, the modified SSA exhibits its simplicity in obtaining the optimal solution for the large scale ELD problems.

Quande Qin et. al. (2017) developed an Improved Orthogonal Design Particle Swarm Optimization (IODPSO) for obtaining the optimal solution for non-convex ELD problems. In this method, an orthogonal designed method is used for the construction of an exemplar. For improving the efficiency, multiple auxiliary vector generating strategy is implemented. For the purpose of adapting the acceleration coefficients, a tent chaotic map is employed.

1.3.2 Combined Emission-Economic Dispatch (CE-ED) Problems

Khamsawang et. al. (2010) presented an improved PSO-DE (IPSO-DE) based on the conventional PSO for solving the multi-objective optimization problems considering various constraints. For the purpose of improving the diversity exploration in PSO, the mutation operators of DE are involved. These operators are activated only if the PSO value comes to zero or violating from the boundaries. The hybrid algorithm has been tested on various test cases and the performance has been evaluated.

Senthil & Manikandan (2010) adopted Improved Tabu Search (ITS) algorithm for solving the ELD problems. ITS follows the adaptive memory structures and associated strategies for the purpose of exploring the search space to obtain the feasible solution. The elements from the current solution to its selected neighbour are partially or completely recorded in the Tabu List to forbid reversal of the replacement in future iterations. Considerable success is achieved for short term memory, which makes use of frequency information and more advanced principles. This influences the effective implementation of ITS.
Apostolopoulos & Vlachos (2011) presented the application of firefly algorithm developed by Dr. Xin-She Yang. The FA is inspired by the behaviour of fireflies. The main advantage when compared with other optimization techniques is the usage of real random numbers and the communication globally among the fireflies. It has three flashing rules such as all fireflies are unisex and its movement towards the other firefly is based on the brightness and attraction, the proportionality between the brightness and the distance. The determination of the brightness value is carried out with the help of the objective function. The algorithm has been tested on different cases and the result obtained proves the efficiency of the algorithm.

Vinodkumar & Lakshmi Phani (2011) applied the aggregate objective function approach for solving the multi-objective CE-ED problems using FA. In the initial stage all the fireflies are placed at random location in the search space. The lights are produced based on the fitness function evaluation, in such a way that the produced lights are proportional to fitness. Pareto-optimal front has been formulated for different load demands. IEEE 6 machine system is chosen for the purpose of analysis and robustness of the algorithm is proved by comparing with various algorithms.

Guvenc et. al. (2012) implemented GSA for obtaining the optimal solution for the CE-ED problems. In GSA, each agent is considered as an object and its mass delivers the performance. All the denoted objects act as a solution or a part of the solution. The objects in the search space are attracted towards the heavier objects by means of gravitational force. The GSA has been applied for different cases, having VPL effect with transmission losses and having VPL effect without transmission losses.

Hassan et. al. (2012) presented the Adaptive Tumbling Foraging Optimization (ATFO) for obtaining the better solution for CE-ED problems. The Bacteria Foraging Algorithm (BFA) has been designed based on the
movement of the Escherichia coli bacteria in the human intestine. With the help of fuzzy system rules, this algorithm helps in optimizing the two objectives, fuel cost and the emission simultaneously. The methodology adopted using BFOA involves the alterations in tumbling strategy for developing the low cost and steady BFOA strategy. For evaluation tournament, Meta EP, an iteration routine is selected. The IEEE 118 bus system is taken for analysis and the results obtained proves the efficiency of the algorithm.

Anurag Gupta et. al. (2012) dealt with PSO technique for solving CE-ED problems by satisfying various constraints. Only the inequality constraints are considered on active powers in the cost function. The remaining constraints are considered in the load flow process. The load flow process in the PSO gives the updated voltages and angles. It also points out the generators that exceed the reactive limits. This load flow process works based on NR algorithm which uses the optimal multiplier technique. IEEE 30 bus 6 generator system has been evaluated using this method and the obtained results are compared with the many algorithms.

Khokar & Parmar (2012) presented the Weight Improved PSO (WIPSO) technique for solving CE-ED problems. In this method, the cognitive and the social components are initialized as the WIPSO parameters which help in fine tuning the results. This strategy has been compared with the classical PSO strategy and it is found that the results obtained from WIPSO strategy are better than the general PSO.

Rajkumar et. al. (2013) discussed the application of Non-dominated Sorting Genetic Algorithm-II (NSGA-II) and Modified NSGA-II to solve CE-ED problems. In this discussion, the pareto front obtained with the help of NSGA-II and MNSGA-II are compared. With the help of Real Coded GA (RCGA), the reference pareto-front is generated with multiple numbers of runs and it is compared with weighted sum of objectives. In addition, various
parameters like convergence, diversity and inverted generational distance are also evaluated for the purpose of closeness. IEEE 57 bus and IEEE 118 bus systems are chosen for validating the effectiveness of the algorithm.

Hamedi (2013) presented an advanced Parallelized Particle Swarm Optimization algorithm (PSPSO) for determining the optimal solution for CE-ED problems. The PSPSO technique exhibits its efficiency when three conditions are satisfied. First the interrupt free access to the homogeneous cluster of computers, secondly the amount of time taken for evaluating any set of design variables and thirdly the equal distribution of parallel paths among the processors present. If any of the above conditions is not satisfied, the PSPSO technique fails in giving out the optimal solution. This algorithm has been tested on four different test systems and the results are compared with various algorithms.

Zerigat et. al. (2013) applied the Galaxy-based Search Algorithm (GbSA) for solving CE-ED problems. This algorithm uses the Modified Hill Climbing Algorithm (MHCA) for the purpose of local search and resembles the spiral arms of some galaxies to search the optimum solution. The demonstration of this algorithm has been carried out for two test systems. The results obtained with the help of this algorithm are very encouraging.

Afandi & Miyauchi (2014) presented an evolutionary algorithm referred as Harvest Season Artificial Bee Colony (HSABC) algorithm for solving CE-ED problems. HSABC is mainly inspired by nature’s harvest season situation for providing flowers. Here MFS consists of First Food Source (FFS) and Other Food Sources (OFS). The direction for each position of OFS is lead by a harvest operator (ho) from FFS. This algorithm follows three different phases such as bee phase, onlooker bee phase and scout bee phase. For the purpose of validation, IEEE 30 bus system has been chosen and the results are compared with other algorithms.
Gonidakis & Vlachos (2015) presented the BAT Algorithm (BA) for solving CE-ED problems. Two different approaches are followed to avoid various conflicts. One approach hybridizes the BA with DE and the other is helpful in inserting the mutation operator into classical BA. Mutated BA applies the fixed loudness along with pulse emission and it sets the velocity margins. Hybrid BA applies the operation of DE for local search rather than a random walk. Both the approaches are applied to 10 generator system and the simulated results are compared with the other algorithms.

Hadji et. al. (2015) introduced the Dance Bee Colony (DBC) with Dynamic Step Size (DSS) algorithm for solving CE-ED problems. This algorithm has been tested on IEEE 30 and 40 unit system considering the VPL effects and power losses. Apart from the normal operation of the DBC, a special variant is proposed for the enhancement of the original DBC.

Delshad & Rahim (2016) applied the Backtracking Search Algorithm (BSA) to solve the CE-ED problems. This optimization algorithm has only one parameter for solving the optimization problems. This involves the crossover and the mutation process for bringing out the optimal solution. An elicit external archive is used for storing the non-dominated solutions referred as pareto-front. This algorithm has been tested on three different test cases and the results show the effectiveness of the BSA.

Nguyen & Ho (2016) proposed the BA for solving CE-ED problems along with quadratic fuel function. This is a meta-heuristic algorithm in which the solutions are obtained in a powerful manner due to the selection of easily controllable parameters. The successful rate is high as the usage dealt with many complex problems with complex constraints. IEEE 6 machine system with two different load demands are analyzed for proving the performance of BA. The results obtained with BA are compared with other algorithms.
Abdelaziz et. al. (2016) applied the Flower Pollination Algorithm (FPA) for solving the dual-objective CE-ED problems with equality and inequality constraints. In general, the activities of flower pollination will be carried out in all scales. But in reality, the patches are likely to be pollinated with the help of the nearest flower pollen than those are far away. In order to avoid this, the switching probability can be adopted between the common global pollination to intensive local pollination. IEEE test systems considering 3 unit, 10 unit and 40 unit systems considering emission constraints were solved using the FPA.

Eghbalpour et. al. (2016) proposed the Multi-operator Imperialist Competitive Algorithm (MuICA) to solve the CE-ED problems. The classical ICA suffers from the premature convergence as the other meta-heuristic algorithms. This algorithm merges the advantages of the repulsion factor, chaos and mutation factor in order to maintain the diversity and also to avoid the premature convergence. The MuICA is validated for two different test cases and the obtained results are compared with the other algorithms.

Radosavljevic (2016) proposed the hybrid approach referred as Hybrid PSO-GSA for solving CE-ED problems. This hybrid approach combines the profitable abilities such as the social thinking in PSO and local search capability of GSA. All the agents are initially random in structure and each solution is considered as a candidate solution. After the initialization process, the calculation of the constant and the resultant forces takes place. At the end, the best solutions are updated as the new solution. This hybrid approach has been validated on 3, 6 and 40 generating units with different constraints.

1.3.3 Dynamic Economic Dispatch (DED) Problems

Maheswarapu Sydulu (1999) presented a very fast and effective non-iterative λ-logic based algorithm for ED of thermal units. This method
doesnot require any initial value of $\lambda$ as this is a non-iterative / direct method. Failing to select the proper values of $\lambda$ might lead to very slow convergence or sometimes pave the way for divergence for the conventional algorithms. This method offers the solution in the non-iteration mode with low solution and fast computation. The efficiency of the method has been tested on a 38-generator system.

Balamurugan & Subramanian (2007) introduced the Improved Differential Evolution (IDE) for solving the problems related to DED including VPL effects. This method uses the heuristic crossover technique and gene swap operator for improving the convergence of the DE algorithm. The advantage of using this operator is to determine the direction of the search with the obtained values of the objective function, where it leads to the production of one offspring. This method has been tested on 5 and 10 generating units for proving the effectiveness of the algorithm.

Hemamalini & Simon (2010) proposed the Maclaurin Series based Lagrangian method (MSL) for solving DED problems considering various constraints. In this method, the sine component used for the VPL effect is expanded with the help of maclaurin series and it is solved using the lagrangian method. The validation of this method has been carried out for 5 and 40 unit system.

Hemamalini & Simon (2011) presented the Artificial Immune System (AIS) based Clonal Selection (CS) algorithm for solving DED problems. AIS are the adaptive systems that are inspired by the theoretical immunology, immune functions, principles and models. The implementation of AIS to DED problems involves four main features such as generating pool of immune cells, followed by proliferation, maturation and interaction of antibody-antigen. The evaluation of this method has been performed on 5 and 10 unit system.
Alsumait et. al. (2010) devised the Improved Pattern Search (IPS) algorithm for solving DED problems considering all the necessary constraints. The important feature of this algorithm is that it is not only developed for a particular day of time horizon but also it automatically moves on to the next day making sure that the power system operation is not getting affected. IEEE 5 unit system considering transmission losses are taken for analysis. The obtained results are compared with other optimization techniques.

Sivasubramani & Swarup (2010) proposed the new hybrid optimization technique combining the Seeker Optimization Algorithm (SOA) and SQP for solving DED problems considering VPL effects. The SOA algorithm simulates the act of the human search where the direction of the search is based on the Empirical Gradient (EG). It is used as base search criteria that provide a required pathway for obtaining the global solution. SQP is used for fine tuning the solution obtained with the help of SOA. Two different test systems are considered for proving the effectiveness of this hybrid approach and it is found that SOA-SQP outperforms other algorithms.

Basu (2011) designed the Clonal Selection based AIS for obtaining the optimal solution for DED problems. The application of CS implements various strategy like adaptive cloning in nature, hyper-mutation, aging operator and selection of tournament. The purpose of clonal selection is to show how the immune system fights against the antigen present in the body. The cells which recognize the antigen are selected to proliferate. Depending on the affinity of the antibodies, the cloning of the member takes place. The rate of the proliferation is directly proportional to the affinity of the antibodies. IEEE 10 unit system is chosen for the purpose of evaluation of this algorithm.

Ganesan & Subramanian (2011) developed the simple methodology referred as Sequential Approach with matrix framework for solving DED problems. The optimal solution for all the generators is determined with the help
of maiden attempt in a single execution. For identifying an economic schedule of the generation, a square matrix (I) is framed. IEEE 5, 6 and 15 unit systems are taken for evaluation of this approach.

Benhamida et al. (2011) proposed the Hopfield Neural Network (HNN) for solving DED problems considering various system constraints. HNN is mainly based on the continuous transfer function which provides continuous output variables. The positive weighting factors introduce the minimum power and the fuel cost of the ELD objective function. The feasibility of this method is demonstrated using 6 and 15 unit systems. The results are compared with other algorithms in terms of fuel cost and computational efficiency.

Hemamalini & Simon (2011) applied the ABC algorithm for solving DED problems considering VPL effects. The search procedure of ABC is population based technique and it is applied for solving non-linear non-convex optimization problems. In this algorithm, three different groups of bee are involved. They are employed bees, onlookers and scouts. The feasibility of the algorithm is tested with 5 and 10 unit system for a period of 24-hours and in addition the study on the parameters of the control parameters of ABC is studied.

Elaiw et al. (2012) presented the hybrid DE-SQP algorithm which combines the DE and SQP for solving DED problems considering VPL effects. Here DE is considered as global optimizer and SQP is set as fine tuner for determining the optimal solution. The efficiency of the algorithm is tested by implementing this hybrid approach on 5 and 10 unit systems.

Ivatloo et al. (2013) designed and developed the heuristic algorithm referred as Hybrid Immune Genetic Algorithm (HIGA) for solving DED problems considering various constraints. The best characteristic of the Immune Algorithm (IA) is combined with GA for finding the best solution in the entire search space. The affinity factor helps in identifying the antibodies that are
similar to stranger antigens. This algorithm has been tested on 5, 10 and 30 unit systems. The obtained results are compared with various algorithms.

Ashouri & Hosseini (2014) applied two algorithms named Krill Herd (KH) and Water Cycle Algorithm (WCA) to solve the complicated DED problems. The principle of WCA depends on the waterflow towards the sea and change back. With help of the transpiration process, the rivers and lake water gets evaporated. When the evaporated water is carried as atmosphere, the clouds are generated. Implementing this concept to the DED problem, the best solution in the search space is selected among a large number of solutions. Common case studies 5 and 10 unit systems are considered for proving the effectiveness of this approach.

Hemavathi & Devarajan (2016) presented the Enhanced Hybrid Differential Evolution and PSO (EHDE-PSO) algorithm for solving DED problems. This method is equipped with Dynamic Sigmoid Weight using parallel procedures, which is particularly used for increasing the computational time and obtaining optimal solution. Selection, mutation and recombination are the steps involved in HDE and the solution are given to EPSO for early convergence. The local optimal solution is trapped in the EPSO and the rate of convergence in HDE is improved. This hybrid approach has been tested on 6 unit system with various power demands and the obtained results are compared with other algorithms.

Pandit et. al. (2016) developed the IPSO for obtaining the minimum fuel cost for the DED problems by improving the search deficiency and avoiding the stagnation to a sub-optimal result. In this method, the previous position of the parameter is varied chaotically for increasing the population diversity. The swarm exploration is stimulated during the initial search and when moving towards the convergence, exploitation is strengthened. The developed algorithm is tested for very large scale systems and its performance is exhibited.
Ram Jethmalani et. al. (2016) presented the GSA for employing the transmission line losses using A-loss co-efficients using the solution obtained for DED problems. The repair strategy plays a major role in constraint management in such a way the constraints are not violated for any power demands. The movement of each object in the space is carried out by its mass and the vector sum of gravitational pull exerted on it. This algorithm has been applied for three different bus systems; IEEE 30, IEEE 39 and IEEE 118. The results obtained with the proposed method are very challenging and compared with many other optimization algorithms.

Sonmez et. al. (2016) proposed the Symbiotic Organisms Search (SOS) algorithm for solving DED problems with VPL effects. The SOS algorithm has been applied for many optimization problems by the way of simulating the organism relationship that exists for long time. The implementation of the SOS algorithm to DED problem involves the generation of initial ecosystem, organism building, calculating the fitness value of organisms, applying the operators such as symbiosis, mutualism, commensalism and parasitism. For validating this approach, 5, 10 and 13 unit systems are considered.

Nawaz et. al. (2017) presented the new approach referred as Constrained Globalized Nelder-Mead (CGN-M) algorithm for solving DED problems considering and neglecting VPL effects. The advantage of this simple algorithm is that derivatives need not be calculated. Due to this the convergence will be faster in order to find the best optimal solution. This algorithm has been applied for both the convex and the non-convex problems. The result obtained with the help of the proposed method has been compared with many other optimization algorithms.
1.3.4 ELD Problems Considering Multiple Fuel Options (MFO)

Lin & Viviani (1984) presented the Hierarchical Method (HM) for solving the piecewise quadratic cost functions. The generators involved in this method are in the form of decentralized configuration which lends them to be in decentralized approach. All the plants involved are aware of the multiple input fuels and so they are capable of determining the best fuel cost curves associated with them. This generalized approach was more convenient in determination of the cost curves representing different operational characteristics. This method was tested on 10 unit system considering various power demands and the simulation results are presented.

Park et. al. (1993) proposed the Hopfield Neural Network (HNN) to solve the piecewise quadratic cost function. A piecewise quadratic function is considered to make the problem more reality in nature. In this approach, multiple intersecting cost functions are applied for single unit. The hierarchical structure contains many subsystems and each subsystem contains several generators. The power outflow from each system is called subsystem demand. The system chosen for analysis has been solved with neural method and the results obtained are compared with the numerical method.

Lee et. al. (1998) developed the advanced method referred as Adaptive Hopfield Neural Networks (AHNN) for speeding up the convergence property of HNN. In addition, the adaptive learning rate was developed with the help of energy functions. Later it was applied to slope and bias adjustment methods. The results obtained with the help of AHNN are compared with the numerical method and HNN. The simulated results exhibit the efficiency of AHNN in solving the ELD problems considering MFO.

Chao-Lung Chiang (2005) proposed an improved method of GA with multiplier updating referred as Improved Genetic Algorithm with Multiplier
Updating (IGA-MU) for solving the DED problems along with VPL effects. Improved evolutionary direction search operator and a migration operator together search the solution effectively. MU is used to handle the equality and the inequality constraints. To exhibit the performance of the proposed method, 10 unit system considering VPL effects are analyzed.

Panigrahi et. al. (2007) devised the new optimization algorithm based on the process of hypermutation, referred as Clonal Algorithm (CA). Encoding, initialization and cloning are the steps involved in the search of the solutions. The process of hypermutation plays a major role as the probability depends upon the fitness of the clone. The proficiency of the algorithm is analyzed by solving the 3, 6, 10 and 15 unit systems for various power demands. The results are compared with the state-of-the-art algorithms.

Balamurugan & Subramanian (2007) proposed the Self-Adaptive Differential Evolution (SADE) for solving the power economic dispatch problems considering VPL effects and MFO. In this approach, the control parameters in DE such as the crossover constant CR and the weight factor F are self-adapted. 13 unit test system including VPL effects, 10 unit system with MFO and neglecting VPL effects are analyzed using this approach. The results obtained with the help of SADE are promising and the effectiveness of this algorithm is proved.

Manoharan & Kannan (2008) presented the novel hybrid evolutionary algorithm for solving the ED problems considering MFO, known as Evolutionary Programming-Levenberg-Marquardt optimization (EP-LMO) algorithm. Here the evolutionary technique is used for base level search to find the direction of the optimal solution and LMO is used to fine tune the determined optimal solution. ED problems with MFO, ED problems with MFO and VPL are considered for determining the minimal fuel cost. The results are then compared with modified hopfield neural network, modified PSO and IGA-MU methods.
Min et. al. (2008) developed the Combinatorial Optimization Problems (COP) combined with GA for solving the ED problems considering non-convex fuel cost functions. One non-convex fuel cost function is divided into many convex fuel cost function and each convex function is represented as G-type. Here GA is used for solving the COP and $\lambda$-P table method is used for calculating the ED for the fitness function of GA. ED with VPL effects, ED with MFO and ED with POZ are analyzed with the help of this algorithms. The improvement in the results obtained proves the robustness of the algorithm.

Anandhakumar & Subramanian (2011) implemented the Composite Cost Function (CCF) to solve the ELD problems with MFO. This method comprises two important stages. Initially, the economic fuel for each generator can be easily identified by developing the CCF of the plant. In the latter stage, evaluation of the CCF takes place and best solution is obtained. The feasibility of the operating region is determined only when the dispatch of each generator is set. Standard IEEE 10 unit system with various power demands are chosen for analysis. The results obtained are compared with other optimization algorithms.

Hemamalini & Simon (2013) presented the Artificial Bee Colony (ABC) algorithm for solving the ED problems consisting of VPL effect, POZ, MFO and ramp rate limits. ABC algorithm works based on the foraging behavior of the honeybees. The fitness of the solution is represented by the total nectar amount. The number of onlooker bees is equal to the number of possible solutions. The robustness of the algorithm is tested on 10, 13, 15 and 40 generating units with the incorporation of non-linearities.

Barisal (2013) proposed the Dynamic Search Space Squeezing (DSSS) strategy based IPSO for solving the ED problems considering MFO. This intelligent approach uses the new constraint handling mechanism for accelerating the optimization process. The originality of the conventional PSO is preserved in this process. The performance of various algorithms such as
DE, PSO and IPSO are considered for ED with various constraints and MFO. The results obtained with the help of IPSO reveals the performance when compared with various algorithms.

Sreelekha & Riya Scaria (2013) formulated the FA for solving the power dispatch of generators with MFO. This algorithm depends upon the behavior of fireflies and has many similarities like PSO, BFA and ABC. The major objective of FA is that the optimal solution is determined by the global communication among fireflies and it uses real random numbers. The FA has been applied for a 10 unit system considering various power demands with various input fuel types. The obtained results are compared with SDE algorithm and the results were found to be challenging.

Vigneshwaran et. al. (2015) presented the FPA for solving the ED problems with MFO. This algorithm involves the two different processes in pollination based on the way of transferring of pollens. The a-biotic process takes only 10% of the pollination process where it does not need pollinators. The remaining 90% is taken care by the biotic process. The switching probability is used for the purpose of switching between the common global pollination to intensive local pollination. Two different test systems such as 6 unit considering transmission losses and 10 unit system has been considered for simulation.

Vijayaraj & Santhi (2016) developed the IBA for solving the ED problems with MFO considering VPL effects. This algorithm is motivated by the echolocation behaviour of bats in finding their prey. The exploitation process in the BAT algorithm is efficient when compared to exploration process. There are many chances of getting trapped at local minimum point. To overcome this problem, few modifications are carried out in the update process for improving the exploration and exploitation capability of BA. 10 unit system with a power demand of 2700 MW has been chosen for analysis. The results obtained with the help of IBA were compared with various optimization algorithms.
Srikanth et. al. (2016) applied the GA in Matlab for solving the ED problems considering MFO. The search process in GA includes the selection, crossover and mutation. Best chromosomes are selected by the selection parameter which has the highest fitness value. The new offspring solution is determined by the crossover process selecting two parents which are random in nature. The purpose of mutation is to maintain the diversity of solutions and to enhance the information present in the problem. 4 generating units with three input fuels and 10 units with a power demand of 2700 MW have been considered for proving the efficiency of the algorithm.

Mostafa Kheshti et. al. (2017) proposed the newly developed Lightning Flash Algorithm (LFA) for solving the large scale economic dispatch problems with VPL effect and ED with MFO. This algorithm combines the advantages of swarm based optimization technique and evolutionary algorithms. Swarm based techniques involves the process of interaction with local agents which leads to the evolution of intelligent global behaviour. Evolutionary computational techniques involve the mechanisms like reproduction, mutation, recombination and selection process. Five different IEEE test systems are considered for the purpose of evaluation of the proposed algorithm and the results obtained proves to be best of other compared algorithms.

1.4 OBJECTIVES OF THE THESIS WORK

In this thesis a newly developed algorithm named as Power Search Algorithm (PSA) is proposed to solve various types of ELD problems.

- To obtain the optimum fuel cost for ELD problems considering valve-point loading (ELD-VPL) effects
- To solve the Combined Emission-Economic Dispatch (CE-ED) problems
- To validate and obtain minimum fuel cost for Dynamic Economic
Dispatch (DED) problems

- To determine the optimum fuel cost for ELD problems considering Multiple Fuel Options (ELD-MFO)

1.5 ORGANIZATION OF THE THESIS

The organizational structure of the thesis is presented below:

- Chapter 1 presents the Introduction, literature survey for various ELD problems, objectives of the thesis work and the organization of the thesis.
- Chapter 2 describes the proposed Power Search Algorithm (PSA) based two different search techniques Power Search Algorithm-Forward Search Approach (PSA-FSA) and Power Search Algorithm-Reverse Search Approach (PSA-RSA) for solving various ELD problems with their corresponding flow charts.
- Chapter 3 discusses the solution to ELD problems considering VPL effects (ELD-VPL) and its comparison with state-of-the-art algorithms.
- Chapter 4 discusses the solution to the Combined Emission-Economic Dispatch (CE-ED) problems with and without considering transmission losses for various IEEE standard test systems.
- Chapter 5 elucidates the performance of the proposed algorithm applied to the Dynamic Economic Dispatch (DED) problems for standard test systems.
- Chapter 6 describes the application of the proposed algorithm to ELD problems considering Multiple Fuel Options (MFO) for various power demands and its comparison with other algorithms.
- Chapter 7 epitomizes the conclusion of the proposed work and future enhancements to be carried out for the ELD problems.
1.6 CONCLUSION

In this chapter, introduction to ELD problems, various problems of ELD, and the literature survey has been discussed in brief for the development of the proposed algorithm. The objectives of the thesis and the organization of the proposed thesis are summarized. The traditional approaches like $\lambda$-iteration method, Lagrange’s method and Taguchi method delivers the minimum fuel cost based on the procedure of simple iteration. The drawbacks of the traditional approaches are the high computational time and single optimum solutions. Many heuristic and meta-heuristic algorithms such as GA, PSO, BBO, ABC, ACO, GSA, BFA, and LFA provide better optimal solutions due to its global search characteristics. These methods are very popular as they depend on natural behavior of the living beings. These methods have huge search space and quicker convergence characteristics. Many hybrid optimization techniques are framed by combining the characteristics of two different algorithms to provide the output in a hybridization form. Few examples of hybrid algorithms are PSO-SQP, DE-SQP, DE-BBO, IPSO-DE and PSO-GSA. Due to the combination of two different characteristics of two algorithms, these methods are capable of eliminating the drawbacks of earlier methods.