Voltage Stability Analysis with Integration of DG into the Distribution System

[1]Rudresha S J, [2]Dr. Shekhappa G. Ankaliki, [3]Dr.T. Ananthapadmanabha

[1]Research Scholar, [2]Professor, [3]Principal
[1,2]S.D.M.C.E.T, Dharwad
[3]NIE IT, Mysuru

***ABSTRACT*: One of the modern and important techniques in the electrical distribution systems is to solve the networks problems service availability, high loss and to improve system voltage these can be resolved by accommodating small scaled de-centralized generating stations in networks, which is known as Distributed Generation (DG).Distributed generation (DG) units reduce electric power losses and hence improve reliability and voltage profile. Determination of appropriate size and location of DG is important to maximize overall system efficiency. 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 magnitude and system losses are analyzed. Simulation result shows that optimal placement and sizing of DG will reduce the system losses and improve the voltage profile within the acceptable limits there by improve voltage stability.**

***Index Terms*: Distributed generation, Optimum size, Optimum location, Power loss, Sensitivity analysis, 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 [5].

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 [6].
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 [7].

- 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 [8].

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 has been taken as the bench mark problem in many IEEE papers.

IEEE 33 - BUS TEST SYSTEM

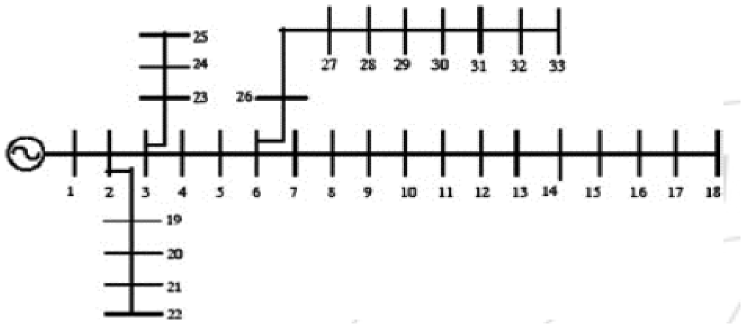

Figure.1. IEEE 33- bus test system

The IEEE 33-bus Test system is modeled using power world simulator as shown in figure.2.

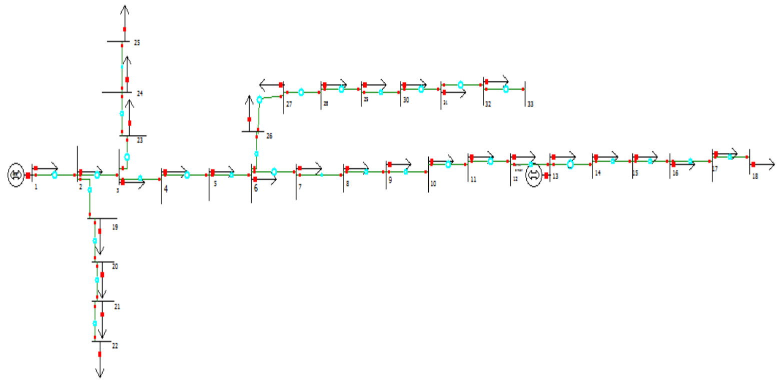

Figure.2. 33-bus Test system with DG is modeled using power world simulator

The load flow analysis is carried out using power world simulator for the existing system without distributed generation and results are tabulated in Table -1.

Table -1

Slack bus MW generation	Slack bus MVAR generation	Slack bus MVA Generation	Total MW loss	Total MVAR Loss
4.0501	2.5258	4.7731	0.3355	0.2294

The voltages at the different buses without DG are given in Table-2.

Table – 2

Bus number	Voltage in p.u	Bus number	Voltage in p.u
1	1.00000	**18**	0.83969
2	0.99522	**19**	0.99435
3	0.97243	**20**	0.98845
4	0.96036	**21**	0.98727
5	0.94810	**22**	0.98614
6	0.91751	**23**	0.96686
7	0.91227	**24**	0.96071
8	0.89225	**25**	0.95996

9	0.88107	**26**	0.91444
10	0.86894	**27**	0.91038
11	0.86736	**28**	0.89213
12	0.86465	**29**	0.87999
13	0.85370	**30**	0.87693
14	0.85041	**31**	0.87238
15	0.84762	**32**	0.87200
16	0.84490	**33**	0.87200
17	0.84070		

As seen from the Table-2, voltages at some of the buses are below V_{min} (0.94) and therefore it reaches voltage instability. The voltage at the other buses are also moving towards voltage instability margin as load increases and it may lead to voltage collapse therefore it is required to place a DG at optimum location in order to improve voltage at the different buses so that voltage stability is maintained.

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

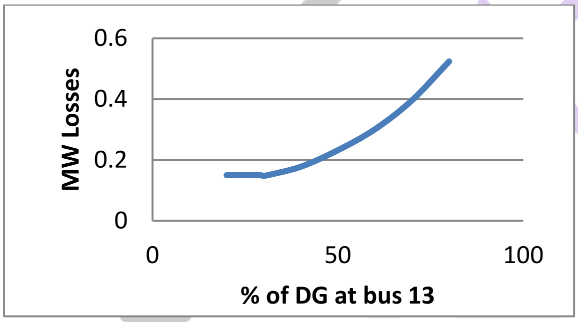

Figure 3.MW loss v/s % of DG at bus 13

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.

The comparison of voltages at the various buses with and without DG is shown in figure .4

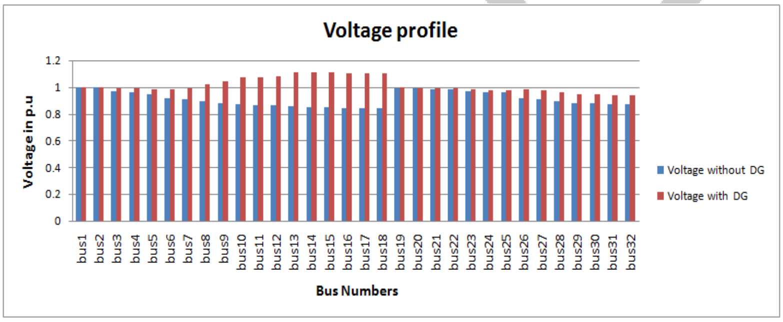

Figure 4. Voltage Profile of 33- bus system before and after placement of DG

It can be seen from the diagram that the voltage profile is improved in all the buses which improves the voltage stability in the distribution system.

Table -3 gives the optimal location, optimal size and percentage loss reduction with DG at bus 13 in 33-Bus distribution system.

Table -3

DG Location	Bus-13
Active power supplied by DG in MW	2.025
Reactive power supplied by DG in MVAr	1.26
Active power Loss in MW without DG	0.33
Active power Loss in MW with DG	0.2
Reactive power Loss in MVAr without DG	0.22
Reactive power Loss in MVAr with DG	0.09
P Loss reduction in %	39.39
Q Loss reduction in %	59.09

The figure.5 and 6 shows the active power loss and reactive power loss with and without DG in 33-Bus system respectively.

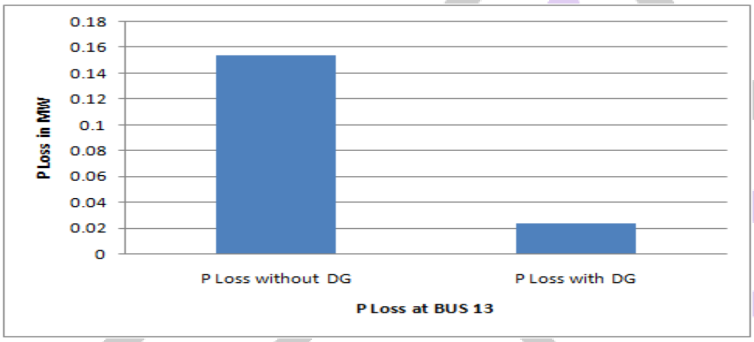

Figure. 5. Active power loss with and without DG in 33-Bus system

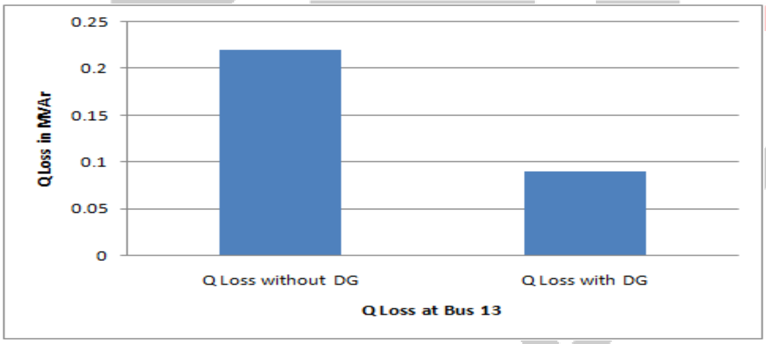

Figure.6. Reactive power loss with and without DG in 33-Bus system

VII- 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. 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 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.

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