ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 9, September 2013

A NATURE INSPIRED ALGORITHM FOR REDUCTION OF CO_2 EMISSION IN THERMAL POWER STATION

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ABSTRACT*:* The fossil fuels such as coal, natural gas or oil based power plants plays a major role in greenhouse gas emissions. In this paper presents a computational approach to reduce the carbon dioxide emissions by using Firefly Algorithm (FA). The Firefly Algorithm is a meta-heuristic, nature-inspired, optimization algorithm is based on the flashing behaviour of fireflies or lighting bugs. The objective of this work proposes to minimize the emission of thermal units. The proposed test system is coherent group of units it consists of six generators with respect to various load demands. The analytical computation and simulation of above test system has been performed using the MATLAB environment. The performance analysis of proposed algorithm is compared with conventional and other meta-heuristic algorithms.

Keywords*:* Emission dispatch, Firefly Algorithm, Test System, Simulation and Performance analysis.

I.INTRODUCTION

Scheduling of power plant generation is gives a great importance in electric power utility systems. One of the prime concerns from social and environment aspects is that both human and non-human life forms are severely affected by the atmospheric pollution caused during generation of electricity from fossil fuels. The fossil fuel releases several contaminants such as sulphur oxides (SO_x), nitrogen oxides (NO_x) and carbon dioxide (CO_2) into the atmosphere. This may give rise to the problem of global warming [1]. Recently the problem has attracted much attention is pollution minimization due to increasing concern over the environmental consideration [2], society demands adequate and secure electricity not only at the cheapest possible price, but also at minimum level of pollution. So the optimal scheduling of generation in a thermal power plant system involves the allocation of generation so as to optimize the fuel cost and emission level simultaneously.Several strategies to reduce the atmospheric emissions have been proposed and discussed [3-5]. These include installation of pollutant cleaning equipment, switching to low emission fuels, replacement of the aged fuel-burners with cleaner ones, and emission dispatching. Different optimization techniques like particle swarm optimization (PSO), Genetic algorithm (GA), simulated annealing (SA), Artificial Bee Colony (ABC) have been reported [6-10] in the literature pertaining to environmental / economic dispatch (EED) problem.

This paper proposes the Firefly optimization Algorithm to reduce the carbon dioxide emission from thermal power stations. The implementation of the above algorithm is organized as follows. The mathematical formulation of emission dispatch problem is discussed in section II. The proposed firefly algorithm and their characteristics are analysed in section III. The implementation of above algorithm is presented in section IV. In section V gives a description of test system. In section VI includes the simulation results with discussion and conclusions in section VII.

II. PROBLEM FORMULATION

The objective of solving emission dispatch problem is to minimize the emission level of the electric power system, while satisfying a set of constraints. This can be formulated as follows:

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A. Problem objective

Minimization of emission: The objective function for the total (kg/hr) emission can be expressed as

$$E(P) = \sum_{i=1}^{N} E_i(P_i) \quad (1)$$

The emission equation of a generating unit is usually described by a quadratic function of power output P_i as follows:

$$E_i(P_i) = \sum_{i=1}^{N} (d_i P_i^2 + eP_i + f_i) \frac{kg}{hr} \quad (2)$$

where, E_i (P_i) is the emission (Kg/hr), P_i is the power generated (MW) and d_i, e_i, f_i is the emission coefficients of the i th unit.

B. Problem constraints

Generation capacity constraint: For stable operation, real power output of each generator is restricted by lower and upper limits as follows

$$P_i^{min} \le P_i \le P_i^{max}, i = 1,2,..,N \quad (3)$$

Power balance constraint: The total power generation must cover the total demand P_D and the real power loss in transmission lines P_L. Hence,

$$\sum_{i=1}^{n} P_i = P_D + P_L \ \text{MW} \quad (4)$$

C. Problem Statement

Aggregating the objective and constraints, the problem can be mathematically formulated as a nonlinear emission constrained single objective optimization problem as follows

$$Minimize : [E(P)] \quad (5)$$
$$Subject\ to : g(P) = 0 \, , h(P) \le 0 \quad (6)$$

where, g is the equality constraint representing the power balance and h is the inequality constraint representing the unit generation capacity.

III. PROPOSED APPROACH

Recently the proposed Firefly algorithm can be effectively used to eliminate the carbon dioxide emission in thermal power plants. The Firefly optimization algorithm is based on the biochemical and social behavior of the fireflies.

A. Firefly Algorithm

The Firefly algorithm (FA) is a meta-heuristic algorithm, inspired by the flashing behavior of fireflies or lighting bugs. The primary purpose for a firefly's flash is to act as a signal system to communicate with other fireflies, especially to prey attractions.

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This firefly algorithm by assuming: [11]

1) All fireflies are unisexual, so that one firefly will be attracted to other fireflies.

2) Attractiveness of each firefly is proportional to its brightness, thus for any two flashing fireflies, the less bright firefly 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.

3) The brightness of a firefly is determined according to the nature of the objective function.

(i) Attractiveness

The attractiveness of a firefly is determined by its brightness or light intensity which is obtained from the objective function of the optimization problem. The attractiveness β can be defined by [12]:

$$\beta = \beta_o e^{-\gamma} r^m \quad \text{with } m \geq 1 \qquad (7)$$

Where r is the distance of two fireflies, β_o is the attractiveness at r = 0, and γ is the light absorption coefficient.

(ii) Distance and Movement

The distance between any two fireflies i and j at positions x_i and x_j, respectively, can be defined as a Cartesian or Euclidean distance as follows [13]:

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \qquad (8)$$

Where $x_{i,k}$ is the k^{th} component of the spatial coordinate x_i of the i^{th} firefly and d is the number of dimensions.

The movement of a firefly i towards a more attractive (brighter) firefly j is determined by the following equation:

$$X_i = x_i + \beta_o e^{-\gamma r_{ij}^2}(x_j - x_i) + \propto \varepsilon_i \qquad (9)$$

where the first term is the current position of a firefly, the second term is related to the attraction and the third term is randomization with the vector of random variables ε_i using a normal distribution.

IV. IMPLEMENTATION OF THE PROPOSED ALGORITHM

In this algorithm all the fireflies initially will be the random locations in the search space. The pseudo code for the Firefly optimization algorithm is as follows:

Input : f(x), $x = (x_1, x_2, \ldots, x_d)$ {Objective function}
$S = [a_i, b_i]$ for i=1,2,…,n {Constraints of the problem}
α,β_0,γ, n, Max and Min Gen,ß {Algorithm inputs}

Output : P_{Gi} for i= 1,…, 6, f(x), $f(x_1)$,$f(x_2)$
x_{imin}{Global minima point}

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```
Begin;
for i= 1: n
x (i) =>  Initialize the positions of the flies
end
Repeat
Begin
i_min<= arg min_i f(x_i)
x_imin<= argmin_xi f(x_i)
while (t< Max Generation)
for i=1:m     {all m fireflies}
for j=1:m {all fireflies}
if ( f(x_j)> f(x_i) ) then              {Move firefly i towards j}
r_j<=calculate distance (x_i ,x_j )
ß <= β_o  e^(-γr)                       {Obtain attractiveness}
U_i<= Generate Random vector             {min u_i, max u_i}
for k=1:n
x_imin,k<= x_imin,k+ U_imin,k
end
        end
        end
end
end of algorithm
```

V. TEST SYSTEM

The emission dispatch problem based on firefly optimization algorithm has applied to the six generator test systems at different load conditions. Multiple generator limits and total emission level of the system is simulated in order to evaluate the correctness and quality of the method.

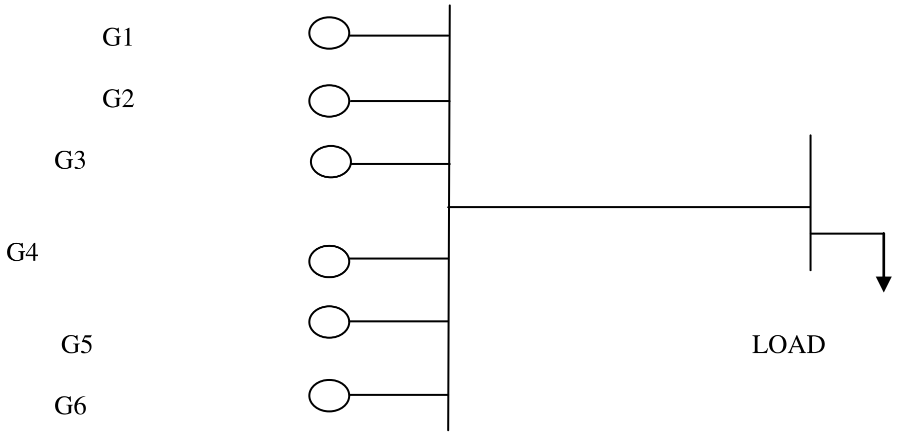

Fig.1 Test system

The emission constants and the generator limits of a 6 generator system are tabulated below.

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Unit	Emission Coefficients			P_i (min) MW	P_i (max) MW
	d_i	e_i	f_i		
G1	0.0042	0.3300	13.86	10	125
G2	0.0042	0.3300	13.86	10	150
G3	0.0068	-0.5455	40.26	35	225
G4	0.0068	-0.5455	40.26	35	210
G5	0.0046	-0.5112	42.96	130	325
G6	0.0046	-0.5112	42.96	125	315

Table.1 Input Data for Emission Coefficients

VI. SIMULATION RESULTS AND DISCUSSIONS

The proposed approach was tested on the six generator system for various load demands. Table.2 Show that the comparisons of the performance of the firefly algorithm with the particle swarm optimization Technique.

Generation in MW	Total Emission (kg/hr)		
	Proposed method	Particle swarm optimization [15]	Conventional method [15]
500	252.3889	251.8220	261.634
600	327.8649	329.3599	338.992
700	416.9956	428.5095	434.380
800	522.7557	540.2801	547.796
900	645.1195	650.4240	679.240
1000	784.6992	793.7640	828.720
1100	945.5675	953.3311	996.224

Table.2 Comparison for the FA with Other optimization technique

The individual powers to the six generators for various demands are tabulated below.

Generation in MW	Individual Generator Power (MW)					
	G1	G2	G3	G4	G5	G6
500	35.92	35.92	86.56	85.56	130.0	125.0
600	56.97	56.97	99.56	99.56	143.4	143.4
700	76.73	76.73	111.7	111.7	161.4	161.4
800	96.48	96.48	123.9	123.9	179.5	179.5
900	116.2	116.2	136.1	136.1	197.5	197.5
1000	125.0	138.7	150.0	150.0	218.0	218.0
1100	125.0	150.0	167.9	167.9	244.5	244.5

Table.3 Individual Generator Power

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Fig.2 show that the comparison graphs for emission of carbon dioxide for six generator test system. The graphs contain the emission (kg/hr) on the Y axis and Load demand (MW) on the X axis.

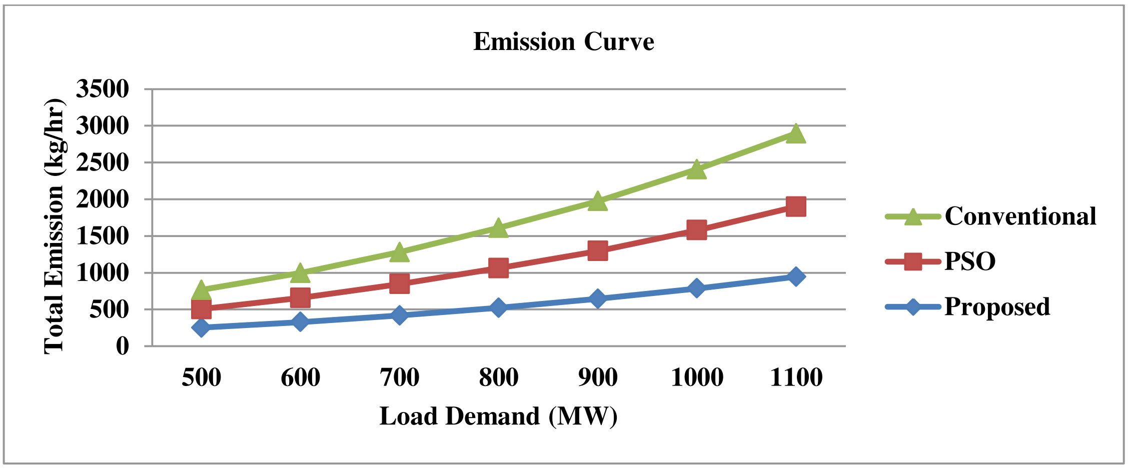

Fig.2 Comparison of total emission for six generator systems

VII. CONCLUSIONS

The Firefly Algorithm has been applied for optimizing the economic dispatch problem for minimizing the emission level of the thermal power plants. It is seen from the simulation results that the proposed method reduces the global warming by minimizing the concentration of co_2 in fossil burning of fuels. The numerical solution is analytic in nature with high accuracy involving less computational time. Simulations and results indicate that the proposed firefly algorithm is superior to existing meta-heuristic algorithms.

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Vol. 2, Issue 9, September 2013

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BIOGRAPHY

Palaniyappan Sobtained his Bachelor degree in Electrical & Electronics Engineering from A.C.College of Engineering and Technology Karaikudiin the year 2009 and Master degree in Power Systems Engineering from Anna University, University College of Engineering, BIT Campus Tiruchirappalli in the year 2013. He is currently working as an Assistant Professor with the department of Electrical & Electronics Engineering in Sudharsan Engineering College at Pudukkottai District, India. His research area includes the application of soft computing techniques in power system and Smart grid technologies.

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