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Placement of Distributed Generating Units into Distribution Networks by Considering Losses at different loading conditions

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Abstract- This paper presents two different but very important aspects of distribution network that's voltage profile and losses. By keeping in view of these parameters this is to be decided where the distributing generating Units must be placed in distribution network. In the present and future Distributed generation (DG) has its vital importance due to more demand of electricity and renewable nature of DG. But there are some constraints when its comes to place DG in a distribution network so here proper placement of DG will be done by going through the losses reduction at different buses in a 15 bus network.

Index Terms – distributed generation, distribution systems, power losses, voltage stability, protection coordination.

I. INTRODUCTION

A distribution system plays an important role in electrical studies and most wide part of the power system. The penetration of distributed generation and wind power in particular is expected to increase significantly over the coming years, and a huge shift in control, operation and planning of distribution networks is going to be necessary if this generation is to be connected in a cost effective manner. Traditionally, distribution networks have been operated as passive networks with uni-directional power flows and were designed through deterministic (load flow) studies considering the critical cases so that distribution networks could operate with a minimum amount of control. With the connection of increasing amounts of distributed generation, these networks are becoming active and with power flowing in the two directions, hence requiring more intelligent forms of management. So proper care must be taken of the technical and economical aspects.

Distributed generation (DG), is the important power that is available near the load and can be attached to the main distribution system. There are many forms of distributed generation and each of these has varying ratings as:

- Reciprocating Engine: Diesel:30kW–6 MW
- Micro turbine 30-400kW
- CombustionGas Turbine:500 kW – 30 MW
- Fuel Cell 100 kW -3MW

It is, however, important to emphasize that if the predictions of the Electric Power Research Institute (EPRI) and the Natural Gas Foundation, which predict that by the year 2010, 25–30% of new generation will be distributed, will become reality, it will be likely that DG satisfies the majority of the energy needs within certain distribution networks. Therefore, the analysis of DG should always take into consideration that the penetration of DG could reach a significant level. Because voltage oscillations, interfere in voltage control processes, reduce or increase losses, etc.

Generally, distribution systems should be reanalyzed as the DG impacts are significant for both planning and operation of distribution networks. Nevertheless, problems related with protection devices and coordination schemes require a special attention since they may weaken the reliability of the system. The connection of DG to electric power systems has been a topic of investigation with high relevance in the last years. In result of that, many research activities on the impacts resulting from DG connection to distribution systems has been presented.

In the view point of power losses, an assessment of energy distribution losses for increasing penetration level of distributed generation was presented [7]. Another point discussed with DG units is the impact of distributed generation on distribution contingency analysis [8]. Quantifying of DG units was presented with their suitable site was performed using an optimal and analytical quantifying [2] and [9], respectively. A review of the DG units for protective devices coordination was presented [10, 11]. From the literature[3], it is found that: the major customers' applications of DG insertion are:

- Properly located, installed and operated DG can improve reliability of energy supply, increasingly critical to business and industry in general, and essential to some where interruption of service is unacceptable economically or where health and safety is impacted;

- The various DG technologies offer the opportunity of selecting the right energy solution at the right location. DG technologies can provide a stand-alone power option for areas where transmission and distribution infrastructure does not exist or is too expensive to build;
- DG may offer efficiency gains for on-site applications by avoiding line losses, and using both electricity and the heat produced in power generation for processes or heating and air conditioning;
- Its flexibility of operation because of small modular units enables savings on electricity rates by self generating during high-cost peak power periods and adopting relatively low cost interruptible power rates;
- Benefits for environmental quality may come from distributed generation's role in promoting renewable energy sources, less-polluting forms of fossil energy, and high efficiency technologies. DG allows power to be delivered in environmentally sensitive and pristine areas by having characteristically high efficiency and near-zero pollutant emissions;
- Affords customers a choice in satisfying their particular energy needs and Provides siting flexibility by virtue of the small size, superior environmental performance, and fuel flexibility.

Impact of DG on the power system

In traditional power systems large central generation plants have been utilized to generate electrical power. The traditional or classical power system can generally split up into three parts :

1. Generation of electrical power
2. Transmission of electrical power
3. Distribution of electrical power

Large power plants are built in areas with sufficient cooling water and where fuel supply routes are available. Hence, most central power plants are located at specific remote sites and are connected to an extended transmission grid which transfers bulk electrical power to the distribution grids. The distribution grids take parts of the transmitted power and serves the connected loads. This way of power system operation is often called a vertically-operated power system. Most local decentralized (distributed) generation sources are small in size and mainly connected to the distribution grid. Because of the implementation of DG in the distribution grid the electrical power is generated closer to the load which will affect the local power flow . In the near future an increasing penetration level of DG is expected and the total amount of generated electric power can exceed the total connected load. As a consequence the distribution grid can start exporting electrical power to neighboring distribution grids what converts the power system into a horizontally operated power system. Large scale integration of DG in distribution grids can have a significant impact on power system operation. Therefore many research projects are defined and numerous studies on integration issues of DG are carried out. In general it is necessary to keep the voltage of a transmission or distribution grid within specified limits for all possible loading conditions. The integration of DG can significantly change the power flow in the distribution feeder and hence affect the feeder voltage. The voltage profile is not violated when the injected power by the DG is less or about equal to the load of the feeder. In this case the energy supplied by the grid is decreasing as well as the current through the feeder and it results in a reduced voltage drop. However, when the generated power exceeds the load of the feeder, the power flow reverses and voltage rise occurs. This voltage rise is a function of the amount of DG and the short-circuit power of the grid at the point of connection.

The effect of reversed power flow is getting worse when the DG injects reactive power as well. However, in distribution grids with cables with a large diameter, the resistance cannot be neglected and hence the voltage drop depends both on active and reactive power.

DG might have an intermittent character like wind turbines generate electrical power during periods of sufficient wind and solar panels are producing electricity when sufficient sunlight is available. Because these natural resources have a stochastic behavior the output of these renewable energy resources behave in a similar matter. In stochastic modeling of power systems is developed and applied on distribution grids to determine what the effect of the stochastic behavior of DG-units is on power flows and voltage profiles of distribution feeders. Traditional power systems are characterized by a relative low number of high rated generators spread out over a defined area. Integration of a large number of DG, but also aggregated power plants built up from small generators like for instance wind parks, leads to an additional high number of units with a relative low rating in these power systems. To cope with these large number of units in power system dynamic studies, aggregated models have to be developed. In an aggregated model of a wind park is obtained by applying a method based on the detection of a group of coherent wind turbines within the wind park. The coherent wind turbines are defined as units within a farm that obtain a similar input wind profile and, therefore, have similar operating points. A single equivalent wind turbine can replace such a group of units during the simulation of the power system without significant influence on the dynamic behavior of the farm.

It was concluded that a DG penetration level of 30 % does not lead to main transient stability problems. In the power system sufficient inertia have to be present to guarantee stability for higher penetration levels of DG especially when DG is grid connected via power electronic interfaces . Besides the studies on the effect of DG on

power systems detailed studies on the effect of DG on distribution grid operation are also performed. In a faulted distribution grid the connected DG can contribute to the fault current and directly influences the fault detection in the distribution grid. Because of the increasing number of small inverter connected DG it might be expected that in the distribution grids the harmonic currents increase as well. It is studied what effect harmonic currents have on the performance of the protective system and it is concluded that modern protection relays are insensitive for harmonic currents. The effect of DG on fault current detection in low voltage grids is investigated and it is stated that in these grids the effect of DG on the fault current is the largest for a single phase to neutral fault. In this thesis the results are verified and the study is extended with an analysis of the effect of distribution grid protection on the dynamic behavior of DG.

Distributed generation (DG) is currently being used by some customers to provide some or all of their electricity needs. There are many different potential applications for DG technologies. For example, some customers use DG to reduce demand charges imposed by their electric utility, while others use it to provide primary power or reduce environmental emissions. DG can also be used by electric utilities to enhance their distribution systems. Many other applications for DG solutions exist. The following is a list of those of potential interest to electric utilities and their customers.

II. TECHNICAL ASPECTS OF DG INTEGRATION

The increasing penetration of DG affects the various parameters which much be kept in mind while inserting DG into a distribution network. The definition of distributed generation does not define the rating of the generation source, as the maximum rating depends on the local distribution network conditions, e.g. voltage level. It is, however, useful to introduce categories of different ratings of distributed generation. The following categories are suggested:

Micro DG	: 1 Watt to 5 KW
Small DG	: 5 KW < 5 MW
Medium DG	: 5 MW < 50 MW
Large DG	: 50 MW < 300 MW

The aspects referred to the technical side are Voltage rise effect, power quality, protection and stability. These aspects are presented as follows:

Voltage rise effect

The voltage rise effect is a key factor that limits the amount of additional DG capacity that can be connected to rural distribution networks.

Power quality

Two aspects of power quality are usually considered to be important. These aspects are transient voltage variations and harmonic distortion of the network voltage. DG plant can either decrease or increase the quality of the voltage received by other users of the distribution network.

Protection

A number of different aspects of DG protection can be identified as protection of the generation equipment from internal faults; protection of the faulted distribution network from fault currents supplied by the DG; anti-islanding or loss-of-mains protection (islanded operation of DG will be possible in future as penetration of DG increases) and impact of DG on existing distribution system protection. All these aspects are important and need to be carefully addressed in connecting DG to distribution networks.

Stability

Traditionally, distribution network design did not need to consider of stability issue. The areas that need to be considered include transient stability as well as long term dynamic stability and voltage collapse.

III. PROPOSED APPROACH

This paper aimed at evaluating the integration of DG units to a real distribution system through measurable indices as:

- The active and reactive system power losses which equal the difference between the total generated power and the total power demand.
- The voltage profile at generation nodes

The steps of the proposed approach are:

- Simulating the power system using Power World simulator software.
- Ranking the nodes according to their loading level,
- Measuring evaluation indices for the operating case.
- Selecting the DG best location at different loading levels according the measurable power loss index.
- Check the effects of DG insertion.

IV. APPLICATIONS

A. Test System

Figure 1 given in appendix represents a 15 bus system of a town near Panipat city in India. The distribution system configuration contain 15 nodes. The voltage level of all the buses at 11 KV. The basic data for the distribution system is given in table 1

For all studied case, the average power factor for the feeder is (0.82). The load factor and load loss factor are assumed as 0.8307 and 0.7322, respectively. The voltage at the first node on the feeder is (11 kV).

Table 1: Basic Data for the Distribution System

Node	line		length	Line parameters		
	From	to		R (Ω/km)	X (Ω/km)	Y/2
2	1	2	0.08	0.163	0.0892	.00007
3	2	3	0.85	0.266	0.0949	.00005
4	3	4	0.22	0.569	0.1062	.00004
5	4	5	0.05	0.569	0.1062	.00004
6	4	6	0.33	0.569	0.1062	.00004
7	6	7	0.2	0.569	0.1062	.00004
8	7	8	0.04	0.569	0.1062	.00004
9	7	9	0.65	0.266	0.0949	.00005
10	9	10	0.15	0.569	0.1062	.00004
11	10	11	0.1	1.113	0.1172	.00003
12	6	12	0.44	0.569	0.1062	.00004
13	12	13	0.15	0.266	0.0949	.00005
14	13	14	0.45	0.266	0.0949	.00005
15	14	15	0.2	0.266	0.0949	.00005

B. DG Simulation Methods

This paper represents three cases of simulation, in each case at selected buses the DG capacity will be increased at the rate of 0.5 MW, and simultaneously P & Q Losses and Voltage will be observed.

In Starting, an Ideal source is inserted at 11 KV , asymmetrical at load angle 30° , frequency at 50 Hz (R&L series sources $R_s=0.00893 \Omega$ - $L_s= 16.52e-5 \text{ H}$)

C. Three Cases has been studied

For all the Cases same different loads have been taken.

Case 1 : Insertion of DG at Bus 7

The total Power Losses without inserting the DG is 0.43 MW and when the DG is inserted at the rate 0.5 MW upto to 5 MW capacity then Losses are reduced to 0.12.The DG is inserted to the simulation model at the same voltage and load angle with R&L series parameters as $R_{DG}=0.08829 \Omega$ & $L_{DG} = 15.92 \text{ mH}$. The results have been mentioned in table 2 after insertion of DG at Bus 7.For case 1

$L_1 = 2 \text{ MW}$, $L_2 = 1 \text{ MW}$, $L_3 = 1 \text{ MW}$

$L_4 = 1 \text{ MW}$, $L_5 = 1 \text{ MW}$, $L_6 = 1 \text{ MW}$

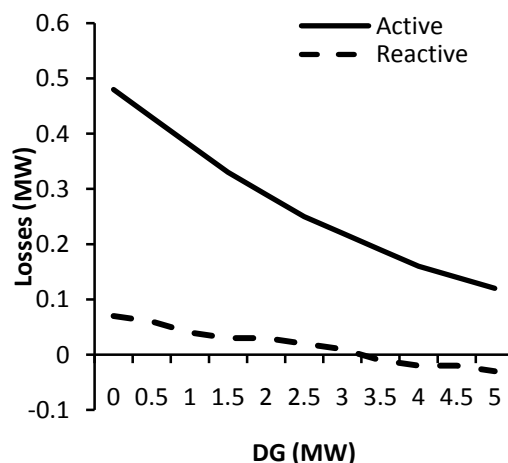


Figure 1: Case 1 losses when DG is at Bus 7

Case 2 : Insertion of DG at Bus 9

The total Power Losses without inserting the DG is 6.74 MW and when the DG is inserted at the rate 0.5 MW upto to 5 MW capacity then Losses are reduced to 2.99. The DG is inserted to the simulation model at the same voltage and load angle with R&L series parameters as $R_{DG}=0.08829 \Omega$ & $L_{DG} = 15.92 \text{ mH}$. The results have been shown in Figure 2 after insertion of DG at Bus 9. For Case 2

L1 = 5 MW , L2 = 3 MW , L3 = 4 MW

L4 = 6 MW , L5 = 5.5 MW , L6 = 3.5 MW

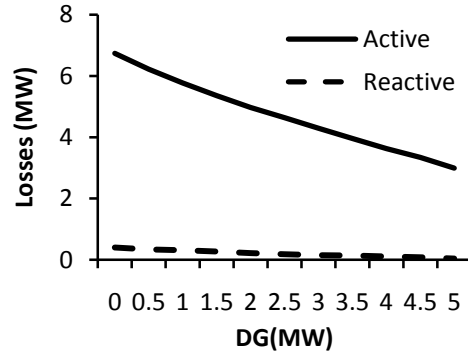


Figure 2: Case 2 losses when DG is at Bus 9

Case 3 : Insertion of DG at Bus 2

The total Power Losses without inserting the DG is 7.89 MW and when the DG is inserted at the rate 0.5 MW upto to 5 MW capacity then Losses are reduced to 2.5. The DG is inserted to the simulation model at the same voltage and load angle with R&L series parameters as $R_{DG}=0.08829 \Omega$ & $L_{DG} = 15.92 \text{ mH}$. The results have been shown in figure 3 after insertion of DG at Bus 2. For Case 3

L1 = 6.6 MW , L2 = 3.9 MW , L3 = 4.5 MW

L4 = 9.6 MW , L5 = 5.5 MW , L6 = 7.5 MW

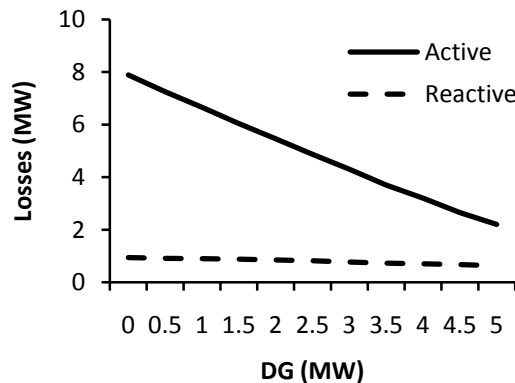


Figure 3: Case 1 losses when DG is at Bus 9

Voltage Profile:

From all the above three case, it has been observed that the voltage profile of the system is improved, and results are mentioned in Figure 4

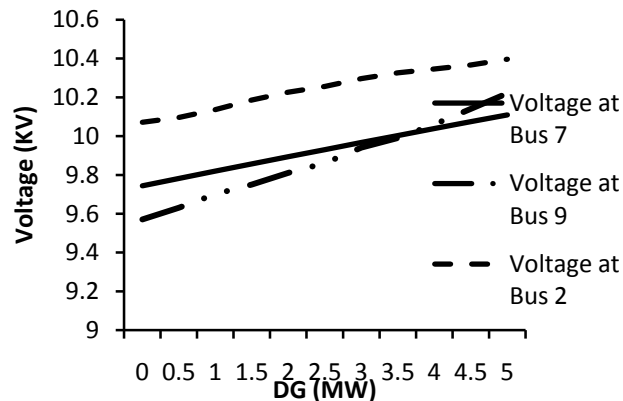


Figure 4: Voltage Profile at different buses

V. CONCLUSIONS

This Paper presents three cases of integrating Distributed Generation into Distribution system. Loads are different for all the cases, a 15 bus network have been taken at 11 KV. Three cases of DG integration have been discussed. DG have been inserted at bus 7, 9 and 2. The active and reactive for all the three cases have been studies. Losses are decreasing in every case. Maximum reduction of losses are in first case when DG is located at Bus 7. So that is the best location for DG.

By going through the results of all the three locations it can be concluded that the Bus 7 is the best location for the DG placement, as the percentage reduction of loss is observed here at bus 7. Therefore it is concluded that DG reduces the active/reactive power losses and improve the voltage profile of the distribution system.

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