Implementation of Firefly Algorithm on Economic Load Dispatch

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***Abstract*-The power utility needs to ensure that the electrical power is generated with minimum cost. Hence, for an economic operation of the system, the total demand is to be appropriately shared with an objective to minimize the total generation cost for the system. So, economic load dispatch (ELD) has become one of the major problems of power system operation and control. This total cost is further minimised by the implementation of a nature inspired Firefly Algorithm. ELD problems has been solved with lambda iteration method and firefly Algorithm at different load demands and effectiveness of firefly algorithm is investigated.**

Index Terms: Economic Load Dispatch (ELD), Firefly Algorithm(FA), objective function

1.INTRODUCTION

WITH large interconnection of power system, the increasing energy crisis and price hikes, it is very essential to reduce the operating cost of electrical energy. Presently the major problem of the power utilities is to deal with both that is satisfaction of the consumer power demand as well as to do it in the most economic way.

In a typical power system, several generators are implemented to satisfy total consumer demand. Each of these generating units usually has a unique cost-per-hour characteristic for its output operating range. When transmission losses are considered then it becomes much more complicated for the utilities.

The main aim of the power utilities is to provide smooth electrical energy to the consumers with an assurance of minimum cost of generation. Hence in order to achieve economic operation of system, total demand must be appropriately shared among all the generators.

Economic load dispatch is one of the major and challenging issues in power system. It is mainly an optimisation problem with a goal of obtaining generation with a minimum cost along with the satisfaction of the constraints. Various conventional methods are used solve the economic load dispatch problem such as Lagrange multiplier method, lambda iteration method etc.

In these, it is difficult to get the optimal solution of problem, hence to get an good optimal solution, advanced computing techniques such as various algorithms are becoming popular in solving complicated problems of ELD.

In this paper, firefly algorithm (FA) is used to solve the ELD problem. FA is a nature inspired and population based algorithm. It is inspired by the flashing behaviour of fireflies. This paper has been organised as follows. The ELD is discussed in section 2 followed by the concept of FA in section 3. The application of FA into the ELD problem has been discussed in section 4. In section 5, the case study along with result and discussion is presented. Finally the conclusion has been stated.

2. CLASSIC ECONOMIC LOAD DISPATCH

ELD aims at finding out the optimal power generation in order to match with the load demand with a minimum cost so that the system load is supplied entirely and most economically subjected to the satisfaction of the constraints [1].

The objective of ELD is to minimise the cost of generation which is given by

$C=\sum_{i=1}^{n} Ci(Pgi)$ and is given by

$CGi(PGi)=a_i+b_iP_{Gi}+c_iP_{Gi}^2$

where a_i,b_i ,c_i are the coefficients of the ith generator.

Subjected to equality and non equality constraints:
The equality constraints are the complex power injected by the source into the ith bus of the power system and are given by

$P_{Gi}-P_{Gi}=V_i \sum_{i=1}^{n} Vj(Gij \cos\delta ij + Bij \sin \delta ij)$

$Q_{Gi}-Q_{Gi}=V_i\sum_{i=1}^{n} Vj(Gij \cos\delta ij + Bij \sin \delta ij)$

The inequality constraints are given by
(a) Generator constraints:
P_p active power generation
Q_p reactive power generation

$$P_{pmin} \leq P_p \leq P_{pmax}$$

P_{pmin} is limited by flame instability of boiler.
P_{pmax} is limited by thermal limit consideration.

$$Q_{pmin} \leq Q_p \leq Q_{pmax}$$

Q_{pmin} is limited by stability limit of machine.
Q_{pmax} is limited by the overheating of rotor

(b)Voltage constraints:
It should be within specified limits otherwise various equipments connected to the system will not operate satisfactorily or additional use of voltage regulating devices will make system uneconomical. It is given by

$$V_{pmin} \leq V_p \leq V_{pmax}$$

(c)Running spare capacity constraints:
These constraints are mainly required to meet the

(a) the forced outages of one or two generators of the system.

(b) the unexpected load on system.

The total generation of a system should be such that in addition to the meeting of load demand as well as losses in the system ,a minimum spare capacity should be available for an emergency purpose.

$$G \leq P_p \leq P_s \text{, where}$$

G is the total generation
P_p is the active power generation
P_s is the pre specified power
In a well planned system, P_s is minimum.
The objective of the ELD problem is to minimize the generation cost without violating the constraints.

3. FIREFLY ALGORITHM

Firefly algorithm is one of the recent swarm intelligence method and is done to optimise power dispatching[5]. It was developed by Dr. Xin-She Yang. FA is based on the flashing behaviour of fireflies mainly found in the summer sky of the tropical temperate regions. The flashing signifies the signal to attract other fireflies, and the objective function is associated with the flashing light or the light intensity which helps the fireflies to move to brighter and more attractive locations to achieve optimal solution.

There are in random about two thousand fireflies species .The flashes of these fireflies are unique for a particular species. Two fundamental functions of such flashes are to attract mating partners (communication) and to attract potential prey.

3.1. 3 Ideal Rules For Firefly Algorithm

(a)All fireflies are unisex, so that one firefly should be attracted to other fireflies regardless of their sex.
(b) The intensity of attractiveness is proportional to the brightness of a firefly, which is indirectly proportional to the distance of the firefly.
(c)Brightness of firefly depends on the objective function.

FA main advantage is that it can find both global and local optima simultaneously and effectively. Also, parameters of FA can be tuned to control the randomness with the increase no. of iteration, so that convergence can be tuned to get the increased number of iteration. As a result, FA proves itself to be more effective in the optimization of ELD problem.

3.2 Behaviour of Firefly Species

Near about two thousand species of fireflies are seen in the summer sky and they produce flashes. The rhythm of their flashes, rate of their flashing and observed time of their flashes altogether forms a pattern which attracts both the male and female fireflies to each other.

We know that the intensity of light(I) at a certain distance (r) from the light source relates to the inverse square law. According to it, the intensity of the light (I) goes on decreasing as the distance (r) increases that is $I \alpha 1/r^2$.

As the air keeps on absorbing the light, it becomes weaker with the increase in distance. These two combined factors are responsible for making most visible within a certain range of distance. It becomes quite enough for the fireflies for communicating with each other and this has developed the basics for firefly algorithm. The flashing light of the fireflies is mainly associated with the objective function to be optimised and hence these algorithms are used to optimisation.

3.3. Characteristics Offirefly Algorithm

(a) Attractiveness
The attractiveness function is a The attractive function of a firefly is a monotonically decreasing function. It is given by

$$ß(r)=ß_0 \exp(-\gamma\, r^m) \text{ where,}$$

r is distance between any of the two fireflies,
β_0 is the initial attractiveness of fireflies at r = 0
γ is the absorption coefficient, it controls the decrease of the light intensity.
The absorption coefficient (γ) characterizes the variation of the attractiveness and its value is important to determine the speed of the convergence and how the FA behaves.
Attractive function is associated with brightness which in turn is associated with the objective function.

(b) Distance
The distance between any two fireflies *i* and *j*, at positions x_i and x_j respectively ans is defined by

$$r_{ij} = \sum_{k=1}^{d} (xi,k - xj,k)^{1/2}$$

Where $x_{i,k}$ is the *kth* component of the coordinate *xi* of the *ith* firefly and *d* is the number of dimensions.

(c) Movement
The movement of a firefly i which is attracted by a brighter firefly j is given by:

$$x_i = x_i + ß_0 \exp(-\gamma\, r^m)(x_j - x_i) + \alpha(rand-1/2)$$

First term represents the current position of firefly. Second term is used for description of firefly's attractiveness to light intensity. Third term is used for the random movement of the firefly.

Thus, a change in the FA parameters changes the effectiveness of the algorithm and tuning of these parameters highly affects the performance of FA and finally results in good optimised search results

3.4 Search Optimality

Search optimality is essential for an algorithm. It gives the optimal solution of an search.

The main components of any metaheuristic algorithm are :**intensification** (exploitation) and **diversification** (exploration).

Intensification is to search in a local optimal region where as diversification is to explore and search in a global scale. This is done for the selection of the best solutions.

3.5. PARAMETERS OF FIREFLY ALGORITHM

Parameter	Notation in Algorithm
Brightness	Objective function
Beta (β)	Attractiveness parameter
Alpha (α)	Randomization parameter
Gamma (γ)	Absorption coefficient
Number of generations	Iterations
Number of fireflies	Population
Dimension	Problem dimension
R	Radius, time interval etc. (depends on application

In firefly algorithm, parameter alpha (α) controls exploration and parameter gamma (γ) controls exploitation. These parameters describe the variation of the attractiveness and its value is responsible for the speed of firefly algorithm convergence.

For most of the cases, randomisation parameter (α) belongs to (0, 1) and attractiveness parameter (ß) equals to 1. The absorption coefficient varies from 0.1 to 1.0.

The parameters values of the firefly algorithm i.e attractiveness, randomisation and absorption coefficients are tuned in such a manner that the balance between exploration and exploitation is maintained and a desired optimal solution is being obtained. More number of iterations and more number of populations actually provides us a better result of optimisation.

4. ECONOMIC LOAD DISPATCH USING FIREFLY ALGORITHM

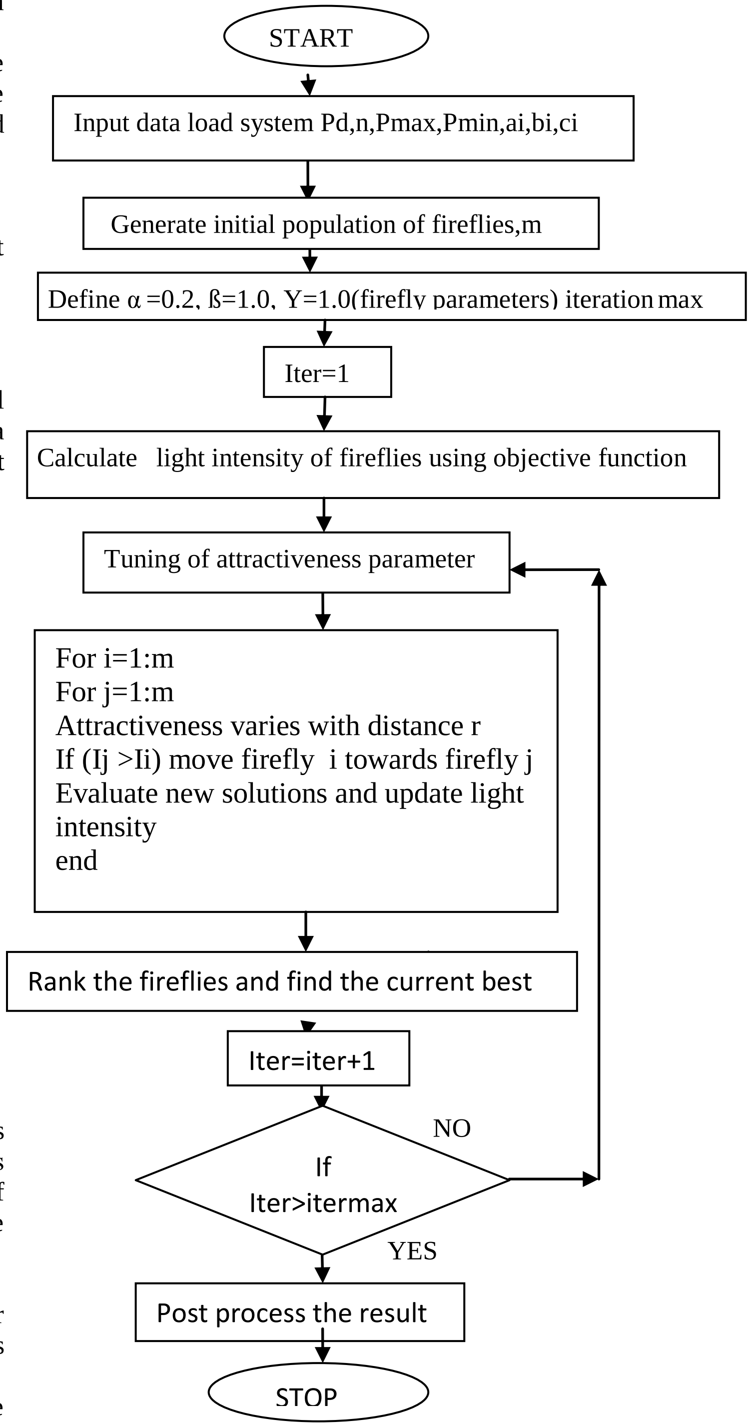

Figure1: Flowchart showing implementation economic load dispatch using Firefly Algorithm

4.1. Steps for Eld With Fa

Step 1: Start of the program

Step 2: entering of the load system input data

Step 3: generation of initial population of fireflies xi (i = 1, 2, ..., n)

Step 4: determination of light intensity Ii and xi is determined by f (xi)

Step 5: to set iteration count iter=1

Step 6: to calculate the ith firefly for i=1:n for all the n fireflies.

Step 7: to calculate the jth firefly for j=1:n for all the n fireflies.

Step 8:To check if (Ij> Ii), Move firefly i towards j in dimensions.

end if

Step 9: To calculate attractiveness, when attractiveness varies with distance r.

Step10: To evaluate new solution and update light intensity.

Step11: end for j

Step12: end for i

Step13: Ranking of the fireflies and finding the current best.

Step14: To evaluate Iter =Iter+1

Step15: Checking if Iter > Itermax; the condition no means goto step 4.

Step16: Print the results

Step17: Stop the program.

By using MATLAB or any other programming tools, FA can be implemented based on the objective function.

5. RESULTS AND DISCUSSION

TABLE I: Solving economic load dispatch using classical method.

Total load demand(Pd)	Thermal units(MW)						Fuel cost FC(Rs/hr)
	P_1	P_2	P_3	P_4	P_5	P_6	
259.2	134.142	48.506	18.714	18.100	27.738	12.000	705.118
249.2	157.657	54.543	15.000	10.000	10.000	12.000	689.284
239.2	153.279	20.000	23.271	15.930	10.671	16.094	635.930

TABLE II: Solving economic load dispatch using firefly algorithm

Total load demand(Pd)	Thermal units(MW)						Fuel cost FC(Rs/hr)
	P_1	P_2	P_3	P_4	P_5	P_6	
259.2	164.99	30.000	20.455	15.735	10.000	18.031	693.428
249.2	159.51	20.0000	15.00	10.00	28.06	16.61	678.218
239.2	172.2	20.000	15.000	10.000	10.000	12.000	630.608

From Table I and II it is been found that fuel cost for various load demand in iteration method of economic load dispatch is more than that of the economic load dispatch using firefly algorithm for different load demands, hence the Firefly algorithm is proved to be more economical, convergent and gives optimal values than that of the normal solving iteration method of economic load dispatch.

Firefly algorithm proved has itself to be efficient in cost minimisation of thermal generators and thus a strong tool for economic load dispatch.

6. CONCLUSION

The new meta-heuristic and swarm based firefly algorithm is a very effective and powerful technique and is used for the optimisation of the cost of economic load dispatch problems. It is a simple method and is easy for implementation. In this work we have demonstrated and tested this algorithm to optimise the problem of minimisation of cost function. The parameters of firefly algorithm such as the absorption coefficient, the population of fireflies and the number of iterations depend on the optimized problem.

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