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Comparative analysis of optimal load dispatch through evolutionary algorithms

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Abstract This paper presents an evolutionary algorithm named as Cuckoo Search algorithm applied to non-convex economic load dispatch problems. Economic load dispatch (ELD) is very essential for allocating optimally generated power to the committed generators in the system by satisfying all of the constraints. Various evolutionary techniques like Genetic Algorithm (GA), Evolutionary programming, Particle Swarm Optimization (PSO) and Cuckoo Search algorithm are considered to solve dispatch problems. To verify the robustness of the proposed Cuckoo Search based algorithm, constraints like valve point loading, ramp rate limits, prohibited operating zones, multiple fuel options, generation limits and losses are also incorporated in the system. In the Cuckoo Search algorithm, the levy flights and the behavior of alien egg discovery is used to search the optimal solution. In comparison with the solution quality and execution time obtained by five test systems, the proposed algorithm seems to be a promising technique to solve realistic dispatch problems.

1. Introduction

In this advancing age economic load dispatch (ELD) problem is one of the major issues in power system operation. With the fuel demand proliferation, there is a need to obtain an optimized solution with reduced generating cost of different generating units in a power system. Using various mathematical programming methods and optimization techniques, the problems are solved. The conventional methods include lambda-iteration method, base point methods which are clearly mentioned in [1,2]. All these mentioned methods compute the optimal solutions by taking the incremental cost curves as a linear function of generating units. But practically, a highly non-linear cost curves cannot be solved by the above method and for this reason the final optimized solution is slightly far from the actual result. This can be neglected for generating units of power system for a small period of time, but focusing on a long term basis, its negligence causes a huge loss.

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Nomenclature

P_D	load demand
P_i	real power output of ith generating unit
a_i, b_i and c_i	fuel cost coefficients of ith generating unit
e_i, f_i	coefficients of the ith unit with valve point effects
m	number of committed online generators
P_{Loss}	transmission loss
B_{ij}, B_{0i}, B_{00}	B-matrix coefficients for transmission power loss
$P_{i\min}$	minimum real power output of ith generator
$P_{i\max}$	maximum real power output of ith generator
P_i^0	previous real power output of ith generator
U_{ri}	up ramp limits of the ith generator
D_{ri}	down ramp limits of the ith generator
P_{iL}^{pzk}	lower limits of kth prohibited zone for ith generating unit
P_{iU}^{pzk}	upper limits of kth prohibited zone for ith generating unit
$Iter$	maximum number of iterations
It	current iteration number

The nonlinear characteristics of certain generating units include different factors like discontinuous prohibited zones, ramp rate limits, multiple fuel options, start-up cost functions and valve point loadings [3] which are in general non-smooth. While taking the large power system into consideration due to oscillatory problem in load change, conventional method is quite unreliable and takes huge time for computation. In order to solve the ELD problem, dynamic programming (DP) method is properly studied in [4]. But the main disadvantage of this method is that when applied to higher number of units of power system requires enormous computational efforts.

During the last decade, various computational algorithms such as Genetic Algorithms (GA) [5–9], Evolutionary programming [10], Artificial neural networks (ANNs) [11–14], Particle Swarm Optimization (PSO) [15–20] are applied to obtain an optimized solution. To make these numerical methods more convenient and simpler toward solving of ELD problem, intelligent algorithms have been applied. Hopfield neural networks have been successfully implemented in [11–14] but this method suffers some huge calculation due to involvement of higher numbers of iterations. Recently GA is found to be deficient in its performance due to its high correlation between the crossover and mutation which give rise to high average fitness toward the end of the evolutions. PSO is very much concerned about the higher number of iterations which result higher execution time. Various swarm intelligence based algorithms such as Ant colony optimization ACO [21], Artificial bee colony algorithm (ABC) [22], Hybrid Harmony search algorithm (HHS) [23] and Fuzzy based chaotic ant colony optimization (FCACO) [24] algorithms have been successfully applied to economic load dispatch problems.

Cuckoo search based optimization is found to be one of the most sophisticated, less time consuming evolutionary algorithms in order to solve the nonlinear economic load dispatch problems. Though Cuckoo search highly depends upon the tolerance value but its converging logic is really commendable [25–29]. In this paper, 6, 15, 40, 140 and 320 units system are taken into consideration. For more realistic analysis the loss coefficients are included in few cases in the system under consideration. Different costs of various generating units under study are calculated by three evolutionary techniques named Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Cuckoo Search algorithm and the results are compared by both numerically and graphically by taking the minimum operating cost as objective function.

2. Problem formulation

2.1. Economic dispatch

The ELD problem is a nonlinear programming optimization task and its aim is to minimize the fuel cost of generating real power outputs for a specified period of operation so as to accomplish optimal dispatch among the committed units and satisfying all the system constraints. Here, two models for ELD are considered, viz. one with smooth cost functions of the generators and the other with non-smooth cost functions with valve point loading effects as detailed below.

2.2. ELD problem with smooth cost functions

The main objective of the ELD problem is to determine the most economic loadings of generators to minimize the generation cost such that the load demands P_D in the intervals of the generation scheduling horizon can be met and simultaneously the practical operation constraints like system load demand, generator output limits, system losses, ramp rate limits and prohibited operating zones are to be satisfied.

Here, the constrained optimization problem is formulated as

$$\text{Minimize} \quad F = \sum_{i=1}^{m} f_i(P_i) \tag{1}$$

F is the total cost function of the system.

In general, the cost function of ith unit $f_i(P_i)$ is a quadratic polynomial expressed as

$$f_i(P_i) = a_i + b_iP_i + c_iP_i^2 \quad (\$/h) \tag{2}$$

This minimization problem is subjected to a variety of constraints depending upon assumptions and practical implications like power balance constraints, generator output limits, ramp rate limits and prohibited operating zones. These constraints and limits are discussed as follows.

(a) Power balance constraint or demand constraint: The total generation $\sum_{i=1}^{m}(P_i)$ should be equal to the total system demand P_D plus the transmission loss P_{Loss} that is represented as

$$\sum_{i=1}^{m}(P_i) = P_D + P_{Loss} \tag{3}$$