ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ECONOMIC LOAD DISPATCH PROBLEM WITH VALVE POINT EFFECT USING FIREFLY ALGORITHM

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ABSTRACT

This paper proposes application of Firefly algorithm for solving economic load dispatch problem with valve point effect. Firefly algorithm is a metaheuristic population based method which was based on the flashing patterns and behaviour of fireflies. The proposed approach has been examined and tested with the numerical results of economic load dispatch problems with three and five generating units with valve point loading without considering prohibited operating zones and ramp rate limits. The results of the proposed Firefly algorithm are compared with that of other techniques such as lambda iteration and ABC.

KEYWORDS: Economic dispatch, Firefly algorithm, Artificial Bee Colony algorithm, valve point loading, Mathematical modelling, PSO, GA.

INTRODUCTION

Economic load dispatch (ED) is an important task in the power plants operation which aims to allocate power generations to match load demand at minimal possible cost while satisfying all the power units and system constraints. The complexity of the problem is due to the nonlinear and non-smooth characteristics of the input-output curves of the generators, because of valve-point effect, ramp rate limits and prohibited operating zones. The mathematical programming based optimization methods such as lambda iteration, base point participation method, Gradient and Newton's methods can solve successfully the convex ED problems [1-4]. But unfortunately, these methods are ineffective to handle the non convex ED problems with non-differentiable characteristics due to high complexity. Dynamic programming can solve such type of problem, but it suffers from curse of dimensionality. Hence for optimal solution this problem needs a fast, robust and accurate solution methodology. Now days heuristic search methods such as simulated annealing (SA) [5]-[6], genetic algorithm (GA) [7],[14-16], evolutionary programming (EP) [8], particle swarm optimization (PSO) [9], Biogeography based optimization [10], chaotic ant swarm optimization [11] and firefly algorithm [12] are employed to solve the ED problems All the approaches have achieved success to a certain extent.

This paper presents the application of proposed Firefly algorithm [13] to economic load dispatch problem with valve point loading.

ECONOMIC LOAD DISPATCH PROBLEM

The economic load dispatch problem is defined as to minimize the total operating cost of a power system while meeting the total load plus transmission losses with in the generator limits. Mathematically, the problem is defined as to minimize equation (1) subjected to the energy balance equation given by (2) and the inequality constraints given by equation (3).

$$F_i(P_i) = \sum_{i=1}^{NG}(a_i P_i^2 + b_i P_i + c_i) \quad (1)$$

$$\sum_{i=1}^{NG} P_i = P_D + P_L \quad (2)$$

$$P_{imin} \le P_i \le P_{imax} \quad (i=1, 2, 3\ldots NG) \quad (3)$$

Where a_i, b_i and c_i are cost coefficients
P_D is load demand
P_i is real power generation
P_L is power transmission loss
NG is number of generators

One of the important, simple but approximate methods of expressing transmission loss as a function of generator powers is through B- coefficients. The general form of the loss formula using B- coefficients is

$$P_L = \sum_{i=1}^{NG}\sum_{j=1}^{NG} P_i B_{ij} P_j \ \text{MW} \quad (4)$$

Where P_i, P_j are real power injections at the *i*th, *j*th buses
B_{ij} are loss coefficients

The above loss formula (4) is known as George's formula.

In normal economic load dispatch problem the input – output characteristics of a generator are approximated using quadratic functions, under the assumption that the incremental cost curves of the units are monotonically increasing piecewise-linear functions.

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However, real input-output characteristics display higher – order nonlinearities and discontinuities due to valve – point loading in fossil fuel burning plants.

The generating units with multi – valve steam turbines exhibit a greater variation in the fuel cost functions. The valve – point effects introduces ripples in the heat – rate curves. Mathematically operating cost is defined as:

$$F_i(P_i) = \sum_{i=1}^{NG}(a_i\, P_i^{\,2} + b_i P_i + c_i + \left|d_i \times \sin\{e_i \times \left(P_i^{min} - P_i\right)\}\right|) \qquad (5)$$

Where a_i, b_i, c_i, d_i and e_i are cost coefficients of ith unit.

Mathematically, economic dispatch problem considering valve point loading is defined as minimizing operating cost given by equation (5) subjected to energy balance equation and inequality constraints given by equations (2) and (3) respectively.

FIREFLY ALGORITHM

Over the last 20 years new meta-heuristic algorithm has been introduced almost every year. The nature-inspired ones have become very interesting and distinguished.

The Firefly Algorithm (FFA) is a meta-heuristic nature-inspired population-based optimization algorithm, introduced in 2010 by X. S. Yang [2]. It is based on the firefly bugs behaviour, including the light emission, light absorption and the mutual attraction, which was developed to solve the continuous optimization problems. The Firefly Algorithm is inspired from a mating phase of the firefly bioluminescent communication. Bioluminescent signals are known to serve as element of courtship rituals, methods of prey attraction, social orientation or as a warning signal to predators.

In comparison with the other evolutionary algorithms, FFA has many major advantages in solving complex nonlinear optimization problems. Some of these advantages are simple concepts, usage of real random numbers, easy implementation, higher stability mechanism, depends on the global communication among the swarming particles and less execution efforts.

The development of firefly-inspired algorithm was based on three idealized rules

1. Artificial fireflies are unisex so that sex is not an issue for attraction.
2. Attractiveness is proportional to their flashing brightness which decreases as the distance from the other firefly increases due to the fact that the air absorbs light. Since the most attractive firefly is the brightest one, to which it convinces neighbors moving toward. In case of no brighter one, it freely moves any direction.
3. The brightness of the flashing light can be considered as objective function to be optimized. For maximization problems, the light intensity is proportional to the value of the objective function.

Attractiveness

Suppose it is a night with absolute darkness, where the only visible light is the light produced by fireflies. The light intensity of each firefly is proportional to the quality of the solution, it is currently located at. In order to improve own solution, the firefly needs to advance towards the fireflies that have brighter light emission than is his own. Each firefly observes decreased light intensity than the one firefly actually emit, due to the air absorption over the distance.

There are two important issues in the firefly algorithm, variation of light intensity and formulation of the attractiveness. For simplicity, we can always assume that the attractiveness of a firefly is determined by its brightness. Attractiveness of a firefly abides the law

$$\beta(r) = \beta_0 * \exp\left(-\gamma r_{ij}^{n}\right) \text{With } n \geq 1 \qquad (6)$$

Where, r is the distance between any two fireflies, β0 is the initial attractiveness at r =0, and γ is an absorption coefficient which controls the decrease of the light intensity.

Distance

The distance r between firefly i and j at positions xi and xj respectively and is defined as Cartesian distance

$$r_{ij} = \parallel x_j - x_i \parallel \qquad (7)$$

Movement

The movement itself consists of two elements: approaching the better local solutions and the random step. Moreover, the movement of firefly i which is attracted by a more attractive or brighter firefly j is given by i.e., brighter firefly j is given by

$$x_{inew} = x_{iold} + \beta_0 e^{-\gamma r_{ij}^{\,2}}\left(x_j - x_i\right) + \alpha * \left[rand - \frac{1}{2}\right] \qquad (8)$$

Where the first term is the current position of a firefly, the second term is used for considering a firefly's attractiveness to light intensity seen by adjacent fireflies and the third term is used for the random

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movement of a firefly in case there are no brighter ones.

The coefficient α is a randomization parameter determined by the problem of interest, rand is a random number generator uniformly distributed in the space [0, 1]. The parameter γ characterizes the variation of the attractiveness and its value is important to determine the speed of the convergence and how the FA behaves. For the most cases of implementations, β0 = 1.

RESULTS AND DISCUSSION

The applicability and efficiency of FFA algorithm for practical applications has been tested on two test cases. The programs are developed using MATLAB 8.0.

The Parameters for FFA algorithm considered here are: noff=20, α=0.5, β_0=1, β_{min}=0.2, γ=1.

Test case 1: The system consists of three thermal units [1]. The cost coefficients of all thermal generating units with valve point effect are listed in table1. The generating limits are listed in table 2. The transmission losses are neglected. Prohibited zones and ramp rate limits of generating units are not considered. The economic load dispatch problem is solved to meet a load demand of 850 MW and 1050 MW.

Table 1: Cost coefficients for Three Generating units

Unit	Fuel cost coefficients				
	a_i	b_i	c_i	d_i	e_i
G1	0.0016	7.92	561	300	0.032
G2	0.0048	7.92	78	150	0.063
G3	0.0019	7.85	310	200	0.042

Table 2: Limits for Three Generating units

Unit	$P_{G\,min}$ MW	$P_{G\,max}$ MW
G1	100	600
G2	50	200
G3	100	400

Table 3: Comparison of results for test case 1

Load demand	Parameter	Lambda	ABC	FFA
850	P1,MW	382.258	300.26	384.4228
	P2,MW	127.419	149.73	151.6428
	P3,MW	340.323	400.00	313.9343
	Total cost, Rs/h	8575.68	8253.1	8253.10
1050	P1, MW	487.500	492.69	492.6993
	P2, MW	162.500	157.30	158.1006
	P3, MW	400.000	400.00	399.2001
	Total cost, Rs/h	10212.459	10123.73	10123.6954

Table 3 show the summarized result of all the existing algorithms along with FFA algorithm for test case 1. Form Table 3 it is clear that FFA algorithm gives optimum result in terms of minimum fuel cost compared to other existing algorithms shown.

Test case 2: The system consists of five thermal units [1]. The cost coefficients of all thermal generating units with valve point effect are listed in table4. The generating limits are listed in table 5. The transmission losses are neglected. Prohibited zones and ramp rate limits of generating units are not considered. The economic load dispatch problem is solved to meet a load demand of 730 MW.

Table: 4 Cost coefficients for Five Generating units

Unit	Fuel cost coefficients				
	a_i	b_i	c_i	d_i	e_i
G1	0.0015	1.8	40	200	0.035
G2	0.0030	1.8	60	140	0.040
G3	0.0012	2.1	100	160	0.038
G4	0.0080	2.0	25	100	0.042
G5	0.0010	2.0	120	180	0.037

Table: 5 Limits for Five Generating units

Unit	$P_{G\,min}$ MW	$P_{G\,max}$ MW
G1	50	300
G2	20	125
G3	30	175
G4	10	75
G5	40	250

Table: 6 Comparison of results for test case 1

Load demand	Parameter	Lambda	ABC	FFA
730	P1, MW	218.028	218.0184	229.5195
	P2, MW	109.014	109.0092	125.00
	P3, MW	147.535	147.5229	175.00

ISSN: 2277-9655
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	P4,MW	28.380	28.3784 4	75.00
	P5,MW	272.042	227.027 5	125.480 4
	Total cost, Rs/h	2412.70 9	2412.53 8	2252.57 2

Table 6 show the summarized result of all the existing algorithms along with FFA algorithm for test case 2. Form Table 6 it is clear that FFA algorithm gives optimum result in terms of minimum fuel cost compared to other existing algorithms shown.

CONCLUSION

In this paper, a new Firefly algorithm has been proposed for economic load dispatch with valve point effect problem. In order to prove the effectiveness of algorithm it is applied to three and five generating units. The results obtained by proposed method were compared to those obtained by lambda iteration method and ABC. The comparison shows that FFA algorithm performs better than above mentioned methods. The FFA algorithm has superior features, including quality of solution, stable convergence characteristics and good computational efficiency.

REFERENCES

1. D.P. Kothari, J.S. Dhillon, power system optimization, second edition, PHI learning private limited, 2011, pp 536-591.
2. X.-S. Yang, “Firefly Algorithm, Levy Flights and Global Optimization”, Research and Development in Intelligent Systems XXVI (Eds M. Bramer, R. Ellis, Petridis), Springer London, 2010, pp. 209-211.
3. M.E. EI-Hawary and G.S. Christensen: Optimal Economic Operation of Electric Power System. New York Academic (1979).
4. J., Wood & B. F. Wollenberg, Power Generation, Operation, and Control, New York: Wile 1996.
5. K. P. Wang and C.C.Fung, “Simulate annealing base economic dispatch algorithm”, IEE Proeeding - C, vol.140, no.6, pp.509-515, 1993.
6. K.P. Wong and Y.W.Wong, “Genetic and genetic/simulated-annealing approaches to economic dispatch. Inst. Elect Eng Proceedings - C, vol.141, no.5, pp.507-513, 1994.
7. C-L.Chiang, “Genetic–based algorithm for power economic load dispatch”, IEE Proceeding on Generation, Transmission and Distribution, vol.1, no.2, pp.261-269, 2007.
8. N.Sinha et al, “Evolutionary programming techniques for economic load dispatch”, IEEE Transactions on Evolutionary Computation, vol.7, no.1, pp.83-94, 2003.
9. A.I Selvakumar and K.Thanuskodi, “A new particle swarm optimization solution to non-convex economic dispatch problem”, IEEE Transactions on Power System, vol.22,no.1, pp.42-50, 2007.
10. P.K.Roy, S.P.Ghoshal, S.S.Thakur, “Biogeography based optimization for multi-constraint optimal power flow with emission and non-smooth cost function, “Expert Systems with Applications,” vol.37, no.12, pp.8221-8228, 2010.
11. J Cai, X Ma, Li-Xiang LI, Y Yang, H Peng, X Wang, “Chaotic ant swarm optimization to economic dispatch”, Electrical Power System and Research, The Journal of China Universities of Post Telecommunications,vol.77.no10,pp.1373-1380, 2007.
12. Sekhar, JN Chandra. "Application of Firefly Algorithm for Combined Economic Load and Emission Dispatch."
13. Suresh, M. C. V. "Optimal capacitor placement using firefly algorithm for power loss reduction in distribution system."
14. LeelaLakshmi, V. "IMPROVEMENT OF VOLTAGE PROFILE IN POWER SYSTEM NETWORK WITH SVC AND UPFC BY USING OPTIMAL GETNTIC ALGORITHM."
15. Sreenivasulu, A. "Optimal Capacitor Placement for Loss Reduction in Distribution Systems Using Fuzzy and Hybrid Genetic Algorithm." International Journal of Engineering 2.11 (2013).
16. Reddy P, Dinakara Prasad. "Application of Loss Sensitivity Factor and Genetic Algorithm for Capacitor placement for Minimum Loss in radial distribution system." International Journal of Engineering Sciences & Research Technology (2013): 2400-2403.
17. Dinakara Prasad Reddy P, C. Hari Prasad, M C V Suresh, "Capacitor Placement Using Bat Algorithm for Maximum Annual Savings in Radial Distribution systems"Vol. 4 - Issue 11 (November - 2014), International Journal of Engineering Research and Applications (IJERA) , ISSN: 2248-9622 , www.ijera.com