International Journal on
“Technical and Physical Problems of Engineering”
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2012 Issue 10 Volume 4 Number 1 Pages 114-119

APPLICATION OF ABC ALGORITHM FOR ACTION BASED DISPATCH IN THE RESTRUCTURED POWER SYSTEMS

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Abstract- This paper addresses an Artificial Bee Colony (ABC) based method to search and find global solution on auction based dispatch algorithm in a deregulated power system. For this reason, the generation cost is replaced by seller’s bidden cost function including not only the generation cost, but also the market strategy, which may become concave, whereas the conventional Economic Load Dispatch (ELD) algorithm relies on the convexity of the cost function. The scheduling problem of an auction-based dispatch problem in a deregulated power system is formulated as the least bidden cost optimization problem, in which the seller’s total bidden cost is minimized while the balance of supply and demand constraint and the capacity limit constraints are satisfied. It is solved by ABC algorithm which describes the food foraging behavior, memorizing and information sharing characteristics of honey bee swarm to find the best possible solution within a reasonable computation time. The plausibility of the proposed algorithm is demonstrated and its performance is compared with other methods on 3 and 8 machines standard power systems. Simulation results reveal that the proposed ABC based solution method has better outperforms than the other algorithms.

Keywords: ABC Algorithm, Auction-Based Dispatch, Economic Dispatch, Seller’s Bidden Cost

I. INTRODUCTION

A first characteristic of a market settlement is the nature of supply and demand bids. The auction power pools refer to strategies where only supply is based on bids and demand is estimated. Meanwhile, double auction power pool allows both supply and demand to be based on bids from participants. Commodities markets are usually organized according to the double auction. In short, the market settlement aggregates supply and demand bids and the intersection of the two curves defines the market price.

A need for optimality exists in the highly nonlinear and computationally difficult power system analysis environment. In the classical Economic Load Dispatch (ELD) method, the quadratic generation cost function and incremental cost function are used to make the algorithm simple, accurate and efficient. However, the conventional ELD algorithm relies heavily on the production cost function property: “the higher the output, the higher the incremental cost” [1-7]. In a restructured power system, the generation cost objective function is replaced by seller’s bidden cost function including not only the generation cost, but also the market strategy. The property of the bidden cost function may become, “higher the output, lower the incremental cost” [4-9] which makes the conventional ELD algorithm inapplicable.

As an alternative to the auction based dispatch, global optimization techniques like genetic algorithms (GA) [8], and simulated annealing [9], Differential Evolution (DE) technique [10] have been applied for the bidding problem optimization to find global or near global optimal solution in recent years. These evolutionary based techniques are heuristic population-based search procedures that include random variation and selection operators. Although, these techniques seem to be good methods for the solution of the proposed optimization problem, however, when the system has a highly epistatic objective function (i.e. where optimized parameters are highly correlated), and number of parameters to be optimized is more, then they have degraded efficacy to obtain the global optimum solution and also simulation process involve a large number of iterations and are sensitive to the parameter settings. In order to overcome these drawbacks, an Artificial Bee Colony (ABC) algorithm is proposed to find the optimal generation dispatch solutions for an action based economic dispatch in the restructured power system to improve power system operation scheduling in this paper.

The ABC algorithm is a typical swarm-based approach to optimization, in which the search algorithm is inspired by the intelligent foraging behavior of a honey bee swarm process [11] and has emerged as a useful tool for engineering optimization. Unlike the other heuristic techniques such as PSO, it performs both global search and local search in each iteration for significant probability increasing of the optimal solution finding and efficiently avoiding local optimum to a large extent. In the ABC, while the intensification process is controlled by the greedy selection and stochastic schemes, the diversification is controlled by the random selection. Hence, ABC incorporates a flexible and well-balanced mechanism to adapt to the global and local exploration and exploitation abilities within a short computation time due to the selection schemes used and the neighbour production mechanism employed [12].

Also, it has fewer control parameters and a higher success rate since it does exploration and exploitation processes together efficiently. This newly developed algorithm is simple, robust and capable to solve multi-variable, multi-modal and difficult combinatorial optimization problems. The effectiveness and robustness of the proposed ABC method is tested on 3 and 8 seller’s test systems to demonstrate their ability to provide efficient solution for optimal dispatch. To show the superiority of the proposed approach, the simulations results are compared with the Particle Swarm Optimization (PSO), DE and GA algorithms through some performance indices. The numerical results show that the proposed ABC method for the solution of auction-based dispatch problem can generate high-quality solutions and superior computation efficiency than the other heuristic methods. Also, it has lower generation cost and more stable convergence characteristics than the other stochastic methods.

II. PROBLEM FORMULATION

The sellers bidden cost function is assumed to be a quadric function, which is given by:

$$B_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 \text{ \$/h} \tag{1}$$

The incremental cost is defined of the bidden cost function as follows:

$$IC_i(P_i) = b_i + 2c_i P_i \tag{2}$$

The auction-based dispatch problem is formulated as the least bidden cost optimization problem, in which the seller’s total bidden cost is minimized while the balance of the supply a demand constraint and the capacity limit constraints of generation units are satisfied. Thus, the objective function for optimization of auction-based dispatch problem is considered as follows:

$$\begin{aligned} &\text{minimize } \sum_{i=1}^{n} F_i(P_i) \\ &\text{S.I.: } \sum_{i=1}^{Ng} P_i = P_d \text{ , } P_i^{\min} \le P_i \le P_i^{\max} \end{aligned} \tag{3}$$

This is the formulation for classical economic dispatch problem, but the difference is that the objective function used here is the seller’s bidden cost. The necessary condition for optimal solution is:

When $\sum_{i=1}^{Ng} P_{i\max} > P_d$ or $\sum_{i=1}^{Ng} P_{i\max} = P_d$, there is no feasible solution; when, each seller’s contracted $\sum_{i=1}^{Ng} P_{i\min} = P_d$ amount is at its capacity lower limit: when $\sum_{i=1}^{Ng} P_{i\max} = P_d$ each seller’s contracted amount is at its capacity upper limit. In the non-trivial case, when $\sum_{i=1}^{Ng} P_{i\min} < P_d$ and $\sum_{i=1}^{Ng} P_{i\max} > P_d$ the following equations can be obtained from Kuhn-Tucker theorem:

$$\begin{aligned} &\frac{\partial F_i}{\partial P_i} - \lambda - \mu_{i\min} + \mu_{i\max} = 0, \ \ i = 1,...., Ng \\ &\sum_{i-1}^{Ng} P_i = P_d \\ &\mu_{i\min} \times (P_{i\min} - P_i) = 0, \ \ i = 1,...., Ng \\ &\mu_{i\max} \times (P_i - P_{i\max}) = 0, \ \ i = 1,...., Ng \\ &\mu_{i\min} \ge 0, \ \ i = 1,...., Ng \\ &\mu_{i\max} \ge 0, \ \ i = 1,...., Ng \end{aligned} \tag{4}$$

For the seller’s contracted amounts that do not hit the capacity limits, i.e.: $P_{i\min} < P_i^* < P_{i\max}$, $i \in [1, Ng]$ we have:

$$\frac{\partial F_i}{\partial P_i} = \lambda \tag{5}$$

For the seller’s contracted amounts that hit the capacity upper limits, we have:

$$\frac{\partial F_i}{\partial P_i} = \lambda - \mu_{i\max} \le \lambda \tag{6}$$

For the seller’s contracted amounts that hit the capacity lower limits,

$$\frac{\partial F_i}{\partial P_i} = \lambda + \mu_{i\max} \ge \lambda \tag{7}$$

Suppose $P^* = (P_1^*, ..., P_{Ng}^*)$ is an optimal solution of problem. Define $\lambda = IC_i\left(P_i^*\right)$ for $P_{i\min} < P_i^* < P_{i\max}$, then, a necessary condition for optimal solution is:

$$IC_i\left(P_i^*\right) \ge \lambda \text{ for } P_i^* = P_{i\min} \text{ , } IC_i\left(P_i^*\right) \le \lambda \text{ for } P_i^* = P_{i\max} \tag{8}$$

The following notations are used consistently in this paper:

Ng is the number of sellers; a_i, b_i, c_i is The parameters in the *i*th sellers bidden cost function; P_i is The contracted amount of *i*th sellers; $P_{i\max}, P_{i\min}$ are The capacity upper and lower limit of *i*th sellers bidden amount; P_d is The total market demand; $\lambda, \mu_{i\max}, \mu_{i\min}$ are Lagrange multipliers; $F_i\left(P_i\right)$ is *i*th sellers bidden cost function and $IC_i\left(P_i\right)$ is *i*th sellers bidden incremental cost.

III. ABC ALGORITHM

The ABC algorithm describes the foraging behavior of honey-bees for numerical optimization problems. The algorithm simulates the intelligent foraging behavior of honey bee swarms. It is a very simple, robust and population based stochastic optimization algorithm [11]. The minimal model of forage selection in honey bee swarms intelligence consists of three essential components: food sources, employed foragers and unemployed foragers, and two leading modes of the behavior, recruitment to a nectar source and abandonment of a source, are defined [12]. A food source value depends on many factors, such as its proximity to the nest, richness or concentration of energy and the ease of extracting this energy. The employed foragers are associated with particular food sources, which they are currently exploiting or are ‘‘employed”. They carry with them information about these food sources and share this information with a certain probability. There are two types of unemployed foragers, scouts and onlookers. Scouts search the environment surrounding the nest for new food sources, and onlookers wait in the nest and find a food source through the information shared by employed foragers.

In the ABC algorithm, the colony of artificial bees contains of three groups of bees: employed bees, onlookers and scouts. The food source represents a possible solution of the optimization problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution. Every food source has only one employed bee. Thus, the number of employed bees or the onlooker bees is equal to the number of food sources (solutions). An onlooker bee chooses a food source depending on the probability value associated with that food source, p_i, calculated by the following expression:

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n} \tag{9}$$

where fit_i is the fitness value of the solution i evaluated by its employed bee, which is proportional to the nectar amount of the food source in the position i and SN is the number of food sources which is equal to the number of employed bees (BN). In this way, the employed bees exchange their information with the onlookers.In order to produce a candidate food position from the old one, the ABC uses the following expression:

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}) \tag{10}$$

where, $k \in \{1, 2, ..., BN\}$ and $j \in \{1, 2, ..., D\}$ are randomly chosen indexes. Although k is determined randomly, it has to be different from i. ϕ_{ij} is a random number between [0, 1]. It controls the production of a neighbour food source position around x_{ij} and the modification represents the comparison of the neighbor food positions visually by the bee. Equation (10) shows that as the difference between the parameters of the x_{ij} and x_{kj} decreases, the perturbation on the position x_{ij} decreases, too. Thus, as the search approaches to the optimum solution in the search space, the step length is adaptively reduced [13].

The food source whose nectar is abandoned by the bees is replaced with a new food source by the scouts. In the ABC algorithm this is simulated by randomly producing a position and replacing it with the abandoned one. If a position cannot be improved further through a predetermined number of cycles called *limit* then that food source is assumed to be abandoned [14]. After each candidate source position v_{ij} is produced and then evaluated by the artificial bee, its performance is compared with that of x_{ij}. If the new food has equal or better nectar than the old source, it is replaced with the old one in the memory. Otherwise, the old one is retained. In other words, a greedy selection mechanism is employed as the selection operation between the old and the current food sources. The main steps of the algorithm are given by [13, 14]:

i) Initialize the population of solutions & evaluate them.
ii) Produce new solutions for the employed bees, evaluate them and apply the greedy selection mechanism.
iii) Calculate the probabilities of the current sources with which they are preferred by the onlookers.
iv) Assign onlooker bees to employed bees according to probabilities, produce new solutions and apply the greedy selection mechanism.
v) Stop the exploitation process of the sources abandoned by bees and send the scouts in the search area for discovering new food sources, randomly.
vi) Memorize the best food source found so far.
vii) If the termination condition is not satisfied, go to step 2, otherwise stop the algorithm.

It is clear from the above explanation that there are three control parameters used in the basic ABC: The number of the food sources which is equal to the number of employed or onlooker bees (SN), the value of *limit* and the Maximum Cycle Number (MCN). Figure 1 shows the flowchart of the ABC algorithms.

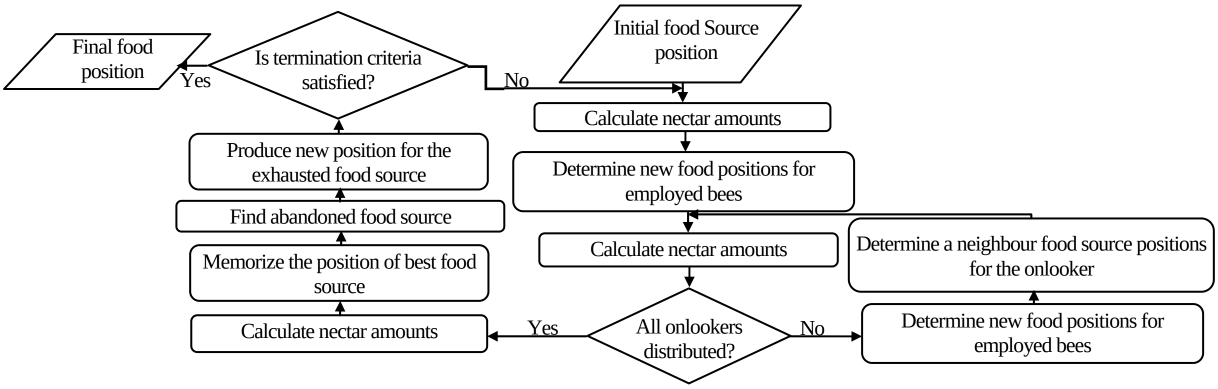

Figure 1. The flowchart of the proposed ABC algorithm

IV. SIMULATION RESULTS

In order to illustrate the efficiency of the proposed ABC algorithm for the solution of the auction based dispatch problem in deregulated power market, two power systems, including 3 and 8 sellers are considered as test systems. In these studied systems, the balance of the supply a demand constraint and the capacity limit constraints of generation units were taken into account for the practical application. The found results are compared with the represented results of GA [10], DE [10] PSO methods in the literature. The ABC technique is implemented in Matlab software. The program was written in Matlab 7.8 and executed on Intel, 2.53GHz with 4 Gig RAM. In each test system, 30 independent runs were made for each of the optimization methods. In order to acquire better performance, maximum cycle number, colony size and *limit value* are chosen as 50, 40 and 10 to different studies system, respectively for ABC algorithm.

A. Case 1: Three Sellers Test System

This case study system consists of 3 sellers and system data are given in Table 1 [10]. The final demand is 850 MW. The optimal contracted demands results using the proposed ABC method in comparison than the other heuristic methods are shown in Table 2 and 3 that satisfies the generator constraints. From the Table 3, it is evident that the ABC algorithm can provide lower fuel generation cost than the recent studied methods in the literature. It can be apparent from these Tables that the proposed technique provided superior solutions with a high probability always satisfying the equality and inequality constraints compared with other reported evolutionary algorithm methods.

A convergence characteristic of the 3 sellers system using ABC algorithm in comparison that of GA and PSO algorithms is shown in Fig. 2. It can be seen that the ABC algorithm has high-quality convergence property, thus resulting in good evaluation value and low generation cost. After some iteration the ABC characteristics shows signs of premature convergence and settle to near optimal results. Hence, it can be concluded that the proposed ABC method has the stronger ability to find the superior quality solution and its convergence characteristic is also better.

Table 1. Three sellers test systems

Unit	Lower Limit (MW)	Upper Limit (MW)	*a*	*b*	*c*
1	100	600	561	7.92	0.001562
2	100	400	310	7.85	0.00194
3	50	200	78	7.97	0.00482

Table 2. Sellers contracted demands for case 1

Method	P_{G1} (MW)	P_{G2} (MW)	P_{G3} (MW)
DE [9]	393.153	334.6087	122.2383
GA	589.172	120.1982	140.1341
PSO	592.287	115.718	141.8227
ABC	600.001	100.0001	149.9921

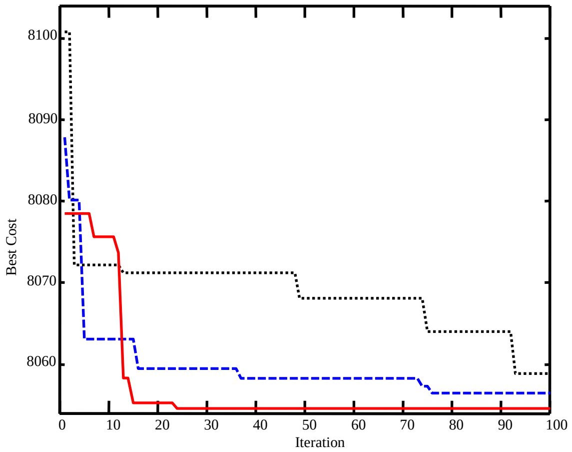

Figure 2. Converge Characteristics of 3 sellers system; ABC (Solid), PSO (Dashed) and Dotted (GA)

Table 3. Results for three sellers test systems

Method	Run time	Cost
DE [9]	0.28	8194.35
GA	0.2512	80598.76
PSO	0.1724	80572.81
ABC	0.1101	80569.85

B. Case 2: 8 Sellers Test System

This case study system consists of 8 sellers and system data are given in Table 4 [10]. The final demand is 450 MW. The optimal contracted demands results using the proposed ABC method in comparison than the other heuristic methods are given in Tables 5 and 6 that satisfies the generator constraints. From the Table 6, it is evident that the ABC algorithm can provide lower fuel generation cost than the recent studied methods in the literature. It can be apparent from these Tables that the proposed technique provided superior solutions than the other reported evolutionary algorithm methods.

A convergence characteristic of the 8 sellers system is shown in Fig. 3. It is evident that the ABC algorithm demonstrates its superiority in computational complexity, success rate and solution quality than the PSO and GA methods.

Table 4. Eight sellers test systems

No. of Units	Lower Limit (MW)	Upper Limit (MW)	*a*	*b*	*c*
1	20	100	100	7.92	-0.001562
2	20	100	100	7.92	-0.001562
3	20	100	100	7.92	-0.001562
4	20	100	100	7.92	-0.001562
5	20	100	100	7.92	-0.001562
6	20	100	100	7.92	-0.001562
7	20	100	100	7.92	-0.001562
8	20	100	100	7.92	-0.001562

Table 5. Sellers contracted demands for scenario 2

No. of Units	DE	GA	PSO	ABC
1	70	73.8277	79.7162	80.1617
2	20	22.2154	34.272	36.6219
3	20	20.2511	21.0291	20.0000
4	20	21.9288	40.2873	42.8943
5	100	97.8273	23.1872	20.0000
6	20	21.2761	97.2812	100.0000
7	100	94.8262	82.1092	79.6176
8	100	99.2983	71.2653	70.7045

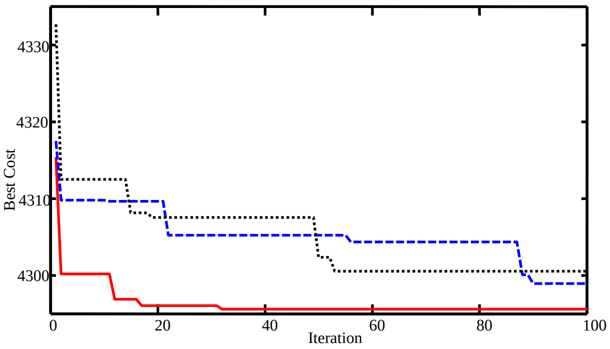

Figure 3. Converge characteristics of eight sellers system; ABC (solid), PSO (dashed) and GA (dotted)

Table 6. Results for eight sellers test systems

Method	timer	Cost
DE [9]	31.75	4306.98
GA	9.71	4301.28
PSO	7.83	4298.63
ABC	5.65	4290.62

V. CONCLUSIONS

In this paper, the ABC optimization technique has been successfully applied for the solution of action based economic dispatch problem in the restructured power systems. The ABC has fewer control parameters and is easy to implement without additional computational complexity. Thus, the convergence precision and speed are remarkably enhanced and therefore the high precision and efficiency are satisfied. The comparable studied that of the recent reported algorithms show the robustness of the proposed ABC algorithm and their capability to provide superior quality solution, high computation efficacy and better convergence characteristics. The results obtained for two test systems were always better that the earlier best reported results. From these comparative studies, it is evident that the ABC can be effectively used for the solution of action based economic dispatch problems in the real world restructured power systems.

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BIOGRAPHIES

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