

# Solving Combined Economic and Emission Dispatch using Firefly Algorithm

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**ABSTRACT:-**In this paper, fuel cost and the environmental emission functions are considered and formulated as a multi-objective economic load dispatch problem. For obtaining the solution of multi-objective economic load dispatch Fire Fly Algorithm was used. Potency of the algorithm is tested on six unit system. The promising results show the quick convergence and effectiveness of the firefly Algorithm.

**KEYWORDS:** Economic Load Dispatch, Emission, Firefly algorithm(FFA).

## I. INTRODUCTION

Nowadays, the planning and operating power system is a challenging task for power engineers because of its complexity and to satisfy the demand for electric energy of the area served by the system with Continuity of service and reliability. An elite objective here is to perform the service at the lowest possible cost. The role of soft computing techniques has influenced a lot in the field of power system especially in solving optimization problems because of their reliability, speed of convergence and robustness [1]. The ELD problem, one of the different non-linear programming commitment in power system, is about minimizing the fuel cost of generating units for a specific period of operation so as to accomplish optimal generation dispatch among operating units and to satisfy the system load demand and generator operation constraints with ramp rate limits and prohibited operating zones [2]. S.K.Dash [3] was presented a new method to solve the problem of optimal generation dispatch with multiple fuel options using a Radial basis function neural network along with a heuristic rule based search algorithm and a Hopfield neural network. Dr .G. Srinivasan, et al. [4] solved economic load dispatch problem with Valve point effects and multi Fuels using particle swarm algorithm with chaotic sequences and the crossover operation to improve the global searching capability by preventing premature convergence through increased diversity of the population. Radhakrishnan Anandhakumar, et al. [5] was proposed a non-iterative direct Composite Cost Function method, to solve economic dispatches of the online units with less Computation time. Umamaheswari Krishnasamy, et al. [6] presented a Refined Teaching-Learning Based Optimization Algorithm for Dynamic Economic Dispatch of Integrated Multiple Fuel integrated with Wind Power Plants. R. Balamurugan, et al. [7] proposed a self-adaptive mechanism is used to change these control parameters during the evolution process. These control parameters are applied at the individual levels in the population to solve economic dispatch with valve point and multi fuel options.

In this paper, combined Economic and emission load Dispatch has been solved by using the Firefly Algorithm(FFA). The FFA algorithm approach has been verified by applying it to test system. The performance of the proposed FFA algorithm is analysed and its parameters was self tuned. Because this parameter plays a major role in controlling the searching process of algorithm.

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## II. PROBLEM FORMULATION

### MATHEMATICAL MODEL OF OBJECTIVE FUNCTION AND CONSTRAINTS

In this paper two objective functions were considered. First objective is to minimize the total generation cost of generating power plant and the second objective is to minimize the environmental emission of the generating plants.

#### OBJECTIVE I

Economic Generation Cost Function. Generation quadratic fuel cost characteristic of generating power plant is formulated as follows:

$$F_T = \text{Min } f(\text{FC}) \quad (1)$$

$$f(\text{FC}) = \sum_{i=1}^N a_i P_i^2 + b_i P_i + c_i$$

#### OBJECTIVE II

Emission Objective Function. In this paper environmental emission was evaluated with consideration of NO<sub>x</sub> gas. A typical NO<sub>x</sub> emission at thermal power plants can be formulated as shown. Consider the following:

$$E_T \text{ Min } \sum_{i=1}^N f(E_i(P_i)) \quad (2)$$

$$E_i(P_i) = (\alpha_i + \beta_i P_i + \gamma_i P_i^2) + \varepsilon_i \sin(\lambda_i P_i) \quad (3)$$

Now both objectives may be combined in a single objective as given in (4), (5), and (6). The generation cost of each generator was evaluated at its maximum output:

$$F_i(P_{i \max}) = (a_i P_{i \max}^2 + b_i P_{i \max} + c_i) \quad (4)$$

NO<sub>x</sub> emission of each generator at its maximum output was evaluated:

$$E_i(P_{i \max}) = (\alpha_i + \beta_i P_{i \max} + \gamma_i P_{i \max}^2) \quad (5)$$

By (4) and (5) get

$$\frac{F_i(P_{i \max})}{E_i(P_{i \max})} = k_i \quad (6)$$

So the final objective incorporated total generation cost and environmental emission generation which is given as

$$F_{\text{final\_object}} = F_T + k_i(E_T) \quad (7)$$

#### POWER BALANCE CONSTRAINTS.

The total generated power should be equal to the sum of total load demand and line loss. It can be formulated as (8).

Consider the following:

$$\sum_{i=1}^n P_i = P_D + P_L \quad (8)$$

$$P_L = \sum_{i=1}^n \sum_{j=1}^n P_i B_{ij} P_j \quad (9)$$

#### GENERATOR LIMITS CONSTRAINT.

Generating output of each generating unit should lie between the maximum and minimum limits as given in

$$P_i^{\min} \leq P_i \leq P_i^{\max} \quad (10)$$

## III. FIREFLY ALGORITHM

### FIREFLY IN NATURE

Fireflies or glowworms are the creatures that can generate light inside of it. Light production in fireflies is due to a type of chemical reaction. This process occurs in specialized light-emitting organs, usually on a firefly's lower abdomen. It is thought that light in adult fireflies was originally used for similar warning purposes, but evolved for use

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in mate or sexual selection via a variety of ways to communicate with mates in courtships. Although they have many mechanisms, the interesting issues are what they do for any communication to find food and to protect themselves from enemy hunters including their successful reproduction. The pattern of flashes is often unique for a particular species of fireflies. The flashing light is generated by a chemical process of bio luminescence. However, two fundamental functions of such flashes are to attract mating partners or communication, and to attract potential victim. Additionally, flashing may also serve as a protective warning mechanism. Both sexes of fireflies are brought together via the rhythmic flash, the rate of flashing and the amount of time form part of the signal system. Females respond to a male's unique pattern of flashing in the same species, while in some species, female fireflies can mimic the mating flashing pattern of other species so as to lure and eat the male fireflies who may mistake the flashes as a potential suitable mate. The light intensity at a particular distance from the light source follows the inverse square law. That is as the distance increases the light intensity decreases. Furthermore, the air absorbs light which becomes weaker and weaker as there is an increase in the distance. There are two combined factors that make most fireflies visible only to a limited distance that is usually good enough for fireflies to communicate each other. The flashing light can be formulated in such a way that it is associated with the objective function to be optimized. This makes it possible to formulate new meta-heuristic algorithms.

The firefly algorithm (FFA) is a meta-heuristic algorithm, inspired by the flashing behaviour of fireflies. The primary purpose for a firefly's flash is to act as a signal system to attract other fireflies. Now this can idealize some of the flashing characteristics of fireflies so as to consequently develop firefly inspired algorithms. For simplicity in describing our new Firefly Algorithm (FFA) [30], there are the following three idealized rules. On the first rule, each firefly attracts all the other fireflies with weaker flashes. All fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex. Secondly, attractiveness is proportional to their brightness which is inversely proportional to their distances. For any two flashing fireflies, the less bright one will move towards the brighter one. The attractiveness is proportional to the brightness and they both decrease as their distance increases. If there is no brighter one than a particular firefly, it will move randomly. Finally, no firefly can attract the brightest firefly and it moves randomly. The brightness of a firefly is affected or determined by the landscape of the objective function. For a maximization problem, the brightness can simply be proportional to the value of the objective function. Other forms of brightness can be defined in a similar way to the fitness function in genetic algorithms. Based on these three rules, the basic steps of the firefly algorithm (FFA) can be summarized as the pseudo code shown below.

### PSEUDO CODE OF THE FFA:

#### Begin FFA Procedure;

Initialize algorithm parameters:

MaxGen: the maximal number of generations

$\gamma$ : the light absorption coefficient

r: the particular distance from the light source

d: the domain space

Define the objective function of  $f(x)$ , where  $x = (x_1, \dots, x_d)^T$

Generate the initial population of fireflies or  $x_i$  ( $i=1, 2, \dots, n$ )

Determine the light intensity of  $I_i$  at  $x_i$  via  $f(x_i)$

**While** ( $t < \text{MaxGen}$ )

**For**  $i = 1$  to  $n$  (all  $n$  fireflies);

**For**  $j=1$  to  $n$  ( $n$  fireflies)

**If** ( $I_j > I_i$ ), move firefly  $i$  towards  $j$ ; **End if**

      Attractiveness varies with distance  $r$  via  $\exp[-\gamma r^2]$ ;

      Evaluate new solutions and update light intensity;

**End for**  $j$ ;

**End for**  $i$ ;

  Rank the fireflies and find the current best;

**End while**;

Print the results;

**End procedure**;

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In the firefly algorithm there are two important issues of the variation of light intensity and the formulation of the attractiveness. For simplicity, it is assumed that the attractiveness of a firefly is determined by its brightness which in turn is associated with the encoded objective function of the optimization problems. On the attractiveness of the FFA the main form of attractiveness function or  $\beta(r)$  can be any monotonically decreasing functions such as the following generalized form of

$$\beta(r) = \beta_0 e^{-\gamma \cdot r^m} \tag{11}$$

where  $r$  or  $r_{ij}$  is the distance between the  $i^{\text{th}}$  and  $j^{\text{th}}$  of two fireflies.

$\beta_0$  is the attractiveness at  $r = 0$  and  $\gamma$  is a fixed light absorption coefficient. The distance between any two fireflies 'i' and 'j' at  $x_i$  and  $x_j$  is the Cartesian distance as follows:

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^d (x_{ik} - x_{jk})^2} \tag{12}$$

where  $x_{ik}$  is the  $k^{\text{th}}$  component of the  $i^{\text{th}}$  firefly ( $x_i$ ). The movement of a firefly 'i' is attracted to another more attractive (brighter) firefly 'j', is determined by

$$x_{i+1} = x_i + \beta_0 e^{-\gamma \cdot r_{ij}^2} (x_j - x_i) + \alpha(\text{rand} - 0.5) \tag{13}$$

where the second term is due to the attraction while the third term is the randomization with  $\alpha$  being the randomization parameter. Rand is a random number generator uniformly distributed in the range of [0, 1]. For most cases in the implementation,

$$\beta_0 = 1 \text{ and } \alpha = [0,1]$$

Furthermore, the randomization term can easily be extended to a normal distribution  $N(0, 1)$  or other distributions. The parameter  $\gamma$  characterizes the variation of the attractiveness, and its value is crucially important in determining the speed of the convergence and how the FFA behaves. In most applications, it typically varies from 0.001 to 100.

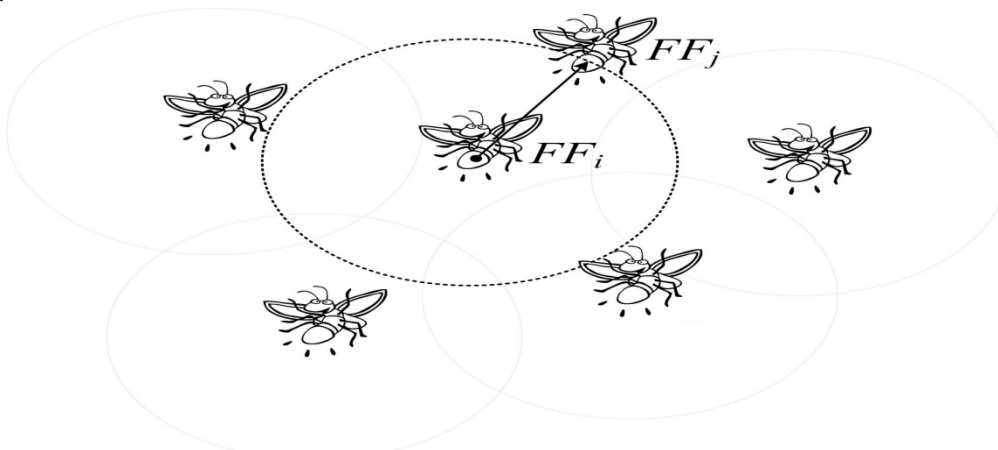


Figure 1: Schematic representation of Fireflies.

## IV. RESULT

In this case FFA is employed to solve the economic dispatch of IEEE 30bus system with demand 283.4MW. the simulation results and the converge of the cost function is shown in Fig-1 for 500 iterations.

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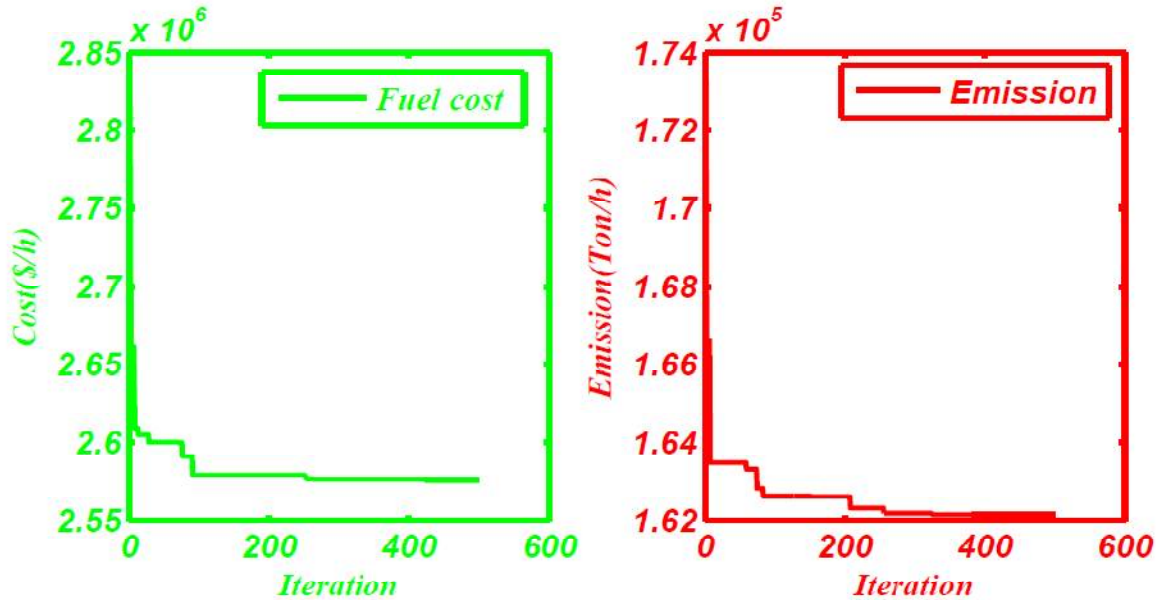


Figure 1. Convergence characteristics of Fuel cost and Emission.

Table.1. Results of IEEE 30 bus systems for the load of 283.4MW with line loss

Unit power output	CPSO [20]	WIPSO [20]	MRPSO [20]	Proposed FFA with minimum Emission	Proposed FFA with minimum Fuel cost
P1 (MW)	146.034	147.581	145.7801	146.564	146.0885
P2 (MW)	46.0732	46.889	43.0912	42.0854	46.836
P5 (MW)	34.0742	47.0705	43.07654	42.1506	34.074
P8 (MW)	26.0198	16.7863	24.0763	25.3844	25.0125
P11 (MW)	24.108	24.7219	23.1732	24.3856	24.8
P13 (MW)	26.0911	19.8925	23.0453	22.1458	25.148
Loss (MW)	19.0003	19.5407	18.8468	18.584	18.332
Fuelcost(\$/h)	2607622	2661327	2575426	2607638	<b>2575419</b>
Total power output	302.4	302.9407	302.2468	302.7191	302.0092
Emission (Ton/h)	162228.5	167729.1	162153.6	<b>162145.1</b>	163338.3

## V. CONCLUSION

In this paper, FFA is applied to economic emission load dispatch problems with six unit system as a test case. The results obtained by this method are compared with other soft computing techniques. The comparison shows that FFA performs better and got good convergence characteristics. The FFA has superior features, including quality of solution, stable convergence characteristics and good computational efficiency. Therefore, this results shows that FFA is a promising technique for solving complicated problems in power system.

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