International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.3, 2015

RESEARCH ARTICLE

ISSN: 2321-7758

GREY WOLF OPTIMIZATION FOR SOLVING NON-CONVEX ECONOMIC LOAD DISPATCH

Dr.SUDHIR SHARMA[1],SHIVANI MEHTA[2], NITISH CHOPRA[3]

[1]Associate Professor, [2]Assistant Professor, Student in Master of Technology[3]

Department Electrical Engineering, D.A.V.I.E.T., Jalandhar, Punjab, India

Article Received: 29/04/2015 | Article Revised on:03/05/2015 | Article Accepted on:05/05/2015

ABSTRACT

This paper presents a competent approach for solving non-convex economic load dispatch (ELD) problems in diverse test power systems using grey wolf optimization (GWO) technique. Grey Wolf Optimizer (GWO) is a novel meta-heuristic inspired by grey wolves. The pecking order and hunting method of the grey wolves is imitated in GWO. The proposed technique is implemented on different test systems for solving the ELD with valve point effects. To show the efficiency of GWO to solve ELD problem with valve point effects, results were compared with other existing techniques.

Keywords—Economic load dispatch; GWO & valve point effects

I. INTRODUCTION

One of the main significant issues of power system is economic load dispatch (ELD) optimization problem. The ELD problem is to plan the output power for each devoted generating unit such that the cost of operation is minimized and concurrently, matching power operating limits and load demand. Conventionally the operation of power system is based on minimizing operational cost while satisfying system constraints. The problem is occasionally made simpler by building assumptions like smooth /convex cost curve of generating units, which outcomes in quadratic cost functions for a generator. Actually, ED problem objective function has non-differentiable points because of valve-point effects due to which cost curves are non-linear; therefore, non-smooth cost functions must be included in objective function. Main traditional methods to solve ELD problem include the linear programming method, gradient method, lambda iteration method and Newton's method [1].

In the past years many meta-heuristic techniques such as Genetic algorithm [2,3], Tabu search [4],Evolutionary programming (EP) techniques [5], Differential evolution [6] , particle swarm optimization (PSO) [7-10],gravitational search algorithm (GSA) [11] ,Biogeography based optimization[12], Seeker optimization algorithm [13],Firefly algorithm [14],Simulated annealing (SA)[15],Harmony search[16,17],Shuffled frog leaping algorithm(SFLA) [18],Hybrid genetic algorithm(HGA) [19],Binary bat algorithm[20] etc. have been used to solve ELD with valve loading effect.

Grey wolf optimization (GWO) is a new heuristic algorithm motivated by the social behavior and hunting way of grey wolves has been proposed by Mirjalili et.al.[21].The GWO have been applied effectively to solve diverse nonlinear functions. Results obtained verify the better performance and efficiency of GWO in these problems [21]. In this article, the GWO algorithm has been used to solve economic load dispatch problem with valve-point effect for 13 and 40 units systems. In common terms, the contribution of this article is the novel competent GWO approach for ELD problem with valve-point effect. The obtained results with the GWO algorithm were evaluated and compared with other techniques stated in literature.

II. PROBLEM FORMULATION

The objective function to be minimized for economic load dispatch with valve point effects is given by:

$$F(P_g)=\sum_{i=1}^{n}(a_iP_{gi}^2+b_iP_{gi}+c_i)+\left|d_i\sin(e_i(P_{gi}^{\min}-P_{gi}))\right| \quad (1)$$

where fuel-cost coefficient's of the ith unit are a_i , b_i, and c_i, and d_i & e_i are the fuel-cost coefficient's of the ith unit with valve-point effects[5].

The total fuel cost has to be minimized with the following constraints:

1) Power balance constraint

The sum of power demand (P_d) and power loss (P_l) should be equal to power generation (P_{gi}).

$$\sum_{i=1}^{n}P_{gi}-P_d-P_l \quad ..... (2)$$

The power loss P_l calculated by:

$$P_l=\sum_{i=1}^{n}\sum_{j=1}^{n}P_iB_{ij}P_j+\sum_{i=1}^{n}B_{0i}P_i+B_{00} \quad .... (3)$$

2) Generator limit constraint

Each generator's real power generation is to be controlled within its respective lower operating limits P_{gi}^{min} and upper operating limits P_{gi}^{max}.

$$P_{gi}^{min}\le P_{gi}\le P_{gi}^{max} \quad i=1,2,...,ng \quad .....(4)$$

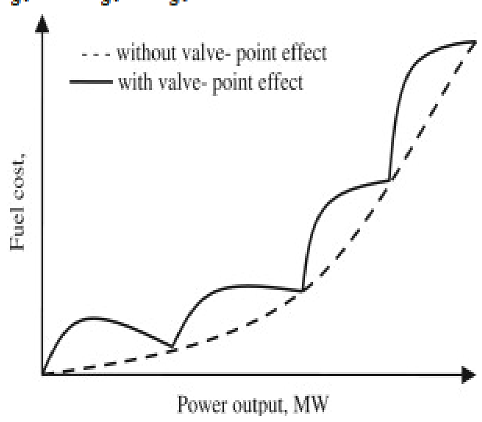

Fig. 2.1 The valve-point effect

III. Grey Wolf Optimization (GWO)

This segment summarizes the key steps in grey wolf optimization (GWO) to solve economic load dispatch .The GWO is proposed by Mirjalili et al., [21]. The algorithm was motivated by the social pecking order and the hunting activities of grey wolves. The leaders of the pack are called alpha (α). The second level of grey wolves, which are subordinate wolves that help the leaders, are called beta (β). Deltas (δ) are the third level of grey wolves which has to submit to alphas and betas, but dominate the omega. The lowest rank of the grey wolf is omega (ω), which have to surrender to all the other governing wolves[22].

In the mathematical model of the social hierarchy of the grey wolves, alpha (α) is considered as the fittest solution. Accordingly, the second best solution is named beta (β) and third best solution is named delta (δ) respectively. The candidate solutions which are left over are taken as omega (ω). In the GWO, the optimization (hunting) is guided by alpha, beta, and delta. The omega wolves have to follow these wolves[22].

The grey wolves encircle prey during the hunt. The encircling behavior can be mathematically modeled as follows[21]:

$$\vec{D}=|\vec{C}.\vec{X}_p(t)-\vec{X}(t)| \quad .... (5)$$

$$\vec{X}(t+1)=\vec{X}_p(t)-\vec{A}.\vec{D} \quad .... (6)$$

Where $\vec{A}$ and $\vec{C}$ are coefficient vectors, $\vec{X}_p$ is the prey's position vector, $\vec{X}$ denotes the grey wolf's position vector and 't' is the current iteration.

The vectors A and C are calculated as follows[21]:

$$\vec{A}=2.\vec{a}.\vec{r}_1.\vec{a} \quad .... (7)$$

$$\vec{C}=2.\vec{r}_2 \quad .... (8)$$

Where values of '$\vec{a}$ 'are linearly reduced from 2 to 0 during the course of iterations and r1, r2 are arbitrary vectors in gap [0, 1].

The hunt is typically guided by alpha, beta and delta, which have superior knowledge about the probable location of victim. The other search agents must revise their positions according to best search agent's position. The update of their agent position can be formulated as follows [21]:

$$\begin{Bmatrix}\vec{D}_\alpha=|\vec{C}_1.\vec{X}_\alpha-\vec{X}|\\ \vec{D}_\beta=|\vec{C}_2.\vec{X}_\beta-\vec{X}|\\ \vec{D}_\delta=|\vec{C}_3.\vec{X}_\delta-\vec{X}|\end{Bmatrix} \quad ... (9)$$

$$\begin{Bmatrix}\vec{X}_1=\vec{X}_\alpha-\vec{A}_1.(\vec{D}_\alpha)\\ \vec{X}_2=\vec{X}_\beta-\vec{A}_2.(\vec{D}_\beta)\\ \vec{X}_3=\vec{X}_\delta-\vec{A}_3.(\vec{D}_\delta)\end{Bmatrix} \quad .. . (10)$$

$$\vec{X}(t+1)=\frac{\vec{X}_1+\vec{X}_2+\vec{X}_3}{3} \quad ... (11)$$

The 'A' is an arbitrary value in the gap [-2a, 2a]. When |A| < 1, the wolves are forced to attack the prey. Attacking the prey is the exploitation ability and searching for prey is the exploration ability. The random values of 'A' are utilized to force the search agent to move away from the prey. When |A| > 1, the grey wolves are enforced to diverge from the prey[22].

IV. RESULTS & DISCUSSIONS

GWO is used to solve the ELD problem with valve point effects for two different test cases. The results have been compared with other methods in literature to show the effectiveness of the GWO. The iterations performed for each test case are 2000 and number of search agents (population) taken in both test cases is 30.

1) Test system I: Thirteen generating units

The input data for thirteen generators is derived from reference [5].The economic load dispatch for 13 generators system is solved with power demand of 1800 MW.

The minimum cost, mean cost and maximum cost among 50 runs of solutions obtained from GWO for test system 1 is given in table 4.1 below.

Table 4.1: Comparison results of GWO for 13-Unit system

Methods	Minimum Cost($)	Mean Cost($)	Maximum Cost($)
CEP[5]	18048.21	18190.32	18404.04
FEP[5]	18018.00	18200.79	18453.82
MFEP[5]	18028.09	18192.00	18416.89
IFEP[5]	17994.07	18127.06	18267.42
PSO[8]	18,030.72	18,205.78	--
GWO	17974.73	18085.49	18213.62

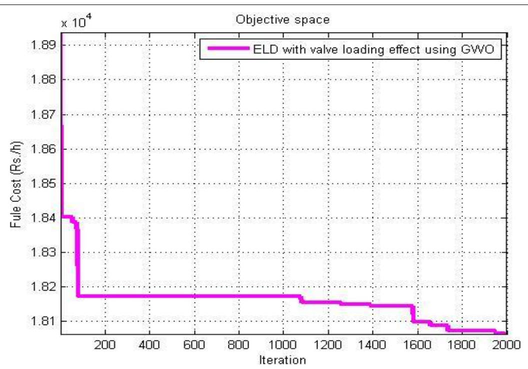

Fig 4.1: Convergence characteristics of test system I with 1800 MW demand

The comparison of the results obtained with GWO is shown in table 4.1 and bar chart is plotted in fig 4.3.

2) Test system II: Forty generating units

The input data for forty generators is derived from reference [5].The economic load dispatch for 40 generators is solved with 10,500 MW power demand. The minimum cost, mean cost and maximum cost among 50 runs of solutions obtained from GWO for test system 2 is given in table 4.2 below.

Table 4.2: Comparison results of GWO for 40-Unit system

Method	Minimum Cost($)	Mean Cost($)	Maximum Cost($)
CEP[5]	123488.29	124793.48	126902.89
FEP[5]	122679.71	124119.37	127245.59
MFEP[5]	122647.57	123489.74	124356.47
IFEP[5]	122624.35	123382.00	125740.63
MPSO[7]	122252.27	----	---
PSO [8]	123930.45	124154.49	---
GWO	121963.721	122731.166	123884.827

The comparison of the results obtained with GWO for 40 units is shown in table 4.2 and bar chart is plotted in fig 4.4

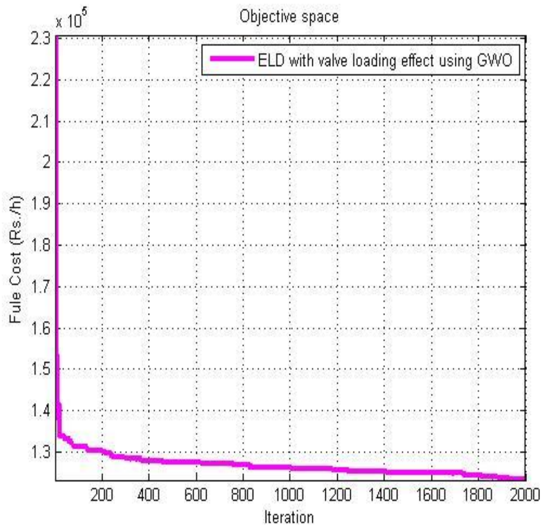

Fig 4.2: Convergence characteristics of test system II with 10,500 MW demand

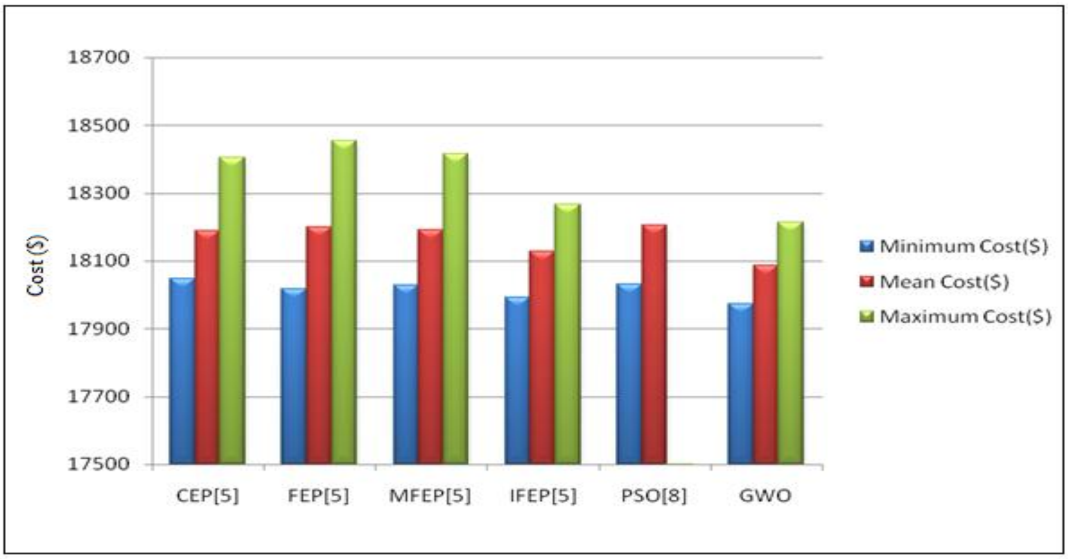

Fig-4.3Comparison chart showing the minimum, mean and maximum cost for 13 generators with different algorithms

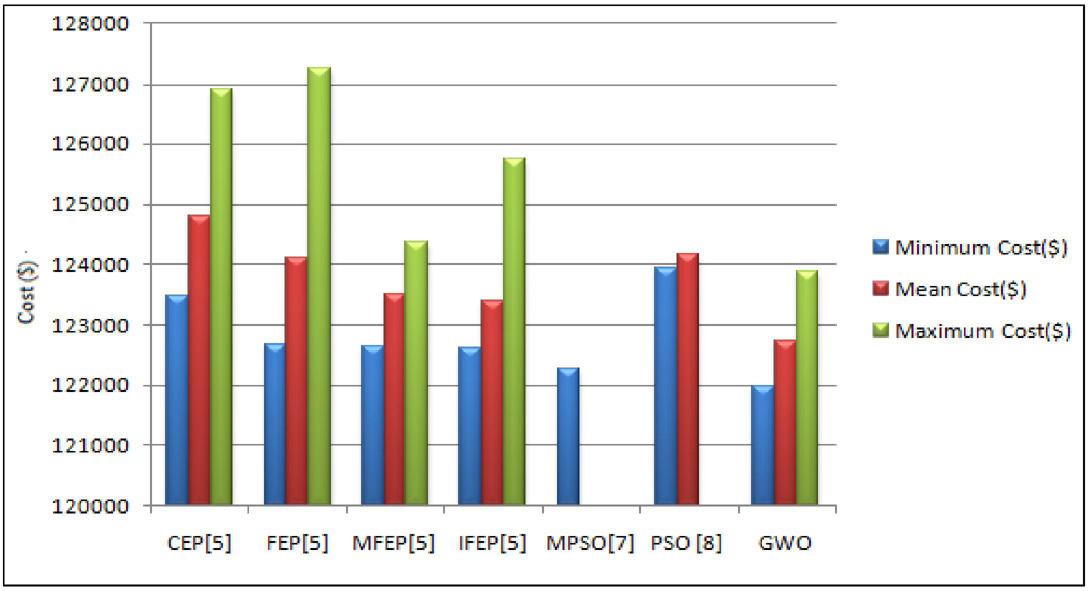

Fig-4.4 Comparison chart showing the minimum, mean and maximum cost for 40 generators with different algorithms

CONCLUSION

GWO is one of the newly developed meta-heuristic techniques. In this article GWO is used to solve ELD problem with valve point effects for two different test cases. The simulation outcome reveals the efficacy and sturdiness of the proposed algorithm to solve ELD problem in power systems. The algorithm is programmed in MATLAB(R2009b) software package. The comparisons of the results with other techniques reveal the success of GWO algorithm for solving the economic load dispatch problem

REFERENCES

[1] A.J Wood and B.F. Wollenberg, Power Generation, Operation, and Control, John Wiley and Sons, New York, 1984.

[2] David C. Walters and Gerald B. Sheble. Genetic algorithm solution of economic dispatch with valve point loading. IEEE Transactions on Power Systems. 1993: 8.

[3] Chiang, Chao-Lung. "Improved genetic algorithm for power economic dispatch of units with valve-point effects and multiple fuels."

Power Systems, IEEE Transactions on 20, no. 4 (2005): 1690-1699.

[4] S. Khamsawang, C. Boonseng and S. Pothiya. Solving the economic dispatch problem with Tabu search algorithm. IEEE Int Conf Ind Technol. 2002; 1: 274–8.

[5] Nidul Sinha, R. Chakrabarti, and P. K. Chattopadhyay. Evolutionary programming techniques for economic load dispatch. IEEE Transactions on Evolution Computation. 2003; 7: 83-94.

[6] N. Noman and H. Iba. Differential evolution for economic load dispatch problems. Electric Power Systems Research. 2008; 78: 1322-31.

[7] J. Park, K. Lee and J. Shin. A particle swarm optimization for economic dispatch with non-smooth cost functions. IEEE Transactions on Power Systems. 2005; 20: 34-42.

[8] T. Aruldoss Albert Victoire and A. Ebenezer Jeyakumar. Hybrid PSO-SQP for economic dispatch with valve-point effect. Electric Power Systems Research. 2004; 71: 51-9.

[9] L. D. S. Coelho, V. C. Mariani, Particle swarm approach based on quantum mechanics and harmonic oscillator potential well for economic load dispatch with valve-point effects, EnergyConversion and Management, vol. 49, 2008, pp. 3080-3085.

[10] Niu, Qun, Xiaohai Wang, and Zhuo Zhoua. "An Efficient Cultural Particle Swarm Optimization for Economic Load Dispatch with Valve-point Effect." Procedia Engineering 23 (2011): 828-834.

[11] Duman, S., U. Güvenç, and N. Yörükeren. "Gravitational search algorithm for economic dispatch with valve-point effects." International Review of Electrical Engineering 5, no. 6 (2010): 2890-2895.

[12] Bhattacharya, Aniruddha, and Pranab Kumar Chattopadhyay. "Solving complex economic load dispatch problems using biogeography-based optimization." Expert Systems with Applications 37, no. 5 (2010): 3605-3615.

[13] Shaw, B., S. Ghoshal, V. Mukherjee, and S. P. Ghoshal. "Solution of Economic Load Dispatch Problems by a Novel Seeker Optimization Algorithm." International Journal on Electrical Engineering and Informatics 3, no. 1 (2011): 26-42.

[14] Yang, Xin-She, Seyyed Soheil Sadat Hosseini, and Amir Hossein Gandomi. "Firefly algorithm for solving non-convex economic dispatch problems with valve loading effect." Applied Soft Computing 12, no. 3 (2012): 1180-1186.

[15] Vishwakarma, Kamlesh Kumar, Hari Mohan Dubey, Manjaree Pandit, and B. K. Panigrahi. "Simulated annealing approach for solving economic load dispatch problems with valve point loading effects." International Journal of Engineering, Science and Technology 4, no. 4 (2013): 60-72.

[16] Wang, Ling, and Ling-po Li. "An effective differential harmony search algorithm for the solving non-convex economic load dispatch problems." International Journal of Electrical Power & Energy Systems 44, no. 1 (2013): 832-843.

[17] Hatefi, A., and R. Kazemzadeh. "Intelligent tuned harmony search for solving economic dispatch problem with valve-point effects and prohibited operating zones." Journal of Operation and Automation in Power Engineering 1, no. 2 (2013).

[18] Roy, Priyanka, Pritam Roy, and Abhijit Chakrabarti. "Modified shuffled frog leaping algorithm with genetic algorithm crossover for solving economic load dispatch problem with valve-point effect." Applied Soft Computing 13, no. 11 (2013): 4244-4252.

[19] Kherfane, R. L., M. Younes, N. Kherfane, and F. Khodja. "Solving Economic Dispatch Problem Using Hybrid GA-MGA." Energy Procedia 50 (2014): 937-944.

[20] Bestha, Mallikrjuna, K. Harinath Reddy, and O. Hemakeshavulu. "Economic Load Dispatch Downside with Valve-Point Result Employing a Binary Bat Formula." International Journal of Electrical and Computer Engineering (IJECE) 4, no. 1 (2014): 101-107.

[21] Mirjalili, Seyedali, Seyed Mohammad Mirjalili, and Andrew Lewis. "Grey wolf optimization." Advances in Engineering Software 69 (2014): 46-61.

[22] Dr.Sudhir Sharma,Shivani Mehta,Nitish Chopra, “Economic Load Dispatch using Grey Wolf Optimization” Vol.5- Issue 4 (April-2015), International Journal of Engineering Research and Applications(IJERA).