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PERFORMANCE OF FRUIT FLY ALGORITHM IN OPTIMAL REACTIVE POWER DISPATCH PROBLEM

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ABSTRACT:
ORPD problem is a nonlinear programming problem containing both continuous and discrete control variables. Generator bus voltages, transformer tap settings and SVC settings are the decision variables in this problem.Optimal reactive power dispatch (ORPD) is necessary for security enhancement of power systemThe newly introduced fruit fly algorithm is proposed to be used for optimizing the reactive power flow. This algorithm is simple yet efficient in engineering optimization. The proposed algorithm is tested on IEEE-30 bus test system and results are expected to be better than results reported in the literature**.**

1.INTRODUCTION:

Optimal reactive power dispatch problem is one of the major problems in power systems. (ORPD) means controlling maintaining equipment to optimize reactive power flow reduce active power and voltage losses and improve voltage quality .Nowadays; voltage instability has become a new challenge to power system planning and operation. Insufficient reactive power availability or non-optimized reactive power flow may lead a power system to insecure operation under heavily loaded conditions [1]-[2]. To overcome the operating requirements of a reliable power system is to maintain the voltage within the permissible ranges. The equality constraints are the nodal power balance equations, while the inequality constraints are the limits of all control or state variables. Minimizing an active power loss through the optimal adjustment of the power system control variables[3], while at the same time satisfying various equality and inequality constraints detected by electrical network.

The reactive power dispatch problem[4] involves best utilization of the existing generator bus voltage magnitudes, transformer tap setting and the output of reactive power sources so as to minimize the loss and to enhance the voltage stability of the system. Reactive power flow can be controlled by suitably adjusting the following facilities such as, generating units' reactive power capability variation, switching of capacitors, switching of unloaded or unused lines and flexible AC transmission system (FACTS) devices[5].. It has a non-linear optimization problem with a mixture of discrete and continuous variables. The continuous control variables are generator bus voltage magnitudes, while the discrete variables are transformer tap settings and reactive power of shunt compensators. Therefore minimizing the real power loss ensures optimized reactive power flow (ORPF) through the lines and it is an important tool in terms of secure and economic operation of power systems.

Techniques such as non linear programming technique [6] and gradient based optimization algorithm [7] are used to solve the ORPF problem. But they have several disadvantages like large numerical iteration and insufficient convergence properties which leads to large computation and more execution time. These algorithms are better utilised for power system optimization.some of them are recentely developed algorithms are Genetic Algorithm (GA) [8], Evolutionary Programming (EP) [9], Hybrid Evolutionary Programming (HEP) [10], Particle Swarm Optimization PSO [11] Unfortunately, PSO is easy to be trapped into local minima and its calculation efficiency is low., Differential Evolution (DE)[12] is an improved version of GA for faster optimization which provides fast and optimal solution for reactive power optimization, Cat Swarm Optimization (CSO) ,it is the convergence speed of CSO is significantly better than that of DE. a new meta-heuristic algorithm is introduced that uses a novel metaphor as guide for solving optimization problems. The League Championship Algorithm (LCA) is a novel algorithm designed based on the metaphor of sporting competitions in sport leagues [13]. such methods lack a mechanism able to bias efficiently the search towards the feasible region in constrained search spaces.

To recover drawbacks, a considerable amount of research has been devoted and a wide variety of approaches have been suggested in the last few years to handle the constraints efficiently during the search [14], [15] .Chien-Feng Yang proposed a system for limiting voltage variations by means of switchable shunt reactive compensation and transformer tap setting. The OPRD problems, programmed work is done by Matlab. IEEE-30 bus system expresses better result and performance result analysis .

2.PROBLEM FORMULATION

The objective function of this work is to find the optimal settings of reactive power control variables including the rating shunt of varcompensating devices which minimizes the real power loss and voltage deviation. Hence, the objective function can be expressed as:

2.1 REALPOWERLOSS MINIMIZATION (P_L)

The total real power of the system can be calculated as follows

$$f = \min(P_L) = \sum_{k=1}^{N_L} G_k[V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j)] \qquad (1)$$

Where , $N_L$is the total number of lines in the system; G_k is the conductance of the line 'k'; $V_i$and V_j are the magnitudes of the sending end and receiving end voltages of the line; $\delta_i$and$\delta_j$are angles of the end voltages.

2.2 CONSTRAINTS

The minimization problem is subject to the following equality and inequality constraints

2.2.1 EQUALITY CONSTRAINTS:

LOAD FLOW CONSTRAINTS:

$$P_{Gi} - P_{Di} - \sum_{j=1}^{N_B} V_i V_{ij} Y_{ij} \cos\left(\delta_{ij} + \gamma_j - \gamma_i\right) = 0 \qquad (2)$$

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{N_B} V_i V_{ij} Y_{ij} \sin\left(\delta_{ij} + \gamma_j - \gamma_i\right) = 0 \qquad (3)$$

2.2.2 INEQUALITY CONSTRAINTS:

REACTIVE POWER GENERATION LIMIT OF SVCS:

$$Q_{ci}^{min} \leq Q_{ci} \leq Q_{ci}^{max}; i \in N_{SVC} \qquad (4)$$

VOLTAGE CONSTRAINTS:

$$V_i^{min} \leq V_i \leq V_i^{max}; i \in N_B \qquad (5)$$

TRANSMISSION LINE FLOW LIMIT:

$$S_i \leq S_i^{max}; i \in N_l \qquad (6)$$

TAP POSITION CONSTRAINTS:

$$T_{Pi}^{min} \leq T_{Pi} \leq T_{Pi}^{max}; \qquad i \in N_T \qquad (7)$$

POWER GENERATION LIMITS:

$$P_{G\,i}^{min} \leq P_{G\,i} \leq P_{G\,i}^{max}; \qquad i \in N_G \qquad (8)$$

$$Q_{G\,i}^{min} \leq Q_{G\,i} \leq Q_{G\,i}^{max}; \qquad i \in N_G \qquad (9)$$

3.FRUIT FLY OPTIMIZATION ALGORITHM

Fruit Fly Optimization Algorithm was put forward by Taiwanese scholar Pan. It is a new optimization method based on fruit fly's foraging behaviors and most researchers used this algorithm for many optimization problem. 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.

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

1:Randomly generate a fruit fly swarm's initial position

$$\text{Init X axis; Init Y axis} \qquad (10)$$

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

$$X_i = X_{axis} + RandomValue \qquad (11)$$

$$Y_i = X_{axis} + RandomValue \qquad (12)$$

Since food's 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.

$$Dist_i = \sqrt{(X_i^2 + Y_i^2)}; \quad S_i = 1/Dist_i \qquad (13)$$

3: Substitute the judged values of smell concentration (S*i*) into the smell concentration judge function (also called fitness function) to get the smell concentrations (Smell*i*) of at positions of each and every fruit flies

$$\text{Smell}_i = \text{Function}(S_i) \qquad (14)$$

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

$$[\text{bestSmellbestIndex}] = \max(\text{Smell}) \qquad (15)$$

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

$$\text{Smellbest} = \text{bestSmell} \quad (16)$$

$$\text{X axis} = \text{X(bestIndex)} \quad (17)$$

$$\text{Y axis} = \text{Y(bestIndex)} \quad (18)$$

3.1 FOA ALGORITHM APPLIED TO ORPD MINIMIZATION:

FOA algorithm involves the steps shown below in reactive power flow control.

Step 1: Form an initial generation of NP flies in a random mannerrespecting the limits of search space. Each fruit fly is a vector of all control variables, i.e. [V_g,T_k,Q_{sh}]. There are 6V_g's,4T_k'sand 9 inSVC'sthe IEEE-30 system and hence a fly is a vector of size 1X19.

Step 2: Calculate the smell concentration values of all flies solution byrunning 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 candidates are calculated.

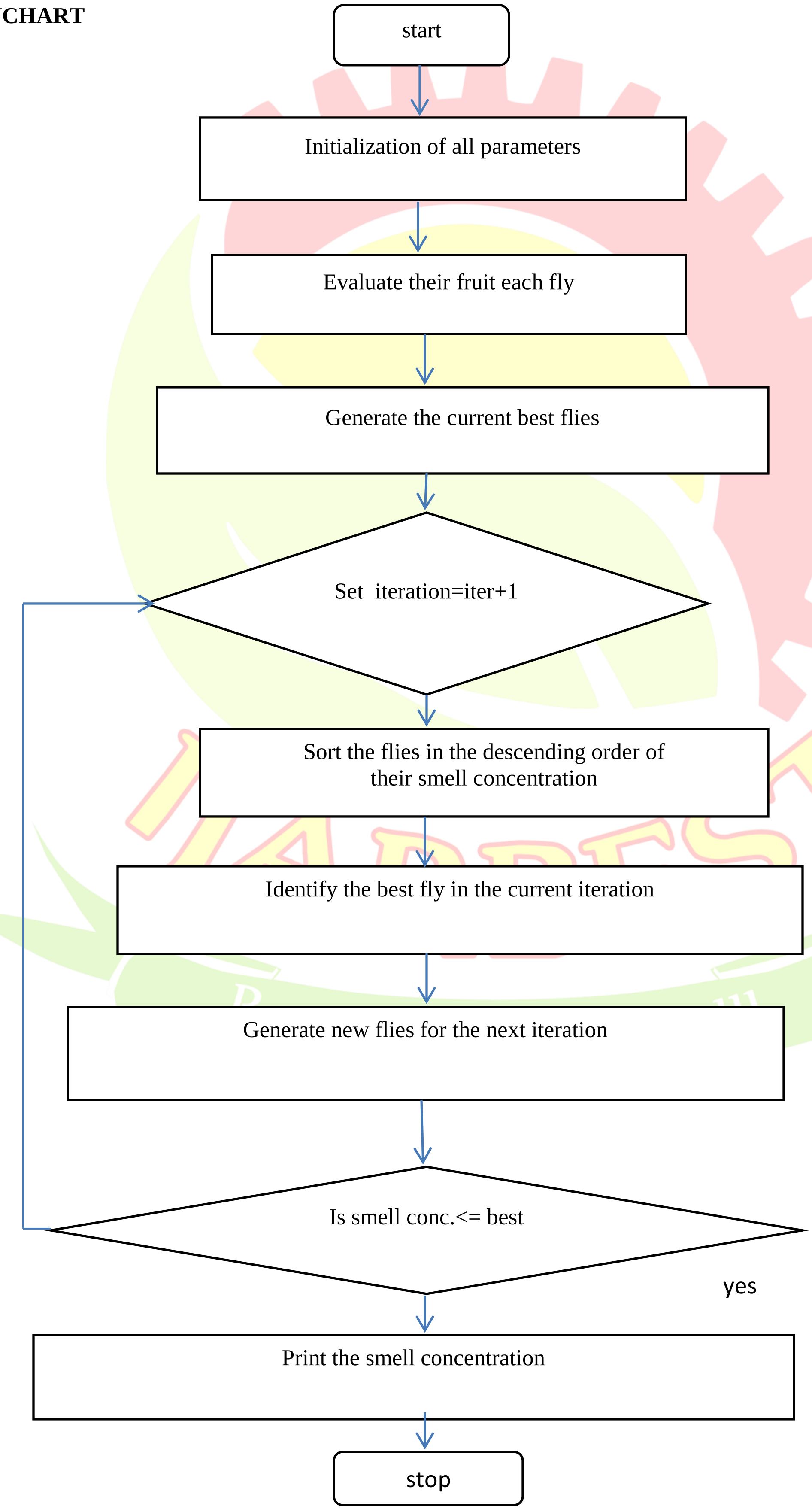
6: Enter iterative optimization, repeat steps 2-5 and judge whether the smell concentration is higher than that in the previous iteration; if so, carry out step 6.

Step 3: Determine the best fly which has global best smell concentrationusing equation (9). The flies are arranged in the ascending order their (smell concentration) and the first fly will be the candidate with best smell (minimum cost).

Step 4: Generate new fly around the global best fly by adding/subtractinga normal random number according to equation (10). It should be ensured that the control variables are within their limits otherwise adjust the values ofr' 'andα'. '

Step 5: Repeat steps 2-4 until stopping criteria has not been achieved.

FLOWCHART


start
Initialization of all parameters
Evaluate their fruit each fly
Generate the current best flies
Set iteration=iter+1
Sort the flies in the descending order of their smell concentration
Identify the best fly in the current iteration
Generate new flies for the next iteration
Is smell conc.<= best
yes
Print the smell concentration
stop

5.RESULTS AND DISCUSSIONS

The effectiveness of the proposed FOA based approach is tested in IEEE-30 and IEEE 57 bus systems. The algorithm parameters are tuned well to suit the proposed work. The optimal parameters of the FOA algorithm are; maximum number of generations; 200, velocity limits V; [0.005, -0.005], frequency *f*; [-0.09, 0.09] and loudness limits A; [-65, 65]. Reactive power is optimized by optimally setting the values of the design variables. Generator bus voltages, transformer tap positions and settings of SVCs are the control variables or design variables. The population size is taken as 30 and the algorithm is run for 20 times for obtaining the best results. The upper and lower limits of the control variables are given table 1.

Table 1. Control Variables and their limits

Control Variable	Limit
Generator voltage (V_G)	(0.9-1.1) p.u.
Tap setting (T_P)	(0.9 -1.1) p.u.
MVAR by static compensators (Q_C)	(0-30) MVAR

Three different objective functions are considered to optimize the reactive power in the system. In case '1' only real power loss is minimized, case '2' considers optimization of voltage profile at the load buses and both real power loss and sum of voltage deviation are taken for reactive power optimization in case '3'.

4.1 TEST SYSTEM:

IEEE-30 bus system is a medium size test system and is widely used for many power system related research works. The system line data and bus data are taken from [36].The test system taken has six generating units connected to buses 1, 2, 5, 8, 11 and 13. There are 4 regulating transformers connected between bus numbers 6-9, 6-10, 4-12 and 27-28. Two shunt compensators are connected in bus numbers 10 and 24. The system is interconnected by 41 transmission lines. The dimension of this optimization problem is 12. The system is considered under base load conditions.

IEEE-30BUS SYSTEM

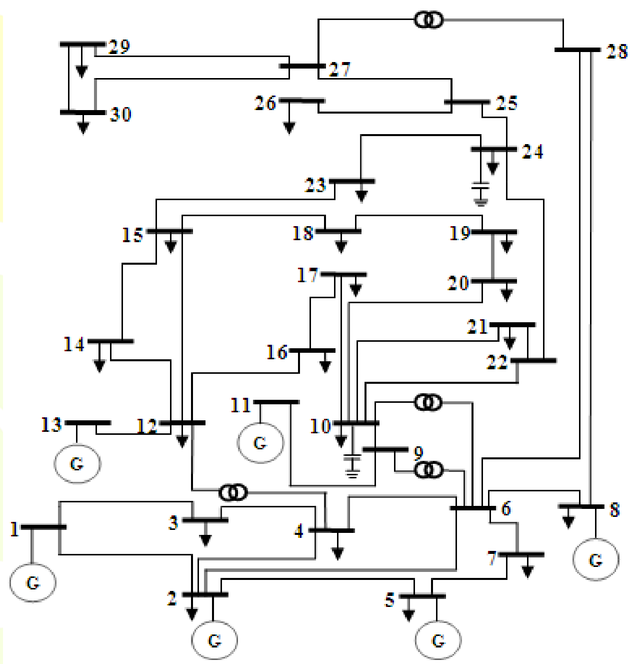


Figure 1.one line diagram of IEEE-30bus system

Table 1. Parameters of the IEEE-30 bus system

Sl.No.	Parameter	30-bus system
1	Buses	30
2	Branches	41
3	Generator Buses	6
4	Shunt capacitors	9
5	Tap-Changing transformers	4

4.1.1 Case 1: Minimization of Real Power Loss

The real power transmission loss minimization is the major component of reactive power optimization objective and it needs more attention. This case takes only the real power loss minimization as the objective function. The proposed algorithm is run and the optimal value of total line loss is obtained. Tuned values of control variables corresponding to different objectives are given in table 2.

Table 2. Optimal control variables for IEEE-30bus system

Parameter	Case 1	Case 2
V_1	1.1000	1.1000
V_2	1.0980	1.0914
V_5	1.0750	1.0739
V_8	1.0784	1.0746
V_{11}	1.0962	1.0210
V_{13}	1.1000	1.0303
TP_{6-9}	0.9373	1.0966
TP_{6-10}	1.0534	0.9410
TP_{4-12}	0.9733	1.0638
TP_{27-28}	0.9425	1.0309
Q_{c10}	5.1008	3.2856
Q_{c12}	4.2008	4.8543
Q_{c15}	2.7997	3.5072
Q_{c17}	5.2950	1.1518
Q_{c20}	2.5160	4.5688
Q_{c21}	6.8957	2.1141
Q_{c23}	5.5363	2.6727
Q_{c24}	5.8135	4.7017
Q_{c29}	-0.8077	1.7905
P_L	**4.5668**	4.7081
VD	2.0583	0.5318

Table 3. Minimization of objective terms (Case 1)

Parameter	**Real Power loss Minimization**		
	FOA	**BBO[1]**	**PSO[11]**
P_{loss}	4.5668	4.9650	5.09219
VD	2.0583	2.1410	---

Var output from SVCs is adjusted for real power optimization. It can be seen from table 4 that the var output required by BA is small. By way of minimizing var generation, reactive power reserve is maximized. It results in improved voltage stability margin. This an additional benefit offered by BA than other algorithms compared here.

Table 4. Reactive power requirement suggested (Case 1)

Bus Number	Q requirement		
	FOA	BBO[1]	PSO[11]
10	5.1008	28.910	15.3650
24	5.8135	10.070	6.22000

The strength of an optimization technique is usually tested by its convergence reliability and speed. The excellent convergence quality of BA is depicted in figure 1. It encourages the use this algorithm for further research.

Bus Number	Q requirement	
	FOA	BBO[1]
10	3.2856	20.67
24	4.7017	12.10

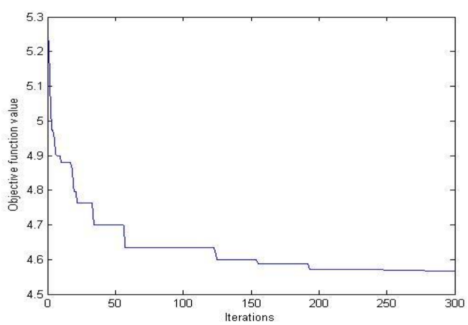


Figure 2. Convergence of FOA (IEEE-30 bus loss minimization)

4.1.2 Case 2: Minimization of Both Real Power Loss and Voltage Deviation.

Unlike the two previous cases, this case considers both real power loss and voltage deviation optimization simultaneously. This approach is most suitable for reactive power optimization as all the parameters of reactive power is included.. FOA performs in an excellent manner in optimizing both real power loss and voltage deviation.

Table 5. Minimization of objective terms (Case 3)

Parameter	Both Real Power Loss & Voltage Deviation Minimization	
	FOA	BBO
P_{loss}	4.7081	5.6320
VD	0.5318	0.1549

Reduced amount of reactive power by FOA in this case is tabulated in table 6. The convergence behavior is shown in figure

Table 6. Reactive power requirement suggested (Case 3)

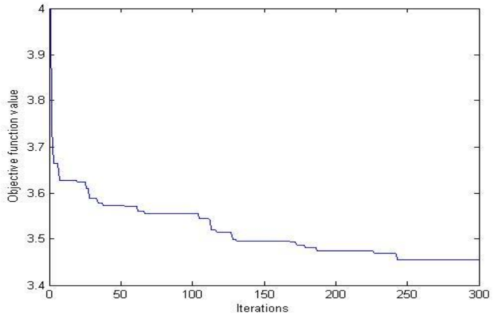


Figure 3. Convergence of FOA (IEEE-30 bus loss+VD minimization)

6.CONCLUSION

In this paper, a novel FOA based optimization algorithm is proposed to solve multi-objective reactive power optimization problem. The performance of the proposed algorithm in solving this multi-objective optimization is demonstrated using IEEE-30 bus system. The results are compared to those of other algorithms like PSO . The test results clearly show that FOA outperforms other reported methods in terms of solution quality. The superiority of the proposed FOA method is more pronounced in optimization of power system operation. From the simulation results it may finally be concluded that among all the algorithms, FOA based optimization method is capable of achieving global optimal solution. This paper proves that the proposed FOA optimization technique is good in dealing with power system optimization problems.The problem can be approached by any other recent optimization algorithms in the future for enhancement of this work.In future the work can be enchanced by objective of a multiobjective optimization technique. FACTS devices can also be used for further improvement.

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