ABSTRACT

Electrical power plays a pivotal role in the modern world to satisfy various needs. It is therefore very important that the electrical power generated is transmitted and distributed efficiently in order to satisfy the power requirement. Electrical power is generated in several ways. The most significant work in the planning and operation of electric power generation system is the effective scheduling of all committed generators in a system to meet the required demand. Today's power system is characterized by high proportions, large number of interconnections and high nonlinearities, because the size of the power system is growing exponentially due to heavy demand of power in all the sectors viz. agricultural, industrial, residential and commercial ones. Increase in the electrical energy demand and trends in privatization and deregulation result in overloading impact on electrical grids. The situation necessitates the development of electrical grid at the same pace as the increase in demand. But, economical commitment and scheduling has the ability to tackle the time-varying power demand and environmental constraints and leads to full exploitation of the accessible grid. The economic load dispatch and unit commitment are two important power system optimization problems for scheduling the generation among thermal generating units.

In the modern power system networks, there are various generating resources like thermal, hydro, nuclear etc. Also, the load demand varies during a day and attains different peak values. Thus, it is required to decide time of turning on the generating unit as per requirement of the power system network. It also decides the sequence of shutting down the units keeping in mind the cost effectiveness of turning on and shutting down of respective units. The entire process of computing and making the decisions for turning on and shutting down the units is known as unit commitment. The scheduled unit to be connected to the power system network is known as the committed unit. The unit commitment is an important research challenge and vital optimization task in the daily operational planning of modern power systems due to its combinatorial nature. It is a non-linear, non-convex, large scale, mixed integer and constrained optimization problem, which aims to schedule the operation of various generating units at minimum operating cost while satisfying the demand and other equality and inequality constrains. Generators

cannot be immediately turned on to meet up power demand. So, it is required that the planning of generating units must be so done that there is enough generation available to fulfill the load demand along with an ample reserve generation to avoid the effect of sudden failures and malfunctions under adverse conditions.

Industries, agriculture and software companies require consistent and uninterrupted power supply for toeing the needs of continuous customer demand. It, therefore, drew the attention of researchers to determine the optimal and most economic condition for power generating units to operate in each period so as to satisfy a predictably varying demand for electricity. Further due to complexity of multi area generation system, the determination of economic condition for committed units along with economic dispatch and minimum emission is most important. Thus, there is an urgent need to implement a trusted and foolproof algorithm to solve unit commitment of electric power system in single and multi-objective and multi-area framework.

In recent years, global warming and carbon dioxide (CO_2) emission reduction have become important issues in India, as CO_2 emission levels are continuing to rise in accordance with the increased volume of Indian national energy consumption under the pressure of global warming, it is crucial for Indian government to impose the effective policy to promote CO_2 emission reduction. Carbon tax policy is a cost-effective method for emission reduction. However, setting the carbon tax is one of the challenging tasks for policy makers as it will lead to higher price of emission-intensive sources especially the utility price. Challenge of supplying the nation with high quality and reliable electrical energy at a reasonable cost, converted government policy into deregulation and restructuring environment. Inclusion of restructuring into electricity industries brought more choice. As the objective of restructuring in electricity market is to abolish the domination in the power production and trading sectors and introducing opposition at diverse levels. In deregulation, power generation utilities pierce into mutual agreements to supply the generated electricity to power distributors/dealers or volume patrons or sell the power in a pool, where power brokers and patrons can participate. In this energy exchange process, the buyers offer for their demands along with ability/willingness to reimburse. Power generation or power trading become free from the conformist policy and turn into spirited environment, as customers/companies are free to buy power, as per

their requirements, either from a federal spot market or unswervingly from marketers or generators through prearranged mutual agreements. However, increase in the electrical energy demand and trends in privatization and deregulation result in overloading impact on electrical grids. The situation necessitates the development of electrical grid at the same pace as the demand increases, but economical commitment and scheduling has the ability to tackle the time-varying power demand, environmental constraints and led to the full exploitation of accessible grid. Thus, combined operation of electric generation resources in an inter-connected multi area system is required, which result in reduced environmental pollution and operational cost savings. The multi-area unit commitment problem represents two or more interrelated regions or areas of electric power system, which are interconnected by means of tie lines. The major purpose of multi-area unit commitment problem in interconnected multi-area power system is to establish the optimal commitment and scheduling generation strategy for electric power generating units situated in manifold areas, which are interconnected through tie lines and whose combined operation of generation units can result in noteworthy operational cost savings and due consideration of environmental effects.

The present research study is dedicated to investigate the novel technique to define, extend and establish optimal unit commitment strategies in scalar and multi-objective framework for single and multi area unit commitment optimization problem while considering various system and physical constraints explicitly on the input-output characteristics of thermal power generation units. To solve the multi-objective and multi-area unit commitment problem conventional and non-conventional search techniques are explored. Random search algorithm is exploited to improve the exploitation ability and global performance of conventional Harmony search and Differential evolution algorithms.

The thesis deals with introductory aspects of economic load dispatch and unit commitment problem and their significance for modern electric power system in the full chapter. Also, this chapter contains the significant contribution of various researchers in the field of economic load dispatch and unit commitment optimization problem. As unit commitment deals with the economic operation of the generating units and leads to a minimized cost of generation, it has attracted many researchers over past few years. The

researchers are trying to implement various techniques on various problems and are able to find the solutions successfully. The work is going on to find new algorithms and also their hybrid forms to rectify any drawbacks in the existing techniques. This chapter deals with the literature survey of various techniques successfully applied on various real world problems including the unit commitment problem. The chapter covers a thorough review of the work done by various researchers on unit commitment optimization problem from 1959-2015 along with advantages and disadvantages of various optimization algorithms.

Ensuing chapter represents the various methodologies to solve unit commitment problem. As unit commitment is a large, non-convex, non-linear and mixed integer optimization problem, the attempt to obtain the optimal schedule of committed generating units is challenging. A variety of methods have been developed to solve the unit commitment problem with intention of minimizing the operating cost in a reasonable computational time. The aim of this chapter is to summarize existing unit commitment methodologies and to explain the state of the art for the proposed hybrid solution methodologies for the solution of single and multi area unit commitment optimization problem under single and multi-objective framework. The proposed integrated *differential evolution and harmony search* (DE-HS), hybrid *differential evolution and random Search* (DE-RS) and hybrid *harmony search and random search* (HS-RS) algorithms are discussed in detail.

The succeeding chapter represents the solution of single area, scalar-objective unit commitment problem of electric power system. The chapter explains integrated DE-HS, hybrid HS-RS and hybrid DE-RS algorithms to solve single area, scalar objective unit commitment optimization problem of electric power system to obtain unit commitment table and the optimal schedule for operating the generating units in a most economic manner to meet the load demand and at the same time accomplish the system and physical constraints' requirements. In order to obtain the integrated DE-HS, hybrid HS-RS and hybrid DE-RS algorithms, the general operators of harmony search algorithm, differential evolution algorithm and random search algorithm are combined recursively. Heuristics procedure is adopted to tackle various physical and operational constraints of unit commitment optimization problem. A non-linear, non-convex, mixed integer, combinatorial and constrained unit commitment optimization problem is solved by using

integrated DE-HS, hybrid HS-RS and hybrid DE-RS algorithms for small and medium electric power systems. The effectiveness of proposed hybrid algorithms is authenticated by performing comparison with other well-known evolutionary, heuristics and meta-heuristics search algorithms. After statistical analysis, it has been concluded that proposed hybrid HS-RS and hybrid DE-RS algorithms yield better feasible solutions in comparison to integrated DE-HS algorithm. The overall generation cost in hybrid DE-RS algorithm is better than hybrid HS-RS algorithm due to self-adaptive mutation and parallel processing nature of differential evolution algorithm. However, hybrid DE-RS algorithm lacks in computational efficiency due to large number of fitness evaluations.

In the next chapter, integrated DE-HS, hybrid HS-RS and hybrid DE-RS algorithms are extended to solve multi-objective unit commitment optimization problem. Operating cost and gaseous pollutant emission (CO_2) are undertaken into consideration to formulate the objective function for multi-objective unit commitment optimization problem. The effect of randomness or variation of various system parameters is elegantly investigated in the framework of multiple objectives. The solution set of such formulated problems is non-inferior due to contradictions among the competing objectives. The weighting method is employed to simulate the trade-off relation between the conflicting objectives in the non-inferior domain. In order to determine the Pareto front from a large set of multi-objective points, two different efficient algorithms are implemented. The algorithm considers the logical relationship between dominated and non-dominated points to avoid duplication of comparisons as much as possible so that the overall operations get reduced and then algorithm splits the given objective set into several smaller groups to be examined. Then, the Pareto fronts of each group are combined to determine the overall Pareto front. To handle the operational and physical constraints of multi objective unit commitment problem, heuristics procedure is adopted. Multi-objective unit commitment problem is tested for 5- to 10-units system and it have been observed that performance of hybrid DE-RS algorithm is better than conventional differential evolution, harmony search, integrated DE-HS and hybrid HS-RS algorithms. The hybrid DE-RS algorithm outperforms due to direct search and derivative-free capability of random search algorithm and greediness of differential evolution algorithm. However, the computational efficiency of hybrid DE-RS algorithm is low due to large number of fitness evaluation.

In the next chapter, multi-area unit commitment strategy is employed, whose objective is to establish optimal commitment and generation schedule for multi-area power system for momentous outfitted cost savings. To achieve significant cost savings, integrated DE-HS, hybrid HS-RS and hybrid DE-RS optimization techniques are again implemented to solve multi-objective and multi area unit commitment and scheduling problem of electric utility system. Two different benchmarks of multi area power system are taken into consideration for proposed research. The first benchmark system has two interconnected areas. Each area consists of five-generating units. Another benchmark system has three interconnected areas. Each area consists of six-generating units. To tackle physical and operational constraints within the same area and power import/export between different areas, heuristics procedure is adopted. The weighting method is employed to simulate the trade-off relation between the conflicting objectives in the non-inferior domain. In order to determine the Pareto front from a large set of multi-objective points, efficient algorithms are implemented. Simulation results show that proposed algorithms have prospective to solve multi area unit commitment and scheduling in deregulated power market with import and export constraints. Also, it has been found that hybrid DE-RS algorithm outperforms integrated DE-HS and hybrid HS-RS algorithm. This is due to direct search and derivative-free capability of random search algorithm and greediness of differential evolution algorithm. However, hybrid DE-RS algorithm lacks in computational efficiency.

The last chapter summarizes the significant conclusions of the research carried out for the proposed study. The contribution and utilization of integrated DE-HS, hybrid HS-RS and hybrid DE-RS algorithms for single and multi-objective unit commitment problem in power system operation studies are systematically presented and summarized. Suggestions for further possible research work are also speculated.