Profit Maximization of GENCO's Using an Elephant Herding Optimization Algorithm

Sundar RAVICHANDRAN[1]*, Manoharan SUBRAMANIAN[2]

[1] Department of Electrical & Electronics Engineering,

Karpagam College of Engineering, Coimbatore, 641032, India*
sundareee1988@gmail.com (*Corresponding author*)

[2] Department of Electrical & Electronics Engineering,
Karpagam College of Engineering, Coimbatore, 641032, India

Abstract: When electrical power systems are restructured managers look for satisfying several objectives that include: the working cost minimization and the profit for the unit commitment problems maximization. Power generating companies that comply with the two above mentioned objectives are able to provide good quality and reliable power at a cheaper cost. The individual power producers, schedule their generating units in such a way that they gain maximum profit. This is known as Profit Based Unit Commitment (PBUC). The target of this proposed work is to obtain an optimum generating schedule of the Power Generating Companies (GENCO's) and maximize the profit of power generating companies when the system is under various constraints like forecasted demand, minimum start-up /shutdown time, spot price, forecasted reserve and ramp rate limits. In order to address this problem, a new meta-heuristic approach called Elephant Herding Optimization (EHO) algorithm is presented. The method may help to solve the complex PBUC problems in the deregulated open market. The effectiveness of projected EHO is tested on various systems with various market conditions. The comparison of the test results with other optimization methods are presented and discussed taking into account their convergence characteristics, solution superiority and reliability.

Keywords: Deregulation, Elephant herding optimization, Profit based unit commitment.

1. Introduction

Restructuring of electric power system network is taking place all over the world. During 90's, worldwide power network companies and many electric utilities started using deregulation instead of vertically integrated structures. The traditional and vertically regulated power industry is replaced by horizontally regulated system therein generation, transmission and distribution are unbundled. The deregulation of the power system created market-based competition in an open electricity pool. Due to the developments in the power industry, the entire network comprising the generation process, scheduling, and running methods are required to be customized in regulated power system network. But it is a very complex process since electricity policy and the applications differ from country to country. This market-based power industry is not yet implemented in Tamil Nadu, India, where the system is owned by the state and operated as vertically integrated.

The restructuring of the power system has unbundled the responsibilities into three categories. They are i. Generation companies (GENCO's), ii. Transmission companies (TRANSCO), iii. Distribution companies (DISCO). In order to balance the supply and demand of the system to preserve the system precautions and consistency, a focal facilitator named Independent System Operator (ISO) is used. In this vertically integrated system, the Customers can choose their individual power supplier which improves the efficiency of the power generation and distribution, delivers at a reduced price with high quality. In this deregulated structure competition is created between GENCO's. Most of the conventional optimization methods are to be modified to address the open market competition. Sequentially, the unit commitment approach with profit maximization plays an important role in the competitive pool power market.

In a deregulated power system, the unit commitment problem with multi-objective function is exposed to various system constraints. The determination of generator scheduling in a power system is a complex optimization problem. Earlier the electric utilities had an appeal to satisfy the customer demand and forecasted reserve. Be that as it may, in the competitive power market, the GENCO's are not mandatory to equalize the power demand. The prepared load schedule may generate less than the forecasted load requirement and reserve with more profit under various constraints. This problem is stated as Profit based

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unit commitment problem. To increase the profit of the GENCO, it is necessary to compute the amount of power required to be introduced in the pool market based on the forecasted power demand and spot pricing at a particular time ‘t’. This is a more flexible and more complex problem under a deregulated environment. Different solutions were obtained for the unit commitment problem in the vertically regulated power system. In the recent days, the researchers concentrate on the best possible unit commitment algorithms for PBUC problems which will be more suitable for large size power system with low storage space and less computational time.

Based on the reviews carried out, large number of numerical optimization approaches were implemented to give solutions for complicated profit-based unit commitment. Many classical approaches were developed and implemented effectively. Some of the frequently used approaches are deterministic approach and meta-heuristic approach. The deterministic approaches include enumeration method, priority list, Benders decomposition, branch and bound, dynamic programming method, Lagrangian relaxation technique and mixed integer technique which give local optimum solutions. The meta-heuristic approach includes Genetic algorithm (GA), Ant colony algorithm (ACA), Fuzzy logic(FL), artificial neural network(ANN), Tabu search(TS), particle swarm optimization (PSO), Muller method, Simulated annealing (SA), Memory management algorithm(MMA), Artificial immune system(AIS). Hybrid meta-heuristic methods like gravitational search LR-ANN, Dynamic programming with particle swarm optimization-(PSO-DP), Particle swarm optimization based Lagrangian relaxation (LR-PSO),Multi-agent system(MAS), Improved pre-prepared power demand(IPPD) optimization, Teaching –learning optimization(TLO), Binary fish swarm algorithm (BFSA) are also presented for PBUC problems under restructured market.

The major limitation of this numerical approach is that they are unable to handle large size power system network and it fails to give an accurate solution within a short duration of time (ie.) Computational time is also more under the open market environment. Researchers developed a mimicking mechanism of biological evolution for optimization problem known as evolutionary algorithm. Chen &Wang (2002) presented a cooperative algorithm for solving the UC problems. Contreras.et.al (2006) proposed a technique which determined best feasible solution with least computational time for a UC problem.

Chendur Pandian et.al (2014) & Daneshi et.al presented a price-based solution for PBUC problem using fuzzy logic application. Mixed integer programming approach also addresses the problem and it is very practical with the consideration of uncertainties in the parameters. Sasaki et.al (2002) Used a Hopfield neural network approach to explore the probability to the UC problem when more inequality constraints were considered. Yamin et.al (2007) presented a method for Genco’s PBUC in a day ahead open power market. The forecasted demand and generated power are also taken into account in the formulation to simulate the reserve uncertainty. Annakkage et.al (1995) investigated the application of parallel simulated annealing for unit commitment problem to reduce the computational time. Tabu search optimization has been applied to a combinatorial optimization problem. Mantawy et.al (1998) presented a unit commitment solution using Tabu search and introduced a new perturbation scheme for conventional UC problems.

Jing-yu et.al (2004) explored an approach with PBUC multi-agents’ system having command agent, mobile agent and generator agent. They are placed with a distributed generator and operate together to get the satisfying operation of PBUC solution. Mori &Okawa (2009) developed a Tabu search evolutionary PSO technique to PBUC. Here Genetic algorithm is derived from the biological model of evolution and it operates on the Darwinian principle of natural selection. Richter & Sheble (1997) formed a bidding strategy using GA which maximizes the profit of the generating companies in the competitive pool electricity market. Richter & sheble (2000) proposed a PBU using GA for Competitive environment which considers the demand constraints and it schedules for more profit. GA to PBUC provided optimal UC and also optimal MW values for demand, reserve.

Vargas & Chen (2010) combined LR and GA to solve PBUC problems. Attaviriyanupap et.al (2003) illustrated a hybrid LR-EP approach which actuates Genco's -generating schedule with the quantity of generated power and spinning reserve to be sold by the bidding process to get the maximum profit. Valenzuela et.al (2001) examined a new method of solution for individual power producer to tackle UC problem in electric power markets. Dimitroulas et.al (2011) explored a solution for PBUC problems by a hybrid model of GA and narrow search algorithm. To obtain the maximum profit with the best possible solution in the power market, Muller Optimization method is explored by Chandram et.al (2009). To maintain the high search capability, a new nodal ant colony optimization is introduced by Columbus et.al (2011). Srikanth Reddy et.al (2016) & (2019) proposed a new approach called Binary firework's algorithm and binary whale optimization algorithm for PBUC problem to obtain a maximum profit for GENCO's. The dimension of the problem, complex programming and computation time are notified as major limitations of these methods. In this connection, the upgrading of the existing methods is required in order to obtain the optimal solution for PBUC problems.

In this research article, a swarm based meta-heuristic approach, Elephant Herding Optimization algorithm is presented to maximize the profit of GENCO's. EHO algorithm is stimulated by the herding activity of elephants. The food and shelter searching method is the main idea in this algorithm. This EHO method is implemented to solve the above -mentioned optimal scheduling and profit maximization under the deregulated power market. The article sequence is as follows: formulation of the multi-objective function for Profit Based Unit Commitment problem is dealt with in section 2. Section 3 presents the idea of the proposed Elephant Herding Algorithm. Section 4 discusses the implementation of EHO algorithm for the PBUC problems under deregulated pool market. Section 5 deals the meticulous outcomes and discussion followed by conclusion with comparative results of the work in section 6.

2. Problem formulation

The objective function varies between a cost-minimized conventional market and profit maximized restructured power market. The objective of the restructured power marketplace in PBUC is not only to reduce the participation cost but also to maximize the generating companies (GENCO's) profit under customary constraints like forecasted demand, reserve capacity, ramp rate limits, spot price, and minimum up/downtime. Revenue received from energy sold in the power market minus the net participation cost gives the profit of the GENCO.

2.1 Objective Functions

The objective function for profit maximization is given by

$$Max(PF) = \max(TR - TC) \tag{1}$$

Where TR is total revenue, TC is the total operating cost for the power demand as well as the reserve demand.

$$TR = \sum_{i=1}^{N}\sum_{t=1}^{T}\{(P_{it} * SP_t)U_{it}\} \tag{2}$$

$$TC = \sum_{i=1}^{N}\sum_{t=1}^{T}\{(C_{it}(P_{it}) + S_{it}) * U_{it}\} \tag{3}$$

The total input cost is the summation of the power generation cost and cost calculated with startup/shut down constraint of all generating units over whole optimum scheduling time. The fuel cost of generating unit 'i' at hour't' is calculated by using the quadratic cost function.

$$C_{it}(P_{it}) = a_i + b_i P_{it} + c_i P_{it}^2 \tag{4}$$

Where $C_{it}(P_{it})$ is the Power generation cost of unit 'i' at hour 't'. P_{it} is the output power from the generating unit "i" at hour t; a_i, b_i and c_i are fuel cost function coefficients of unit "i". SP_t is the forecasted power price at hour't'.

Startup cost:

$$S_{it} = S_{oi}\left[1 - D_i \exp\left(\frac{T_{off,i}}{T_{down,i}}\right)\right] + E_i \tag{5}$$

Where S_{it} is Startup Cost, S_{oi} is Cold startup cost, D_i & E_i are the startup cost coefficients.

The various constraints considered for PBUC problems are as follows:

2.2 System Constraints

2.2.1 Load constraints or Demand constraints

The balancing load demand constraints of PBUC are given as

$$\sum_{i=1}^{N} P_{it} * U_{it} \leq PD_t ; 1 \leq t \leq T \tag{6}$$

Where U_{it} equals to 1 if power generating unit 'i' at hour t is ON and U_{it} equals to 0 if power generating unit 'i' at hour t is OFF. These two variables are known as Decision Variables. PD_t is a power demand at hour 't'. In a deregulated power system, it is not obligatory to generate the same power as demand.

2.2.2 Forecasted reserve constraints

The forecasted whole system reserve capacity and GENCO's reserve capacity together form the inequality constraint as follows,

$$\sum_{i=1}^{N} P_{it} * U_{it} \leq SR_t ; 1 \leq t \leq T \tag{7}$$

Where SR_t is a forecasted reserve of hour 't'. This is also a Decision variable.

2.3 Thermal Unit Constraints

2.3.1 Generation limit/ Dispatching limit

The generation boundaries linked with the committed generating units,

$$P_{it}^{min} \leq P_{it} \leq P_{it}^{max} ; i = 1,2,3.....N, t = 1,2,3....T \tag{8}$$

Where P_{it}^{min} & P_{it}^{max} are the min and max bound on the output power of unit 'i'.

2.3.2 Minimum up/ Minimum downtime

$$T_i^{on} \geq T_i^{up} \tag{9}$$

$$T_i^{off} \geq T_i^{down} \tag{10}$$

Where T_i^{on} & T_i^{off} are the continuous ON and OFF time period. T_i^{UP} & T_i^{down} are the Min Up and Down time of unit 'i'.

2.3.3 Ramp up/Down limits

The ramp up/down limits are the permissible timely modification in power generating stations,

$$P_{it}^{max} = \min\{P_i^{max}, P_{i(t-1)} + \tau RU_i\} \tag{11}$$

$$P_{it}^{min} = \max\{P_i^{min}, P_{i(t-1)} + \tau . RD_i\} \tag{12}$$

PBUC time input step function τ is assumed to be 60 mins. Where, RU_i & RD_i are the ramp up and down limits for unit 'i'.

2.3.4 Crew constraints

When more units are in 'ON' state at an equal time period, then crew constraints are restricted.

3. Elephant Herding Optimization

Wang et.al (2015) introduced a metaheuristic algorithm called Elephant Herding optimization for solving multi-objective optimization problems. It is a nature-inspired algorithm that imitates the crowding activities of elephants in groups. It has a mixed behavior of swarm intelligence and evolutionary algorithm. The elephant behavior modeling has both abuse (Group updating operator) and examination (separating operator). In nature, elephants live together as a clan. Even though they belong to various groups, they will live together under the captainship of the eldest and largest female elephant matron of the group. The male elephants leave their nuclear family unit when they reach adulthood as shown in Figure 1.

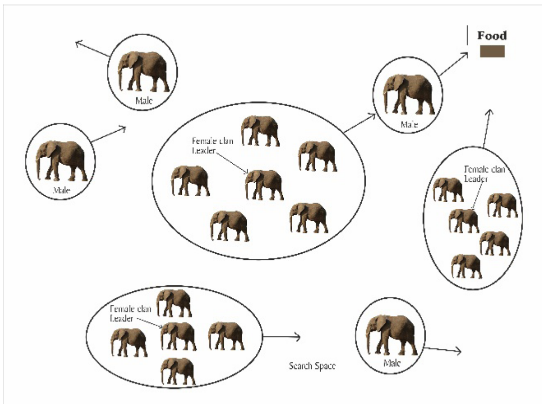

Figure 1. Elephant herding behavior nature

In spite of the fact, though the male elephants live away, they make contact with their clan through low-frequency pulsations. From this, it is observed that exploration is done by male and exploitation is done by female respectively. When any of the male elephants finds the enhanced location, then the whole clan will move towards that position. The female elephant does a local search of that region. To form the global optimization method, the crowding activities of elephants are considered with (i) Clan updating operator-which updates the elephant's & matron's current position in each clan, (ii) Separating Operator- which enhances the inhabitant range at every search period.

3.1 Clan updating operator

Initially, the total elephant population is assumed as 'n' clans. While organizing the elephants, clan updating operator is applied based on their fitness function. Each member j of the ith clan moves according to the elephant matriarch, Ci with best fitness value as,

$$\gamma_{new,C_{i,j}} = \gamma_{C} + \alpha * (\gamma_{best,C_i} - \gamma_{C_{i,j}}) * r \tag{13}$$

Where $\gamma_{new,\ Ci,j}$ and $\gamma_{Ci,j}$ are recently restructured and old location of elephant j in group C_i, respectively. α €[0,1] is a level parameter which decides the impact of i[th] matron C_i on $\gamma_{Ci,j}$,$\gamma_{best,Ci}$ represents the matron C_i which is the best individual elephant in group C_i and r€[0,1] explained by R. Vijay, et.al (2018). The best elephant can't be updated in the group by eqn. 13 which means $\gamma_{best,Ci} = \gamma_{Ci,j}$. For the best elephant, it can be updated accordingly,

$$\gamma_{new,C_{i,j}} = \beta * \gamma_{center,C_i} \tag{14}$$

β€ [0,1] is another tuning parameter which decides the impact of $\gamma_{center,Ci}$ on $\gamma_{best,\ Ci,j}$. d[th] dimension is determined by the below equation,

$$\gamma_{center,C_{i,d}} = \frac{1}{n} * \sum_{j=1}^{nci} \gamma_{C_{i,j,d}} \tag{15}$$

Where the dimension limits are1≤d≤D. Here D is the total dimension of the problem. n_{ci} is the total quantity of elephants in the clan Ci.

3.2 Separating operator

When the separating operator is applied in each interaction, the elephant is moving to a new position & replacing it with the worst fitness in the i[th] group.

$$\gamma_{worst,C_i} = \gamma_{min} + (\gamma_{max} - \gamma_{min} + 1) * r \tag{16}$$

Where γ_{max} and γ_{min} are max and min limit of the individual elephant's location, respectively. r€[01] is a kind of stochastic distribution. Therefore, the elephant herding algorithm implies the iterative applying 13-16 for a predefined no of iterations. The Population size and Maximum no. of iterations are indirectly controlled by the no. of clans and clan size, whereas α and β are fixed for certain application.

4. Implementation of EHO Algorithm

The PBUC optimization problem is accomplished using the EHO procedure following the steps mentioned below:

Step 1:

Read the GENCO's unit and system data like Generation limits, cost coefficients, min up/downtime, etc.

Step 2:

Read the EHO parameters such as maximum no. of elephants, no. of clans, α and β.

Step 3:

Compute the feasible units for forecasted demand or Market price of all objectives Function.

Step 4:

Calculate the objective function (power generation, cost, revenue, etc.) for entire load scheduling time periods and Compute the PBUC schedule prevailing the system constraints. If it is completed, then go to the next step or else back to step 3.

Step 5:

Call the EHO algorithm and Set the iteration count i=1 and assign the population size. Calculate the Fitness function (Profit of Units) for all of the solutions in each clan.

Step 6:

Update the clan operator with the best and worst position of the elephants using eqn. 13 -16 for the aforesaid objective function of PBUC problems.

Step 7:

Separate the worst (local optimum) elephant using the separating operator by eqn. 16. The elephant will communicate with others to update the current worst position among the iteration.

Step 8:

Check for the total no. of a clan. If it is reached then go to next step, otherwise go to step 5 with new values of α and β which are normally assumed €[0,1].

Step 9:

After updating the best and worst elephant (Global and local optimum), check for the optimum solution for the PBUC problem. If it is reached, then save the best simulation results and then stop the process otherwise change the PBUC variables and proceed to step 4.

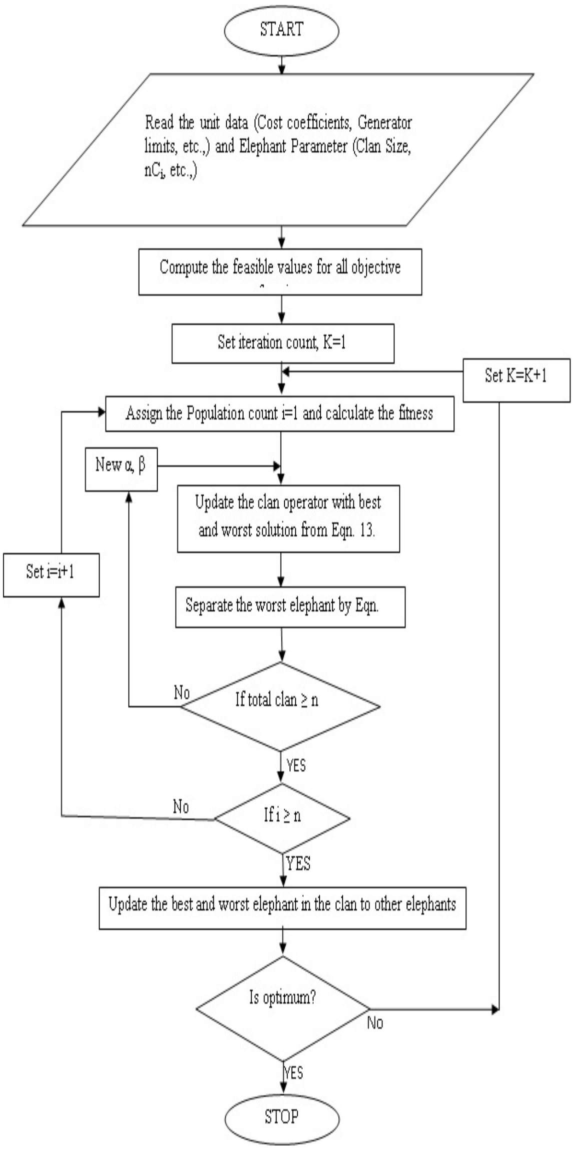

Figure 2. Flow Diagram of PBUC with proposed method

5. Numerical Results and Discussion

The elephant Herding Optimization algorithm was developed in MATLAB 7.10 and the machine configuration is Intel I5 processing unit with the 3.55GHz speed with 8 GB RAM. In this article, 2 GENCO's (Three units, and ten units) test systems were taken for simulation. The computational outcomes of Profit Based Unit Commitment acquired by the EHO algorithm for 2 GENCO's and the simulation outcomes were compared with the various standing optimization methods.

5.1 GENCO I (3 Units 12-hour Schedule)

Elephant Herding Optimization algorithm chooses only the best fit optimum allocation if the number of units is less than two. Before executing the PBUC-EHO algorithm, it is necessary to find an accurate hourly power demand of GENCO's and a scheduled period spot price. The generator cost function is always derived in the quadratic equation.

Table 1 is the system operating data for GENCO-I consisting of 3 units 10 bus system. When the generators are in Continuous operation, the abuse of min up/downtime limitations may be avoided.

Table 1. Unit cost and performance data of GENCO-I

Parameter	G1	G2	G3
P_{mn} (MW)	600	400	200
P_{mx} (MW)	100	100	50
a(Constant)	500	300	100
b(Linear)	10	8	6
C(quadratic)	0.002	0.0025	0.005
Initial Status	-3	3	3
Min up/downtime (hr)	3/3	3/3	3/3
Startup cost ($)	450	400	300

Table 2 explains the simulation input parameter of Elephant Herding optimization algorithm. In view of the demand data and related spot pricing in the power market, the generating units are committing at regular time period. Table 3 clarifies the optimum allocation of GENCO-I at the end of each generation which defines the PBUC optimum schedule with revenue and profit. Figure 3 shows the performance of total cost, GENCO's revenue and its profit over 12 hours' time period. The profit is found to be enhanced from the graphical observation. Figure 4 and Figure 5 gives a comparative analysis from the optimum allocation of the PBUC schedule.

Table 2. Input Parameters of EHO

Population size	30
No. of Generations	50
α	0.5
β	0.1
Clan number	5
Number of the elephants in each clan	10

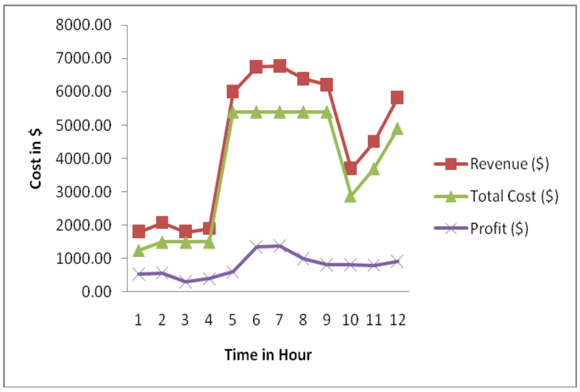

Figure 3. Performances of Total cost, Revenue, and Profit in GENCO-I

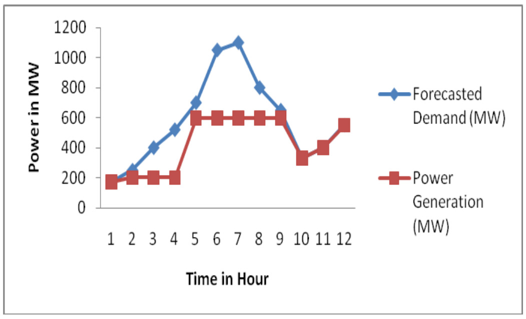

Figure 4. Comparison between power demand and power generation

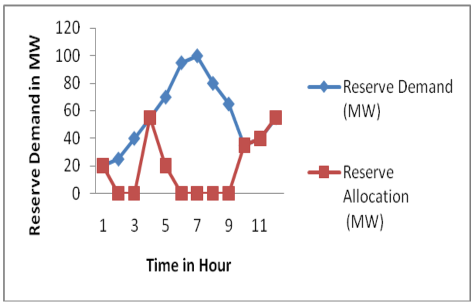

Figure 5. Comparison between Reserve power demand and reserve allocation

Table 4 provides a comparison between profits obtained with other optimization methods like LR-EP, MPPD-ABC, MMA.

Table 4. Profit comparison between proposed methods and existing methods for GENCO-I

S. No	Scheme	Profit ($)
1	Swarup et.al	9136
2	K Asokan et.al	9457.50
3	A. Amudha et.al	9168
4	EHO Method	9735.5

Table 3. Optimum Allocation of GENCO-I (3 units 10 Bus System)

Hour	Forecasted Demand (MW)	Power Generated (MW)	Forecasted spot Price ($/MW-hr)	Reserve Demand (MW)	Allocated Reserve (MW)	Total Cost ($)	Revenue ($)	Profit ($)	Profit (Rs)
1	170	170	10.55	20	20	1253.50	1793.50	540.00	37530.00
2	250	200	10.35	25	0	1500.00	2070.00	570.00	39615.00
3	400	200	9.00	40	0	1500.00	1800.00	300.00	20850.00
4	520	200	9.45	55	55	1500.00	1890.00	390.00	27105.00
5	700	600	10.00	70	20	5400.00	6000.00	600.00	41700.00
6	1050	600	11.25	95	0	5400.00	6750.00	1350.00	93825.00
7	1100	600	11.30	100	0	5400.00	6780.00	1380.00	95910.00
8	800	600	10.65	80	0	5400.00	6390.00	990.00	68805.00
9	650	600	10.35	65	0	5400.00	6210.00	810.00	56295.00
10	330	330	11.20	35	35	2882.25	3964.00	1081.75	75181.63
11	400	400	10.75	40	40	3700.00	4500.00	800.00	55600.00
12	550	550	10.60	55	55	4906.25	5830.00	923.75	64200.63
					Total	**53977.50**	**44242.00**	**9735.5**	**676617.25**

5.2 GENCO-II (10 units 24-hr schedule)

Table 5 gives the system working information and the power demand data for 10 units' system. The ramp rate limits are calculated by using eqn.11 and 12. With this ramp limit, the continuous load scheduling for PBUC problem can be obtained under the deregulated power market.

Table 6 gives the optimum load dispatch schedule of the GENCO-II with total operating costs, revenue, and profit over a period of 24 hours. GENCO-II receives high profit even though only a few units are operating at a particular period. Figure 6 and Figure 7 show comparisons of various test results provided in Table 6. From Table 7, it can be observed that the total cost

Table 5. Unit cost and performance data of GENCO-II

Parameter	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
P_{mn} (MW)	455	455	130	130	162	80	85	55	55	55
P_{mx} (MW)	150	150	20	25	25	20	25	10	10	10
a (constant)	0.00048	0.00031	0.00200	0.00211	0.00398	0.00712	0.00079	0.00413	0.00222	0.00173
b (linear)	16.19	17.26	16.60	16.50	19.70	22.26	27.74	25.92	27.27	27.79
c (quadratic)	1000	970	700	680	450	370	480	660	665	670
Up / downtime	8/8	8/8	5/5	/55	6/6	3/3	3/3	1/1	1/1	1/1
Rampup/ down	40/60	62/73	75/91	51/109	133/142	119/257	270/276	51/83	158/145	152/90
Startup cost ($)	4500	5000	550	560	900	170	260	30	30	30
Initial Status	8	8	-5	-5	-6	-3	-3	-1	-1	-1

Table 6. Operating costs, Revenue and Profit for GENCO-II

Time (Hour)	Power Demand (MW)	Generated Power (MW)	Reserve Demand (MW)	Allocated Reserve (MW)	Forecasted Spot Price ($/MW)	Startup Cost($)	Total operating Cost ($)	Revenue ($)	Profit ($)
1	700	700	70	70	22.15	0	15246	17056	1810
2	750	750	75	75	22.00	0	15864	18150	2286
3	850	850	85	60	23.10	0	17353	21021	3668
4	950	910	95	0	22.65	0	17353	20364	3011
5	1000	910	100	0	23.25	0	17353	21158	3805
6	1100	1040	110	0	22.95	1120	20214	23868	3654
7	1150	1150	115	0	22.50	1100	22709	24756	2047
8	1200	1170	120	0	22.15	0	23106	27344	4238
9	1300	1300	130	0	22.80	1800	26184	29640	3456
10	1400	1400	140	120	29.35	340	29048	41442	12394
11	1450	1412	145	0	30.15	0	29048	42572	13524
12	1500	1412	150	0	31.65	0	29048	44690	15642
13	1400	1400	140	120	24.60	0	29048	36953	7905
14	1300	1300	130	0	24.50	0	26184	31850	5666
15	1200	1170	120	0	22.50	0	23106	26325	3219
16	1050	1050	105	105	22.30	0	22809	26091	3282
17	1000	1000	100	100	22.25	0	20214	23366	3152
18	1100	1040	110	0	22.05	0	20214	22392	2178
19	1200	1040	120	0	22.20	0	20214	23088	2874
20	1400	1040	140	0	22.65	0	20214	23556	3342
21	1300	1040	130	0	23.10	0	20214	24024	3810
22	1100	1040	110	0	22.95	0	20214	23868	3654
23	900	900	90	10	22.75	0	17353	20703	3350
24	800	800	80	80	22.55	0	16827	19844	3017
					Total	**4360**	**519137**	**634121**	**114984**

and profit of the EHO based on PBUC solution for GENCO-II are higher than those of the conventional existing methods.

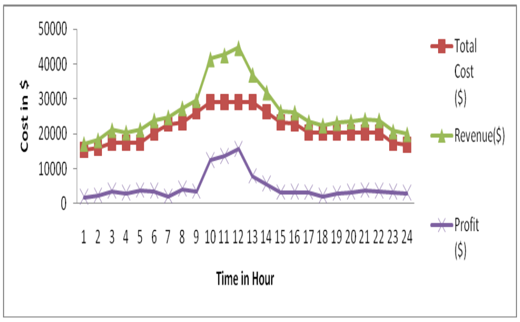

Figure 6. Comparison of Total cost, revenue and profit of 3 units' 24-hours

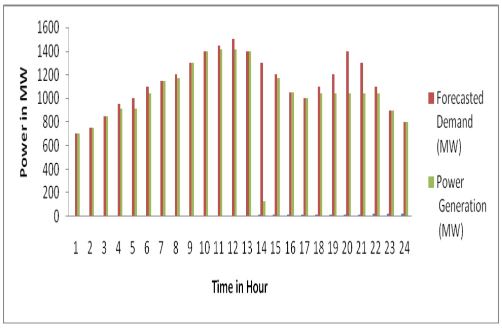

Figure 7. Comparison of demand & generation for 24 hours

Table 7. Comparison of total cost and profit with existing search methods for PBUC

S. No	Authors	Total Cost ($)	Profit ($)
1	Tim & Sheble	623441	27889
2	Kazarlis et.al	610500	40830
3	Swarup et. al	609023	42306
4	Ganguly et. al	591715	59615
5	Logavani et.al	581541	69788
6	PBUC-EHO (Proposed)	519137	114984

6. Conclusion

In this article a new meta-heuristic approach, the Elephant Herding optimization algorithm is utilized to get solution for the PBUC problem under deregulated power marketplace. This works on grouping behavior of the elephants in the clan. Based on the exploration and exploitation operator of the Elephant clan, PBUC solution procedure was developed using the EHO algorithm. This makes way for extensive simulation experiment for various economic conditions. The numerical outcomes are presented with reference to the solution excellence and its features of various EHO algorithms. EHO algorithms optimally allocate the generators to evaluate the fitness value of the objective function (Profit Maximization) in a balanced and oscillated power market. The numerical results are tested on a proposed system which includes optimum UC schedule, power generation total cost, startup cost, revenue, and profit. The comparative study is also done with other benchmark existing approaches. From the solution, it is evident that the proposed elephant herding algorithm has more ability, accuracy, robustness with less computational time for the solution of power system optimization problem in a deregulated open pool market. Future enrichment of this work will concentrate on the performance improvement in a large power system with reserve uncertainty and sensitivity for reserve changes.

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