Optimal Bidding Strategies using New Aggregated Demand Model with Particle Swarm Optimization Technique

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ABSTRACT

In this paper, Particle Swarm optimization(PSO) and Artificial Bee Colony (ABC) algorithms are used to determine the optimal bidding strategy in competitive auction market implementation. The deregulated power industry meets the challenges of increase their profits and also minimize the associadted risks of the system. The market includes generating companies(Gencos) and large Consumers. The demand prediction of the system has been determined by the neural network, which is trained by using the previous day demand dataset, the training process is achieved by the back propagation algorithm. The fitness of the system compared with PSO and ABC technique, the maximized fitness is the optimal bidding strategy of the system . The results for two techniques will be analyzed in this paper. The implementation of the two techniques could be implemented in the MATLAB Platform.

Keywords*:* Neural Network (NN), Bidding Strategy,Market Clearing Price (MCP),Artificial Bee Colony algorithm (ABC), Fittness, Particle Swarm Optimization (PSO).

1. INTRODUCTION

The deregulation of the power industry across the world has greatly increased market competition by reforming the traditionally integrated power utility into a competitive electricity market, which essentially consists of the day-ahead energy market, real-time energy market and ancillary services market, The market operation in a deregulated power market is explained in [3][7]. Therefore, in a deregulated environment, GENCOs faced with the problem of optimally allocating their generation capacities to different markets for profit maximization purposes. Moreover, the GENCOs have greater risks than before because of the significant price volatility in the spot energy market introduced by deregulation. However, the electricity market is more akin to an oligopoly market and GENCOs may achieve benefits by bidding at a price higher than their marginal cost. Therefore, developing an optimal bidding strategy is essential for achieving the maximum profit and has become a major concern for GENCOshence have been extensively studied [12][13][14] [15]. Usually, developing optimal bidding strategies is based on the GENCO's own costs, anticipation of other participants' bidding behaviors and power systems' operation constraints. The PoolCo model is a widely employed electricity market model. In this model, GENCOs develop optimal bidding strategies, which consist of sets of price–production pairs. The ISO implements the market clearing procedure and sets the MCP (Market Clearing Price)[10]. Theoretically, GENCOs should bid at their marginal cost to achieve profit maximization.

Identifying the potential for the abuse of market power is another main objective is investigating bidding strategies. Regardless of market design, the generator's self-scheduling problem is complicated by several factors [8], in particular, the presence of multiple markets, market design rules, and non-convexity of cost curves, inter-temporal constraints, and price uncertainty. For bidders with relatively low generation cost units, it is not difficult to build bids to make sure that the units can be dispatched at each hour, since they are competitive. However, for a bidder with a marginal or near marginal unit, if the unit cannot be dispatched in one or more hours in the day-ahead market, three alternatives have to be considered. The first is to shut off and cool down the unit. The second is to shut off the unit but keep it in banking, and the third is to build the bid for each of these hours to make sure that the unit can be dispatched to supply its minimum stable output and hence remain in continuous operation. The final decision can be determined by using a unit commitment program to account for the unit's operating constraints and start-up costs for the three alternatives and choosing a solution which maximizes total benefits and cost minimization[2].

A producer of power must decide their offer curve and a consumer must decide their bid curve. In addition, the ISO or market maker must clear the market by finding the equilibrium clearing price of the auction based on the submitted bids. Given the importance of the role of day-ahead markets in the generation and allocation of power normative models of the agents have been emerging in the literature over the last decade in the optimal bid construction, unit commitment, and payment /pricing and other decisions in the context of day-ahead markets. Herewith, we give a review of the literature on the various types of optimization modeling of the power producers i.e. those agents that generate and supply power into the market[1].

2. RELATED WORKS

Numerous related research works are already existed in literature which based on optimal bidding strategy for maximize the profits of the generating companies and minimize the associated risks. Some of them reviewed here. J. VijayaKumar et al. [16] have discussed about electricity market, power generating companies and large consumers and they have found that there is a need for suitable bidding models to maximize their profits. Therefore, each supplier and large consumer was chosen the bidding coefficients to counter the competitors bidding strategy. The given paper, bidding strategy problem modeled as an optimization problem and solved using Particle Swarm Optimization (PSO). PSO shared many similarities with evolutionary computation techniques such as Genetic Algorithm (GA). The system was initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. A numerical example with six suppliers and two large consumers were used to illustrate the essential features of the proposed method and the results are compared with the Genetic Algorithm (GA) approach. Test results indicated that the proposed algorithm outperforms the Genetic Algorithm approach with respect to total profit and convergence time.

R. Moreno et al. [17] have discussed about the implementation of auctions of long-term electricity contracts is arising as an alternative to ensure generation investment and therefore achieve a reliable electricity supply. The aim is to reconcile generation adequacy with efficient energy purchase, correct risk allocation among investors and consumers, and the politico-economic environment of the country. In this paper, a generic proposal for a long-term electricity contracts approach is made, including practical design concepts for implemented. This proposal is empirically derived from the auctions implemented in Brazil and Chile during the last 6 years. The study is focused on practices and lessons which are especially useful for regulators and policy makers that want to facilitate the financing of new desirable power plants in risky environments and also efficiently allocate supply contracts among investors at competitive prices. Although this mechanism is generally seen as a significant improvement in market regulation, there are questions and concerns on auction performance that required careful design and which are identified in this paper. In addition, the experiences and proposal described can serve to derive further mechanisms in order to promote the entrance of particular generation technologies, e.g. renewable, in the developed world and therefore achieve a clean electricity supply.

Reinhard Haas et al. [18] have discussed about the core objective of this paper is to elaborate on historically implemented promotion strategies of renewable energy sources and the associated deployment within the European electricity market. Hence, at a first glance, the historic development of renewable energy sources in the electricity (RES-E) sector is addressed on Member State and on sectoral level as well as consequently discussed according to available RES-E potentials and costs. The specified focus of this paper, are promotion strategies for RES-E options as they are the key driver of an efficient and effective RES-E deployment. Therefore, the paper depicts the main types of different promotion schemes and their properties. Additionally, several cases studies of different European Member States show an in-depth analysis of the different RES-E promotion schemes. In this context, special emphasizes are put on the question of effective and efficient promotion scheme designs of different RES-E technologies. Generally, conducted research led to the conclusion, that technology specific financial support measures of RES-E performed much more effective and efficient than others did. Hence, it is not all about the common question of feed-in tariffs vs. quota systems based on tradable green certificates, but more about the design criteria of implemented RES-E support schemes.

FatemehSarkhosh et al [19] have proposed a wind generation is currently undergoing the fastest growth rate for electricity generation in the world. Integration of wind power into electricity systems has been some problem due to volatility and intermittency of wind so it is profitable to integrate the energy storage system with wind generators to reduce the uncertainty of wind generation. As a proven storage technology, pumped- storage may provide/absorb additional capacity so as to hedge against adverse situations. Generation companies which have been large scales of wind units will not be price-takers anymore. They should actively bid into the market and be price-makers. This paper investigated the optimal participation of wind energy as a price-maker in a day-ahead electricity market. On the other hand, profit maximization of power companies are highly related to their bidding strategies. In this paper, a game-theoretical model has been used for bidding strategy of a generation company considering wind unit as a price-maker, in a day-ahead electricity market. Meanwhile optimization of the proposed model has been done by genetic algorithm. The experimental results show that the proposed method is both satisfactory and consistent with expectation.

Reza Ghodsi et al. [20] have discussed about important to forecast electricity price in a deregulated electricity market for choosing the bidding strategy, and it is the most important signal for other players. It engulfs information for both customers and producers in order to maximize their profit. Thus, choosing the best method of price forecasting is a crucial task to have the most accurate forecast. In this paper the price forecasting is done based on different methods including autoregressive integrated moving average (ARIMA), artificial neural network (ANN) and fuzzy regression. The method was examined by using data of Ontario electricity market. The results of different methods are compared and the best method is chosen. Fuzzy regression model was a new method in forecasting and it is rare in the literature review; it is shown that it leads to the best results.

The proposed work intends to rectify all the aforesaid drawbacks in an efficient way so that the optimal bidding strategies, which could be developed, will be proficient. As the lack of precise aggregation model seems to be the primary drawback, I have intended to propose a generalized aggregated model, which considers not only demand aggregation but also the competitors' pricing models and the precise rise in demand. Based on the aggregated model, optimal bidding strategies will be developed for such a deregulated market. In order to develop such bidding strategies, recent advancements in soft computing methodologies will be incorporated. Such defined strategies will satisfy the criteria such as maximizing profit levels, meeting the demand levels and at minimum pricing levels. The proposed model and the strategies will be implemented in MATLAB and the performance will be studied under various demand environments.

3. PROBLEM FORMULATION

The power system generating companies and large consumers need a suitable bidding model to maximize their profits but at the same time to minimize the associated risks. Instead of this the demand of the system must be satisfied. Suppliers should bid slightly higher at their marginal production cost, it depends on the market behaviors, competitors and technical constraints. In this proposed system consider p number of generators network is controlled by the ISO and contains a q number of large consumers, who participates the demand side bidding. The supplier and the consumers should require to bid a linear non decreasing supply and non increasing demand curve to a power exchange. The optimum linear supply curve and the linear demand curve are described in the following equations (1) and (2) respectively.

$$S_i(P_i) = a_i + b_i P_i \tag{1}$$

For large consumers linear demand curve is

$$D_j(L_j) = c_j - d_j L_j \tag{2}$$

Where, $i = 1,2 \ldots p$ and $j = 1,2 \ldots q$, P_i is the active power output of the i^{th} generation unit, a_i and b_i is the bidding coefficients of the i^{th} supplier, c_j and d_j is the bidding coefficients of the j^{th} large consumer and L_j is an active power load of the j^{th} large consumer, a_i, b_i, c_j and d_j is positive values. The power exchange of the system is mainly considers the generation, demand dispatch and schedule that meets the constraints to maximizing the bribe. In addition, when the power generation suppliers and large consumers bid linear supply and demand functions and the network constraints are ignored, maximizing payoff leads to a uniform market clearing price for all suppliers and consumers. Thus when only the constraints like, generation output, load flow and customer demand are considered. Power exchange finds the set of generation outputs $P = (P_1, P_2 \ldots P_p)^T$ and large consumer demand $L = (L_1, L_2 \ldots L_q)^T$. The following function is used to determine the power generation outputs.

$$\sum_{i=1}^{p} P_i = Q(R) + \sum_{j=1}^{q} L_j \tag{3}$$

Where, P_i is the active power output of the i^{th} generation unit, $Q(R)$ is the aggregate a pool load forecast, L_j is an active power load of the j^{th} large consumer. The consideration of the constraints is given by the following,

$$P_{\min,\, i} \le P_i \le P_{\max,\, i} \quad i = 1,2,3 \ldots p \tag{4}$$

$$L_{\min,\, j} \le L_j \le L_{\max,\, j} \quad j = 1,2,3 \ldots q \tag{5}$$

$P_{\min,\, i}$ & $P_{\max,\, i}$ are the generator output limits of the i^{th} supplier, $L_{\min,\, j}$ & $L_{\max,\, j}$ are the demand limits of the j^{th} large consumer. The optimum bidding strategy objective function of the proposed method is given by the following section 3.1.

3.1. DETERMINATION OF OBJECTIVE FUNCTION

The proposed method used to generation companies and the large consumers are optimally bidding the cost. The objective is should maximize the profit of both the suppliers and the supplier and the consumers and also minimize the associated risks of the system. These functions are must satisfy the demand of the system. The maximization of the objective for building a bidding strategy can be described as the following equation (6).

$$Max\ \ F = F(a_i, b_i) = RP_i - C_i(P_i) \qquad (6)$$

Where, $C_i(P_i) = e_i P_i + f_i P_i^2$ is the production cost function of the i^{th} supplier, e_i and f_i are the cost coefficients of the i^{th} supplier. The objective is to determine a_i and b_i so as to maximize $F(a_i, b_i)$ subject to the constraints (1) to (5). Similarly the consumers have the revenue function, the maximization of the objective for building a bidding strategy can be described as the following equation (7).

$$Max\ \ B = B(c_j, d_j) = B_j(L_j) - R_j L_j \qquad (7)$$

Where, $B_j(L_j) = g_j L_j - h_j L_j^2$ is the demand function of the j^{th} large consumer, g_j and h_j are the demand coefficients of the j^{th} large consumer. The objective is to determine c_j and d_j so as to maximize $B(c_j, d_j)$ subject to the constraints (1) to (5). The fitness of the bidding strategy function is calculated by the following section 3.2.

3.2. FITNESS CALCULATION

The maximization of the fitness should provide the optimum bidding strategy of the power system. Both the suppliers and the large consumers bidding strategy are the difficult to make the optimum outputs. Then the fitness function is introduced in the proposed technique, it is the average function of the suppliers and the large consumers bidding strategy. Thus the fitness function is given in the following equation (8).

$$Fitness = \frac{1}{2} * (Max\ \ F + Max\ \ B) \qquad (8)$$

The fitness of the bidding strategy ids calculated using the above equation (8). The other values like the aggregate load forecast $(Q(R))$, power generation (P_i), demand of the large consumer (L_j) and the Market clearing price (R), are used in the equation (1) to (7). These values are determined by the following equations (9), (10), (11) and (12). The expression of the aggregate load forecast $(Q(R))$ is given in the linear form, that is given by.

$$Q(R) = Q_o - KR \qquad (9)$$

Where, Q_o is the constant number, K is a coefficient denoting the price elasticity of the aggregate demand. If pool demand is largely inelastic, then $K = 0$. If the inequality constraints are ignored, the formulation of the power generation (P_i), demand of the large consumer (L_j) and the Market clearing price (R) are given by.

$$P_i = \frac{R - a_i}{b_i} \qquad i = 1,2,3 \ldots p \qquad (10)$$

$$L_j = \frac{c_j - R}{b_j} \qquad i = 1,2,3 \ldots q \qquad (11)$$

$$R = \frac{Q_o + \sum_{i=1}^{p} \frac{a_i}{b_i} + \sum_{j=1}^{q} \frac{c_j}{d_j}}{K + \sum_{i=1}^{p} \frac{1}{b_i} + \sum_{j=1}^{q} \frac{1}{d_j}} \qquad (12)$$

Where, R is the market clearing price, the above equations (10), (11) and (12) violates the generation and consumer demand limits (4) and (5) , it must be customized to accommodate these constraints. In a sealed bid auction based electricity market means, there is no need to solve the equations (6) and (7). The fitness function is used for the ABC algorithm, depending on the fitness function the best value can be calculated. The hybrid technique using PSO at the third step of the ABC algorithm. The large consumer demand has been given by the NN. It is trained with the datasets of the generating units on the bus system. The detailed explanation of the proposed hybrid technique is given in the following section 3.3.

3.3. FORMATION OF THE PARTICLE SWARM OPTIMIZATION (P.S.O.) METHOD

The proposed PSO is used for the determination of the best fitness, it could be a maximized value. Here the ABC algorithm is used to determine the best fitness of the system, in this the third stage of the ABC uses the PSO method. The proposed method is implemented in two ways, i.e., demand predicting and the optimum bidding strategy determination. The first stage of the proposed method predicting the demands of the system using the Neural Network (NN), it trained with the historical data i.e.,the previous year demand. It produces the demand of the system. Then the next step is the determination of the best fitness using the ABC and the PSO method.

4. DEMAND PREDICTION USING NN

The first stage of the proposed method is demand prediction, this can be done by the NN technique. The NN consists of three layers like, input layer, hidden layer and output layer, which is trained with the historical datasets, i.e., the previous year demand dataset. The dataset consists of the demand variation for every period, which is used for the training of the NN. The demand of each period is varying according to the load, so it generates the exponential output of the demand. The training process of the NN is done by the back propagation algorithm, it is given by the following.

TRAINING PROCESS

Step 1: Initialize all the values like input, output and weight of the neuron.

Step 2: Determine the BP error of the input dataset T .

$$E_{BP} = D_{\exp}{}^{NN}{}_{T} - D_{\exp}{}^{NN}{}_{out} \tag{13}$$

Where, $D_{\exp}{}^{NN}{}_{T}$ is the target demand of the system, $D_{\exp}{}^{NN}{}_{out}$ is the actual output demand.

Step 3: Evaluate the output demand of the system using the following relation.

$$D_{\exp}{}^{NN}{}_{out} = \sum_{n=1}^{N} w_{2n1} D_{\exp}{}^{NN}(n) \tag{14}$$

Where,

$$D_{\exp}{}^{NN}(n) = \frac{1}{[1 + e^{(-w_{1n}e(n) - w_{2n}\Delta e)}]}$$

The above equations are represented the output layer and hidden layer activation functions respectively.

Step 4: To determine the new weight of all the neurons using the following relation.

$$w_{new} = w_{old} + \Delta w \tag{15}$$

Where, Δw is the change in weight,The change in weight can be determined by the following relation, $\Delta w = \xi D_{\exp}{}^{NN} E_{BP}$, ξ is the learning rate which is ranging from 1/5 to 1/2.

Step5: To determine the minimized E_{BP} value. This process will be repeated from step 2, until gets the least error value.

$$10\, E_{BP} < 1 \tag{16}$$

Once the process is completed, the network is well trained and give the demand of the system. The predicted demand is used for the evaluation of the optimal bidding strategy. The second stage of the proposed technique is to determine the best fitness values.

5. OPTIMUM BIDDING STRATEGY DETERMINATION USING PSO TECHNIQUE

The ABC algorithm is used in the best fitness solutions, the final stage of the ABC algorithm uses the PSO technique. Artificial Bee Colony (ABC) is one of the most recently defined algorithms by Dervis Karaboga in 2005, motivated by the intelligent behavior of honey bees. It is as simple as Particle Swarm Optimization (PSO) and Differential Evolution (DE) algorithms, and uses only common control parameters such as colony size and maximum cycle number. The ABC algorithm mainly considers the three processes of bees, like employee bee, onlooker bee and scout bee. The employee bee is searching best fitness of the given process, onlooker bee check the conditions produce the solutions for the process and finally the results do not satisfy the constraints,it could be given to the scout bee. It is an optional process, if the second process doesn't satisfy the limits, that is used to produce the random solutions of the given process.

The particle swarm optimization (PSO) algorithm is first present by Dr. Kennedy and Dr. Eberhart, and is a random evolution method based on intelligent search of the group birds. It has quick convergence speed and optimal searching ability for solving large-scale optimization problems. Here it is used for the scout bee stage of the ABC algorithm and it is used to find the random generation of optimum fitness values. This value is used for the onlooker bee iterations. The procedure for the ABC algorithm and the PSO is given in the following section.

PROCEDURE

The main steps of the ABC algorithm are as below:

1: Initialize Population

2: repeat

3: Place the 3 employed bees on their food sources

4: Place the onlooker bees on the food sources depending on their nectar amounts

5: Send the scouts to the search area for discovering new food sources

6: Memorize the best food source found so far

7: until requirements are met

The Main steps of the PSO algorithm are given below:

1: Initialize Population

2: repeat

3: Calculate fitness values of particles

4: Modify the best particles in the swarm

5: Choose the best particle

6: Calculate the velocities of particles

7: Update the particle positions

8: until requirements are met

Particles’ velocities on each dimension are clamped to a maximum velocity Vmax. If the sum of accelerations would cause the velocity on that dimension to exceed Vmax, which is a parameter specified by the user, then the velocity on that dimension is limited to Vmax.

- Produce the new solutions for the problem (food positions) in the onlooker bee.

  $$V_{i,j} = m_{i,j} + \Phi_{i.j}(m_{i,j} - m_{k,j})$$

  Where, k is the solution the neighborhood of i and Φ is a random number in the range [-1,1], $V_{i,j}$ is the neighborhood solution of $M_{i,j}$.

- Apply the fitness function for the new food positions or the new solutions, the selected best value depends on the following conditions.
- If the neighborhood solution $E_{i,j}$ is greater or most fit value compare to the initial $M_{i,j}$ value means, it has replaced the best fitness value.
- If the neighborhood solution $E_{i,j}$ is not a fittest value compare to the $M_{i,j}$ value means, it has replaced the best fitness va

The best fitness values are not satisfied for the constraints means go to the next step .

The scout bee has used the PSO technique, which generates the random solutions and it fixed the initial velocity is zero.

6. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this technique mainly to increase the profit of the suppliers, while satisfying the demands. Also minimize the associated risks of the system, this can be done by the optimal bidding strategy. The demand prediction of the proposed method is done by the NN technique, this could be produce the demand of the system using the historical data analysis. The third stage of the ABC technique uses the PSO method, it is used for the random numbers of solution generation. The optimum bidding for every demand is calculated and the performance of each method are analyzed in this section. The standard IEEE 30 bus system optimum bidding strategy was determined by the various techniques like ABC technique & PSO method are given in the following tables. The standard IEEE 30 bus system is given in the following figure. 1.

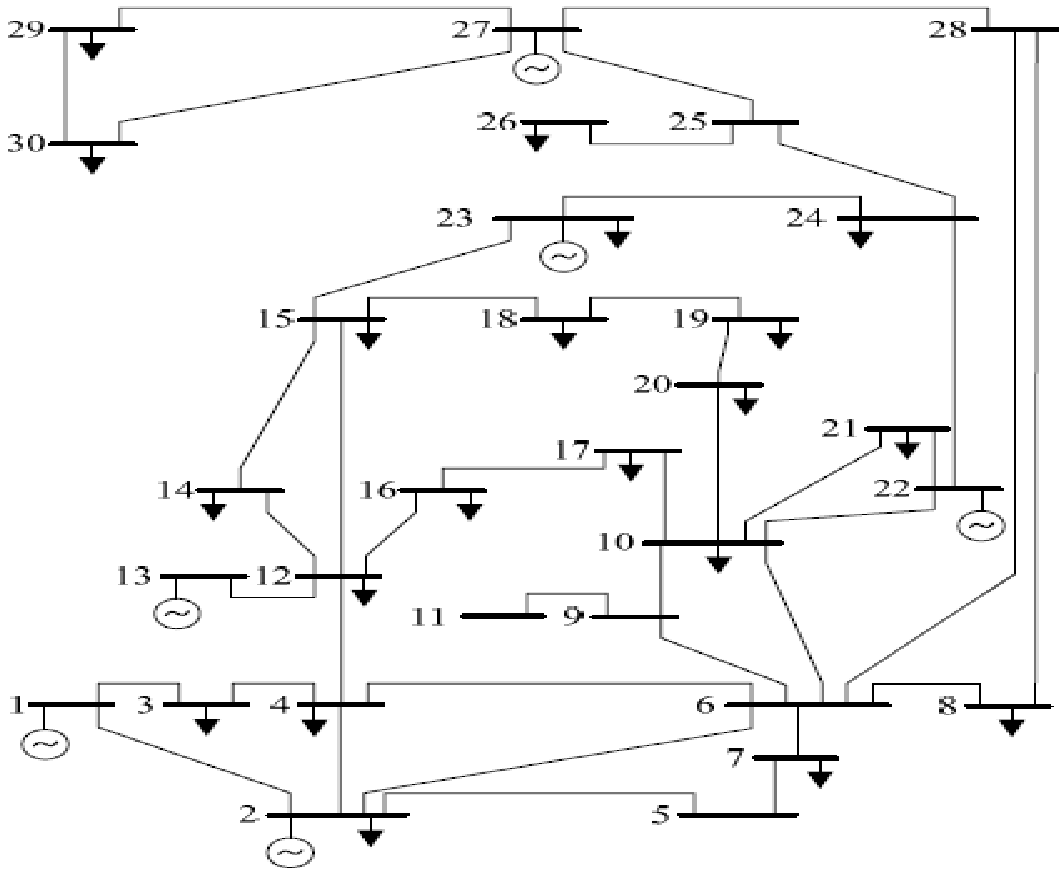

Figure 1: Structure of the IEEE 30 bus system

The figure.1 illustrates tested IEEE 30 bus system structure, this system consists of six generators. The forecasted load and best fitness evaluations for ABC technique & PSO method given in the following tables 1,2 and 3.

TABLE 1: FORECASTED LOAD WITH ABC METHOD

S.No	Generator1	Generator2	Generator3	Generator4	Generator5	Generator6
1	120.3171	81.1629	110	82.8354	81.9100	86.0000
2	32.0119	35.5077	24	27.9050	55.4025	46.0000
3	25.9671	21.4041	23	25.4937	21.0965	23.5000
4	16.1408	15.9263	13	17.7532	12.8340	24.0000
5	25.2368	26.4850	13	18.7405	17.6390	17.5000
6	19.6224	26.9562	18	25.2595	18.6805	16.5000

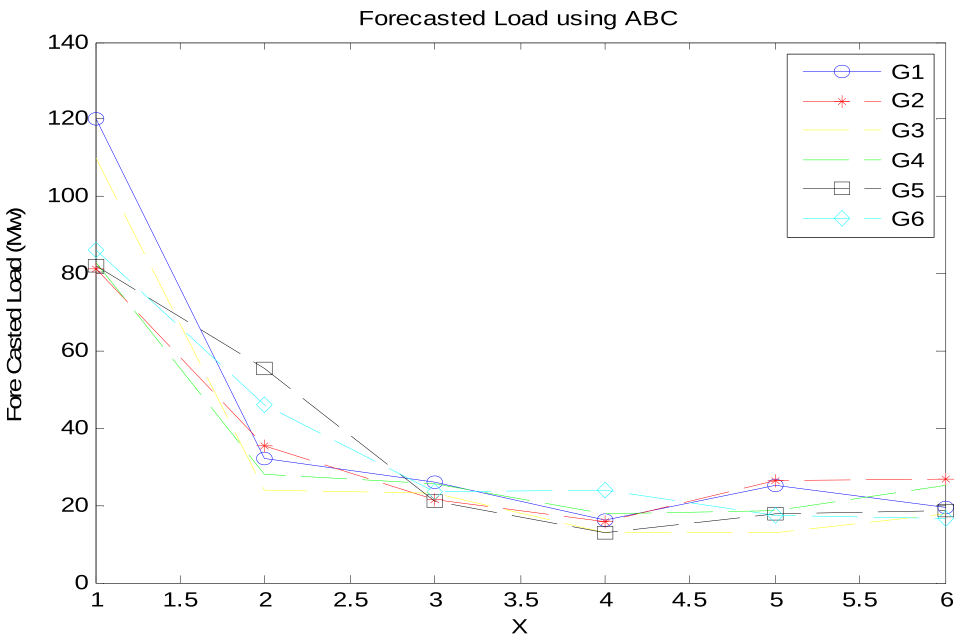

Figure 2: Plot of Forecasted Load with ABC method.

TABLE 2: FORECASTED LOAD WITH PSO METHOD

S.No	Generator1	Generator2	Generator3	Generator4	Generator5	Generator6
1	90	31	92	57	64	134
2	18	8	9	22	20	23
3	25	11	21	25	21	13
4	3	2	10	8	30	1
5	24	12	1	30	23	1
6	5	9	6	0	13	21

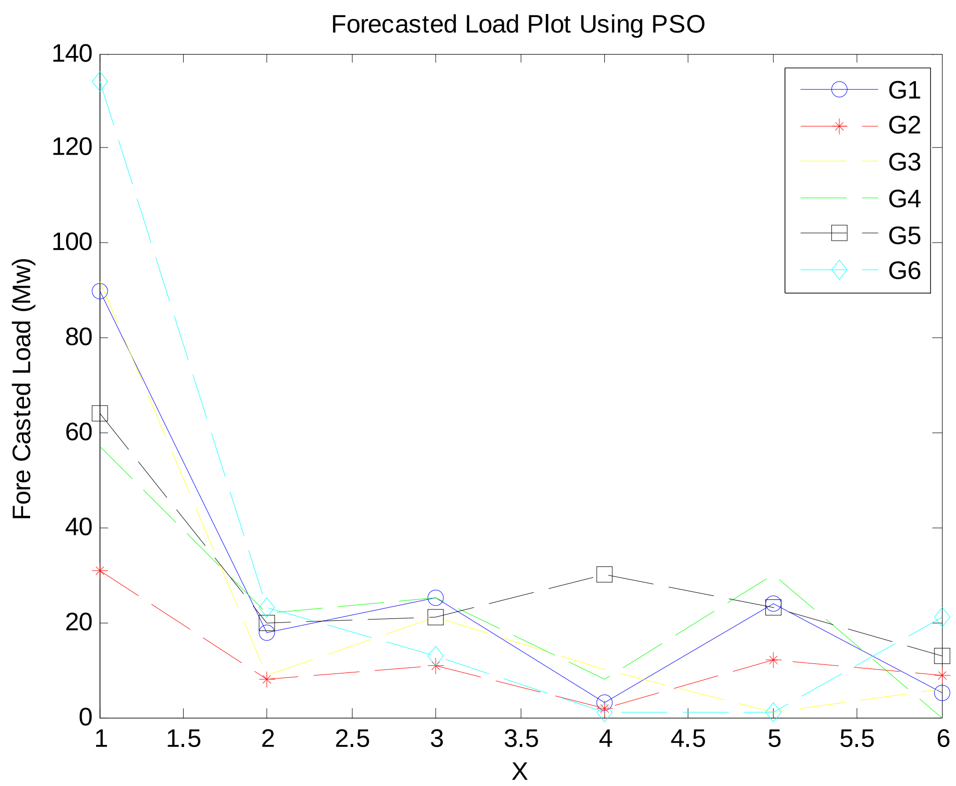

Figure 3: Plot of Forecasted Load with PSO method.

TABLE.3. COMPARISON OF FITNESS VALUES

Generator No.	ABC technique best fitness	PSO method best fitness
Generator 1	880.4932	918.5324
Generator 2	287.9744	345.8604
Generator 3	1429.9	1468.3
Generator 4	2171.3	2213.2
Generator 5	2625.0	2648.3
Generator 6	2755.8	2827.6

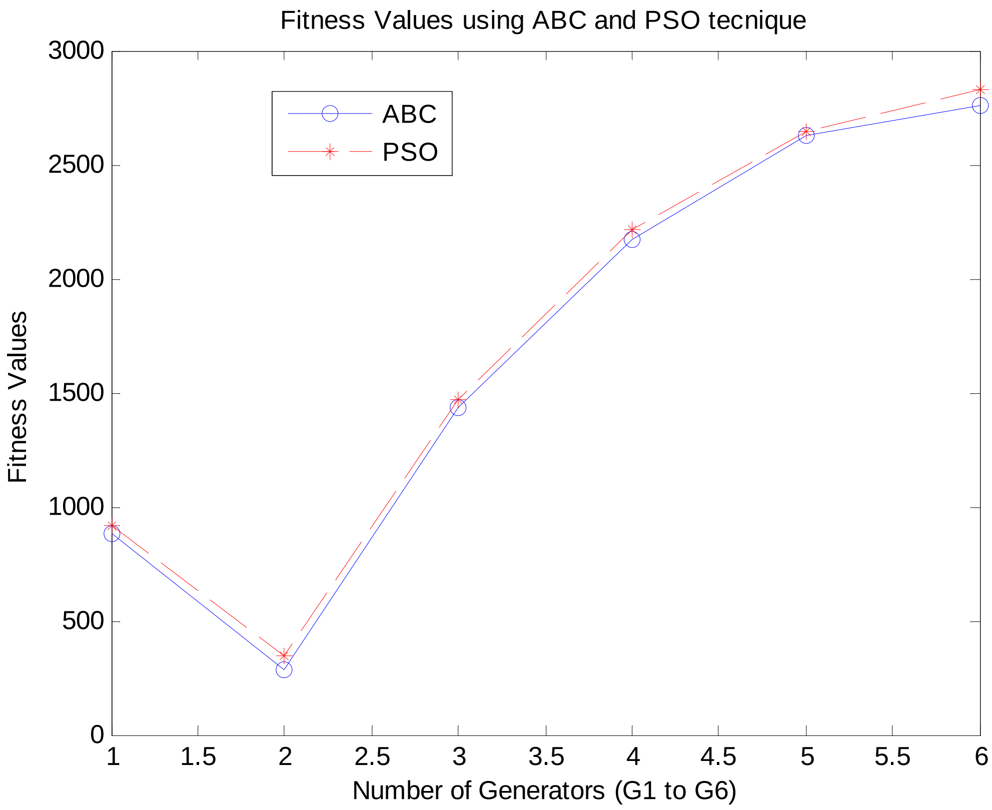

Figure. 4: Comparison of best fitness

The above table 3 shows the best fitness evaluations of the IEEE 30 bus system using the ABC technique and PSO method respectively. The best fitness for each method comparison is illustrated in the table.3. During the operation time, the optimum bidding strategy using the ABC algorithm with the following fitness values, 880.4932, 287.9744, 1429.9, 2171.3, 2625.0 and 2755.8 while the generators are on condition. The PSO method for using the evaluation of the best fitness values are 918.5324, 345.8604, 1468.3, 2213.2, 2648.3 and 2827.6. The fitness values are improved by using the proposed PSO technique. The final stage of the ABC algorithm uses the PSO method, it could be generate the random number of solutions. The maximized values of the fitness has been selected for the best fitness. The comparison of the best fitness value is analyzed using the graph, it is given in the following figure.4.

The comparison of the best fitness for ABC algorithm and proposed PSO technique is graphically analyzed in the figure.4. It illustrates the performance of the two methods and shows the best method among the two methods. The x axis denotes the generated values of the six generators in MW and y axis denotes the fitness values. The figure shows that the proposed PSO method is the best method to evaluate the optimum bidding strategy.

CONCLUSION

The development of optimal bidding strategies using the new aggregated demand model and the PSO technique was discussed in this paper. Here the proposed method is used to maximize the profit of the suppliers, while satisfying the demand and to minimize the associated risks of the system. The demand of the system was predicted by the NN technique, which is used to the PSO method. ABC method consists of employee bee, onlooker bee and scout bee. The final stage of the ABC algorithm i.e., scout bee, uses the PSO technique, which produces the random number of solutions of the problem. The output of the proposed system is the maximized fitness value. These two techniques fitness results were tabulated and compared to each other. The comparative results proved that the proposed technique contains the maximized fitness values which are competent over the other techniques.

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