Optimizing the Bidding Data for power industry with elastic demand using hybrid Water Cycle Moth Flame Optimization Algorithm

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ABSTRACT

Strategic Optimal Bidding of the data is a compulsory duty for Independent System Operators (ISO) which is the most complicated task that maximizes the profit of the supplier by handling bidding coefficients strategically. This paper endorses a strategy of optimal bidding coefficient data to improve the profit value by the latest optimizing technique named hybrid Water Cycle Moth Flame Optimization Algorithm, which achieves a heuristic search thereby obtaining a global search of a stream using Levy flight movement. This method is applied and tested on an Indian-75 Bus system to test and investigate the new strategy of receiving the best solution of profit in comparison with other conventional techniques explained widely. On adding it evaluates the efficacy of the proposed method on the mentioned system through assessing total profit obtained, revenue, power generation, Market Clearing Price and cost of the individual GENCO. In order to show the Statistical Analysis the Box-plot is done to perform the visual data representation of the proposed and conventional methods.

Keywords: restructured power market, bidding strategy, market clearing price, water cycle algorithm, moth flame optimization, hybrid based water cycle

Abbreviations

GENCO	Generating Company
ISO	Independent System Operator
MO	Market Operator
MCP	Market Clearing Price
GWO	Grey Wolf Optimization
SFLA	Shuffled Frog Leap Algorithm
PSO	Particle Swarm Optimization
WMFO	Hybrid Water Cycle Moth Flame Optimization Algorithm

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1. INTRODUCTION

In the 1990's various countries have elevated the restructuring electricity market from monopoly to an oligopoly for increasing the competition level within the country. Among all, one is pool-co [1] bringing out the concept of the demand and supply in the market. The seller-buyer presents the demand of the energy along with the power generation and price for the GENCO in the auction. If the supply-demand bids are submitted within the tenure period then the ISO ranks the price based on the high cost in buying and low cost in selling. All the GENCO in the system then do pay-the-bid price which is indeed set up by the marginal unit [2]. For a perfectly competitive market the supplier guides the maximum capacity and offers it equal marginal cost. But then the price of the bidding can be more than the marginal cost hence named strategic bidding for a better commercial market. We therefore feature a massive competition within different GENCO in the electrical market using latest optimizing techniques accessible in the market and put on to receive a fruitful response and mollify the demand of the load at bidding auction. The bid data strategy is projected by the statuses of the market from producer-customer view point, constraints with MCP from [3] for the system occupied into contemplation with ample computation of the profit with the various other existing methods.

The bidding data strategy concept started getting the place into the market at [4] from the market monopoly to the competitive one. The bidding strategy is applicable to a widespread or a local power market [5] for the enactment of the producer selling the power in the market using mathematical model format. Bidding data also investigates in a double sided auction using Agent based algorithm [6]. Development of the system from producer side with Distribution system Operator had discussed in [7]. In order to get an idea of the block-chain requirement is explained for the IEEE-14 bus system at [8]. Using the concept of bidding strategy at parking of EV vehicles of hydrogen based using IoT have its detail at [9]. Bidding strategic concept applied for DER in order to consider the flexibility demand presence from [10]. Optimal data bidding for the maximized profit using Whale optimization were introduced at [11]. Action advertising concepts using real-time bidding strategy concepts were explained at [12] for the problem mentioned as Knapsack. Real-time bidding [13] strategies were used for MCP calculation due to application of the proposed techniques. Whale optimization algorithm [14] techniques were used in the latest research paper for best bidding response to obtain the maximized profit. Further research is done on the consumer side also where the system will be elastic market from [15-16] to calculate the maximized profit.

WCA was first discovered by Eskander [17] that deals with the hydraulic cycle involving stream, river towards sea. In the latest paper this technique had been implemented to the over current relay [18] operation and coordination on its system also applied on PV [19] on its system. It is used on a Fractional order PID controller [20] for optimization of the energy and handling various stage evaporators. It was also implemented on a fuzzy controller [21] for stability analysis. WCA is also implemented on IEEE-30 Bus system for the strategic bidding data [22] for an inelastic demand market which also has secured a good fitness value along with good convergence rate. Moth optimization technique had been mainly used for its search characteristics with respect to a fixed angle. Going through the papers using MFO among which [23] modelling the Moth-Flame Optimization demonstrates five objective functions to solve OPF problems. Simulations on IEEE-30 bus system to recognize effectiveness of the proposed method. [24] Explains the information in details about the levy flight that helps in the exploration and exploitation phase of MFO. MFO being quite a suitable one for solving multiple peaks of PV-systems said in brief in [25]. Performance analysis of MFO for the AGC system explained in [26].The WCMFO optimized techniques help to solve the exploration and exploitation phase of the problem space. [27] executed hybrid algorithms together with WCA and MFO in order to handle optimization engineering constrained problems. Information on WCMFO for the numerical and constraints optimized problem solution explained. WCMFO to determine the parameter of proton exchange membrane fuel cell stack electrical model explained in [28] WCMFO was also applied on overcurrent relay [29] and received an appropriate response. Latest two fields where WCMFO was seen to get a good response are the brain [30] MR image segmentation and system stability enhancement [31] of the power with the hybridization method of WCA and MFO.

Although the existing reviewed methods that are available in the market on strategic bidding are provide a good quality review on the system but they do not provide the challenge or the complete review regarding the invested area to contribute in addition to the betterment in the area for benefit of the customer as well as the balanced market investment for the supplier side as well. More over the load demand of the customer where in SFLA and PSO the power consumption is near about 2.5 times more generation and hence the cost directly more. All the upper and lower limits of the power generation for all the GENCO to be maintained to obtain the convergent curve whereas SFLA and PSO do not maintain the inequality constraints for three GENCO that violate in developing the function.

This paper is exclusive in the sense that it provides an idea in detail regarding the parameter analyze the effect of the variable utilization. WCMFO had been proposed and tested on the Strategic bidding topic for the first time on an Indian-75 Bus systems having fifteen Generating Company and compared with other existing methods. It maximises the capability of Evaporation and raining process of the WCA using Levy flight part of the MFO together that helps give the best optimal search data and avoid premature convergence. The profit of the Indian-75 Bus System seems to obtain the value better than the methods with minimum cost. Also the Rate of rise in percentage of the profit using WCMFO hybrid method with other existing methods is also discussed under Conclusion. The Box Plot analysis had also shown for better understanding of the proposed over conventional methods after running the individual techniques for better comparative study.

Paper is well-ordered as, section-2 proposes a structure of the problem confronted by the community frame wise through documentation of the bidding coefficient data with the introduction of new optimization techniques to obtain the bid data. Section-3 regulates the well-framed equation on WCMFO while Section-4 clarifies the Operation of the proposed WCMFO technique. Section-5, 6 denotes the result discussion with conclusion is clarified clearly in the paper.

2. PROBLEM FORMULATION

Considering in a restructured power market with “x” power producers [22], ISO, MO that have participated in the optimal bid data strategy where a preserved auctions MCP is affianced. Each supplier involved in the system requires to bid non-decreasing supply is denoted as,

$$G_m\left(P_m\right) = \alpha_m + \beta_m P_m \text{ for m} = 1, 2, ...\text{x}[15] \tag{1}$$

P_m as active power output, and α_m, β_m are the non-negative bidding coefficients.

Knowing the generation outputs and demand loads to calculate the total cost function purchase as well as the profit maximization using the below equations derived from Eq. (2 - 6).

$$\sum_{m=1}^{x}(\alpha_m + \beta_m P_m) = Q \text{ where, m} = 1, 2 \ldots \text{x}. \tag{2}$$

Power balance equation with generation/load equality constraints are;

$$\sum_{m=1}^{x} P_m = R\,(Q) \tag{3}$$

$$P_{m,min} \leq P_m \leq P_{m,max} \tag{4}$$

where, Q is denoted as MCP, the point of intersection between supply curve of the power producer and demand load curve of customers known as the equilibrium point. The Equation (3) defines the aggregate pool load which is equal to summation of the total active load where in Equation (4) shows the boundary limitation of $P_m$with conditions that if the value of P_m is more than the $P_{m,max}$ then the value is taken $P_m = P_{m,max}$. And if the value of P_m is less than $P_{m,max}$ then the value of$P_m = P_m$. If the value of $P_m$less than$P_{m,min}$, then $P_m = 0$ the feasibility of the equation goes wrong for which it has to be completely removed from the bidding auction market.

$$R(Q) = R_0 - KQ \tag{5}$$

$R(Q)$, denotes the aggregate pool load forecast dependent on elasticity price shown in the Equation (5). R_0 , a constant variable (=1000) and K denotes elasticity price. If the pool-demand is inelastic then it is considered as K is set to zero and as the system used in the paper is purely elastic where the actual demand of the customer is considered and hence the value of K=10 is chosen from [36] for the better comparison of the proposed and the conventional methods discussed.

Equations (6-7) are the MCP (‘Q’) calculation performed along with the active power consumption for each generating company is given,

$$Q = \frac{R_0 + \sum_{m=1}^{x} \frac{\alpha_m}{\beta_m}}{K + \sum_{m=1}^{x} \frac{1}{\beta_m}} \tag{6}$$

$$P_m = \frac{Q - \alpha_m}{\beta_m} \tag{7}$$

With mth power producer or for the nth power consumer at a significant hour, objective function for the maximized profit [32-34] is expressed as:

$$Profit = Revenue - Cost \tag{8}$$

$$max\pi_m\left(\alpha_m, \beta_m\right) = Q * P_m - C_m\left(P_m\right) \tag{9}$$

The mth power producer production cost function is expressed as

$$C_m\left(P_m\right) = e_m P_m + f_m P_m^2 \tag{10}$$

where, $e_m$and f_m is the cost coefficient of mth power producers. The objective is to maximize Equation (9) maintaining the constraints which were defined in the above mentioned Equation (3-4). Solving Equation (9-10) we should know the numerical data of the bid data coefficient i.e. α_m, β_m. Therefore with the application of the optimized technique the data will be obtained whose graph would converge to contribute the appropriate result and can be realistic to the objective function equation giving improved response then in comparison to the other techniques with minimum cost using the same bidding coefficient data.

Among the two bidding coefficients one is fixed and the other‘ one received using Equation (??) as changing both might complicate the solution [15]

$$Y_{pdf}\left(\alpha_m, \beta_m\right) = \frac{1}{2\pi\sigma_m^\alpha\sigma_m^\beta\sqrt{1-\zeta^2}} \exp\left\{-\frac{1}{2(-\zeta)^2}\left[\frac{(\alpha_m-\mu_m^\alpha)^2}{\sigma_m^\alpha} + \frac{(\beta_m-\mu_m^\beta)^2}{\sigma_m^\beta} - \frac{2\zeta(\alpha_m-\mu_m^\alpha)(\beta_m-\mu_m^\beta)}{\sigma_m^\alpha\sigma_m^\beta}\right]\right\} \tag{11}$$

This is also expressed in the compressed form

$$(\alpha_m, \beta_m) \sim N\left\{\left[\mu_m^\alpha \;\; , \mu_m^\beta\right], \left[(\sigma_m^\alpha)^2\zeta\sigma_m^\alpha \; \sigma_m^\beta\zeta\sigma_m^\alpha\sigma_m^\beta \; (\sigma_m^\beta)^2\right]\right\} \tag{12}$$

This joint probability density function is used to estimate the bidding coefficient. μ_m^α,μ_m^β are the mean and σ_m^α and $\sigma_m^\beta$are the standard deviation of the coefficient of the pre-historical data using other methods and ζ are the correlation coefficient of α_m, β_m. Here β_m are considered to get optimized keeping the other coefficient $\alpha_m = e$ as only one variable at a time could be optimized. Here ‘e’ is the cost coefficient whose values are mentioned under the generation Table 1.

In order to satisfy the profit in the maximized numerical figure than the other conventional techniques taken to be discussed in this paper, the value of β_m ranging between $[\beta_m * M]$(where M=10, as M is a constant [22] should always be more than c_m or else if it goes less, generation will be more due to which the cost which is dependent on the generation output will increase and indirectly reduces the profit. The coefficient data using WCMFO along with the other conventional techniques are shown in Table 3.

3. OPTIMIZING BIDDING DATA USING WCMFO

3.1 Water Cycle Algorithm

3.1.1 Initial Population

The algorithm starts [17] with the generation of an initial population representing the streams in the form of matrix $N_{pop} * N_{var}$, where N_{var} denotes the constraint parameters under system discussed and $N_{pop}$the population size as an initialization.

$$N_{SR} = Number\ of\ rivers + 1\,(Sea) \tag{13}$$

$$N_{streams} = N_{pop} - N_{SR} \tag{14}$$

$$Population\,of\ Streams = \begin{bmatrix} Stream_1 \\ Stream_2 \\ Stream_3 \\ \vdots \\ Stream_{N_{Stream}} \end{bmatrix} = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_N^1 \\ x_1^2 & x_2^2 & \cdots & x_N^2 \\ \vdots & \vdots & \vdots & \vdots \\ x_1^{N_{Stream}} & x_2^{N_{Stream}} & \cdots & x_M^{N_{Stream}} \end{bmatrix} \tag{15}$$

$$Total\ Population = \begin{bmatrix} Sea \\ River_1 \\ River_2 \\ \vdots \\ Stream_{N_S+1} \\ Stream_{N_S+2} \\ Stream_{N_S+3} \\ \vdots \\ Stream_{N_P} \end{bmatrix} = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_D^1 \\ x_1^2 & x_2^2 & \cdots & x_D^2 \\ \vdots & \vdots & \vdots & \vdots \\ x_1^{N_P} & x_2^{N_P} & \cdots & x_D^{N_P} \end{bmatrix} \quad (16)$$

Cost function obtained by the following equation [25].

$$C_i = f\left(x_1^i, x_2^i, x_3^i \ldots \ldots x_{N_v}^i\right) \quad (17)$$

where $i = 1, 2, 3, \ldots ..N_{pop}$.

$$C_m = cost_n - cost_{N_{SR}+1} \quad (18)$$

where $m = 1, 2, 3, \ldots ..N_{SR}$.

$$NS_n = round\left\{\left|\frac{cost_n - cost_{N_{SR}+1}}{\sum_{n=1}^{N_{SR}} C_n}\right| * N_{streams}\right\} \quad (19)$$

where $n = 1, 2, 3, \ldots ..N_{SR}$.

With, $NS_n$are the numeral of streams which particularly flows into some rivers and a sea.

Calculation of the exploitation phase of WCA, Newly positioned streams and rivers are written below 't' is an iteration index, $1 < B < 2$, and the random variables denoted as *rand* lies within zero and one.;

$$\vec{Z}_{stream}(t+1) = \vec{Z}_{stream}(t) + rand * B * (\vec{Z}_{sea}(t) - \vec{Z}_{stream}(t)) \quad (20)$$

$$\vec{Z}_{stream}(t+1) = \vec{Z}_{stream}(t) + rand * B * (\vec{Z}_{river}(t) - \vec{Z}_{stream}(t)) \quad (21)$$

$$\vec{Z}_{river}(t+1) = \vec{Z}_{river}(t) + rand * B * (\vec{Z}_{sea}(t) - \vec{Z}_{river}(t)) \quad (22)$$

3.1.2 Evaporation and raining condition:

It is necessary to check if the river or streams are near to the sea for the occurrence of the evaporation process. The criteria for such purposes are:

$$if \|\vec{Z}_{sea}^j - \vec{Z}_{River}^j\| < d_{max} \quad or\ rand < 0.1 \quad j = 1, 2, 3 \ldots \ldots ..N_{SR} - 1 \quad (23)$$

Next step is the raining process with random search *End* where d_{max} is a value near about null. If the value of d_{max} is very high then further additional will not be done. So d_{max} increase the search intensity nearest to the sea.

$$d_{max}(t+1) = d_{max} - \frac{d_{max}(t)}{Max\_iteration} \quad (24)$$

where $t = 1, 2, 3, \ldots Max\_iteration$.

As soon as the evaporation condition gets satisfied then the raining process needs to be used,

$$\vec{Z}_{new\_stream}^t = LB + rand(UB - LB) \quad (25)$$

where LB as Lower Boundary and UB as the Upper Boundary in the problem.

The next equation will help in the exploration part of the algorithm giving an optimum solution.

$$Z_{stream}^{new} = Z_{sea} + \sqrt{\mu} * rand(1, nvar) \quad (26)$$

where $'\mu'$ is the concept of variance, reaching the optimum solution to the problem.

3.1.3 End of loop:

The end of the loop is taken repeatedly until a good convergence numerical value is obtained.

3.2 Hybrid Water Cycle Moth Flame Optimization:

In WCMFO technique two major processes are considered. The first step is the training step to generate new solutions. The next step is letting the streams to randomly flow in the solution space using Levy flight. To increase the randomness of the proposed WCMFO technique, streams do change or update the location by the help of Levy flight with equation,

$$\mu_{i+1} = \mu_i + Levy(\dim) \otimes \mu_i \quad (27)$$

where u_{i+1} will be the next location of the stream, u_i is the current location of the stream and dim is the dimension of the problem or number of decision variables. The Levy flight is,

$$Levy(\mu) = \frac{0.01 * \sigma * w_1}{|w|_2^{1/\beta}} \quad (28)$$

where w_1, and w_2 are generated random numbers from zero to one $\beta = 3/2$. With the Equation (25), σ is calculated.

$$\sigma = \left(\frac{\Gamma(1+\beta) * \sin\left(\frac{\pi\beta}{2}\right)}{\Gamma\left(\frac{1+\beta}{2}\right) * \beta * 2^{\left(\frac{\beta-1}{2}\right)}}\right)^{\frac{1}{\beta}} \quad (29)$$

4. WCMFO TO CALCULATE PROFIT MAXIMIZATION

Step 1: First generate the population in random of profit π_m, as π_m is the profit of the mth producer of the system.

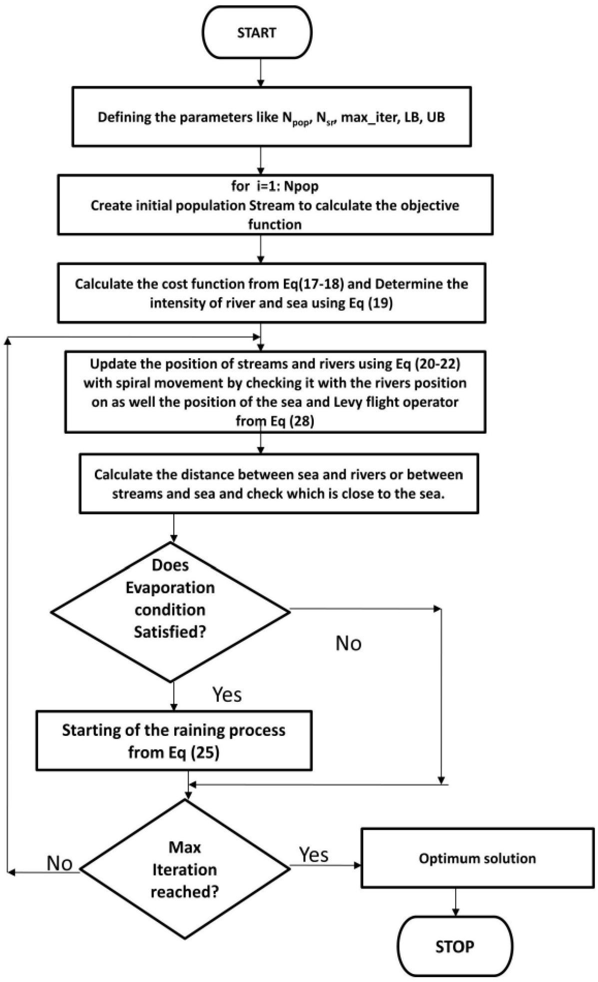

***Fig. 1**: Flowchart of the WCMFO.*

***Table 1**: Generation data given for an Indian-75 Bus practical system.*

Generator	e	f	$P_{m,min}$	$P_{m,max}$
1	0.8140	0.0008	100	1500
2	1.3804	0.0014	100	300
3	1.5662	0.0016	40	200
4	1.6069	0.0016	40	170
5	1.5662	0.0016	2	240
6	1.7422	0.0018	1	120
7	1.7755	0.0018	1	100
8	1.7422	0.0018	20	100
9	1.1792	0.0012	60	570
10	1.6947	0.0017	30	250
11	1.6208	0.0016	40	200
12	0.4091	0.0004	80	1300
13	0.6770	0.0007	50	900
14	1.4910	0.0015	10	150
15	1.0025	0.0010	20	454

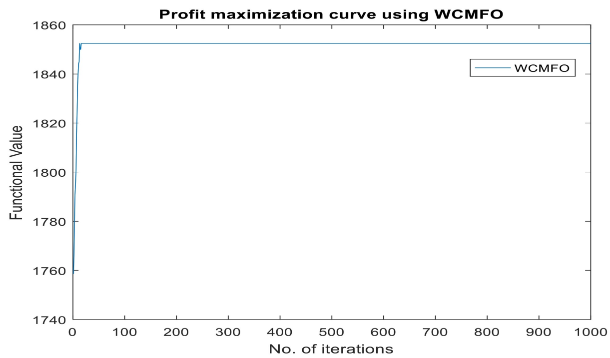

***Fig. 2**: Profit maximization curve using WCMFO.*

Step 2: Read the generator data input mentioned in Table 1 to calculate the cost function coefficient for the individual GENCO keeping in mind the limitation of the generation output.
Step 3: IF the generation output is more than the upper limit then use the upper limit as the output and if it is beyond the lower limit then it is considered as null during auction.
Step 4: Add all the generation output that should satisfy the equation mentioned in (3).
Step 5: Error=total generation output-total demand.
Step 6: Find out the best and the worst fitness of profit for the mentioned iteration for better comparison calculating the MCP for the system.
Step 7: Repeat the process until it reaches the maximum limited iteration.
Step 8: Print the profit obtained for the proposed technique.

5. RESULT AND DISCUSSION

The WCMFO were implemented using MATLAB software (2016) to find out the bidding coefficient data that gives maximum profit for the Indian-75 Bus system. It can validate the efficacy of WCMFO over GWO, SFLA and PSO. SFLA and PSO has the power generation seems to have 2.5 times more than mentioned in its paper using the same values of elasticity that does not satisfy Equation (2) from problem formulation. Using WCMFO, the equality constraint of the paper, power demand from Equation (2) gets satisfied hence justifies the first factor of the result. With the help of WCMFO, the profit for the overall system is observed to get a better number compared to the GWO and PSO with minimum cost and power generation whereas it is observed in few of the GENCO have crossed the boundary limit of the power generation in case of SFLA and PSO technique and marked in **BOLD** at Table 4 thereby not satisfying the inequality constraint of the main function and so holds the final factor to justify the result using the proposed technique. The Generator data of the Indian-75 Bus system is mentioned under Table-1. Essential Parameters are mentioned under Table-2. The bidding data obtained using WCMFO and conventional techniques are under Table-3. Power and Profit calculation using techniques are obtained under Table-4. Revenue and cost calculation for individual GENCO are executed in Table-5 with the

Table 2*: Parameters for different methods.*

WCMFO	GWO [32]	SFLA [33]	PSO [34]
Population = 200 Iteration = 1000	Population = 200 Iteration = 1000	Population = 200 Maz. Iteration = 1000	Population = 200 Generation = 1000

Table 3*: Obtained bidding coefficient of the conventional bidding model with proposed method.*

Generator	WCMFO(β_m)	GWO(B_i) [32]	SFLA(b_i) [33]	PSO(b_i) [34]
1	0.02181	0.0179	0.0029	0.0022
2	0.01535	0.0123	0.0045	0.0032
3	0.0351	0.0260	0.0024	0.0070
4	0.030221	0.0250	0.0063	0.0067
5	0.6176	0.5200	0.3340	0.1347
6	1.1255	0.8640	0.0115	0.0110
7	0.10068	0.0346	0.0191	0.0062
8	0.04781	0.0353	0.0049	0.0098
9	0.028816	0.0240	0.0104	0.0083
10	0.038348	0.0339	0.0062	0.0034
11	0.03268	0.0318	0.0055	0.0029
12	0.0108	0.0080	0.0074	0.0056
13	0.017232	0.0140	0.0047	0.0020
14	0.03831	0.0300	0.0024	0.0056
15	0.023678	0.0200	0.0061	0.0025

Table 4*: Total power consumption that meets the load demand and profit shown for both conventional and proposed method.*

	WCMFO		GWO [32]		SFLA [33]		PSO [34]	
Sl. no	Power (MW)	Profit($)	Power(MW)	Profit($)	Power(MW)	Profit($)	Power(MW)	Profit($)
1	100.0459	210.2927	100	171.33	333.48	485.76	471.3	160.02
2	105.2508	154.5344	100	108.69	164.14	178.30	175.4	25.6
3	40.73504	55.58801	40	39.09	**280**	256.98	74.1	27.5
4	45.96473	60.46919	40	37.46	165.20	304.62	**172.6**	158.80
5	2.315091	3.301541	2	2.07	3.44	6.74	10.3	3.7
6	1.113994	1.394492	1	0.8634	64.92	85.93	54.2	24.3
7	12.12257	14.53107	5.85	5.12	39.52	50.16	**160**	225.7
8	26.22464	31.64254	24.46	20.10	**170.15**	211.80	77.2	43.5
9	63.04831	109.7761	60	81.37	75.19	105.44	77.2	37.6
10	33.93397	42.2007	30	25.85	137.44	205.82	180	92.7
11	42.08078	55.03623	40	36.90	163.46	252.61	**209**	116.7
12	239.5278	596.685	275.29	573.84	156.5	325.54	252.5	257.1
13	134.5752	299.4026	137.92	252.85	226.38	408.14	603.1	198.1
14	39.28478	56.80866	37.21	39.46	**250**	571.30	**250**	343.0
15	84.19208	160.7486	80.21	122.47	270	747.60	232.1	37.6
MCP	2.99		2.60		8.60		7.68	
Total Profit	1852.412		1517.50		4196.80		1752.60	

Statistical analysis in Table 6. Fig. 1 shows the flowchart of the WCMFO. Fig. 2 shows the Profit maximization curve obtained using WCMFO for 1000 iterations. Fig. 3 shows the increasing nature and the stabilization of the profit curve with respect to per iteration for the better visualization of the curve. Figs. 4 and 5 explain the statistical analysis of power and profit between WCMFO with GWO, as well as PSO with a bar chart. Fig. 6 shows the box plot visual statistical analysis for the proposed and the conventional techniques.

Hence using the value 'Q' from Table 4 the value of $R(Q)$ is found out with the Equation (6). So,

$$\begin{aligned} R(Q) &= 1000 - 10Q \\ &= 970.1 \approx 970\,\text{MW} \end{aligned}$$

***Table 5**: Calculation of the profit for Indian-75 bus system using WCMFO.*

Sl. No	Power (P_m)(MW)	Revenue($P_m * Q$)	Cost $C_m(P_m)$	Profit($)
1.	100.0459	299.7374	89.44466	210.2927
2.	105.2508	315.3314	160.7971	154.5344
3.	40.73504	122.0422	66.45417	55.58801
4.	45.96473	137.7103	77.24113	60.46919
5.	2.315091	6.936012	3.63447	3.301541
6.	1.113994	3.337525	1.943034	1.394492
7.	12.12257	36.31921	21.78814	14.53107
8.	26.22464	78.56902	46.92648	31.64254
9.	63.04831	188.8927	79.11667	109.7761
10.	33.93397	101.6662	59.46548	42.2007
11.	42.08078	126.074	71.0378	55.03623
12.	239.5278	717.6252	120.9402	596.685
13.	134.5752	403.1873	103.7848	299.4026
14.	39.28478	117.6972	60.88855	56.80866
15.	84.19208	252.2395	91.49086	160.7486

***Table 6**: Analytics of statistics.*

Total Profit($)	**WCMFO**	**GWO [32]**	**SFLA [33]**	**PSO [34]**
Best Profit($)	1852.412	1517.50	4196.80	1752.60
Worst Profit($)	1758.5784	672.75	4092.16	1627.34
Avg. Profit($)	1805.4952	1045.12	4144.48	1689.97
P.D=(Best profit-Worst profit)/Best profit*100	5.075	55.67	2.4	7.1

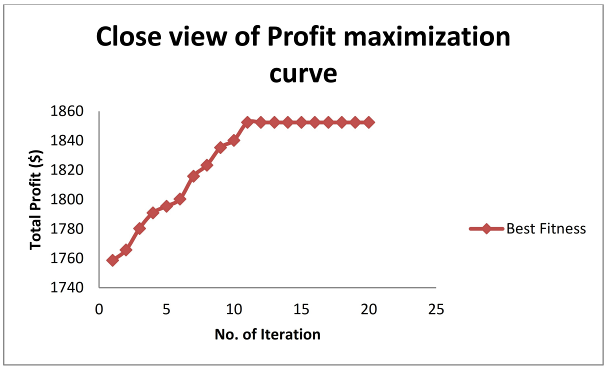

***Fig. 3**: Profit curve for viewing increasing nature and better stabilization using 20 iteration.*

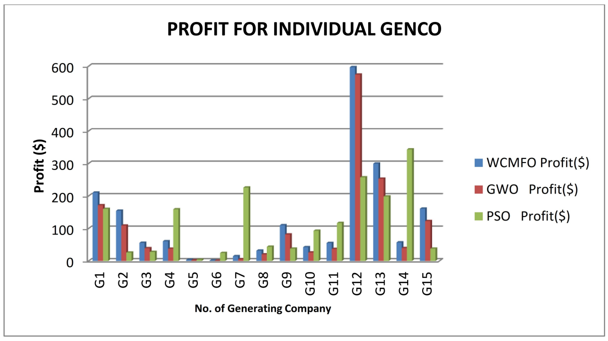

***Fig. 4**: The response of the profit between three methods.*

$$\sum_{m=1}^{15} P_m = 970.4156 \approx 970\,\text{MW}$$

Therefore it completely satisfies Equation (3). Thus it proves to fulfil the demand of the customer.

Box-Plot Analysis

Box-plot also known as the box and whisker plot is a method of pictographic illustration of the statistical data by signifying the locality, spread and skewness with the quartile data obtained providing the visual summary. Box-plot is represented along with the whiskers that are the straight lines right and left at the end of the box. Though the plot can be shown either vertically or horizontally, here it's used as a vertical box-plot. It also shows the upper and lower quartile for the three methods along with the median that separates the whole box into two and the inter-quartile range (IQR) as well. The box-plot shown in Fig 6 is the skewed type plot as the median does not divide the box equally and is skewed towards lower quartile hence named positive skewed box-plot. Taking a comparative study among the three box-plot as the median of each box do not lie outside the others so there are no differences between groups, moreover the larger inter-quartile (length of the box) denotes the more dispersed data. Even the spreading of the whole start and end whisker denotes the larger distribution with a more scattered data of the profit for the GENCO which is seen from the box-plot of WCMFO. Median of the GWO is obtained before than WCMFO followed by PSO

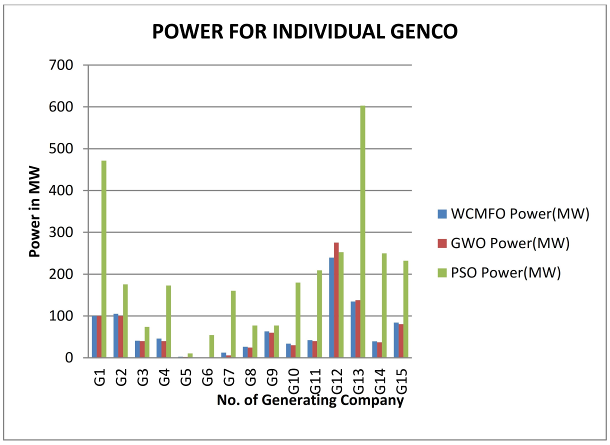

***Fig. 5**: The response of the power between three methods.*

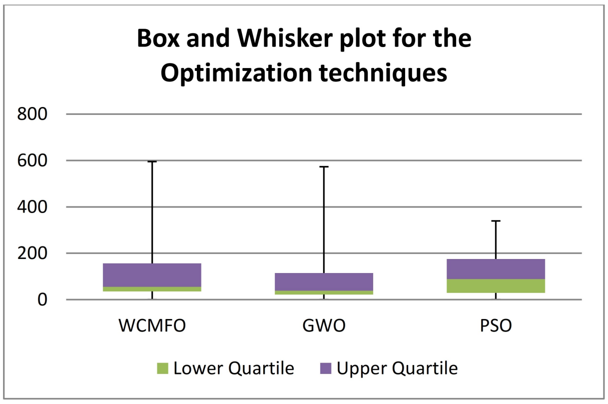

***Fig. 6**: Box-plot for the three methods.*

indicating GWO to be faster followed by WCMFO and PSO. 50% data will be served by the IQR and so the spread of the PSO comes more than the WCMFO and then comes GWO signifies the consistency of the data among three methods.

6. CONCLUSION

This paper presents an approach of strategic bidding data using WCMFO, the latest meta-heuristic optimized technique to obtain the improved maximized profit quantity that is tested on the Indian-75 Bus system having fifteen GENCOs fulfilling the equal and inequality constraints which is an ultimate goal of the paper. The statistical analysis of the outcomes with the WCMFO technique in case of profit on the basis of the best, worst, average, percentage deviation (PD (in %)) have been discussed well above. The total profit of the WCMFO technique proved to be the best method with the Levy flight operator in comparison with the conventional method GWO with a rise in profit by 22.06% and with PSO rise is 5.695% for 200 Population with the computational time of 13.86 sec using 1000 iterations and avoiding the premature convergence. SFLA method is not used for comparison as the power generation is 2.5 times than the demand, same in case of PSO where profit obtained doesn't fulfil all the constraint with huge power generation, moreover it is also seen in Table-3 for SFLA the power for GENCO $G_3, G_8,$ *and* G_{14} and for PSO the power for GENCO $G_4, G_7, G_{11},$ *and* G_{14} that crossed the range of the active power boundary and also on other hand using PSO, though the profit for GENCO $G_5, G_8,$ *and* G_{10} may not have increased in number but the huge power consumption for the GENCO is almost five times than WCMFO therefore the overall cost of the system has increased which is also not acceptable as the total power generation obtained should be equal to the pool load forecasted by ISO discussed in equations above. Hence WCMFO not only increased the profit of the system of the market but also maintained all the constraints with minimum cost and power generation. All though WCMFO had several advantages while implementing it in the paper but the drawback of this method is that since the method is a combination of the two renowned meta-heuristic methods hence the convergence time is reduced compared to the other existing techniques discussed but the time taken for the individual iteration to run the program takes quite a longer time. That is the only drawback of the method but does not add any impact on getting the best result over the other methods. The flowchart of the WCMFO is incorporated Fig. 1 for the better explanation of the method. The Profit curve shown denotes the increasing nature satisfying the objective function along with the stability at the particular iteration had also been clearly displayed through Figs. 2 and 3. The bar chart in the result section represents the power and the profit for three methods while studying the comparative study for the profit and the bidding data. Hence the WCMFO converges and receives better global value. The box plot at Fig. 6 is shown for the better form of visual analysis of the profit data.

Nomenclature

α_m, β_m	The two bidding coefficient data.
a_m, b_m, c_m	Cost coefficients to calculate the cost.
b	Convergence constant from -1 to -2
β	Constant parameter value
C_m	Cost of the Generating Company
C_i, C_n	Cost function calculation in the WCA algorithm
d_{max}	value near about null
dim	Dimension of the problem
F_i	Flame matrix
K	elasticity price
LB	Lower Boundary
$Levy$	Levy flight
μ	Variance
μ_m	Mean
μ_i, μ_{i+1}	Current and next location of the stream
M	a constant
M_i	Moth matrix
N_{pop}	No. of population
n	Decision variables
N_{var}	No of user defined parameter
N_{stream}	No. of Streams
NS_n	numeral of streams which particularly flows into some rivers and a sea
N_{SR}	Total rivers and sea
P_m	The power for each Generating Company from m=1,2,3,….x
Q	The Market Cleared Price
R_0	Constant variable
$R(Q)$	The aggregate pool load forecast
σ_m	Standard deviation
t	Random uniform no between -1 to +1
UB	Upper Boundary
w_1, w_2	are generated random numbers from zero to one in Levy flight
x	No. of power producers or the Generating Company in an Indian-75 Bus System
Y_{pdf}	Probability density function
Z_{sea}, Z_{river}, $Z_{new_{stream}}$	Calculation of the position of new river, sea and Stream and choose the best position for the fitness value or else their position is exchanged.

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