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Profit maximization through bid based dynamic power dispatch using symbiotic organism search

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Abstract. Deregulation of power system has created competition in the power market shifting the focus from cost optimization to profit maximization, which has created different trading mechanisms. The power companies and their customers submit their bids for each trading interval of the next day and the independent system operator (ISO) conducts a bid based dynamic economic dispatch (BBDED) to allocate power to the generating companies and customers in such a manner that the total profit is maximized while all constraints such as power balance, operating limits and ramp rate limits are satisfied. Nature inspired (NI) optimization techniques score over the classical numerical methods for solving such complex practical problems due to (i) their population based random search mechanism and (ii) their non-dependence on initial solution. This paper proposes a symbiotic organisms search (SOS) based solution for solving BBDED problem in the deregulated electricity market. The SOS algorithm depicts the interaction between different species in nature, the three symbiotic relationships. The performance of the proposed approach has been tested on standard power system bench marks from literature having 10 generators, 6 customers and varying power demands over 12 dispatch periods. The results have been validated with published results and SOS is found to be more effective than the other methods for solving the BBDED problem.

Keywords: BBDED; deregulated electricity market; social profit; SOS.

1. Introduction

In a competitive electricity market the dynamic economic dispatch is carried out in a bid-based frame work to maximize the social profit under changing demands and bids. Matching the continuously changing power demand with generation is a complex task for complex power system networks with large number of variables. A competitive bidding mechanism needs to allocate power generation to customers having different demands in such a way that the social profit is maximized and the scheduled generation for two consecutive time periods satisfies the ramp rate constraints. Due to randomly changing load demands and ramping constraints, BBDED is a complicated optimization problem requiring efficient algorithms.

Optimization is a branch of mathematics which means making something better [1][2]. The maximization of profit and minimization of operating cost have to satisfy certain practical operating conditions known as constraints. The most flexible form of energy is electric energy that is used in various applications such as it is used to operate electrical equipment in factories and domestic appliances in houses. Cost of generating the power is very high because in most of the countries power generation depends on fossil fuels. The fossil fuel resources are depleting very fast and therefore their optimal utilization is receiving tremendous research focus. The objective of traditional economic dispatch (ED) is to allocate generation to committed generating units such that the fuel cost is minimized [3, 4]. The demand of electricity is raising day by day ED helps in saving the fuel cost by optimal allocation of generation [5]. Storage of electricity in large amounts is not possible as it is not a true commodity, so it has to be consumed when it is generated [6]. Maintaining a balance between generation and continuously varying load is a very challenging task.

In competitive electricity market there is a paradigm shift as cost minimization objective gets converted to profit maximization, taking into consideration the bids submitted by generating companies as well as by the consumers. Henceforth, the traditional ED problem gets converted to a bid based ED in the competitive market. The ED problem can be solved either as a static problem or as a dynamic problem. The static ED minimizes the generation cost while satisfying the load demand of customers for a single time period [7] assuming the load to be constant. In practice this assumption is not correct [8]. To overcome the difficulty the ED is formulated in a dynamic environment where the power outputs of two consecutive time intervals must satisfy ramp rate constraints. The dynamic ED (DED) is the realistic representation which is solved by dividing all dispatch periods assuming the power demand to be constant in each small interval [9]. In Bid based electricity market there are two types of trading mechanisms, bilateral trading and central auction. In bilateral trading mechanism suppliers and customers submit their bids and the quantities traded are at the discretion of the participants; this mechanism does not involve independent system operator (ISO). In central auction trading mechanism all participant (i.e. suppliers and customers) submit their bids to an ISO who matches the bids and dispatch them in an economic manner based on the price offered by suppliers and load demanded by customers while maintaining the security and reliability of the system [10]-[12]. Traditionally the main goal of ED problem was to minimize the cost; deregulation shifts that goal from cost minimization to maximization of social profit. Therefore BBDED is sometimes also referred to as profit based DED. It is concerned with ensuring high social profit from customer benefit and increasing the competitiveness of the participating parties [13]-[17]. Various mathematical programming methods have been employed in the past decade to solve the ED problem such as quadratic programming [18], dynamic programming [19] etc. Conventional methods include convex, linear and differentiable function which is not easy to handle and do not converge to optimum solution. Solution of large scale ED problem using quadratic programming and GAMES is presented in [20]. ED problem exhibit the nonlinear and non-convex features which is difficult to solve by conventional method. On the other nature inspired (NI) techniques that follow heuristic approaches have been proven to be effective for solution of complex optimization problem. Among NI techniques Genetic Algorithm (GA) [21], Particle swarm optimization (PSO)[3], Biogeography-based optimization (BBO)[22], Invasive Weed Optimization (IWO)[23], Simulated Annealing [24], Flower pollination algorithm(FPA)[25], social spider algorithm [26], applied to solve complex constraints ED problem. A comprehensive study of NI optimization algorithms and their application to ED is presented in [27].

Symbiotic organisms search (SOS) is a new NI algorithm proposed by cheng and prayogo in 2014 [28]. SOS algorithm finds the optimum solution based on the symbiotic interaction behavior of organism. No algorithm specific parameters and fast convergence rate is the main advantage of SOS algorithm [29][30]. For solving engineering field problems SOS found very efficient.

2. Mathematical model of BBDED

A bid consist of load which is demanded by the customers and price offered by generation companies. The mathematical model of BBDED is based on central auction trading mechanism. The operator dispatches the requested transactions if constraints are not violated and sellers/buyers charges for the services. The demand side and supply side bids are matched by operator to maximize the social benefit. Profit maximization for BBDED problem is formulated as:

2.1. Objective function

$$\text{Maximize} \quad PF = \sum_{t=1}^{T}\left[\sum_{j=1}^{N_c} BC_j\left(D_j^t\right) - \sum_{i=1}^{N} BG_i(P_i^t)\right] \tag{1}$$

$$BC_j\left(D_j^t\right) = a_{dj}(D_j^t)^2 + b_{dj}D_j^t \tag{2}$$

$$BG_i\left(P_i^t\right) = a_{pi}(P_i^t)^2 + b_{pi}P_i^t + c_{pi} \tag{3}$$

2.1.1. Power balance constraints: This constraint keeps the power system in equilibrium between total generation of generators and customers demand in electricity market.

$$\sum_{i=1}^{N} P_i^t = \sum_{j=1}^{N_c} D_j^t + P_l^t \qquad t=1, 2, 3 \ldots T \tag{4}$$

2.1.2. Generator bid quantities constraints: Generators related to its generator design have its lower and upper generation limits that is given by

$$P_{i\,min}^t \le P_i^t \le P_{i\,max}^t \tag{5}$$

2.1.3. Customer bid quantities constraints: Customer bid quantities are related to minimum and maximum bid load of user which is presented as:

$$D_{j\,min}^t \le D_j^t \le D_{j\,max}^t \tag{6}$$

2.1.4 Ramp rate limits constraints: The ramp up/down limits or rate of increase/decrease of power is kept within a safe limit to avoid shortening the life of generators.

$$DR_i \le P_i^t - P_i^{t-1} \le UR_i \tag{7}$$