International Journal of Engineering and Techniques - Volume 7 Issue 5,September-October 2021

RESEARCH ARTICLE OPEN ACCESS

FLOWER POLLINATION ALGORITHM FOR SOLVING COMBINED ECONOMIC AND EMISSION DISPATCH PROBLEM

M.Venkata Sai Madhuri[1], J.Krishna Kishore[2]
[1](PG Student, *Electrical and Electronics Department, QISCET, Ongole)*
Email: `msreemadhuri@gmail.com`)
[2](Professor, *Electrical and Electronics Department, QISCET, Ongole)*
Email: `kishorejampan@gmail.com`)

Abstract:

ELD (Economic Load Dispatch) is the process of allocating the required load between the available generation units such that the cost of operation is minimized. The ELD problem is formulated as a nonlinear constrained optimization problem with both equality and inequality constraints. The Multi-objective CEED (Combined Economic Emission Dispatch) problem is considering the environmental impacts that accumulated from emission of gaseous pollutants of fossil-fuel power plants.

In this paper, an attempt has been made to optimize each objective individually and also by combining using Flower Pollination Algorithm. The developed algorithm for Optimization of each objective is tested on two systems i.e. on IEEE 9 and IEEE 39 bus system with supporting numerical and graphical results.

Keywords **— Economic Load Dispatch, Combined Economic Emission Dispatch, Flower Pollination Algorithm.**

I. INTRODUCTION

Power system should be operated in such a fashion that simultaneously real and reactive power is optimized. Real power optimization problem is the traditional economic dispatch which minimizes the real power generation cost. Traditional economic dispatch aims at scheduling committed generating unit’s outputs to meet the load demand at minimum fuel cost while satisfying equality and inequality constraints.

On the other hand thermal power plants (Which contribute major part of electric power generation) create environmental pollution by emitting toxic gases such as carbon dioxide (CO2), Sulphur dioxide (SO2), Nitrogen oxides (NOx). Increasing public awareness against environmental pollution and Kyoto agreement has forced thermal power plants to limit these emissions. Several strategies for minimizing these emissions

have been proposed among which dispatch of generating units to minimize emissions as well as fuel cost is the most attractive approach as this can be applied to the traditional economic dispatch algorithm with slight modification.

Initially Economic dispatch (ED) problem was solved by minimizing fuel cost, later different methods have been reported in literature for solving multi objective CEED problem economic dispatch. Traditionally electric power plants are operated on the basis of least fuel cost strategies and only little attention is paid to the pollution produced by these plants. The generation of electricity from the fossil fuel releases several contaminants, such as carbon dioxide (CO2), Sulphur dioxide (SO2), Nitrogen oxides (NOx), into the atmosphere. Combined Economic Emission Dispatch problem was solved by minimizing both fuel cost and emission together.

The passage of the ‘Clean Air Act Amendment of 1990’ and its acceptance by all the nations has forced the utilities to modify their operating strategies to meet the rigorous environmental standards set by the legislation. Thus the modern operating strategies of the generating plants now include reduction of pollution level up to a safe limit set by environmental regulating authority, in addition to minimum fuel cost strategy and transmission security objective. The characteristics of emission of various pollutants are different and are usually non-linear. This increases the complexity of the Combined Economic Emission Dispatch (CEED) problem.

In this paper, two objectives are minimization of fuel cost and emission cost proposed. The combined economic emission dispatch (CEED) problem is a multi- objective problem and it can be formulated as a single objective function by using penalty factor.

A global optimization technique known as Particle Swarm Optimization (PSO) technique, which is a form of probabilistic heuristic algorithm, was adopted for CEED problem.

Particle Swarm optimization (PSO) method is an unconstrained optimization method. A PSO method that includes the constraints penalty factor approach is used to convert the constrained optimization to an unconstrained optimization problem. In PSO, the search for an optimal solution is conducted using a population of particles, each of which represent a candidate solution to the optimization problem. Particles change their position by flying round a multidimensional space by following current optimal particles until a relatively unchanged position has been achieved or until computational limitation are exceeded. Each particle adjusts its trajectory towards its own previous best position and towards the global best position attained till then. PSO is easy to implement and provides fast convergence for many optimization problems and has recently gained lot of attention in power systems applications recently.

i

Many phenomena in nature have unique characteristics that can be utilized or converted into a mathematical model or even an algorithm to solve real world problems. Over a last few decades inspired algorithms so as to attempts to find the best solution for many optimization problems. Nature still has many other phenomenon that can be utilized to solve different types of problems. One such phenomenon is flowering plant reproduction strategy which inspired Yang in 2012 to propose a new algorithm called Flower Pollination Algorithm (FPA).

II. OBJECTIVES

The main purpose of this project work is to investigate the applicability of Flower Pollination Algorithm to the various optimization problems and prove that this algorithm can be used effectively, to determine solution to various complex problems. This method will be tested on several case studies that are extremely difficult or impossible to solve by standard techniques. Due to the non-convex, non-continuous and highly nonlinear solution space of the problems.

III. PROBLEM FORMULATION & ALGORITHMS

The Combined Economic Emission Dispatch problem is to minimize two computing objective functions simultaneously, fuel cost and emission, while satisfying various equality and inequality constraints.[10] In the previous chapters we discussed the economic dispatch problem as a quadratic equation

i

$$F_i(P) = a_i + b_iP_i + c_iP_i^2$$

and the emission dispatch problem as a quadratic equation

$$E_i(P) = \alpha_i + \beta_iP_i + \gamma_iP_i^2$$

In this paper, combine both the economic and emission dispatch problems using a penalty factor. The total cost function is

$$G_i(P) = F_i(P) + h_i * E_i(P)$$

$$G_i(P) = (a_i + b_iP_i + c_iP_i^2) + h_i * (\alpha_i + \beta_iP_i + \gamma_iP_i^2)$$

The minimization is performed subject to the equality constraint that the total generation cost should be equal to the demand plus loss thus

$$\sum_{i=1}^{n} P_i = P_D + P_L$$

The total transmission loss using kron's formula is given in the below equation

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{m} P_iB_{ij}P_j + \sum_{i=1}^{n} P_iB_{i0} + B_{00}$$

It is assumed that these coefficients are constant.

The price penalty factor is the ratio between the maximum fuel cost and maximum emission of corresponding generator in \$/kg, blends the emission with fuel cost then F is the total operating cost in \$

$$h_i = \frac{F_t(P_i^{max})}{E_t(P_i^{max})}$$

Flower Pollination Algorithm

FPA is a nature inspired algorithm that mimics the main pollination behavior of flowering plants. The four idealization rules were used by yang in 2012 and they can be summarized as follows.

RULE 1:Global pollination involves biotic and cross pollination where pollinators carry the pollen based on levy flights.

RULE 2:Local pollination involves abiotic and self-pollination.

RULE 3:Flower constancy can be considered as a reproduction probability that is proportional to similarity between any two flowers

RULE 4:Switch probability P ∈ [0,1] can be controlled between local pollination and global pollination due to some external factors, wind. Local pollination has a significant fraction P in overall pollination activities.

To illustrate the mechanism of FPA based on these four rules, three key steps can be discussed in the following subsections.

Global search of FPA (biotic):

As mentioned above, pollinators such as birds and bats can transfer pollen over long distances during biotic pollination, ensuring the diversity and fittest pollination for reproduction. Therefore the first(Rule 1) and third(Rule 3) FPA rules can be mathematically formulated as follows.

$$x_i^{t+1} = x_i^t + \gamma L(\lambda)(g^* - x_i^t)$$

Where, $x_i^t$is the pollen or solution vector at iteration t

g* is the best solution found among all solutions at the current iteration γ is a scaling factor controlling the step size

L is a parameter which represents the strength of pollination, which is essentially a step size. Because pollinators move over long distances with various distance intervals, the levy flight can be used to mimic this behavior efficiently.

This is L>0 from a levy distribution.

$$L \sim \frac{\lambda T(\lambda) sin(\frac{\pi\lambda}{2})}{\pi} (\frac{1}{S^{1+\lambda}})(S \gg S_0 > 0)$$

Where T(λ) involves standard gamma function and this distribution is valid for large steps i.e. S>0. Normally it is recommended that λ=1.5 is used.

Local search for FPA (Abiotic):

As abiotic pollination occurs by wind or diffusion without any pollinators, the local pollination (Rule2) and flower constancy can be represented as follows

$$x_i^{t+1} = x_i^t + \varepsilon(x_j^t - x_k^j)$$

Where $x_j^t$and $x_k^j$are pollen from different flowers of same plant type.

This equation essentially mimics the flower constancy in a limited neighborhood.

Mathematically speaking if and are from same species that can be selected from same population, the equation becomes a local random walk if we draw $\varepsilon$from a uniform distribution in [0,1] and the new solution vector generated will not be too far from the existing solutions.

Switch probability in FPA:

Though we have simulated both biotic and abiotic pollination, we have not considered the percentage and frequency of each pollination type. To mimic this feature we use a switch probability (Rule 4), where the value of P determines whether the solution modification follows either global or local pollination. Though a naïve value of P=0.5 can be used, a more realistic and effective value of P=0.8 gives better performance for various applications.

Steps:

The steps involved in Flower pollination Algorithm are population initialization, exploration process, exploitation process and solution update.

Step 1: The algorithm starts by setting the initial values of most important parameters such as population size n, switch probability P and maximum number of generations.

Step 2: The initial populationx_i, i=1,2,3,….,n is generated randomly and the fitness function of each solution f(x_i) in the population is evaluated by calculating its corresponding objective function

Step 3: The following steps are repeated until the termination criterion is satisfied which is to reach the desired number of generations.

Step 3.1: The global pollination process is started by generating a random number r, where r∈[0,1] for each solution of x_i.

Step 3.2: If r<P, where P is a switch probability, the new solution is generated by levy distribution as follows

$$x_i^{t+1} = x_i^t + \gamma L(\lambda)(g^* - x_i^t)$$

Where L is Levy flight and L>0 can be calculated as

$$L \sim \frac{\lambda T(\lambda)\sin(\frac{\pi\lambda}{2})}{\pi}\left(\frac{1}{S^{1+\lambda}}\right)(S \gg S_0 > 0)$$

T (λ) is the standard gamma function and this distribution is valid for large values of s>0.

Step 3.3: Otherwise the local pollination process is started by generating a random numberε, εin [0, 1] as follows:

$$x_i^{t+1} = x_i^t + (x_j^t - x_k^j)$$

Where $x_j^t$and $x_k^j$are pollen from different flowers of same plant type. This equation essentially mimics the flower constancy in a limited neighborhood.

Mathematically speaking if$x_j^t$and $x_k^j$are from same species that can be selectedfrom same population, the equation becomes a local random walk.

Step 3.4: Evaluate each solution x_i^{t+1} in the population and update the solution in population according to their objective values.

Rank the solutions and find the current best solution g*

Step 4: Produce the best found solution so far.

IV. SIMULATION RESULTS

Test system-1: IEEE 9 bus system

The IEEE 9 bus system data is presented at appendix A. The PSO parameters used in this case study are:No of particles 60 learning factors c1=2.05 c2=2.05,weight factor w=1.2 constriction factor K=0.7925,Maximum number of iterations=100.

The FPA parameters used in this case study are: Maximum number of iterations = 500 population size = 25 Probability switch = 0.75.

Case (a): Without loss

The penalty factor for IEEE 9 bus are obtained as : h= 47.8222 43.1703 44.8063

The following table shows the values of generation cost, emission and total cost values for IEEE 9 bus system without losses.

Table 4.1 comparison table with load demand of 400 MW

Generation	λ-iteration method	PSO method	FPA method
P_{G1}	96.67	97.97	98.734
P_{G2}	154.4164	153.846	153.231
P_{G3}	148.9136	148.211	148.111
PT	400	400.027	400.076
λ	82.2237	82.1132	82.0678
Fuel cost	20504	20502.1	20501.76
Emission	194.1176	193.124	192.923
Total cost	29237	29236.1	29235.2

Case (b): With loss

The following table shows the values of generation cost, emission and total cost values for IEEE 9 bus system with losses.

Table 4.2.Comparison table with load demand of 400 MW

Generation	**λ-iteration method**	**PSO method**	**FPA method**
P_{G1}	99.0744	102.612	102.4408
P_{G2}	157.1412	153.809	153.8341
P_{G3}	151.2185	150.991	151.1321
PT	407.4341	407.412	407.407
λ	86.6563	86.245	86.1678
PL	7.4341	7.412	7.407

Fuel cost	20830	20828.3	20828.1
Emission	200.5499	200.221	200.22
Total cost	29852	29559.9	29559.81

Test System-2: IEEE 39 bus system

The IEEE 39 bus system data is presented at appendix B. The PSO parameters used in this case study are: No of particles 60, learning factors c1=2.05, c2=2.05, weight factor w=1.2, constriction factor K=0.7925. Maximum number of iterations=100.

The FPA parameters used in this case study are: Maximum number of iterations = 500, population size = 25, probability switch = 0.75.

Case (a): Without loss

The penalty factor values for IEEE 39 bus system is obtained as h= 12.7990, 14.5235, 13.3245, 13.1120, 62.2875, 52.7099, 32.5952, 28.1256, 28.5743, 28.4789.

The following table shows the values of generation cost, emission and total cost values for IEEE 39 bus system without losses.

Table 4.3 Comparison table with load demand of 2000 MW

Generation	**λ-iteration method**	**PSO method**	**FPA method**
Pg1(MW)	55	55	55
Pg2(MW)	80	80	79.12
Pg3(MW)	111.9775	111.9775	101.45
Pg4(MW)	111.4855	111.4855	105.98
Pg5(MW)	111.5762	111.5762	104.222
Pg6(MW)	134.3320	134.332	138.22
Pg7(MW)	254.4231	254.4231	267.89
Pg8(MW)	287.9801	287.9801	288.32
Pg9(MW)	424.8799	424.8799	425.68
Pg10(MW)	428.3456	428.3456	434.12
PgT(MW)	1999.9999	1999.9999	2000.002
Generation Cost	107470	107470	107466.3
Emission cost	3913.2	3913.2	3902.98
Total Cost	203380	203380	203125.9

Case (b): With loss

The following table shows the values of generation cost, emission and total cost values for IEEE 39 bus system with losses.

Table 6.4 Comparison table with load demand of 2000 MW.

Generation	**λ-iteration method**	**PSO method**	**FPA method**
Pg1(MW)	55	55	53.188
Pg2(MW)	80	80	79.975
Pg3(MW)	117.35	81.14	78.105
Pg4(MW)	117.5773	84.216	97.119
Pg5(MW)	121.6207	138.3377	152.74
Pg6(MW)	147.6913	167.5086	163.08
Pg7(MW)	266.5299	296.8338	258.61
Pg8(MW)	301.9255	311.5824	302.22
Pg9(MW)	437.3207	420.3363	433.21
Pg10(MW)	438.5833	449.1598	466.07
PT(MW)	2083.5987	2084.1736	2084.3
PL(MW)	83.5987	84.1736	84.3
Generation Cost	112700	113420	113370
Emission cost	4187.2	4120.1	3997.7
Total Cost	216300	215359.8	212281

V. CONCLUSIONS AND FUTURE SCOPE

In this paper, need for optimization techniques, limitations of traditional methods and the benefits of nature inspired algorithms are discussed. Study indicates that Flower Pollination Algorithm is simple, flexible and exponentially better to solve optimization problems. Flower Pollination Algorithm is used to solve both single objective and multi objective optimization problems. Flower Pollination Algorithm reduces the time, improves the results and the performance is better compared to other optimization techniques. Flower Pollination Algorithm looks very promising for optimization problems of any kind.

REFERENCES

[1]. J. Kennedy and R. Eberhart, "Particle swarm optimization," in Proc. IEEE Int. Conf. Neural Networks (ICNN'95), vol. IV, Perth, Australia, pp1942-1948, 1995.

[2]. M. R. AlRashidi, Student Member, IEEE, and M. E. El-Hawary, Fellow, IEEE "A Survey of Particle Swarm Optimization Applications in Electric Power Systems" IEEE Trans. On Evolutionary Computation 2006

[3]. Jong-Bae Park, Ki-Song Lee, Joong-Rin Shin, Kwang Y. Lee, "A Particle Swarm Optimization for Economic Dispatch with Non-smooth Cost Functions", IEEE Trans. on Power Syst., Vol. 20, No.1, pp 34- 42, February 2005.

[4]. Zwe-Lee Gaing, "Particle Swarm Optimization to Solving the Economic Dispatch Considering the Generator Constraints", IEEE Tans. on Power Syst., Vol 18, No. 3, pp 1187- 1195, Aug. 2003.

[5]. A.Y. Abdelaziz, E.S.Ali, S.mm. Abd Elazim "Implementation of flower pollination algorithm for solving economic load dispatch and combined economic emission dispatch problems"

[6]. Allen J. Wood, Bruce F. Wollenberg, "Power Generation, Operation, And Control", John Wiley &Sona, Inc., New York, 2004

[7]. El-Keib, A.A.; Ma, H.; Hart, J.L,Economic dispatch in view of the CleanAir Act of 1990, IEEE Trans PwrSyst, Vol. 9 (2), May 1994, pp.-972 -978

[8]. J.H.Talaq, F.El-Hawary, and M.E.El-Hawary, "A Summary of Environmental/EconomicDispatch algorithms," IEEE Trans. Power Syst., vol. 9, pp. 1508–1516, Aug. 1994.

[9]. Immanuel Selva Kumar, K. Dhanushkodi, J. Jaya Kumar, C. Kumar Charlie Paul, "Particle Swarm Optimization Solution to Emission and Economic Dispatch Problem", IEEE TENCON 2003.

[10]. lakshmi devi and O. Vamsi Krishna "Combined economic and emission dispatch using evolutionary algorithms- A case study", ARPN, volume 3 No 6 , December 2008.