Optimal Allocation of Distributed Generation in Distribution System for Loss Reduction

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Abstract— Electricity is an essential requirement for all facets of our life. It has been recognized as a basic human need and it is critical infrastructure on which the socio economic development of a country depends. With ever growing population, improvement in the living standard of the humanity, industrialization of the developing countries, the global demand for energy is expected to increase rather significantly in the near future. Today, the challenge of power sector is to match the ever increasing demand for power supply through newer environment friendly power projects with minimal transmission and distribution losses Even though globally the power generating capacity is increasing steadily, the growth in demand is exceeding the generation capacity and as a result of this many countries are facing acute shortage in peak and energy demand. Further, people in large number of village have no access to electricity. The electricity supply is not even sufficient for those who have been connected. The end users of electricity like household, farmers, commercial establishment and industries are confronted with frequent power cuts, both scheduled and un scheduled power cuts, erratic voltage and low or high supply frequency have added to the 'power woes' of the consumer Transmission and distribution losses have been concern for the developing countries, electricity sector since these have been very high when compared with developed countries. The present T&D losses including unaccounted energy are about 30% and there is a need to reduce these losses through efficient management and the best operation and maintenance practice of the transmission and distribution system so that more energy is made available to final consumer at reduced cost. Distribution generation(DG) is attracting increasing interest and policy attention. There are five major factors behind this trend: electricity market liberalization, developments in DG technology, constraints on the construction of new transmission lines, increased customer demand for highly reliable and quality electrical power, and concerns about climate change. DG have also become popular because they reduce the distribution loss substantially which is a major component of T&D losses and it will also improve voltage of the distribution network. The optimal allocation of DG units in power system has been a major challenge to distribution system planners as well as researches in the field. The reason for this is that DG affects the power flow and voltages conditions in the distribution system, contrary to its traditional unidirectional nature in radial configuration. Distributed Generation (DG) offers various techno-economical benefits when integrated in distribution system. Those benefits are always depends on the placement and sizing of DG. To maximise the benefits it is necessary to find optimal allocation of DG in distribution system. Optimal allocation of DG is a very important factor in planning & operation of distribution system. In present work a simple and efficient technique to implement DG at optimal is suggested. This technique has been applied to ieee 33 bus system, there is a remarkable improvement in voltage profile as well as reduction of losses in the system. The minimum voltage before implementing DG was 0.9038 pu, after DG implementation it improves to 1.0281 pu for DG of 1.5 MVA at 0.9 pf lag and 0.9713 pu for DG of 1.0 MVA at unity pf. Further, initially the system was having active and reactive power of 0.0021 pu and 0.0014 pu and subsequent to DG implementation the active and reactive power losses have come down to 0.0011 pu and and 0.0008 pu for DG of 1.5 MVA at 0.9 pf lag, and 0.0014 pu and 0.0009 pu for DG of 1.0 MVA at unity pf.

Key words: Optimal Allocation of Distributed Generation in Distribution System, Electrical Distribution System

I. INTRODUCTION

Energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environmentally friendly. Electrical energy in particular is the most preferred secondary form of energy. Further, it is a major energy source used widely in the community because of its flexibility and its ease of application. It is an efficient, versatile, convenient, and relatively safe pollution free source of energy. Undoubtedly, electrical energy will be an essential component for achieving the goals for sustainable development.

For the past 60 years, utilities are continuously planning the expansion of their electrical networks in order to face the load growth and to properly supply their consumers. The traditional solution is the construction of new substations or the expansion of those already exists.

Due to limitation on fossil fuel resources, alternative solutions to traditional large power stations are under high priority in recent years to meet growing energy demand of the future. Also large power stations are discouraged due to many environmental concerns. On the other hand, renewable energy resources have been considered as the best alternative to traditional fossil fuels. The sizes of renewable energy based electricity generators would be very small as compared to large fossil fuel based power plant. Technically, they are suitable for installation at low voltage distribution system, near loads centers.

Electric power systems have been originally designed based on the unidirectional power flow, but the concept of distributed generation (DG) has led to new considerations concerning the distribution networks. The penetration of DG may impact the operation of a distribution network in both beneficial and detrimental ways. Some of the positive impacts of DG are: voltage support, power loss reduction, support of ancillary services and improved reliability, whereas negative ones are protection coordination, dynamic stability and islanding. In order to maximize benefits and minimize problems, technical constraints concerning the interconnection of DG units and their penetration levels are being adopted worldwide. Furthermore, the presence of DG in the deregulated market has raised new regulatory issues, concerning financial incentives, cost allocation methods, generation management techniques, etc.

Losses reduction initiatives in distribution systems have been activated due to the increasing cost of supplying electricity, the shortage in fuel with ever-increasing cost to produce more power, and the global warming concerns. One of the method to minimize power losses is optimal allocation of DG, in this method we determine the location and size of local generators to be placed in systems. This project proposes a technique for selecting the suitable location and correct size of D.G for minimizing the system losses

II. OVERVIEW OF ELECTRICAL DISTRIBUTION SYSTEM

The part of power system which distributes electric power for local use is known as distribution system

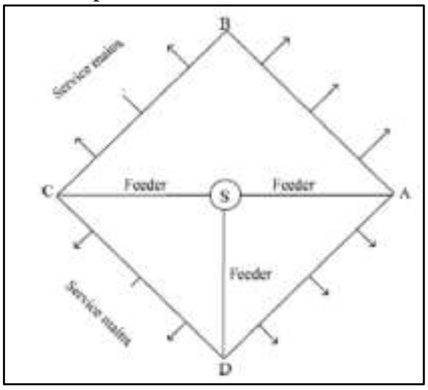

Fig. 1: Single Line Diagram of a typical low tension distribution system.

In general, the distribution system is the electrical system between the substation fed by the transmission system and the consumer's meters. It generally consists of feeders, distributors and the service mains. Figure.1 shows the single line diagram of a typical low tension distribution system.

- Feeders: A feeder is a conductor, which connects the sub-station (or localized generating station) to the area where power is to be distributed. Generally, no tapping are taken from the feeder so that the current in it remains the same throughout. The main consideration in the design of a feeder is the current carrying capacity.
- Distributor: A distributor is a conductor from which tapping are taken for supply to the consumers. In Fig.1 AB, BC, CD, and DA are the distributors. The current through a distributor is not constant because tapping are taken at various places along its length. While designing a distributor, voltage drop along its length is the main consideration since the statutory limit of voltage variations is ± 10% of rated value at the consumer's terminals.
- Service mains: A service mains is generally a small cable which connects the distributor to the consumer terminals.

III. PROBLEM FORMULATION

The objective of this work is to find the best location and size the distribution generation unit which results in maximum decrease in power loss.

IV. SOLUTION METHODOLOGY

A. For optimal location of DG

The load flow analysis used in this methodology is backward and forward sweep method, the Conventional NR and Gauss Seidel (GS) methods may become inefficient in the analysis of distribution systems, due to some special features in the distribution networks, i.e. radial structure, high R/X ratio and unbalanced loads, etc. due to these features in the distribution system makes the power flow computation different and difficult to analyze as compared to the transmission systems. These conventional methods can also be utilized by proper modification of existing methods. Due to its low memory requirements, computational efficiency and robust convergence characteristic backward and forward sweep method is used to find out the load flow solution.

Firstly voltage sensitive nodes are identified by penetrating DG at all the buses having capacity of 25% of the total feeder loading capacity. Then voltage sensitivity index (VSI) is calculated. When DG is connected at bus i, VSI for bus i is defined as

$$VSI_i = \sqrt{\frac{\sum_{k=1}^{n}(1-V_k)^2}{n}}$$

Where Vk is voltage at kth node and n is the number of nodes.

The bus with least VSI is taken as optimal location for the placement of DG

B. For optimal size of DG

After identification of optimal location for DG placement, the optimal size is determined, here firstly we are placing DG at a bus having minimum VSI. Then the size of the DG is varied from minimum value to a value equal to feeder loading capacity in constant steps by keeping power factor of DG constant. The of DG is varied until minimum loss in the system is achieved. The DG size corresponding to minimum system loss is taken as optimal size of DG.

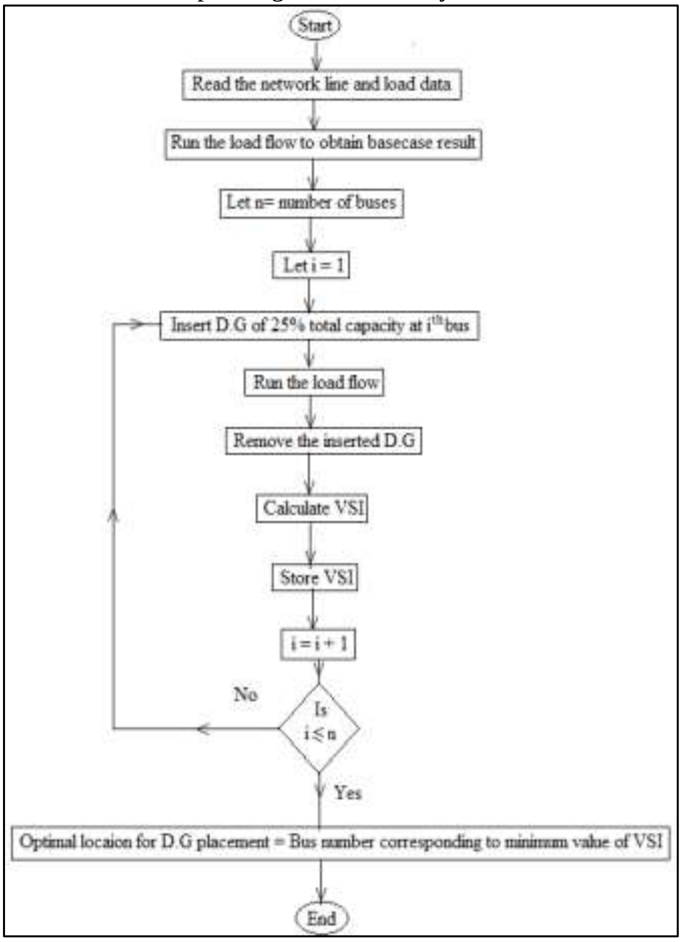

Fig. 1(a): Flow chart for Optimal Location of D.G

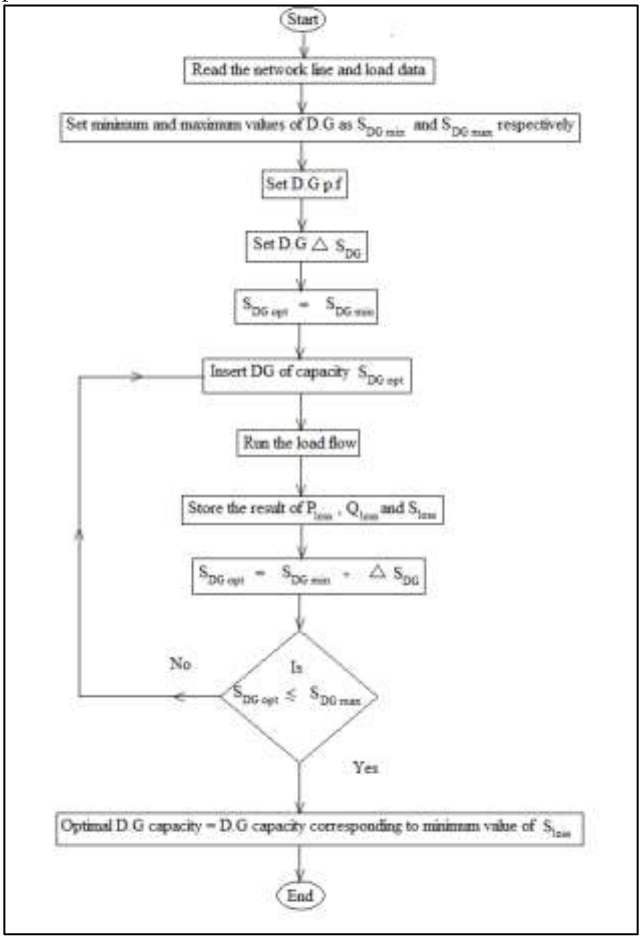

Fig. 1(b): Flow chart for optimal sizing of D.G

V. CASE STUDY AND NUMERICAL RESULTS

The system under study is an IEEE-33 bus network having system voltage of 12.66 kV and the total real and reactive power demand of 3.715 MW and 2.3 MVAr respectively. The IEEE-33 bus test system is shown below

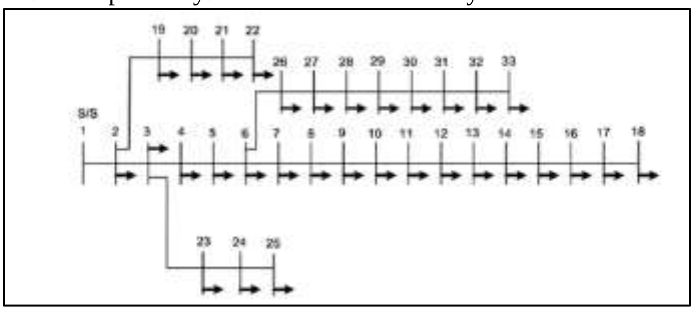

Fig. 2: IEEE-33 bus test system

Following two cases are considered in this study for analysis:

- Case I: DG is operated at power factor 0.9 lag
- Case II: DG is operated at unity power factor

First base case load flow (without DG) analysis is done to calculate the bus voltage magnitudes and total network power loss in the radial distribution system (RDS). Further, load flow with DG capacity of 25% of the total feeder loading capacity is carried out to find VSI at various buses. Figure 2 shows the variation of VSI at various buses. As seen from table 1 and figure 2, bus number 16 is having the lowest VSI value of 0.0306. Therefore, bus 16 is considered as the optimal location for the DG placement.

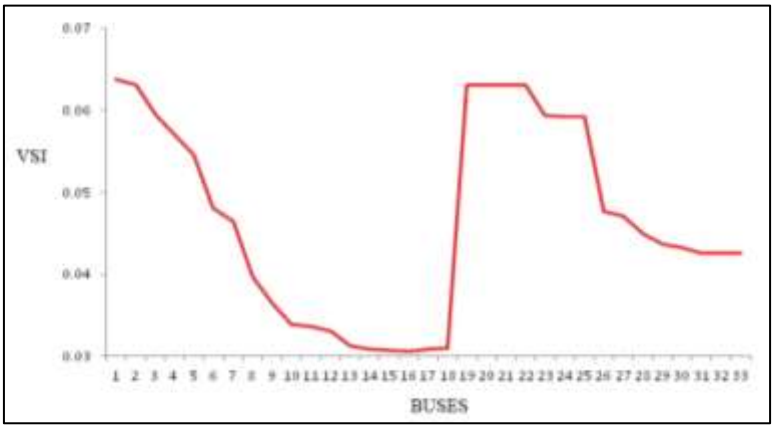

Fig. 3: Variation of VSI at various buses

To find the optimal DG size, DG working at 0.9 power factor lag (for case I) and unity power factor(for case II) is considered and its size is increased from 0.5 MVA to 4.5 MVA in step of 0.5 MVA. table 1 and figure 3 shows the variation of power loss with DG size.

DG Capacity (in MVA)	Real power losses (in P.U)	
	DG at 0.9 pf lag	DG at unity power factor
0.5	0.0014	0.0015
1.0	0.0011	0.0014
1.5	0.0011	0.0014
2.0	0.0015	0.0019
2.5	0.0022	0.0027
3.0	0.0032	0.0038
3.5	0.0046	0.0052
4.0	0.0062	0.0070
4.5	0.0082	0.0090

Table 1: Variation of power losses for different cases

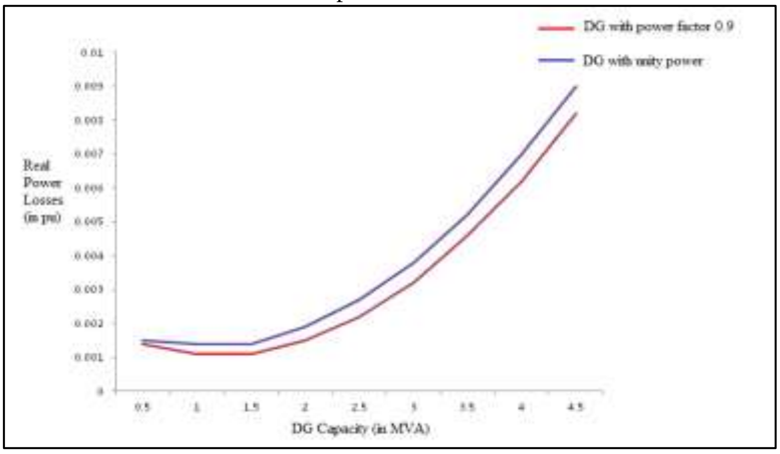

Fig. 4: Improvement in system performance for different cases

From figure 3, it can be observed that the power losses are varying non-linearly with respect to generator capacity. The losses first decrease to some minimum values and then increase with increment in DG capacity. Table 2 shows optimal size of DG obtained and table 3 and figure 4 shows the improvement in system performance for different cases.

Case	**DG Size**
Case I	1.5 MVA at 0.9 power factor lag
Case II	1.0 MVA at unity power factor

Table 2: Optimal Size of DG for Different Cases

Parameters	Base case	Case I	Case 2
Active power losses (in pu)	0.0021	0.0011	0.0014
Reactive power losses (in pu)	0.0014	0.0008	0.0009

Real power from substation (in pu)	0.0393	0.0248	0.0285
Reactive power from substation (in pu)	0.0244	0.0172	0.0239

Table 3: Improvement in system performance for different cases

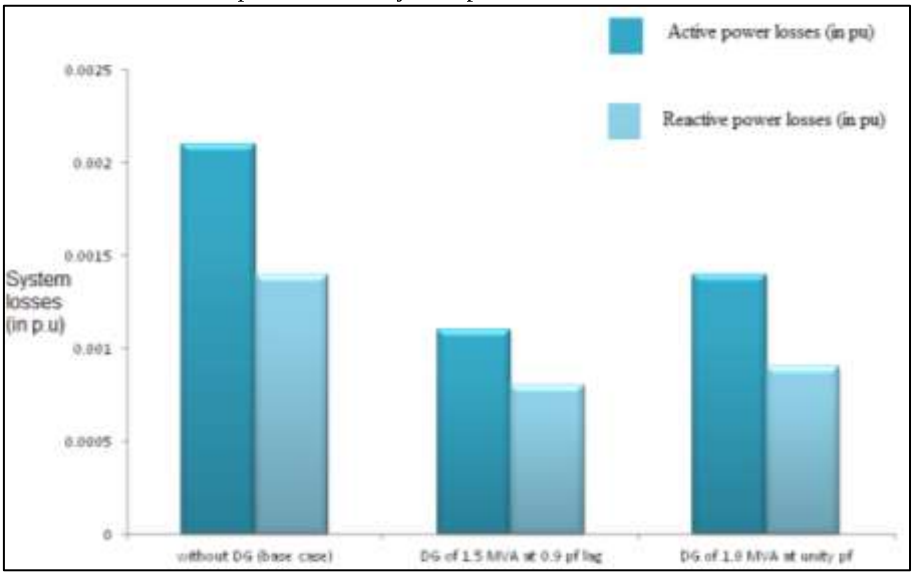

Fig. 5: Reactive Power Losses

From the figure 5 and table 3, it is evident that the base case (without DG) total real and reactive power losses are 0.0021 pu and 0.0014 pu, respectively, whereas these losses for the optimal DG of size 1.5 MVA at 0.9 power factor lag results in the more loss reduction compared to optimal sizes and power factor of DG of 1.0 MVA at unity power factor. Therefore, higher power loss reduction in distribution networks in the presence of DG depends on the optimal size, location and also on the power factor (DG technology). Table 3 also shows the comparison of substation capacity release caused in different cases as a result of the introduction of DG. It can be seen that for the case I substation capacity release is more as compared to case II.

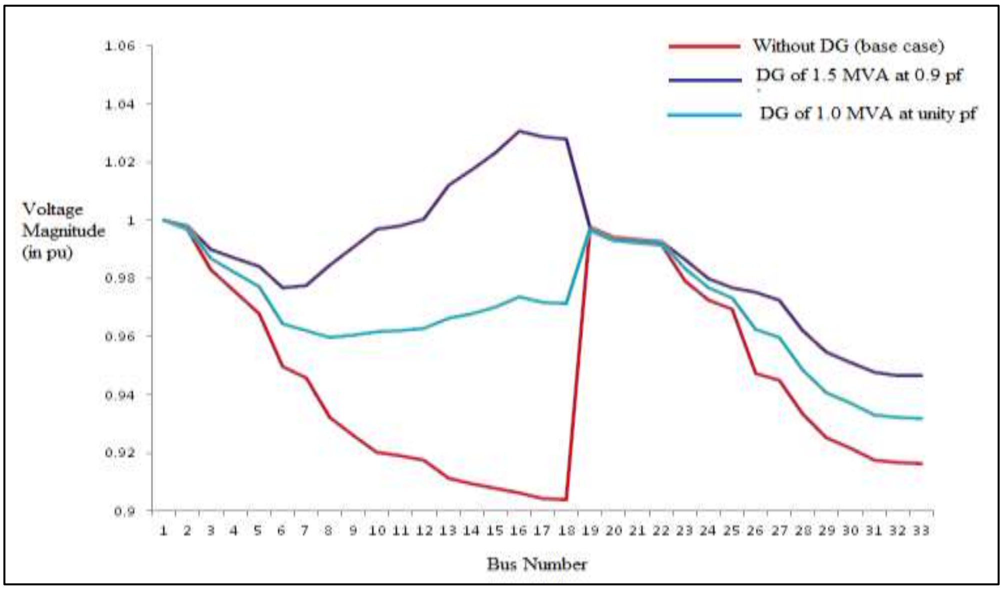

Fig. 6: The voltage profile when optimal DG size is placed at optimal location

The voltage profile when optimal DG size is placed at optimal location is shown in table 3 figure 6. By introducing DG in the system, voltage profile is improved because DG can provide a portion of the real and reactive power to the load locally, thus helping to decrease current along a section of the distribution line, which, in turn, results in a boost in the voltage magnitude at the customer site. The comparison of voltage profile variation for different cases viz. base case (without DG, indicating in red line), case I (1.5 MVA DG at 0.9 power factor, indicating in dark blue line) and case II (1.0 MVA DG at unity power factor, indicating in ligth blue line) shows that the voltage profile improvement for 1.5 MVA DG operating at 0.9 power factor is superior compared to other case. Above bar chart shows the improvement in the voltage, this bar chart is drawn for a bus having minimum voltage

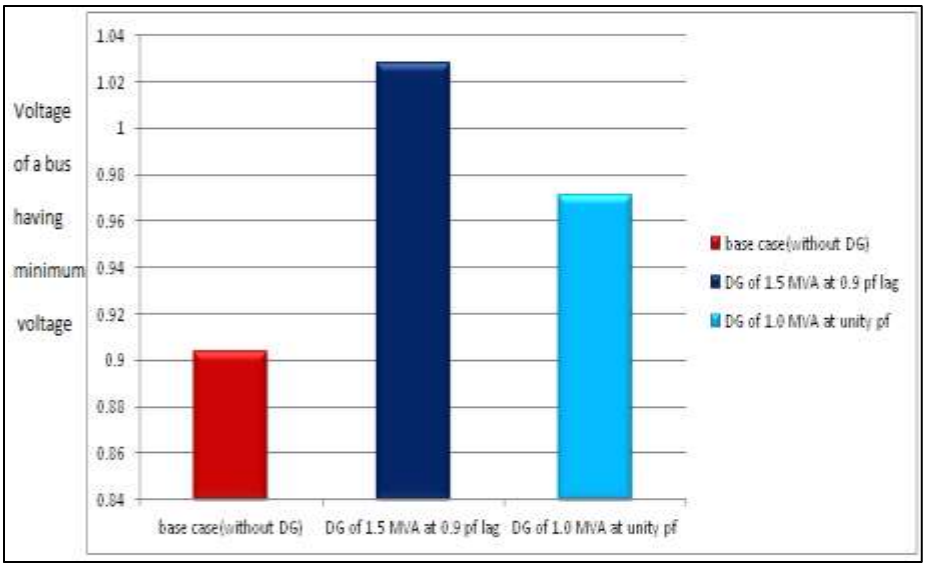

Fig. 7: Voltage of a bus having minimum voltage

VI. CONCLUSION

Distributed generation is one of the new trends in power system used to support the increased energy demand. Distributed generation refers to an electrical power source connected directly to the distribution network or on the consumer side of the meter. Distributed generation provides an enhanced power quality and high reliability of distribution system. Employing distribution generation in a distribution system results in line loss reduction and the voltage profile improvement. In present work a simple and efficient technique to implement DG at optimal is suggested. This technique has been applied to IEEE 33 bus system, there is a remarkable improvement in voltage profile as well as reduction of losses in the system. The minimum voltage before implementing DG was 0.9038 pu ,after DG implementation it improves to 1.0281 pu for DG of 1.5 MVA at 0.9 pf lag and 0.9713 pu for DG of 1.0 MVA at unity pf. Further, initially the system was having active and reactive power of 0.0021 pu and 0.0014 pu and subsequent to DG implementation the active and reactive power losses have come down to 0.0011 pu and and 0.0008 pu for DG of 1.5 MVA at 0.9 pf lag, and 0.0014 pu and 0.0009 pu for DG of 1.0 MVA at unity pf.

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