Voltage stability Analysis and Loss Minimization with Integration of Different Types of DGs into the Distribution system

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***Abstract*: In present days Loss minimization in distribution networks has considered as great importance since demand is continuously increasing supply companies are not able meet this increase in load due so many constraints to increase the generation. Furthermore, voltage instability phenomena is also playing important role in distribution systems and caused a major blackout in the network. The decline of voltage stability level will restrict the increase of load served by distribution system. To solve the above problem one technology that is drawing more attention is Distributed Generation (DG). DG development will support the traditional distribution systems. However, Installation of DG in non-optimal places can result in an increasing in system losses and voltage instability problems, etc.**

In this paper, a method has been presented to determine the appropriate size and proper location of DG in a distribution network in order to reduce the losses and improve the voltage stability in the distributed system. In this work the IEEE 33-Bus system is simulated in Power World Simulator (PWS) and the voltage stability and system losses are analyzed with different types of DGs. Simulation result shows that optimal placement and sizing of DG will reduce the system losses and improve the voltage profile within the acceptable limits and the loss reduction and voltage profile improvement will vary depending on the types of DGs placed in the distribution system

***Index Terms*: Distributed generation, Optimum size, Optimum location, Power loss, Sensitivity analysis, Power world simulator voltage stability.**

I.INTRODUCTION

A traditional electrical generation system consists of large power generation plants, such as thermal, hydro, and nuclear. Because these plants are located at significant distances from the load centres, the energy must be transported from the power plants to the loads through transmission lines and distribution systems. These plants, transmission lines, and distribution systems are currently being utilized to their maximum capacity, but the load demand is growing. This increase in load demand requires that new generation power plants be built and that the transmission and distribution systems be expanded, neither of which is recommended from an economic or environmental perspective [1].Therefore, interest in the integration of distributed generation (DG) into distribution systems has been rapidly increasing, distributed generation is defined as small-scale electricity generation fuelled by renewable energy sources, such as wind and solar, or by low-emission energy sources, such as fuel cells and micro-turbines[2].

DG units are typically connected so that they work in parallel with the utility grid, and they are mostly connected in close proximity to the load [3]. DG units have not so far been permitted without a utility grid. However, the economic advantages of utilizing DG units, coupled with the advancements in techniques for controlling these units, have led to the definite possibility of these units being operated in an autonomous mode, or what is known as a micro grid. Hence, distribution systems with embedded DG units can operate in two modes: grid-connected and autonomous mode.

In grid-connected mode, although the voltage and frequency are typically controlled by the grid and the DG units are synchronized with the grid, integrating DG units can have an impact on the practices used in distribution systems, such as the voltage profile, power flow, power quality, stability, reliability, and protection [4]. Since DG units have a small capacity compared to central power plants, the impact is minor if the penetration level is low. However, if the penetration level of DG units increases the impact of DG units will be profound. Furthermore, if the DG units operate in autonomous mode, as a micro grid, the effects on power stability and quality are expected to be more dramatic because of the absence of the grid support and also it depends on which types of DGs are used in the system[5].

Types of Distributed Generation (DG).

The DG's are grouped into four major types based on the real and reactive power delivering capability [6].

Type1: DG capable of delivering both active and reactive power. DG units based on synchronous machines (cogeneration, gas turbine, etc.) come under this type.

Type2: This type of DG is capable of delivering only active power such as photovoltaic, micro turbines, fuel cells, which are integrated to the main grid with the help of converters/inverters.

Type3: DG capable of delivering only reactive power. Synchronous compensators such as gas turbines and capacitor banks are the example of this type and operate at zero power factors.

Type4: DG capable of delivering active power but consuming reactive power. Mainly induction generators, which are used in wind farms, come under this category. However, doubly fed induction generator (DFIG) systems may consume or produce reactive power i.e. operates similar to synchronous generator

II.STATEMENT OF THE PROBLEM

Interest in Distributed Generation (DG) in power system networks has been growing rapidly. This increase can be explained by factors such as environmental concerns, the restructuring of electricity businesses, and the development of technologies for small-scale power generation. DG units are typically connected so as to work in parallel with the utility grid, however, with the increased penetration level of these units and the advancements in unit's control techniques, there is a great possibility for these units to be operated in an autonomous mode known as a micro grid.
Integrating DG units into distribution systems can have an impact on different practices such as voltage profile, power flow, power quality, stability, reliability, and protection. The impact of the DG units on stability problem can be further classified into three issues: voltage stability, angle stability, and frequency stability. As both angle and frequency stability are not often seen in distribution systems, voltage stability is considered to be the most significant in such systems [7].
In fact, the distribution system in its typical design doesn't suffer from any stability problems, given that all its active and reactive supplies are guaranteed through the substation. However, the following facts alter this situation:

- With the development of economy, load demands in distribution networks are sharply increasing. Hence, the distribution networks are operating more close to the voltage instability boundaries [8].
- The integration of distributed generation in distribution system introduces possibility of encountering some active/reactive power mismatches resulting in some stability concerns at the distribution level [9][10].

The inappropriate size and allocation of DG can cause low or over voltage in the distribution system leading to voltage instability. Therefore, another goal of our analysis is to check whether the voltage profile remains within permissible limit. So, voltage constraint becomes,

$$V_{min} \leq V \leq V_{max}$$

During this analysis, as per the standard we considered 6% variable voltage as acceptable stable voltage limit i.e. V_{min}=0.94 p.u and V_{max}=1.06 p.u.In the following section, we will show how optimum size and location of DG impacts on voltage level of the interconnecting buses.

III.PROPOSED ANALYSIS METHOD

In our analysis, Based on sensitivity, a new methodology has been proposed to calculate optimum size and location of DG using power world simulator package in order to reduce the losses and improve the voltages at the different buses which improves the voltage stability in the system. The results are tested for 33-bus system with and without DG for optimal location and optimal size required to minimize losses and improve the voltage stability of the system.

IV.FORMULA TO FIND SENSITIVITY

For any distribution system, if DG size is varied from P_{DG1} to P_{DG2} and their corresponding change in power loss is respectively P_{L1} to P_{L2}, then the sensitivity factor becomes,

$$\frac{dP_L}{dP_i} = \frac{P_{L1} - P_{L2}}{P_{DG1} - P_{DG2}}$$

In our analysis, Sensitivity factors are evaluated for each bus using equation and the bus with maximum sensitivity is identified. Only those buses which have sensitivity factors close to the maximum value have been considered in our analysis. Thus solution space is reduced to only a few buses. After that, for each of these buses, power loss has been determined using large step size of DG variation and then graph is drawn using these few samples.
The minimum value of the curve that represents the minimum loss gives the optimum size for that bus and corresponding generation is the optimum DG size. The bus which is responsible for minimum loss of the system is the appropriate location for DG allocation.

V.STEPS TO CARRY OUT SIMULATION USING POWER WORLD SIMULATOR

The following steps are carried out to model the test system in the power world simulator

- Draw the buses and enter the data.
- Draw the transmission lines and enter the data as given in the test system.
- Draw the generators and enter the data.
- Draw the load and enter the data.
- Now run the model and observe the voltage at all the buses and total losses in the system without DG.
- Calculate sensitivity of each bus with small penetration of DG
- Make list of most sensitive buses
- Select a bus from the list and calculate power loss for large variation of DG size
- Continue until power loss starts to increase and record each sample

- Check whether all sensitive buses have been analyzed
- Find the bus which has minimum power loss
- Find corresponding DG size
- Find the voltages at all the buses with optimum DG size and location
- Check for voltage stability of the system
- If the voltage stability is not maintained at all the buses then increase the DG size at a optimum location until the voltage stability is maintained

VI. SIMULATION RESULTS AND DISCUSSION

The proposed method has been applied to a standard 33-bus system which have been taken as the bench mark problem in many IEEE papers.

IEEE 33 - BUS TEST SYSTEM

- **Type 1 DG**

Proposed method is applied to 33-bus system with type1 DG using power world simulator.

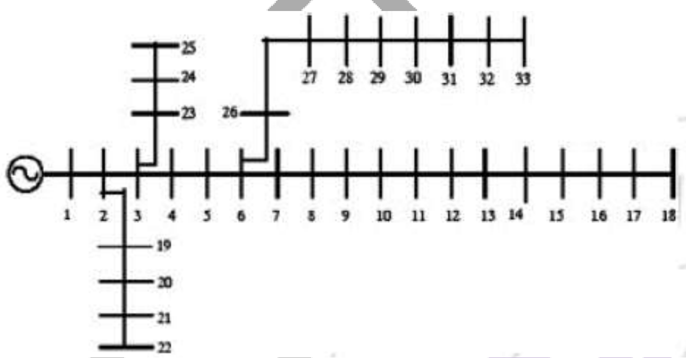

Fig.1. IEEE 33- bus test system

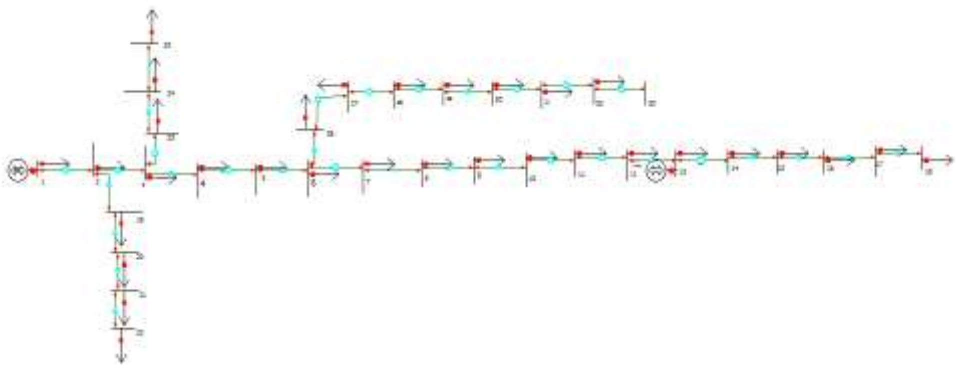

Fig.2.The IEEE 33-bus Test system is Modeled using power world simulator

By applying the proposed method as given in the algorithm the minimum MW loss is occurred when Type1 distributed generation is incorporated at bus 13 with 30 % of generation and it is shown in figure 3.

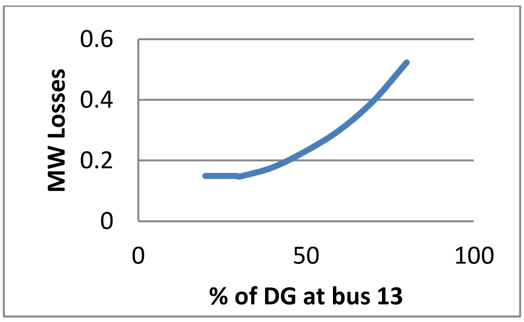

Fig.3. MW loss v/s % of DG at bus 13

Therefore the bus -13 can be chosen as optimum location due to minimum losses with 30% DG at bus -13.The voltages at bus -13 with this 30% of DG are not within the limits therefore in order to obtain the voltage within the limits and to maintain the voltage stability in the system % DG is increased at bus -13 till the voltages at the all the buses are within the limits. In this case for 50% of DG at bus -13, all the bus voltages are within the limits.

VII.ANALYSIS OF POWER LOSS AND VOLTAGE STABILITY WITH INTEGRATION OF TYPE2, TYPE3 AND TYPE4 DG

Power loss and voltage stability analysis is done by placing Type2, type3 and type4 DG in the 33-bus system.DG is placed at optimal location with optimal size which is different for different types of DG and is calculated by using the above sensitivity factor method as done for type1 DG. The table below gives the DG size, location, losses and percentage reduction in losses in 33-bus system for different types of DG.

Real and Reactive power losses with different Types of DG connected into the IEEE 33-Bus system

DG Type installed	Without DG	DG Type 1	DG Type 2	DG Type 3	DG Type 4
DG location at bus	-	13	11	14	12
Active power supplied by DG in MW	-	2.025	2.025	0	1.62
Reactive power supplied by DG in MVAr	-	1.26	0	1.5120	-1.008
Active power Loss in MW	0.33	0.1968	0.2069	0.272	0.2804
Reactive power Loss in MVAr	0.22	0.1518	0.1498	0.179	0.2055
P Loss reduction in %	-	40.36	37.30	17.57	15.03
Q Loss reduction in %	-	31	31.90	18.63	6.59

From the above table it is clear that with sensitivity factor method which is tested in IEEE 33 bus system the loss reduction is more in type1 and type 2 DG when compared to loss reduction in type3 and type 4.

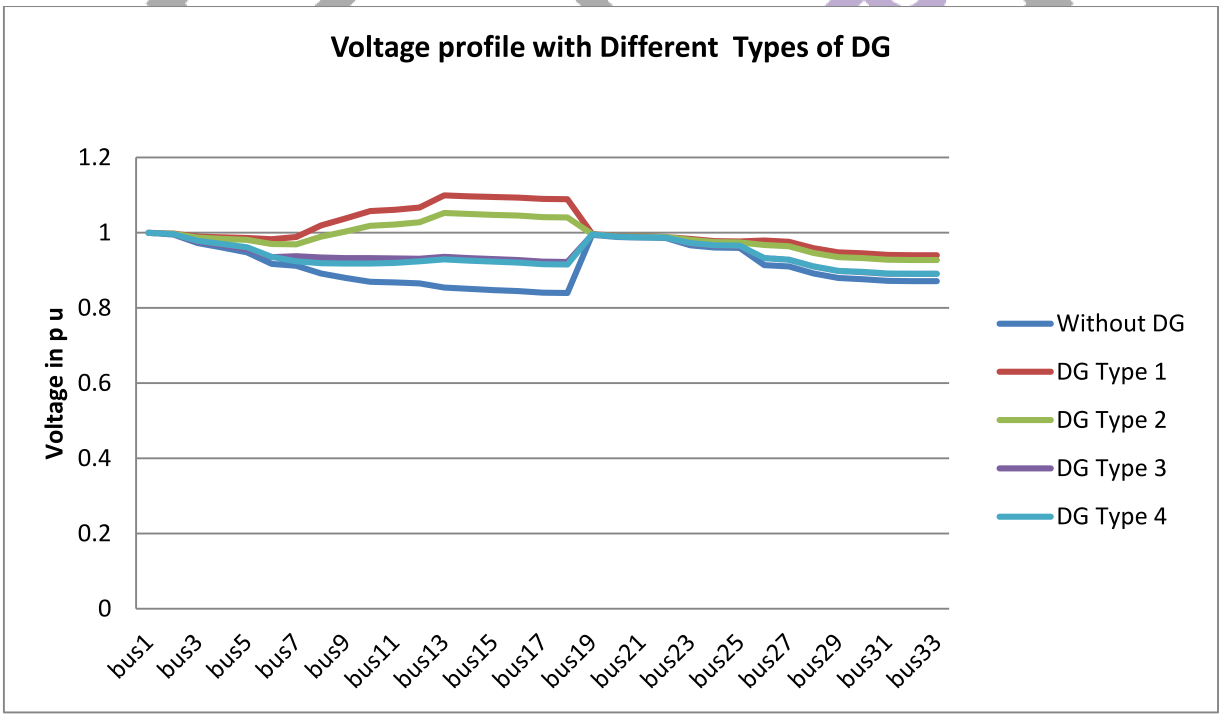

Figure 4. Voltage Profile of 33- bus system with different types of DG

It can be seen from the diagram that the voltage profile is improved in all the buses only for type1 and type2 DG which improves the voltage stability in the distribution system. For type3 and type4 DG it is difficult to maintain the voltage stability due to increase in losses it is not possible to increase the DG size above certain limit so it is not possible to maintain the voltage stability with sensitivity factor method for type3 and type4 as shown in fig4.

VIII- CONCLUSION

Proper Size and location of DG are important factors in the application of DG for loss minimization and voltage stability improvement. This paper presents an algorithm to calculate the optimum location of DG at various buses and to identify the best size corresponding to the optimum location for reducing total power losses and improve the voltage profile in primary distribution network for different types of DGs. In this paper IEEE-33 bus system is taken for analysis and simulation is done using power world simulator software, the results shows that the location of the type1 and type2 DG has a main effect on the power losses and Voltage stability can be improved by selecting proper size of DG at a selected optimal location in distribution system. But with type3 and type4 losses can be reduced but it is difficult to maintain the voltage stability with this method.

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