Optimal Load Dispatch Problem to Reduce Power wastage using Evolutionary Programming

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Abstract

This paper presents an Efficient and Reliable Evolutionary Algorithm (EA) for solving Economic Load Dispatch Problem with Reduce Power Losses (ELD). The main objective is to minimize the total fuel cost of the generating units having quadratic cost characteristics subjected to limits on generator True power output & transmission losses. It has been achieved by using optimization techniques such as dynamic programming, integer programming, and mixed-integer non linear programming. On the other hand, a broad class of Meta heuristics has been developed for reliability-redundancy optimization. Recently, a new meta-heuristics called Firefly Algorithm (FA) algorithm has emerged. The FA is a stochastic Meta heuristic approach based on the idealized behavior of the flashing characteristics of fireflies. This paper presents an application of the Firefly Algorithm (FA) to ELD for different Test Case system. ELD is applied and compared its solution quality and computation efficiency to Genetic algorithm (GA), Particle swarm optimization (PSO), Artificial Bee Colony optimization (ABC), Biogeography-Based Optimization (BBO) and Bacterial Foraging algorithms (BFA) and other optimization techniques. The simulation results show that the proposed algorithm outperforms previous optimization methods.

Keywords: *Economic load dispatch; Genetic algorithm; Particle swarm optimization; Artificial Bee Colony optimization;*

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1.INTRODUCTION

Biology-inspired Meta heuristic algorithms have recently become the forefront of the current research as an efficient way to deal with many NP-hard combinatorial optimization problems and non-linear optimization constrained problems in general. These algorithms are based on a particular successful mechanism of a biological phenomenon of Mother Nature in order to achieve optimization, such as the family of honey-bee algorithms, where the finding of an optimal solution is based on the foraging and storing the maximum amount of flowers' nectar [1]. A new algorithm that belongs in this category of the so-called nature inspired algorithms is the firefly, algorithm which is based on the flashing light of fireflies. Although the real purpose and the details of this complex biochemical process of producing this flashing light is still a debating issue in the scientific community, many researchers believe that it helps fireflies for finding mates, protecting themselves from their predators and attracting their potential prey [1–4]. In the firefly algorithm, the objective function of a given optimization problem is associated with this flashing light or light intensity which helps the swarm of fireflies to move to brighter and more attractive locations in order to obtain efficient optimal solutions.

In this research paper we will show how the recently developed firefly algorithm can be used to solve the famous ELD optimization problem. This hard optimization problem constitutes one of the key problems in power system operation and planning in which a direct Solution cannot be found and therefore Meta heuristic approaches, such as the firefly algorithm, have to be used to find the near optimal solutions.

This optimization problem deals with allocating loads to power generators of a plant for minimum total fuel cost while meeting the power demand and transmission losses constraints. this is numerous variation of this problem which model the one objective functions and the constraints in many different ways. Moreover, we will demonstrate how the firefly algorithm works and how this method can be easily adapted in order to solve this objective optimization problem. Therefore, we will discuss why this method is sufficiently accurate and easy to implement for real-time operation and control of power systems.

2. PROBLEM FORMULATION

The ELD may be formulated as a nonlinear constrained problem. The convex ELD problem assumes quadratic cost function along with system power demand and operational limit constraints.

2.1 ELD with quadratic cost functions without transmission loss.

The objective function F_T of ELD problem may be written as:-

$$F_T = MIN(\sum_{k=1}^{n} F_k [P_k]) \quad (1)$$

$$F_T = MIN(\sum_{k=1}^{n} a_k + b_k P_k + c_k P_k^2) \quad (2)$$

$$F_k(P_k) = a_k + b_k P_k + c_k P_k^2 \quad (3)$$

The ELD problem consists in minimizing subject to the following constraints: -

1.Real Power Balance Constraint:

$$\sum_{k=1}^{n} P_k - (P_D) = 0 \quad (4)$$

2.Generator Capacity Constraints:

The power generated by each generator shall be within their lower operating limit and upper operating limit.So that,

$$P_k^{min} \le P_k \le P_k^{max} \quad (5)$$

2.2. ELD with quadratic cost f unction with transmission loss.

The objective function F_T of ELD problem may be written as:-

$$F_T = MIN(\sum_{k=1}^{n} F_k [P_k]) \quad (6)$$

$$F_T = MIN(\sum_{k=1}^{n} a_k + b_k P_k + c_k P_k^2) \quad (7)$$

$$F_k(P_k) = a_k + b_k P_k + c_k P_k^2 \quad (8)$$

The ELD problem consists in minimizing subject to the following constraints

1.Real Power Balance Constraint:

$$\sum_{k=1}^{n} P_k - (P_D + P_L) = 0 \quad (9)$$

2.Generator Capacity Constraints:

The power generated by each generator shall be within their lower operating limit and upper operating limit.So that,

$$P_k^{min} \le P_k \le P_k^{max} \quad (10)$$

F_T = the total fuel cost, \$/hr.

P_k = the power output of k-th generator, MW.

a_k, b_k , c_k = the cost coefficient of k-th enerator.

P_D = total load demand.

P_L = total transmission losses.

P_k^{min} = the power generated lower limit.

p_k^{max}= the power generated upper limit.

3.THE EVOLUTIONARY ALGORITHM

The Firefly Algorithm [FA] is a Meta heuristic, nature-inspired, optimization algorithm which is based on the social flashing behavior of fireflies, or lighting bugs, in the summer sky in the tropical temperature regions[1–3, 15].

The FA has three particular idealized rules which are based on some of the major flashing characteristics of real fireflies [2–4, 15]. These are the following:

[1] All fireflies are unisex, and they will move towards more attractive and brighter ones regardless their sex.

[2] The degree of attractiveness of a firefly is proportional to its brightness which decreases as the distance from the other firefly increases due to the fact that the air absorbs light. If there is not a brighter or more attractive firefly than a particular one, it will then move randomly.

[3] The brightness or light intensity of a firefly is determined by the value of the objective function of a given problem. For maximization problems, the light intensity is proportional to the value of the objective function.

3.1 Hybridization

In a recent bibliography, a new Meta heuristic algorithm has been developed and formulated based on the concept of hybridizing the firefly algorithm. In particular, the new Levy flight Firefly algorithm was developed by Dr. Xin-She Yang at Cambridge University in 2010 and it combines the firefly algorithm with the Levy flights as an efficient search strategy [4]. It combines the three idealized rules of the firefly algorithm together with the characteristics of Levy flights which simulate the flight behavior of many animals and insects. In this algorithm, the form of the attractiveness function and the calculation of distance between two fireflies are the same as in firefly algorithm, but in the movement function, the random step length is a combination of the randomization parameter together with a Levy flight. In particular, the movement of a firefly is a random walk, where the step length is drawn by the Levy distribution [4].

4. THE PROPOSED SOLUTION METHOD

Mathematical calculations and comparisons can be done very quickly and effectively with Mat lab and that is the reason that the proposed Firefly algorithm was implemented in Mat lab 2009 programming environment. In this proposed method, we represent and associate each firefly with a valid power output (i.e., potential solution) encoded as a real number for each power generator unit, while the fuel cost objective i.e., the objective function of the problem is associated and represented by the light intensity of the fireflies. In this simulation, the values of the control parameters are: $\alpha = 0.2$, $\gamma = 1.0$, $\beta_0 = 1.0$, and $n = 12$, and the maximum generation of fireflies (iterations) is 50. The values of the fuel cost, the power limits of each generator, the power loss coefficients, and the total power load demand are supplied as inputs to the firefly algorithm. The power output of each generator, the total system power, the fuel cost with/without transmission losses are considered as outputs of the proposed Firefly algorithm. Initially, the objective function of the given problem is formulated as defined in (1) and it is associated with the light intensity of the swarm of the fireflies. The initial solution of the given problem is generated based on the mathematical formulation given below:

$$x_j = \text{rand} *(\text{upper-range} - \text{lower-range}) + \text{lower-range}, \qquad (15)$$

Where x_j is the new solution of j^{th} firefly, that is, created, rand is a random number generator uniformly distributed in the space [0, 1], while upper range and lower range are the upper range and lower range of the j^{th} firefly (variable), respectively.

After the evaluation of the initial population /generation (i.e., solution), the firefly enters its main loop which represents the maximum number of generations of the fireflies. This is actually the values of the algorithm's control parameters is $\alpha = 0.2$, $\gamma = 1.0$, $\beta_0 = 1.0$, and rand is a random number which is uniformly distributed in the space [0,1]. As we can see the distance between two fireflies is calculated using the Euclidean distance (Section II.2) and the generation of a new solution is actually a sum of the current solution (xi), the metric of the evaluation of the current solution based on the current optimal solution (Euclidian metric), and a random step/move of the algorithm(Section III.3).. To avoid such violation, a repair process is applied to each solution (firefly) in order to guarantee that the generated power outputs are feasible. Pk, Pk min and Pk max denote the current, the minimum, and the maximum power outputs of the ith unit, which is associated with the ith firefly. Finally, it is notable that for each generation (iteration), the swarm of 12 fireflies is ranked based on their light intensity, and the firefly with the maximum light intensity (i.e., the solution with the higher objective function value) is chosen as the brighter one (i.e., it is a potential optimal solution), while the others are updated based on (16). In the final iteration, the firefly with the brighter light intensity among the swarm of 12 fireflies is chosen as the brightest one which represents the optimal solution of the problem.

5. CONCLUSION

In this paper, authors have successfully introduced Biogeography Based Optimization algorithm to solve Economic Load Dispatch problem and compared its results to those of other well established algorithms. It is observed that the proposed algorithm exhibits a comparative performance with respect to other population based techniques. It is clear from the results that Biogeography Based Optimization algorithm is capable of obtaining higher quality solution with better computation efficiency and stable convergence characteristic.

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BIOGRAPHIES

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