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Efficient Evolutionary Particle Swarm Optimization Approach for Nonconvex Economic Load Dispatch Problem

Abstract. *The main objective of economic load dispatch (ELD) is to allocate the output power generator at minimum cost while satisfying all the operation constraints. This paper presents a new hybrid method by integrating particle swarm optimization with time varying acceleration coefficients and evolutionary programming (TVAC-EPSO) for solving nonconvex ELD problem. The competition, sorting and selection in EP method are used to determine the best particle in PSO for finding the optimum solution efficiently. The proposed TVAC-EPSO has been tested on three different power system benchmarks. The simulation results have demonstrated the effectiveness of the proposed method in solving nonconvex ELD problem.*

Streszczenie. *W artykule przedstawiono hybrydową metodę ekonomicznie uzasadnionego określenia założeń dotyczących generowanej energii elektrycznej (ang. Economic Load Dispatch - ELD). Algorytm oparty jest na wykorzystaniu metody optymalizacji roju cząstek ze współczynnikami zmiennymi w czasie i programowaniu ewolucyjnym. (ang. TVAC-EPSO). Proponowana metoda została poddana weryfikacji na trzech różnych systemach energetycznych. Wyniki symulacyjne potwierdzają jej efektywność w analizie problemu ELD. (**Zagadnienie ekonomicznie uzasadnionego określenia wytwarzanej energii elektrycznej o charakterystyce niewypukłej – wykorzystanie metody optymalizacji roju cząstek**).*

Keywords: Economic load dispatch, particle swarm optimization, evolutionary programming, time varying acceleration coefficients.
Słowa kluczowe: zapotrzebowanie energetyczne, optymalizacja roju cząstek, programowanie ewolucyjne, zmienne w czasie współczynniki przyspieszenia.

Introduction

The economic load dispatch (ELD) is about minimizing the total generation cost of generating units in order to meet the power demand while satisfying equality and inequality constraints. Traditionally, the cost function of the generator is assumed to be piecewise linear and represented by a quadratic function. However, in practical, this assumption is no longer valid due to the valve point effect and prohibited operating zones (POZ) of generating units. This makes the ELD problem highly non linear and nonconvex optimization problem, which is difficult to be solved by mathematical approach. Moreover, the ELD problem becomes more complicated when ramp-rate limits and transmission losses are taken into account.

Many optimization methods have been used for solving classical ELD problem, such as lambda iteration, gradient method, linear programming and quadratic programming [1]. Most of these methods might be unable to solve nonconvex and discontinuous ELD problem efficiently. This is because these methods required monotonically increasing of incremental cost function, where the derivative information of the cost function exists.

In order to solve nonconvex ELD problem, heuristic methods such as evolutionary programming (EP), genetic algorithm, artificial immune system, tabu search, ant colony optimization and particle swarm optimization (PSO) have been implemented to solve nonconvex and discontinuous ELD problems [2]. These methods do not require the derivative information of the cost function. Thus, it can be used to solve nonconvex ELD problem due to valve point effects, prohibited operating zones, multi fuels options and nonlinear power flow constraints that cannot be solve by classical methods. However, these methods are not guaranteed in finding the optimum solution due to premature convergence.

Among these methods, the PSO method is widely used for solving ELD problem due to its simple implementation, less memory storage and able to find global solution. Many modifications and hybrid of PSO methods were proposed for solving the nonconvex ELD problem such as IPSO [3], SOH-PSO [4], PSO-MSAF [5], GA-PSO [6] and hybrid CPSO-SQP [7]. Nevertheless, the classical PSO can be further improved to obtain a good solution.

In this paper, a new hybrid approach is proposed by integrating particle swarm optimization with time varying acceleration coefficients and evolutionary programming named TVAC-EPSO for solving nonconvex ELD problem. The concepts of EP method based on competition, sorting and selection are applied for finding the best individual and group particle in PSO method. In addition, the time varying acceleration coefficients for both cognitive and social components are used to find the global optimum solution. The performance of the proposed TVAC-EPSO is tested on different power system which consists of 3, 6 and 15 generating units. The results obtained by TVAC-EPSO were compared with the existing results from the literature in terms of optimum cost and execution times.

Problem formulation

The objective of the ELD problem is to determine the optimal output power of a scheduled generator that minimizes the total generation cost (F_c) while equality and inequality constraints are satisfied as follows:

$$\text{Minimize } F_C = \sum_{i=1}^{N} F_i(P_i) \tag{1}$$

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \tag{2}$$

When the valve point effect is considered, the generation cost function in (2) is added with rectified sinusoidal function to obtain an accurate ED modelling,

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i + \left| e_i \sin(f_i(P_i^{\min} - P_i)) \right| \tag{3}$$

where $F_i(P_i)$ is the total generation cost for generator i, P_i is the real power output of generator i, a_i, b_i and c_i are the cost coefficients for unit i and e_i and f_i are the cost coefficients for unit i with presence valve point effects.

Power balance constraints

The total power generated should be equal to the total power demand and transmission loss,