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DEVELOPMENT OF OPTIMAL BIDDING STRATEGIES USING NEW AGGREGATED DEMAND MODEL AND HYBRID TECHNIQUE

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ABSTRACT

The deregulated power industry meets the challenges of increase their profits and also minimize the associated risks of the system. Instead of this the demand of the system must be satisfied. This can be done by the optimum bidding strategies of the generating companies and the large consumers. Here we proposed a new hybrid technique with an aggregate demand model to develop the optimum bidding strategies. The demand prediction of the system has been determined by the Neural Network, which is trained by using the previous year demand dataset. The training process is achieved by the back propagation algorithm. The proposed hybrid technique is the combination of the Artificial Bee Colony (ABC) algorithm and Particle Swarm Optimization (PSO) method. The ABC algorithm has three stages like employee bee, onlooker bee and scout bee. The third stage of the ABC algorithm i.e., the scout bee, uses the PSO technique. This could improve the fitness of the system, the maximized fitness is the optimal bidding strategy of the system. The other techniques like ABC and PSO fitness results also will be evaluated. The results for all the three techniques will be analyzed in this paper. The implementation of the proposed technique could be implemented in the MATLAB platform.

Keywords: *Neural Network (NN), Artificial Bee Colony Algorithm (ABC), Particle Swarm Optimization (PSO), Hybrid Technique.*

1. INTRODUCTION

The restructuring 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-

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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].

[4] , [5] Optimal bidding strategies for competitive suppliers in a day-ahead energy market is addressed with consists of each supplier bids 24 linear energy supply functions, one for each hour into the day-ahead energy market and used two different bidding schemes with an objective of maximizing total benefits and example with six suppliers has been used to demonstrate the feasibility and efficiency of the method using GA.

[11] , [6] in this paper similar to [4] stepwise bidding protocols are used and solved by monte carlo method with five generation companies in a power market used.

2. 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.

$$S_i(P_i) = a_i + b_i P_i \qquad (1)$$

For large consumers linear demand curve is

$$D_j(L_j) = c_j - d_j L_j \qquad (2)$$

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.

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

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

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the j^{th} large consumer. The consideration of the constraints is given by the following,

$$P_{\min,i} \le P_i \le P_{\max,i} \qquad i = 1,2,3\ldots p$$
(4)

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

$P_{\min,i}$ & $P_{\max,i}$ 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. 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).

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

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

3.1. 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).

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

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

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

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

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.

3.2. Formation Of The Proposed Hybrid Method

The proposed hybrid method is the combination of the ABC algorithm and the PSO method. This technique 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 determination using the ABC and the PSO method. The proposed method demand predicting is given in the next section.3.3.1.

3.3. 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 .

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

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.

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

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.

$$w_{new} = w_{old} + \Delta w \quad (15)$$

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.

$$10 E_{BP} < 1$$

(16)

Once the process is completed, the network is well trained and give the demand of the system. The

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predicted demand is used for the evaluation of the optimal bidding strategy. The second stage of the proposed hybrid technique is to determine the best fitness values, which is briefly given in the next section.3.3.2.

3.3.1. Optimum bidding strategy determination using hybrid technique

Hybrid technique is the combination of the ABC algorithm and the 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 proposed hybrid technique PSO used as the random solution generation. 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

Step 1: Initialize the population of the generating units solutions $M_{i,j}$.

Step 2: Evaluate the populations using the employee bee, it could select the best value for the next iteration. It is the best value, that satisfies the maximized fitness value, it is given by,

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

Step 3: The best fitness values are denoted by $E_{i,j}$.

Step 4: Set the iteration count is one, i.e., *cycle=1*.

Step 5: 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 $M_{i,j}$.

Step 6: 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 value.

The best fitness values are not satisfied for the constraints means go to the next step 7.

Step 7: The scout bee has used the PSO technique, which generates the random solutions and it fixed the initial velocity is zero.

Step 8: Initialize the populations of the modified solutions $E_{i,j}$.

Step 9: Generate the random solutions, i.e., update the particle positions using the following equation.

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$$V_{id}^{k+1} = wV_{id}^{k} + C_1 rand*(Pbest_{id} - S_{id}^{k}) + C_2 rand*(Gbest_{id} - S_{id}^{k})$$
(11)

Current position can be modified by

$$S_{id}^{k} = S_{id}^{k} + V_{id}^{k+1}, i = 1,2,\ldots n \text{ and } d = 1,2,\ldots m.$$
(12)

Where, S^k is the current searching point, S^{k+1} is modified searching point, V^k is the current velocity, V^{k+1} is modified velocity, n is the number of particles in a group, m is the number of members in a group, w_i is the weight function for the velocity of the agent i. The weight function is given in the equation.

$$w_i = w_{\max} - \frac{w_{\max} - w_{\min}}{F_{\max}} * F \qquad (13)$$

Step 10: Then the value is given to the step 2, the process continues until the maximized value obtained.

Once the process has completed, the network is ready to produce the optimum bidding strategy of the system. The operation of the proposed method flow chart is given in the following figure.1.

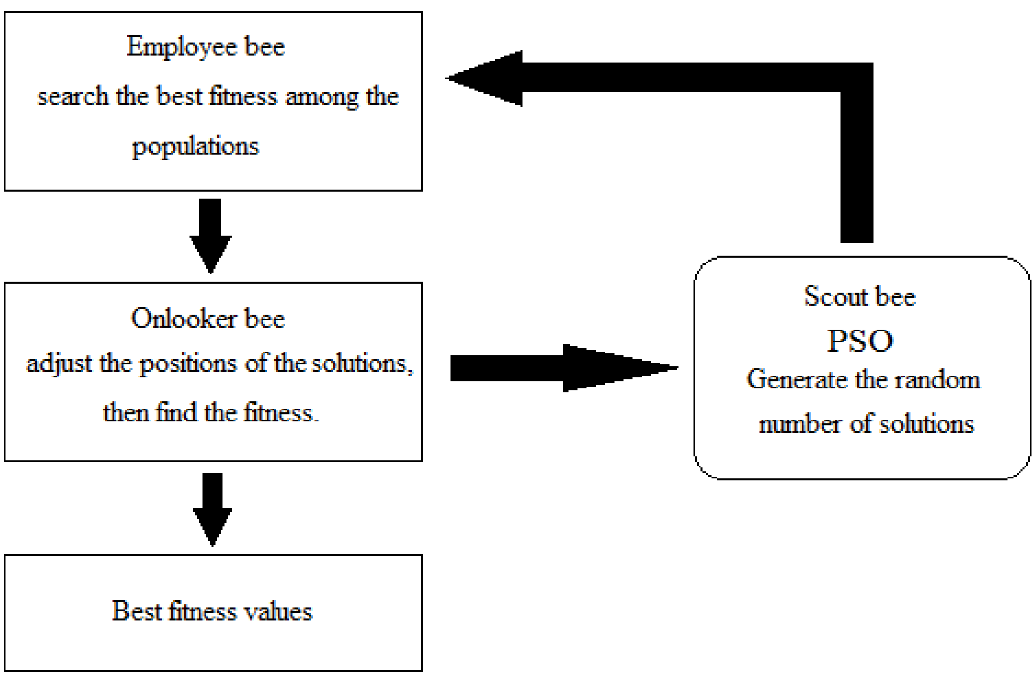

Figure .1. Flowchart of the proposed hybrid method

The above figure.1. shows the working of the proposed hybrid method, in which the best fitness for the appropriate demand is determined. The performance of the all the three methods such that proposed hybrid method, ABC technique and PSO are analyzed using the MATLAB platform. The corresponding results are tabulated and the graphical representation of the proposed system is given in the next section.4.

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4. EXPERIMENTAL RESULTS AND DISCUSSIONS

The proposed hybrid method was implemented in MATLAB platform. 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 proposed technique is the combination of the ABC and the PSO technique. 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 and the proposed methods are given in the following tables. The standard IEEE 30 bus system is given in the following figure. 2.

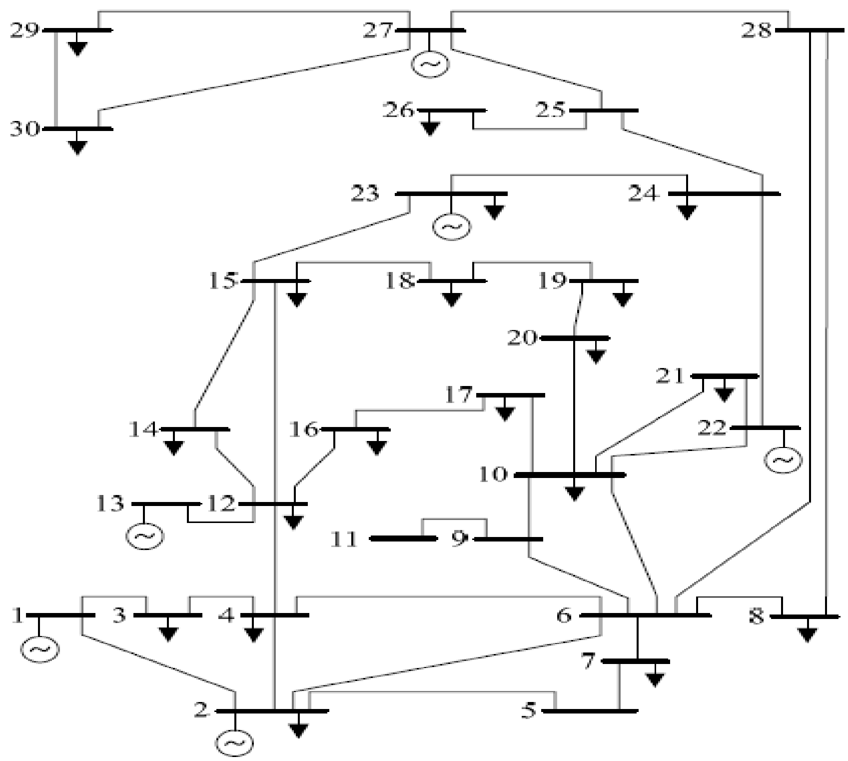

Figure .2. Structure of the IEEE 30 bus system

The figure.2 illustrates tested IEEE 30 bus system structure, this system consists of six generators. The Forecasted Load evaluations for ABC technique,PSO method and Hybrid method is given in the following tables 1,2 and 3.

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TABLE.1. Forecasted Load Values Using ABC Method

S.No	Generator1	Generator2	Generator3	Generator4	Generator5	Generator6
1	91.0000	79.2500	86	94	109.1250	112.0005
2	32.9688	46.2500	27	39	36.6250	49.4932
3	23.6250	22.0000	21	30	31.3750	28.5015
4	26.2188	28.5000	16	23	19.3750	21.5000
5	20.6250	14.7500	18	11	19.0000	16.5012
6	22.4063	23.5000	13	19	21.1250	20.5022

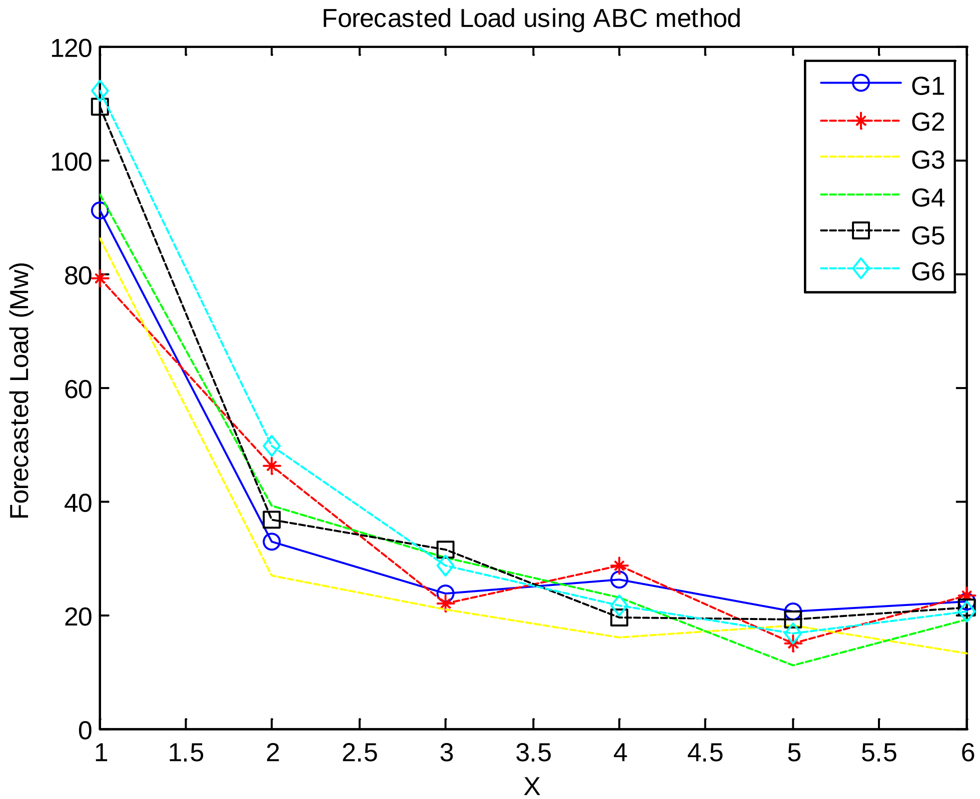

Figure 3: Forecasted Load with ABC method.

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TABLE.2. Forecasted Load Values Using PSO Method

S.No	Generator1	Generator2	Generator3	Generator4	Generator5	Generator6
1	133	107	40	128	133	126
2	7	24	51	22	30	42
3	29	27	19	22	13	29
4	8	18	0	2	1	12
5	2	12	13	20	4	14
6	8	2	2	17	23	7

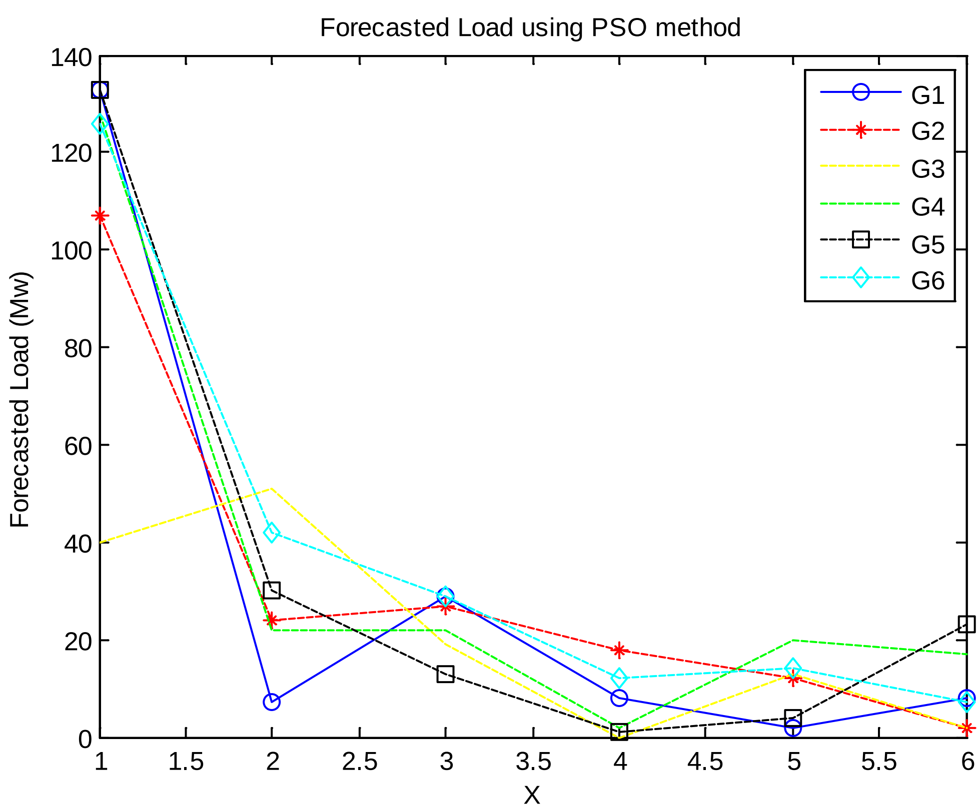

Figure 4: Forecasted Load with PSO method.

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TABLE.3. Forecasted Load and Fitness Values Using ABC_PSO Method

S.No	Generator1	Generator2	Generator3	Generator4	Generator5	Generator6
1	60	94	62	37	16	104
2	12	23	41	1	5	21
3	16	33	36	27	10	22
4	1	29	19	34	8	10
5	1	15	9	12	2	2
6	1	18	12	6	15	3

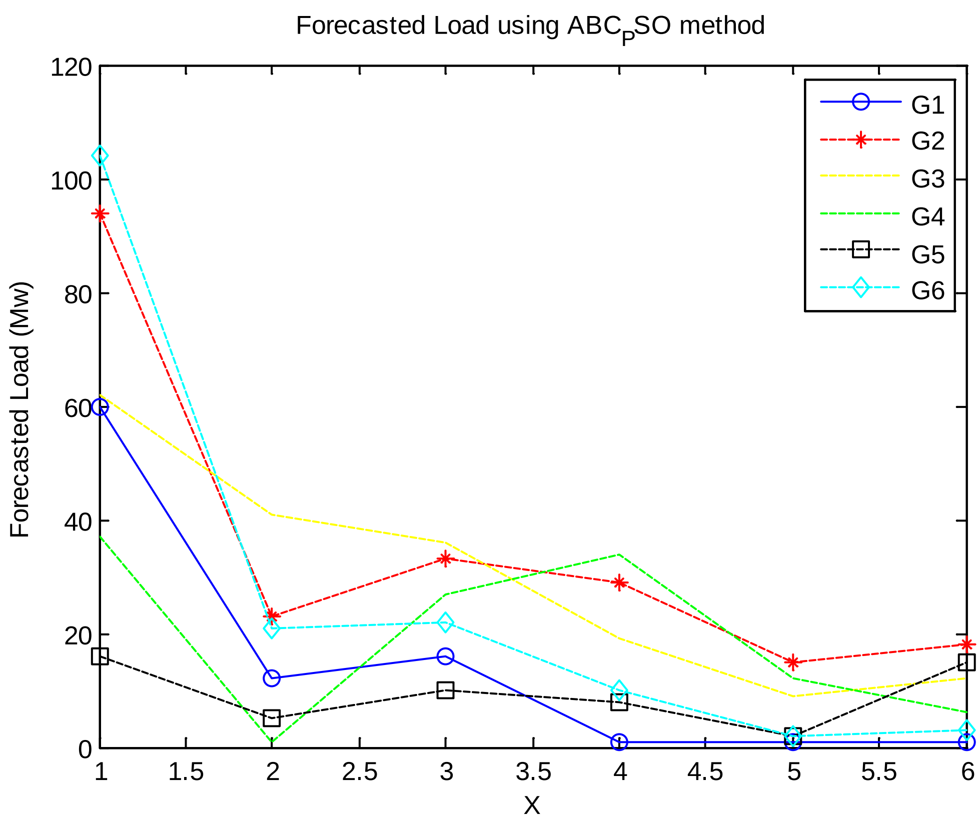

Figure 5: Forecasted Load with ABC_PSO method.

The comparison of the best fitness evaluation of all the techniques were denoted in the following table.4.

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TABLE.4.Comparison of Fitness Values

Gen. No.	ABC technique best fitness	PSO method best fitness	ABC_PSO method best fitness
Generator 1	1247.4	1312.4	1367.6
Generator 2	36.0484	81.1516	25.1191
Generator 3	1376.7	1394.2	1357.5
Generator 4	2266.4	2250.1	2259.2
Generator 5	2737.8	2717.5	2806.1
Generator 6	2792.9	2724.0	2901.1

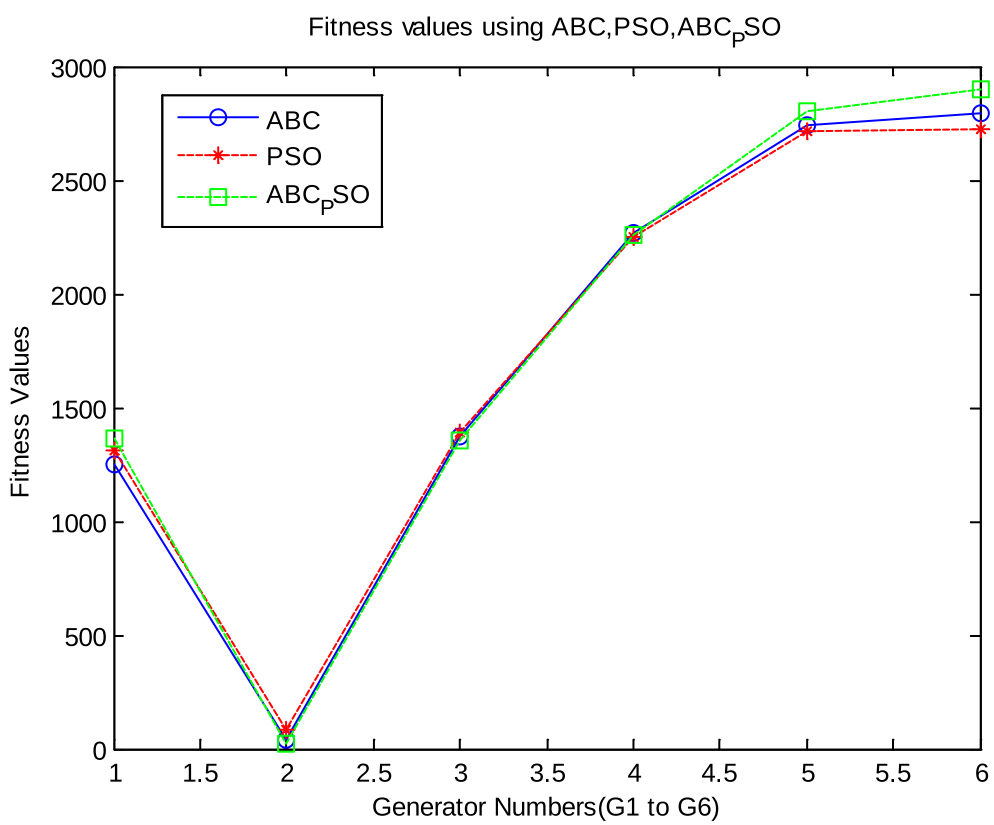

Figure 6: Comparison of best fitness

The above tables 1,2 and 3 shows the load forcasting evaluations of the IEEE 30 bus system using the ABC technique, PSO method and Proposed hybrid method respectively. The best fitness for each method comparison is illustrated in the table.4. During the operation time, the optimum bidding strategy using the ABC algorithm with the following fitness values, 1247.4, 36.0484, 1376.7, 2266.4, 2737.8, 2792.9, while the generators are on condition. The PSO method for using the evaluation of the best fitness values are 1312.4, 81.1516, 1394.2, 2250.1, 2717.5, 2724.0. The fitness values are improved by using the proposed hybrid technique, this is the

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combination of the ABC and the 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 improved values, i.e., optimum bidding strategy values are 1367.6, 25.1191, 1357.5, 2259.2, 2806.1, 2901.1. The comparison of the best fitness value is analyzed using the graph, it is given in the following figure.3.

The comparison of the best fitness for ABC algorithm, PSO method and proposed hybrid technique is graphically analyzed in the figure.3. It illustrates the performance of the three methods and shows the best method among the three 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 hybrid method is the best method to evaluate the optimum bidding strategy.

5. CONCLUSION

The development of optimal bidding strategies using the new aggregated demand model and the hybrid 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 hybrid method. The hybrid model of the proposed system is the combination of the ABC algorithm and the PSO technique. It 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. In this paper also analyzed the optimal bidding strategy output of the other techniques like ABC technique and PSO method separately. These three 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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