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Optimal Distributed Generation Allocation and Sizing in Distribution Systems

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ABSTRACT: Several potential benefits of integrating renewable energy based distributed generation (DG) units to conventional distribution systems have been seen. The power input from renewable DG units placed close to the load centres provide an opportunity for system voltage support, reduction in energy losses and emissions, and reliability improvement. Therefore, the allocation of DG units and their optimal sizing is an important concern. This paper presents a simple approach for real power loss reduction, voltage profile improvement, substation capacity release and is based on voltage sensitivity index analysis. Load flow analysis is done using the forward-backward sweep method. Study carried out on an IEEE-33 bus test system validates the suitability of this proposed method.

KEYWORDS: Distributed Generation, Optimal DG location. Optimal DG size, real power loss reduction, voltage stability index

I.INTRODUCTION

Distribution systems are employed with radial structure in order to obtain operational simplicity. An interconnected transmission network is a means through which primary distribution substation receives power from generating stations. Radial Distribution System (RDS) network is passive in nature and transfers power to consumers from the substation. Thus, in RDS the power flow is unidirectional. Due to high R/X ratio in case of distribution lines, high voltage drops, large power loss will occur. Everyday distribution networks are experiencing many changes in the load. In many instances, the nodes of RDS experience a sudden collapse in the voltage during critical load conditions because of low voltage stability index. In this paper, for RDS a voltage stability index (VSI) is proposed for all the nodes. It is observed that node with minimum VSI value is more sensitive and leads to collapse in voltage.[8]

During past years, several techniques were implemented by placing dispersed sources injecting reactive power like capacitor banks in order to obtain improvement in voltage and to reduction in power losses.[9] Even through the implementation of capacitor placing method which is promising in nature, the voltage profile improvement obtained is below desired voltage level (1.0 p.u.). As RDS is passive in nature, it is less reliable.

Many solutions are suggested recently by incorporating electrical sources based on renewable energy technology to overcome the passiveness of RDS and also to improve reliability of the system and voltage profile. These embedded generations in RDS are called as Distributed or Dispersed Generation (DG).

Originally power systems are designed based on power flow in single direction, but the DG concept has led to new considerations concerning the distribution networks. The penetration of DG impacts the distribution system operation in a beneficial way or it may increase line losses which is a negative effect. Positive aspects of DG are**:** provides Voltage Support, reduces Power Loss, and the negative aspects of DG are Dynamic Stability and Protection Coordination. So, for adopting the DG into distribution network, care should be taken for technical constraints and penetration levels, in such a way that the benefits should be maximised.

Dispersed generation is a power source directly connected to customer site or to distribution network. It consists of two aspects:

1. DG located on customer side or directly to distribution system
2. Demand-side resources, such as load management systems and energy efficiency options.

Interesting aspect of DG resources is, it acts as a means for customer demand and also generate the power on the customer side. Now-a-days distributed capacity includes all impacts of DG and distributed resources and reserve capacity for minimizing requirements for over dimensioning of distribution/ transmission system.

Many approaches are proposed for placing and sizing of Dispersed Generators. In this paper, an easy technique for reducing the real power loss, improving the voltage profile is presented. Power flow analysis is done by using forward-backward sweep technique. In RDS, the optimal locations for placing the DG units are identified by VSI technique. The optimal sizing of the DG units is computed by using analytical algorithm.

Lot of study is carried out in this area. Dugan, R.C. and McDermott, T.E. [1] defined the DG system as follows. Dispersed Generators that are inter-connected to utility distribution systems will be smaller than 10MW. Generally larger units are directly connected to transmission facilities. The DG units installed in general will not be more than 1 or 2 MW and they are majorly installed by utility. This technique of generating power is called as "Dispersed Generation (DG)".

The main use of a load flow analysis is to get network operational conditions like phasor voltages of every bus, reactive and real power flows by considering known network topology. Several efficient algorithms have been developed for solving power flow problem of a transmission network.However, these algorithms may not maintain their efficiency and reliability when applied to a low voltage distribution network. Augusto Cesar dos Santos and Marcelo Nanni presented Forward and Backward Sweep (FBS) methods for the power flow analysis because of its ease of implementation and robustness. They consider unique feature distribution network (radial structure) [2]. Using them, load flow solution can be attained without solving the equations.

Because of increase in load demand the distribution system is facing problems. They are experiencing many changes from a low level to high level of load. M. Chakravorty, D.Das [3] proposed a voltage stability index technique for radial distribution systems. Voltage stability index represents a numerical solution to identify the sensitive node of the system. It also helps to check the system to prevent from voltage collapse by initiating automatic remedial actions. Main aim of VSI is to find the distance between the current working point and stable point. Voltage collapse generally starts at most sensitive node in the system and then passes to all other nodes which are sensitive.

Kyu-Ho Kim, Yu-Jeong Lee [4] presented a Fuzzy-GA technique to solve DG placing for RDS. Its objective is to reduce the costs of power loss of RDS. Original objective function and constraints are transformed into the unconstrained multi-objective function using fuzzy logic.

An analytical method for calculating optimal size of DG and an efficient methodology for identifying optimum location for DG was proposed by Caisheng Wang [5] in order to reduce the losses. For three distributed networks the proposed technique is applied and tested with different sizes and complexities. Obtained results are compared with exhaustive power flow techniques.

Optimal Dispersed Generation unit placing by using fuzzy logic was discussed by A. Lakshmi Devi in paper [6]. The analytical method of finding optimal size of DG is computed. Node for placing DG is identified by using approximate reasoning technique. Power loss indices and voltages of RDS nodes are designed by using fuzzy membership function values and the DG is placed at the node with high suitability index.

II.LOAD FLOW ANALYSIS

Due to special features of distribution systems such as Radial structure, high ratio of R/X and wide-ranging reactance and resistance values. Newton Raphson (NR) and Gauss Seidel (GS) techniques may become ineffective. In particular, in standard fast-decoupled NR method, the assumptions that are used for the simplifications are not

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valid in RDS. This makes the transmission systems power flow computation different from distribution systems. Hence, for distribution networks, an efficient power flow algorithm is desired.

In order to carry out the unbalanced and balanced RDS analysis various methods are proposed. Basically they are divided into two types. The first type includes modification of traditional techniques such as GS and NR. Second type is based on forward and backward sweep process using Kirchhoff's laws. For distribution networks power flow analysis, backward and forward sweep based techniques gained more popularity because of its high computational efficiency, low memory requirements and strong convergence characteristic. In this, load flow study is carried by using backward and forward sweep method.

In this algorithm, bus-branch oriented data is the only input. Solving the power flow for RDS directly and developing the formulation that includes advantages of topological characteristics of the distribution networks are the main goals of this chapter. It means in the new method, forward/backward substitute of Jacobian matrix and time-consuming LU decomposition are not performed as in the traditional NR and GS methods. In this new method, to get the load flow solution, **BIBC**, bus-injection to branch-current matrix and simple matrix operations are performed. Compared to all conventional methods, this method is very efficient and robust. The results explain the validity and feasibility of the proposed method.

A. MATHEMATICAL MODEL FOR RADIAL DISTRIBUTION SYSTEMS

Assuming a three phase RDS is balanced and can be represented by a single line diagram. A simple radial distribution system with source at one end and loads at the different nodes is shown in the Fig. 1.

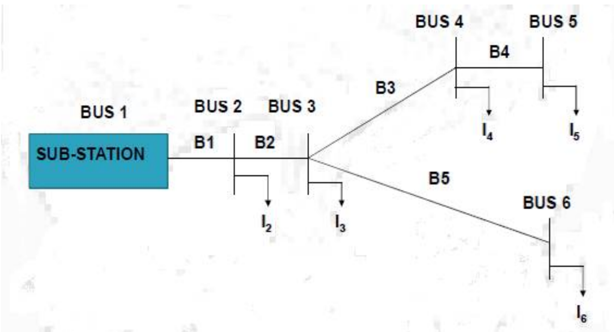

Fig. 1. Simple Distribution System

This method carries out the load flow analysis for Radial Distribution System under balanced operating condition employing constant power load model. This method has three important steps, listed below:

- Equivalent current injection
- Formulation of BIBC matrix
- Formulation of BCBV matrix

Equivalent current injection

This method based on the current injection. At bus i, the complex power Si is specified and the corresponding equivalent current injection at the k-th iteration of the solution is computed as

$$Si = (Pi + jQi) \qquad i=1, 2\text{----} N \tag{2.1}$$

$$I_i^k = I_i^r(V_i^k) + j(I_i^i)(V_i^k) = ((Pi + jQi)/ (V_i^k))^* \tag{2.2}$$

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Where,

Si is the complex power at i-th bus
Pi is the real power at i-th bus
Qi is the reactive power at i-th bus
V_i^k is the bus voltage at the k-th iteration for i-th bus
$I_i^{k\,is}$ equivalent current injection at the k-th iteration for i-th bus
I_i^r and I_i^i are the real and imaginary parts of the equivalent current injection at the k-th iteration for i-th bus

Formulation of BIBC matrix

The sample Radial Distribution System (RDS) shown in Fig. 1. will be used as an example. The power injections can be converted into the equivalent current injections using Equation (2.2). And a set of equations can be written by applying Kirchhoff's Current Law (KCL) to the distribution network. Then, the branch currents can be formulated as a function of the equivalent current injections. For example, the branch currents
*B*5, *B*3 and *B*1 can be expressed as,

$B5 = I_6$
$B3 = I_4+I_5$
$B1 = I_2+I_3 +I_4+I_5+ I_6$ (2.3)

Furthermore, the Bus-Injection to Branch-Current (***BIBC***) can be obtained as,

$$\begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_2 \\ I_3 \\ I_4 \\ I_5 \\ I_6 \end{bmatrix}$$

$$B = BIBC \quad I \qquad (2.3)$$

Observing eq. (2.3), an algorithm for BIBC matrix can be designed as:

1) For RDS with ***n***-buses and ***m***-branches, the dimension of BIBC matrix is ***m*** x ***(n-1)***.
2) If a branch (**B**$_k$) is located between ***i*** bus and ***j*** bus, copy the column of ***i***-th bus to the column of the ***j***-th bus and mark +1 in position of kth row and jth column.
3) Until all branch sections are included in the **BIBC** repeat step2.

The BCBV (Bus Current to Bus Voltage) matrix is responsible for the relations between the branch currents and bus voltages. The corresponding variation of the bus voltages, which is generated by the variation of the branch currents, can be found directly by using the BCBV

$V_2 = V_1 – B_1 Z_{12}$ (2.4)
$V_3 = V_2 – B_2 Z_{23}$ (2.5)
$V_4 = V_3 – B_3 Z_{34}$ (2.6)

By using Equation (2.4) and Equation (2.5), the voltage of Bus 4 can be rewritten as,

$V_4 = V_1 – B_1 Z_{12} – B_2 Z_{23} – B_3 Z_{34}$ (2.7)

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From Equation (2.7), it can be seen that the bus voltage can be expressed as a function of the branch currents, line parameters and substation voltage. Similar procedures can be utilized for other buses, and the Branch-Current to Bus Voltage (***BCBV***) matrix can be derived as,

$$\begin{bmatrix} V_1 \\ V_1 \\ V_1 \\ V_1 \\ V_1 \end{bmatrix} - \begin{bmatrix} V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \end{bmatrix} = \begin{bmatrix} Z_{12} & 0 & 0 & 0 & 0 \\ Z_{12} & Z_{23} & 0 & 0 & 0 \\ Z_{12} & Z_{23} & Z_{34} & 0 & 0 \\ Z_{12} & Z_{23} & Z_{34} & Z_{45} & 0 \\ Z_{12} & Z_{23} & 0 & 0 & Z_{36} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \end{bmatrix}$$

$$\Delta V \quad = \quad BCBV \quad B$$

1. Create a null matrix of dimension (n-1) * m
   i. m =number of branches
   ii. n = number of buses
2. If a line section (B_k) is located between Bus *i* and Bus *j*, copy the row of the *i*-th bus of the *BCBV* matrix to the row of the *j*-th bus and fill the line impedance (Z_{ij}) in the position of the j-th bus row and the k-th column.

3. Repeat Procedure (2) until all the line sections are included in the *BCBV* matrix

Rewriting Equation (2.7) in the general form, we have

$$\blacktriangle V = [BCBV][B] \qquad (2.8)$$

Algorithm for distribution system load flow

1. Input data.
2. Form the *BIBC* matrix.
3. Form the *BCBV* matrix.
4. Form the *DLF* matrix.
5. Iteration $k = 0$.
6. Iteration $k = k + 1$.
7. Solve the equations iteratively and update voltages

$$I_i^k = (P_i+Q_i)/V_i^*$$

$$[\blacktriangle V^{k+1}] = [DLF]\,[I^k]$$

If $I_i^{k+1} - I_i^k$ >tolerance, go to step(6) else print result.

III. VOLTAGE STABILITY INDEX

Voltage stability index represents a numerical solution to identify the sensitive node of the system. It also helps the operator to check the system to prevent from voltage collapse by initiating automatic remedial actions. Main aim of VSI is to find the distance between the current working point and stable point. Voltage collapse generally starts at most sensitive node in the system and then passes to all other nodes which are sensitive. The node with most sensitivity to voltage collapse exhibits any one of the below features:

1) Highest critical point

2) Low margin of reactive power.

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3) More deficiency of reactive power.

A.MATHEMATICAL FORMULATION

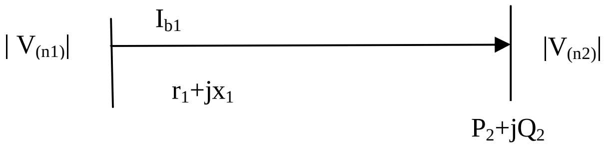

Fig 2. Simple 2 bus system

From figure:

$$I(kk)=\frac{|V(n1)\delta(n1)|-|V(n2)\delta(n2)|}{r(kk)+x(kk)} \quad (3.1)$$

$$P(n2)-jQ(n2)=V^{*}(n2)\ x\ I(kk) \quad (3.2)$$

From equations 3.1 and 3.2 we get

$$\frac{|V(n1)\delta(n1)|-|V(n2)\delta(n2)|}{r(kk)+x(kk)}=\frac{P(n2)-jQ(n2)}{V*(n2)} \quad (3.3)$$

By solving and simplifying equation 3.3 we get

$$|V(n1)|^4-4\{P(n2)r(kk)+Q(n2)x(kk)\}^2-4\{P(n2)r(kk)+Q(n2)x(kk)\}>=0$$

Let,

$$SI(n2)=|V(n1)|^4-4\{P(n2)r(kk)+Q(n2)x(kk)\}^2-4\{P(n2)r(kk)+Q(n2)x(kk)\}>=0 \quad (3.4)$$

where

SI(n2) =Voltage Stability Index of Node n2. (n2=2,3,4….,NB)

For stable operation of the RDS,

SI(n2)>=0 for n2=2,3,…NB

By using VSI, stability level of radial distribution networks can be measured and an suitable action can be taken if VSI represents a poor stability level. All nodal voltages and branch currents will be obtained after the load flow study, and hence P(*n2*) and Q(*n2*) can be calculated easily. Thus one can calculate the voltage stability index easily at each node. Node with minimum VSI value is more sensitive to collapse in voltage. The effectiveness of this technique has been explained using 33node RDS

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IV.PLACING AND SIZING OF DG

In order find the optimum location for placing DG units a number of methods are developed. In this thesis, a technique based voltage stability index (VSI) has been developed for optimal placing of DG units. A node with minimum value of VSI is considered as the optimum location for placement of DG.

In order to obtain optimal DG size, below steps should be followed:

1) A node with minimum VSI should be found first and then the DG is placed at that node.
2) Assuming Distributed generation power factor as constant, size should be varied in constant steps from a minimum value to a maximum value (feeder loading capacity) till minimum losses are obtained
3) The size of DG which produces minimum loss is considered as optimal size.

The system considered here is an IEEE-33 bus system. It has a voltage of 12.66 kV and total real power demand of 3.715 MW and reactive power demand 2.3 MVAr. In the first case load flow without DG is analysed and bus voltages magnitudes and total power loss of the network in RDS are computed. VSI at various buses is also calculated. From the analysis, we found that the bus 18 is having lowest VSI value of 0.66721. Hence, bus 18 is optimal location for placing DG. For finding the optimal size of DG, the DG size is varied from 0.5 MVA to 4.0 MVA in step of 0.5 MVA.

From the test result we observe that power losses are non-linearly varying with capacity of generator. First the power losses are decreased up to some minimum values and then start increasing with DG capacity increment. Hence from the test results, it is observed that in the base case without DG, total respective real and reactive power losses are 210.99 kW and 143.03 kVAr.

Comparison of the voltage variation for different cases viz. base Case1 (without DG)and Case 1(with DG) proves that improvement in voltage for case 2 is more compared to case1.

V. SIMULATION RESULT AND DISCUSSION

A.PERFORMANCE OF IEEE 33 BUS SYSTEM WITHOUT INSTALLATION OF DG

Total Real Power Loading: 3715 kW

Total Reactive Power Loading: 2300 kVAr

LOSSES IN THE NETWORK

Total Real Power Loss: 210.99 kW

Total Reactive Power Loss: 143.03kVAr

Minimum Bus Voltage: 0.9038 p.u.

Corresponding Bus No.: 18

Table 2 represents voltage stability index calculated at each bus. The VSI shows a decreasing pattern till bus 18 and then again start increasing after that. Hence, the most appropriate position for the most stable operation of the system is assumed to be bus 18, and further voltage profile is compared for both the cases.

Minimum Voltage Stability Index**:** 0.66721

Corresponding Bus No.**:** 18

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B. PERFORMANCE OF IEEE 33 BUS SYSTEM WITH INSTALLATION OF DG

LOSSES IN THE NETWORK

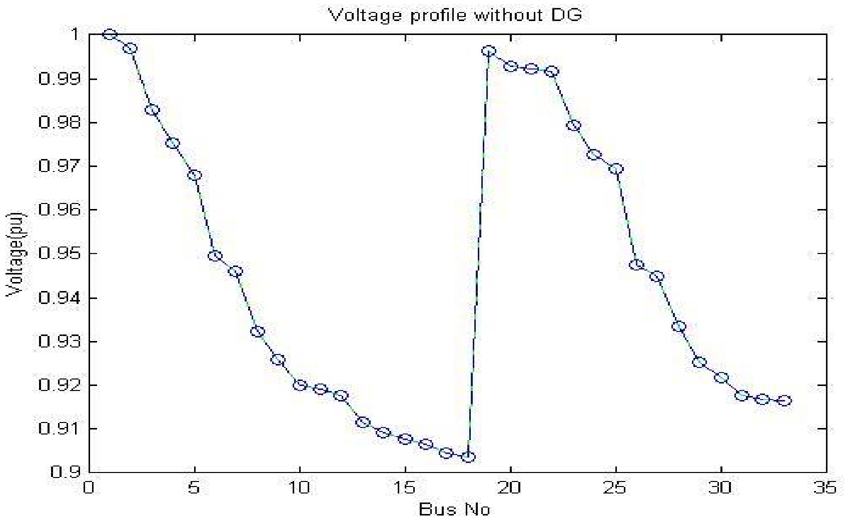

Fig .1 IEEE 33 bus voltage profile without installation of DG

Bus No	V (pu)	Bus No	V (pu)	Bus No	V (pu)
1	1	14	0.909248	27	0.944974
2	0.997014	15	0.907821	28	0.933532
3	0.982882	16	0.906439	29	0.925312
4	0.975373	17	0.904391	30	0.921754
5	0.967946	18	0.903778	31	0.917592
6	0.949468	19	0.996486	32	0.916676
7	0.945943	20	0.992908	33	0.916393
8	0.932287	21	0.992204		
9	0.925955	22	0.991566		

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10	0.920097	23	0.979296		
11	0.919229	24	0.972625		
12	0.917714	25	0.969299		
13	0.911538	26	0.947538		

Table .1 IEEE 33 bus voltage profile without installation of DG

Bus No	VSI	Bus No	VSI	Bus No	VSI
1	-	14	0.683486	27	0.8060 97
2	0.988111	15	0.679206	28	0.7974 06
3	0.933267	16	0.67508	29	0.7594 81
4	0.90507	17	0.668999	30	0.7330 83
5	0.877819	**18**	**0.667186 (minimum)**	31	0.7218 72
6	0.812684	19	0.986018	32	0.7089 22
7	0.800683	20	0.971934	33	0.7060 97
8	0.755439	21	0.969178		
9	0.735121	22	0.96669		
10	0.716697	23	0.919721		
11	0.713994	24	0.894914		
12	0.709299	25	0.882738		
13	0.690398	26	0.683486		

Table 2. IEEE 33 bus Voltage Stability Index without installation of DG

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Total Real Power Loss: 147.381 kW
Total Reactive Power Loss: 104.1292 kVAr
Size of DG is: 1.5 MVA

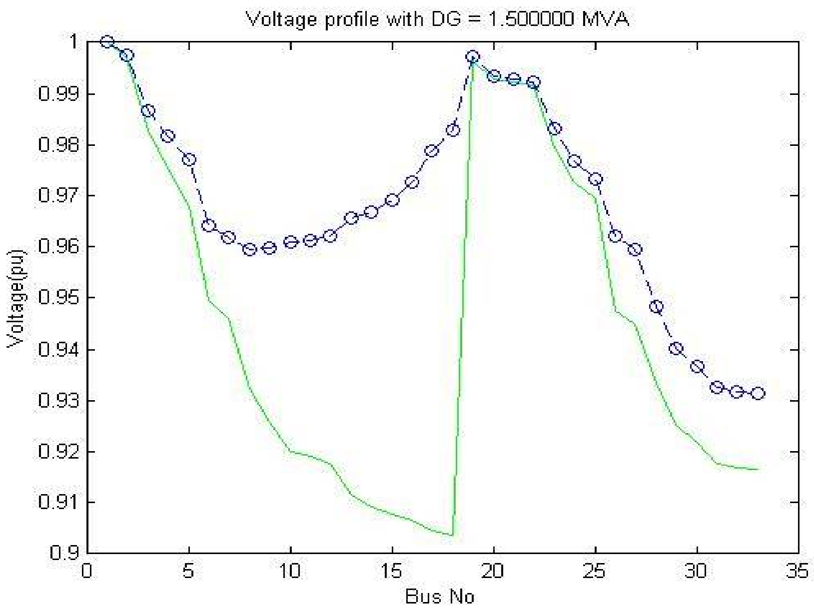

Fig .2 IEEE 33 bus voltage profile with installation of DG

Bus No	V (pu)	Bus No	V (pu)	Bus No	V (pu)
1	1	14	0.96556	27	0.95964
2	0.997638	15	0.966781	28	0.948382
3	0.986842	16	0.969155	29	0.940295
4	0.981801	17	0.972566	30	0.936794
5	0.976948	18	0.978776	31	0.9327
6	0.964062	19	0.982853	32	0.931799
7	0.961796	20	0.99711	33	0.93152
8	0.959435	21	0.993535		
9	0.959861	22	0.992831		

10	0.960823	23	0.992193		
11	0.961242	24	0.983271		
12	0.962175	25	0.976627		
13	0.962175	26	0.973315		

Table .3 IEEE 33 bus Voltage profile with installation of DG

Table 3 represents voltage profile after placement of DG of 1.5MVA at bus 18. As shown in figure 2, the voltage profile is seen to be improved in this case. Hence, bus 18 is the most optimal location of placing the DG. 1.5 MVA size of DG is the most optimal size of DG.

VI.CONCLUSION

From the test result we observe that power losses are non-linearly varying with capacity of generator. First the power losses are decreased up to some minimum values and then start increasing with DG capacity increment. Hence from the test results, it is observed that in the base case without DG, total respective real and reactive power losses are 210.99 kW and 143.03 kVAr. Whereas the losses after placing a DG with 1.5 MVA at unity power factor produces more loss reduction when compared without DG. Hence, optimal placing and sizing of DG reflects the power loss reduction in radial distribution system.

Parameters	Without DG	With DG
Active Power Loss	210.9876	147.3811
Reactive Power Loss	143.1284	104.1293

As DG injects real and reactive power to the load centres locally, it helps in improving the bus voltages and also reduces the losses at the load side. Comparison of the voltage variation for different cases viz. Case 1 (without DG), Case 2(with DG) proves that improvement in voltage for case 2 is more compared to case 1.

REFERENCES

[1] Dugan R.C, McDermott, T.E. "Distributed Generation", Industry Applications Magazine, *IEEE Vol.8, Issue 2*, Mar/Apr 2002, Page(s):19-25.
[2] A. C. Santos, M. Nanni, M. R. Mansour "A Power Flow Method Computationally Efficient for Large-Scale Distribution Systems", *IEEE Vol 8, Issue 4*, 2008.
[4] M. Chakravorty, D. Das, "Voltage stability analysis of radial distribution networks", *International Journal Of Electrical Power and Energy Systems*, Vol. 23, (2), pp.129 – 135, 2001.
[5] Kyu-Ho Kim, Yu-Jeong Lee "Dispersed Generator Placement using Fuzzy-GA in distribution Systems", *Power Engineering Society Summer Meeting*, 2002 IEEE Volume:3 Publication year :2002
[6] Caisheng Wang and M.HashemNehrir, "Analytical Approaches for optimal placement of Distributed Generation sources in Power Systems", *IEEE Transactions on Power Systems*, Vol 19,November 2004.
[7] A.Lakshmi Devi andB.Subramanyam, "Optimal DG Unit Placement For Loss Reduction in Radial Distribution System", *ARPN Journal of Engineering and Applied Sciences*Vol 2, December 2007.
[8] B V Srikanth and A Laxmi Devi,"Voltage Stability Analysis and Bifurcation Techniques: A Detailed Survey ", International Journal of Latest Trends in Engineering and Technology (IJLTET), Vol 7 issue 3 June 2016 Summer Special Issue
[9] Akwukwaegbu I. O, Okwe Gerald Ibe, "Concepts of Reactive Power Control and Voltage Stability Methods in Power System Network", IOSR Journal of Computer Engineering (IOSR-JCE) e-ISSN: 2278-0661, p- ISSN: 2278 8727Volume 11, Issue 2 (May. - Jun. 2013), PP 15-25.