International Journal of Engineering Works
Kambohwell Publisher Enterprises
ISSN: 2409-2770 Vol. 2, Issue 12, PP. 99-103, Dec. 2015
www.kwpublisher.com

The Effect Of Distributed Generation On Voltage Profile and Electrical Power Losses

Muhammad Waqas[1], Zmarrak Wali Khan[2]

***Abstract*—**Distributed Generation is gaining popularity with the recent advancements in the renewable energy sources. DGs are used as a source of energy as well as performance enhancers by utilities. Subject to the weather of a certain location different DG sources are used in which Wind Turbines, Small Hydro Plants, Photovoltaic and Fuel Cells are commonly used. In this research work, a detailed comparative analysis is made among Wind Turbine, Photovoltaic and Synchronous machine to suggest the most suitable source. The said comparison is made on the technical factors such as voltage and electrical power losses and on the basis of this comparison a suitable DG source is suggested. A radial distribution feeder is simulated in Electrical Transient Analyzer Program (ETAP) to study the effect of these sources on the test distribution network.

Keywords*—*Disributed generation, Voltage profile improvement, Electrical power losses, Synchronous and Induction Machines, Photovoltaic

Nomenclature

SG= Synchronous Generation

WTG= Wind Turbine Generator

PV= Photovoltaic

DG= Distributed Generation

RctPow= Reactive Power

I. INTRODUCTION

The power system is divided into three main categories; electrical generation, transmission and distribution. Each one of these is run by a different owner. Out of these three; distribution system is a more complex and costly, interms of providing electricity to the far ended rural areas. In a radial distributive system, voltage regulation is a difficult task to achieve as the voltage fluctuation can be of ± 10% [1]. DGs have many positive aspects on the system like decrease in line losses and voltage profile improvement [2]. DG can be classified into five major categories depending on the amount of contribution of active and reactive power to the system [3].

Category 1:

Injection of both the Real and Reactive power.

Category 2:

Injection of Real and absorption of Reactive power.

Category 3:

Only Real power injection.

Category 4:

Only Reactive power absorption.

DG units that are based on synchronous machine (cogeneration, gas turbine, etc.) falls in Category 1. Category 2 mainly covers induction generators that are used in wind farms. Photovoltaic, micro turbines and fuel cells lies in category 3. Category 4 covers synchronous compensators and gas turbines [3]. As the impact of these sources is different from one another, so it is important to analyze each one separately. This research work concentrates on different results obtained from simulation performed on the DG interconnection scenarios and also on technical factors .

The principal factors analyzed in this research work are voltage profile and electrical power losses of a network. These results will be useful for power distribution companies to select the most desirable type of a DG source to improve the voltage profile and to tackle electrical power loss, considering the main characteristics of the distribution network.

This particular paper is organized in four sections. Section II addresses system configuration. The test system is discussed in Section III. Simulation results of voltage profile and electrical losses of the system are discussed in Section IV and V respectively. While conclusion of this research work is discussed in Section VI.

II. SYSTEM CONFIGURATION

Network components in this paper are represented by three phase models. For the analysis of voltage profile and power losses Newton-Raphson iteration is applied in ETAP. This iteration method uses (1) to calculate load flow [4].

[1]Bahria University, Department of Electrical Engineering, Shangrila Road, Islamabad, Pakistan, mwaqas2050@gmail.com, +923339351219

[2]CECOS University, Department of Electrical Engineering, Hayatabad, Peshawar, Pakistan, zmarrakwali123@gmail.com, +923349186780

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix}\begin{bmatrix}J_1 & J_2\\ J_3 & J_4\end{bmatrix}=\begin{bmatrix}\Delta V\\ \Delta Z\end{bmatrix} \quad (1)$$

Where P and Q are the real and reactive powers of the system buses, V and Z are the bus voltage magnitude and angle vectors respectively. While $J_{1,}$ $J_{2,}$ $J_{3\ \text{and}}$ J_4 are the elements of the Jacobin matrix.

11kV radially distributive feeder is selected which supplies power to five buses (from bus 2 to bus 7) having a total of six distribution points. System under consideration is a balanced system. 3-phase 3-wire overhead cables are used to connect these distribution points. Size of the cables are selected per load requirement with a 2% drop in them. Real time data of electrical parameters is feed to the simulation software. This feeder powers seven distribution transformers of 11/0.4kV rating and lumped loads are connected to each of it. ETAP version 12.6 is used for simulation purposes. Transformer ratings at the test feeder buses is given in Table I.

A. *Synchronous Generator*

The synchronous generator installed as a DG source is a steam type generator with ratings of 1.5MW, 11kV, 1.765 MVA operating at 1500 rpm. It is a 4 pole machine with a power factor of 85% and a full load current (FLA) of 92.62A. The rotor type is Round-Rotor while the excitation method used is Thyristor Self- Excitation. It is used in voltage control mode and is solidly grounded.

B. *Induction Generator*

The induction generator installed as a DG source is a wind turbine. Ratings of induction generator are 1.5MW, 11kV, 1.765 MVA operating at 1500 rpm. It is a 4 pole machine with a power factor of 85% and a full load current (FLA) of 92.62A. Average wind speed is 15 m/s while the cut-in and cut-out speed of the turbine are 4 and 25 m/s respectively. It is openly grounded and the reactive power required for induction generator is absorbed from the system.

C. *Photovoltaic*

In this paper, the modeled PV array is manufactured by Moser Baer Solar. It is a Poly- Crystalline model with 220.9W rated power. Maximum peak voltage is 29.61V with 36.21V open circuit voltage. Maximum power of an individual panel is 7.46A while aximum peak power (MPP) of 1500.06 kW is obtained from a combination of 126 panels in series and 159 in parallel. The module efficiency is 13.4% while the calculated solar irradiance is 367W/m2.

III. PROPOSED SYSTEM STUDIES

A. *Description of the Test Feeder*

Careful consideration is required in the analysis of a certain DG source because each DG source has a certain unique impact on the performance of a Network. A feeder from Cant Grid Station located in Peshawar, Pakistan is selected for simulation because of the higher line losses and longer power outage durations. The test feeder is carefully designed on the basis of actual data collected from the grid station and from field surveys. Bus number 7 is excluded from the simulation. Figure 1 shows the single line diagram of the test feeder.

B. *DG Interconnection Scenarios*

In order to verify the effects of PV, synchronous and induction machines on the test system, the following scenarios are modeled with three different combinations:

1. In this case no DG unit is connected and the results obtained from this will be used as a base for comparison of different DG sources.
2. 1.5MW synchronous generator is connected to the system in the following scenario.
   a) First the DG unit is connected at bus 2.
   b) Then the DG unit connected at bus 6.
3. 1.5MW induction machine (Wind Turbine Generator) is connected to the system in the following scenario.
   a) First the DG unit is connected at bus 2.
   b) Then the DG unit is connected at bus 6.
4. 1.5MW PV module is connected to the system in the following scenario.
   a) First the DG unit is connected at bus 2.
   b) Then the DG unit is connected at bus 6.

TABLE I. RATINGS OF TEST FEEDER TRANSFOMERS

ID	Transformer Ratings (kVA)
At bus 2	50
At bus 3	100
At bus 4	100
At bus 5	100
At bus 6	200
At bus 7	1000

ISSN: 2409-2770

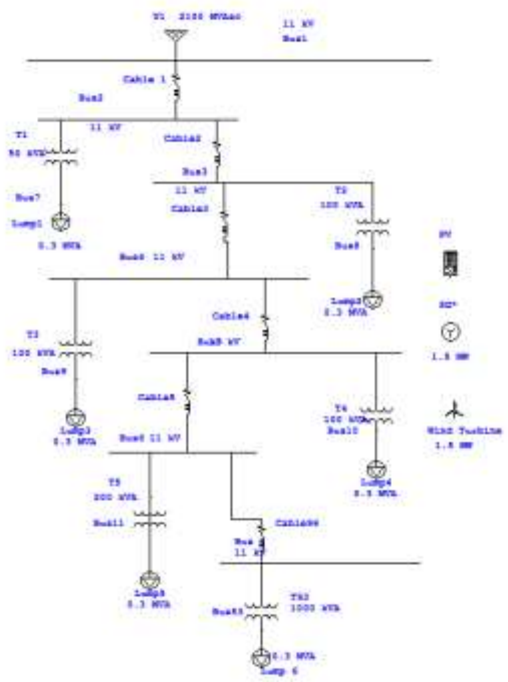

Figure 1. Test System

IV. IMPACT OF DG ON VOLTAGE PROFILE

Voltage stability analysis has been done using different techniques such as static and dynamic methods. The static technique can be analyzed by using the relation between the receiving power and the voltage at a certain point in a system [5]. The injection of a certain DG unit in a distribution system can enhance or decrease the voltage profile of the system depending on their operation at unity, leading or lagging power factors [6]. Voltage drop occurs due to the impedance of a certain component. The voltage drop varies with the injection of a certain DG unit. Table II shows the bus voltages for all the buses with and without the impact of DG; with DG units installed only on bus 2 and 6 respectively.

When no DG unit was connected in first case, voltage drops were increasing towards the final load point, because of the radial structure of the test system. This is shown in the figures 2, 3 and 4 respectively.

The effects of SG, WT and PV on the voltage profile of the buses are also shown in the figures 2, 3 and 4 respectively. The source voltage of the test circuit is 11kV. With the injection of a DG unit, voltage levels of the system buses varies; subject to the type, size and location of the DG unit. 132 kV Power grid is considered as a source for the test system. All the DG units connected to the test feeders are synchronized with the system having same terminal voltage at point of common coupling.

TABLE II. VOLTAGE PROFILE OF ALL BUSES WITH AND WITHOUT DG(S) IN KV

Bus No	No DG	SG at BUS 2	SG at BUS 6	WTG at BUS 2	WTG at BUS 6	PV at BUS 2	PV at BUS 6
2	10.93	10.99	10.98	10.97	10.97	10.97	10.97
3	10.81	10.87	10.95	10.86	10.95	10.86	10.95
4	10.72	10.78	11.01	10.77	10.96	10.74	10.96
5	10.67	10.72	11.07	10.71	10.99	10.71	11.01
6	10.64	10.69	11.15	10.68	11.06	10.68	11.07

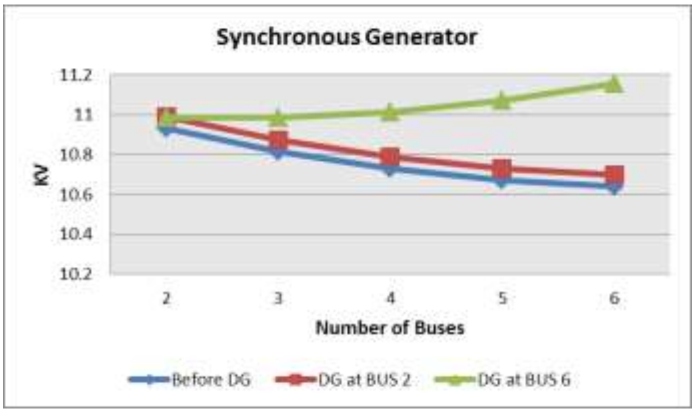

Figure 2. Voltage profile of all buses with Synchronous Machine.

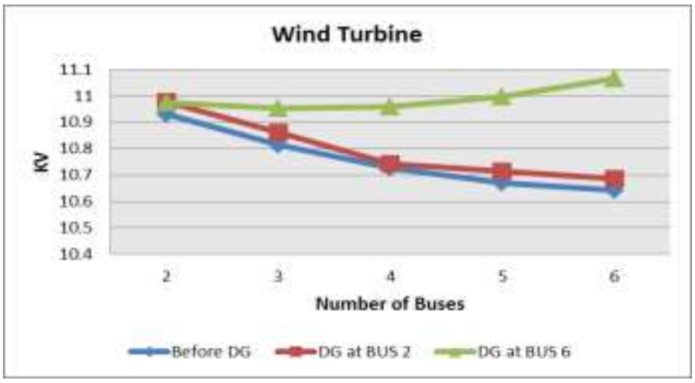

Figure 3. Voltage profile of all buses with Induction Machine

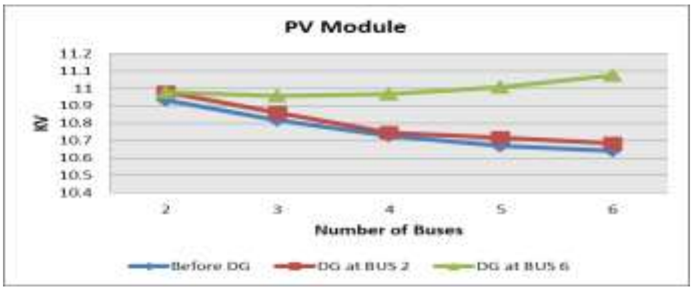

Figure 4. Voltage profile of all buses with PV

V. Impact Of DG On Power Losses

DG units may increase or decrease grid losses depending on their nature and the installed capacity [7]. The transmission of active and reactive power via overhead lines, underground cables and transformers gives rise to power losses. Insertion of a certain DG unit nearer to the consumers might have a positive or a negative effect on the system losses. In a purely loaded networks a DG unit of smaller size is likely to decrease the losses, provided both load and generation are located on the same feeder [8].

Different simulation results obtained from this research work reflects the impact of DG units on the system's active as well as the reactive power losses. Losses of all the lines in different scenarios are given in table III and IV respectively.

Figure 5 shows that the active power losses are decreasing with all the DG sources installed at bus 2. However when they were placed at bus 6, losses of the system increased significantly with WT compared to the SG and PV; as both the sources are indicating a decrease in active power of the system. On the other hand, figure 6 shows that the reactive power losses are decreasing with all the DG units installed at bus 2. With the DG units at bus 6 reactive power losses have minimized in the case of SG as well as with PV in comparison with DG units at bus 2, however with WT at bus 6 the said losses have increased significantly.

TABLE III. Effect of DGs on Losses (Active) of the System in KW

Bus Number	Before DG	With SG	With WTG	With PV
2	56	53.2	55.6	54
6	56	49.2	62.3	50

TABLE IV. Effect of DGs on Losses (Reactive) of the System in Kvar

Bus Number	Before DG	With SG	With WTG	With PV
2	54.4	41.5	53	45
6	54.4	25.5	90.3	28.6

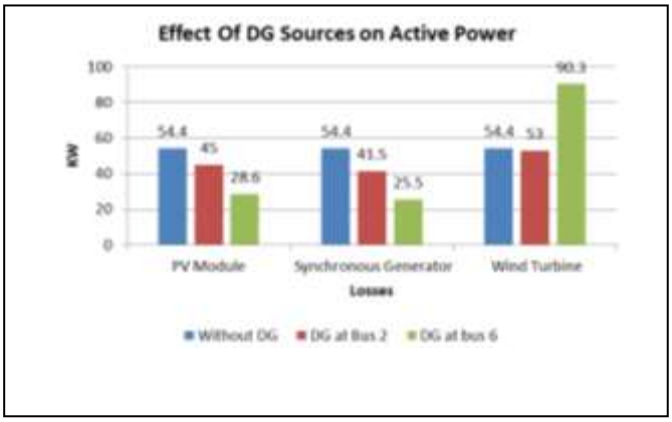

Figure 5. Effect of DGs on Active power

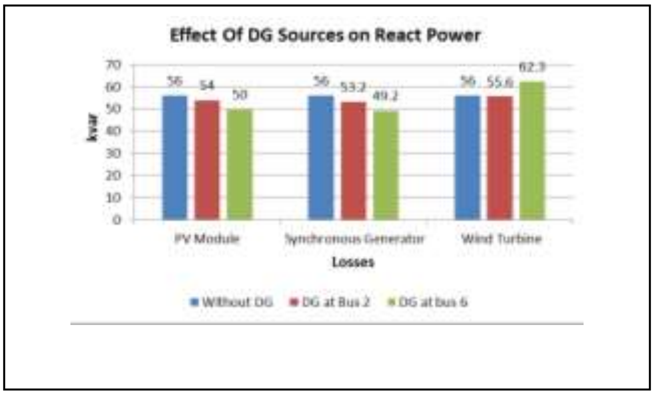

Figure 6. Effect of DG on Reactive Power

Some losses also occur in distribution transformers of rating 11/0.4 kV and cables which supplies power to 11kV loads directly. A 2% drop in cables is considered for simulation purposes, which is also the default rating of ETAP though these losses remain constant for all the test scenarios.

Results clearly show that the power losses can be altered with a certain DG source in a radial distribution system but that purely depends on the generating capacity and nature of DG unit as well as its location in the system.

VI. Conclusion

From the analysis of the test system, it can be concluded that integration of DG units significantly effects the traditional distributive network. It can be clearly seen from the results that all the sources improves voltage profile of the system. Among the sources synchronous machine shows significant improvement in the voltage profile. On the hand, power losses are greatly affected by the use of different sources. PV injects only real power in the system which in turn reduces the current flow in the lines and thus reduces active power losses. On the other hand synchronous machine injects both the active as well as reactive power into the system resulting a reduction in overall losses of the system, while induction machine (Wind Turbine Generator) injects only real power and absorbs reactive power from the system due to which current flowing in the lines increases thus enhancing the overall line losses of the system.

References

[1] W. EL-Khattam, and M. M. A. Salama, “Impact of Distributed Generation on Voltage Profile in Deregulated Distribution System,” Proceedings of the Power Systems 2002 Conference, Impact of Distributed Generation, Clemson, SC, USA, pp. 13-14, March 2002

[2] P. Barker, and R. W. De Mello, " Detennining the Impact of Distributed Generation on Power Systems: Part 1 - Radial Distribution Systems," IEEE Trans. Power Delivery, vol. 15, no. 4, pp. 22-28, April 1999K. Elissa, “Title of paper if known,” unpublished.

[3] D.Q. Hung, N. Mithulananthan, and R.c. Bansal, "Analytical expression for DG allocation in primary distribution network," IEEE Trans. on energy conservation, vol.2 5, pp 814-820, Sept 2010.

[4] E. Bamdad, “High Penetration Photovoltaic System Analysis”, MSc. dissertation, Department of Electrical Engineering, California State University, Northridge, 2014, Pg 37-38.

[5] C.A.Canizaresand and F.L.Alvarado,“Point of collapse and continuation methods for large AC/DC systems,” IEEE Trans. Power Syst., vol. 8, no. 1, pp. 1–8, Feb. 1993.

[6] R. A. Walling, R. Saint, R. C. Dugan, J. Burke, and L. A. Kojovic, “Summary of distributed resources impact on power delivery systems,” IEEE Trans.Power Del.,vol.23,no.3,pp.1636–1644,Jul.2008.

[7] M. Wolter and L. Hofmann, ”General estimation of the impact of additional DG sources on distribution grids”, accepted for presentation at IEEE PES General Meeting 2011, Detroit, United States 2011.

[8] I. Leiße, “Efficient Integration of Distributed Generation in Electricity Distribution Networks”, PhD. dissertation, Department of Measurement Technology and Industrial Electrical Engineering, Lund University, 2013, Pg 174.