IMPLEMENTATION OF FLOWER POLLINATION ALGORITHM FOR OPTIMAL POWER FLOW

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Abstract: *The primary goal of Optimal Power flow problem is to deliver power at a cheapest cost and simultaneously maintaining the voltage profile, minimizing losses and provide reactive power support. In this paper optimal power flow problem is solved using Flower pollination algorithm. The main goal of this optimization is to minimize the fuel cost and power loss in short computational time satisfying the constraints. The ability of this method is tested on standard IEEE 30 bus test system. Comparative analysis of the proposed FPA algorithm with the existing algorithm results reveals that proposed algorithm exhibit significant improvement in terms of fuel cost, loss and voltage profile..*

Keywords: *Optimal Power Flow(OPF), Flower Pollination Algorithm (FFA)*

1. Introduction

Dommel and Tinney in 1968 introduced the optimal power flow(OPF) and considered as the important tool for modern power system operations and planning [1]. This OPF provide solution for reducing electricity production cost and transmission line losses. The control and dependent variables limit and real, reactive power balance is ensured for the optimization.

Alsac and Stott extended the OPF for steady state contingency analysis [2]. The solution methodologies can be broadly grouped in to two namely Conventional methods and Intelligent methods. Traditionally, conventional methods are used to effectively solve OPF.The popular conventional methods are Gradient Method Newton Method, Linear Programming Method , Quadratic Programming Method, Interior Point Method. These conventional mathematical approaches are inferior to non-convex, discontinuous and prohibited operating zones of OPF objective functions. To overcome these difficulties intelligent algorithms were used. To overcome the limitations and deficiencies in analytical methods, Intelligent methods based on Artificial Intelligence (AI) techniques have been developed in the recent past. These methods can be classified or divided into the following, Artificial Neural Networks (ANN) , Genetic Algorithms (GA), Particle Swarm Optimization (PSO),Ant Colony Algorithm(ACA), evolutionary programming (EP) , differential evolution (DE), biogeography-based optimization (BBO), gravitational search algorithm (GSA)[3].,etc.

Niknam used improved particle swarm optimization (IPSO) to solve multi-objective OPF and fuzzy technique to extract best solution from pareto-solutions [4]. The most commonly used multi-objectives of OPF are generating cost, emission, loss and voltage improvement. To overcome these difficulties intelligent algorithms were used. The non-linear, complex, multi-objective OPF requires a powerful intelligent optimization algorithm. In 2012 new intelligent algorithm proposed based on the pollination process of flowers in the tree or plant [5] and named as flower pollination algorithm (FPA). The plants and trees are survive billions of years using the process of pollination. FPA is a new met heuristic algorithm well suited to solve real world problems . This efficient FPA application is extended in this paper to engineering application particularly in power system optimization process for this OPF optimization.

This paper deals with solving of optimal power flow problem using FPA. Various issues like voltage balance, power loss minimization and minimum operating cost are obtained using this optimization. Furthermore problem formulation, Flower Pollination algorithm and results obtained are explained in the upcoming sections.

2. Problem Formulation

OPF is power system optimization problem and has objective function need to be optimized which is subjected to constraints. There are two types of constraints namely equality and inequality constraints. This complex, non linear OPF problem has multi-objectives of minimization of fuel cost or generation cost, minimization of emission, minimization of loss and improvement voltage stability and improvement of security for power transmission between two areas. These objective functions' mathematical models are given below.

Minimize $F_i(P_i)$

$$F_i(P_g) = \sum_{i=1}^{NG} x_i + y_i * P_{gi} + z_i * P_{gi}^2 \quad (1)$$

Where

F_i is minimization of fuel cost

x_i, y_i, and z_i are quadratic coefficient of fuel cost

2.1 Equality Constraints

The Power balance equation for the test system is given by

$$\sum_{i=1}^{NG} P_{gi} = \sum_{j=1}^{NB} P_{dj} + \sum_{k=1}^{NBR} P_{lk} \quad (2)$$

$$\sum_{i=1}^{NG} Q_{gi} = \sum_{j=1}^{NB} Q_{dj} + \sum_{k=1}^{NBR} Q_{lk} \quad (3)$$

WhereP_{gi}, P_{dj}, P_{lk} are real power generation, real power demand and real power loss, and Q_{gi}, Q_{dj}, Q_{lk} are reactive power generation, reactive power demand and reactive power lossare represented

Transmission losses calculated using B-coefficient method are represented by

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j \quad (4)$$

2.2 Inequality Constraints:

Active Power Constraint: The active power generation limits for the thermal generators are given by

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \quad (5)$$

Where $P_i^{\min}, P_i^{\max}$ are minimum and maximum active power of the i^th generating unit

2.2.1 Generator constraints

Real and reactive power generation bounded between minimum and maximum limit, and similarly control variable of generator bus voltage magnitude,

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max}\text{, for i=1 to NG} \quad (6)$$

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max}\text{, for i=1 to NG} \quad (7)$$

$$V_{gi}^{\min} \le V_{gi} \le V_{gi}^{\max}\text{, for i=1 to NG} \quad (8)$$

where P_g^i, Q_g^i, V_g^i are active power, reactive power generated and voltage magnitude of i^th generator.

2.2.2 Transformer constraint

Transformer tap position may control the voltage magnitude and there by reactive power in the power system and becomes the control variable but bounded on its minimum and maximum tap position.

$$T_i^{\min} \le T_i \le T_i^{\max}\text{, for i=1 to NTrans} \quad (9)$$

The OPF problem is also subjected inequality constraints which comprises of limits on control and depended variables and stated from equation (5) to (9)

3. Flower Pollination Algorithm:

Flower pollination algorithm was proposed by X.S.Yang in 2012 is a nature inspired new meta-heuristic technique of optimization stimulated by nature of the flower pollination processing[5]. The FPA development is separated into self-pollination and cross-pollination. From the FPA discussions, four various rules has been carried out

Rule I: Cross-pollination is taken as a worldwide pollination method with pollen-carrying pollinators (insects or animals) travel over long distances activity movements which will be modeled as the Levy flights.

Rule II: Self-pollination is taken as a local pollination method that in nature is considered by the rain or the wind.

Rule III: The same flowers or the plant of the similar species are taken as a Self-pollination or local pollination

Rule IV: switch probability function controls the Cross or Self-pollination process by $P_x \in [0,1]$.

We declare from the rules estimated that we know how to formulate the FPA algorithm as described below:

Let us represents of ith flower pollination, control vector is defined as x_n. The worldwide cross pollination process is termed out as generating of random numbers $L(\lambda)$ described below:

$$x_n^{t+1} = x_n^t + L(\lambda).\left(x_n^t - g^{\alpha}\right) \quad (10)$$

Therefore, The $L(\lambda)$ step size is shown from distribution of Levy and the equation termed as a Levy flight. Mantegna's estimate is used to create Levy of random numbers.

Local pollination is determined by means of step sizes as distributed of random number vector $\in_n$ determined consistently between 0 and 1.

$$x_n^{t+1} = x_n^t + \in_n \cdot\left(x_n^t - g^{\alpha}\right) \quad (11)$$

here the current generation is termed as t x_j^t and x_k^t are differ from flowers of the similar plant species . Accurately, the same species is generated from same population of x_n^{t+1} and x_n^t,Switch probability of parameter which changes levy flights to the random walks according to, if $P_x > rand(0,1)$

Where, the Levy Flights -

$$x_n^{t+1} = x_n^t + L(\lambda).\left(x_n^t - g^{\alpha}\right) \quad (12)$$

Where, the random walks -

$$x_n^{t+1} = x_n^t + \in_n \cdot\left(x_n^t - g^{\alpha}\right) \quad (13)$$

Algorithmic steps for solving the OPF problem

Step 1: Initialize N - flower whose values are within in its boundary where N corresponds to number of solutions.

Step 2: The FPA parameters considered are no of flowers = 20, iterations = 100,switch probability = [0.8]

Step 3: For each flower pollinate either global or local pollination based on switching probability which corresponds to optimal generator scheduling.

Step 4: Evaluate flower if pollinated flower gives better solution then replace the original flower.

Step 5: Replace the original flower.

Step 6: Repeat pollination and evaluation update the process until the stopping criterion satisfied

Step 7: Update the process until the stopping criterion satisfied i.e. number of iterations are done.

Step 8: Print the current best solution.

4. Results and Discussion:

Optimal power flow is solved using FPA. Equality and inequality constraints are included in the system. Additionally transmission line constraint is also considered in the problem.

Table 1 Generator cost coefficient and Active power limits of IEEE 30 bus system

Unit	Pgmin	Pgmax	ai	bi ($/MW)	ci ($/MW^2)
1	50	200	0	2	0.00375
2	20	80	0	1.75	0.0175
3	15	50	0	1	0.0625
4	10	55	0	3.25	0.00834
5	10	30	0	3	0.025
6	12	40	0	3	0.025

The proposed method is tested on IEEE 30 bus system and the results are compared. The cost coefficients of the thermal generators and limits on power generation of the system are given in Table 1. The best solutions obtained for cost minimization objective are given in Table 2.

Table 2 Optimal Power flow analysis for IEEE 30 bus system

Bus No	VM (p.u)	VA (p.u)	Pg (MW)	Cost ($/hr)
1	1.06	0	176.232	468.930
2	1.034	-0.034	48.793	127.053
5	1.02	-0.169	21.406	50.044
8	1.01	-0.147	21.4	73.369
11	1.062	-0.153	12.012	39.644
13	1.051	-0.187	12.000	39.600
PL (MW)		8.44		
Total Cost ($/hr)		798.642		
Time/Iteration		0.119s		
Iterations		100		

From the table it is inferred that the FPA took a very less computation time for producing a optimal cost of 798.6421 $/hr. The power loss (PL) obtained for the case is 8.44MW. The voltages(VM) and angles (VA) at the generator buses are in the desired limits. Fig 1 shows the convergence curve of FPA for minimization of cost objective

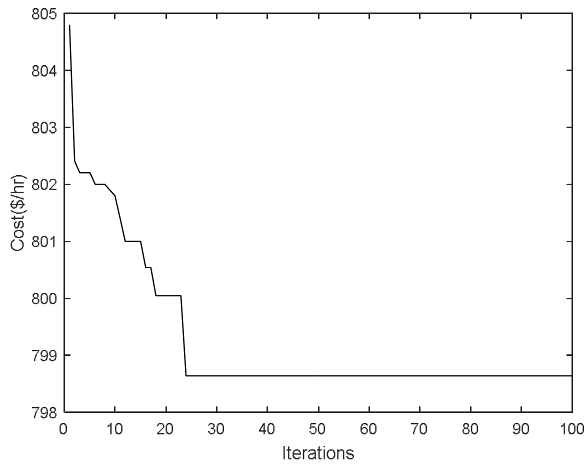

Fig 1 Convergence curve for IEEE 30 bus system cost minimization objective

Table 3 Comparison of dispatch obtained for IEEE 30 bus system using FPA

Method	G1 (MW)	G2 (MW)	G3 (MW)	G4 (MW)	G5 (MW)	G6 (MW)	PG (MW)	PL (MW)	COST ($/hr)
RGA[6]	174.04	46.8	22	23.9	11	14.5	292.24	8.84	804.02
MDE[7]	175.974	48.884	21.51	22.24	12.251	12	292.859	9.46	802.376
TS[8]	176.04	48.76	21.56	22.05	12.44	12	292.85	9.45	802.29
EGA[9]	176.2	48.75	21.44	21.95	12.42	12.02	292.78	9.38	802.06
PSO[10]	176.958	48.981	21.301	21.189	11.971	12	292.4	9.00	800.409
EADDE [11]	177.19	48.51	21.39	21.21	12.03	12.01	292.34	8.94	800.204
ARCBBO[12]	177.159	48.561	21.428	21.295	11.980	12.004	292.425	9.025	800.515
FPA	176.232	48.7936	21.406	21.4	12.0123	12	291.844	8.44	798.642

The cost and dispatch obtained with FPA method are compared with methods like RGA[6], MDE[7], TS[8], EGA[9], PSO[10], EADDE[11], ARCBBO [12]. It is observed that the FPA method gives a minimum cost and also simultaneous reduction in loss compared to the others methods. The values are given in Table3. The figure representing cost minimization is shown in Fig 2. From the figure it can be inferred that cost obtained by FPA optimization is very less compared to other methods.

A comparison of minimum cost, average cost and maximum cost obtained using various methods is shown in Table 4. The FPA algorithm is run for 50 trails and the observations were made.

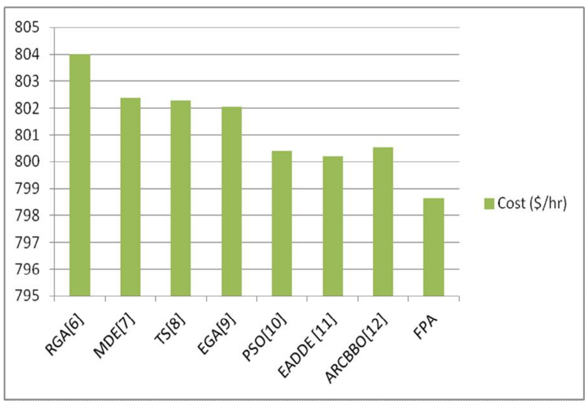

Fig 2. Cost comparison with various optimization techniques

It is observed from the table that FPA gives these result in short computational time. The improved voltage profile using FPA compared to PSO and convectional load flow is shown in Fig 3. It is observed that the voltages at the buses are in desirable limits with the FPA.

Table 4 Comparison of results for minimum cost

Method	Min cost ($/hr)	Avg. Cost ($/hr)	Max Cost ($/hr)	Time (sec)
MDE [7]	802.376	802.382	802.404	23.25
EGA [9]	802.060	NR*	802.14	76
EADDE [11]	800.204	800.241	800.278	3.32
PSO[10]	800.409	800.450	801.231	11.10
ARCBBO [12]	800.515	800.641	800.926	-
FPA	798.642	799.101	799.199	4.37

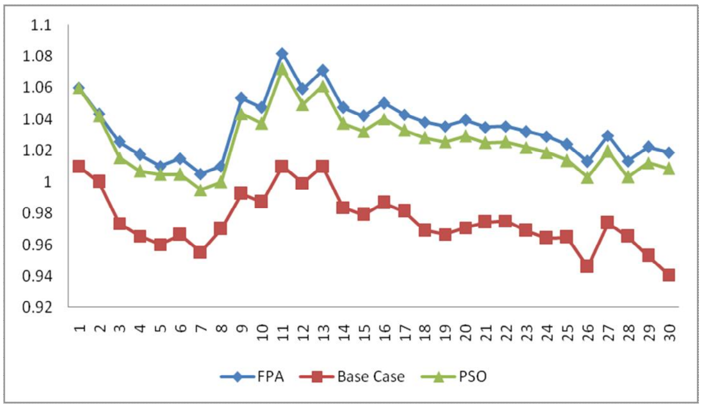

Fig 3 Voltage Profile of IEEE 30 bus system with FPA optimization

5.Conclusion

Optimal power flow is solved using Flower pollination algorithm in this paper. The objectives considered here are the cost minimization, loss reduction and improvement of voltage profile. The analysis is carried out on standard IEEE 30 bus test system and the obtained values are compared with recent methods. The results shows FPA gives a better outcomein very few iterations and also less computational time.

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