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Biogeography based optimization technique for best compromise solution of economic emission dispatch

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ABSTRACT

This paper attempts to develop an elegant biogeography based optimization algorithm for obtaining the best compromise solution of EED problem. The basic philosophy orients to create a modified objective function that provides equal significance to both fuel cost and emission cost components. Besides it requires only three solution runs unlike other strategies involving more solution runs. The performance is evaluated through three test systems and the simulation results are presented to demonstrate the validity and effectiveness of the scheme for practical applications.

1. Introduction

Economic dispatch (EcD) is one of the prime functions in power system operation, management and planning and its objective echoes to schedule the committed generating units' output so as to meet the load demand at minimum operating cost while satisfying all units and system operational constraints [1,2]. The generation of electricity from fossil fuel releases several contaminants such as sulfur dioxides, nitrogen oxides and carbon dioxide into the atmosphere. In the past few decades, environmental awareness led to impose rigid environmental policies such as "US Clean air amendments of 1990" on power utilities to minimize their emissions. A host of strategies are in vogue to reduce power plant emissions like installing post-combustion cleaning equipment, switching to low emission fuels and replacement of the aged fuel burners or dispatching with emission considerations. The latter option is preferred in many cases due to economical reasons and its immediate availability for short-term operation. However, the other alternatives are considered as a long term option as they incur additional capital cost [3].

Emission dispatch (EmD) is similar to EcD except that it extends to minimize the net emissions instead of fuel cost. Operating either at absolute minimum fuel cost or at lowest pollution level is no longer acceptable owing to the fact that both of the objectives are conflicting in the sense that minimization of one causes the other to increase. This endears to the formation of combined Economic emission dispatch (EED) that focuses to simultaneously minimize both the fuel cost and emission levels by satisfying all unit and systems constraints. There is no single optimal solution to the bi-objective EED problem unless exact preference or weight of both the objectives is known. It gives rise to finding a set of compromise solutions known as Pareto optimal solutions, which show the trade-off between the two competing objectives.

Traditional mathematical programming techniques such as lambda iteration, gradient search, linear programming and Lagrangian relaxation [1] and modern heuristic optimization techniques such as genetic algorithms [4], evolutionary programming [5,6], differential evolution [7] and particle swarm optimization [8] have been widely applied in solving the EED problems. An efficient niched Pareto genetic algorithm for multiobjective environmental/economic dispatch for obtaining the Best Compromise Solution (BCS) through fuzzy mechanism from a set of Pareto-optimal solutions has been proposed in [4]. An approach based on strength Pareto evolutionary algorithm that inherits a diversity-preserving mechanism for environmental/economic dispatch problem has been suggested to obtain Pareto optimal solutions in [5]. A fuzzy based mechanism is then applied to extract the BCS from the Pareto optimal set. An optimization procedure based on the linear programming incorporating the technique of selection, reduction and the third simplex method has been described in [9]. A direct NR method based on alternative Jacobian matrix to solve EED problem with line flow constraints has been presented in [10]. A nondominated sorting genetic algorithm based approach for EED for producing Pareto-optimal set of solutions with a view to overcome premature convergence through diversity-preserving mechanism has been suggested in [11]. A comparative study of various algorithms involving nondominated sorting genetic algorithm, niched Pareto

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Nomenclature

$a_i\, b_i\, c_i$	fuel cost coefficients of the ith generator
$d_i\, e_i$	coefficients of valve point effects of the ith generator
$B\, B_o\, B_{oo}$	loss coefficients
BBO	biogeography based optimization
BCS	best compromise solution
E	maximum possible emigration rate
EED	economic emission dispatch
EcD	economic dispatch
EmD	emission dispatch
ECPI	emission cost performance index
$E_i(P_{Gi})$	emission cost function of the ith generator (ton/h)
FCPI	fuel cost performance index
$F_i(P_{Gi})$	fuel cost function of the ith generator ($/h)
F^{min} and E^{max}	net fuel cost and emissions of EcD respectively
F^{max} and E^{min}	net fuel cost and emissions of EmD respectively
F_G^{min} and E_G^{max}	net fuel cost and emissions of the global best EcD solution respectively
F_G^{max} and E_G^{min}	net fuel cost and emissions of the global best EmD solution respectively
h_i	price penalty factor of the ith generator in $/*ton*
I	maximum possible immigration rate
$Iter^{max}$	maximum number of iterations for convergence check
k	number of species in kth *island*
K_1 K_2	weight constants
n	maximum number of species
nd	number of decision variables
ng	number of generators
ni	number of *islands*
nei	number of elite *islands*
PM	proposed method
P_{Gi}	real power generation at ith generator
P_{Gi}^{min} and P_{Gi}^{max}	minimum and maximum generation limits of ith generator respectively
P_D	total power demand
P_L	net transmission loss
P^{mod}	*island* modification probability
P_m	mutation probability
S^{max}	maximum species count
SIV	suitability index variable
SI	suitability index
w	trade-off parameter in the range of [0,1]
$\alpha_i\ \beta_i\ \gamma_i\ \xi_i$ and δ_i	emission coefficients of ith generator
λ	immigration rate
μ	emigration rate
Φ	objective function to be minimized
Φ^M	modified objective function to be minimized
Ψ	augmented objective function to be minimized

genetic algorithm and strength Pareto evolutionary algorithm in obtaining the Pareto front and extracting the BCS of environmental/economic dispatch has been elaborated in [12]. A chaotic particle swarm optimization method based on Logistic and Tent equations for EED problem in order to evade the hitch of being trapped into local optima has been outlined in [13]. A fuzzy based bacterial foraging algorithm for EED has been developed to extract the BCS from a set of nondominated solutions over the trade-off curve in [14]. A multi-objective harmony search algorithm for EED problem involving nondominated sorting and ranking procedure with dynamic crowing distance has been explained to obtain a well distributed Pareto-optimal set in [15].

Recently, a biogeography-based optimization (BBO) modeled on the theory of biogeography, which is the study of the geographical distribution of biological organisms, has been proposed for solving optimization problems by Simon [16]. Like other evolutionary algorithms, BBO is a population based stochastic optimization technique sharing information between candidate solutions based on their fitness values with a view of obtaining the global best solution. Since its introduction, it has been applied to a variety of problems including sensor selection [16], power system optimization [17–19], ground water detection [20], satellite image classification [21], optimal meter placement [22], parameter estimation [23] and CT-scan image segmentation [24].

The effort in this article encompasses a solution strategy using BBO with a view of obtaining the BCS for EED problem to explore its applicability for emerging power systems. The paper is divided into six sections. Section 1 gives the introduction, Section 2 explains the BBO technique, Section 3 outlines the EED problem, Section 4 describes the proposed method, Section 5 discusses the simulation results and Section 6 concludes the article.

2. Biogeography-based optimization

BBO, suggested by Simon [16], is a stochastic optimization technique for solving multimodal optimization problems. It is based on the concept of biogeography, which deals with the distribution of species that depend on different factors such as rain fall, diversity of vegetation, diversity of topographic features, land area, temperature, etc. In the science of biogeography, an *island*/habitat is defined as the ecological area that is inhabited by particular plant or animal species and geographically isolated from other habitats.

Over evolutionary periods of time, some *islands* may tend to accumulate more species than others as they posses certain environmental features that are more favorable than *islands* with fewer species. Many species like plants and animals on *islands* with large population emigrate into neighboring *islands* with less number of species for their survival and better living and share their characteristics with those *islands* enabling *islands* with less population to inherit a high species immigration rate. The immigration and emigration processes help the species of less favorable area to acquire good features from the species in the favorable *islands* and strengthen the weak elements. The rate of immigration (λ) and the emigration (μ) are the functions of the number of species in the *islands*. Fig. 1 shows the immigration and emigration curves indicating the movement of species in an *island*.

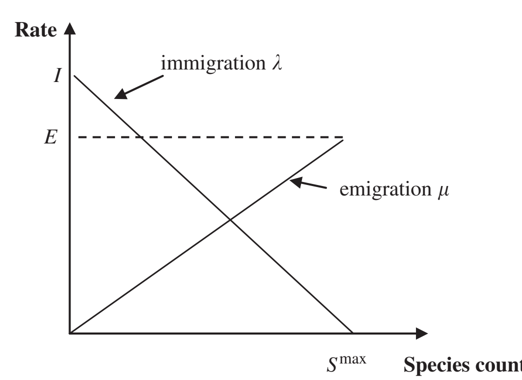

Fig. 1. Species model of an *island*.