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Nature Inspired Optimization for Emission Dispatch

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ABSTRACT: Emission Dispatch (ED) is a computational process of allocating generations to various generation plants so as to minimize the release of emissions subject to load and operational constraints. This paper proposes a method involving firefly optimization (FFO), for solving ED 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 six generating plants are presented to exhibit the superior performance of the suggested method.

KEYWORDS: emission dispatch; lambda iteration method; firefly optimization

I. INTRODUCTION

Operating at minimum fuel cost is not the only criterion for dispatching electric power, as the public are more concerned about environmental pollutions. Besides the enactment of the 'Clean Air Act Amendment of 1990' force the utilities to change their operating methodologies to meet environmental standards. The power plants using coal, oil and gas, releases pollutions such as sulphur oxides (SOx), nitrogen oxides (NOx) and carbon dioxide into the atmosphere. In the light of the fact that the economic load dispatch leads a large fuel cost savings, it causes large emissions. One of the simplest methodology in reducing the pollutions is the Emission Dispatch (ED), which however results in higher operating cost. Several researchers have considered emissions either in the objective function or treated emissions as additional constraints. Emission function, which is similar to fuel cost function, is the sum of all types of emissions, whose characteristic is sometimes non linear and the slope of the curve is not always positive [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 ED 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 nature 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 ED 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 ED problem to overcome the drawbacks of classical methods.

II. PROBLEM FORMULATION

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

$$\text{Minimize} \quad E(P_G) = \sum_{i=1}^{ng} \alpha_i P_{Gi}^{\;2} + \beta_i P_{Gi} + \gamma_i + \xi_i \exp(\delta_i P_{Gi}) \tag{1}$$

Subject to

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

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

Where

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

B B_o B_{oo} indicates loss coefficients

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

ng represents number of generators

P_D denotes the total power demand

P_L indicates the net transmission loss

$\alpha_i, \beta_i, \gamma_i$, ξ_i and δ_i are the emission cost coefficients.

$E(P_G)$ denotes the net emissions

III. Proposed Method

The proposed method (PM) employs FFO for solving ED 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

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

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.

IV. Simulation Results

The PM is applied on a test system comprising 6 generating units. The emission coefficients and generation limits of the test system are available in [9] and furnished in Table.1. The optimal generations and the corresponding emissions are compared with the results of two existing methods [10,11] for a power demand of 2.834 per unit in Table 2. It can be observed that the PM offers the lowest emissions of 0.19435 ton/h while the existing methods leads to 0.19510 ton/h and 0.19685 ton/h, thereby exhibiting that the proposed method is robust in obtaining the global best solution.

Table 1 Emission coefficients and generation limits

Gen. No.	Emission Coefficients					Generation Limits (per unit)	
	α_i	β_i	γ_i	ξ_i	δ_i	$P_{Gi}^{\min}$	$P_{Gi}^{\max}$
1	6.49	-5.554	4.091	2.0e-4	2.857	0.05	0.50
2	5.638	-6.047	2.543	5.0e-4	3.333	0.05	0.60
3	4.586	-5.094	4.258	1.0e-6	8.000	0.05	1.00
4	3.380	-3.550	5.326	2.0e-3	2.000	0.05	1.20
5	4.586	-5.094	4.258	1.0e-6	8.000	0.05	1.00
6	5.151	-5.555	6.131	1.0e-5	6.667	0.05	0.60

Table 2 Comparison of generations of ED

Gen. No	PM	Ref.[10]	Ref.[11]
1	0.4089	0.4937	0.4972
2	0.4619	0.3908	0.6047
3	0.5417	0.5506	0.4655
4	0.3874	0.3774	0.3326
5	0.5419	0.5420	0.4655
6	0.5134	0.5021	0.4990
Emissions (ton/h)	0.19435	0.19510	0.19685

V. CONCLUSION AND FUTURE WORK

ED is a computational process of allocating generations to various generation plants so as to lower the release of emissions subject to load and operational constraints. A FFO based method for solving ED 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 6 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 ED problem at energy control centers. The objective function can be modified to include fuel costs and the method can be extended to obtain a compromised solution.

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