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Firefly Optimization Based Economic Load Dispatch

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ABSTRACT: Economic Load Dispatch (ELD) is a computational process of economically allocating generations to various generation plants subject to load and operational constraints. This paper proposes a method involving firefly optimization (FFO), for solving ELD to overcome the drawbacks of classical methods. FFO is inspired from the flashing behavior of fireflies in solving optimization problems. The firefly in the proposed method is modeled to denote the real power generations, and the brightness function is tailored involving the objective function along with power balance constraint. The simulation results of a test system with thirteen generating plants are presented to exhibit the superior performance of the developed method.

KEYWORDS: economic load dispatch; lambda iteration method; firefly optimization

I. Introduction

Today's power systems have the requirement of operating the system in an economical and reliable manner under changing load conditions. Economic dispatch (ELD), an opt methodology in operating the system economically, is a computational process whereby the total required generation is distributed among the generating units in operation so as to lower the total generation cost, subject to load and operational constraints [1].

In recent years, several classical methods such as lambda iteration, gradient search, linear programming, dynamic programming, quadratic programming and so on [2] were outlined in the literature for solving the ELD problems. A few of these methods have drawbacks involving natural complexity and convergence issues. For example, the classical lambda-iteration method has convergence problems which depends on the initial choice of lambda values, leading to oscillatory issues and larger computation time. Another family of algorithms, called bio-inspired optimization algorithms, such as have been suggested for solving genetic algorithms (GA) [3], particle swarm optimization (PSO) [4], evolutionary programming (EP) [5], differential evolution (DE) [6], ant colony optimization (ACO) [7] etc. were applied for solving ELD problems. These algorithms differ from one another only by the way of representing the problem variables, formation of fitness/cost functions and the mechanism adapted for creating new off-springs. These algorithms have been considered as a robust method, as they do not require derivatives of the functions.

Recently, Firefly Optimization (FFO), a bio-inspired algorithm mimicking the flashing behaviour of fireflies, was suggested for solving optimization problems by Xin She Yang [8]. This paper proposes a method involving FFO for solving ELD problem to overcome the drawbacks of classical methods.

II. Problem Formulation

The ELD problem may be developed by defining an objective function involving minimization of net fuel costs of real power generations while satisfying several equality and inequality constraints as

$$\text{Minimize} \quad F(P_G) = \sum_{i=1}^{ng} a_i\, P_{Gi}{}^2 + b_i\, P_{Gi} + c_i + \left| d_i \sin\left\{ e_i (P_{Gi}^{\min} - P_{Gi}) \right\} \right| \tag{1}$$

Subject to

$$\sum_{i=1}^{ng} P_{Gi} - P_D - P_L = 0 \tag{2}$$

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \qquad i = 1, 2, \cdots, ng \tag{3}$$

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Where

$$P_L = \sum_{i=1}^{ng}\sum_{j=1}^{ng} P_{Gi} B_{ij} P_{Gj} + \sum_{i=1}^{ng} B_{oi} P_{Gi} + B_{oo} \tag{4}$$

$a_i \; b_i \; c_i$ represent fuel cost coefficients of the i^{th} generator

$B \; B_o \; B_{oo}$ indicates loss coefficients

$F(P_G)$ denotes net fuel cost in $\$/h$

ng represents number of generators

P_D denotes the total power demand

P_L indicates the net transmission loss

P_{Gi} represents real power generation at i^{th} generator

III. PROPOSED METHOD

The proposed method (PM) employs FFO for solving ELD problem. The procedure involves representation of problem variables and the formation of a brightness function (B). Each firefly (F) in the FFO is defined to indicate the real power generations of all generating plants as

$$F = [P_{G1}, P_{G2}, P_{G3}, \cdots, P_{Gng}] \tag{5}$$

The FFO explores the solution space for optimal solution by maximizing a brightness function (B), which is formed as

$$Maximize \quad B = \frac{1}{1 + F(P_G) + w\left(\sum_{i=1}^{ng} P_{Gi} - P_D - P_L\right)^2} \tag{6}$$

Fireflies usually move towards the brighter fireflies. In FFO, i-th firefly move towards j-th firefly, if j-th firefly's brightness (B) is larger than that of i-th firefly's, by the following expression:

$$F_i(t) = F_i(t-1) + A_{i,j}\left(F_j(t-1) - F_i(t-1)\right) + \alpha\left(rand - 0.5\right) \tag{7}$$

Where $A_{i,j}$ denotes the attractiveness between i-th and j-th fireflies and is computed by

$$A_{i,j} = \left(A_{\max i,j} - A_{\min i,j}\right)\exp\left(-\theta_i \, E_{i,j}^{\;2}\right) + A_{\min i,j} \tag{8}$$

Where $E_{i,j}$ is the Euclidean distance between i-th and j-th fireflies.

α and θ_i are constants

An initial population of fireflies is obtained by generating random values to every individual in the population. The brightness (B) is evaluated for each firefly. The brightness of all fireflies are compared and the fireflies with lower brightness are allowed to move towards the brighter fireflies by Eq. (5). This process represents an iteration. The iterative procedure is repeated until the number of iterations reaches the maximum number of iterations. The best firefly in the population represents the optimal real power generations.

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IV. SIMULATION RESULTS

The PM is applied on a test system comprising 13 generating units. The fuel cost coefficients and generation limits of the test system are available in [9] and furnished in Table.1. The fuel cost data includes valve point effects and represents non-convex cost function. The optimal generations and the corresponding fuel cost are compared with the results of two existing methods [4,10] for a power demand of 1800 MW in Table 2. It can be observed that the PM offers the lowest fuel cost of 17959.283 S/h while the existing methods leads to 17963.829 and 17976.9512, thereby exhibiting that the proposed method is robust in obtaining the global best solution.

Table 1 Fuel cost coefficients and generation limits

Gen. No.	Fuel Cost Coefficients					Generation Limits (MW)	
	a_i	b_i	c_i	d_i	e_i	P_{Gi}^{min}	P_{Gi}^{max}
1	0.00028	8.10	550	300	0.035	0	680
2	0.00056	8.10	309	200	0.042	0	360
3	0.00056	8.10	307	150	0.042	0	360
4	0.00324	7.74	240	150	0.063	60	180
5	0.00324	7.74	240	150	0.063	60	180
6	0.00324	7.74	240	150	0.063	60	180
7	0.00324	7.74	240	150	0.063	60	180
8	0.00324	7.74	240	150	0.063	60	180
9	0.00324	7.74	240	150	0.063	60	180
10	0.00284	8.60	126	100	0.084	40	120
11	0.00284	8.60	126	100	0.084	40	120
12	0.00284	8.60	126	100	0.084	55	120
13	0.00284	8.60	126	100	0.084	55	120

Table 2 Comparison of economic generations

Gen. No	PM	Ref. [4]	Ref. [10]
1	628.3181	628.3185	448.8000
2	149.5995	149.5995	300.5000
3	222.7389	222.7492	299.2000
4	109.8662	109.8666	60.0000
5	109.8661	109.8666	109.9000
6	109.8661	109.8666	109.0000
7	109.8660	60.0000	61.9000
8	60.0000	109.8666	109.9000
9	109.8659	109.8665	109.9000
10	40.0000	40.0000	40.0000
11	40.0000	40.0000	40.0000
12	55.0000	55.0000	55.0000
13	55.0000	55.0000	55.0000
Fuel Cost	17959.283	17963.829	17976.9512

V. CONCLUSION AND FUTURE WORK

ELD is a computational process of economically allocating generations to various generation plants subject to load and operational constraints. A FFO based method for solving ELD problem was proposed in this paper. The firefly was represented to denote the real power generations and the brightness function was built comprising objective function and power balance constraint. The method has been run for 100 iterations and the obtained results were compared with those of existing methods for a system with 13 generating units. The results have illustrated the effectiveness of the algorithm in finding the global best solution.. The proposed method involving FFO will culminate itself as a powerful tool in solving ELD problem at energy control centers. The objective function can be modified to include emissions and the method can be extended to obtain a compromised solution.

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