CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Dynamic Economic Dispatch (DED) is a real time power system problem. The output power generation of each unit is determined with respect to predicted load demand over a period satisfying the system constraints and ramp-rate constraint. The basic static economic dispatch problem is to minimize the total generation cost among the committed units satisfying all unit and system equality and inequality constraints. In practical systems, with change in load conditions, the power generation has to be altered to meet the demand. In such cases, static economic dispatch incorporates practical difficulties in the control network. To overcome this difficulty, dynamic economic dispatch is implemented which takes into account the dynamic costs involved in changing from one-generation level to the other. However, most of them have considered the cost characteristics to be linear in nature in order to simplify the mathematical formulation of the problem and to allow many of the conventional optimization techniques to be used. In reality the input-output characteristic of generating units are non-linear due to valve-point loading and more advanced algorithms are worth developing to obtain accurate dispatch results.

DED is a dynamic problem, due to the dynamic nature of the power system and the large variation of load demand. This problem can be solved by discretization of the entire dispatch period into a number of small intervals,
over which the load is assumed to be constant, and the system is considered to be in temporal steady state. Since the ramping constraints couple the time intervals, a traditional approach of a DED with \( N \) units and \( T \) time intervals would require the solution of an optimization problem of size \( N \times T \), a considerably more complex task than the solution of \( T \) economic dispatch problems with \( N \) units each.

2.2 SOLUTION METHODOLOGIES

2.2.1 Dynamic Programming

Wood (1982), proposed an efficient algorithm for the solution of a reserve constrained economic dispatch, which is the static optimization technique used at each interval. The problem is expressed as a dynamic programming scheduling problem, and a feasible, but sub optimal solution is proposed, which eliminates the usual search space problem. This method reduces the problem to a backward sequence of dispatch problems, with the generator limits being carefully adjusted between each time interval in the solution sequence.

Bechert & Chen (1977) formulated dynamic programming for a dynamic optimal control. In their work optimal trajectories are found for up to five maneuverable generators, using a new multi-pass dynamic programming method to make such solutions feasible. Dynamic valve point loading and singular solutions are considered.

Travers & Kaye (1998) proposed a new method of solving the dynamic dispatch problem. The method employs from concepts dynamic programming and linear programming. Dispatch decisions that minimize system variable cost and marginal costs are determined. Generator outputs are not discretised. Efficiency gains over dynamic programming are achieved
by exploiting the underlying convex geometry of the problem and avoiding discretisation of the state space.

Liang & Glover (1992) proposed an iterative dynamic programming method for solving the economic dispatch problems of a system of thermal generating units including transmission line losses is presented along with a clear explanation of modifying generator cost functions during each iteration. A zoom feature is applied during the iterative process in order to converge to the economic dispatch solution with low computer time and storage requirements.

Ferrero & Shahidehpour (1997) analysed the effect of dynamic constraints on power transactions in deregulated environments. They also calculated the transition states using successive dynamic programming, and apply the Newton method to calculate optimal states within a utility for a given set of transactions. Network flow constraints are considered by using a DC load flow model.

2.2.2 Quadratic Programming

Somuah & Khunaizi (1990) employed two solutions of methods for the problem of dynamic generation allocation. The first method is quadratic programming technique combined with linear programming redispach technique. The latter utilizes a linear programming formulation of the dynamic dispatch problem about the base case static economic dispatch solution. The second method is based on the Dantzig-Wolfe decomposition technique.

Abdelaziz et al (2008) proposed a solution for the dynamic economic dispatch (DED) problem using a hybrid approach of Hopfield neural network (HNN) and quadratic programming (QP). The hybrid
algorithm is based on using enhanced HNN; to solve the static part of the problem, the QP algorithm for solving the dynamic part of the DED. This technique guarantees the global optimality of the solution due to its look-ahead capability.

Papageorgiou & Fraga (2007) presented, an optimization-based approach is proposed using a mixed integer quadratic programming model for the economic dispatch of electrical power generators with prohibited zones of operation. The main advantage of the proposed approach is its capability to solve case studies from the literature to global optimality quickly and without any targeting of solution procedures.

2.2.3 Linear Programming

Hindi & Ab Ghani (1991) modelled the dynamic multi-period economic dispatch problem for large-scale power systems as a linear programming problem the solution algorithm is based on Lagrangian relaxation and on exploiting the intimate relationship between optimizing the dual Lagrangian function and Dantzig-Wolfe decomposition. The dual Lagrangian function is optimized using sub gradient optimization. If an overall solution feasible in all constraints and sufficiently close to a computed best lower bound is discovered during sub gradient optimization, it is deemed optimal. Otherwise, Dantzig-Wolfe decomposition is invoked, using almost all the information generated during sub gradient optimization to ensure a speedy conclusion.

Wang & Shahidehpour (1993) proposed a rigorous mathematical method for dealing with the ramp-rate limits in unit commitment and the rotor fatigue effect in economic dispatch. An iterative procedure is employed to coordinate the unit commitment and the power dispatch for obtaining an economical solution within a reasonable time. The Lagrangian relaxation
method is used to generate the unit commitment schedule with relaxed power balance constraints. In this regard, linear programming is used to dispatch the power generation among committed units by considering a ramping penalty for the fatigue effect in rotor shafts, while preserving the operational constraints of the system as well as the generating units.

Han & Gooi (2007) proposed an effective model and solution method based on the look-ahead technique. The technique finds the number of time intervals to guarantee the solution optimality. Next, an efficient technique for finding the optimal solution via the Interior-Point Method (IPM) based linear programming is described.

2.2.4 Non-Linear Programming

Van den Bosch (1985) formulated an efficient method that deals with the formulation and solution of the optimal dynamic dispatch problem owing to spinning-reserve and power rate limits. The power production of a thermal unit is considered as a dynamic system, which limits the maximum increase and decrease of power. The solution is obtained with a special projection method having conjugate search directions that quickly and accurately solves the associated non-linear programming problem with up to 2400 variables and up to 9600 constraints.

Han (1975) recently developed Newton and quasi-Newton methods for nonlinear programming possess only local convergence properties. Adopting the concept of the damped Newton method in unconstrained optimization, we propose a step size procedure to maintain the monotone decrease of an exact penalty function. In so doing, the convergence of the method is globalized.
Michalewicz & Schoenaer (1996) have discussed (1) difficulties connected with solving the general nonlinear programming problem, (2) survey several approaches which have emerged in the evolutionary computation community, and (3) provide a set of eleven interesting test cases, which may serve as a handy reference for future methods.

2.2.5 Interior Point Method

Irisari et al (1998) described an approach to the economic dispatch problem that combines both time-separated constraints (e.g., Demand and network flow) and intertemporal constraints (e.g., ramping) into a single optimization problem that can be solved efficiently by interior point methods. By including generator ramping limits as well as network line flow constraints, both economic and security issues are treated simultaneously, avoiding ad hoc post processing.

Lin & Chen (2002) proposed an efficient interior point algorithm for solving the bid-based dynamic economic dispatch (BBDED). This algorithm is an extension of interior point quadratic programming (IPQP), and is called the predictor-corrector interior point quadratic programming (PCIPQP) algorithm. In this research, BBDED allows both supply-side and demand-side bids in the spot market, which includes multi-player, multi-period and a large number of constraints.

Jabr et al (2000) described a study of the homogeneous interior point (HIP) method for the economic dispatch problem that combines both independent blocks of constraints (generation demand balance, network flows) and coupling constraints (ramping) into a single optimization problem. By approximating the network constraints through the DC load flow, and the transmission losses through the B-matrix loss formula, the problem is
reduced to a convex optimization problem that possesses nonlinear inequality constraints and free variables.

Yamin et al (2004) presented an approach for maximizing a GENCO's profit in a constrained power market. The proposed approach considers the Interior Point Method (IPM) and Benders decomposition for solving the security-constrained optimal generation scheduling (SC-GS) problem. The master problem represents the economic dispatch problem for a GENCO which intends to optimize its profit. The formulation of the master problem does not bear any transmission network constraints. The sub problem will be used by the same GENCO to check the viability of its proposed bidding strategy in the presence of transmission network constraints.

2.2.6 Genetic Algorithm

Zhang et al (2005) proposed a new economic load dispatch model that considers cost coefficients with uncertainties and the constraints of ramp rate. The uncertainties are represented by fuzzy numbers, and the model is known as fuzzy dynamic economic load dispatch model (FDELD). A novel hybrid genetic algorithm with quasi-simplex techniques is proposed to handle the FDELD problem. The algorithm creates offspring by using generic operation and quasi-simplex techniques in parallel. The quasi-simplex techniques consider two potential optimal search directions in generating prospective offspring. One direction is the worst-opposite direction, which is used in the conventional simplex techniques, and the other is the best-forward direction, which is a ray from the centroid of a polyhedron whose vertexes are all the points but the best one towards the best point of the simplex.

Zhang et al (2006) proposed a new hybrid real-coded genetic algorithm with quasi-simplex techniques was proposed to solve the builded model. Furthermore, a novel way to generate initial population is suggested to
speed up the search process. This research builds a dynamic economic dispatch model with a non-smooth cost function and ramp rate constraints.

Shang et al (2008) presented a preference-based non-dominated sorting genetic algorithm (PNSGA) is introduced to optimize multi-objective problems. PNSGA adopts the technique of the decision maker, which can combine Pareto dominance with partial preference information. And the preferable relationship is defined based on Pareto dominance and goal function. The algorithm is utilized to optimize a novel multi-objective model of the dynamic economic dispatch in power system.

Hosseini & Kheradmandi (2004) proposed a method for centralized economic dispatch in deregulated power systems is presented. The considered constraints are minimum and maximum power generation of units, capacity of transmission lines and ramp rate limits. A genetic algorithm is used to solve a nonlinear objective function.

Hong & Li (2002) presented a new method based on genetic algorithms (GA) is proposed for optimal dispatch among multiplant (cogeneration systems) with multi co generators, which transmit MW to designated buyers (load buses) via wheeling. The operation constraints in the cogeneration systems and security constraints in the third party (transmission system owner) were considered. Varying weighting coefficients for penalty functions and determination of gene variables for GA were discussed.

Holland (1992) presented a mathematical model that allows for the nonlinearity of such complex interactions. He demonstrates the model's universality by applying it to economics, physiological psychology, game theory, and artificial intelligence and then outlines the way in which this approach modifies the traditional views of mathematical genetics. Initially applying his concepts to simply defined artificial systems with limited
numbers of parameters, he goes on to explore their use in the study of a wide range of complex, naturally occurring processes, concentrating on systems having multiple factors that interact in nonlinear ways. Along the way he accounts for major effects of co adaptation and co evolution: the emergence of building blocks, or schemata, that are recombined and passed on to succeeding generation to provide, innovations and improvements.

2.2.7 Hybrid Genetic Algorithm

Li et al (1997a) proposed hybrid genetic algorithms (HGAs) to determine the economic scheduling of electric power generation over a fixed time period under various system and operational constraints. proposed hybrid scheme is developed in such a way that a simple GA is acting as a base level search, which makes a quick decision to direct the search towards the optimal region, and a local search method (gradient search technique) is next employed to do the fine tuning. The aim of the strategy is to achieve the cost reduction within a reasonable computing time.

Basu (2008) presented a non dominated sorting genetic algorithm-II for dynamic economic emission dispatch problem. The proposed approach has a good performance in finding a diverse set of solutions and in converging near the true pareto-optimal set. Numerical results for a sample test system have been presented to demonstrate the capabilities of the proposed approach to generate well-distributed pareto-optimal solutions of dynamic economic emission dispatch problem in one single run.

Li & Aggarwal (2000) formulated a relaxed hybrid genetic algorithm (RHGA) and gradient technique (GT) to economically allocate power generation in a fast, accurate, and relaxed manner. The proposed hybrid scheme is constructed in such a way that a GA performs a base-level search, makes rapid decisions to direct the local GT to quickly climb the
potential hill. The proposed method further ensures the dispatch quality as well as speed by allowing a loose match between the power generation and the load demand at the base search, and compensates for any mismatch at the beginning of the local search. Consequently, a GA is able to deliver equal effort to the search for the least cost and power balance without the risk of attaining infeasible solutions.

2.2.8 Dantzig-Wolfe Decomposition

Hindi & Ab Ghani (1989) presented a solution algorithm based on a Dantzig-Wolfe decomposition, which yields a capacitated transshipment subproblem along with a master problem solved by the revised simplex method. Dynamic multiperiod economic dispatch for large-scale power systems is considered; the formulation presented provides for loading and de-loading rates, limits on generator outputs, spinning-reserve requirements and group power import-export limits. It is also suitable for implementation within a constraint relaxation strategy.

2.2.9 Evolutionary Programming

Attaviriyapanupap et al (2002) proposed a new hybrid methodology for solving DED. The proposed method is developed, in such a way that a simple evolutionary programming (EP) is applied as a based level search, which can give a good direction to the optimal global region, and a local search sequential quadratic programming (SQP) is used as a fine tuning to determine the optimal solution at the final.

Basu (2007) proposed an evolutionary programming based fuzzy satisfying method to determine the optimal non inferior generation schedule. This research treats economy and emission as competing objectives for optimal dispatch, which requires some form of conflict resolution to arrive at
a solution. The multi-objective problem is configured as a minimax problem under the assumption that the decision-maker has fuzzy goals for each of the objective functions. The present algorithm employs evolutionary programming technique in solving this problem. The solution methodology can offer a global or near-global non-inferior solution for the decision-maker.

Titus & Jeyakumar (2008) presented a hybrid evolutionary programming (EP), particle swarm optimization (PSO), and sequential quadratic programming (SQP) methods to solve the dynamic economic dispatch problem (DEDP) of generating units considering non-convex features. The non-convex feature considered is the valve-point effects, which is modeled in two different representations in the DEDP formulation. The proposed method is a two-phase optimizer. In the first phase, the candidates are treated by both the EP and PSO techniques to explore the solution space freely. In the second phase, the SQP method will be invoked when there is an improvement of solution (a feasible solution) in the first phase of the run.

Victoire & Jeyakumar (2005a) presented a deterministically guided particle swarm optimization (DGPSO) algorithm to solve the dynamic economic dispatch problem (DEDP) of generating units considering the valve-point effects. The cost function of the generating units exhibits the non-convex characteristics, as the valve-point effects are modeled and imposed as rectified sinusoid components in the cost function. The DGPSO method is a two-phase optimizer: in the first phase the PSO technique will explore the solution space freely. In the second phase, SQP (sequential quadratic programming) will be called only when there is an improvement of solution (a feasible solution) in the PSO run.

Victoire & Jeyakumar (2005) designed a modified hybrid evolutionary programming–sequential quadratic programming (MHEP–SQP) method to solve the dynamic economic dispatch problem (DEDP) of
generating units considering the valve-point effects. The proposed method is a two-phase optimizer. In the first phase, the candidates of EP will explore the solution space freely. In the second phase, the SQP will be invoked when there is an improvement of solution (a feasible solution) in the EP run. Thus, the SQP guides EP for better performance in the complex solution space.

Swamp & Natarajan (2005) proposed a novel methodology for solving dynamic economic dispatch. It determines the optimal settings of generator units with predicted load demand over a certain period of time. The objective is to operate an electric power system most economically while the system is operating within its security limits.

Joned et al (2006) proposed an optimization technique to solve dynamic economic dispatch (DED) in the electric power system using ant colony optimization (ACO) technique. Ensuring a smooth electrical energy to the consumer has been identified as the main role of electric supply utility. In doing so, the power utility needs to ensure that the electrical power is generated with minimum cost. Hence, for economic operation of the system, the total demand must be appropriately shared among the generating units with an objective to minimize the total generation cost for the system with the voltage level maintained at the secure operating limit.

Rajan & Mohan (2007) presented a new approach to solve the short-term unit commitment problem using an evolutionary programming based simulated annealing method. The objective of this research is to find the generation scheduling such that the total operating cost can be minimized, when subjected to a variety of constraints. This also means that it is desirable to find the optimal generating unit commitment in the power system for the next $H$ hours.
Fogel (1994) presented that natural evolution is a population-based optimization process. Simulating this process on a computer results in stochastic optimization techniques that can often outperform classical methods of optimization when applied to difficult real-world problems. There are currently three main avenues of research in simulated evolution: genetic algorithms, evolution strategies, and evolutionary programming. Each method emphasizes a different facet of natural evolution. Genetic algorithms stress chromosomal operators. Evolution strategies emphasize behavioural changes at the level of the individual. Evolutionary programming stresses behavioural change at the level of the species.

Wang & Yuryevich (1998) developed an efficient and reliable evolutionary-programming-based algorithm for solving the environmentally constrained economic dispatch (ECED) problem. The algorithm can deal with load demand specifications in multiple intervals of the generation scheduling horizon. In research, the principal components of the evolutionary-programming-based ECED algorithm are presented. Solution acceleration techniques in the algorithm which enhance the speed and robustness of the algorithm are developed.

2.2.10 Sequential Quadratic Programming

Song & Yu (1997) proposed a Linear Programming (LP) based approach applied to dynamic load dispatch of electric power systems considering security and environment constraints. In addition to the basic constraints (such as generator real power limits and real power demand), a comprehensive set of constraints are considered including transmission line capacity limits, generators dynamic ramp rate, voltage security margin and/or environmental issues.
Victoire & Jeyakumar (2005) addressed a hybrid solution methodology integrating particle swarm optimization (PSO) algorithm with the sequential quadratic programming (SQP) method for the reserve constrained dynamic economic dispatch problem (RCDEDP) of generating units considering the valve-point effects. The hybrid method incorporates the PSO algorithm as the main optimizer and SQP as the local optimizer to fine-tune the solution region whenever the PSO algorithm discovers a better solution region in the progress of its run. Thus, the SQP guides PSO for better performance in the complex solution space.

Gaiing (2003) proposed the particle swarm optimization (PSO) to solve the constrained dynamic economic dispatch (DED) problem in power system operation. The feasibility of the proposed PSO method is demonstrated for two power systems, and it is compared with the other stochastic methods in terms of solution quality and computation efficiency.

Yuan et al (2009a) addressed an improved particle swarm optimization (IPSO) to solve DLED with valve-point effects. In the proposed IPSO method, feasibility-based rules and heuristic strategies with priority list based on probability are devised to handle constraints effectively. In contrast to the penalty function method, the constraint-handling method does not require penalty factors or any extra parameters and can guide the population to the feasible region quickly. Especially, equality constraints of DLED can be satisfied precisely.

Sriyanyong (2008) proposed an enhanced Particle Swarm Optimization (EPSO), where a modified heuristic search method is incorporated with Particle Swarm Optimization (PSO) in order to address the Dynamic Economic Dispatch (DED) problem, while it is also aimed at overcoming the deficiency of the solution feasibility. The results from optimizing the standard test systems show that the proposed technique is
indeed better than other approaches in terms of the solution quality. Thus, it
 can be concluded that the EPSO is recommended to be a promising method
for solving the DED problem.

Sripanyong (2008) presented the application of an enhanced Particle
Swarm Optimization (EPSO) combined with Gaussian Mutation (GM) for
solving the Dynamic Economic Dispatch (DED) problem considering the
operating constraints of generators. The EPSO consists of the standard PSO
and a modified heuristic search approaches. Namely, the ability of the
traditional PSO is enhanced by applying the modified heuristic search
approach to prevent the solutions from violating the constraints. In addition,
Gaussian Mutation is aimed at increasing the diversity of global search, whilst
it also prevents being trapped in suboptimal points during search.

model to maximize the social profit in a competitive electricity market. The
model synthetically considers various constraints such as ramp rates,
transmission line capacity and emission constraints to obtain a physically
feasible resource scheduling.

Gang (2004) proposed a particle swarm optimization (PSO) method
for solving the economic dispatch (ED) problem in power systems. Many
nonlinear characteristics of the generator, such as ramp rate limits, prohibited
operating zone, and non smooth cost functions are considered using the
proposed method in practical generator operation.

Panigrahi et al (2008) presented a novel heuristic optimization
approach to constrained economic load dispatch (ELD) problems using the
adaptive–variable population – PSO technique. The proposed methodology
easily takes care of different constraints like transmission losses, dynamic
operation constraints (ramp rate limits) and prohibited operating zones and
also accounts for non-smoothness of cost functions arising due to the use of multiple fuels.

Pothiya et al. (2008) presented a new optimization technique based on a multiple tabu search algorithm (MTS) to solve the dynamic economic dispatch (ED) problem with generator constraints. In the constrained dynamic ED problem, the load demand and spinning reserve capacity as well as some practical operation constraints of generators, such as ramp rate limits and prohibited operating zone are taken into consideration. The MTS algorithm introduces additional mechanisms such as initialization, adaptive searches, multiple searches, crossover and restarting process.

Chandran et al. (2006) proposed an equal embedded algorithm is used to solve dynamic economic dispatch problem. This problem satisfies the load demand over a certain period of time and some practical operation constraints of generators such as ramp rate limits. The results obtained by the proposed method were compared with lambda iterative method and particle swarm optimization method.

Kennedy & Eberhart (1995) introduced a concept for the optimization of nonlinear functions using particle swarm methodology. The evolution of several paradigms is outlined, and an implementation of one of the paradigms is discussed. Benchmark testing of the paradigm is described, and applications, including nonlinear function optimization and neural network training, are proposed. The relationships between particle swarm optimization and both artificial life and genetic algorithms are described.

Del Valle et al. (2008) presented a detailed overview of the basic concepts of PSO and its variants. Also, it provides a comprehensive survey on the power system applications that have benefited from the powerful nature of PSO as an optimization technique. For each application, technical details that
are required for applying PSO, such as its type, particle formulation (solution representation), and the most efficient fitness functions are also discussed.

Alrashidi & El-Hawary (2006) presented a comprehensive coverage of PSO applications in solving optimization problems in the area of electric power systems. Particle swarm optimization (PSO) has been getting added attention in many research fields.

Lee & Park (2006) proposed the state-of-art particle swarm optimization (PSO) applications for resolving the economic dispatch (ED) problem, which is considered as one of the complex problems to be tackled. The PSO techniques have drawn much attention from the power system community and been successfully applied in many complex optimization problems in power systems. This research focuses on the application of PSO techniques to the ED problems and describes their advantages and disadvantages in resolving the ED problems.

Basu (2006) proposed particle swarm optimization based goal attainment method for solving dynamic economic emission dispatch problem. In this article, cost and emission are treated as competing objectives. Assuming that the decision maker has goals for each of the objective functions, the multiobjective problem is converted into a single-objective optimization by goal-attainment method which is then handled by particle swarm optimization method.

Panigrahi et al (2007) presented DED control with valve point loading effect based on Particle Swarm Optimisation (PSO) algorithm for the determination of the global or near global optimum dispatch solution and its solution is compared with Static Economic Dispatch (SED). In the present case, load balance constraints, operating limits, valve point loading, ramp constraints and network losses using B-loss coefficients are incorporated.
2.2.11 Fuzzy Satisfying Method

Abido (2003) presented a new multi-objective evolutionary algorithm for environmental/economic power dispatch (EED) problem. The EED problem is formulated as a nonlinear constrained multiobjective optimization problem. A new strength Pareto evolutionary algorithm (SPEA) based approach is proposed to handle the EED as a true multiobjective optimization problem with competing and noncommensurable objectives. The proposed approach employs a diversity-preserving mechanism to overcome the premature convergence and search bias problems. A hierarchical clustering algorithm is also imposed to provide the decision maker with a representative and manageable Pareto-optimal set. Moreover, fuzzy set theory is employed to extract the best compromise nondominated solution.

Attaviriyaprap & Kita (2004) proposed a fuzzy optimization approach to dynamic economic dispatch considering uncertainties in deregulated energy and reserve markets. The methodology was developed from the viewpoint of a generation company wishing to maximize its own profit and to hedge its risks as a participant in the energy market and 10-min spinning reserve market. The uncertainties in the current research were represented with fuzzy numbers, and consist of the demand and reserves required in each market, prices cleared in each market, and the probability that reserves are called upon in actual operation.

2.2.12 Gradient Projection Algorithm

Granelli et al (1989) proposed a gradient projection algorithm is presented for the dynamic dispatch of thermal generations, based upon an active set strategy and exploiting second order information in determining the descent directions. The algorithms adapted to the model of the dynamic dispatch problem which consists of the minimisation of a
nonlinear objective function subject to quadratic equality constraints and linear inequality constraints. The envisaged algorithm can be applied to the dispatching of thermal units during the steep load pick-up and drop-down periods over short time intervals, and can also be used in the day-before scheduling after the unit commitment has been performed.

2.2.13 Neural Network

Fukuyama & Ueki (1994) presented an application of neural networks to dynamic dispatch. The proposed method uses a neural network with appropriate noises and can give efficient initial neuron conditions which are specific to the problem. Therefore, convergence to a local minimum can be suppressed. The method is implemented on a transputer, that is one of the efficient parallel processors, and the appropriate number of processors is examined. It can develop optimal and feasible generator output trajectories quickly by applying forecasts of system load patterns to practical thermal generating unit systems.

Liang (1999) proposed a dispatch approach based on the Hopfield neural network is proposed for solving the dynamic generation allocation problem. This research considers the dynamic dispatch problem that involve the allocation of system generation optimally among dispatchable generating units while tracking a load curve and observing power ramping response rate limits of the units, system spinning reserve requirements. The solution algorithm for solving the dynamic economic dispatch problem is divided into two major stages. First, the lambda-iteration method is employed to obtain the static economic dispatch as the base case. Then, the dynamic economic dispatch problem is linearized about this base case and is solved using the Hopfield neural network re dispatch approach.
Ramanathan (1994) presented a methodology to include emission constraints in classical economic dispatch (ED), which contains an efficient weights estimation technique. Also, a partial closed form technique is presented to implement the emission constrained economic dispatch (ECED). A simple technique is proposed to identify the binding constraints. The methods proposed do not need any user-supplied tuning or conversion factors. Dispatch quality is not compromised, and any practical sized problem can be solved efficiently. The proposed methods have rapid and consistent convergence to the Kuhn-Tucker optimality conditions.

Hopfield (1984) presented a model for a large network of "neurons" with a graded response (or sigmoid input-output relation). This deterministic system has collective properties in very close correspondence with the earlier stochastic model based on McCulloch - Pitts neurons. Collective analog electrical circuits of the kind described will certainly function. The collective states of the two models have a simple correspondence. The original model will continue to be useful for simulations, because its connection to graded response systems is established.

2.2.14 Simulated Annealing

Panigrahi et al (2006) presented DED based on a simulated annealing (SA) technique for the determination of the global or near global optimum dispatch solution. In the present case, load balance constraints, operating limits, valve point loading, ramp constraints, and network losses using loss coefficients are incorporated. Numerical results for a sample test system have been presented to demonstrate the performance and applicability of the proposed method.

Kirkpatrick et al (1983) proposed a solution methodology that gives deep and useful connection between statistical mechanics (the behavior of
systems with many degrees of freedom in thermal equilibrium at a finite
temperature) and multivariante or combinatorial optimization (finding the
minimum of a given function depending on many parameters). A detailed
analogy with annealing in solids provides a framework for optimization of the
properties of very large and complex systems. This connection to statistical
mechanics exposes new information and provides an unfamiliar perspective
on traditional optimization problems and methods.

2.2.15 Parallel Micro Genetic Algorithm

Ongsakul & Tippayaichai (2002) proposed a parallel micro genetic
algorithm based on merit order loading solutions (PMGA-MOL) to solve
constrained dynamic economic dispatch (DED) problems for combined cycle
(CC) units with linear decreasing and decreasing staircase incremental cost
(IC) functions. To minimize the synchronization overheads, the PMGA-MOL
employs the load balancing and migration strategies among processors. This
PMGA-MOL algorithm is implemented on the eight-processor scalable
multicomputer implementation using low-cost equipment (SMILE) Beowulf
cluster with a fast ethernet switch network on the generating unit system size
in the range of 5–80 units over the entire dispatch periods.

2.2.16 Relaxed Simplex Method

Irving & Sterling (1983) presented a simplex method based
approach. Computational experience with large-scale problems, including
dynamic dispatch over several time steps, is given, which indicates that the
method has very low memory and processor time requirements and is suitable
for implementation on minicomputer systems. The algorithm is extended to
allow for hierarchical constraint relaxation and removal in cases where an
infeasible problem has been specified inadvertently.
2.2.17 Differential Evolution

Balamurugan & Subramanian (2007) presented an improved differential evolution (IDE) method to solve the DED problem of generating units considering valve-point effects. Heuristic crossover technique and gene swap operator are introduced in the proposed approach to improve the convergence characteristic of the differential evolution (DE) algorithm.

Balamurugan & Subramanian (2008) presented the novel and efficient approach to solve the dynamic economic dispatch (DED) problem, including valve-point effects. In the proposed approach, the conventional economic load dispatch, for each time interval in a forward and reverse sequence, is independently performed using the DE algorithm with suitable modifications of the generation limits of the units due to the ramp-rate constraints of the generators. A certain load profile requires the traditional DED for a given set of committed units is determined by checking each interval in the scheduling horizon for the power-balance constraint violation due to the ramp-rate constraints of generators.

Yuan et al (2008) proposed MDE method, feasibility-based selection comparison techniques and heuristic search rules are devised to handle constraints effectively. In contrast to the penalty function method, the constraints-handling method does not require penalty factors or any extra parameters and can guide the population to the feasible region quickly. Especially, it can be satisfied equality constraints of DED problem precisely.

Yuan et al (2009) proposed a novel hybrid method to solve DED problem with valve-point effects, by integrating an improved differential evolution (IDE) with the Shore’s r-algorithm. The proposed method is developed in such a way that IDE is applied as a based level search, which can give a good direction to the optimal global region, and a local search
Shore’s r-algorithm is used as a fine tuning to determine the optimal solution at the final. A feasibility-based selection comparison technique and a heuristic rule are devised to handle constraints effectively in IDE, which does not require penalty factors or any extra parameters and can guide the population to the feasible region quickly.

Noman & Iba (2008) used differential evolution technique for solving economic load dispatch (ELD) problems in power systems. DE has proven to be effective in solving many real world constrained optimization problems in different domains. ELD problems are complex and nonlinear in nature with equality and inequality constraints and here special measures were taken to satisfy those. Five ELD problems of different characteristics were used to investigate the effectiveness of the proposal.

Storn & Price (1997) presented a new heuristic approach for minimizing possibly nonlinear and non-differentiable continuous space functions is presented. By means of an extensive test bed it is demonstrated that the new method converges faster and with more certainty than many other acclaimed global optimization methods. The new method requires few control variables, is robust, easy to use, and lends itself very well to parallel computation.

2.2.18 Gradient Based Algorithm

Innorta et al (1988) adopted a discrete formulation of the dispatch problem, with step variations of the loads. Dynamic constraints on the rate of change of the present loading output of thermal units are added to the ordinary constraints of the static approach. Costs associated with the act of quickly changing the thermal generation are included in the model. The solution of the problem uses a modified version of the Han-Powell algorithm in a compact-reduced model.
formulation. A sparsity technique used in the construction and in the updating of the Hessian matrix of the Lagrangian function, allows the solution of large-scale problems arising from a minute sub division of the dispatch interval in large electrical systems.

Cova et al (1987) formulated a second-order algorithms derived from the Han-Powell method are applied to real power optimization both in a static and in a dynamic dispatch procedure with security constraints. These procedures employ suitable compact reduced models for large-scale applications. In the dynamic approach a time-varying load is shared among the control units by adopting a discrete formulation of the dispatch problem. This involves the subdivision of the optimization interval into a certain number of sub-intervals with constant loads and the addition, to the ordinary constraints of the static approach, of dynamic constraints on rate of change of MW output of thermal units.

2.2.19 Unclassified

Happ (1977) presented the progress of optimal dispatch, also called economic dispatch, since its inception to the present in chronological sequence. The classic single area as well as multiarea cases are summarized, and the important theoretical work in optimal load flows suggested to date reviewed. Approaches to the optimal load flow taken by industry are also reported, as well as an itemization of problems that still remain to be solved.

Chowdhury & Rahman (1990) presented aspects of economic dispatch. The time period considered is 1977-88. Four related areas of economic dispatch are identified and research published in the general areas of economic dispatch are classified into these. These areas are: optimal power flow, economic dispatch in relation to AGC, dynamic dispatch, and economic dispatch with nonconventional generation sources.
Bechtel & Kwatny (1972) proposed a static optimization techniques to solve the economic load allocation problem. Experience has shown that a number of difficulties arise when these solutions are incorporated in the feedback control of dynamic electric power networks. This research attempts to overcome the disadvantages of such controllers by combining economic load allocation and supplementary control action into a single dynamic optimal control problem.

Kwatny & Bechtel (1973) presented static optimization techniques have been used by the electric power industry for several years to solve the problem of economic load allocation. Experience has shown that difficulties frequently arise when these solutions are incorporated in the feedback control of dynamic electric power networks. In a recent research, economic load allocation was formulated as a dynamic optimal control problem in an effort to overcome the disadvantages of controllers currently used.

Ross & Kim (1980) developed a set of procedures and algorithms for dynamic economic dispatch of generation units. When coupled with a short-term load predictor, "look-ahead" capability is provided by the dynamic economic dispatch that coordinates predicted load changes with the rate-of-response capability of generation units. Dynamic economic dispatch also enables valve-point loading of generation units. Two examples are provided which demonstrate that our approach overcomes the severe limits on the number of units that could be dynamically dispatched in past approaches.

Han et al (2007) Examined the factors that affect the feasibility and optimality of solutions to this problem. It proposes two new solution methods. The first is guaranteed to find a feasible solution even when the load profile is nonmonotonic. The second is an efficient technique for
finding the optimal solution. The results obtained with these methods are compared with those obtained using previously published methods.

Barcelo & Rastgoufard (1997) proposed an algorithm for solving the power system Multi-stage Dynamic Economic Dispatch (MDED) problem in real-time is presented. The MDED problem is formulated by formally adding ramp rate constraints to the Extended Security Constrained Economic Dispatch (ESCED) problem for all stages beyond the first stage. The MDED problem is then solved using the ESCED algorithm with ramp rate constraint sensitivity coefficients. A new two-component method of observing regulating margin constraints is also introduced and test results are presented comparing the one and two-stage dynamic EDC results.

Isoda (1982) presented a novel load dispatching method which takes into account the response capabilities of thermal units and short-term future load demand. This method has been successfully applied to a sample system. From a series of simulation results, it may be concluded that the optimum forecast period is approximately one hour in which the load demand should be forecast for a total of 4 to 6 points. Application of this method to an on-line load dispatching control in every utility is sufficiently possible at the present time and would be in the future.

Muki et al (1981) proposed to dispatch economically the load imposed on the area by the customers, while maintaining frequency and tie line schedules. The three stages of the algorithm involve successively shrinking time horizons (one day, one half hour, and one half minute) along with detailed knowledge of the actual load variations and progressively more detailed descriptions of the system. A ch algorithm stage draws on the results of the preceding stage and retains those features of the results which depend on the longer horizon of the preceding stage.
Lee et al (1994) presented a price-based ramp-rate model. This model is particularly suited for application to power system scheduling models that are based on dual formulation (i.e. price-based). In this model, the impact of binding ramp-rate limits is reflected via the hourly marginal ramp-rate values (\$/MW-Hr) of generators. In the research, the proposed ramp-rate model is applied to price-based dynamic dispatch and price-based unit commitment. Simple examples are used throughout the research to illustrate the concept of the proposed model.

Xia et al (2009) formulated the optimal power dispatch problem of generators in two ways. One way is the optimal control dynamic dispatch (OCDD) approach based on control theory, the other way is the dynamic economic dispatch (DED) based on optimization theory, and the two formulations are usually believed to be the same. In this research we show the difference between the two formulations and also propose a Model Predictive Control (MPC) approach to the dynamic dispatch problem by the OCDD framework. This MPC approach provides solutions converging to the optimal solution of an extended version of the DED problem and the MPC algorithm is also robust under certain disturbances and uncertainties.

Moya (1999) proposed Bender's decomposition in order to solve the problem by stages and is applicable to any power system. Application to Chilean Northern System is included to test the proposed method. Results show good convergence and easiness to obtain an optimum despite the wide range of feasible solutions for the problem. The composed cost of reserve and load shedding represents an important percentage of this system operating costs.

Ng (1981) developed a set of Generalized Generation Distribution Factors (GGDF's) to replace the conventional Generation Shift Distribution Factors (GSDF's). This model relates the line flows with generations for a
given network configuration. Being in an integral form, new flows on lines can be obtained directly without running load flows when total system generation changes. Conforming load change is also demonstrated. These new factors are especially suitable for constraint formulation in mathematical programming, such as optimal generation dispatch with security contingencies considered.

Bansal (2005) employed most efficient optimization methods to take full advantages in simplifying the formulation and implementation of the problem. This article presents an overview of important mathematical optimization and artificial intelligence (AI) techniques used in power optimization problems. Applications of hybrid AI techniques have also been discussed in this article.

Chandran et al (2008) presented application of Brent method to solve dynamic economic dispatch (DED) problem with transmission losses. The algorithm involves the selection of incremental fuel costs (lambda values) and then the optimal lambda is evaluated from the power balance equation by Brent method at predicted power demand. In real time operation, thermal gradients inside the turbine should be kept within safe limits to avoid shortening the life of generating units. This mechanical constraint is translated into a limit on the rate of increase and decreases of the output power during the variation in the power demand and is known as ramp rate limits. The constraint of ramp rate limits distinguishes the DED problem from the traditional static economic dispatch (ED) problem. Due to ramp rate limits, DED problem cannot be solved for a single value of the power demand.

Han et al (2003) proposed a dispatch technique based on the analysis of the system ramp-up/down megawatts (MW). If a dispatch is feasible, it can be show that the total unavailable ramp-up MW of all the slow units in any future time intervals must be less than or equal to the MW
difference between the maximum system MW capacity and the load demand at the end of study intervals. Likewise, the same can be said for the total unavailable ramp-down MW of all the slow units. These two constraints can be used to guide the system away from infeasible dispatch.

Talaq et al (1994) presented a summary of algorithms of environmental-economic dispatch in electric power systems since 1970. The algorithms attempt to reduce the production of atmospheric emissions such as NO\textsubscript{x} and SO\textsubscript{x} caused by the operation of fossil-fueled thermal generation. Such reduction is achieved by including emissions either as a constraint or as a weighted function the objective of the overall dispatching problem.

Yalcinoz & Koksoy (2007) presented an optimization technique based on progressive articulation of preference information is presented to solve the multiobjective environmental economic dispatch. For the multiobjective optimization problem, the use of weights to form a composite objective function reduces a multiple problem to a single problem. However, it also obviously “loses” some information in the conversion and this strategy is not expected to provide a robust solution or to even help trace the efficient frontier of solutions.

2.2.20 Bidding Strategy

David in (1993) states that significant additional capacity comes on line in the United Kingdom; a genuine commercially competitive electricity supply market will gradually replace the prevailing somewhat artificial 'market' conditions. In genuinely competitive conditions, several producers compete to win a share of the market and bid against each other to supply the grid. The prices bid by suppliers for blocks of generation offered to the grid would reflect what portions of the load curve a supplier hopes to win for each type of plant in its possession. This, in turn, depends on production cost
estimates, temporal considerations of system demand variation, unit
commitment costs, and commercial considerations such as profit or economic
utility maximization and expectations of competitor behaviour. This is a
wholly new situation, and has not been theorized or modelled to any
significant extent. The research develops conceptual models and
mathematical tools for a fuller understanding of these issues.

David & Wen (2000) presented that participants in a competitive
electricity market develop bidding strategies in order to maximize their own
profits. On the other hand, it is necessary for regulators to investigate strategic
bidding behavior in order to identify possible market power abuse and to limit
such abuse by introducing appropriate market management rules. An
interesting body of work has been done on this subject, and this research
presents a literature survey based on more than 30 research publications.

Wen & David (2001) proposed a new framework to build bidding
strategies for power suppliers in an electricity market in this research. It is
assumed that each supplier bids a linear supply function, and that the system
is dispatched to minimize customer payments. Each supplier chooses the
coefficients in the linear supply function to maximize benefits, subject to
expectations about how rival suppliers will bid. A stochastic optimization
formulation is developed and two methods proposed for describing and
solving this problem. A numerical example serves to illustrate the essential
features of the approach and the results are used to investigate the potential
market power.

Allen & Ilie (2000) defined a price-based decision making process
for participating in a reserve market for power systems reliability. Reserve
power is a fundamentally different commodity from spot market power. It is
suggested that depending on the payment mechanism in place, two different
types of formulae would be used by power producers and users when
participating in such markets. The research points out that despite the imminent trend to create reserve markets, several fundamental questions concerning reliable operation must be studied.

Padhy (2004) presents a bibliographical survey, mathematical formulations, and general backgrounds of research and developments in the field of UC problem for past 35 years based on more than 150 published articles. The collected literature has been divided into many sections, so that new researchers do not face any difficulty in carrying out research in the area of next-generation UC problem under both the regulated and deregulated power industry.

Chua et al (2001) presented a novel economic dispatch strategy for a generation company which owns several units with different fuel costs, efficiency, and locations, and has a bilateral contract with several large customers. The proposed strategy not only considers the generation cost, but also takes into account the wheeling charge for the use of the transmission system. A modified megawatt-mile method is proposed to calculate the wheeling cost in this research. Finally, the calculation results of economic dispatch for a generation company with two units and their loads in a real power system is demonstrated.

2.3 CONCLUSION

This research presents important features of DED problem. This problem is a traditional problem and solved using several methods based on the requirements of the problem formulation. These methods are classified into mathematical programming based methods, Artificial Intelligence (AI) techniques and hybrid methods. It is expected that this review of the DED problem based on the solution methods to solve them is first of its kind and it
is also believed that this review will be helpful for all those who do research related to DED problem.

The next chapter will discuss the hybrid methods combining probabilistic methods and deterministic methods are found to be very effective in solving complex optimization problems. In most of the hybrid methods the probabilistic methods will be used as a base level search algorithm, which makes a decision to direct the search towards the optimal region. Later the deterministic procedure will be used to fine-tune the final solution. In this research a novel hybrid method is presented to solve the Ramp Constrained Economic Dispatch Problem (RCEDP) by integrating the Differential Evolution (DE) with the Interior Point Method (IPM).