Economic Dispatch Problem Using Valve Point Loading Effect by Firefly Algorithm

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Abstract-The major issue in power system is Economic Dispatch problem. It is an optimization problem and to reduce the total generation cost of units by satisfying equality and inequality constraints. Most of the classical problem formulation in ED problem presents deficiencies due to the simplicity of the cost models. In real life generating stations the valves control the steam entering the turbine through separate nozzle groups. Each nozzle group achieves best efficiency. Here, the economic dispatch problem formulation takes in to account of non-smooth fuel cost function due to valve point effects and making this to a real world problem. The main objective of this project is to optimize the cost using Firefly Algorithm [FA]. This algorithm is a type of swarm intelligence algorithm based on the reaction of a firefly to the light of other fireflies. The 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. The proposed approach has been examined and tested with the numerical results of ED problems with three- generation units.

Index Terms - Economic Load Dispatch(ED), Firefly Algorithm(FA),Valve Point Loading Effect, Particle Swarm Optimization.

I.INTRODUCTION

Electricity is the most important aspect of our livelihood, without which it's probably impossible to sustain. Electricity starts with generation, followed by transmission and distribution. While generating the electricity it should be noted that the generated electricity should have the same efficiency as that of the distributed electricity and hence it's a comprehensive process. 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.

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.

As an engineer it is always in concern to obtain a product at a minimum cost by reducing either the product operating cost or by reducing the raw or input cost to the

Production unit. In this project it's all about reducing the cost of generation of electricity. In order to economies the production of electricity we consider Economic Load Dispatch (ELD). The Economic Load Dispatch (ELD) has a common meaning that involves the practice of operating a coordinated power system such that the lowest operating costgenerators are used to the greatest extent and the highest operating cost generator are used to the lowest extent. Economic Load Dispatch (ELD) is the fundamental issuewhich aims to find the optimal power generation to match with the demand at minimum cost by satisfying all the system constraints. 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. Thesolution 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, andLambda iteration method and so on.[8] 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 [4]. 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.
ELD has become a important fundamental necessity in operation and control of the power system [5]. Several deterministic optimization approaches were proposed to solve the ELD problem, including lambda iteration method, gradient method, linear programming, non-linear programming, dynamic programming and quadratic programming. But these methods require enormous efforts in terms of computation .Due to complexities of computing, therefore developing efficient algorithm to find Optimal solution[9]. One such algorithm is discussed in this project.
Bio-inspired meta-heuristic algorithms have recently shown the efficiency in dealing with many non-linear optimizations constrained problems for finding the optimal solution. In the same stream, a newly nature based optimization technique Firefly Algorithm (FA) is developed based on the flashing behavior of fireflies [1]. This Firefly Algorithm (FA) is the one which is discussed in this project.
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[3]. In this paper we will show how the firefly algorithm can be used to solve the economic dispatch problem.
Presented a new path for determine the economic load dispatch problem considering valve point constraints. The results are compared with various stochastic search algorithms. 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.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.

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. Presented a new approach to clarify the economic dispatch problem. The feasibility of the proposed algorithm is demonstrated. Presented a comprehensive review of a firefly algorithm can deals with multimodal functions efficiently and naturally.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.[11] Presented a efficient method for solving economic dispatch 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.presented a GA.Solution for solving economic dispatch considering valve point loading[14].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 likemyopia for nonlinear, discontinuous search spaces, whichleads them to a less desirable performance and these methodsoften use approximations to limit complexity.So,later modernheuristics stochastic optimization technique are introduced. They are Simulated Annealing (SA), Genetic Algorithm (GA), Evolutionary Program (EP)[12-15], Tabu Search and so on. These methods are efficient in solving optimization problems. Although these methods don't guarantees that theygive 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. PROBLEMFORMULATION

The operation of generation facilities is 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 problem is to minimize the following cost function [2],[10],[15]

$$\textbf{Minimize } C_T = \sum_{n=1}^{n} C_n(P_n) \qquad \textbf{(1)}$$

Where,

: Total generation cost (Rs/hr)

: Number of generators

: Real power generation of n^{th} generator (MW)

b) Cost function

$$(P_n) = a_n P_n^2 + b_n P_n + c_n \qquad \textbf{(2)}$$

Where,

proble m[10]. By using PSO with SQP.Presented a PSO

$\boldsymbol{a_n}$, $\boldsymbol{b_n}$

$\boldsymbol{c_n}$:

′ constant of the cost function

c) Constraints

The equality and inequality constraints are as follows.

***1)* Equality Constraints-** In Economic Dispatch problem, the real power balance equation is considered for the equality constraints. The power balance equation is as follows:

$$\sum_{n=1}^{n} P_n - P_D = 0 \quad \textbf{(3)}$$

: Total Power Generated P_D : Maximum Demand

***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 ofinequality 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 ofreal power generation at generator buses, lower bounds ofreal power generation at generator buses.

$$P_{n,n} \leq P_n \leq P_{n,max} \quad \textbf{(4)}$$

$P_{n,n}$: Minimum generation limit in MW

$P_{n,x}$: Maximum generation limit in MW

III. ED PROPBLEM CONSIDERING WITH VALVE-POINT EFFECTS

Valve point loading is considered so as to minimize the cost of the objective function. Power plants commonly composed of multiple valves to control the output. When steam inlet valves are first opened, there will be a sudden increase in losses which introduce ripples in cost function. This is knownas valve point loading. Smooth quadratic functions are commonly used to model the generators to relate power output to production cost[12] This simplifies the power economic dispatch problem. For practical cases, quadraticrepresentations do not model properly generators, so more accurate models are required to get better solutions. Power plants commonly composed of multiple valves to control the output. When steam inlet valves are first opened, there willbe a sudden increase in losses which introduce ripples in cost function. This is known as valve point loading [13].The fuel cost function with valve point effect which will result non- linear, non-smooth and non-convex cost function.

$$C_n(P_n) = a_n P_n^2 + b_n P_n + c_n + |e_n * sin(f_n(P^{min} - P_n))| \quad (5)$$

Where e_n, f_n are the fuel cost coefficients of n[th] unit considering valve point effects.

IV. FIREFLY ALGORITHM

The Optimization techniques provide the best possible solution of objective function when all its constraints are satisfied. They can be classified into two main categories: deterministic and stochastic algorithms [7] Hill climbing approach is a deterministic approach which produces the same set of solutions if the iterations start with the same initial guess.Whereas the stochastic algorithm produces different solutions with same initial starting point, although the results differ slightly.

Deterministic algorithms are basically local search algorithms and are efficient in finding local optimal value .A common practice is to introduce some stochastic component to an algorithm so that it becomes possible to jump out of such locality and find the global optima and in such case the algorithm is called as stochastic. Stochastic algorithm has two components, deterministic and random component associated with it. The stochastic component can take many forms such as simple randomization by randomly sampling the search space or by random walks. Most stochastic algorithms can be considered as meta heuristic viz. Genetic Algorithm (GA), Particle Swarm Optimization (PSO), FireflyAlgorithm (FFA), Harmony Search Algorithm (HAS), etc.[1] The Firefly Algorithm (FA) is a metaheuristic, 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. It was developed by Dr. Xin-She Yang at Cambridge University in 2007, and it is based on the swarm behavior such as fish, insects, or bird schooling in nature. In particular, although thefirefly algorithm has many similarities with other algorithms which are based on the so-called swarm intelligence, such as the famous Particle Swarm Optimization (PSO), Artificial Bee Colony optimization (ABC), and Bacterial Foraging (BFA) algorithms, it is indeed much simpler both in concept and implementation.[10,15] Furthermore, according to recentbibliography, the algorithm is very efficient and can outperform other conventional algorithms, such as genetic algorithms, for solving many optimization problem; a fact that has been justified in a recent research, where the statistical performance of the firefly algorithm was measured against other well-known optimization algorithms using various standard stochastic test functions . Its main advantageis the fact that it uses mainly real random numbers, and it is based on the global communication among the swarmingparticles (i.e., the fireflies), and as a result, it seems more effective in multiobjective optimization such as the economicload dispatch problem in our case [15] .The firefly algorithm has three particular idealized rules which are based on some of the major flashing characteristics of real fireflies

V. STRUCTURE OF FIREFLY ALGORITHM:

The firefly algorithm has three idealized rules or assumptions which are been developed to define the characteristics of fireflies [4]

1) All fireflies are unisex and they move towards the more attractive and brighter one irrespective of their sex.

2) The level of attraction of firefly is proportional to brightness which reduces with the increase in the distance between two fireflies since air absorbs the light.

If there is no brighter or more attractive firefly than a particular one, it will then move randomly.

3) The brightness or light intensity is determined by the value of the objective function of a given problem and it is proportional to the light intensity for a maximizationproblem.

VI. CHARACTERSTICS OF FIREFLY ALGORITHM

The proper designing of the firefly algorithm can defined on two important issues:

The variation of the light intensity and the formulation of the attractiveness.[6-8]

1) Attractiveness

In the firefly algorithm, the form of attractiveness function of a firefly is the following monotonically decreasing function:

$$(\boldsymbol{r}) = \mathrm{Q}_{\mathbf{0}} * \mathbf{ex}(-\boldsymbol{r}^{\boldsymbol{m}}), \text{ with } \mathbf{m} \geq \mathbf{1} \quad \textbf{(6)}$$

where, $\boldsymbol{r}$ is the distance between any two fireflies, $\mathrm{Q}_{\mathbf{0}}$ is the initial attractiveness at $\boldsymbol{r}$ = 0, and is an absorption coefficient which controls the decrease of the light intensity.

2) Distance:

The distance between the two fireflies i and j at x_i and x_j respectively is the Cartesian distance.

$$\boldsymbol{rij} = \sqrt{(\boldsymbol{xi} - \boldsymbol{xj})^2 - (\boldsymbol{yi} - \boldsymbol{yj})^2} \quad (7)$$

where r is the distance between the i^{th} and j^{th}fireflies.

3) Movement:

The movement of a firefly *i* which is attracted by a more attractive (i.e., brighter)firefly*j* is given by the following equation:

$$\boldsymbol{X_i} = \boldsymbol{x_i} + \mathrm{Q}_{\mathbf{0}} * \boldsymbol{exp}(-\boldsymbol{rij}\ \mathbf{2}) * (\boldsymbol{x_j} - \boldsymbol{x_i}) + \boldsymbol{a} * (\boldsymbol{rand} - \mathbf{1/2}) \quad (8)$$

where the first term is the current position of a firefly, the second term is used for considering a firefly's attractiveness to light intensity seen by adjacent fireflies, and the third term is used for the random movement of a firefly in case there arenot any brighter ones. The coefficient α is a randomization parameter determined by the problem of interest, while rand is a random number generator uniformly distributed in the space. As we will see in this implementation of the algorithm, we will β_0=2.5, α =1, and the attractiveness or absorption coefficient γ = 1, which guarantees a quick convergence of the algorithm to the optimal solution. [15]

VII.FIREFLY ALGORITHM STEPS

Step1: Read the system data such as cost coefficient, min and max power limits of all generating units, power demand, and valve point constants.

Step2: Initialize the parameters and constant of firefly algorithm. They are max iteration count, alpha, beta, beta0, and gamma.

Step3: Generate set of ten population pop1[i],pop2[i],pop3[i] randomly between max and min power.

Step4: Generate valve point loading val1[i],val2[i],val3[i] for the corresponding cost function cost1[i],cost2[i],cost3[i] by using the formulae:

$$\boldsymbol{C_n}(\boldsymbol{P_n}) = \boldsymbol{a_n}\boldsymbol{P_n^2} + \boldsymbol{b_n}\boldsymbol{P_n} + \boldsymbol{c_n} + |\boldsymbol{e_n} * \boldsymbol{sin}(\boldsymbol{f_n}(\boldsymbol{P^{min}} - \boldsymbol{P_n}))|$$

Step5: Set the iteration count 1.

Step6: Calculate the fitness function of corresponding total cost [i] for the generated population by summing all the three cost.

Step7: Obtain the best fitness function total cost[i] by comparing all the fitness function and also obtain the best firefly values of total cost[i] corresponding to the best fitness value i.e "best cost". Arrange the best fitness function in ascending order.

Step8: Determine the distance between two fireflies i and j by using the formula

r[i]=(totalcost[i]-totalcost[j])*(totalcost[i]-totalcost[j]);

where r[i] is the distance between those generated population totalcost[i]. Find the value of m[i] by finding the square root of the above found parameter using the formula **m[i]=sqrt(r[i])**.

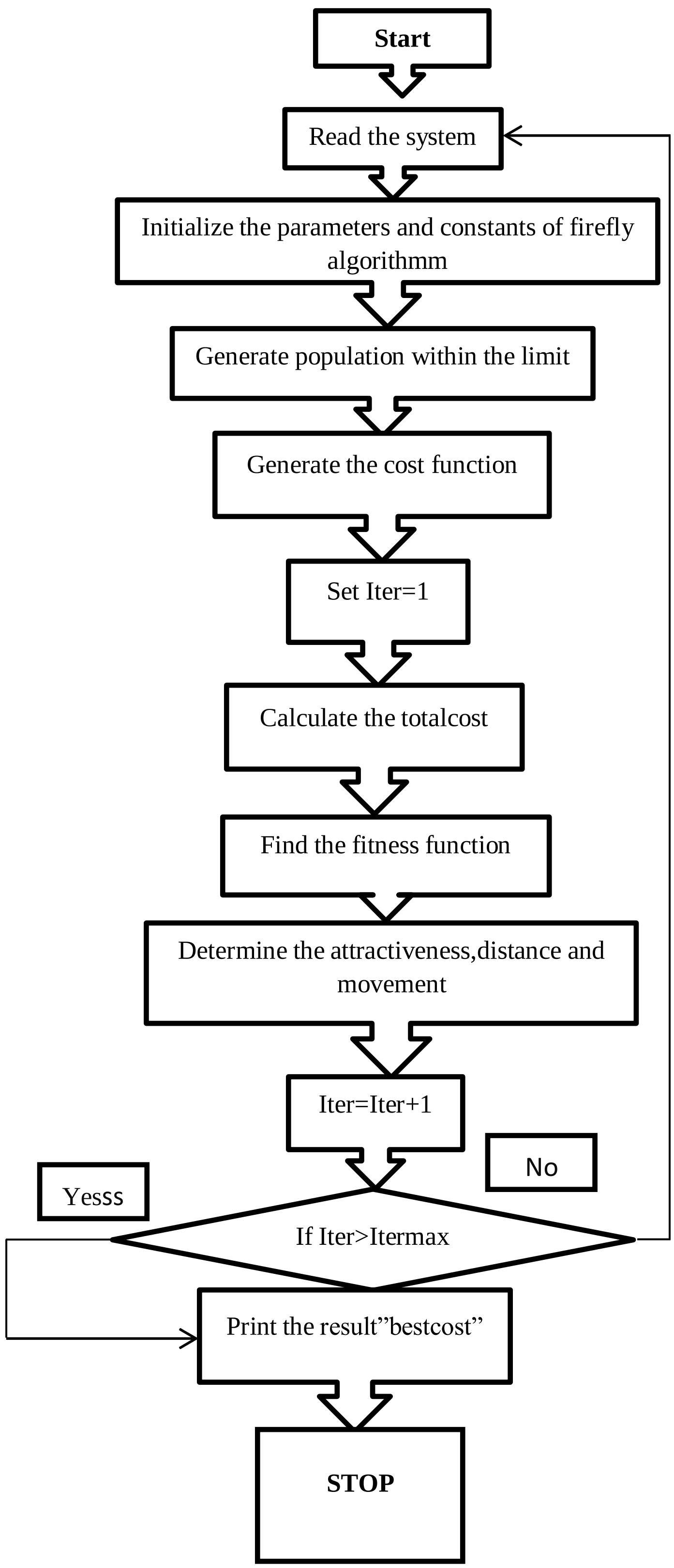
Step9: Determine the attractiveness of the fireflies using **beta[i]=beta0*(exp(-Gama)*Thom[i])** where the value of beta0=2.5 and gamma=1,thom[i] is generated in the above step.

Step10: Determine the new cost values by using the movement equation.Thenthe fireflies are moved according to the priority.

Step11: Iteration count is incremented and if iteration count is not reached max goes to step 5.

Step12: "**Best cost:"** gives the optimal solution of the Economic Load Dispatch problem and the results are printed.

VIII. FLOWCHART-



XI.RESULTS AND DISCUSSION-

The effectiveness of the proposed firefly algorithm is tested with three and six generating unit systems. Initially, the problem is solved by conventional Lambda iterative method and then Firefly algorithm optimization method is used to solve the problem. Furthermore to reduce the cost the valve point loading effect is also considered.The following tabular column shows the simulated result.

The simulation is done using C++ program for better optimization.

Three-Unit System-

The generator cost coefficients, generation limits and B-coefficient matrix of three unit system are given below. Economic Load Dispatch solution for three unit system is solved using conventional Lambda iteration method and Firefly Algorithm method also by considering the valve point loading effect which reduces the cost furthermore.

Table 1: Cost coefficients and power limits of 3-Unit system.

Sl No	a[i]	b[i]	c[i]	P_{min}	P_{max}
1	a_1=500	b_1=5.3	c_1=0.004	300	500
2	a_2=400	b_2=5.5	c_2=0.006	150	300
3	a_3=200	b_3=5.8	c_3=0.009	50	250

Table 2: Comparison of test results of Lambda- iteration method and Firefly Algorithm for 3-Unit System

Sl No.	Power Demand (MW)	Fuel Cost(Rs/hr)	
		Lambda Iteration Method	Firefly Algorithm
1	450	2571.3	2231.5
2	500	2630.6	2453.23
3	550	2968.8	4523.15
4	600	3012.7	2937.3
5	650	3489.1	3369.8
6	700	3794.4	3569.32
7	750	4587	4398
8	800	6682.5	5388.91

Table 3: Comparison of test result of Lambda - Iteration method and Firefly Algorithm for 3-Unit System using valve point effect.

Sl No.	Power Demand (MW)	Fuel Cost(Rs/hr)	
		Lambda Iteration Method	Firefly Algorithm
1	450	2571.3	2139.6
2	500	2630.6	2356.8
3	550	2968.8	2469.4
4	600	3012.7	2867.5
5	650	3489.1	3274.6
6	700	3794.4	3487.4
7	750	4587	4269.7
8	800	6682.5	5286

Six-Unit System

The generator cost coefficients, generation limits and B-coefficient matrix of six unit system are given below. Economic Load Dispatch solution for six unit system is solved using conventional Lambda iteration method and Firefly Algorithm method.

Table 4: Cost Coefficients and Power Limits of 6-Unit System

Unit	a[i]	b[i]	c[i]	Pn,Min	Pn,Max
1	750.795	3.2	0.14761	10	125
2	452.321	4.0	0.10547	10	150
3	650	4.6	0.10254	35	225
4	480.231	3.8	0.02342	35	210
5	892.314	3.6	0.03264	130	325
6	200	3.8	0.00231	125	315

Table5:Comparison of Test Result of Lambda-Iteration method and Firefly Algorithm for 6-Unit System

Sl No	Power Demand	Fuel Cost(Rs/Hr)	
		Lambda Iteration method	Firefly Algorithm
1	600	6987.32	6852.32
2	650	7014.12	6923.58
3	700	7135.48	7015.36
4	750	7423.2	7213.5
5	800	7745.3	7624.12
6	850	7965.3	7851.32
7	900	8032.1	7962.3
8	950	8597.2	8236.32

Table 6: Comparison of test result of Lambda - Iteration method and Firefly Algorithm for 6-Unit System using valve point effect

Sl No	Power Demand	Fuel Cost(Rs/Hr)	
		Lambda Iteration method	Firefly Algorithm
1	600	6987.32	6657.9
2	650	7014.12	6822.5
3	700	7135.48	6917
4	750	7423.2	7118.9
5	800	7745.3	7374.10
6	850	7965.3	7641.37
7	900	8032.1	7772.4
8	950	8597.2	8196.2

X. CONCLUSION

Economic Load Dispatch problem is solved by using Lambda iteration method and Firefly Algorithm. The programs are written in C++ software package. The solution algorithm has been tested for two test systems with three and six generating units. The results obtained from Firefly Algorithm are compared with the results of Lambda iteration method.To reduce the cost furthermore valvepoint loading effect is also considered while generating the firefly algorithm. Comparison of test results of both methods reveals that Firefly Algorithm with valve point loading effect is able to give more optimal solution than Lambda iteration method. Thus, it develops a simple tool to meet the load demand at minimum operating cost while satisfying all units and operational constraints of the power system.

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