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# A hybrid multi-agent based particle swarm optimization algorithm for economic power dispatch

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ABSTRACT

This paper presents a new multi-agent based hybrid particle swarm optimization technique (HMAPSO) applied to the economic power dispatch. The earlier PSO suffers from tuning of variables, randomness and uniqueness of solution. The algorithm integrates the deterministic search, the Multi-agent system (MAS), the particle swarm optimization (PSO) algorithm and the bee decision-making process. Thus making use of deterministic search, multi-agent and bee PSO, the HMAPSO realizes the purpose of optimization. The economic power dispatch problem is a non-linear constrained optimization problem. Classical optimization techniques like direct search and gradient methods fails to give the global optimum solution. Other Evolutionary algorithms provide only a good enough solution. To show the capability, the proposed algorithm is applied to two cases 13 and 40 generators, respectively. The results show that this algorithm is more accurate and robust in finding the global optimum than its counterparts.



## 1. Introduction

Economic power dispatch (EPD) is the scheduling of the committed generating unit outputs so as to meet the load demand at minimum operating costs while satisfying all units and system equality and inequality constraints. The main aim in the economic dispatch problem is to minimize the total cost of generating real power (production cost) at various stations while satisfying the loads and the losses in the transmission links [1,2]. EPD is thus one of the most important problems to be solved in the operation of power system. Since modern unit's input–output characteristics are highly non-linear due to valve-point loading, multiple-fuel effects and other constraints, a continuous search for better solver is going on [3–5].

A lot of classical methods have been developed and are being used for optimization problem. Golden section search, Fibonacci search, Newton's method and Secant method are some one dimension search method. Gradient methods, Newton's method, conjugate direction method and neural networks are commonly used for unconstrained optimization [2]. These methods are problem specific and use gradients. Consequently they are applicable to a much smaller classes of optimization problem.

A genetic algorithm (GA) is a probabilistic search technique that has its roots in the principles of genetics. It gives more emphasis on natural selection of surviving species and process of reproduction of new offspring. The algorithm works on process of mutation and crossover to create new population [6]. Since its conception, genetic algorithm has been used widely as a tool in computer programming, artificial intelligence and optimization.

Mimicking the behavior of intelligence available in various swarms a new intelligence comes into existence which is known as swarm intelligence (SI). Swarm intelligence is artificial intelligence which based on the collective behavior of decentralized, self-organized systems which mimics natural behavior of organisms. SI systems are typically made up of a population of simple agents interacting locally with one another and with their environment. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local interactions between such agents lead to the emergence of complex global behavior [7]. A natural example of SI includes ant colonies, bird flocking, animal herding, bacterial growth, and fish schooling. Various algorithms derive from SI are Ant Colony Optimization (ACO), GA and particle swarm optimization (PSO) [6–8].

Particle swarm optimization (PSO) algorithm is based on social behavior of groups like flocking of birds or schooling of fish. It is a stochastic, population-based evolutionary computer algorithm for problem solving. It is a kind of swarm intelligence that predicts each individual solution as "particles" which evolve or change their positions with time. Each particle modifies its position in search space in accordance with its own experience and also that of neighbouring particle by remembering the best position visited by itself and its neighbours, then calculating local and global positions. These techniques are free from use of

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gradients hence can be applicable to a wider class of optimization problems [8,9].

The bees algorithm is an optimization algorithm inspired by the natural foraging behavior of honey bees to find the optimal solution for food as well as next site selection [10]. This algorithm performs a kind of neighborhood search combined with random search and can be used for both combinatorial optimization and functional optimization. Bee Colony Optimization (BCO), Bee System (BS) algorithms are some of the examples where algorithms are based on *Waggle dance* perform by scouts' bee to inform other foraging bees about the nectar site [11].

The practical EPD problems with valve-point effects is represented as a nonsmooth optimization problem having complex and non-convex features with heavy equality and inequality constraints [2]. This kind of optimization problem is hard, if not impossible, to solve using traditionally deterministic optimization algorithms. Recently, as an alternative to the conventional mathematical approaches, modern stochastic optimization techniques, evolutionary algorithms, Tabu search, neural networks, genetic algorithms, particle swarm optimization and other heuristic approaches algorithms have been given much attention by many researchers due to their ability to find potential solutions [2–6,13].

In this paper, we use our own developed a new algorithm, which is hybrid version on PSO which mimics its search algorithm from PSO and modify Nelder–Mead method [12] to find optimal solution. The decision making technique is mimicked from Bee decision-making process. The decision-making process is based on the algorithm used by bees for finding a suitable place for establishing new colony. The experimental results show the robustness and accuracy of hybrid PSO over genetic algorithm and PSO. Due to its hybrid nature this algorithm provides only deterministic solutions. Making use of these agent–agent interactions and evolution mechanism of PSO in a lattice-like environment, the proposed method can find high-quality solutions reliably with the faster convergence characteristics in a reasonably good computation time.

This paper is organized as follows. The hybrid algorithm is comprises of two parts search algorithm and other as decision-making process. The Section 2 details the economic dispatch problem formulation with valve-point effect. The Section 3 details the standard PSO and the related issues about accuracy and convergence to optimal solutions. Section 4 describes the basic requirements of MAS. The development and working of the Hybrid PSO is elaborated in the Section 5. The decision-making process in the honey bees make them an interesting swarm research area to work. Section 5 also discusses the decision making method used by the bees in the proposed algorithm. Section 6 discusses simulation and experimental results made on some standard test systems and draws inferences on the convergence characteristics from the results obtained. Finally, Section 7 concludes the paper.

## 2. Economic dispatch problem formulation

### 2.1. Basic economic dispatch formulation

The economic dispatch problem is to simultaneously minimize the overall cost rate and meet the load demand of a power system while satisfying an equality and inequality constraints [2,13]. Assuming the power system includes N generating units. The aim of economic power dispatch is to determine the optimal share of load demand for each unit in the range of 3–5 min. Generally, the economic power dispatch problem can be expressed as minimizing the cost of production of the real power which is given by objective function $F_T$

$$F_T = \sum_{i=1}^{n} F_i(P_i) \tag{1}$$

which is subjected to the constraints of equality in real and reactive power balance

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

where $a_i$, $b_i$ and $c_i$ are the cost coefficients of the $i$th generator and $N$ is the number of generators committed to the operating system. $P_i$ is the power output of the $i$th generator.

#### 2.1.1. Real power balance equation

For power balance, an equality constraint should be satisfied. The generation-demand balance including losses is given by the following equation

$$\sum_{i=1}^{N} P_i - P_l - P_d = 0 \tag{3}$$

where $P_d$ is the total system demand and is the total line loss. However, in the case study presented here,we disregarded the transmission losses (i.e. $P_l = 0$).

#### 2.1.2. Minimum and maximum power limits

Generation output of each generator should lie between maximum and minimum limits. The inequalities of real power limits on the generator output are:

$$P_{\min,i} \leqslant P_i \leqslant P_{\max,i} \quad \text{where} \quad i = 1, 2, \ldots, N \tag{4}$$

where $P_{\min i}$ and $P_{\max i}$ are the minimum and maximum real power limits of $i$th generator output in the system.

### 2.2. Valve-point effects

The generator costs are usually approximated using quadratic functions. However, it is more practical to consider the valve-point loading for fossil–fuel-based plants. In this context, a cost function is obtained based on the ripple curve for more accurate modeling. This curve contains higher order nonlinearity and discontinuity due to the valve-point effect as shown in Fig. 1. One way of representing this effect is to use a rectified sinusoidal function to represent the valve-point loading in the cost function [13]. In this case Eq. (2) can be written as

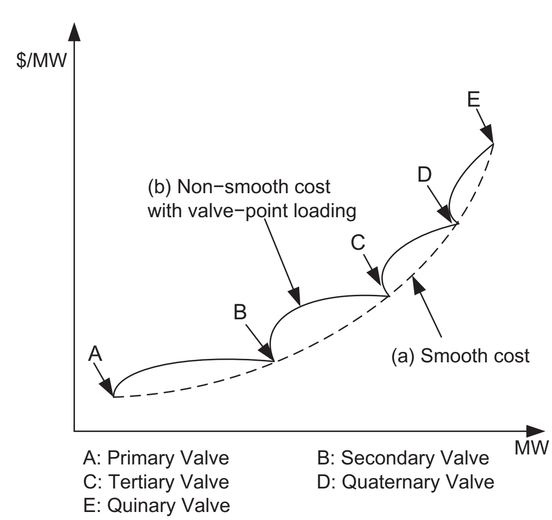


**Fig. 1.** Incremental fuel cost versus power output for a five valve steam turbine unit.