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Optimal Placement of the DG in Radial Distribution System to Improve the Voltage Profile

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Abstract: ***One of the modern and important techniques in the electrical distribution systems is to solve the networks problems service availability, high loss and to improve system voltage these can be resolved by accommodating small scaled de-centralized generating stations in networks, which is known as Distributed Generation (DG). DG is an approach that employs small scale technologies to produce electricity close to the end users of power requirement. DG is placed optimally in the system in order to improve system voltage profile, improve service availability, power quality, reliability and reduce loss. The problem of voltage deviation and power loss is mostly addressed in distribution system by growing commercial, Industrial, domestic load day by day. Effective distribution system planning may be required to minimize these problems. By optimal DG placement effective and reliable planning of distribution system is achieved. Optimal DG placement is to determine the location of DG to be installed in the distribution network buses where power losses should be minimum and cost saving should be maximum. SAVI was evaluated before and after placement of DG, to know the number of customer affected due to voltage deviations.***

Keywords: Distribution Generation, ABC Algorithm, BIBC and BCBV Matrix Method, Reliability, SAVI, IEEE 33 Bus Test System

1. Introduction

Major part of research in distribution system was made on power loss, voltage profile improvement by conducting load flow analysis. Placement of DG was being suggested to improve system performance and to meet the excess load. In this paper an attempt was made in addition to the load flow studies and placement of DG in optimal location, the number of customer affected due to voltage deviation are evaluated with an reliability index called SAVI before and after DG placement. With improvement of this index we can efficiently say that, with DG placement reliability of system was improved [1].

2. Load Flow Studies

Load Flow Studies (LFS) are needed to be conducted to evaluate the voltage at each bus, branch currents, system losses and to verify weather the conductors and transformers are overloaded or not. As the distribution system has a topological characteristic like high R/X and unbalanced loads, the frequently used LFS methodologies are not applicable such methods are GS, NR and decouple methods. So in order to overcome all these difficulties and efficient and powerful method which suits for radial structure are developed. This type of methodologies requires new data format and some data manipulations are needed to be performed [2].

The methods which suits for radial distribution system LFS are
1) Power Summation Method
2) Single Line Equivalent Method
3) Very Fast Decouple Method
4) BIBC and BCBV Matrix Method
5) Forward and Backward Method.

In this respective research the BIBC and BCBV matrix method was adopted, due to its easy implementation and fast convergence characteristics and better performance. In this method two matrices Bus injection to branch currents (BIBC) and Branch Current to Bus Voltage (BCBV) are needed to be developed.

The step by step methodology for conducting BIBC and BCBV matrix method was discussed in [3].

2.1. Algorithm for BIBC and BCBV Matrix Method

Step-1: Read the line and load data of System.
Step-2: BIBC Matrix can be formulated using above steps. The relationship can be expressed as

$$[B]=[BIBC][B]$$

Step-3: BCBV Matrix can be formulated using above steps. The relationship can be expressed as

$$[\Delta V]= [BCBV][B]$$

Step-4: Form the DLF matrix

$$[DLF]=[BIBC][BCBV]$$
$$[\Delta V] = [DLF]\,[I]$$

Step-5: Set iteration k=0
Step-6: Iteration k=k+1
Step-7: Update the voltages by using, $[\Delta V] = [DLF]\,[I]$
Step-8: If V>Tolerance go to step-6.
Step-9: Calculates final voltage at each bus.
Step-10: Print bus voltages.

2.2. Total Real and Reactive Power Loss of the system

Real and reactive power loss in the system was calculated by using,

$$[\text{Realpowerloss}] = \sum_{i=1}^{n} I_i^2 Ri \quad (1)$$

$$[\text{Reactivepowerloss}] = \sum_{i=1}^{n} I_i^2 Xi \quad (2)$$

With this efficient power flow technique the system losses, voltage at each bus are evaluated. To reduce the losses in the system a DG was needed to be placed.

3. Distributed Generation

According to Ministry of Power DG is defined as modular generation or storage technique located near point of use. DG may be renewable or non renewable type, most probably renewable type DG is adoptable in distribution system because of its eco-friendly operation. With placement of DG availability of supply to the customers can be increased with improved voltage profile. So that power quality of system can be achieved [4].

DG was also be classified based on its sizes that is Micro DG (1kw-5kW), Small DG (5kW-5MW), Medium DG (5MW-50MW), Large DG (50MW-300MW). Normally in radial distribution system micro and small DG's are employed. Indefinite size of DG in radial system will increase the electrical losses. So size of DG was to be selected accordingly [5]-[7]. DG placement was the other parameter to be discussed. There are several approaches to place DG in RDS. Which are classified as,
1) Analytical Method
2) Numerical Method
3) Heuristic Method.

All this methods provides an Optimal DG Placement (ODGP), in which analytical method was based on exact formulae. Numerical methods are in efficient and time consuming techniques. Heuristic methods are swarm intelligence technique, that deals with natural and artificial systems composed of many individuals that coordinate using decentralized control and self-organization system.

Heuristic Methods are,
1) Ant Colony Optimization
2) Artificial Bee Colony
3) Particle Swarm Optimization
4) Fire Fly [1]
In this paper Artificial Bee Colony was adopted because of its fast convergence characteristics and both exploration and exploitation can be done in single stage.

3. Artificial Bee Colony Algorithm

The algorithm was developed by Karaboga in 2005. ABC is one of the newest and most promising nature-inspired metaheuristic algorithm [8]-[11].

ABC Algorithm for DG Placement:

Step-1: Initialize the food-source positions X_i (solutions population), The X_i form is as follows.

$$x_{i,j} = x_{min,j} + \text{rand}(0,1)(x_{max,j} - x_{min,j}) \quad (3)$$

Step-2: Calculate the nectar amount of the population by means of their fitness values using

$$\text{Fitness} = \frac{1}{1 + [\text{TotalLosses}]} \quad (4)$$

Total Losses=Real Power Losses + Reactive Power Loss

Step-3: Produce neighbor solutions for the employed bees by using below equation and evaluate them as indicated by Step 2.

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}) \quad (5)$$

Step-4: Apply the greedy selection process between X_{ij} and V_{ij}.

Step-5: If all onlooker bees are distributed, go to Step 9. Otherwise, go to the next step2.

Step-6: Calculate the probability values $P(X_{ij})$ for the solutions X_{ij} using equation,

$$P(X_{ij}) = \frac{F(X_i)}{\sum_{I=1}^{n} F(X_i)} \quad (6)$$

Step-7: Produce the new solutions (new positions) V_i for the onlookers from the solutions xi, selected depending on P_i, and evaluate them

Step-8: Follow Step 4 i.e; apply the greedy selection process between X_{ij} and V_{ij}.

Step-9: Determine the abandoned solution for the scout bees, if it exists, and replace it with a completely new solution using below equation and evaluate them as indicated in Step 2.

$$X_{ij}^{new} = \min(X_{ij}) + \text{rand}(0,1)[\max(X_{ij}) - \min(X_{ij})] \quad (7)$$

Step-10: Memorize the best solution attained so far.

Step-11: If cycle = MCN, stop and print result. Otherwise follow Step 3.

4. Reliability Index

System Average Voltage Index (SAVI), this was a new formulated index which was used to calculate the customers effected due to deviation in voltage.

The acceptable voltage level deviation in PU is ±0.5%, i.e., 1.05PU to 0.95PU. The number of customers affected due to voltage variations are calculated with this indices. The SAVI is defined as,

$$\text{SAVI} = \frac{\text{Total Customer Voltage Sags Below X(PU)}}{\text{Total Number of Customers Served}} \quad (8)$$

Without placement of DG this index was evaluated to know the effected customers, and with DG placement by reevaluating the same index shows the decrement in the customers affected. So by evaluating the index with and without DG the no. of customers how are effected with this voltage deviation can be know.

5. Test System

IEEE 33 bus test system was taken for validating the results and to evaluate the performance of load flow studies and ABC Algorithm. Base MVA=100, Conductor type = All Aluminum Alloy Conductor (AAAC), Base Voltage = 11KV, Resistance = 0.55ohm/KM, Reactance = 0.351ohm/KM. The 33 bus system has 32 sections with the total load 3.72 MW and 2.3 MVAR shown in Figure 1. Table 1 and 2 indicates the line and load data of IEEE 33 bus test system. The single line diagram of IEEE 33 bus system was represented in Figure 1.

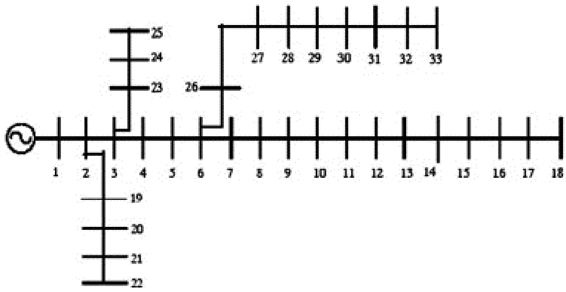


Figure 1: IEEE 33 bus Test System

Table 1: Line Data of IEEE 33 Bus Test System

Bus No.	*Sending End node*	*Receiving End node*	*Resistance R (ohm)*	*Reactance X (ohm)*
1	1	2	0.0922	0.0470
2	2	3	0.4930	0.2511
3	3	4	0.3660	0.1864
4	4	5	0.3811	0.1941
5	5	6	0.8190	0.7070
6	6	7	0.1872	0.6188
7	7	8	1.7114	1.2351
8	8	9	1.0300	0.7400
9	9	10	1.0440	0.7400
10	10	11	0.1966	0.0650
11	11	12	0.3744	0.1238
12	12	13	1.4680	1.1550
13	13	14	0.5416	0.7129
14	14	15	0.5910	0.5260
15	15	16	0.7463	0.5450
16	16	17	1.2890	1.7210
17	17	18	0.7320	0.5740
18	2	19	0.1640	0.1565
19	19	20	1.5042	1.3554
20	20	21	0.4095	0.4784
21	21	22	0.7089	0.9373
22	3	23	0.4512	0.3083
23	23	24	0.8980	0.7091
24	24	25	0.8960	0.7011
25	6	26	0.2030	0.1034
26	26	27	0.2842	0.1447
27	27	28	1.0590	0.9337
28	28	29	0.8042	0.7006
29	29	30	0.5075	0.2585
30	30	31	0.9744	0.9630
31	31	32	0.3105	0.3619
32	32	33	0.3410	0.5302

Table 2: Load Data and no. of customers for IEEE 33 Bus Test System

Bus No.	Real load (kW)	Reactive load (kVAR)	No.of Customers
1	100	60	210
2	90	40	210
3	120	80	210
4	60	30	1
5	60	20	1
6	200	100	10
7	200	100	10
8	60	20	1
9	60	20	1
10	45	30	210
11	60	35	210
12	60	35	200
13	120	80	1
14	60	10	1
15	60	20	10
16	60	20	10
17	90	40	200
18	90	40	200
19	90	40	200
20	90	40	1
21	90	40	1
22	90	50	10
23	420	200	1
24	420	200	1
25	60	25	1
26	60	25	1
27	60	20	1
28	120	70	1
29	200	600	1
30	150	70	1
31	210	100	20
32	60	40	20

6. Computation of Proposed Methodologies

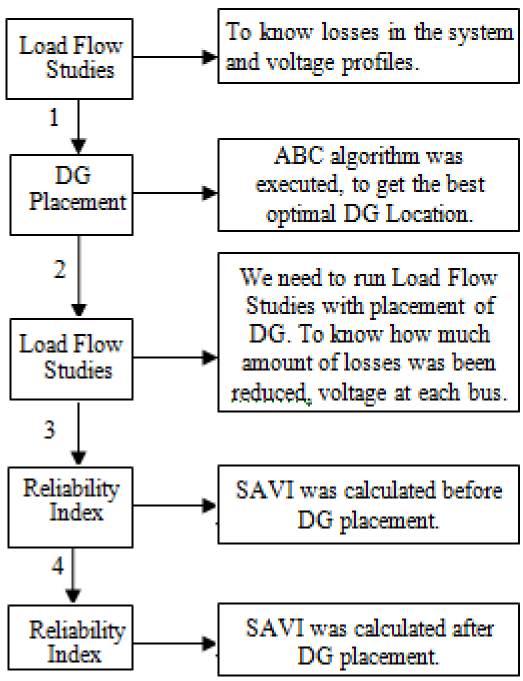


Figure 2: Step by Step Methodology

7. Results and Discussion

Load Flow Studies i.e., BIBC and BCBV Matrix method was conducted on IEEE 33 bus test system. The losses due to active component of current are 0.204MW and reactive component of current is 0.136MW as shown in Table 3.

Table 3: Load Flow Studies

Parameter	BIBC and BCBV Matrix Method
Total MW Loss	0.2044
Total MVAR Loss	0.1369
Total Loss	0.3412
V_{min}(p.u)	0.9055
V_{max}(p.u)	1.0000

To reduce the losses in the system and improve the voltage profile a DG is need to be placed. ABC Algorithm was used here for optimal placement of DG. Here a program is written for single DG Placement in MATLAB.

The constrains for ABC Algorithm was defined as

1) Swarm size=200
2) Employed bees=100
3) Onlookers=100
4) Scouts=10
5) Limit =5
6) Dimension=1

For the first iteration the maximum saving is occurring at bus 6. The location for DG is bus 6 with a loss of 0.104 MW. The optimum size of DG at bus 6 is 2.59MW.

The Table 4 gives the details about the total active, reactive power loss, Line Loss of IEEE 33 bus system with variation of DG size from for 2MW to 5MW at bus No.6.

Table 4: Total System Losses With and Without DG

Parameter	**Without DG**	**2 MW**	**2.59 MW**	**3 MW**	**4 MW**	**5 MW**
Real power Loss(MW)	0.204	0.066	0..61	0.067	0.108	0.188
Reactive power loss (MVAR)	0.136	0.052	0.050	0.054	0.083	0.136
Line losses (MW)	0.360	0.146	0.104	0.152	0.226	0.361

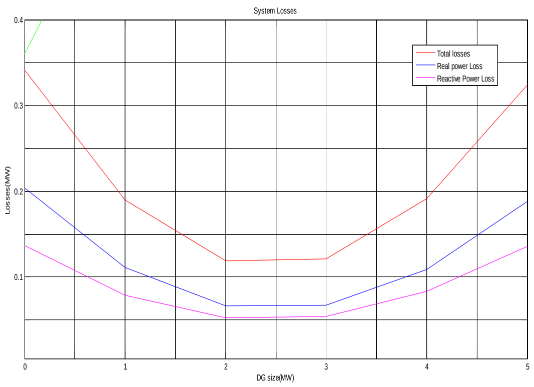


Figure 3: Real and Reactive Power loss

The Voltage Profiles of IEEE 33 bus Test System with and without DG was shown in Table 5.

Table 5: Voltage Profile of Test System

Bus No	*Voltage Profiles*			
	Without DG	*2 MW*	*2.59MW*	*3 MW*
1	1.0000	1.0000	1.0000	1.0000
2	0.9971	0.9983	0.9987	0.9989
3	0.9834	0.9912	0.9934	0.9948
4	0.9763	0.9888	0.9924	0.9949
5	0.9690	0.9866	0.9916	0.9929
6	0.9508	0.9794	0.9874	0.9900
7	0.9477	0.9763	0.9844	0.9786
8	0.9358	0.9648	0.9730	0.9723
9	0.9291	0.9586	0.9667	0.9664
10	0.9230	0.9524	0.9607	0.9655
11	0.9220	0.9515	0.9598	0.9640
12	0.9205	0.9500	0.9583	0.9578
13	0.9139	0.9437	0.9521	0.9559
14	0.9120	0.9418	0.9502	0.9543
15	0.9103	0.9402	0.9486	0.9528
16	0.9087	0.9386	0.9470	0.9504
17	0.9062	0.9362	0.9446	0.9498
18	0.9055	0.9356	0.9440	0.9984
19	0.9966	0.9978	0.9981	0.9957
20	0.9929	0.9941	0.9945	0.9947
21	0.9922	0.9934	0.9938	0.9940
22	0.9915	0.9927	0.9931	0.9933
23	0.9800	0.9878	0.9900	0.9915
24	0.9762	0.9840	0.9862	0.9877
25	0.9758	0.9836	0.9858	0.9873
26	0.9490	0.9776	0.9857	0.9912
27	0.9466	0.9753	0.9834	0.9889
28	0.9358	0.9648	0.9730	0.9786
29	0.9286	0.9579	0.9661	0.9717
30	0.9268	0.9561	0.9644	0.9700
31	0.9241	0.9535	0.9618	0.9674
32	0.9239	0.9533	0.9616	0.9672
33	0.9239	0.9533	0.9616	0.9672

System Average Voltage Index

Total number of customers = 1956.

Table 6 represents the voltage levels below 0.95PU without DG and With DG. The number of customers affected and its corresponding bus number was shown in Table 7.

Table 6: Voltage Deviations below 0.95PU

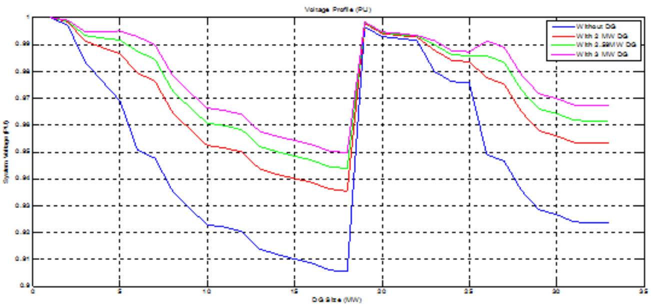
Bus No	Voltage Profiles			
	Without DG	2 MW	2.59MW	3 MW
7	0.9477	---	---	---
8	0.9358	---	---	---
9	0.9291	---	---	---
10	0.9230	---	---	---
11	0.9220	---	---	---
12	0.9205	---	---	---
13	0.9139	0.9437	---	---
14	0.9120	0.9418	---	---
15	0.9103	0.9402	0.9486	---
16	0.9087	0.9386	0.9470	---
17	0.9062	0.9362	0.9446	0.9498
18	0.9055	0.9356	0.9440	---
26	0.9490	---	---	---
27	0.9466	---	---	---
28	0.9358	---	---	---
29	0.9286	---	---	---
30	0.9268	---	---	---
31	0.9241	---	---	---
32	0.9239	---	---	---
33	0.9239	---	---	---

Table 7: Bus Number affected and its corresponding customers

Constrains	Bus Number affected	Total No. of Customers affected
Without DG	7-18, 26-33	1099
2 MW DG	13-18	422
2.59MW DG	15-18	420
3 MW DG	17	200

Table 8: SAVI Without DG and With DG size Variation

Constrains	SAVI
Without DG	0.561861
2 MW DG	0.215746
2.59MW DG	0.214724
3 MW DG	0.102249



Without DG the number of customers affected was 1099. Therefore by placing DG in optimal location i.e. bus no. 6, from ABC algorithm and reconducting the load flow studies with DG size 2MW, 2.59 MW, 3MW, the customers affected from voltage deviation are reduced to 422, 420, and 200. Therefore SAVI values are shown in Table 8.

8. Conclusion

Here a new reliability index called System Average Voltage Index was computed to know the number customers affected due to voltage deviations. Before DG placement the customers affected was high, and with DG placement at bus no. 6, from ABC algorithm the customers affected from voltage deviations are reduced. Therefore SAVI was improved with DG placement optimally.

References

[1] PS.Georgilakis and ND.Hatziargyriou, "Optimal DG Placement in power Distribution Network: Models, Methods and Future Research", IEEE Transactions on Power Systems, Vol. 25, No.3, pp. 3420-3428, August, 2013.

[2] A.G.Bhutad, S.V.Kulkarni, and S.A.Khaparde, "Three-phase Load Flow Methods for Radial Distribution Networks", IEEE Transactions on Power Systems,Vol. 18, No. 1, pp. 781-785, August, 2012.

[3] A.Alsaadi, and B.Gholami, "An Effective Approach for Distribution System Power Flow Solution", World Academy of Science Engineering and Technology, Vol. 3, pp. 177-181, January, 2009.

[4] A.Lakshmi Devi and A.Chaithanya, "A New Analytical Method for the Sizing and Siting of DG in Radial System to Minimize Real Power Losses", International Journal Of Computational Engineering Research, Vol. 2, No. 7, pp. 31-37, November 2012.

[5] Sarang Pande and Prof. Dr. J.G. Ghodekar, 'Computation of Technical Power Loss of Feeders and Transformers in Distribution System using Load Factor and Load Loss Factor", International Journal Of Multidisciplinary Sciences And Engineering, Vol. 3, No. 6, pp. 23-25, June 2012.

[6] Thomas Ackermann, Goran Andersson b, and Lennart Soder "Distributed generation: a definition", Electric Power Systems Research, pp. 195–204, December, 2000.

[7] A.A.Bayod Rujula, J.Mur Amada, and J.L.Bernal-Agustin, J.M.Yusta Loyo, "Definitions for Distributed Generation: a revision", Electric Power Systems Research, pp. 550–555, December, 2001.

[8] Soo Hyoung Lee and Jung-Wook Park, "Optimal Placement and Sizing of Multiple DGs in a Practical Distribution System by Considering Power Loss", IEEE Transactions On Industry Applications, VOL. 49, NO. 5, pp. 2262-2270, September/October, 2013.

[9] Benjamin Kroposki and Pankaj K. Sen, "Optimum Sizing and Placement of Distributed and Renewable Energy Sources in Electric Power Distribution Systems", Ieee Transactions On Industry Applications, Vol.49, No.6, pp. 2741-2752, November/December 2013.

[10] K. Siva Ramudu, M. Padma Lalitha, P. Suresh Babu, "Siting and Sizing of DG for Loss Reduction and Voltage Sag Mitigation in RDS Using ABC Algorithm", International Journal of Electrical and Computer Engineering (IJECE), Vol. 3, No. 6, pp. 814-822, December 2013.

[11] R. Srinivasa Rao, K. Ravindra, K. Satish, and S. V. L. Narasimham, "Power Loss Minimization in Distribution System Using Network Reconfiguration in the Presence

of Distributed Generation", IEEE Transactions On Power Systems, Vol. 28, No. 1, February 2013.
[12] Mahmud Fotuhi-Firuzabad, and Abbas Rajabi-Ghahnavie "An Analytical Method to Consider DG Impacts on Distribution System Reliability", IEEE/PES Transmission and Distribution Conference & Exhibition Asia and Pacific Dalian, pp. 1-6, China, February, 2005.

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