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EFFICIENCY AND COMPENSATION UNDER MODERN POWER SYSTEM OF DISTRIBUTED GENERATION

Vaibhav Koshta, Department of Electrical Engineering, Raipur Institute of Technology, Raipur, India 1;
Manoj Kumar Nigam Department of Electrical Engineering, Raipur Institute of Technology, Raipur, India 2;

Abstract

Distributed generation (DG) units are based on the renewable sources of energy like solar energy, tidal energy, wind energy etc. and are proving to be a boon in today's power generation utilities. The Distributed Generation is playing a very important role in today's scenario, therefore it is important to study the characteristics of the distributed generation and also what changes are to be made in the existing network so that its function is not altered with the integration of distributed generation. For the purpose of study, an IEEE-14 bus radial distribution network is selected and the simulation results were obtained using PSAT 2.1.7 showed the effects of Distributed Generation on the network's voltage profile, reactive power profile as well as active power profile.

Introduction

The traditional methods used in the past for power generation include a centrally located power generation unit which can generate power from few MW (Mega Watt) to several MW. But the main disadvantage of these power generation units indicated to use the non-renewable sources of energy like coal to produce harmful gases and toxic elements affect the ecological balance in the direct or indirect way. As per the demand of power requirement increasing day by day it will be not possible to install such a huge production plant everywhere on the basis of economical view and due to the limited sources of non-renewable energy. Therefore there is a felt of need of the engineer to look upon an alternate method to utilize chief sources of renewable energy. A small generation unit of distributed generation can be installed at any of the location and have variable production capabilities over a large range depending on the requirement of a particular site. Also DG units are based on the renewable sources of pollution free energy (viz. wind, solar, tidal energy etc.) and do not produces any harmful industrial toxic by-products in nature adversely affecting the surroundings. On the basis of these reasons, distributed generation technology is one of the prime interests of the engineers presently.

Although, distributed generation has several meaningful advantages. Besides this their integration into the existing network causes disturbances on the network operation like:

1) The voltage stability of the network
2) Reactive power requirement
3) Active power requirement of the network etc.

Prior to this much work has been done in the past related to the integration of distributed generation like optimal size and location of the distributed generation to avoid the network affect. Under the present study, the detailed analysis at the time of introducing a DG for the normal operation of any pre-existing network was done. The effects caused by DG had been done on an IEEE-14 bus radial distribution network and the simulation of the network by using PSAT 2.1.7.

Few of the available DGs' technologies are listed out as below:

1) Micro Turbines.
2) Wind Turbines.
3) Fuel Cells.
4) Internal Combustion engines.
5) Photovoltaic Arrays.
6) Biomass Gasifies.

Several methods have also been suggested by different authors for determining the optimal size and location of distributed generation like the genetic algorithm approach was suggested in [6], Monte Carlo search method for determining the optimal size of DG in [5], an optimization using particle swarm method which considers a cluster of particle moving in a random manner and reaching to their destiny thus the particle with minimum value of the desired variable considered as the optimal was recorded by [19]. Likewise, some other methods viz. Ant Colony Optimization, Optimal Power Flow, etc. had been suggested in [2], [7].

Several methods had also been suggested for the compensation of the effects of DG in [17] as follows:

1) Lined voltage regulators
2) Increased size of conductors
3) Reduced output of generators
4) Installation of shunt reactance in the network
5) Reduced voltage at the feeding substation
6) Allowing a greater reactive power for the generator

to import.

The method was adopted for finding the optimal location of DG and suggested implementation had been explained under methodology section. A STATCOM had been applied to compensate the effects. Results of the effect of DG and compensation technique are stated under result section.

Methodology

IEEE-14 bus radial distribution network has been designed using the PSAT 2.1.7 (Power System Analysis Toolbox). It uses the MATLAB for simulating any network configuration. Configuration of an IEEE-14 bus network (**Figure. 1**), IEEE-14 bus network with DG connected (**Figure. 2**) and network architecture of an IEEE-14 bus network with DG and STATCOM connected (**Figure. 3**) are explained likewise.

The simulation results provided the optimal location of DG from the study of the weakest bus. However the variation in the voltage profile without DG (**Figure. 4**) and with DG and STATCOM (**Figure. 5**) may be seen respectively.

The load flow result without DG connected to the power system (**Table. 1**), the load flow results with DG connected (**Table. 2**), the load flow result with DG and STATCOM both connected (**Table. 3**) and the reactive power and active power loss when DG and STATCOM are connected (**Table. 4**) are listed respectively.

A. Size and location of Distributed Generation

The placement of distributed generation in a distribution system improved the voltage profile with reduced losses. However, placing DG only at optimal location is not sufficient wherein the size of the DG should also be determined for its efficient working. Wind based distributed generation of 50MVA and 11kV had been connected under the study. Authors of [1], suggested the method for finding the weakest node for the optimal location of DG in any grid connected network. The weakest node may be traced out by searching of the maximum voltage drop i.e. the bus with the smallest voltage magnitude is the weakest bus.

The weakest bus was observed in the bus no. 14, 13, and 12 whereas bus no. 14 being the weakest bus and the most suited location for the installation of DG. The engineers may also advise to install the DGs' at bus no. 12 and 13 as and when required.

B. Size and location of STATCOM

The STATCOM device connected was of 100MVA and 11kV. The location of the STATCOM was obtained from the load flow results of **Table. 2**. From **Table. 2** the most sensitive bus is determined i.e. the bus with maximum amount of reactive power loss and it is showed that the bus-9 is the most sensitive bus.

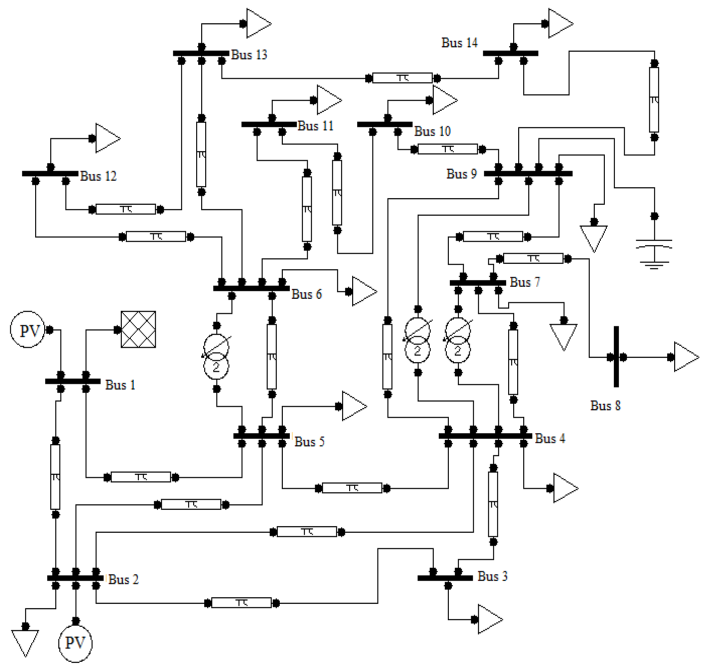

Figure 1. Simple load flow diagram

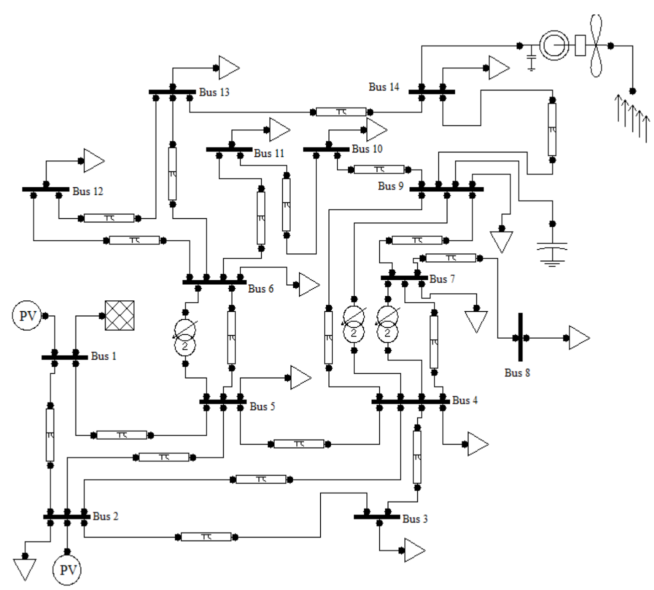

Figure 2. Load flow diagram with DG connected

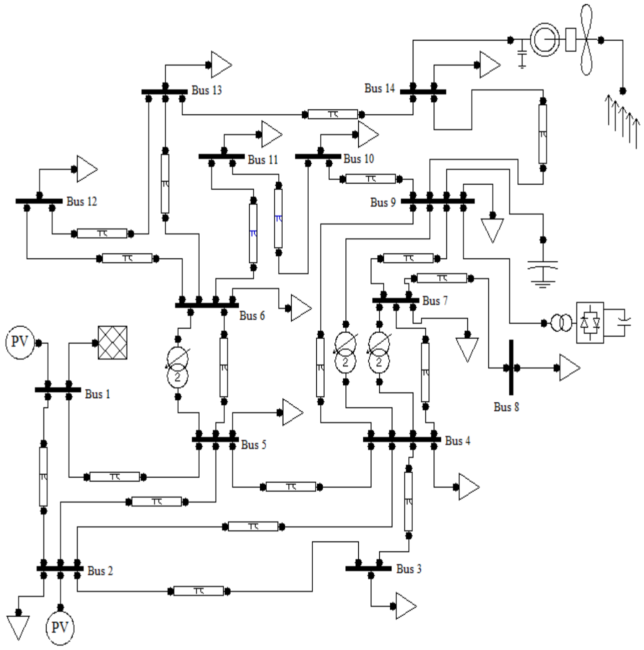

Figure 3. Load flow diagram with DG and STATCOM connected

Result

From the continuation power flow method, voltage profile was improved with the introduction of distributed generation into the network. The disturbances arisen were eliminated through the STATCOM for increasing the stability, reliability and the performance of the power system.

The comparison between the simulation results obtained from simple load flow and load flow with DG and STATCOM connected can be seen (**Figure. 4 and 5**) respectively, showed that with the integration of distributed generation the voltage of the network is improved.

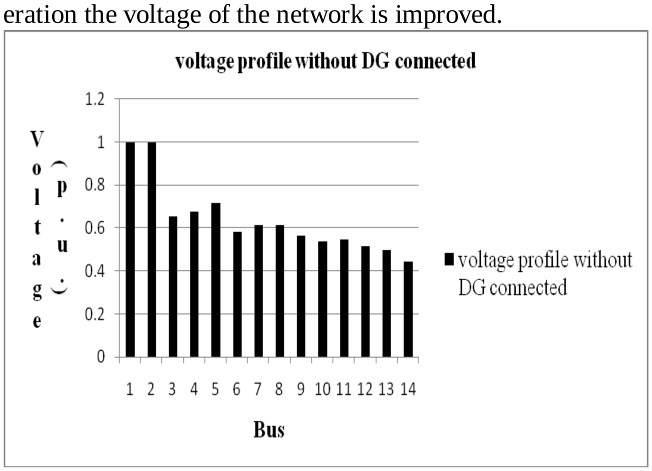

Figure 4. Voltage profile without DG

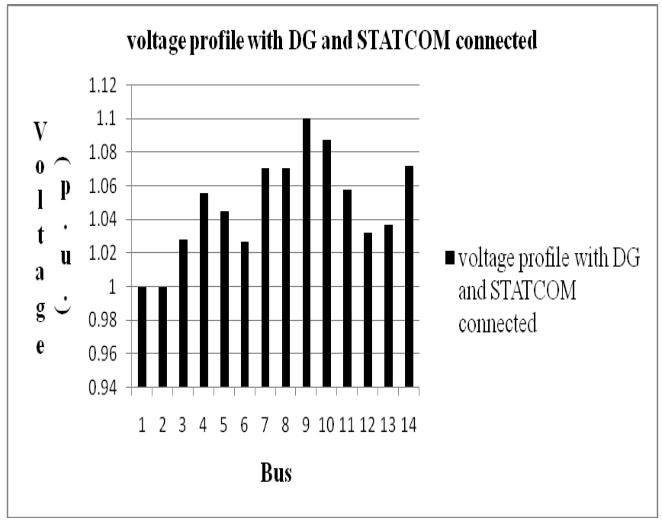

Figure 5. Voltage profile with DG and STATCOM

Table 1. Load flow analysis without DG

Bus	Voltage	Reactive power at load (p.u)	Active power at load (p.u)
Bus 1	1	0	0
Bus 2	1	0.25444	0.43476
Bus 3	0.65532	0.38267	1.8873
Bus 4	0.6775	0.07814	0.95767
Bus 5	0.71529	0.03206	0.15227
Bus 6	0.58035	0.15026	0.22439
Bus 7	0.61492	0	0
Bus 8	0.61497	0	0
Bus 9	0.56355	0.27224	0.59103
Bus 10	0.5372	0.1162	0.18032
Bus 11	0.54466	0.03606	0.07012
Bus 12	0.51611	0.03206	0.12221
Bus 13	0.49604	0.1162	0.27047
Bus 14	0.44386	0.10018	0.29852

Table 2. Load flow analysis with DG

Bus	Voltage	Reactive power at load (p.u)	Active power at load (p.u)
Bus 1	1	0	0
Bus 2	1	0.25445	0.43477
Bus 3	0.65662	0.38268	1.8874
Bus 4	0.67908	0.07814	0.9577
Bus 5	0.71672	0.03206	0.15227
Bus 6	0.58252	0.15027	0.2244
Bus 7	0.61686	0	0
Bus 8	0.61692	0	0
Bus 9	0.56583	0.27176	0.59105
Bus 10	0.53959	0.11621	0.18032

Bus 11	0.547	0.03606	0.07012
Bus 12	0.51869	0.03206	0.12222
Bus 13	0.49877	0.11621	0.27048
Bus 14	0.44707	0.10018	0.29853

Table 3. Load flow analysis with DG and STATCOM

Bus	Voltage	Reactive power at load (p.u)	Active power at load (p.u)
Bus 1	1	0	0
Bus 2	1	0.00598	0.01022
Bus 3	1.0281	0.00899	0.04435
Bus 4	1.0557	0.00184	0.0225
Bus 5	1.0454	0.00075	0.00358
Bus 6	1.0273	0.00353	0.00527
Bus 7	1.0708	0	0
Bus 8	1.0709	0	0
Bus 9	1.1007	-1.103	0.01389
Bus 10	1.0876	0.00273	0.00424
Bus 11	1.058	0.00085	0.00165
Bus 12	1.0323	0.00075	0.00287
Bus 13	1.0372	0.00273	0.00637
Bus 14	1.0724	0.00235	0.00702

Table 4. Line flow result with DG and STATCOM

From Bus	To Bus	Reactive power loss (p.u)	Active power loss (p.u)
Bus 1	Bus 2	-0.00059	0.00013
Bus 2	Bus 3	0.00376	0.00114
Bus 9	Bus 4	0.00262	0
Bus 7	Bus 9	0.00709	0
Bus 10	Bus 9	0.00063	0.00069
Bus 11	Bus 6	0.00308	0.00199
Bus 12	Bus 6	-0.00098	4e-005
Bus 13	Bus 6	-0.00037	0.00035
Bus 14	Bus 9	0.00131	0.00117
Bus 11	Bus 10	0.00288	0.00172
Bus 13	Bus 14	0.00192	0.00149
Bus 12	Bus 13	-0.001	8e-005
Bus 2	Bus 4	0.01778	0.00621
Bus 2	Bus 5	0.01121	0.00401
Bus 1	Bus 5	0.00984	0.00264
Bus 4	Bus 3	0.00323	0.00169
Bus 5	Bus 4	0.00221	0.00105
Bus 6	Bus 5	0.00024	0
Bus 7	Bus 4	7e-005	0
Bus 7	Bus 8	-0.00115	0
Bus 9	Bus 4	0.03252	0.00163
Bus 7	Bus 4	0.00779	0.00039
Bus 6	Bus 5	0.01613	0.00081

The result of the simulation showed that the reactive and the active power losses were reduced with the DG connected to the power system and improvement was noticed in the reactive and active power loss from 5.3766p.u to 0.12023p.u and from 1.4297p.u to 0.02723p.u respectively.

Conclusion

On the basis of above analysis it had been concluded that distributed generation showed many advantages such as this technology does not pollute the environment, support installation at any costumer site, economic, variable production capacity, use of renewable sources of energy, reduces the losses and improve the stability of the network. On the other hand, it can disturb also the normal operation of the network when interfaced. Therefore, it is important that before integrating it to any network the exact location and size of the distributed generation must be identified for its most efficient use.

The method used under the study does not include solving the complex and large mathematical equations for the network parameter identities efficiently and effectively with highly economical software available at free of cost for simulation.

Here, the simulation was done firstly without the connection of DG to the network and the most critical bus is identified for DG connected to the network. It is concluded that the bus-14 is the weakest bus and is the most preferred location of DG, whereas the DG units can also be connected at bus-12 and bus-13 if necessary. The STATCOM position was identified from the nodes with the maximum reactive power loss and the optimal location of STATCOM was the bus no. 9 (**Table. 2**).

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Biographies

FIRST A. VAIBHAV KOSHTA received the B.E degree in Electronics and Telecommunication Engineering from Disha Institute of Management and Technology, Raipur, Chhattisgarh, India in 2011, he is an M.E. scholar in Electrical Engineering department of Raipur Institute of Technology and Engineering, Raipur, Chhattisgarh, India. Vaibhav Koshta may be reached at koshta_vaibhav@yahoo.com

SECOND B. MANOJ KUMAR NIGAM received the B.E. degree in Electrical Engineering from MITS Gwalior, M.P., India in 2002, the M.E. degree in electrical engineering from MITS Gwalior, M.P., India in 2008 and is a Ph.D scholar in Electrical Engineering department of R.K.D.F University, Bhopal, M.P., India. He is an associate professor in the Electrical Engineering department of Christian College of Engineering and Technology, Bhilai, Chhattisgarh, India. His teaching and research area include Distributed generation and power quality Issues in the Power System.