"POWER QUALITY ANALYSIS OF DISTRIBUTION SYSTEM USING HYBRID INTELLIGENT ALGORITHM BY OPTIMAL INTEGRATION OF DG's"

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Abstract: ***Flower pollination algorithm (FPA) is a new nature-inspired algorithm, based on the characteristics of flowering plants. The proposed method combines the standard flower pollination algorithm (FPA) with the particle swarm optimization (PSO) to improve the accuracy. The FPA-PSO algorithm is used to solve constrained optimization problems. This paper gives the integration of distributed generation for enhancement of power quality based on adaptive FP-PSO algorithm. The proposed FP-PSO is evaluated by considering the IEEE 69 bus test system in the MATLAB platform. The efficiency of the algorithm is proved by outperforming the other nature based and evolutionary techniques by giving better voltage profiles and reduction in loss values respectively.***

Key Terms: Distributed Generation, Flower Pollination Algorithm, Loss Reduction, Particle swarm optimization, Power Quality, Voltage Profiles

1. INTRODUCTION

Distributed generator (DG) resources are small, self contained electric generating plants that can provide power to homes, businesses or industrial facilities in distribution feeders. By optimal placement of DG we can reduce power loss and improve the voltage profile. However, the values of DGs are largely dependent on their types, sizes and locations as they were installed in distribution feeders. The types of DG can be categorized as follows:

Type A: DG produces an active power only.
Type B: DG produces active and reactive powers.
Type C: DG produces reactive power only.
Type D: DG produces an active power and consumes reactive power.

Optimal placement of DGs in electric power system is a crucial task where stochastic inclusion of DGs may increase the system losses [2].Several techniques are used to determine the optimal locations and sizes of DGs in network such as analytical techniques [3, 4] and meta-heuristic optimization techniques. Recently, the meta-heuristic optimization algorithms are widely applied for solving many problems in electric power system where these methods have highly searching ability. Several meta-heuristic optimization algorithms have been widely applied to find the optimal sizes and locations of DG in RDS such as artificial bee colony (ABC) [6], genetic algorithms (GA)[7, 8], cuckoo search algorithm(CSA)[9], modified teaching learning based optimization (MTLBO) [10], ant lion optimization (ALO) algorithm, backtracking search

(BSA)algorithm, Differential Evolution (DE). Sensitivity analysis has been performed to determine the most candidate locations for inclusion the compensation devices in RDS to reduce the search space of optimization techniques and simulation time.

Flower pollination algorithm is an efficient optimization algorithm proposed by S. Mirjalili et. al. Recently, Yang developed a new Flower pollination algorithm (FP) that draws its inspiration from the flow pollination process of flowering plants.

In this paper new optimization algorithm i.e. Flower pollination algorithm (FPA) is used with particle swarm optimization technique for sizing and sitting of DGs. In this paper types of DG's are considered for optimal placement. Optimal placement problem has been solved using FP-PSO approach by taking the exact loss formula as objective function for sizing. The algorithm is new and rapidly developed for its easy implementation and few particles required to be tuned as compared to other heuristic approaches.

The remaining of paper is structured as follows: Section II describes the problem formulation that includes the objective functions and the system constraints. Section III explains FP-PSO algorithm procedures. Section IV shows the numerical results and discussion based on standard test systems. Finally, the conclusions of this work are presented in Section V.

2. PROBLEM FORMULATION

2.1. Load flow

The load flow is based on the forward/backward sweep technique as it is a powerful method and has been widely used.

$$P_{m+1} = P_m - P_{L,m+1} - R_{m,m+1}\left(\frac{P_m^2 + jQ_m^2}{|V_m|^2}\right)$$

$$Q_{m+1} = Q_m - Q_{L,m+1} - X_{m,m+1}\left(\frac{P_m^2 + jQ_m^2}{|V_m|^2}\right)$$

$$\begin{aligned} V_{m+1}^2 &= V_m^2 - 2(R_{m,m+1}P_n + X_{m,m+1}Q_m) \\ &\quad + \left(R_{m,m+1}^2 + X_{m,m+1}^2\right)\left(\frac{P_n^2 + jQ_m^2}{|V_m|^2}\right) \end{aligned}$$

Where R_{M+1} and X_{m+1} are resistance and reactance of he branch between buses m and m + 1 respectively. P_M and Q_m are the active and reactive powers flow respectively Vm and Vm+1 are the voltage magnitudes of bus *m* and bus *m* + 1 respectively. The active and reactive power flow with incorporating of DG at bus *m+1* can be give as follows:

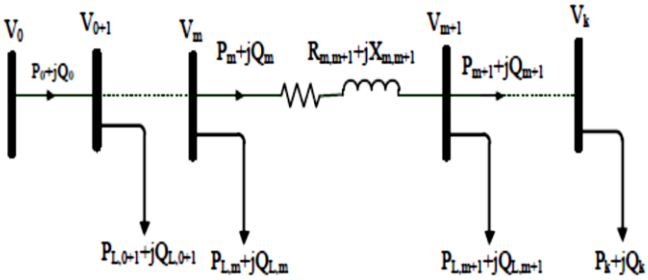

Fig 1: Single line diagram of radial distribution system

$$P_{m+1} = P_m - P_{L,m+1} - R_{m,m+1}\left(\frac{P_m^2 + jQ_m^2}{|V_m|^2}\right) + P_{DG}$$

$$Q_{m+1} = Q_m - Q_{L,m+1} - X_{m,m+1}\left(\frac{P_m^2 + jQ_m^2}{|V_m|^2}\right) + Q_{DG}$$

The active and reactive power losses can be given as follows:

$$P_{loss(m,m+1)} = R_{m,m+1}\left(\frac{P_m^2 + jQ_m^2}{|V_m|^2}\right)$$

$$Q_{loss(m,m+1)} = X_{m,m+1}\left(\frac{P_m^2 + jQ_m^2}{|V_m|^2}\right)$$

The voltage deviations can be given by

$$VD = \sum_{n=1}^{k}\left(V_n - V_{ref}\right)^2$$

Where k is number of buses and V_{ref} is the reference voltage that commonly equals to 1 p.u.

2.2. Fitness function

The fitness function proposed is defined as follows:

$$f_1 = \frac{\sum_{i=1}^{nl}(P_{loss}(i))_{after\ DG}}{\sum_{i=1}^{nl}(P_{loss}(i))_{before\ DG}} \qquad f_2 = \frac{\sum_{i=1}^{nb}(VD)_{after\ DG}}{\sum_{i=1}^{nl}(VD)_{before\ DG}} \qquad f_3 = \frac{1}{\sum_{i=1}^{nb}(|VSI(i)\ |)_{after\ DG}}$$

Where, nl is number of branches in RDS while nb is number of buses. The generalized objective function can be

$$f_t = h_1 f_1 + h_2 f_2 + h_3 f_3$$

Where, h1, h2 and h3 are weighting factors. Value of any weighting factor is selected based on the relative important on the related objective function with others objective functions.

3. FP-PSO ALGORITHM

3.1. FLOWER POLLINATION ALGORITHM

Flower pollination algorithm is a meta-heuristic search algorithm which has been proposed recently by Yang and Deb. The algorithm is inspired by the reproduction strategy of the flow pollination process of flowering plants. For simplicity, the following four rules are used:

Rule #1: Biotic and cross-pollination can be considered processes of global pollination, and pollen-carrying pollinators move in a way that obeys Levy flights.

Rule #2: For local pollination, abiotic pollination and self-pollination are used.

Rule #3: Pollinators such as insects can develop flower constancy, which is equivalent to a reproduction probability that is proportional to the similarity of two flowers involved.

Rule #4: The interaction or switching of local pollination and global pollination can be controlled by a switch probability p € [0,1] slightly biased toward local pollination.

Algorithm 1: Flower pollination algorithm

Define Objective function f (x), x = (x1, x2, ..., xd)
Initialize a population of n flowers/pollen gametes with random solutions
*Find the best solution **B** in the initial population*
Define a switch probability p ∈ [0, 1]
Define a stopping criterion (either a fixed number of generations/iterations or accuracy)
while (t <MaxGeneration)
  for i = 1 : n (all n flowers in the population)
    if rand <p,
      Draw a (d-dimensional) step vector L which obeys a L´evy distribution
      Global pollination via $x_i^{t+1} = x_i^t + L(B - x_i^t)$
    else
      Draw U from a uniform distribution in [0,1]
      Do local pollination via $x_i^{t+1} = x_i^t + U(x_j^t - x_k^t)$
    end if
    Evaluate new solutions
    If new solutions are better, update them in the population
  end for
  *Find the current best solution **B***
end while
Output the best solution found

Fig2: code for FPA

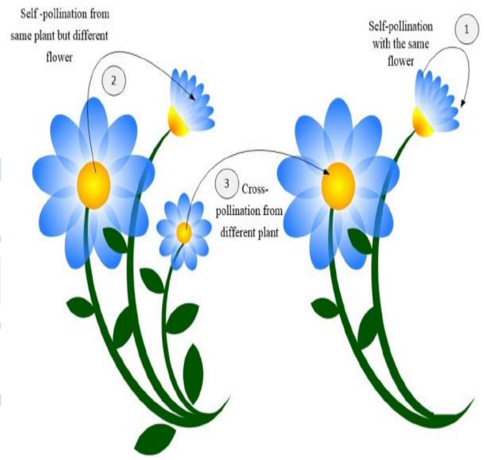

fig3: flower pollination methods

From the algorithm, it is evident that initial step of this algorithm deals with the selection of population size (N) and a parameter (p) which help to decide the amount of self pollination and cross pollination to take place. The algorithm continues by initializing specified number of population (N), with each one containing a group of variables which are optimized using the objective function. Based on the flower constancy, population are queued and best among them is found.

3.2. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) was developed by Kennedy and Eberhartin 1995 based on the swarm behavior such as fish and bird schooling in nature. Since then, PSO has generated much wider interests and forms an exciting, ever expanding research subject called swarm intelligence. This algorithm searches the space of an objective function by adjusting the trajectories of individual agents, called particles, as the piecewise paths formed by positional vectors in a quasi stochastic manner. The movement of a swarming particle consists of two major components: a stochastic component and a deterministic component. Each particle is attracted toward the position of the current global best g and its own best location xi* in history, while at the same time it has a tendency to move randomly. Let xi and vi be the position vector and velocity of particle i, respectively. The new velocity vector is determined by the following formula:

$$v_i^{t+1} = v_v^t + c_1 r_1 (g - x_i^t) + c_2 r_2 (x_x^* - x_i^t)$$

Where *r1* and *r2* are two random vectors and each entry takes the values between 0 and 1.
The parameters *c1*and *c2* are the learning parameters or acceleration constants, which can typically be taken as, say, *c1*≈*c2*≈ 2.The initial locations of all particles should be distributed relatively uniformly so that they can sample over most regions, which is especially important for multimodal problems. The initial velocity

of a particle can be taken as zero, i.e. $vi^t = 0 = 0$. The new positions can then be updated by:

$$x_i^{t+1} = x_i^t + v_i^{t+1}$$

Although vi can be any value, it is usually bounded in some range [0,$vmax$].

3.3. HYBRID FLOWER POLLINATION – PARTICLE SWARM OPTIMIZATION ALGORITHM

In the proposed algorithm, we used chaotic maps to tune the Flower pollination algorithm parameter and improve the performance. The steps of the proposed algorithm for solving optimization problem are as follows:

Step 1 Initialize the swarm by randomly assigning each particle to an arbitrarily initial velocity and a position in each dimension of the solution space.

Step 2 Evaluate the desired fitness function to be optimized for each particle‘s position.

Step 3 for each individual particle; update its historically best position so far, ***BestPi,*** if its current position is better than its historically best one.

Step 4 Identify/Update the swarm‘s globally best particle that has the swarm‘s best fitness value, and set/reset its index as ***g*** and its position at ***gbestP***.

Step 5 Update the velocities of all the particles

Step 6 Move each particle to its new position

Step 7 Repeat steps 2–6 until convergence or a stopping criterion is met.

Step 8 The best solution found by PSO is regarded as initial points for FP algorithm. ***B***

Step 9 Calculate ***p*** by the selected chaotic maps.

Step 10 If (rand <***p***) then global pollination via $x_i^{t+1} = x_i^t + (f\gamma)L(\lambda)(x_i^t - B) // (f\gamma)$ chaotic Le'vy flights else do local pollination via $x_i^{t+1} = x_i^t + U(x_j^t - x_k^t)$

Step 11 Evaluate new solutions if better, update them in the population.

Step 12 Find the current best solution ***B***.

Step 13 Output the best solution found.

4. RESULTS AND DISCUSSION

The proposed method is applied on IEEE 69 Redial distribution system .coding is done for optimal allocation of single and multiple DGs by Hybrid approach of Adaptive Flower pollination and Particle swarm optimization method using MATLAB2016b. The single line diagram of IEEE69 RDS is shown in fig.4 and the system voltage is 12.66 KV with 3801.49 MW active and 2694.6 MVAR Reactive load demand. The active power losses and minimum voltage before placement of DG with the base case load flow results are obtained to be 224.9839 kW and 0.90918 p.u.at bus number 65.

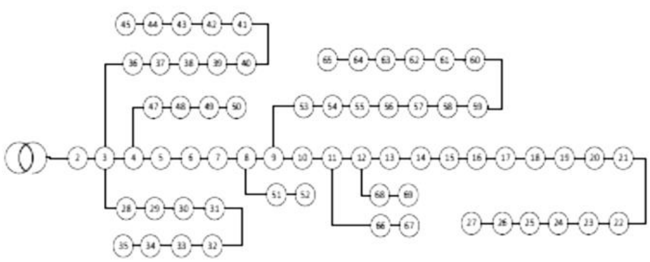

Fig 4 Single line diagram of IEEE 69 bus Radial Distribution System

Fig. 5 shows the LSF for 69-bus distribution system. After normalizing the bus voltage the obtained candidate buses for incorporating the DGs are 57, 58, 61, 60, 59, 15, 64, 19, ,2 ,16, 63, 20, 62, 25, 24, 23, 26, 27, 18, 27, 18 and 22.

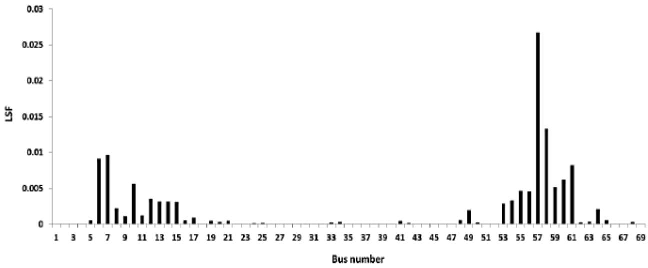

Fig 5: LSF value for 69 bus system

4.1: Integration of single DG

The best location, size and Type of DG is chosen by Hybrid approach of Adaptive Flower pollination and Particle swarm optimization method and the results are obtained as shown in the table 1, where the TYPE 3 DG was suitable with the capacity of 1415.2528KW Active and 1038.227KVAR Reactive power and has been placed at the bus node 65, The total losses are reduced by 72.588 % and the minimum voltage obtained is 0.969p.u.

The following Figures show the voltage profile and power losses at all candidate buses of IEEE69 bus distribution system before and after placement of Type 3 DG and it is observed that voltage profile has been improved at all considered buses and losses at different buses have been reduced after placement of DG.

Test system	Optimal location	Optimal size of different type of dg		Activepower losses		Minimum voltage in pu	
		kW	kVAR	Without DG (kW)	With DG(kW)	WithoutDG (kW)	WithDG(kW)
69	65	1415.2528 kW	1038.2287	224.9839	61.6713	0.90918	0.969

Table1: IEEE69 bus test system data before and after single DG placement

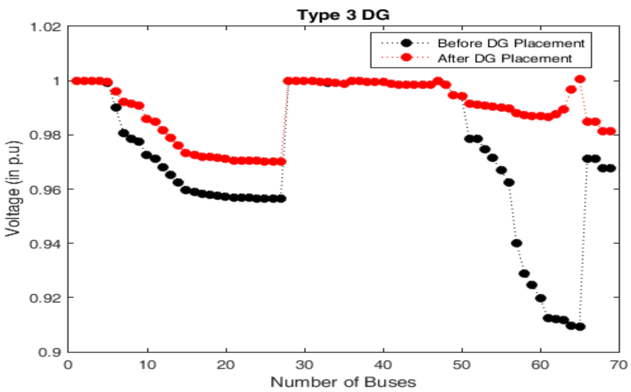

Fig 6: Voltage profile before and after placement of DG at IEEE69 RDS

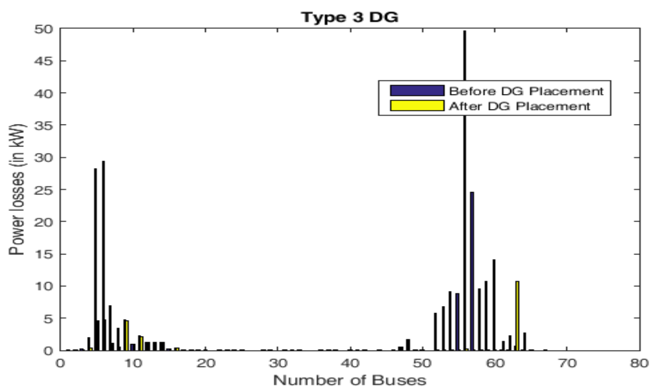

Fig7: Power losses before and after placement of DG at IEEE69 RDS

4.2. Integration of Two DGs

The best location, size and Type of DGs are chosen by Hybrid approach of Adaptive Flower pollination and Particle swarm optimization method and the results are obtained as shown in the table II, where the TYPE 3 DGs of suitable capacity of 346.45124 kW, 610.40278 kVAR and 1193.563 kW, 513.40828 kVAR are placed at the bus node 64 and 65 respectively, The total system active power losses are reduced to 43.6679 kW i.e., 80.5% and the minimum voltage obtained is 0.97013p.u.

Test system	Optimal location	Dg type	Optimal size of different type of dg		Activepower losses		Minimum voltage in pu	
			kW	kVAR	Without DG (kW)	With DG(kW)	WithoutDG (kW)	WithDG(kW)
69	64	III	346.45124	610.40278	224.9838	43.6679	0.90918	0.97013
	65		1193.563	513.40828				

Table2 : IEEE69 bus test system data before and after integration of multiple DGs

Test system	PSO			FP			FP-PSO		
IEEE 69 bus RDS	size of DG	active power losses (KW)	Min Voltage (PU)	size of DG	active power losses in KW	Min Voltage in PU	size of DG	active power losses in KW	Min Voltage in PU
	1900kW 4000kVAR	73.10	0.966	1873kW 1384 kVAR	83.2279	0.9682	1415.2528KW 1038.2287KVAR	61.6713	0.969

The table below compares the result of the proposed technique to the existing methodologies and it is inferred that the **FP-PSO** algorithm reduces the losses and also improves the voltage profile of the system.

5. CONCLUSION

The optimum DG location size and type for power loss reduction and to improve voltage profile is determined through hybrid adaptive Flower pollination algorithm and particle swarm optimization. The optimum DG size is evaluated based on the objective function which minimizes the total active power loss. The proposed hybrid adaptive Flower pollination algorithm and particle swarm optimization technique is used to find the optimum size and location as well as type of DG. It has better convergence characteristics when compared to other algorithms and comparison is done with Flower pollination and particle swarm optimization. The simulation results indicated that the overall impact of the DG units on voltage profile is positive and proportionate reduction in power losses is achieved. It can be interfered that best results can be achieved with type III DG.

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