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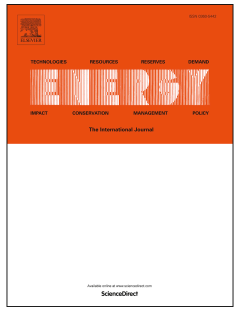

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An enhanced moth-flame optimizer for solving non-smooth economic dispatch problems with emissions

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Abstract-This paper proposes an Enhanced Moth-Flame Optimization (EMFO) algorithm for solving the non-convex economic dispatch (ED) problem with valve point effects and emissions. It determines the optimal generation schedule of generating units by minimizing both fuel cost and emission simultaneously while the system constraints are achieved. The moth-flame optimization (MFO) is a recent nature-inspired method, which is based on the navigation mechanism called transverse orientation of Moths in space. The EMFO combines the merits of the traditional MFO and levy flight by concentration the search space. The usage of Lévy-flight has the prominent properties to increase the diversity of population. The effectiveness of the proposed EMFO method is proven on using 10 benchmark functions and 3 standard test systems consisting of 6, 40 and a large scale 80 generating units with non-convex fuel cost functions. The capability of the proposed algorithm is verified also for single and multi-objective studied cases and its results are compared with several well-known techniques. The results confirm the high performance of the proposed EMFO method for finding the optimal economic generation scheduling at acceptable low emission levels.

Index Terms— ***Moth-Flame Optimization; Multi-objective optimization; Economic dispatch; valve-point effects; emissions; Power loss.***

Nomenclature

P_i^t	Real power generation of the generation unit i	M_i	i^{th} moth
$f_i(P_i^t)$	Cost function of the generation unit i	F_j	j^{th} flame
N_G	Number of generation buses	S	Spiral function
a_i ,b_i and ,c_i,	Smooth cost coefficients of i^{th} generator	D_i	Distance from i^{th} moth to j^{th} flame
d_i and e_i	non-smooth cost coefficients of the valve-point impact of i^{th} generator	n	Number of intervals in the time horizon
N_f	Maximum number of flames	m	The shape of the logarithmic spiral constant
P_i^{min}	Minimum limit of power generation	l	Current number of iteration
P_i^{max}	Maximum limit of power generation	X_i^{t+1}	The i^{th} moth or solution vector X_i^t at iteration t
α_i, β_i and γ_i	Smooth coefficients of the i^{th} unit emission function	$\oplus$	The dot product
,η_i and δ_i	non-smooth emission coefficients of of i^{th} generator	Γ	Standard Gamma function
P_L	Total active power losses	T_{iter}	Maximum number of iterations
P_d	Load demand active power	$E_i(P_i^t)$	Amount of emission from unit i from producing power P_i^t
B_{ij} ,B_{0i} and B_{00}	Transmission loss coefficients	sign[rand − 0.5]	Takes only three values 1, 0, and −1
r_1,r_2,r_3 and r_4	Random parameter which conforms to a uniform distribution		

1. INTRODUCTION

A. *Motivation*

Economic dispatch (ED) is a major operational issue in power systems. It aims to determine the best schedule of generating units output to reduce the total production costs while satisfying constraints of total load demand as well as respecting individual resource capacity limits [1]. Theoretically, to make the cost function of a generator relatively easy to solve, it can be represented by a quadratic convex / linear function [2]. In the conventional formulation of ED problem, it was assumed that the cost function is a quadratic polynomial and convex. In reality, when a steam valve starts to open, there is a rippling effect on a unit's power-cost curve. To model the unit's power-cost curve with the valve-point effects, a sinusoidal function has been added to the traditional quadratic power-cost equation [3].

In real power systems, practical features such as valve point effects, ramp rate limits, prohibited operating zones, and multiple fuel options are usually encountered. Neglecting these features may lead to inaccurate solutions of the ED problem [4, 5]. On the other hand, considering these practical features converts the ED problem to a complex optimization problem in which the cost function is non-convex and non-smooth. In this subject, the need to develop efficient solving methods to such problem becomes