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Optimal Power Flow by using Fruit Fly Algorithm

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Abstract— The major task in power system operation is optimal power flow. Objective of OPF (optimal power flow) is to attain diminution of power loss in transmission lines by incorporating TCSC which is a FACTS device. The control variables for optimizing the power loss are the real power output from generators, bus voltage magnitudes, and VAR outputs from shunt compensators and tap setting transformer. The fruit fly algorithm (FFA) which is based on bio inspired behavior is implemented for optimally selecting the values of control variables. The proposed algorithm is trouble-free and effortless to implement. The recital of the fruit fly algorithm is tested on standard IEEE 14 bus test system in OPF task. Statistical results are compared to literature results and found to be enhanced.

Key words: Optimal Power Flow, Fruit Fly Algorithm, Newton-Raphson Method, Power Loss Minimization

I. INTRODUCTION

OPF control in power systems has a direct impact on system security and economic dispatch. It has become one of the most significant problems and the main objective of the problem is to optimize a chosen objective function through optimal adjustments of power system control variables. While at the same time satisfying system operating conditions with power flow equations and inequality constraints. The equality constraints are the nodal power balance equations, while the inequality constraints are the limits of all control variables. The control variables involve the tap ratios of transformers, the generator real power, the generator bus voltages and reactive power of sources. In general, the OPF problem is a large-scale, highly constrained, nonlinear and non-convex optimization problem.

H.W.Dommel and W.F.Tinney [1] firstly presented the solution of optimal power flow. In the past, conventional methods such as interior point method, linear programming and nonlinear programming have been discussed by K. Deb [2] for optimizing engineering problems. The drawback of these techniques is that it is not possible to use as an efficient tool in practical systems because of nonlinearity of the problem. Recently many population-based methods have been suggested for solving the OPF problem successfully. Examples of such methods are genetic algorithm (GA), particle swarm optimization (PSO), differential evolution (DE), simulated annealing (SA), intelligent search evolutionary algorithm (ISEA) etc. All these techniques are applied for economic dispatch, optimal reactive power flow which are optimization problems.

R.Gnanadass et al. [3] discuss the evolutionary programming algorithm to solve the OPF problem with non-smooth fuel cost function. Hybrid particle swarm optimization algorithm to solve the discrete OPF problem with valve loading effect was proposed by M.R.Al Rashidi and M.E.EI.Hawary[4]. M. Varadarajan and K.S Swarup [5] reported differential evolution approach to solve optimal power flow problem with multiple objectives. A new approach based on two step initialization to solve the OPF problem has been proposed by A.V.Naresh Babu and S.Sivanagaraju.

All these search intelligence techniques are population based and stochastic in nature and they are applied to obtain quality solutions [7] to optimization problems. Big-bangand big-crunch (BBBC) developed by Erol and Eksin [8] from the concept of universal evolution. Fire fly optimization (FFO) also a heuristic algorithm developed by Dr. Xin-she yang [9] and cuckoo optimization algorithm proposed by X.S. Yang[10] are also a population based search technique which are used to solve OPF problem.

In this proposed work, optimal power flow problem is handled by the recently introduced bio inspired fruit fly algorithm [11]. This simple and efficient algorithm is tested on the standard IEEE-14 bus system.

II. PROBLEM FORMULATION

The main objective this work is to reduce the power loss in transmission lines for reasons of economics.

A. Equality Constraints

The equality constraints signify the load flow equations, which are given below for i_{th} bus:

1) Active Power Balance at all the Bus

P_{gi}-P_{di}=$\sum V_i V_j Y_{ij} \cos(\delta_{ij} + \gamma_j - \gamma_i)$(1)

(i=1,2,3,..........NB)

2) Reactive Power Balance at all the Nodes

Q_{gi}-Q_{di}=$\sum V_i V_j Y_{ij} \sin(\delta_{ij} + \gamma_i - \gamma_j)$(2)

(i=NG+1,.......NB)

B. Inequality Constraints

1) Generator Constraints

Generator voltage and reactive power of i_{th} bus lies between their upper and lower limits as given below:

$V_{gi}^{min} \le V_{gi} \le V_{gi}^{max}$(3)

$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}$

(i=1,2,............NG)

Where V_{gi}^{min},V_{gi}^{max} are the minimum and maximum generator voltage of i_{th}generatingunit and Q_{gi}^{min}, Q_{gi}^{max} are the minimum and maximum reactive power of i_{th}generating unit.

2) Load Bus Constraints

$V_{LI}^{min} \le V_{LI} \le V_{LI}^{max}$(4)

(i=1,2,............NL)

Where V_{LI}^{min},V_{LI}^{max} are the minimum and maximum load voltage of i_{th} generating unit.

3) Transmission Line Constraints

$S_{LI} \le S_{LI}^{max}$(5)

(i=1,2............N_{TL})

Where S_{LI} is the apparent power flow of i_{th} branch and S_{LI}^{max} is the maximum apparent power flow limit of i_{th} branch.

4) Transformer Tap Constraints

Transformer tap settings are bounded between upper and lower limit as given below:

$T_i^{min} \leq T_i \leq T_i^{max}$(6)

(i=1,2............N_T)

Where T_i^{min},T_i^{max} are the minimum and the maximum tap settinglimits of i_{th} transformer.

5) Shunt Compensator Constraints

Shunt compensators are restricted by their limits as follows:

$Q_{CI}^{min} \leq Q_{CI} \leq Q_{CI}^{max}$(7)

(i=1,2,………NC)

Where Q_{CI}^{min}, Q_{CI}^{max} are the minimum and maximum VAR injection limits of i_{th} shunt capacitor.

The limits on the control variables of real power generations, voltage magnitudes of generators, transformer tap settings and switchable shunt devices are implicitly handled while generating the parameters random.

III. FRUIT FLY OPTIMIZATION ALGORITHM

Fruit Fly Optimization Algorithm is a new optimization method based on fruit fly's foraging behaviors and this algorithm has been used by most researchers for many optimization problems. Fruit flies are superior to other species in terms of visual senses. They can successfully pick up various odors floating in the air with their olfactory organ, some can even smell food sources 40 kilometers away. Then, they would fly to the food. They may also spot with their sharp vision food or a place where their companions gather. The algorithm is originated from foraging behavior of fruit flies. The algorithm can be easily understandable because of its simple structure. Its updating strategy, which used to find best solution, is simpler than other algorithms.

Fruit fly's foraging characteristics have been summarized and programmed into the following steps, which are:

1) Randomly generate initial position for the swarm of fruit fly.

$$(InitX\_axis, InitY\_axis) \tag{8}$$

2) Randomly assign each fruit fly a direction and distance for their movement to look for food with their olfactory organ.

$$X_i = X_{axis} + \text{Random Value} \tag{9}$$

$$Y_i = Y_{axis} + \text{Random Value} \tag{10}$$

Since food position is unknown, the distance ($Dist_i$) to the origin is estimated first, and the judged value of smell concentration (S_i), which is the inverse of distance, is then calculated.

$$Dist_i = \sqrt{X_i^2 + Y_i^2} \tag{11}$$

$$S_i = 1/Dist_i$$

3) Substitute the values of smell concentration (S_i) into the smell concentration judge function (also called fitness function)to get the smell concentrations ($Smell_i$) at the positions of each and every fruit flies.

$$Smell_i = \text{Function}(Si) \tag{12}$$

4) Identify the fruit fly whose position has the best smell concentration (maximum value)

$$[\text{Best Smell best index}] = \max(\text{Smell}) \tag{13}$$

5) Keep the best smell concentration value and x, y coordinate; the fruit fly swarm will see the place and fly towards the position.

$$\text{Smell best} = \text{best Smell} \tag{14}$$

$$X_{axis} = X(\text{best Index}) \tag{15}$$

$$Y_{axis} = Y(\text{best Index}) \tag{16}$$

6) Enter iterative optimization and judge whether the smell concentration is higher than that by repeating steps 2-5 in the previous iteration; if so carry out step 6.

IV. IMPLEMENTATION OF FFA ALGORITHM

Form an initial generation of NP flies in a random manner respecting the limits of search space. Each fly is a vector of all control variables, i.e. [P_g, V_g, T_{tap}, Q_{sh}]. There are 4 P_g's, 5V_g's, 1 Q_{sh}'s and 3 T_{tap}'s in the IEEE-14 system and hence a fly is a vector of size 1x15. Calculate the smell concentration function values of all flies solution by running the NR load flow. The control variable values taken by different flies are incorporated in the system data and load flow is run. The total line loss corresponding to different flies are calculated. The steps followed in this algorithm is given below.

1) Step 1: Form an initial generation of NP flies in a random manner respecting the limits of search space. Each fruit fly is a vector of all control variables, i.e. [P_g, V_g, T_{tap}, Q_{sh}]. There are 4 P_g's, 5 V_g's, 1 Q_{sh}'s and 3 T_{tap}'s in the IEEE-14 system and hence a fly is a vector of size 1x17.
2) Step 2: Calculate the smell concentration values of all flies solution by running the NR load flow. The control variable values taken by different flies are incorporated in the system data and load flow is run. The total line loss corresponding to different flies are calculated.
3) Step 3: Determine the best fly which has global best smell concentration using equation (13). The flies are arranged in the ascending order their (smell concentration) and the first fly will be the candidate with best smell (minimum cost).
4) Step 4: Generate new fly around the global best fly by adding/subtracting a normal random number according to equation (14). It should be ensured that the control variables are within their limits otherwise adjust the values.
5) Step 5: Steps 2-5 can be repeated until best smell concentration is not achieved.

A. Flowchart

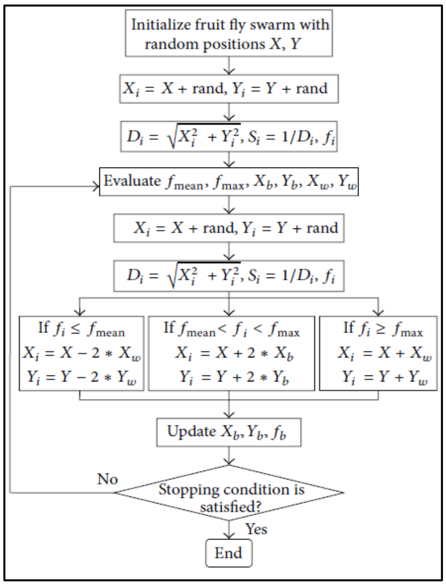

Fig. 1: Flow Chart for FFA Algorithm

V. NUMERICAL RESULTS & DISCUSSIONS

The performance of the proposed fruit fly optimization algorithm based optimal power method is tested in the medium size IEEE-14 Bus system.The algorithm is coded in MATLAB environment and a BT 950 processor, 2.1 MHz, 4GB RAM based PC is used for the simulation purpose.

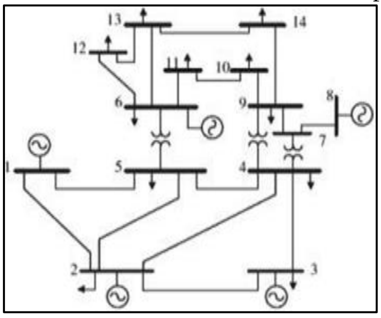

Fig. 2: Single Line Diagram of IEEE-14 Bus System

The test system has five generating units connected to buses 1,2,3,6 and 8.There are 3 regulating transformers connected between bus numbers 5-6, 4-9 and 7-8. One shunt compensator is connected in bus number 7. The system is interconnected by 21 transmission lines. Generator's voltages, tap settings of the regulating transformers and VAR injection of shunt Capacitors are the control variables.

SI.NO	Parameter	Quantity
1	Buses	14
2	Transmission lines	21
3	Generators	5
4	Static VAR compensator	1
5	Tap changing transformer	3

Table 1: System Parameters

SI.NO	Variable	Quantity
1	Generator bus voltage	0.9-1.1p.u
2	Transformer tap position	0.9-1.1p.u
3	SVC VAR output	2-15 MVAR

Table 2: Range of Control Variables

A. *Numerical Results*

Line no	OPF without FACTS(MW)	OPF with FACTS
1	16.950	16.024
2	14.067	12.851
3	16.364	16.171
4	13.980	22.842
5	17.999	17.031
6	5.522	16.579
7	9.099	9.090
8	27.863	27.414
9	14.044	8.060
10	6.951	6.156
11	3.841	4.128
12	7.333	7.021
13	9.122	9.511
14	8.970	13.137
15	39.153	41.620
16	11.515	9.393
17	21.357	20.576
18	7.720	8.358
19	13.648	13.952
20	7.781	8.348
Total	273.279	287.262

Table 3: Load Condition

Line no	OPF without FACTS(MW)	OPF with FACTS(MW)
1	11.895	18.948
2	15.860	14.831
3	13.461	16.526
4	8.207	13.668
5	22.153	18.448
6	7.861	6.084
7	-30.660	5.897
8	-0.542	28.965
9	-3.309	6.194
10	-7.595	9.451
11	9.788	12.044
12	17.586	7.213
13	5.337	8.635
14	9.946	6.107
15	-17.635	40.352
16	2.562	5.227
17	-9.806	21.844
18	12.980	13.498
19	1.987	7.047
Total	209.17	260.979

Table 4: Contingency condition

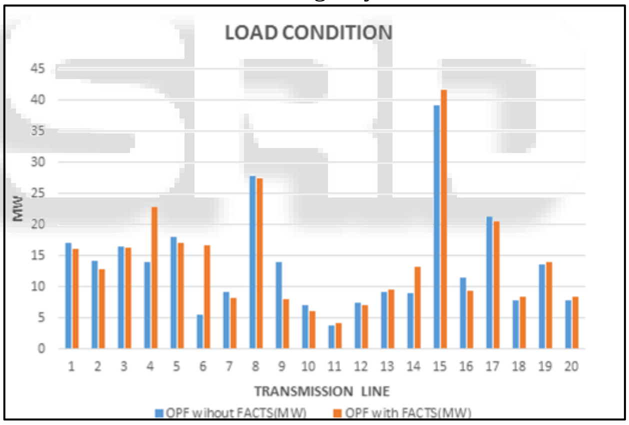

Fig. 3: OPF Improvement at Load Condition

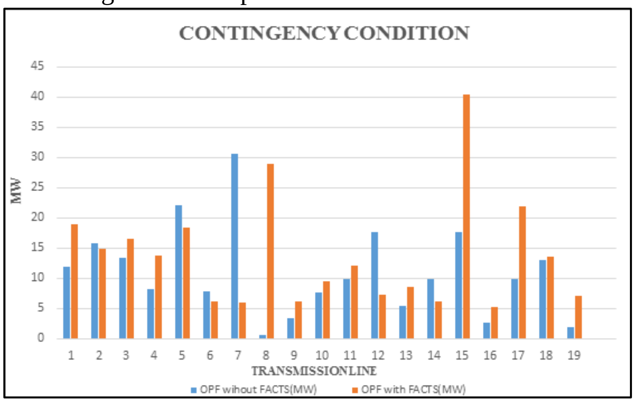

Fig. 4: OPF Improvement at Contingency Condition

VI. CONCLUSION

In this paper, fruit fly based optimization algorithm has been presented to minimize total power losses of the system, where the power transfer capability gets improved after OPF as well.

The optimal power flow was improved by employing the TCSC in the transmission line. Simulations are done on the IEEE 14 bus system. The algorithm achieves the results in relatively less number of iterations. The algorithm is found to be simple in implementation since the number of operators is less.

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