FLOWER POLLINATION INSPIRED OPTIMIZATION FOR ECONOMIC LOAD DISPATCH PROBLEM

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Abstract

The main objective of the power system is to supply the total power requirement to the users at minimum possible fuel cost and with minimum emissions. Combined economic and emission load dispatch determines the optimal generation of the power system by minimizing the fuel cost and emission levels simultaneously. In this paper, a new Hybrid Gravitational Search Flower Pollination based algorithm is proposed for achieving improved results in the ELD problem where gravitational search is used to decide the step size in levy flight mechanism. This algorithm has less number of operators and hence it can be easily coded in any programming language. To prove the feasibility of this algorithm its performance is compared with other existing algorithms.

Index Terms: ELD, FPA, OPTIMIZATION, POLLINATION

I. INTRODUCTION

In the modern world electrical power plays a very vital role to survive and to meet various demands. In order to meet these demands the generation, transmission and distribution of power must be optimized efficiently. Electrical power is generated by different types of power plants using different sources for power generation. To plan a power system and to operate the power generation system efficiently economic scheduling is important for all generating units to meet and supply the necessary load demand of all consumers. In ELD problem, the ultimate goal is to optimize the total generating cost by meeting the various linear and non linear constraints and to supply the load demand efficiently.

Economic operation of power systems is met by meeting the load demand through optimal scheduling of power generation. Minimization of fuel cost is the main objective of finest power flow (OPF) problems. Optimal real power scheduling will guarantee economic benefits to the power system operators and reduce the release of polluting gases.ELD primarily aims at optimal scheduling of real power generation from committed units in such manner that it meets the total demand and losses while satisfying the constraints [10]. Achieving minimum cost while satisfying the constraints makes the ELD problem a highly non-linear constrained optimization problem. The non linearity of the difficulty is due to non linearity and valve point effects of input–output characteristics of generating units. The aim of cost minimization may have multiple local optima. There is always a demand for a proficient optimization technique for these kinds of highly non linear objective functions. Further, the algorithm is expected to produce accurate results for the ELD problem.
In the past, numerous conventional optimization algorithms have been exploited for solving the

OPF problems. The major drawback of those methods was that they required smooth and convex functions for better results and were more likely to get trapped into local optima. Later, evolutionary algorithms are exploited for ELD problems and improved results were obtained.

In the last decade, several bio inspired algorithms are introduced and attempted for many engineering optimization problems. Some of the notable bio inspired algorithms are particle swarm optimization algorithm (PSO), a well received algorithm and utilized in almost all engineering applications successfully. Firefly algorithm is another recently introduced algorithm for engineering optimization that has been effectively used to solve the dynamic ELD problem. Theses algorithms are highly successful and cannot be easily trapped in to local optima. In addition, they are comfortable with all types of objective functions. Flower pollination algorithm FPA is one such nature inspired algorithm developed by Xin She Yang [7]-[8] for engineering tasks.

The efficiency of nature/bio inspired algorithms is proved to be outperforming even the evolutionary based algorithms. In this paper, the new Hybrid Gravitational Search Flower Pollination based algorithm has been proposed for achieving improved results in the ELD problem where gravitational search is used to decide the step size in levy flight mechanism. This algorithm has lesser number of operators and hence can be easily coded in any programming language. To prove the strength of this algorithm its performance is compared with other existing algorithms.

2. Pollination Algorithm

It is believed that 80% of the plants reproduce with the process of pollination. Flower pollination is basically the process of transfer of pollens from one flower (male) to another(female) flower. Pollination is characterized into two types biotic or a biotic. 90% of pollination occurs with the help of insects and animals only the remaining 10 % is carried by wind and other natural sources. Biotic pollination is of two types self-pollination or cross-pollination. [24] Cross-pollination means when pollination takes place between two different flowers, while self-pollination happens in the same flower between its male and female parts. Biotic and cross type pollinations can be assumed as global pollination as here pollination occurs between flowers far away from each other.

The pollinating agents such as insects follow the Levy flight movement, it can be employed for global optimization [4]. Biotic and self pollinations can be considered as local optimization since it occurs in the same flower.

Various design constraints during the development of the algorithm lead to limited flexibility and loss of performance. However, programming an algorithm with optimization helps to overcome such constraints up to a large extent. Rather than building a single program for a given function, software developers develop a large number of programs. From this pattern, programs that perform well in a given framework are automatically generated through powerful optimization techniques. PBO allows us to focus on the imaginative task of creating possible mechanisms for problem solving, while the tedious job of determining what works best in a given use situation is performed automatically, which reduces human labor and the same work can be done in lesser amount of time. Furthermore, using GSFPO, further improves the results and reduces the computational time of the program.

2.1 Working of Pollination Algorithm [8]:-

Based on the concept of flower pollination, pollination algorithm is (PA) is developed.[8]

Rule 1. Biotic and cross-pollination are considered as global pollination process and pollen is carried by a movement which obeys Levy flight movement.[8]

Rule 2. A biotic and self-pollination are equivalent to local pollination process.[8]

Rule 3. Pollinators can develop flower constancy, which is like reproduction probability and proportional to the similarity of two flowers involved.[8]

Rule 4. Changing from local pollination to global pollination or vice versa can be controlled by a probability p ϵ [0, 1].[8]

For implementation of this FPA algorithm, a set of updating formulae are developed by converting the rules into updating equations. In the global pollination step, flower pollen gametes are carried by pollinators such as insects over longer distances. [8]

Therefore, the mathematical equivalent of Rule 1 and flower constancy is written as

$$x_i^{t+1} = x_i^t + \beta L(\lambda)(x_i^t - x) \quad (1)$$

Where, x_i^{t+1} is the solution vector (pollen) xi at iteration t, $x$is the current best solution, β is the scaling factor for controlling the step size. $L(\lambda)$ depicts the strength of the pollination, which essentially is also the step size. Since insects can move over a long distance with various distance steps, we can use a Levyflight to mimic this characteristic efficiently. That is, we draw LF > 0 from a Levy distribution

$$LF \cong \frac{\lambda\Gamma(\lambda)\sin(\pi\lambda/2)}{\pi}\frac{1}{S^{1+\lambda}}(S \gg S_0 > 0) \quad (2)$$

Here, G(λ) stands for standard gamma distribution valid for large steps. i.e. for s > 0. Then, to model the local pollination, both Rule 2 and Rule 3 can be represented as:

$$x_i^{t+1} = x_i^t + \epsilon(x_j^t - x_k^t) \quad (3)$$

Where x_j^t and x_k^t are pollens taken from different flowers of the same plant species. This fundamentally mimics the flower constancy in given vicinity. Mathematically, if x_j^t and x_k^t comes from same variety or is selected from same population, this consistently become local random walk if we derive from a uniform distribution in [0, 1].Pollination may also occur in a flower from the neighboring flower than by the far away flowers. In order to copy this, a switch probability (Rule 4) is used through a proximity probability p to switch between global pollination and local pollination. A preliminary parametric showed that p=0.8 might work better for most applications.

Flowchart for Economic Load Dispatch Problem Solving using FPA

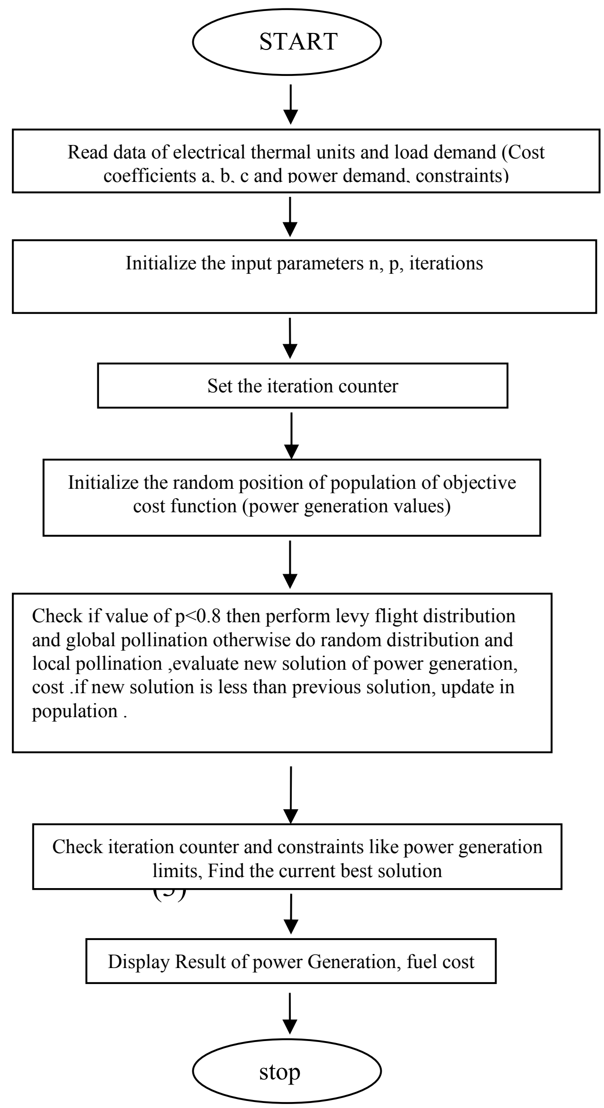

Fig 1. FLOWCHART FOR FPA

II RESULTS

INPUT DATA

Table 1. Input data for 14 bus, 6 generator system [18]

Unit	P_i^{min}	P_i^{max}	a_i($/h)	b_i ($/MWh)	c_i($/($MW^2$)h)
1	10	125	756.9888	38.5390	0.15247
2	10	150	451.3251	46.1591	0.10587
3	35	210	1243.5311	38.3055	0.03546
4	35	225	1049.9977	40.3965	0.02803
5	125	315	1356.6592	38.2704	0.01799
6	130	325	1658.5696	36.3278	0.02111

$$B = \begin{bmatrix} 0.000140 & 0.000017 & 0.000015 & 0.000019 & 0.000026 & 0.000022 \\ 0.000017 & 0.000060 & 0.000013 & 0.000016 & 0.000015 & 0.000020 \\ 0.000015 & 0.000013 & 0.000065 & 0.000017 & 0.000024 & 0.000019 \\ 0.000019 & 0.000016 & 0.000017 & 0.000071 & 0.000030 & 0.000025 \\ 0.000026 & 0.000015 & 0.000024 & 0.000030 & 0.000069 & 0.000032 \\ 0.000022 & 0.000020 & 0.000019 & 0.000025 & 0.000032 & 0.000085 \end{bmatrix}$$

B-Coefficients for 14 Bus, 6 Generator System [18]

Table 2. Input Data for 39 Bus System [18]

Unit	P_i^{min}	P_i^{max}	a_i($/h)	b_i($/MWh)	c_i($/($MW^2$)h)
1	10	55	1000.403	0.5407	0.12951
2	20	80	950.606	39.5804	0.10908
3	47	120	900.705	36.5104	0.12511
4	20	130	800.705	39.5104	0.12111
5	50	160	756.799	38.5390	0.15247
6	70	240	451.325	46.1592	0.10587
7	60	300	1243.531	38.3055	0.03546
8	70	340	1049.998	40.3965	0.02803
9	135	470	1658.569	36.3278	0.02111
10	150	470	1356.659	38.2704	0.01799

$$B = \begin{bmatrix} 0.000049 & 0.000014 & 0.000015 & 0.000015 & 0.000016 & 0.000017 & 0.000017 & 0.000018 & 0.000019 & 0.000020 \\ 0.000014 & 0.000045 & 0.000016 & 0.000016 & 0.000017 & 0.000015 & 0.000015 & 0.000016 & 0.000018 & 0.000018 \\ 0.000015 & 0.000016 & 0.000039 & 0.000010 & 0.000012 & 0.000012 & 0.000014 & 0.000014 & 0.000016 & 0.000016 \\ 0.000015 & 0.000016 & 0.000010 & 0.000040 & 0.000014 & 0.000010 & 0.000011 & 0.000012 & 0.000014 & 0.000015 \\ 0.000016 & 0.000017 & 0.000012 & 0.000014 & 0.000035 & 0.000011 & 0.000013 & 0.000013 & 0.000015 & 0.000016 \\ 0.000017 & 0.000015 & 0.000012 & 0.000010 & 0.000011 & 0.000036 & 0.000012 & 0.000012 & 0.000014 & 0.000015 \\ 0.000017 & 0.000015 & 0.000014 & 0.000011 & 0.000013 & 0.000012 & 0.000038 & 0.000016 & 0.000016 & 0.000018 \\ 0.000018 & 0.000016 & 0.000014 & 0.000012 & 0.000013 & 0.000012 & 0.000016 & 0.000040 & 0.000015 & 0.000016 \\ 0.000019 & 0.000018 & 0.000016 & 0.000014 & 0.000015 & 0.000014 & 0.000016 & 0.000015 & 0.000042 & 0.000019 \\ 0.000020 & 0.000018 & 0.000016 & 0.000015 & 0.000016 & 0.000015 & 0.000018 & 0.000016 & 0.000019 & 0.000044 \end{bmatrix}$$

B-Coefficients for 39 Bus System [18]

OUTPUTS OBTAINED FOR SINGLE OBJECTIVE ECONOMIC LOAD DISPATCH

Table 3. Cost comparison and power generation for 6 unit system

Sr.no.	Method	Power demand (MW)	P_1 (MW)	P_2 (MW)	P_3 (MW)	P_4 (MW)	P_5 (MW)	P_6 (MW)	P_{LOSS} (MW)	Fuel Cost ($)	CPU Time (s)
1	**FPA**	**1200**	**92.34**	**98.76**	**209.18**	**222.56**	**308.89**	**318.91**	**50.64**	**64567.8**	**3.3**
2	MODE[18]	1200	108.6284	115.9456	206.7969	210.0000	301.8884	308.4127	51.61	64843	3.09
3	PDE[18]	1200	107.3965	122.1418	206.7536	203.7047	308.1045	303.3797	51.78	64920	3.52
4	NSGAII[18]	1200	113.1259	116.4488	217.4191	207.9492	304.6641	291.5969	52.12	64962	5.42
5	SPEA 2[18]	1200	104.1573	122.9807	214.9553	203.1387	316.0302	289.9396	51.15	64884	7.05

The table above shows the comparison of power dispatch and fuel cost of 6 generator, 14 bus system using flower pollination optimization technique. The above results clearly state that the power loss, fuel cost and computational time taken by flower pollination optimization is less as compared to other various techniques

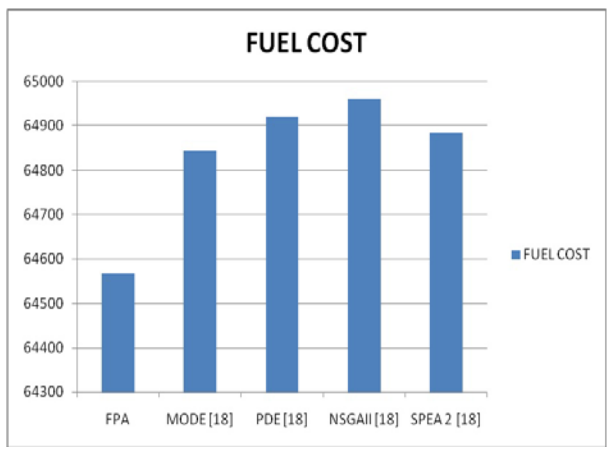

Fig 2 Cost comparison graph for various optimization techniques

The graph shown above represent the fuel cost for various optimization techniques implemented on a 14 bus , 6generator system. The comparison shows that the cost using pollination based algorithm technique is the minimum of all other techniques.

Table 4. Generator Power Output for 6 generator system

Generator	Generator Output(MW)
P_1 P_2	92.34 98.76
P_3	209.18
P_4	222.56
P_5 P_6	308.89 318.91
Total power generation	**1250.64**
Minimum Cost(Rs)	**64018**

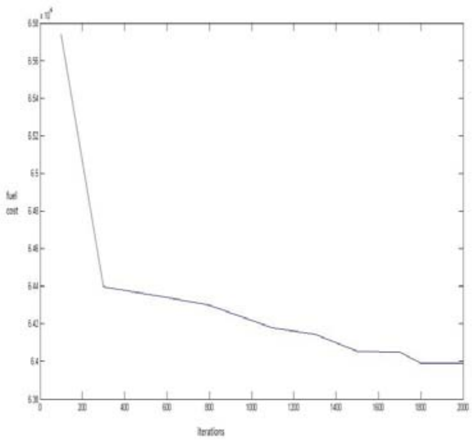

Fig 3. Solution convergence with iteration for 6 unit system

The above graph shows the convergence of PBO technique with iterations for economic load dispatch for 6 unit system. The x axis represents no of iterations and y axis represents fuel cost.

Table 5 . Cost Comparison and power generation for 10 unit system

S.No	Method Power demand (MW)	FPA 2000	MODE[18] 2000	PDE[18] 2000	NSGA II[18] 2000	SPEA 2[18] 2000
1	P_1 (MW)	**50.32**	54.9487	54.9853	51.9515	52.9761
2	P_2 (MW)	**80.21**	74.5821	79.3803	67.2584	72.8130
3	P_3 (MW)	**84.53**	74.4294	83.9842	73.6879	78.1128
4	P_4 (MW)	**112.45**	80.6875	86.5942	91.3554	83.6088
5	P_5 (MW)	**88.79**	136.8551	144.4386	134.0522	137.2432
6	P_6 (MW)	**94.53**	172.6393	165.7756	174.9504	172.9188
7	P_7 (MW)	**288.12**	283.8233	283.2122	289.4350	287.2023
8	P_8 (MW)	**324.56**	316.3407	312.7709	314.0556	326.4023
9	P_9 (MW)	**451.67**	448.5923	440.1135	455.6978	448.8814
10	P_{10} (MW)	**458.76**	436.4287	432.6783	431.8054	423.9025
P_{LOSS} (MW)		**30.94**	109117	84.69	84.81	84.52
FUEL COST		**109117**	113480	113510	113540	113520
CPU Time (s)		**3.5**	3.82	4.23	6.02	7.53

The table above shows the comparison of power dispatch and fuel cost of 10 generator, 39 bus system using flower pollination optimization technique. The above results clearly state that the power loss, fuel cost and computational time taken by flower pollination optimization is less as compared to other various techniques

Table 6 . Generator Power Output for 10 unit system

Generator	Generator Output(MW)
P_1	**50.32**
P_2	**80.21**
P_3	**84.53**
P_4	**112.45**
P_5	**88.79**
P_6	**94.53**
P_7	**288.12**
P_8	**324.56**
P_9	**451.67**
P_{10}	**458.76**
Total power generation	**2033.94**
Minimum Cost(Rs)	**109117**

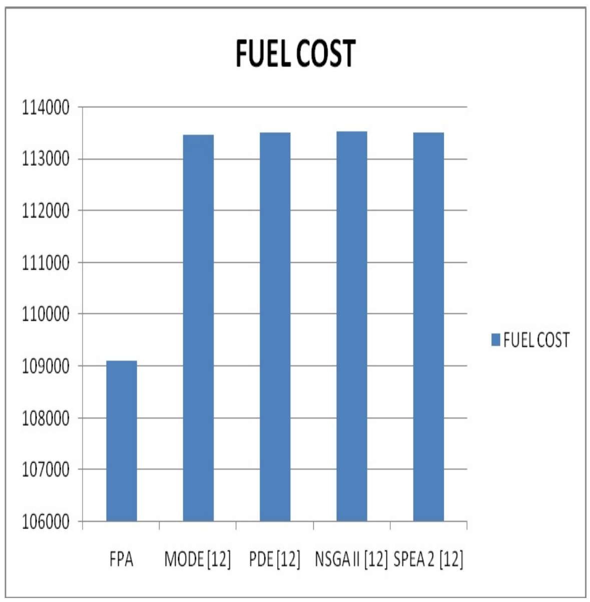

Fig 4. Cost comparison graph for various optimization techniques

The graph shown above represenst the fuel cost for various optimization techniques implemented on a 39 bus, 10 generator system. The comparison shows that the cost using pollination based algorithm technique is the minimum of all other techniques.

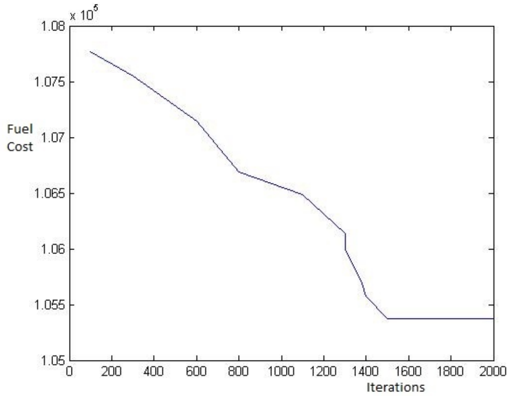

Fig 5. Convergence graph for pollination based optimization technique for 10 unit system

IV CONCLUSION

In this paper the proposed flower pollination algorithm is being used to solve single objective economic load dispatch problem. The foresaid algorithm has been used and tested upon on IEEE 14 and 39 bus systems and has shown to improve the optimization of the combined economic and emission dispatch problem. PBO is an efficient pollination based optimization method that belongs to the class of evolutionary methods. The results obtained by the above mentioned FPA algorithm when tested on Case I and II were far better than those obtained by the existing algorithms in the literature. The given algorithm has lesser number of operators which minimizes the chances of solutions to get trapped in the local minima. The computational time of the following algorithm is also less than the existing algorithms.

The results are found to be improved and encouraging.

Further this technique can be also used to solve multiobjective problems.

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