Distribution Generation Allocation for Power Loss Reduction and Voltage Improvement in the Distribution System

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***Abstract*— Distribution networks are not perfectly balanced all the time due to the nature of dynamic loads in the system. Numerous advantages attained by integrating distributed generators (DG) in the distribution system. These advantages include decreasing power losses and improving voltage profile. This paper presents a way to control voltage and power lossesof distribution networks with DG using reactive power compensation approach. A control voltage and power losses are shown based on the worst case scenario. DGs are becoming more prominent in transmission system due to the increasing demand for the electrical energy and their location will have an impact on the network system losses. Based on this concept analysis is done on a 13-bus distribution system.**

***Keywords*— Distributed Generators,Distribution system,Voltage control,power loss.**

I. INTRODUCTION

Distribution networks are not perfectly balanced all the time due to the nature of dynamic loads in the system. Traditionally, the distribution networks are passive networks where the flow of both real and reactive power is always from the higher to lower voltage levels. However, with significant penetration of distributed generation, the power flows may become reversed since the distribution network is no longer a passive circuit supplying loads but an active system with power flows and voltages determined by the generation as well as load. Hence, there are dramatic changes in the nature of distribution networks with distributed generation.A DGs are started to integrate a power within the distribution networks create some provisions which have positive as well as negative impacts on both distribution network service providers (DNSP) and customers.Connecting a DG into distribution system technical benefits are in terms of voltage profile improvement, line loss reduction and environmental impact reduction are proposed in [1].Active power losses in the transmission are about 4-8% of the total active power generated [2]. A multi-objective performance index for distribution networks with distributed generation is proposed in [3], which considers a wide range of technical issues.

The study proposed in [4] for DG planning models, consider the various technical requirements such as thermal ratings of the equipment, voltage rise, systems fault levels, reverse power flow capability of the tap-changers, power losses, power quality (such as flicker, harmonics), protection, etc. increasing the distributed generation into distributed networks reduce power loss, not always true. If distributed generator not placed properly losses in the distribution network may increase which show in [5]. In [6], by considering current and voltage along the transmission lines, the researchers developed a mathematical model for determining power losses over typical transmission lines, as the resultant effect of ohmic and corona power losses.Application of the classical optimization technique aided the formulation of an optimal strategy for minimization of power losses on transmission lines.The insertion of DGs plants into the distribution system may benefit customers, utilities, and the environment. It may also cause operation and security problems. Power loss is considered to be one of the most vital technical problems concerning the installation of DGs in distribution systems. Characteristics such as the size, location, and operation mode are decisive in determining the impacts of DGs on power losses of distribution systems. Due to the complexity of the networks, to recognize which generator can reduce the power losses may be a difficult task. In such case, successive power flow studies must be carried out, especially in multi-DG systems.

Integration of distributed generation in distributed system is susceptible to voltage variation. The impact of disconnecting a single or few distributed generators may not be an issue, but the connection or disconnection of large distributed generation units may become problematic which may lead to a sudden appearance of hidden loads and affect the voltage profile of low voltage distribution network.To overcome these problems, the distribution network capacity is determined for distributed generation by using optimal power flow with voltage stepconstraints in [7].An optimal power flow (OPF) technique is proposed in [8], for finding the maximum capacity of new adding to the distribution network when active network management control strategies are in place. Which is shown in a worst case scenario of the distribution system with DG is considered in [9].

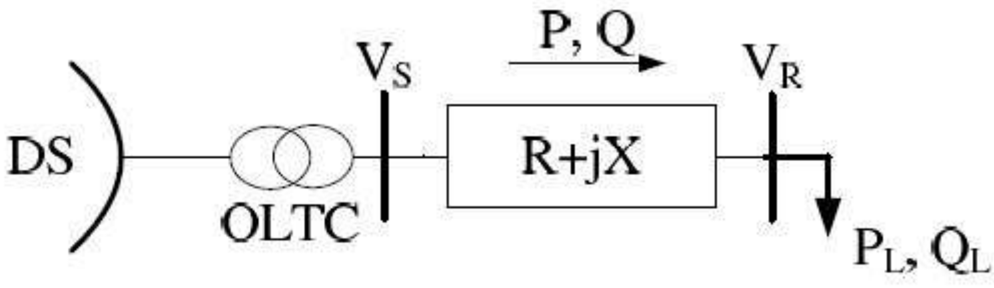

Fig. 1. Conventional Tow-bus Distribution System

A fuzzy-based reactive power and voltage control approach is proposed in [10], and a nonlinear interior-point method and discretization penalties are proposed in [11]. But the accuracy of [10] [11] not feasible. This accuracy overcome by in [12] [13]. An optimization approach used in [12], to control the voltage of distribution and transmission level by limiting the power factor and tap-changer of the distribution networks to keep the voltage profile within limits which have no clarification about the voltage of different buses.

The aim of this paper is to reduce the power loss in the system and a voltage control approach for distribution network with DG by using reactive power compensation. To do this a power losses formula and voltage variation formula is derived based on worst case scenario of the distribution network. This distribution system calculations has done on a 13-bus system.

II. IMPACT OF DG ON DISTRIBUTED SYSTEM BEHAVIOR

Distributed generation have a significant impact on the system and equipment operation in terms of steady-state operation, dynamic operation, reliability, power quality, stability and safety for both customers and electricity suppliers. These impacts may manifest itself either positively or negatively, depending on the distribution system, distributed generators and load characteristics. In this research, the following main impacts will be considered.

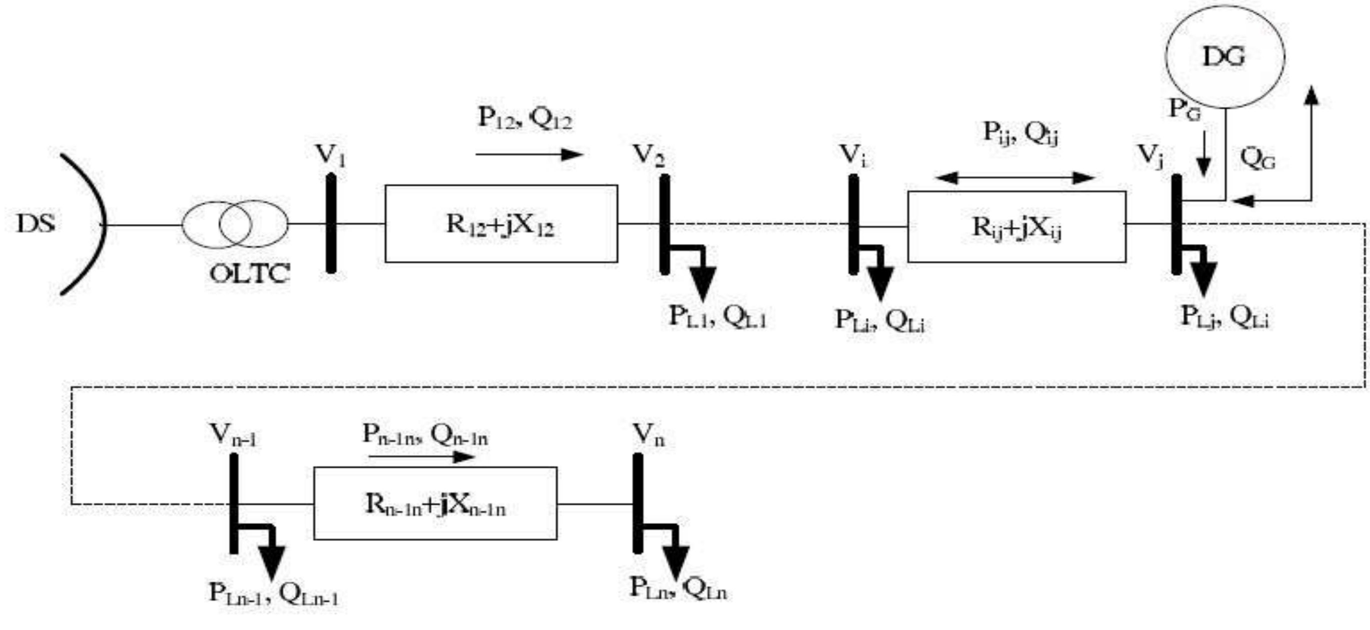

Fig. 2. n-bus Large Distribution System with Distributed Generator

A. Impact on Voltage Profile

When generators are connected to the distribution system no longer passive but active because the power flow and voltage profile are affected. A distributed generator connected to the system power will export, and a generator is likely to operate at a higher voltage as compared to the other nodes where it is supplying power. Power injections from DG can modify power flows inradial distribution networks and lead to voltage rise effect.The generally accepted steady-state range for bus voltages on any power system is 0.94-1.06 per unit (pu), meaning that the voltage at the bus is between 94-106% of the nominal voltageof the bus.

In Fig. 2, a distributed generator is connected bus voltage (V_{GEN}) is assumed to be 11kv, this DG with load is connected to the distribution system, this distribution overhead line impedance R+jX. The voltage rise along the distribution network as shown in Fig. 2 can be written as follows

$$\Delta V = V_{GEN} - V_S \approx \frac{R(P_G - P_L) + X(-Q_L \pm Q_G)}{V_{GEN}} \quad (1)$$

P_G and Q_G are the generated active and reactive power, respectively, by the DG, and P_L and Q_L are the active and reactive power of the load respectively.The generator always export active power ($+P_G$)and export or import reactive power ($\pm Q_G$), whereas the load consumes both active ($-P_L$) and reactive ($-Q_L$) power.

As shown in Fig. 2 the large distribution network connect a distribution generator at j[th] bus of a radial distribution feeder, the voltage variation ΔV_{ji} can be written as

$$\Delta V_{ji} \approx \frac{R_{ij}\left(P_{Gj} - P_{Lj}\right) + X_{ij}\left(\pm Q_{Gj} - Q_{Lj}\right)}{V_j} \quad (2)$$

whereP_{Gj} is active power supplied by the DG and Q_{Gj} is reactive power supplied or absorbed by DG depending on nature of the distributed generator, P_{Lj} and Q_{Lj} are the active and reactive power of the load connected to the j[th] bus of the distribution system.

B. Impact on Power Losses

Power flow in the traditional radial distribution network is unidirectional from the source to the user. However, the introduction of DG to distribution system determines a change in the structure of the network and causes not unidirectional power flow.DG can normally, but not necessarily, helps to reduce current flow in the feeders and hence contributes to power losses reduction. The magnitude of losses depends on amount current flow and the line resistance. Therefore, line losses can be decreased by reducing either line current or resistance or both. When DG is used to provide energy locally to the load, line losses can be reduced because in current flow in some part of the network. However, the DG may increase or reduce losses, be depending on the location, the capacity of DG and the relative size of the load quantity, as well as the network topology and other factors. Mathematically, the real power losses in a system are given (3).

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}\left[\alpha_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}\left(Q_iP_j - P_iP_j\right)\right] \quad (3)$$

where$\alpha_{ij} = \frac{R_{ij}}{V_iV_j}\cos\left(\delta_i - \delta_j\right)$, $\beta_{ij} = \frac{R_{ij}}{V_iV_j}\sin(\delta_i - \delta_j)$ and

In order to study the effect of distribution generator capacity in the power system network, the penetration level of DG can be calculated as a function of the total complex power generation from DGs over complex power peak load demand

$$penetration\ level = \frac{\sum S_{DG}}{\sum S_{Peak}} * 100\%$$

although system losses are not directly a power quality issue, the losses in a system are usually related to the voltage profile of the system.

III. VOLTAGE CONTROL USING REACTIVE POWER COMPENSATION

The amount of voltage variation on a distribution system can be easily described through worst case scenario. Generally, these worst case scenarios are

- minimum load maximum generation
- maximum load minimum generation
- maximum load maximum generation

if we consider minimum load maximum generation, we can write

$$P_L = 0, Q_L = 0 \text{and } P_G = P_{Gmax}$$

asthe time the reactive power compensation can be provided by using a different FACTS devices, then per unit (pu) equation (1) can be written as

$$\Delta V_{worst} \approx RP_{Gmax} + X(\pm Q_{Gmax} \pm Q_C) \quad (4)$$

and for a large system

$$\Delta V_{worstji} \approx R_{ij}P_{Gmaxj} + X_{ij}\left(\pm Q_{Gmaxj} \pm Q_{Ci}\right)$$

A connected DG may export or import power to the grid. When DG export the power equation (5) and import the power equation (6) are

$$\Delta V_{worst} \approx RP_{Gmax} + X(+Q_{Gmax} \pm Q_C)(5)\Delta V_{worst} \approx RP_{Gmax} + X(-Q_{Gmax} \pm Q_C) \qquad (6)$$

and for a large system

$$\Delta V_{worstji} \approx R_{ij} P_{Gmaxj} + X_{ij}\left(+Q_{Gmaxj} \pm Q_{Ci}\right)\Delta V_{worstji} \approx R_{ij} P_{Gmaxj} + X_{ij}\left(-Q_{Gmaxj} \pm Q_{Ci}\right)$$

Therefore, from analysis of worst case scenario, it is clear that reactive power compensation is essential in order to keep the voltage profile within the specified limits. The reactive power compensation can be provided by using different types of FACTS devices. Since the target of this work is to do some static analysis to improve the voltage profile of distribution networks with DG, the shunt capacitors are used as compensators.

IV. SIMULATION RESULTS

The typical 11kv radial distribution system with the topology shown in Fig. 3 has been considered. All bus loads are connected and distributed generator buses are modeled as PQ bus.

A. Voltage Profile Result Analysis

The single line diagram of 13-bus distribution system showing in Fig.3, we have considered a grid connected at bus-1 and there is no distribution generator within the system. Under this condition, the voltages at different nodes are shown in Fig.4.

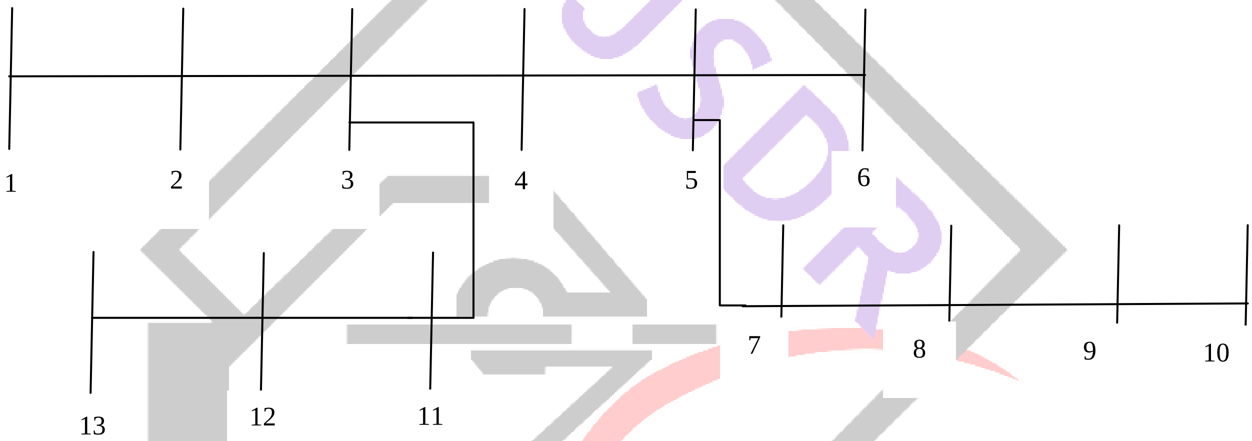

Fig. 3. 13-bus Distribution System

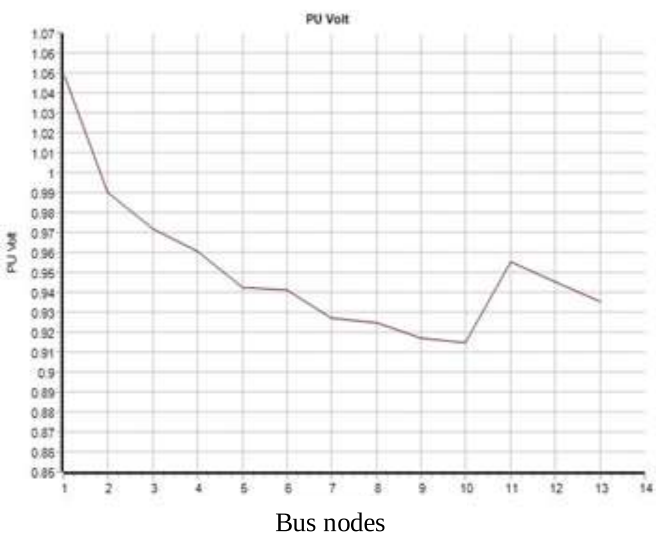

Fig. 4 Voltage profile without DG

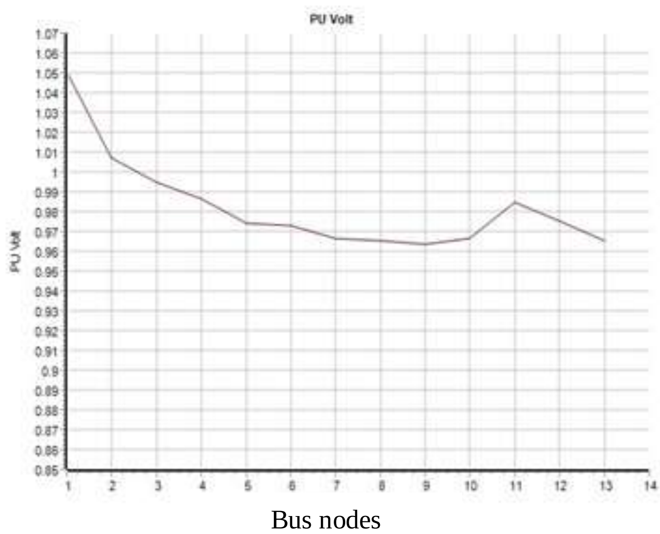

Fig. 5 Voltage profile with DG

From Fig. 4 it is seen that voltage at nodes 7, 8, 9 and 10 are the below the specified limits where the limits are ±6%, because these nodes are far away from main grid, now if a DG is connected at bus-10 and bus-11, the voltages at different nodes are shown in Fig. 5.

B. Power Losses Results Analysis

The power losses in the system are calculated with different penetration level in the different scenario of DG interconnection. The real power losses in the system without any interconnected DG is equal to 1.6MW, and as same time power losses in the system with interconnected DG is equals to 0.9MW. when DG is connected to the network the active power losses are reduced when the penetration level of DG increased, but when penetration increase more and more the power losses in the system increase due to a large amount of power flows in the system.

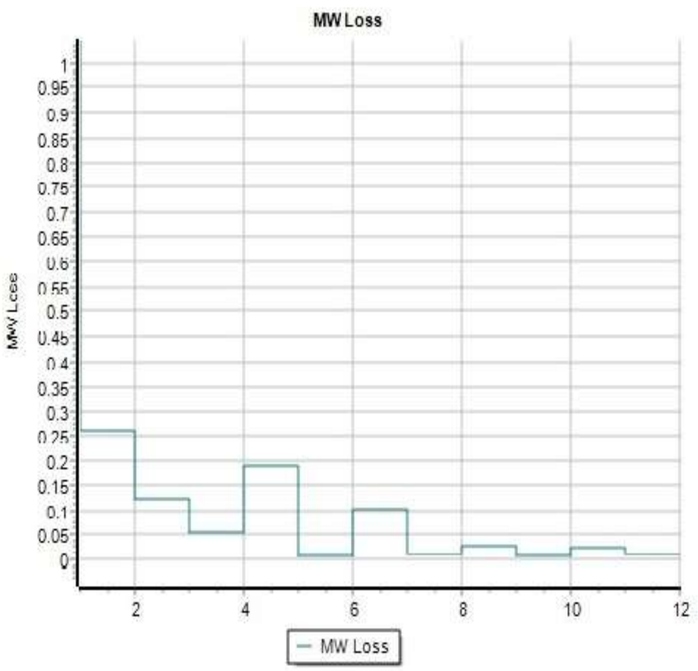

Fig. 6. Real power loss without DG

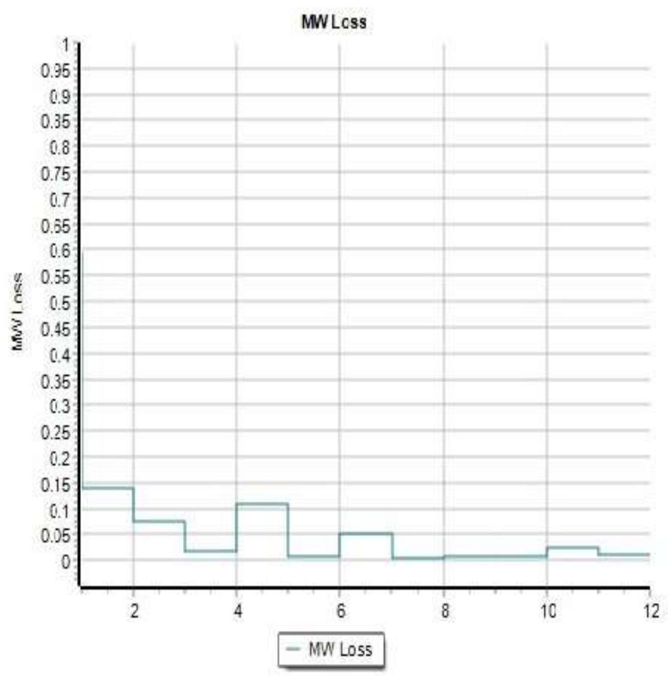

Fig. 7. Real power loss with DG

V. CONCLUSION

This paper presents an idea about the power loss and voltage variation within a distribution network without DG and with DG. The study relating DG and voltage profile indicates that the voltage profile improves in each case by locating the distributed generator close to the load.The improvement is better by increasing the size of the distributed generator. However, the size needs to be limited to a careful study of the system or through the generator regulation as overvoltages can occur for oversized generators. Also, it has been shown that the power losses are significantly reduced by placing DG in distribution system up to a specific penetration level. From the derived voltage variation and power loss formula, the worst case scenario of the network, and it useful for both customers and distribution network service providers. The derived formulas are applicable to small as well as the large distribution network.

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