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Distributed Energy Resources Allocation using Flower Pollination Algorithm in Radial Distribution Systems

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Abstract

To meet the increased load demand and improve the distribution network performance, it is necessary to use Distributed Generators (DGs) and shunt capacitors (SCs) simultaneously in the distribution network. In this paper, simultaneous allocation of distributed generators and shunt capacitors in the distribution system using flower pollination algorithm (FPA) is presented. The objectives are to reduce power loss and improve the voltage profile of the distribution system. The suitable nodes for DG and capacitor placement are identified by using the loss sensitivity factor (LSF) technique. FPA method determines the optimal size of the DGs and SCs. The method developed is studied on IEEE 33 bus test system and the results are compared with other methods.

Keywords: Distributed Generators (DGs); Shunt Capacitors(SCs); Power loss minimization; Voltage profile; Flower Pollination Algorithm(FPA); Radial distribution system(RDS)

1. Introduction

To fulfill the demand in generation and concern about environmental issues, it is necessary to incorporate distributed generation resources (DERs) into the distribution system. In the conventional system, the power loss is higher because of its high resistance to reactance ratio [1]. To reduce the power loss, meet the peak load demand and also to improve the distribution network performance, optimal allocation of these sources plays a significant role. So the simultaneous allocation of distributed

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generators (DGs) and shunt capacitors (SCs) in the distribution system is considered to be important in the present research scenario.

In the last decade, several optimization techniques are used to solve the DG [2-5] and capacitor placement [6-9] problem in the distribution network separately for minimizing power loss and voltage profile enhancement. But simultaneous allocation of these sources in the distribution system increases the efficiency of the system rather than acting individually. Very few authors [10-12] had addressed these problems and achieved promising results. The limitation of the above mentioned techniques are difficult in tuning the control parameters and to providing balance between exploration and exploitation becomes more complex. In case of flower pollination algorithm tuning of only two control parameters that is population size and probability switch is sufficient for achieving optimal results with less computational time. This motivates the author to solve simultaneous DG and capacitor allocation problem in the distribution system using flower pollination algorithm. The objectives are to reduce power loss and improve the voltage profile of the system with different operating constraints. Simulations are performed on an IEEE 33 bus test system considering antithetic scenarios.

The remaining sections of the article are as follows: In section2 problem formulation is explained. In section 3 LSF techniques for identification of the best nodes of DG and capacitor is explained. In section 4 application of flower pollination algorithm for identifying the best size of DGs and SCs with reduced objective function is explained. Simulation results and discussion followed by conclusion are explained in section 5 and 6.

2. Problem formulation

2.1 Load flow equations

The following load flow equations are solved using backward/ forward distribution load flow [13]. Single line diagram of the distribution system is shown in Fig.1.

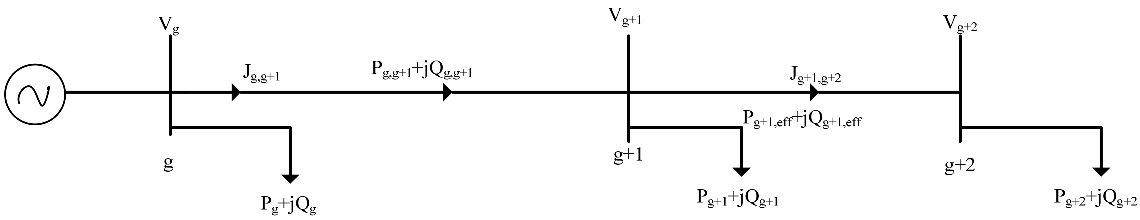

Fig.1. Sample distribution system

$$I_g = \left(\frac{P_g + jQ_g}{V_g} \right)^* \tag{1}$$

$$V_{g+1} = V_g - J_{g,g+1}(R_{g,g+1} + jX_{g,g+1}) \tag{2}$$

$$P_{lossg,g+1} = | I_{g,g+1} |^2 R_{g,g+1} \tag{3}$$

$$P_{Tloss} = \sum_{g=1}^{nbr} P_{loss}(g, g+1) \tag{4}$$

2.2 Formulation of objective function

The aim of formulating an objective function is to reduce the power losses of the distribution system with simultaneous allocation of DGs and SCs in RDS that is given in Eq. (5) and Eq. (6).

$$objfunction = \min(P_{Tloss}) \tag{5}$$

$$P_{Tloss}^{DGandcapacitor} = \sum_{g=1}^{nbr} P_{loss(g,g+1)}^{DGandcapacitor} \tag{6}$$

The objective function is to satisfy the following constraints of the distribution network.

Real power constraints

$$P_{ss} = \sum_{g=2}^{m} P_g + \sum_{g=1}^{nbr} P_{loss}(g, g+1) - \sum_{g=1}^{nbr} P_{cap,g} \tag{7}$$

Reactive power constraints of capacitor

$$\sum_{g=1}^{n_c} Q_{cg} \leq 1.0 \sum_{g=1}^{n_l} Q_c^L \tag{8}$$

DG constraints

$$P_{DGg}^{\min} \leq P_{DGg} \leq P_{DGg}^{\max} \tag{9}$$

3. LSF technique for initial identification of capacitor and DG locations

The best nodes for placement of DGs and SCs were found by using an LSF technique [14] and determined by using Eq. (10) and Eq. (11).

$$\frac{\partial P_{lineloss}}{\partial P_{g+1,eff}} = \frac{2P_{g+1,eff} R_{g,g+1}}{\left|V_{g+1}\right|^2} \tag{10}$$

$$\frac{\partial P_{lineloss}}{\partial Q_{g+1,eff}} = \frac{2Q_{g+1,eff} R_{g,g+1}}{\left|V_{g+1}\right|^2} \tag{11}$$

From the above equations, arrange the buses in descending order based on their sensitivities. The buses which have highest real power loss sensitivity with respect to real and reactive power injection are taken as the candidate buses for DG and capacitor placement.

4. Flower pollination algorithm

Yang and Deb introduced flower pollination algorithm in the year 2012 [15]. It is developed based on the pollination process of flowering plants. For easy understanding and implementation following four rules are used [15].

1) In the global pollination process biotic and cross pollination is considered and pollen carrying pollinators obeys levy flight [15].

2) In local pollination concept, abiotic and self-pollination is considered and it does not require any pollinators.

3) Pollinators such as bats, birds and insects develop flower constancy, which is equivalent to reproduction probability and it is proportional to similarity of two flowers involved.

4) The switch probability Pε [0, 1] controls the interaction of local and global pollination.

Based on the above rules important mathematical equations are developed that is

$$x_i^{t+1} = x_i^t + L(x_i^t - g_*) \tag{12}$$

The parameter L is the strength of pollination and it represents a Levy distribution that is given by

$$L \sim \frac{\lambda \Gamma(\lambda) \sin\left(\frac{\pi\lambda}{2}\right)}{\pi} \frac{1}{s^{1+\lambda}}, (s >> s_o > 0) \tag{13}$$

Flower constancy and local pollination can be represented as

$$x_i^{t+1} = x_i^t + \varepsilon(x_j^t - x_k^t) \tag{14}$$

Based upon these rules and pseudo code of flower pollination algorithm [15] the following steps are used to minimize the objective function.

1) Read the system data
2) Set the parameters of FPA
3) Generate the initial population of flowers and generate a random solution
4) Run load flow and evaluate the objective function
5) Initialize the population of solution using the global pollination concept
6) Check the solution of the objective function; if it is best stop otherwise use, the local pollination concept and evaluate the best solutions.
7) Again, check the solution of the objective function, it is minimized then stop the procedure.
8) Do the same procedure to reach the maximum iterations.
9) Store the best solution

5. Results and discussion

To check the superiority of the proposed FPA method, it is tested on an IEEE 33 bus test system. The parameters related to FPA method are taken as population size=20, probability switch=0.8 and maximum no of iterations=100. The data related to test system are taken from [16]. The developed method is implemented in MATLAB environment. The obtained results with different scenarios are given in Table 1. From Table 1 it is clear that power loss without placement of DGs and shunt capacitors is 210.99kW and minimum voltage is 0.9037 p.u. After placement of distributed generators and shunt capacitors optimally, the power losses reduced effectively.

Table1. Results of 33 bus test system with different scenarios

Particulars	Optimal size of DG in kW (bus)	Optimal size of capacitor in kVAR (bus)	P_{loss}(kW)	P_{loss} reduction(%)	V_{min}(p.u)
Without compensation	NA	NA	211	NA	0.9037
Scenario-1: Single DG	2300(6)	NA	112.20	46.82	0.9339
Scenario-2:Single DG+Capacitor	2490(6)	1200(30)	58.57	72.24	0.9507
Scenario-3: Two DGs	936.5(12) 1050(30)	NA	87.44	58.55	0.9622
Scenario-4:Two DGs+Capacitor	932.2(12) 1209.2(30)	1200(30)	36.53	82.68	0.9758

The maximum power loss reduction and good improvement in voltage profile are observed in scenario 4 i.e. simultaneous placement of multiple DGs along with the capacitor. Next comparison of the proposed method for Scenerio1 that is single DG placement is given Table 2. It is clear that the proposed method minimizes the power loss effectively compared to the other methods. Also a comparison of Scenario 2 i.e. optimal placement of single DG with a capacitor and the results are represented in Table 3. It is clear that proposed reduces the power loss effectively compared to the other methods. Table 4 shows the comparison of the proposed method with optimal placement of two DGs in the system. From the table it can be observed the maximum loss reduction is obtained than other methods.

Table 2 Comparison of the proposed method for scenario1 with other methods

Method	[2]	[5]	Proposed FPA
P_{loss} without DG (kW)	211.20	210.84	210.99
Size of DG in kW (location)	743(18)	1857.5(8)	2300(6)
P_{loss} with DG (kW)	146.82	118.12	112.20
%P_{loss} reduction	30.48	43.97	46.82

Table 3 Comparison of the proposed method for scenario 2 with other methods

Method	[10]	Proposed FPA
P_{loss} without DG and Capacitor (kW)	211	210.99
Size of DG in kW(location)	2510.6(6)	2490(6)
Size of Capacitor in kVAR(location)	1457(30)	1200(30)
P_{loss} with DG and Capacitor(kW)	59.7	58.57
%P_{loss} reduction	71.70	72.24

Table 4 Comparison of the proposed method for scenario 3 with other methods

Method	[3]	[5]	Proposed FPA
P_{loss} without DG (kW)	210.9	210.84	210.99
Size of DG in kW (location)	1200(32)	632(13)	936.5(12)
	863(16)	487(28)	1050(30)
	925(11)	550(31)	
P_{loss} with DG (kW)	103.4	89.05	87.44
% P_{loss} reduction	50.99	57.76	58.55

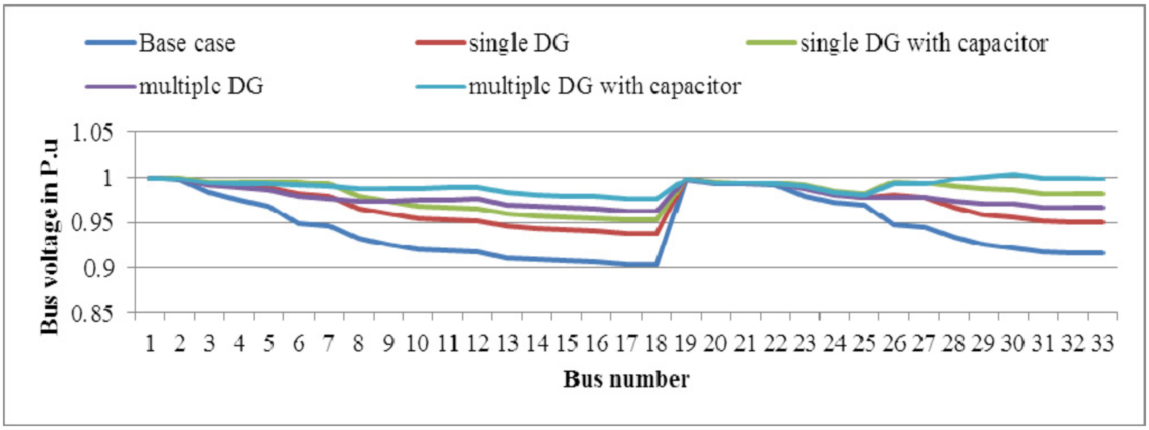

Fig.2. Voltage profile of 33 bus test system with different scenarios

Also voltage profile without and with placement of DGs and shunt capacitors at all scenarios are shown in Fig.2. It is observed that voltage profiles at all buses are improved effectively after placement of DERs optimally.

6. Conclusion

The optimal allocation of DERs in the distribution system is an important research area in recent years for improving the distribution network performance. In this paper, an efficient technique based on flower pollination algorithm (FPA) for simultaneous allocation of distributed generators (DGs) and shunt capacitors (SCs) in the radial distribution system is addressed. The developed method is tested on IEEE 33 bus test system by considering different scenarios. The simulated results clearly show that in all scenarios with optimal placement of distributed sources in the system, there is a good improvement in power loss reduction and voltage profile enhancement. Also the proposed method is compared with other existing methods in the literature. The results show the superiority of the proposed method with articulates highest amount of power loss reduction with good enhancement in the voltage profile compared to all other popular methods. So it can be concluded that the simultaneous allocation of these sources in the distribution system minimizes the power loss effectively compared to use these sources alone. Also proposed method tested for any type of test system with n number of buses.

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