ISSN- 2394-5125 VOL 05, ISSUE 01, 2018

An Effective ALO algorithm-based Profit Based Unit Commitment for GENCOs under Deregulated environment

M. VEERAPAN, N. MOHANDAS

[1]Lecturer, Department of Electrical and Electronics Engineering,Government Polytechnic College,
Gandharvakottai, Tamilnadu, India
[2]Lecturer, Department of Electrical and Electronics Engineering,Government Polytechnic College,Srirangam, Tamilnadu, India

Abstract: The global deregulation of power system introduces competition among the power producers. It improves the efficiency and reliability of power generation at cheaper cost. Better opportunities of financial resources are created in the energy market and many power companies are growing by their proper objectives, roles and utilities. It becomes possible for independent power producers to maximize generation company profit and toparticipate in the electricity market. The generation company adopts Unit Commitment for maximizing their own profit instead of minimizing the total generation cost of theconventional unit commitment. Profit Based Unit Commitment (PBUC) is defined as a method which schedules their generators economically based on forecasted information such as the spot price and demand.

In this article, an intelligent computational algorithm of the Ant Lion Optimizer (ALO) is proposed to solve the PBUC problem in deregulated power system subjected to standard operating constraints. The proposed method has been tested on the IEEE 39 bus (10 units with 24 hours) test system. The ALO algorithm effectively optimizes the thermal variables and determines the best solutions of real power generation, fuel cost, revenue and profit of generation companies (GENCOs). Finally, the simulation results are compared with other available methods to validate the performance of the ALO algorithm.

Keywords:*Deregulation, Generation Company, Unit Commitment, Profit maximization, ALO algorithm.*

1. Introduction:

In the electrical power-supply industry around the world has experienced a period of rapid and critical changes regarding the way electricity is generated, transmitted, and distributed. The need for more efficiency in power production and delivery has led to privatization, restructuring, and, finally, deregulation of the power sectors in several countries traditionally under control of federal and state governments [1]. In any re-structured or deregulated power industry the pool implements a power action based on a unit commitment model reported in [2].

The researches have been projected various mathematical and soft computing techniques to solve the PBUC problem. The mathematical methods are Lagrangian relaxation [3], Mixed-integer programming [4], Muller method [5, 6] and Tabu search [7] were widely used to solve the PBUC problem. The classical methods involve huge computational time and suffer from convergence and always get stuck into a local optimum to obtain the solution because of its complex dimensionality with large number of generating units.The author presented a GA solution to the price based unit commitment problem in [8]. An innovative method based on an advanced memetic algorithm (MA) for the solution of price based unit commitment (PBUC) problem is listed in [9]. The authors' proposed an algorithm to solve the profit based unit commitment problem with operational constraints in a restructured power system using particle swarm optimization [10].

The authors proposed a Hybrid LR-EP algorithm for helping GENCO decide how much power and reserve should be sold in energy and ancillary markets in order to receive the maximum profit in [11].The authors' presented a parallel artificial bee colony (ABC) algorithm using a message passing interface protocol in both distributed and shared memory models [12]. A simple and reliable approach of pre-prepared power demand (PPD) table with an ABC algorithm have been used to solve the PBUC problem presented in [13]. A binary fish swarm algorithm (BFSA) and dynamic economic dispatch (DED) method was used to solve PBUC problem [14] taking into account power and reserve generations simultaneously in a day-ahead competitive electricity markets. The PBUC problem also analysed [15] using LR combined with ABC algorithm. The proposed methodology provides better solutions compared with existing methods. Here the multiplier is updated by proper tuning of ABC algorithm.

ALO is modelled based on the unique hunting behaviour of ant lions. There are five main steps of the algorithm such that random walk of ants, building traps, entrapment of ants in traps, catching preys, and re-building traps in [16]. The application of ALO algorithm has presented for the solution of non-convex and dynamic economic load dispatch problem of electric power system in [17]. The ALO algorithm has been successfully implemented with Loss Sensitivity Factors for optimal location and sizing of DG based renewablesources in various distribution systems [18]. The optimal power flow (OPF) is optimized using the novel meta-heuristic optimizationalgorithm ant lion optimizer reported in [19].

In this article, the Profit Based Unit Commitment (PBUC) problem is described under deregulated environment. A simple and reliable approach of ALO algorithm is proposed to solve the PBUC problem. The devised algorithm finds the most economical scheduling plan for GENCO by considering power generation. To demonstrate the effectiveness and applicability of this method, it has been tested on ten units 24 hour test systems.

2. PBUC problem:

The objective is to determine the generating unit schedules for maximizing the profit of Generation Companies subject to all prevailing constraints such as load demand, spinning reserve and market prices. The term profit is defined as the difference between revenue obtained from sale of energy with market price and total operating cost of the generating company.

Objective Function:

The PBUC problem can be mathematically formulated by the following equations.

$$Maximize \quad PF = RV - TC \quad (1)$$

$$RV = \sum_{t=1}^{T}\sum_{i=1}^{N} P_{it}.SP_t.U_{it} \quad (2)$$

$$TC = \sum_{t=1}^{T}\sum_{i=1}^{N} F(P_{it}).U_{it} + ST.U_{it} \quad (3)$$

Where *PF* is the total profit ($), *RV* is the total revenue ($) and *TC* is the total cost ($).

The total operating cost, over the entire scheduling period is the sum of production cost and start-up/shutdown cost for all the units.The production cost of the scheduled units is given in a quadratic form.

$$Min\ .F_{it}(P_{it}) = a_i + b_i P_{it} + c_i P_{it}^2 \quad (4)$$

Constraints

1. Load demand constraint

$$\sum_{i=1}^{N} P_{it} X_{it} \le P_{Dt} \qquad 1 \le i \le N \quad (5)$$

2. Generator limits constraint

$$P_i^{\min} \le P_i \le P_i^{\max} \qquad 1 \le i \le N \quad (6)$$

3. Spinning reserve constraint

$$\sum_{i=1}^{N} R_{it} X_{it} \le SR \quad 1 \le t \le T \quad (7)$$

4. Minimum up/down time constraints

$$\begin{aligned} Ton_i &\ge Tup_i, & i = 1.........N \\ Toff_i &\ge Tdown_i, & i = 1.........N \end{aligned} \quad (8)$$

3. SOLUTION METHODOLOGY:

3.1 Ant Lion Optimizer (ALO) :

Ant Lion Optimizer (ALO) is a novel nature-inspired algorithm presented by Mirjalili in 2015 [16]and used to solve the several engineering constrained and non-constrained optimization problems. The ALO algorithm mimics the interaction between ant lions and ants in the trap. It is inspired by the life cycle of Antlions (doodlebugs) which belong to the Myrmeleontidae family and Neuroptera order (net-winged insects).

The ALO algorithm mimics the hunting method of antlions (doodlebugs) and is based on the following steps of hunting:

- Random walks of ants
- Trapping in antlion's pits
- Building trap
- Sliding ants towards antlion
- Catching prey and re-building the pit
- Elitism

Further, the mathematical functions of proposed ALO approach has been formulated as follows

Random walks of ants

The ants move stochastically in nature when searching for food, a random walk is chosen for modelling ants' movement as follows:

$$X(t)=[0,cumsum(2r(t_1)-1), cumsum(2r(t_2)-1),\ldots,cumsum(2r(t_n)-1)] \quad (9)$$

Wherecumsum calculates the cumulative sum, n is the maximum number of iteration, t shows the step of random walk (iteration in this study), and r(t) is a stochastic function represented as follows:

$$r(t) = \begin{cases} 1 \ if \ rand > 0.5 \\ 0 \ if \ rand \leq 0.5 \end{cases} \quad (10)$$

where *t* shows the step of random walk (iteration in this study) andrand is a random number generated with uniform distribution inthe interval of [0, 1].

In order to keep the random walks of ants inside the search space, the positions of their walks are normalized using the min–max normalization equation:

$$X_i^t = \frac{(X_i^t - a_i)\times(d_i - c_i^t)}{(d_i^t - a_i)} + c_i \quad (11)$$

Trapping in antlion's pits

The random walks of ants are affected by antlions' traps; the mathematical equation of trapping of ants in antlion's pits can be formulated as follows:

$$c_i^t = Antlion_j^t + c^t \quad (12)$$

$$d_i^t = Antlion_j^t + d^t \quad (13)$$

where $c^t$is the minimum of all variables at *t-th* iteration, d^tindicates the vector including the maximum of all variables at *t-th* iteration.

Building trap

In order to analysis the hunting capability of antlion, a roulette wheel is used. The ants are assumed to be trapped in only one selected antlion. During an optimization, the ALO algorithm is necessary to use a roulette wheel operator for selecting antlions based on their fitness. This process gives high probability to the fitter antlions for catching ants.

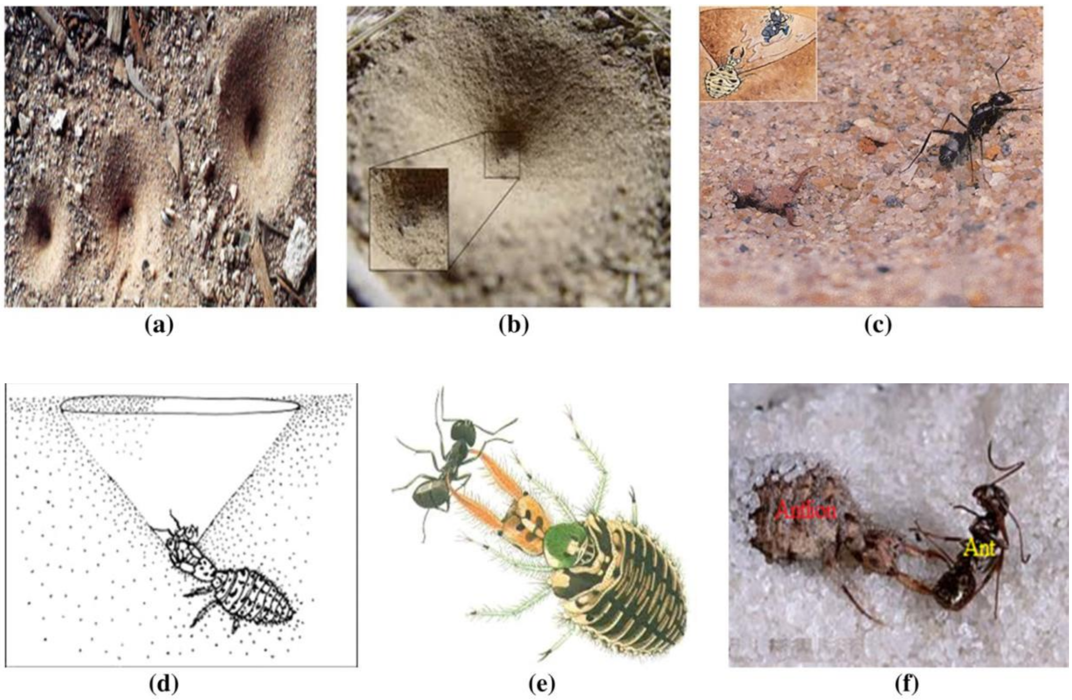

Fig. 1. a–c. building traps and entrapment of ants in traps;
d–f. catching the prey and re-building traps

Sliding ants towards antlion

The sliding ants towards antlion can be mathematicallydefines as

$$c^t = \frac{c^t}{I} \qquad (14)$$

$$d^t = \frac{d^t}{I} \qquad (15)$$

Catching prey and re-building the pit

Catching the ants by antlion and re-building the pit can be formulated as follows

$$\text{Antlion}_i^t = Ant_i^t \, if \; f(Ant_i^t) > f(Antlion_i^t) \qquad (16)$$

Elitism

Elitism is a significant function of evolutionary algorithms for stopping the program. It allows maintaining the finest solution(s) getting at any stage of optimization procedure. In

ISSN- 2394-5125 VOL 05, ISSUE 01, 2018

this problem, the best antlion obtained in all iteration and is saved also it's considered as elite. The elitism operation can be performed by using the following equation,

$$Ant_i^t = \frac{R_A^t + R_E^t}{2} \quad (17)$$

4. Simulation results

To confirm the effectiveness of the proposed ALO algorithm based Profit based unit commitment approach has been tested ona 10 unit system with 24 hour scheduling periods. The proposed ALO algorithm is developed and executed using the MATLAB software. The first important aspect of this algorithm is to assign the number of search agents (population) = 40 and maximum number of iterations = 500 of this system. The fuel data and power demand from 10 unit system are taken from the reference [6].The main objective of this approach is to maximize the profit of generation companies with constraints.The reserve power generation is not considered in the proposed work;conversely the constraints are included in [6] and taken for comparison purposes.The maximum profit obtained by this approach 105,879 $ and the power dispatch of 10 unit system is given in Table 1.

From this table, it is observed that the power dispatch of generating units 7 to 10 shut off at all dedicated period and to sell less power than the forecast for some periods. The proposed result of maximum profit value is compared with tabu search (TS) and Muller methods. The superiority of the proposed method is shown in Table 2. The obtained result of total profit using this approach is slightly 2.5 % higher than the Muller method.

Table 1 Simulation results for ten unit 24 hour system using ALO algorithm

Hour	**P_D (MW)**	**Power Generations (MW)**										**Fuel Cost($)**	**Start Up cost ($)**	**Revenue ($)**	**Profit ($)**
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10				
1	700	455	245	0	0	0	0	0	0	0	0	13683	0	15505	1822
2	750	455	295	0	0	0	0	0	0	0	0	14554	0	16500	1946
3	850	455	395	0	0	0	0	0	0	0	0	16302	0	19635	3333
4	950	455	455	0	0	0	0	0	0	0	0	17353	0	20612	3259
5	1000	455	415	130	0	0	0	0	0	0	0	19544	1100	23250	2606
6	1100	455	385	130	130	0	0	0	0	0	0	21879	1120	25245	2246
7	1150	455	435	130	130	0	0	0	0	0	0	22755	0	25875	3120
8	1200	455	455	130	130	0	0	0	0	0	0	23106	0	25916	2810
9	1300	455	455	130	130	130	0	0	0	0	0	26184	1800	29640	1656
10	1400	455	455	130	130	162	0	0	0	0	0	26851	0	39094	12242
11	1450	455	455	130	130	162	80	0	0	0	0	29048	340	42572	13184
12	1500	455	455	130	130	162	80	0	0	0	0	29048	0	44690	15642
13	1400	455	455	130	130	162	68	0	0	0	0	28768	0	34440	5672
14	1300	455	455	130	130	130	0	0	0	0	0	26184	0	31850	5666
15	1200	455	455	130	130	0	0	0	0	0	0	23106	0	26325	3219
16	1050	455	335	130	130	0	0	0	0	0	0	21005	0	23415	2410

17	1000	455	415	0	130	0	0	0	0	0	0	19513	0	22250	2737
18	1100	455	455	0	130	0	0	0	0	0	0	20214	0	22932	2718
19	1200	455	455	0	130	0	0	0	0	0	0	20214	0	23088	2874
20	1400	455	455	0	130	0	0	0	0	0	0	20214	0	23556	3342
21	1300	455	455	0	130	0	0	0	0	0	0	20214	0	24024	3810
22	1100	455	455	0	130	0	0	0	0	0	0	20214	0	23868	3654
23	900	455	445	0	0	0	0	0	0	0	0	17178	0	20475	3297
24	800	455	345	0	0	0	0	0	0	0	0	15427	0	18040	2613
Total												512558	4360	622797	**105879**

Table 2 Comparison of total profits of proposed method with the existing methods

Method	Profit($)
TS-RP [6]	101086
TS-TRP [6]	103261
Muller Method [6]	103296
ALO (Proposed method)	**105879**

5. Conclusion:

The ALO algorithm has been developed for the maximization of GENCO profit based on unit commitment. It has been successfully implemented to the 10 units 24 hours system. The numerical examples with IEEE 39 bus test system (10 units 24 hour) are considered to illustrate the better performance of proposed method. The simulation results are carried out on a proposed test system it includes optimum UC schedule, power generation, fuel cost, start-up cost, revenue, and profit.

References:

1. N. P. Padhy, “Unit Commitment—A Bibliographical Survey”, *IEEE Transactions on power systems,* vol. 19, no. 2, pp. 1196-1205, May 2004.
2. N. P. Padhy, “Unit commitment problem under deregulated environment - a review”, *Power Engineering Society General Meeting*, vol. 2, pp. 1088-1094, 2003.
3. T. Shiina and I. Watanabe “Lagrangian relaxation method for price-based unit commitment problem”,*Engineering optimization*, vol. 36, no. 6, pp. 705-719, 2004.
4. C. K. Simoglou, P. N. Biskas, and A. G. Bakirtzis, “Optimal self-scheduling of a thermal producer in short-term electricity markets by MILP”, *IEEE Trans Power Systems*, vol. 25, pp. 1965-77, 2010.
5. K. Chandram, N. Subrahmanyam and M. Sydulu, “Improved Pre-prepared Power Demand Table and Muller’s Method to Solve the Profit Based Unit Commitment Problem.”, *Journal of Electrical Engineering & Technology*, vol. 4, no. 2, pp. 159-167, 2009.

6. K. Chandram, N. Subramanian and M. Sydulu. "New approach with Muller method for profit-based unit commitment", *Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century IEEE*, pp. 1-8, 2008.
7. T. A. A Victoire, A. E. Jeyakumar, "Unit commitment by a tabu search-based hybrid optimization technique", *IEE Proceedings Generation. Transmission & Distribution,* vol. 152, no. 4, pp. 563-574, 2005.
8. P. S. Georgilakis, "Genetic algorithm model for Profit maximization of generating companies in deregulated electricity markets", *Applied Artificial Intelligence*, vol. 23, pp. 538-552, 2009.
9. D. K. Dimitroulas, and P. S. Georgilakis, "A new memetic algorithm approach for the price based unit commitment problem", *Applied Energy,* vol. 88, no. 12, pp. 4687-4699, 2011.
10. I. J. Raglend, C. Raghuveer, G. R. Avinash, N. P. Padhy, and D. P. Kothari, "Solution to profit based unit commitment problem using particle swarm optimization", *Applied Soft Computing,* vol. 10, no. 4, pp. 1247-1256, 2010.
11. P. Attaviriyanupap, H. Kita, E. Tanaka, and J. Hasegawa, "A Hybrid LR–EP for Solving New Profit-Based UC Problem Under Competitive Environment", *IEEE Transactions on power systems,* vol. 18, no. 1, pp. 229-237, 2003.
12. C. C. Columbus and S. P. Simon, "Profit based unit commitment: A parallel ABC approach using a workstation cluster", *Computers and Electrical Engineering,* vol. 38, no. 3, pp. 724-745, 2012.
13. K. Asokan, and R. Ashokkumar, "A Simple Approach for Optimal Generation Scheduling to Maximize GENCOs Profit Using PPD Table and ABC Algorithm under Deregulated Environment", *International Journal of Applied Power Engineering,* vol. 2, no. 3, pp. 125-140, 2013.
14. P. K. Singhal, R. Naresh and V. Sharma, "Binary fish swarm algorithm for profit-based unit commitment problem in competitive electricity market with ramp rate constraints", IET Generation, Transmission & Distribution, vol. 9, no. 13, pp. 1697-1715, 2015.
15. R. Ashokkumar, K. Asokan and S. Ranjith Kumar "Optimal Scheduling of Generators to Maximize GENCOs profit using LR combined with ABC Algorithm in Deregulated Power System" *IEEE Conference Preceding,* pp. 75-83,April 2013.
16. S. Mirjalili, "The Ant Lion Optimizer", *Advances in Engineering Software,* vol. 83, pp. 80-98, 2015.
17. V. K. Kamboj, A. Bhadoria, and S. K. Bath, "Solution of non-convex economic load dispatch problem for small-scale power systems using ant lion optimizer", *Neural Computing and Applications,* pp. 1-12, 2017.
18. E.S. Ali, S.M. Abd Elazim, and A.Y. Abdelaziz, "Ant Lion Optimization Algorithm for optimal location and sizing of renewable distributed generations", *Renewable Energy,* vol. 101, pp. 1311-1324, 2017.
19. I. N. Trivedi, P. Jangir and S. A. Parmar, "Optimal power flow with enhancement of voltage stability and reduction of power loss using ant-lion optimizer", *Cogent Engineering,* vol. 3, no. 1, pp. 1-18, 2016.

ISSN- 2394-5125 VOL 05, ISSUE 01, 2018