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# Impact of Distributed Generation on Line Losses for Sensitive Load Location

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***Abstract:*** **Power system consists of three main aspects: generation, transmission and distribution, so a proper and efficient analysis of each of these aspects is required. Distributed Generation (DG) refers to any electric power production technology that is integrated within distribution systems, close to the point of use. DG in a distribution network has several advantages such as reduction in line losses, emission pollutants and overall costs due to improved efficiency, and improvement of voltage profile, power quality, system reliability and security. In order to insert a DG many researchers have applied different methods and algorithms unit in a distribution network, first of all we have to find a suitable location. DG can be inserted on a sensitive load location which shows maximum losses on varying its load. Lot of work has been done over the investigation of sensitive load location. The aim of this paper is to explore the impact of insertion of single DG at first load sensitive location using line losses. The analysis of results show that there is increase in the line losses at some individual bus level but overall both active and reactive losses of a bus system decreases.**

***Keywords:*** **Distributed Generation, Sensitive load.**

## I. INTRODUCTION

In the present era, every developing country in the world is facing a challenge of providing an adequate amount of electrical energy to each of its citizen. As an electric power system consists of three main aspects: generation, transmission and distribution, so a proper and efficient functioning of each of these aspects is required. In recent years with ever increasing population, more load demand by customers and difficulties for construction of new power plants, transmission lines and substations [1], power distribution system is experiencing an urgent need of modification of distribution systems by incorporating distributed generation (DG) sources [2]. Generally, the term Distributed Generation refers to any electric power production technology that is integrated within distribution systems, close to the point of use. Distributed generators are connected to the medium or low voltage grid. They are not centrally planned and they are typically smaller [3]. Employing DG in a distribution network has several advantages such as reduction in line losses, emission pollutants and overall costs due to improved efficiency, and improvement of voltage profile, power quality, system reliability and security [5]. Both renewable and non renewable technologies can be used for DG.

Due to maturing technologies and increasing size of DGs, which play a significant and topical phenomenon in power system, there is as yet no universal agreement on the definition of DGs. Current definition of DG is very diverse and range from 1kW solar installation, 1 MW engine generators to several MW offshore wind farms or more. DGs are classified on the basis of their different technologies used and different capacities as shown in Fig 2.

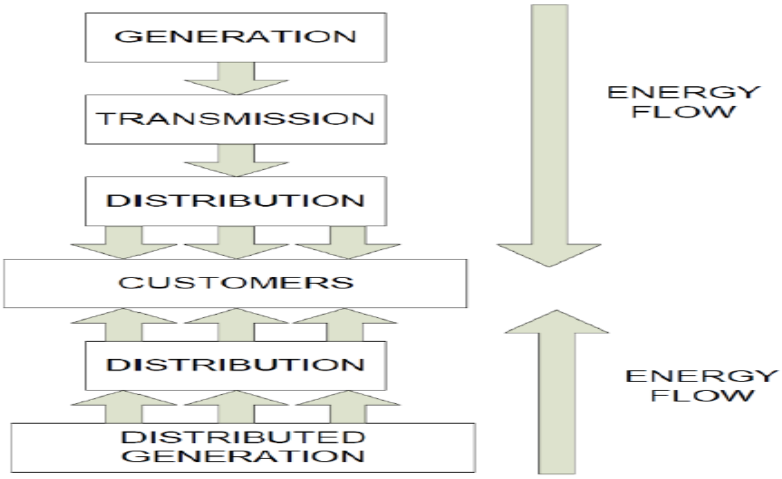


**Fig.1 Block diagram representation for position of distributed generation in a power system [4]**

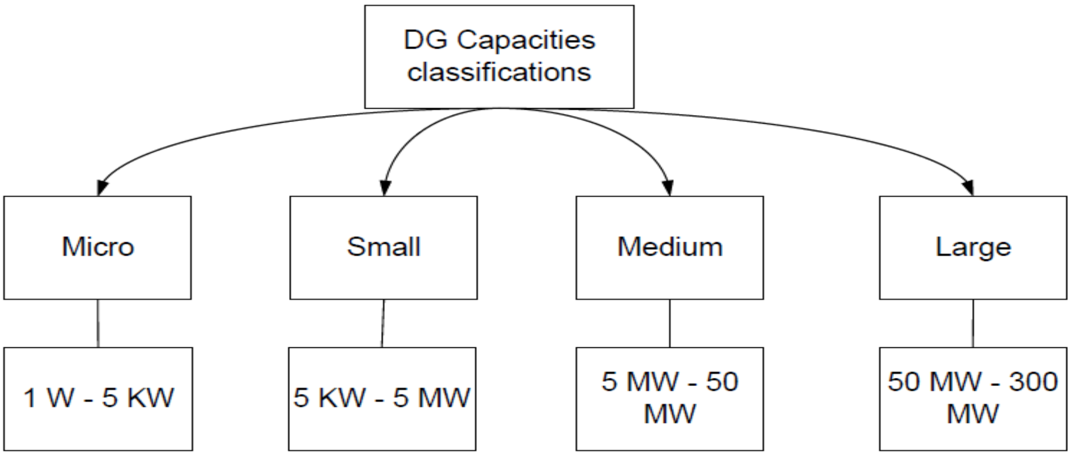


**Fig.2 Different capacities of distributed generation [6]**

DGs are of different capacities and are divided into micro, small, medium, and large. Micro DG ranges from 1W to 5 KW capacity. Small DG ranges from 5 KW to 5 MW. Medium DG ranges from 5 MW to 50 MW capacities. Large DG ranges from 50 MW to 300 MW capacities.

Distribution system provides a final link between the high voltage transmission system and the consumer. Electricity networks are in the era of major transition from stable passive distribution networks with unidirectional electricity transportation to active distribution networks with bidirectional electricity transportation. Distribution networks without any DG units are passive since the electrical power is supplied by the national grid system to the customers embedded in the distribution networks. It becomes active when DG units are added to the distribution system leading to bidirectional power flows in the networks [7]. In an active distribution network the amount of energy lost in transmitting electricity is less as compared to the passive distribution network, because the electricity is generated very near the load centre [8].

While introducing DG in a network, it is essential to determine the adequate size, number and location of DG units. The DG units must be placed at most load sensitive points. These are those points which show a high rate of increase of losses as the load increases beyond certain limit. The poor selection of location would lead to higher losses than the losses without DG. The arbitrary introduction of DG alters the characteristics of the distribution network and leads to several issues such as voltage rise, high losses, and negative impact on power quality, reliability and protection.

Optimum DG allocation may improve voltage profile and minimize power loss, but it depends on the size and location of DG at the distribution network. It is very essential aspect in the planning and operation of distribution system because DG can provide a portion of real and reactive power to the load close by which helps to improve the voltage profile of the network.

Thus, in order to insert a distributed generation (DG) unit in a distribution network, first of all we have to find a suitable location. DG unit can be inserted on a sensitive load location which shows maximum losses on varying its load. The work of M. Raina et. al. [9] provide information about the sensitive load location. The study has been carried out on a 14-bus system. Overall active and reactive losses are calculated by using Newton-Raphson method. Out of all buses, the bus showing highest rate of increase in losses (i.e. Bus 4) is deemed as a load sensitive bus, and requires an urgent penetration of distributed generation (DG) unit in order to curb losses and meeting customer demand. So, the aim of this paper is to explore the impact of insertion of an adequate size of DG units on a load sensitive location of a given bus system. The paper is divided into five sections. Section II explains basic idea load flow. Section III explains methodology followed by results and discussion in section IV. In the last conclusion is explained in the section V.

## II. LOAD FLOW

Generally, there are four quantities associated with each bus in the load flow study, which are listed below:

1. Real Power, P

2. Reactive Power, Q

3. Voltage Magnitude, V

4. Voltage Angle, δ

In every electrical system, two out of these four quantities will be given and the remaining two will be unknowns. Based on this fact, there are three types of line buses: slack or swing bus, generator bus, and load bus. Slack or Swing bus is also known as the reference bus. It is connected to a generator of high rating to the other generators. The voltage of slack bus is always specified and remains constant in magnitude as well as in angle. Thus in slack bus, it the voltage magnitude and voltage phase are known, while real and reactive powers are obtained through the load flow analysis of the system. Mostly, Generator or Voltage Controlled bus is connected to a generator where the voltage is controlled using the excitation and the power is controlled using the prime mover control. In this bus system the voltage magnitude referred as the generator voltage while real power refers to its rating are specified while the reactive power generation and phase angle of the bus voltage are obtained. Sometimes, this bus is connected to a VAR device where the voltage can be controlled by varying the value of the injected VAR to the bus. In Load bus system no generator is connected to this bus. Here, the real and reactive power is specified while the voltage magnitude and phase angle are obtained through load flow solutions [11, 12].

In a three phase ac power system, through complex network of different buses and branches, active and reactive power flow from the generating station to the load centre. The flow of this active and reactive power in the electrical network is known as power flow or load flow. Power flow studies are based on a nodal voltage analysis of a power system. During the planning and operation of power distribution system, power flow analysis is widely used by power distribution professional. Power flow studies provide an efficient mathematical approach for determination of various bus voltages, their phase angles, active and reactive power flows through different branches, generators and loads under steady state condition. There are three methods for load flow studies mainly: Gauss siedel method, Newton-Raphson method, and Fast decoupled method [11], [13].

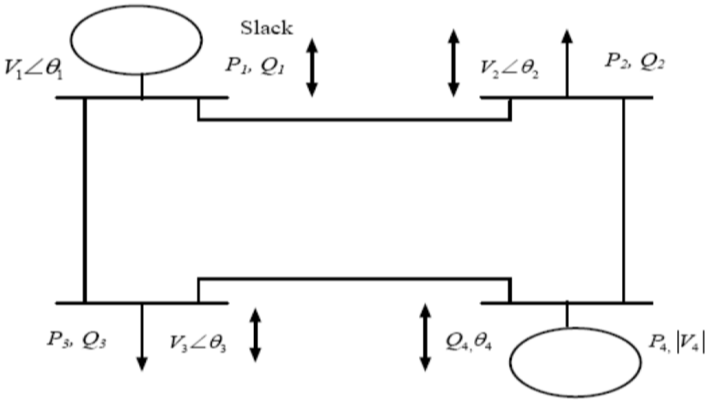


**Fig.3 Basic power distribution system [10]**

## III. METHODOLOLGY

Insertion of DG in a particular bus system may be carried out in two prominent steps. First step includes the investigation of a suitable location which is highly sensitive to load variation. Load sensitive points are those points which show a high rate of increase of losses as the load increases. The second steps includes the investigation of a suitable size of DG unit that should be inserted at the sensitive load location in order to minimize its tendency of giving high losses with varying load. Fig. 4 shows the steps followed for the investigation. The study has been carried out on a 14-bus power system which includes one reference bus (R1), four generator (G2, G3, G6, G8) buses and nine load buses (L4, L5, L7, L9, L10, L11, L12, L13, L14). The bus is subjected to a load variation of 1%, 5%, 10%, 15%, 25%, 35% and 45%, and respective active and reactive losses for each line of 14-bus system are calculated. Out of all the load buses, bus L4 is the most sensitive one, followed by L9. Hence, L9 is chosen for further investigation. After that, DG of different sizes (5 MW, 15 MW, 35 MW and 45 MW) is inserted one by one on the sensitive load bus and respective active and reactive losses for each line of 14-bus system are again calculated. Finally, analysis is done on the basis, whether the insertion of DG on the sensitive bus reduces line losses or not.

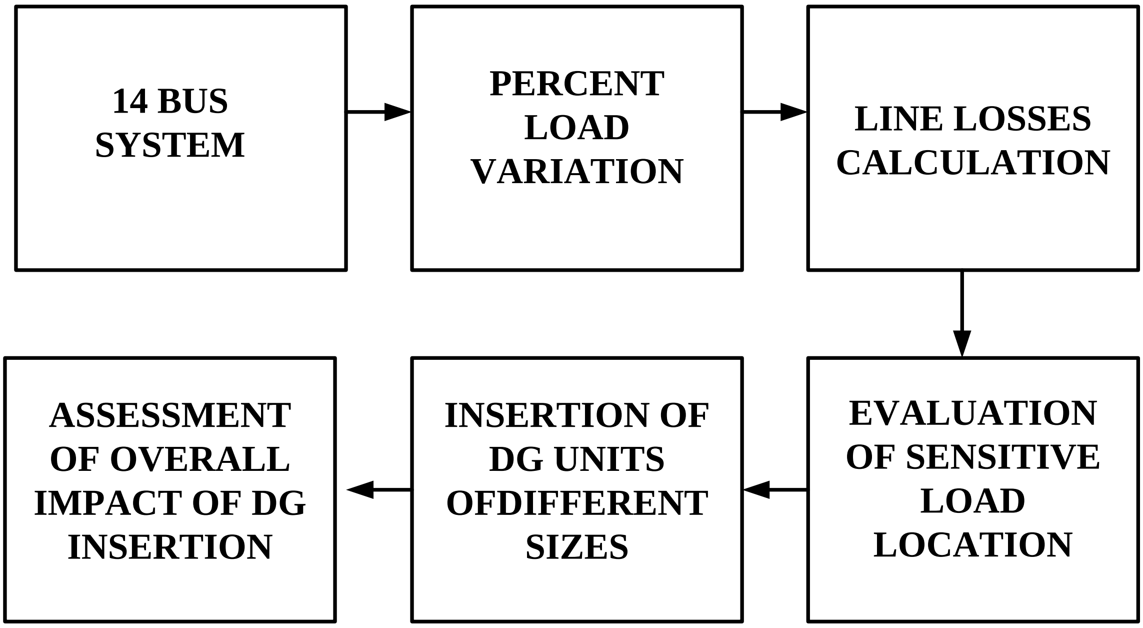


**Fig.4 Overall steps for insertion of DG on a sensitive load location of a given bus system**

## IV. RESULTS AND DISUSSION

After subjecting the load sensitive bus (L4) to a load change of 10%, the respective active and reactive losses are calculated by employing Newton-Raphson method. Then results are calculated by incorporating DG of different sizes in medium range. Medium sized DGs: 5 MW, 15 MW, 35 MW and 45 MW (illustrated by different colours) are used for investigation. It can be observed from Fig. 5 and Fig. 6, having active losses on y-axis and bus to bus numbers on x-axis, that as DG units are incorporated, active losses show an overall decrease. Similarly, in Fig. 7 and Fig. 8, having reactive losses on y-axis and bus to bus number on y-axis, also show a decrease in reactive losses with incorporation of DGs. Here bus to bus numbers signify lines joining different buses (i.e. 1 signifies line joining bus 1 to bus 5, 2 signifies from bus 1 to 5, 3 signifies bus 2 to 3, 4 for bus 2 to 4, 5 for bus 2 to 5, 6 for 3 to 4, 7 for 4 to 5, 8 for 4 to 7, 9 for 4 to 9, 10 for 5 to 6, 11 for 6 to 11,12 for 6 to 12, 13 for 6 to 13, 14 for 7 to 8 , 15 for 7 to 9, 16 for 9 to 10 ,17 for 9 to 14, 18 for 10 to 11, 19 for 12 to 13, 20 for 13 to 14). From the figures it could also be analyzed that though both type of line losses are showing a considerable decrease but in certain buses, the losses are not showing decrease. This depicts that DG units can also be incorporated at those buses which have slightly less sensitivity than the most sensitive bus (e.g. bus 9). Thus, it is concluded that, on a load sensitive bus, both overall active and reactive losses can show significant decrease if adequate sized DG units are incorporated at sensitive locations.

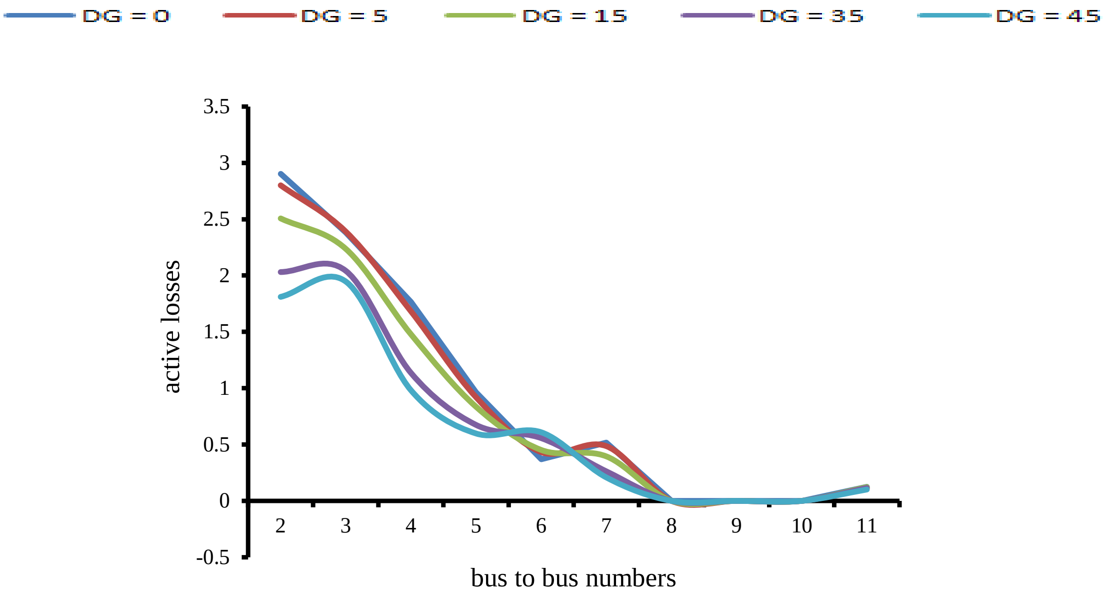


**Fig.5 Variation in active line losses on different DG units insertion**

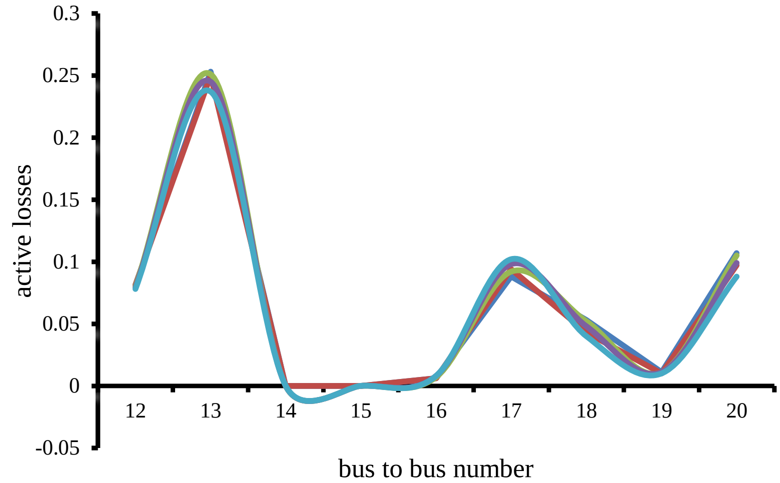


**Fig.6 Variation in active line losses on different DG units insertion**

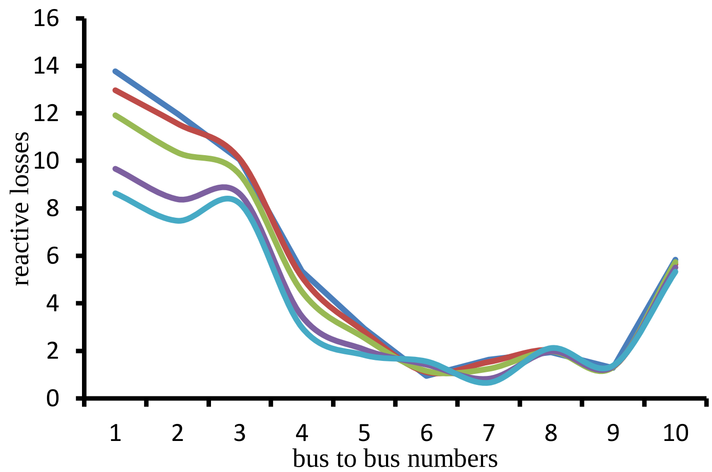


**Fig.7 Variation in reactive line losses on different DG units insertion**

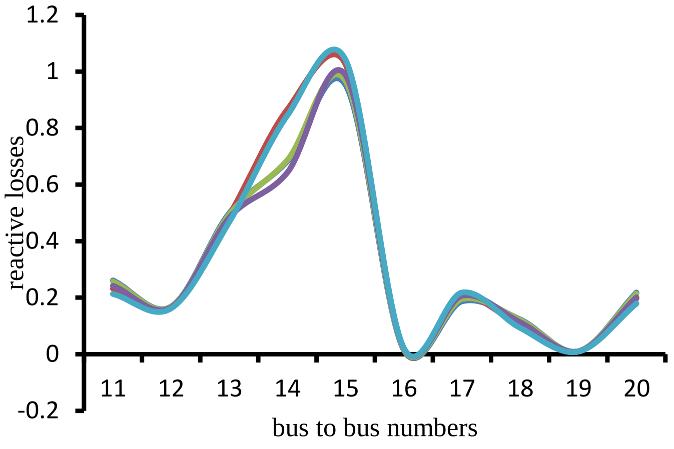


**Fig.8 Variation in reactive line losses on different DG units insertion**

## V. CONCLUSION

The impact of insertion of single DG of medium size, on most sensitive load location of a given bus system has been investigated in this paper. The analysis of results show that there is increase in the line losses in the second sensitive location but overall both overall active and reactive losses of a bus system decreases. Thus overall reduction in losses does not mean better insertion of DG. Each bus parameters has to be taken into account for better DG insertion.

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