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Optimal Placement of Distributed Generator in Distribution System using Fuzzy Composition

Gursharanjit Singh Gill
Student (Electrical Engg),
Deptt. of Electrical Engineering
Bhutta College of Engineering And Technology, Ludhiana
Ludhiana, Punjab

Jagroop kaur
Student (Electrical Engg),
Deptt. of Electrical Engineering
Guru Nanak Dev Engineering College
Ludhiana, Punjab

Abstract **- This paper presents a simple and effective methodology for optimal placement of distributed generator (DG) in distribution system. Three criteria viz. improvement in minimum voltage, reduction in difference between maximum and minimum voltage levels and loss reduction have been selected for optimal placement of DG in distribution system. Backward forward sweep method has been used to carry out base power flow analysis. Fuzzy max-min and max-product compositions have been used for obtaining maximum satisfaction level based on the above said criteria. The proposed methodology has been simulated on 11-bus and IEEE 33-bus distribution systems in the MATLAB environment. The results obtained clearly show the effectiveness of the proposed methodology.***)*

Keywords— Forward Backward Sweep Method, Max-Min Approach, Max-Product Approach, Fuzzy Composition, DG Placement.

I.INTRODUCTION

In present age, Distributed Generator is not a new concept. The small scale generation is the main idea behind the DG. It can be easily placed closer to the point of consumption in the power system. DG is, by definition, small size generators, which can come from some traditional technologies. It may come from variety of technologies and sources. DGs from renewable energy sources, like wind, solar and biomass are often called as 'Green energy distribution feeder with concentrated load. Some of the main benefits of DGs can be named as power generation cost reduction, power losses reduction, voltage deviation improvement, power quality enhancement, the possibility of producing both electrical and thermal energy in the form of combined heat and power (CHP), reducing Total Harmonic Distortion (THD), increasing the efficiency, positive effect on the environment, etc. Based upon three main categories namely, economical, technical and environmental advantages, DG offer a number of benefits. It covers fuel, transmission and distribution cost in economical advantages and on the other hand environmental advantages include low emission and noise. There is wide variety of issues in technical advantages such as good voltage profile, reduce system loss, improved reliability and relaxed thermal constraints. The main reason of using DG units in power system is its numerous benefits that are reduced line losses, Voltage profile improvement, Reduced emissions of pollutants, Increased overall energy efficiency, reliability and security, Improved power quality, Relieved T&D congestion, Deferred investments for upgrades of facilities, Reduced O&M costs of some DG technologies, Reduced fuel costs due to increased overall efficiency, Reduced reserve requirements and the associated costs, Lower operating costs due to peak shaving, Increased security for critical loads. The planning of distribution system with the presence of DG requires definition several factors, like: the best technology to be used, the best location, the network connection way etc. For the impact of DG in distribution system, operating characteristics, such as electric losses, voltage profile, reliability needs to be appropriately evaluated. For the electrical engineers the optimum planning of power distribution system network is one of the most important research fields. Due to the great length and close proximity of networks to the ultimate consumer increase the capital investment and cost because of their losses. The problem of DG allocation is of great importance. The installation of DG at non-optimal places can result into increased system losses and costs, therefore, having an effect opposite to the desired. Fuzzy set theory provides way to comprehend this problem and also allow to integrate on own intuition, intelligence and knowledge acquire from past experience in solving this. A fuzzy set is a set containing elements that have varying degrees of membership in the set. All information contained in a fuzzy set is described by its membership function.

The nature of uncertainty in a problem is a very important point that engineers should ponder prior to their selection of an appropriate method to express the uncertainty [1]. Here fuzzy set provide a mathematical way to represent inaccuracy and vagueness in humanistic system. There are many papers published in the literature that present algorithms for distribution planning implementing DG. Several approaches to solve the DG placement in distribution system have been proposed in references [2, 3] DG placement problems are analyzed to improve the reliability, voltage profile, reduced power loss with considering different demand on load point. In reference [4] the proposed index regards the impact of a distributed generation operation strategy on generation cost and reliability of the network. Ref. [5] Bacteria Foraging Algorithm (BFA) and Binary Genetic Algorithm (BGA) are used to investigate the DG placement with the purpose of power loss and voltage deviation reduction. Reference [6] was studied the effect of DG penetration in network on power loss reduction at different loads.

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The aim in this paper is to improve the voltage profile, reduced loss and to minimize the change in voltage, in this way operation and investment cost can also reduce also maximum potential benefit can be achieved.

II.PROBLEM FORMULATION

The ultimate aim of this paper is to reduce the power loss and to improve voltage profile with the optimal placement of DG. In other words DG should be located at that bus which leads to maximize reduction in system losses and improve the voltage profile also to reduce the change in voltage. Hence the problem of placement of DG is directly related with determining of system losses and voltage profile at each bus. To achieve this, first step is to carry out load flow analysis. For this backward-forward sweep method has been used to carry out base power flow analysis. The backward forward sweep method is a competent method and it is used for solving load flow equations due to its solution accuracies. This method can be applied for both mesh and radial distribution systems. In backward sweep Kirchhoff's current law is used to find the current in each branch by assuming the value of voltages and in the forward sweep, the voltage at each bus is updated by complex component of calculated bus voltage [6].

Calculation of load current at different buses:-

The load currents drawn at different buses are given by:

$$Id_i = \left(\frac{S_i}{V_i}\right)^* \quad (1)$$

Where i = 1, 2, 3…..n

n= number of buses

Id_i = current drawn at ith bus

S_i= complex power drawn at ith bus

V_i= complex voltage at ith bus

In the backward sweep section current of the system can be determined as:

$$I_i = Id_{i+1} + (V_{i+1} - V_{i+2}) y_{i+1,i+2} \quad (2)$$

Where,

i = 1, 2, 3…..n-1

I_n=Id_{n+1}

I_i= current in ith section

I_n= current in nth section

In forward sweep bus voltage of the system can be determined as:

$$V_i = V_{i-1} - I_{i-1}/\ y_{i-1,i} \quad (3)$$

Where

, i = 2………n

$y_{n-1,i}$ = admittance of i-1th section.

Power loss in various sections can be determined as:

$$P_i = I_i^2 r_{i,i+1} \quad (4)$$

$$P_{system} = \sum_{i=1}^{n-1} P_i \quad (5)$$

Where,

P_i = power loss in ith section

P_{system} = power loss in whole system

$r_{i,i+1}$= resistance of ith section.

III.FUZZY COMPOSITION

Fuzzy relation in different product space can be combined with each other by the operation called "Composition". There are many composition methods in use, e.g. max-product method, max-average method and max-min method. But max-min and max-product composition method is best known in fuzzy logic applications. In this proposed methodology two common forms of composition are used: one is called the max-min composition and other the max-product composition.

A. *Max-min composition*

Suppose R is a fuzzy relation on the Cartesian space X×Y,

S is a fuzzy relation on Y×Z, Q is a fuzzy relation on Z×X and T is fuzzy relation on X×Y×Z , then fuzzy max-min composition is define in terms of the set-theoretic notation and membership function theoretic- notation.

T = R•S•Q

$$\mu_{\underset{\sim}{T}}(X,U) = [\ \mu_{\underset{\sim}{R}}(X,U) \wedge \mu_{\underset{\sim}{S}}(X,U) \wedge \mu_{\underset{\sim}{Q}}(X,U)] \quad (6)$$

B. *Max-product composition*

Fuzzy max-product composition is defined in terms of the membership function-theoretic notation as:

$$\mu_{\underset{\sim}{T}}(X,U) = [\ \mu_{\underset{\sim}{R}}(X,U).\ \mu_{\underset{\sim}{S}}(X,U).\ \mu_{\underset{\sim}{Q}}(X,U)] \quad (7)$$

IV.TEST AND RESULTS

The Fig. 3 shows an 11 bus system in which 0.5 MW load is uniformly distributed along the length of the line. DG of 5.5 MW is used for this problem analysis. The input data of bus loadings and line parameters corresponding to 11 bus distribution system has been given in reference [7].

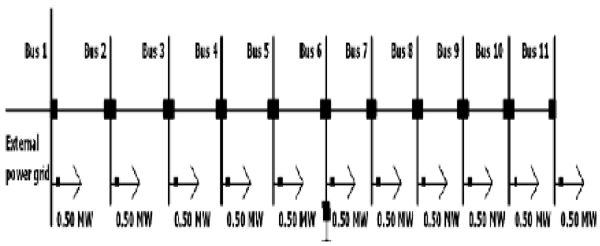

Fig.3 -11 bus distribution system [7]

Table I shows the load flow analysis. These results are obtained with the help of Backward-Forward sweep method, further max-min and max-product composition is applied to this analysis for the optimal placement of DG.

TABLE I.

Series no.	DG placement	System power loss(KW)	Minimum voltage(KV)	Vmax-Vmin(KV)
1	Without DG	33.6552	12.3804	0.1196
2	DG at bus no.1	33.6552	12.3804	0.1196
3	DG at bus no.2	24.9134	12.4042	0.0957
4	DG at bus no.3	18.1321	12.4282	0.0717
5	DG at bus no.4	13.2987	12.422	0.0779
6	DG at bus no.5	10.3979	12.4759	0.024
7	DG at bus no.6	9.4116	12.4996	0.0004
8	DG at bus no.7	10.3196	12.5	0.0021
9	DG at bus no.8	13.0992	12.5	0.0021
10	DG at bus no.9	17.7260	12.5	0.0021
11	DG at bus no.10	24.1733	12.5	0.0020
12	DG at bus no.11	32.4130	12.5	0.0019

Table 2 shows the results of max-min and max-product composition. It is clear from the table 2, that the optimal placement for installation of DG is bus number 6. At bus number 6 the power loss is minimum, voltage profile is good. The change in voltage is also minimum at this bus. Results of bus 6 are given in table 3 and Fig. 4, 5, and 6 shows the graphical representation of the results

TABLE II.

Bus no.	Max-product composition	Max-min composition)
1	0	0
2	0.0144	0.1955
3	0.1005	0.392
4	0.1148	0.3418
5	0.6014	0.7847
6	0.9756	0.979
7	0.9625	0.9454
8	0.0846	0.8313
9	0.6558	0.6443
10	0.3904	0.3838
11	0.0511	0.00013

TABLE III.

Optimal bus no.	Total Power loss(KW)		Minimum voltage(KV)	Change in voltage(KV)
	Without DG	With DG		
6	33.6552	9.4116	12.4996	0.0004

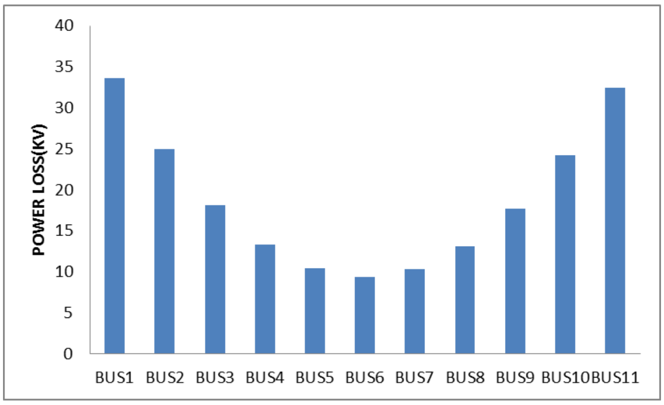

Fig 4 Power losses with DG at each buss

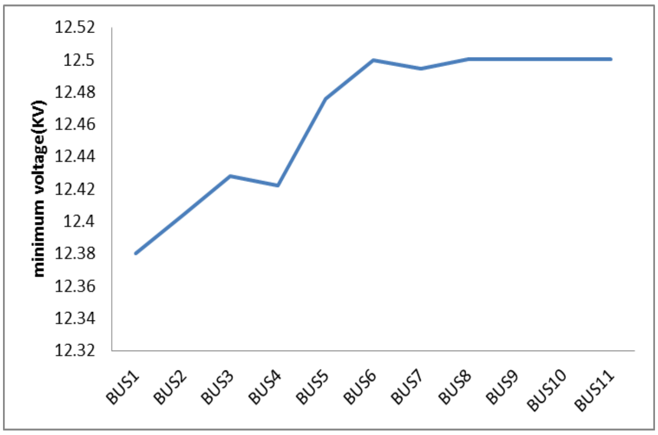

Fig 5Voltage profile at each bus with DG

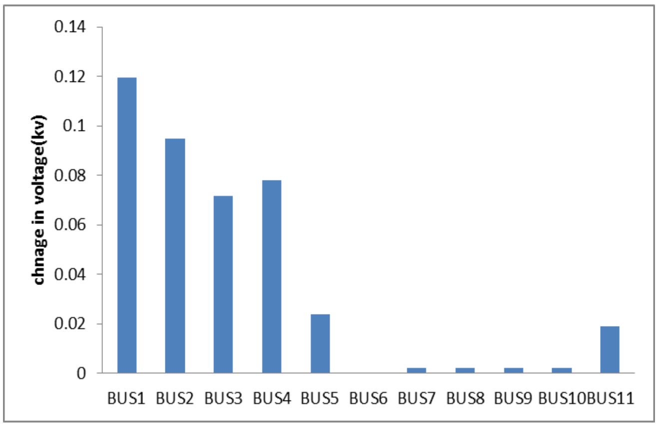

Fig 6 Change in voltage at each bus with DG

The Fig. 7 shows the IEEE 33 bus system, this type of system is usually called a lateral type distribution system. The parameters of the Fig. 7 are given in the refrence [11].

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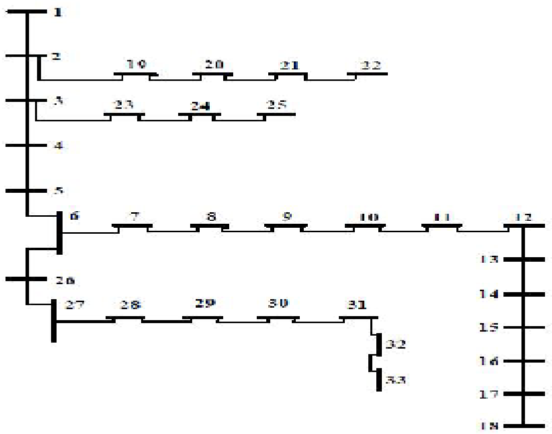

Fig.7 33 bus system [11]

Table 4 shows the load flow analysis of 33 bus system, which is carried out by backward-forward sweep method.

TABLE IV.

Series no.	DG Placemeno.	System Power loss (p.u.)	Vmin (p.u.)	Vmax-Vmin(p.u.)
1	Without DG	0.1264	.91564	0.0846
2	bus 1	0.1264	.9154	0.0846
3	bus 2	0.1174	.9177	0.0823
4	bus 3	0.0828	.9298	0.0702
5	bus 4	0.0747	.9387	0.0613
6	bus 5	0.0688	.9478	0.0522
7	bus 6	0.0595	.9669	0.0330
8	bus 7	0.0651	.9701	0.0299
9	bus 8	0.0914	.9693	0.0307
10	bus 9	0.1360	.9684	0.0316
11	bus 10	0.1808	.9674	0.0326
12	bus 11	0.1894	.9673	0.0325
13	bus 12	0.2061	.9670	0.0322
14	bus 13	0.2708	.9655	0.0345
15	bus 14	0.2942	.9643	0.0352
16	bus 15	0.3214	.9641	0.0359
17	bus 16	0.3556	.9634	0.0366
18	bus 17	0.4127	.9615	0.0385
19	bus 18	0.447	.9608	0.0392
20	bus 19	0.1283	.9176	0.0824
21	bus 20	0.2243	.9182	0.0818
22	bus 21	0.2500	.9175	0.0825
23	bus 22	0.2952	.9175	0.0825
24	bus 23	0.0999	.9297	0.0703
25	bus 24	0.1360	.9295	0.0705
26	bus 25	0.1853	.9292	0.0708
27	bus 26	0.0672	.9668	0.0332
28	bus 27	0.0784	.9666	0.0334
29	bus 28	0.1186	.9656	0.0344
30	bus 29	0.1492	.9649	0.0351
31	bus 30	0.1701	.9644	0.0366
32	bus 31	0.2171	.9632	0.0368
33	bus 32	0.2330	.9628	0.0372
34	bus 33	0.2526	.9621	0.0379

TABLE V.

Bus number	Max-min	Max-product
1	0	0
2	.0425	.0015
3	.2632	.0659
4	.4314	.1765
5	.5923	.3468
6	.9414	.8978
7	.9855	.9855
8	.9176	.9023
9	.8025	.7630
10	.6869	.6287
11	.6647	.6084
12	.6216	.5689
13	.4547	.3913
14	.3943	.3224
15	.3241	.2441
16	.2358	.1836
17	.0885	.0636
18	0	0
19	.0402	.00136
20	.0511	.0015
21	.0383	.0007
22	.0383	.0005
23	.2614	.0619
24	.2577	.0539
25	.2522	.0435
26	.9396	.8765
27	.9360	.8441
28	.8474	.7229
29	.7685	.6374
30	.714	.5685
31	.5932	.4587
32	.5522	.419
33	.5016	.3703

Table 5 shows the results of max-min and max-product compositions. It is clear from the table 5 that the optimal place for installation of DG is bus number 7. System power loss and voltage profile of bus number 7 is given in the table 6. The graphical representation of these results are shown in fig. 8,9 and10.

TABLE VI.

Optimal bus no.	Total Power loss(p.u.)		Minimum voltage(p.u.)	Change in voltage(p.u.)
	Without DG	With DG		
7	0.1294	0.0595	0.9669	0.0330

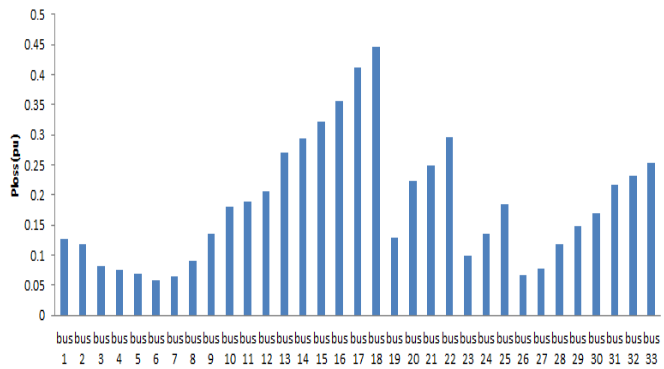

Fig. 8 system power loss at each bus with DG

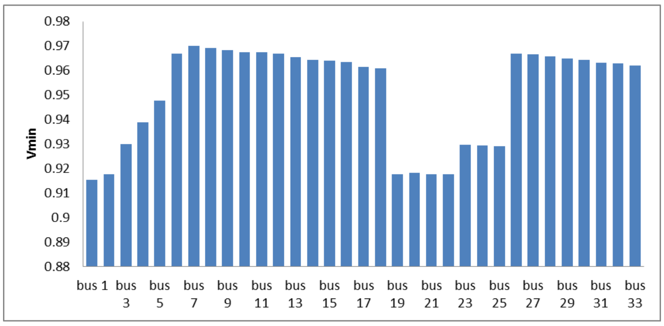

Fig. 9 voltage profile at each bus with DG

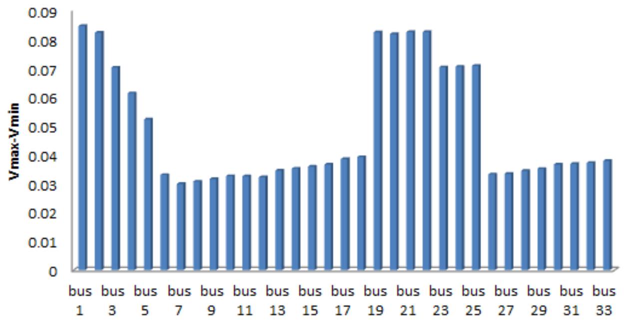

Fig. 10 change in voltage at each bus with DG

CONCLUSION

In this paper, an effective methodology for the optimal location for placement of DG in radial distribution system has been presented. In the presented methodology, the optimal location of DG has been decided based on the criterion of fuzzy composition. The backward-forward sweep method has been used to solve the load flow analysis. The numerical example confirms the validity of the proposed method. The proposed methodology for finding optimal location of DG has been implemented and tested on 11 bus system and 33 bus system. It conclude that in 11 bus system with uniform distribution of load, the system power loss before adding DG was 33.6552 kW, which has been reduced to 9.4116 kW and voltage profile increase to 12.4759 KV after adding DG at optimal location. In 33 bus system system power loss before adding DG was 0.1264 (p.u.), which have been reduced to 0.0595 (p.u.) and voltage profile increase to 0.9669 (p.u.) after the addition of DG at optimal place.

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