Economic Load Dispatch Using Ant Lion Optimization

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Abstract

Ant Lion Optimization (ALO) is recently developed search algorithm. It is a nature inspired and population based algorithm .The inspiration of this algorithm is taken by the hunting process of ant lion in nature. Ant Lion uses mainly five steps for hunting prey, which includes the random walk of ants, build a trap, entrap ants , catch preys, and re-build traps. This paper presents Ant Lion Optimization (ALO) method for solution of Economic load dispatch problems. The prime intend of Economic load dispatch (ELD) is to minimize total cost of generation with the given operating constraints. This proposed method is tested with 3, 6 and 20 units for solving the ELD. Results show that given technique gives good convergence property and precise solution of ELD problems

Keywords - *Ant Lion optimization (ALO), Economic Load Dispatch (ELD), Population-based algorithm*

I. INTRODUCTION

In recent power system many generating units are used like thermal, hydro, nuclear etc solely or in hybrid mode. During real-time operation, a hybrid power system should be controlled to minimize operating cost, satisfy demands within the given constraints. The major significance of ELD is to cut down fuel cost of generators, meanwhile satisfying equality and inequality constraints [1].

The conventional methods to solve the economic load dispatch are limited for linear characteristics of generator, where cost function is represented by single quadratic function. For linear cost function lambda iteration method, dynamic-programming, gradient-based methods etc, gives the good results. Due to number of constraints and nonlinear characteristics of ELD problems, these calculus based methods cannot perform satisfactorily and generally offers local optimum point only. By these conventional methods it is difficult to handle nonlinearities of economic load dispatch problems. Therefore new numerical approaches are needed to cope-up with these difficulties.

Economic load dispatch solutions, with quadratic cost functions, can be solved by an improved Genetic algorithm (IGA). In order to improve the effectiveness of GA, multi-stage algorithm and directional crossover methods are given to satisfy linear equality constraints from power balance [8]. To solve the ELD problems a real coded GA has also been proposed [9].

In recent years several artificial intelligence techniques are developed which are basically nature based optimization techniques. These nature based methods are capable enough to overcome the shortcoming of conventional and traditional methods. Particle swarm optimization (PSO) is also one of the meta–heuristic optimization technique to solve ELD problems [2][3]. A variety of Hopfield's models [4] have been employed for solving ELD problems. Recently a two phase neural network (TPNN) [5] has been proposed which deals with all the constraints in real time and can be realized in hardware for faster operation. The biogeography based optimization (BBO) method, by modifying its migration models, can make it more realistic. This BBO technique can be applied for simple economic load dispatch (ELD) problem and ELD with valve point effect, to analyze the effect of different migration models [6].The combination of biogeography-based optimization (BBO) and particle swarm optimization (PSO) [11] algorithm can be used to solve constrained economic load dispatch (ELD) problems in power system. Different constrained can be considered like valve point loading of generators, prohibited operating zones, ramp rate and spinning reserve.PSO is a popular and robust evolutionary algorithm for solving global optimization problems, whereas BBO is a new biogeography enthused algorithm. The combine use of PSO and BBO (HPSOBBO) is given to improve the speed of convergence and quality of solution. This method also produces stable convergence characteristic and avoids premature convergence [7].

The economic load dispatch (ELD) is an important aspect in power system operation and control. Different techniques have been used to solve these problems. Recently, the soft computing techniques are widely used in practical applications. Reference[10] gives the successful implementation of four evolutionary algorithms, namely particle swarm optimization (PSO), [16] particle swarm optimization with constriction factor approach (PSOCFA), particle swarm optimization with inertia weight factor approach (PSOIWA) and particle swarm optimization with constriction factor and inertia weight factor approach (PSOCFIWA) are used for economic load dispatch problem. Here prohibited zone and ramp-rate limit constraints are considered to solve this problem. Power output of each generating unit and optimum fuel cost obtained using all four algorithms have been compared.

II. PROBLEM FORMULATION

Economic load dispatch (ELD) is one of the basic requirement of modern energy management system, which determines the optimal real power setting of generating units, with an objective to minimize total fuel cost of thermal plants. Equation (1) represents the objective function which is needed to be minimized.

$$F(P_g)= \sum_{i=1}^{N} \left(a_i P_{gi}^2 + b_i P_{gi} + c_i \right) \qquad (1)$$

F (P_g) is the total cost function of generators; P_{gi} is the real power output of ith generator, N is the number of generators used. In equation (1) a_i, b_i and c_i are the cost coefficients of fuel of the ith generating unit.

To minimize total fuel cost the following constraints are required to be implemented.

A. Power balance constraint

Power should be balanced in the system in such a manner that total power of each generating unit must be equal to the losses and the total power demand, which is given by the equation (2).

$$\sum_{i=1}^{N} P_{gi} - \left(P_D + P_L \right) = 0 \qquad (2)$$

Where P_{gi} is the output power of unit i (MW), P_L is the total network loss of the system (MW) and P_D is the total load demand of the system (MW), N is the number of online generating units.

B. Generator limit constraint

As per equation (3) the real power generation of each generator is to be controlled within its particular lower and upper operating limits

$$P_{gi}\, min \leq P_{gi} \leq P_{gi}\, max \quad i = 1, 2 \ldots N \qquad (3)$$

III. ANT LION OPTIMIZATION

Ant Lion Optimization (ALO) [12] is recently projected technique. It is life cycle population based nature inspired search algorithm. The ALO algorithm inspired by the hunting technique of Ant Lions (doodlebug), in nature which belongs to the Myrmeleontid family. Ant Lions comprises two main stage of life: larvae and adult. Usually life of Ant Lion can be considered up to 3-4 years, which is mainly spent in larvae stage. They usually hunt in the stage of larvae and the adulthood period is for reproduction. Ant Lion uses mainly five steps for hunting prey, which includes the random walk of ants, build a trap, entrap ants, catch preys, and re-build traps[15].

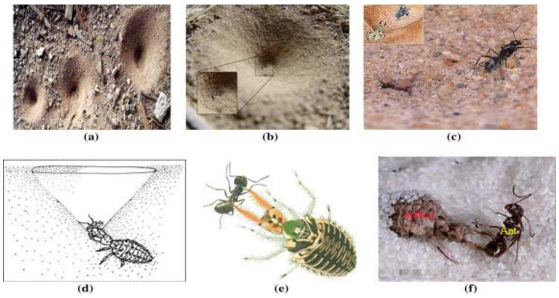

Fig. 1 a–c construction traps and set-up of ants in traps; d–f infectious the prey and reconstruction traps

The building traps and entrapment of ants in traps are show in Fig.1a–c and the process of catching the prey and re-building traps are shown in Fig. 1d–f [13].The mathematical model of ant lion optimizer algorithm can be explained with the help of following steps.

A. Random Walk of Ants

An ant's move stochastically in nature while searching for food, the random/stochastic walks of ants can be described as in equation (4).

$$X_{RW(t)}=[cumsum(2r(t1)-1);cumsum(2r(t2)-1); \ldots\ldots cumsum(2r(t_{Itermax})-1)-1] \qquad (4)$$

Where $X_{RW(t)}$ is the random walks of ants, cumsum is the cumulative summation, Itermax is the maximum iteration, **t** is step of random walk, and r(t) is a function which can be given by equation (5)

$$r(t) = \begin{Bmatrix} 1 \text{ if } rand > 0.5 \\ 0 \text{ if } rand \leq 0.5 \end{Bmatrix} \qquad (5)$$

In equation (5) **t** is step of random walk and *rand* is a random number generated with uniform distribution in the interval of [0, 1] [14].

In order to keep the random walks of ants inside the search space, the positions of their walks is normalized using the min–max normalization as per equation (6)

$$X_i^t = \frac{(X_i^t - a_i) * (d_i - c_i^t)}{(d_i^t - a_i)} + c_i \qquad (6)$$

Where a_i is the minimum of random walk of i-th variable, c_i^t is the minimum of ith variable at tth iteration, and d_i^t indicates the maximum of ith variable at tth iteration.

B. Trap of Ant Lion's pits

As random walks of ants are affected by antlions' traps, the Mathematical formulation of trapping of ants in antlion's pits can be described by Equation (7) and (8) as:

$$C_i^t = Antlion_j^t + C^t \qquad (7)$$

$$d_i^t = Antlion_j^t + d^t \qquad (8)$$

Where C^t is the minimum of all variables at tth iteration, C_i^t is the minimum of all variables for ith ant, d^t indicates the vector including the maximum of all variables at tth iteration, d_i^t is the maximum of all variables for i^{th} ant, and Ant Lion shows the position of the selected j^{th} Ant Lion at t^{th} iteration.

Building trap and sliding ants toward Ant Lion, Roulette wheel concept is used to model the Ant Lion's capability of hunting. The sliding of ants toward Ant Lion can be given as equation (9) and (10).

$$C^t = C^t/I \qquad (9)$$

$$d^t = d^t / I \qquad (10)$$

Where I is the ratio, C^t is the minimum of all variables at t^{th} iteration and d^t is the vector including the maximum of all variable at the t^{th} iteration.

C. Catch Prey and rebuild the pit

The final stage of hunt is when an ant reaches the bottom of the pit and is caught in the Ant Lion's jaw. After this, the Ant Lion tries to pull down the ant inside the sand layer and eat its body. For imitate this procedure, it is supposed that grab prey occur when ants becomes fitter (inside sand) than its corresponding Ant Lion.

Now Ant Lion is requisite to revise its position to the latest position of the hunted ant to improve its chances of catch the new prey. Equation (11) proposed in this regard is

$$Antlion_j^t = Ant_j^t \quad If\ f(Ant_j^t) > f\ (Antlion_j^t\ ) \qquad (11)$$

Where't' shows the current iteration, $Antlion_j^t$ shows the position of selected j^{th} Ant Lion at t^{th} iteration and Ant_j^t shows the position of i^{th} ant at t^{th} iteration.

D. Elitism

Elitism is also one of significant point of evolutionary algorithms that permit them to preserve the best solution(s) obtain at every stage of optimization process. In each iteration the best Ant Lion is obtained and saved as a elite. as the elite be the fittest Ant Lion, it should be clever enough to affect the activities of all the ants throughout all iterations. Therefore, every ant randomly walks around a selected Ant Lion by the roulette wheel and the elite simultaneously as given by equation (12)

$$Ant_i^t = (R_A^t + R_E^t\ )/2 \qquad (12)$$

Where R_E^t is the random walk around the elite at t-th iteration, R_A^t is the random walk around the Ant Lion selected by the roulette wheel at t^{th} iteration and Ant_i^t is the position of i^{th} ant and t^{th} iteration.

IV.RESULTS & DISCUSSIONS

ALO is using to solve the ELD problem. Different cases are being taken into consideration. It is realize on 3, 6 and 20 unit test system where the objective function is limited under the power ranges of the generating units. Number of iteration performed for each test case are 500 and number of search agents (population) taken in each case is 40.

Case-I

Three generating unit test system is given by table-1 and table-2 which shows the optimal fuel cost for 3-unit generating model.

Table-1 Three generating units

Units	a_i	b_i	c_i	P_{gi}^{min}	P_{gi}^{max}
1	0.0354	38.3055	1243.531	35	210
2	0.0211	36.3278	1658.569	130	325
3	0.0179	38.2704	1356.659	125	315

Table-2 Economic Load Dispatch 3-units

Power Demand	**450**	**550**	**650**	**750**	**850**
P1	86.474	107.98	129.48	150.98	210
P2	192.1	228.22	264.34	300.45	325
P3	171.43	213.81	256.19	298.57	315
Cost Rs/Hr.	**22683.15067**	**27203.22387**	**31875.78474**	36700.83329	**41743.22935**

Case-II

Six generating unit test system is given by table-3 and table-4 which shows the optimal fuel cost for 6-unit generating model.

Table- 3 Six generating units

Units	a_i	b_i	c_i	P_{gi}^{min}	P_{gi}^{max}
1	0.15240	38.53973	756.79886	10	125
2	0.10587	46.15916	451.32513	10	150
3	0.02803	40.39655	1049.9977	35	225
4	0.03546	38.30553	1243.5311	35	210
5	0.02111	36.32782	1658.5596	130	325
6	0.01799	38.27041	1356.6592	125	315

Table-4 Economic Load Dispatch 6-units

Power Demand	**450**	**550**	**650**	**750**	**850**	**950**
P1	15.513	19.297	23.082	26.866	30.65	34.306
P2	0	10	10	10	10	13.398
P3	51.226	71.799	92.374	112.95	133.52	153.4
P4	69.974	86.239	102.5	118.77	135.03	150.74
P5	164.39	191.7	219.02	235.08	273.66	300.05
P6	138.9	170.96	203.02	235.08	267.13	298.1
Cost Rs/Hr.	**24825.63943**	**29210.12599**	**33709.95554**	**38325.12808**	**43055.64362**	**47900.21296**

Case-III

Twenty generating unit test system is given by table-5 and table-6 which shows the optimal fuel cost for 20-unit generating model.

Table-5 Twenty generating units

Units	a_i	b_i	c_i	P_{gi}^{min}	P_{gi}^{max}
1	0.00068	18.19	1000	150	600
2	0.00071	19.26	970	50	200
3	0.00650	19.80	600	50	200
4	0.00500	19.10	700	50	200
5	0.00738	18.10	420	50	160
6	0.00612	19.26	360	20	100
7	0.00790	17.14	490	25	125
8	0.00813	18.92	660	50	150
9	0.00522	18.27	765	50	200
10	0.00573	18.92	770	30	150
11	0.00480	16.69	800	100	300
12	0.00310	16.76	970	150	500
13	0.00850	17.36	900	40	160
14	0.00511	18.70	700	20	130
15	0.00398	18.70	450	25	185
16	0.07120	14.26	370	20	80
17	0.00890	19.14	480	30	85
18	0.00713	18.92	680	30	120
19	0.00622	18.47	700	40	120
20	0.00773	19.79	850	30	100

Table-6 Economic Load Dispatch 20-units

Power Demand	**2500**	**3500**	**4500**	**5500**
P1	600	600	600	600
P2	180.97	200	200	200
P3	50	67.366	200	200
P4	51.616	135.35	200	200
P5	84.962	155.47	160	160
P6	28.809	94.121	100	100
P7	121.22	125	125	120
P8	50	122.31	150	150
P9	119.98	185.81	200	200
P10	43.752	103.73	150	150
P11	281.51	300	300	300
P12	426.71	500	500	500
P13	112.94	159.87	160	160
P14	88.312	129.6	130	130
P15	58.032	182.54	185	185
P16	38.963	50.714	80	80
P17	32.844	83.111	85	85
P18	44.212	102.1	120	120
P19	55.167	115	120	120
P20	30	87.919	100	100
Cost Rs/Hr.	60169.81149	80086.9533	722828.2125	1722828.212

V. CONCLUSION

This work presented the solution of economic load dispatch problem by using ALO. All the results of 3, 6 and 20 units are presented and their economic loading is also given with their costs. For programming the ALO algorithm MATLAB (2014b) software is used. ALO is a simple, efficient, reliable and precise technique for solving the economic load dispatch problems in power system.

REFERENCES

[1] A.J.WOOD and B.F.Wollenberg, "Power Generation, Operation and Control". New York: Wiley, 1996.

[2] K.T.Chaturvedi,N.P.Patidar,M.Kolhe,T.Khobargade,"Passive Congregation based PSO with self-organizing hierarchical approach for Nonconvex Economic Dispatch", IEEE - 2nd International Conference on Power and Renewable Energy, ICPRE 2017, Chengdu, China, pp. 571-576, Sept 2017..

[3] K.T. Chaturvedi, Ruchi Solanki,N. P. Patidar "A New modified particle swarm Optimization (PSO) Technique for Non - Convex Economic Dispatch" (IOSR – JEEE)2014,pg 81-88.

[4] Ahmed Y, Saber Ganesh and K. Venayagamoorthy, "Economic Load Dispatch using Bacterial Foraging Technique with Particle Swarm Optimization Biased Evolution" 2008 IEEE Swarm Intelligence Symposium St. Louis MO USA, September 21-23, 2008.

[5] R. Naresh, J.Dubey and J.D. Sharma, "Two Phase neural network based frame work modelling of constrained economic load dispatch", IEE proceedings Gener .Ttrans. Dist, Vol. 151, no. 3, 2004, pp 373 -380.

[6] Shivani Kanoongo and Prerna Jain "Biogeography Based Optimization for Different Economic Load Dispatch Problem with Different Migration Models", 2012 IEEE Conference on Electrical, Electronics and Computer Science, IEEE trans. pp: 362-365.

[7] Barun MandaI ,Provas Kr. Roy, and Kesab Bhattacharya "Hybridization of Particle Swarm Optimization with Biogeography Based Optimization to Solve Economic Load Dispatch Considering Spinning Reserve and Other Non-Linerarities" IEEE- International Conference On Advances In Engineering, Science And Management (lCAESM -2012) March 30, 31, 2012 pp: 403-408.

[8] Youssef, H. K., and El-Naggar, K. M., "Genetic based algorithm for security constrained power system economic dispatch", Electric Power Systems Research, Vol. 53, pp. 4751, 2000.

[9] Wei Yan, Fang Liu, C. Y Chung, Member, IEEE, and K. P. Wong, Fellow, IEEE, " A Hybrid Genetic Algorithm–Interior Point Method for Optimal Reactive Power Flow" IEEE transactions on power systems, vol. 21, no. 3, august 2006.

[10] Koustav Dasgupta and Sumit Banerjee, "An Analysis of Economic Load Dispatch with Prohibited Zone and Ramp-rate limit constraints using Different Algorithms", Power and Energy Systems Towards sustainable Energy (PESTSE 2014) IEEE 2014.

[11] Kennedy J, Eberhart R (1995) ''Particle swarm optimization,'' in neural networks, 1995. In: Proceedings, IEEE international conference on, 1995, pp 1942–1948

[12] Mirjalili S. The Ant Lion Optimizer. Adv Eng Softw (2015).

[13] Kamboj, V.K., Bhadoria, A. & Bath, S.K. "Solution of non-convex economic load dispatch problem for small-scale power systems using ant lion optimizer"Springer,Neural Computer & Applications (2017),Issue 8.

[14] Faseela C.K, Dr. Vennila "MERIT ORDER DISPATCH USING ANT LION OPTIMIZATION ALGORITHM "in International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 10, October 2017, pp. 1718–1727

[15] Menakshi Mahendru Nischal, Shivani Mehta " Optimal Load Dispatch Using Ant Lion Optimization"in Journal of Engineering Research and Applications www.ijera.com ISSN: 2248-9622, Vol. 5, Issue 8, (Part - 2) August 2015, pp.10-19.

[16] KT Chaturvedi, M Pandit, L Srivastava "Self-organizing hierarchical particle swarm optimization for nonconvex economic dispatch" in IEEE transactions on power systems 23 (3), 1079-1087. AUGUST 2008