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Economic Dispatch Using Firefly Algorithm

J.Merlin, R.S.Nagajothi

Assistant Professor, Department of Electrical & Electronics Engineering, K.L.N. College of Engineering, Pottapalayam, India

PG Scholar, Department of Electrical & Electronics Engineering, K.L.N. College of Engineering, Pottapalayam, India

ABSTRACT— This Paper proposes a Firefly Algorithm for solving an Economic Dispatch (ED) problem. It is the most important problem in power system operation and control. Its objective is to determine the optimal combination of power outputs of all generating units in order to minimize the total cost satisfying constraints and load demand in each interval. Several conventional and evolutionary algorithms have been employed to solve this problem. The results obtained by the proposed algorithm have been compared with Genetic Algorithm (GA), Evolutionary Programming (EP) and Gradient Search Algorithm (GSA) is already available in literature. The feasibility of the proposed algorithm was verified with IEEE 30 bus system.

KEYWORDS—Economic Dispatch (ED), Firefly Algorithm (FA) and Meta-heuristic.

I. INTRODUCTION

Economic dispatch is an important problem in power system operation and control. But it is a difficult optimization problem and the purpose of ED or optimal dispatch is to reduce fuel cost for the generation of power. By economic load scheduling, to find the generation of the different generators or power plants, then the fuel cost is minimized and at the same time the total demand and losses at any instant can meet by the total generation. The economic dispatch problems involves in solving of two different problems, i.e., unit commitment and on-line dispatch. A large electric network is a complicated system consisting of generators, transformers, transmission lines, circuit breakers, capacitors, reactors, motors and other power consuming devices. The operation, availability and its continuity in service are very much unpredictable.

Hence, the electric demand at any instant is a continuously varying factor. So the system is a dynamic one. Unless, there is some precious method to determine the behavior of the system, but it becomes difficult to predict the power flow, line losses, cost of generation etc. The job of the planning engineer becomes very complicated in predicting and forecasting to suit the changing needs.

The increasing energy demand from the available energy source, decreasing fuel sources and increasing cost of power generation are another area which necessitates the study of economic load dispatch, in early day's unscientific method of approaches were tried for the cost effective generation. Even with the transmission losses neglected these methods failed to minimize the cost. The solution methods for this problem are as follows.

Preceding efforts on solving economic dispatch have employed various conventional methods and optimization techniques. This mathematical programming method includes Linear Programming, Gradient Method, Dynamic Programming, and Lambda iteration method and so on. The lambda iteration method is one of the important methods of mathematical programming and it is used in solving the optimal power dispatch of generators and system lambda. Lambda is the variable introduced in solving constraint optimization problem and called a Langrangian multiplier. This is used in Gradient method and Newton method. It is important to note that the lambda can also solve manually. It is used in solving systems of equations. Lambda iteration is introduced for the benefit of computing lambda and other associated variables using a computer. In lambda iteration method, the unknown variable lambda, gets its next value based on intrusion. That is, there is no equation, compares the next iteration of lambda. It is projected by interpolating the best possible value until a specified mismatch has been reached. [10]

In this algorithm, the objective function of a given problem is associated with light intensity which helps the fireflies to move. i.e. the less brighter one will move towards the more brighter one and more locations in order to obtain efficient optimal solutions. In this paper we will show how the firefly algorithm can be used to

solve the economic dispatch problem. [1] Presented a new path for determine the economic load dispatch problem considering valve point constraints. The results are compared with various stochastic search algorithms.[2] Presented an artificial bee colony optimization technique for solving an economic dispatch considering valve point loading and prohibited operating zones. The results are compared with DE and EP. [3] Presented a Tabu search algorithm for solving the economic dispatch problem. The problem formulated with base case and contingency case line flow constraints. The results are compared with GA and QN. [4] presented a new approach to economic dispatch problem non smooth cost functions using PSO technique. A dynamic search space reduction strategy is discovered to step up the optimization process. [5] Presented a new approach to clarify the economic dispatch problem. The feasibility of the proposed algorithm is demonstrated. [6] Presented a comprehensive review of a firefly algorithm can deals with multimodal functions efficiently and naturally. [7] Presented the comparative study of FA and PSO for solving nonlinear problems. The results were investigated and correlated. The firefly algorithm tries to perform better for higher level noise. Presented a efficient method for solving economic dispatch problem. By using PSO with SQP. [8] Presented a PSO technique for solving economic dispatch considering generator constraints. The effectiveness of the proposed method is demonstrated for three different systems and is compared with GA.[9] presented a GA Solution for solving economic dispatch considering valve point loading .The formulations of an economic dispatch computer program using GA and these programs has two different encoding techniques.

But these methods may not be able to find the accurate solution, Because these methods relies difficulties like myopia for nonlinear, discontinuous search spaces, which leads them to a less desirable performance and these methods often use approximations to limit complexity. So later modern heuristics stochastic optimization technique are introduced. They are Simulated Annealing (SA), Genetic Algorithm (GA), Evolutionary Program (EP), Tabu Search and so on. These methods are efficient in solving optimization problems. Although these methods don't guarantees that they give the global optimum solution, they provide solution, which is approximately equal to the global optimum. These methods suffer from drawbacks such as large memory requirement, long computation times or premature convergence. However, setting the control parameters in these methods is a difficult task. Recently, in the study of insect's behavior, scientists have found a source for solving the optimization techniques. i.e.., the new algorithm called Firefly Algorithm is proposed.

II. PROBLEM FORMULATION

The operation of generation facilities to produce energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities.

A. Objective Function

The main goal of economic dispatch is to minimize the following cost function.

$$Min\ F = \sum_{i=1}^{N_g} a_i + b_i\left(P_{gi}\right) + c_i\left(P_{gi}\right)^2$$

Where,

F is the total generation cost over the dispatch period,

a_i, b_i, c_i are the cost coefficients of the i^{th} generator,

N_g is the number of generating units,

P_{gi} is the real power output of the i^{th} generator.

B. Constraints

The equality and inequality constraints are as follows.

1) Equality Constraints

Since only the real power generation is considered in this project work for the Economic Dispatch problem, the real power balance equation alone is considered for the equality constraints. The power balance equation is as follows:

i) Power Balance Equations

$$P_{gi} - P_{li} - V_i \sum_{j=1}^{N} V_j (G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij}) = 0$$

$$Q_{gi} - Q_{li} - V_i \sum_{j=1}^{N} V_j (G_{ij} \sin\theta_{ij} - B_{ij} \cos\theta_{ij}) = 0$$

Where,

P_{li} =Active Load of the i^{th} bus

G_{ij} = Transfer conductance between bus i and j

B_{ij} = Transfer susceptance between bus i and j

θ_{ij} =Voltage angle difference between bus i and j

2) Inequality Constraints:

In a power system components and devices have operating limits, & these limits are created for the security constraints. Thus the required objective function can be minimized by maintaining the network components within the security limits. This brings the concept of inequality constraints.

The most usual type of inequality constraints are the upper bus voltage limits at generation at load buses, lower bus voltage limits at generation at load buses, lower bus voltages limits at some generators and maximum line loading limits, upper bounds of real power generation at generator buses, lower bounds of real power generation at generator buses.

i) Real Power Operating Limit

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max}$$

ii) Reactive Power Operating Limit

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max}$$

iii) Bus Voltage Limit

$$V_i^{\min} \le V_i \le V_i^{\max}$$

iv) Line Flow Constraint

$$S_{ij} \le S_{ij}^{\max}$$

III. FIREFLY ALGORITHM

A. Introduction to Firefly

Firefly Algorithm is one of the recent swarm intelligence method developed by Xin She Yang in 2008. It is a kind of stochastic nature inspired meta-heuristic algorithm that can be applied for solving the hardest optimization problems. The stochastic algorithm means that it uses as a kind of randomization by searching for a set of solutions. It is inspired by the flashing lights of the fireflies in nature. Heuristic means to find or to discover solutions by trial and error. In this algorithm lower level means Heuristic and higher level means Meta-Heuristic. The lower level concentrates on the generation of new solution within a search space and thus selects the best solution for survival. On the other hand, randomization enables the search process to avoid the solution being trapped into local optima.

Also, FA is population based. The population-based algorithm has the advantages when compared to other algorithm. [6][7]

B. Biological Foundations

Fireflies (Coleoptera: Lampyridae) are among the most enchantment of all insects, and their spectacular courtship displays have inspired poets and scientists alike. Nowadays, more that 2000species exist worldwide. Usually, fireflies live in a warm environment and they are most active in summer nights. A lot of researchers have studied firefly phenomena in nature and there exist numerous papers researching fireflies, Fireflies are characterized by their flashing light produced by biochemical process bio-luminescence. Such flashing light may serve as the primary courtship signals formatting. Besides attracting mating partners, the flashing light may also serve to warn off potential predators.

Note that in some firefly species some adults are in capable of bio-luminescence. The subspecies attract their mates due to pheromone, similarly to ants. In fireflies, bioluminescent tractions take place from light-producing organs called lanterns. The most bioluminescent organisms provide only slowly modulated flashes (also glows).In contrast, adults in many firefly species are able to control their bioluminescence in order to emit high and discrete flashes. The lanterns' light-production is initialized by signals originating within the central nervous system of firefly.

Most firefly species rely on bioluminescent courtship signals. Typically, the first signalers are flying males, who try to attract flightless females on the ground. In response to these signals, the females emit continuous or flashing lights. Both mating partners produce distinct flash signal patterns that are precisely timed in order to encode information like species identity and sex. Females are attracted according to the behavioral differences in the courtship signal. Typically, females prefer brighter male flashes. It is well known that the flash intensity varies with the distance from the source. Fortunately, in some firefly species females cannot discriminate between more distant flashes produced by stronger light source and closer flashes produced by weaker light sources.

Two features are characteristics for swarm intelligence are self-organization and decentralized decision making. Here, autonomous individuals live together in a common place as, for example, bees in hives, ants in anthills, etc. In order to live in harmony, some interaction or communication is needed among group members who live together. In fact, individuals within a group cannot behave as if they are solitary, but must adapt to the overall goals within a groups. The social life of firefly is not just dedicated to foraging, but more to reproduction. These collective decisions are closely connected with the flashing light behavior that served as the main biological foundation for developing the firefly algorithm [6].

C. Behaviors of Firefly

The azure filled with the lights of fireflies. It is a marvelous sight in the summer season. There are two thousand firefly species, and most of the firefly produces a rhythmic flashes. The pattern of the flashes, amount of flashing and the rate of time for the flashes which are observed together forming a kind of a prototype that attracts both the males and females to each other. Female's species act in response with individual prototype of the male species.

The intensity of light at a certain distance(r) from the light source conforms to the inverse square law. It is the intensity of the light I goes on decreasing as the distance r will increase in terms of I =1/r2. Additionally, the air keeps absorbing the light which becomes weaker with the increase in the distance. These two factors when combined make most fireflies visible at a limited distance, normally to a few hundred meters at night, which is quite enough for fireflies to communicate with each other.[6][7]

D. Concept

Now we can specialize some of the flashing characteristics of fireflies so as to develop firefly-inspired algorithms. Flashing characteristics of fireflies is used to develop firefly-inspired algorithm. Firefly algorithm works on the basis of three rules and three main factors. The main factors are light intensity and attractiveness, distance and movement of the fireflies.

The rules are as follows:

- All the fireflies are unisex so it means that one firefly is attracted to other fireflies irrespective of their sex.
- Attractivity and luminosity are reciprocal to one another, the lesser bright one will move towards the brighter one. If one of the fireflies is brighter than other firefly, it will move randomly.
- The brightness of a firefly is determined by the view of the objective function. For maximization problem, the brightness is simply proportional to the value of the objective function. Other forms of the brightness could be defined in an identical way to the fitness function in genetic algorithms [6].

1.) *Light intensity and Attractiveness:* Light is absorbed by the media, so we should allow the attractiveness to vary with the varying degree of absorption. Light intensity I(r) varies according to the inverse square law.

$$I(r) = \frac{l}{r^2} \tag{3.1}$$

Where I is the intensity at the source. For a stated medium with a fixed light absorption coefficient γ, the light intensity I vary with the distance r.

$$I = I_o e^{-\gamma r} \tag{3.2}$$

Where I_o is the initial light intensity, similarly for attractiveness is proportional to the light intensity. Now we can define the attractiveness β of a firefly as

$$\beta = \beta_o e^{\gamma r^2} \tag{3.3}$$

2.) *Distance:* The distance between the two fireflies i and j at xi and xj respectively is the Cartesian distance.

$$r_{i,j} = \sqrt{(x_i - x_j)^2 - (y_i - y_j)^2} \tag{3.4}$$

3.) *Movement:* The movement of the firefly which is attracted by the more brighter one is determined by

$$x_i = x_i + \beta_o e^{\gamma r_{i,j}^2}(x_i - x_j) + \alpha \varepsilon_1 \tag{3.5}$$

IV. Steps for Firefly Algorithm

The steps involved in firefly algorithm are as follows:

Step 1: Initialize the generation counter, best solution and attractiveness value.

Step 2: Initialize population and parameters value.

The firefly process comprises inside of the while loop and is composed of following steps.

Step 3: The alpha new function is dedicated to modify the initial value of parameter

Step 4: Evaluate FA function i.e.it evaluates the quality of the solution.

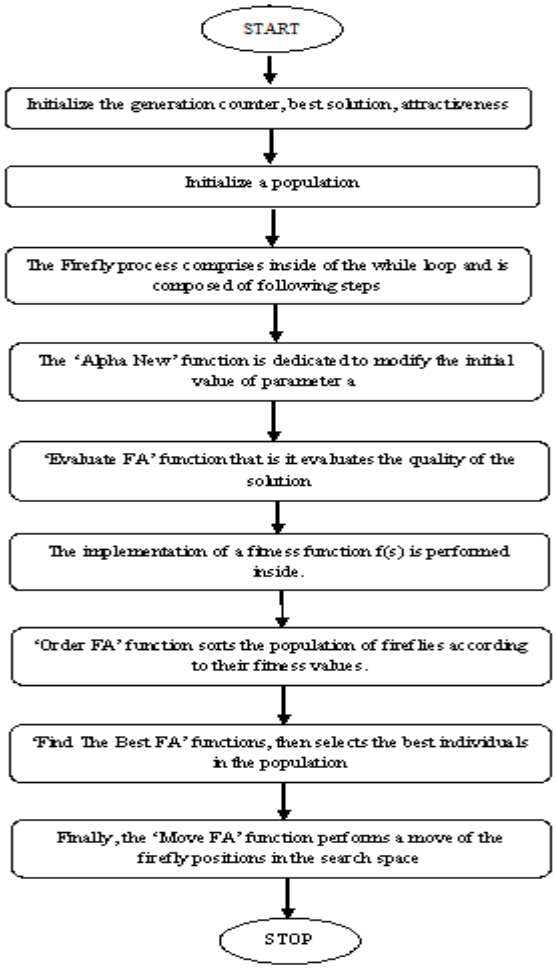
The implementation of a fitness function f(s) is performed inside.

Step 5: Order FA function sorts the population of fireflies according to their fitness values.

Step 6: Find "The Best FA" functions, and then selects the best individuals in the population.

Step 7: Finally, Move FA function performs a moves the firefly positions and Stop the program.

Overview of Proposed Algorithm



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IV. Results and Discussion

The proposed FA algorithm has been tested on IEEE 30 bus system. The computational work was performed on Intel Core 2 Duo with a 2.93 GHz microprocessor in MATLAB 7.0 platform. The firefly algorithm result is compared with Genetic Algorithm, Gradient Based Approach, and Evolutionary Programming already available in literature.

A. IEEE 30 Bus System

IEEE 30 bus test system consists of six generators at buses 1, 2,5,8,11,13 and four transformers with off-nominal tap ration at lines 6-9, 6-10,4-12 and 28-27.To demonstrate the effectiveness of the proposed approach.

Table 1 represents the optimal settings of the control variable using firefly algorithm. From the obtained results generation satisfies the demand and also it satisfies the constraints. i.e. bus voltage, real power operating limits are within the range.

TABLE.1: Optimal Settings of Control Variables for IEEE 30 Bus system Using FA

DESCRIPTION	Firefly Algorithm
P_1(MW)	176.86
P_2(MW)	48.99
P_5(MW)	21.53
P_8(MW)	21.94
P_{11}(MW)	12.25
P_{13}(MW)	11.36
Fuel Cost($/hr)	802.508
Losses	9.513

In this curve, X-axis represents the no of iterations and Y-axis represents the fuel cost. The curve explains the convergence rate of the proposed algorithm.

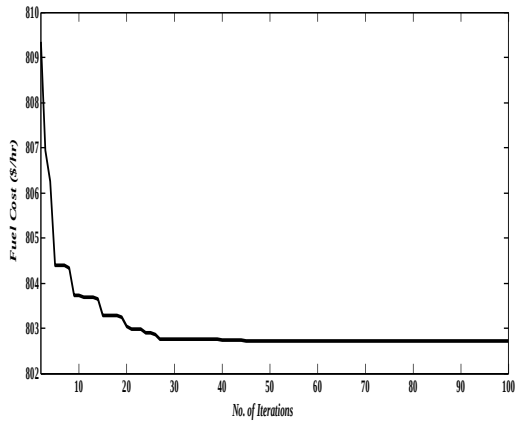

Fig. 1 Convergence Characteristics Curve

Table 2 represents the comparison of fuel cost for different methods. The proposed algorithm has been compared with GA, EP and Gradient approach which is already available in literature.

TABLE.2: Comparison of fuel cost for different methods for IEEE 30 bus system

METHOD	FUEL COST($/hr)
GA[11]	803.699
Gradient based approach[12]	804.853
Evolutionary Programming[13]	802.56
Firefly Algorithm	**802.508**

Based on the above results it is clear that the proposed algorithm for solving the Economic Dispatch better result than other approaches.

V. CONCLUSION

In this work, an attempt has been made to review various optimization methods used to solve ED problems. Even though, excellent new trials have been made in classical methods, but they suffer from the following disadvantages. In several cases, mathematical formulations have to be simplified to get the solutions because of the extremely limited capability to solve real-time hard power system problems. They are weak in handling qualitative constraints. They have premature convergence rate, so they may get struck at minimum optimum. Hence in this work, Firefly Algorithm has been implemented to solve the economic dispatch problem. The proposed algorithm is tested on IEEE 30 bus system and the results obtained show the effectiveness of the proposed algorithm compared to those techniques available in literature.

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