OPTIMAL PLACEMENT AND SIZING OF MULTIPLE DG IN A RADIAL DISTRIBUTED SYSTEM USING LSF METHOD

[1]Nandini S Patil, [2] B.S.Khened, [3]Arthi Lakshman,[4]Kishorini M C

[1]Assistant Professor, [2]Professor and HoD, [3]Assistant Professor, [4]Assistant Professor

[1]Electrical and Electronics Engineering,

[1]Ballari Institute of Technology and Management, Ballari, India.

Abstract : In recent years, power industry has experienced continuous raise in the electrical power demand. For rapid growing demand implementation of smart grid technology and Distribution generation technology can be a potential solution. The distribution system generally designed for radial power flow, but with the introduction DG power flow become bidirectional. Many factor affecting DG allocations are availability of natural resources, types of DG technologies, types of distribution system, size and number of DG units. Distribution Generations can be beneficial in many ways when integrated into a distribution network, depending upon their location and size. This paper focus on use of Loss Sensitivity Factor Method for optimal location and size of DGs in the distribution network. The proposed algorithm is validated by applying it on IEEE33 bus system for single and multiple DG units. Programming is done by using Matlab software.

***Index Terms* - Distribution network, distribution generation, Load flow, loss sensitivity analysis.**

I. INTRODUCTION

In recent years, penetration of distributed generators in distribution systems has been increasing rapidly in many parts of the world. The main reasons for the increase in the penetration are the liberalization of electricity markets, constraints on building transmission and distribution lines, and environmental concerns[1]-[3].Technological advances in small generators ,power electronics and energy storage devices for transient back up have also accelerated the penetration of DG into electrical power generation plants[4].

At present, there are several technologies used for DG applications that the range from traditional to nontraditional technologies. The former is nonrenewable technologies such as internal combustion engines, combined cycles, combustion turbines and micro turbines. The latter is renewable technologies such as solar, photovoltaic, wind, geothermal, ocean and fuel cells. The main advantages of using renewable energy based DG sources are the elimination of harmful emissions and inexhaustible resources of the primary energy. But main disadvantages are relative low efficiency, high cost and intermittency [5][6]. As the penetration of DG units increases in the distribution system, it is the best interest of interest of all players involved to allocate them in a optimal way such that it will increase reliability, reduce some system losses and hence improve the voltage profile while serving primary goal of energy injection.

DG units are modeled as synchronous generators for small hydro, geothermal, and combined cycles; combustion turbines and wind turbines with power electronics. Induction generators used in wind and small hydro power generation. DG units are considered as power electronics inverter generators or static generators for technologies such as photo voltaic plants and fuel cells [7],[8] for instance. For instance, DG using a PV grid-connected converter is controlled on the basis of the droop-control technique presented in [9]. The converter is capable of providing active power to local loads and injecting reactive power to stabilize load voltages. Furthermore, the type of DG technology adopted will have a significant bearing on the solution approach. For example, in [18], the installation of synchronous machine-based DG units that are close to the loads can lead to a gain in the system voltage stability margin; on the other hand, in the case with an induction generator, the system stability margin is reduced. Given the choice, DG units should be placed in appropriate locations with suitable sizes and types to enjoy system-wide benefit. It is evident that any loss reduction is beneficial to distribution utilities, which is generally the entity responsible to keep losses at low levels. Loss reduction is, therefore, the most important factor to be considered in the planning and operation of DG.

For instance, multi objective index for performance calculation of distribution systems for single DG size and location planning has been proposed. DG allocation is basically a complex combinatorial optimization issue which requires concurrent optimization of multiple objectives, for instance minimizations of real and reactive power losses, node voltage deviation, carbon emanation, line loading, and short circuit capacity and maximization of network reliability etc. The goal is to determine the optimal location(s) and size(s) of DG units in a distribution network. The optimization is carried out under the constraints of maximum DG sizes, thermal limit of network branches, and voltage limit of the nodes, sensitivity analysis has been used for finding the optimal location of DG. The optimal location and sizing of DGs is predicted by finding the loss sensitivity factor. There are numerous optimization techniques used in the literature. An analytical approach to determine the optimal location and sizing of DG is presented.

II. PROBLEM FORMULATION

The main objective of this work is to minimize the real power loss in a radial distribution system which can be described as fallows.

Minimize $P_{TLoss} = \sum_{i=1}^{N} P_{iLoss}$

N=Number of bus in system

P_{Loss}=real power loss of the system

Subjected to the constraints

1)$V_{MIN} \le |V_i| \le V_{MAX}$ 0.90 P.U $\le |V_i| \le$ 1.05 P.U where, V_i=voltage at i[th] node

2) $P_{DGMIN} \le |P_{DGi}| \le P_{DGMAX}$

0.25 MW $\le |P_{DGi}| \le$Total Load+ loss

where, P_{DGi}=DG size at i[th] node

III . LOSS SENSITIVITY ANALYSIS

Sensitivity analysis is used to compute sensitivity factors of candidate bus locations to install DG units in the system. Estimation of these candidate buses helps in reduction of the search space for the optimization procedure. Sensitivity factor method is based on the principle of linearization of original nonlinear equation around the initial operating point, which helps to reduce number of solution space. Loss sensitivity factor method is mainly used to solve the capacitor allocation problem. The real power loss in the system is given by "exact loss" formula. Exact loss formula is given by:

$$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} [\alpha_{ij}(P_iP_j + Q_iQ_j) + \beta_{ij}(Q_iP_j - P_iQ_j)]$$

$$\alpha_{ij} = \frac{r_{ij}}{V_iV_j}\cos(\delta_i - \delta_j) \quad \beta_{ij} = \frac{r_{ij}}{V_iV_j}\sin(\delta_i - \delta_j)$$

$$Z_{ij} = r_{ij} + jx_{ij}$$

where,

Z_{ij} the impedance of the line between bus i and bus j

R_{ij} the Resistance of the line between bus i and bus j

X_{ij} the Reactance of the line between bus i and bus j

V_i is the voltage magnitude at bus i

V_j is the voltage magnitude at bus j

The sensitivity factor of real power loss with respect to real power injection is obtained by differentiating exact loss formula with respect to real power injection at bus P_i which is given by

$$\alpha_i = \frac{\partial P_l}{\partial P_i} = 2\sum_{j=1}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j)$$

Sensitivity factors are evaluated at each bus, firstly by using the values obtained at base case load flows. The buses are ranked in descending order of the values of sensitivity factors to form a priority list. The total power loss against injected power is a parabolic function and at minimum of losses, the rate of change of real power loss with respect to real power injection becomes zero.

$$\alpha_i = \frac{\partial P_l}{\partial P_i} = 2\sum_{j=1}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j) = 0$$

$$P_i = \frac{1}{\alpha_{ii}}\left[\beta_{ii}Q_i + \sum_{j=1,\ j\ne i}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j)\right]$$

where P_i represents the real power injection at node i, which is the difference between real power generation and real power demand at that node.

$$P_{DGi} = P_{Di} + \frac{1}{\alpha_{ii}}\left[\beta_{ii}Q_i - \sum_{j=1,\ j\ne i}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j)\right]$$

The above equation determines the size of the DG at which the losses are minimum. By arranging the list in descending order, the bus stood in the top is ranked as the first location of DG..

The procedure to find the optimal location and size of DG using LSF is described as follows

1) Enter the number of DG units to be installed.

2) Run the load flow for the base case and find the loss.

3) Find the optimal location and size of DG using the following steps

a) Find the loss sensitivity factor. Rank the buses in the descending order of the values of LSF's to form a priority list.

b) Locate the highest priority bus.

4) Find the optimal size of the DG and calculate the loss by the following steps

a) Place the DG at the highest priority bus calculated in the step 3,change the DG size in small steps update value of α ,β and calculate the loss at each case by running the load flow.

b) Select and store the optimal size of the DG the gives minimum loss.

5) Update the load data after placing the DG with optimal size obtained in step 4 to allocate the next DG.

6) Stop if either of the following occurs

a) Voltage at the particular bus over the upper limit.

b) The total size of the DG is over the total load plus loss.

c) The minimum number of DG units unavailable.

d) The new iteration loss is greater than the previous iteration loss.

RESULTS

Test system; An IEEE 33- bus radial distribution system has been taken as the test system. The bus connections have been shown in Fig .

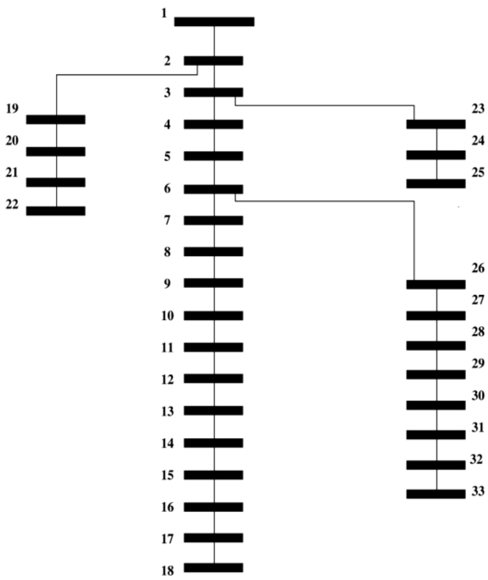

Fig.2 33 bus system

After calculating the loss sensitivity factor at all the buses and arranging in descending order. The first 3 most sensitive buses in the priority list are 18,33 and 25.

Case1: Placement of 1DG

The optimal location obtained for placement of single DG unit is bus number 18 with optimal size of 0.7MW. After placement of DG the system loss reduced to 146kW from 207kW.Also the voltage profile is been improved as shown in Table. and

Base case losses(kW)	207
DG Location	18
DG Size(MW)	0.7
Losses after DG placement(kW)	146

1.loss after placement of 1 DG

Case2: Placement of 2DG

The optimal location obtained for placement of two DG unit is bus number 18 and 33 with optimal size of 1MW and 1.7MW respectively. After placement of DG the system loss reduced to 100kW from 207kW.Also the voltage profile is been improved as shown in Table

Base case losses(kW)	207
DG Location	18,33
DG Size(MW)	01,1.7
Losses after DG placement(kW)	100

2.Loss after placement of 2 DG

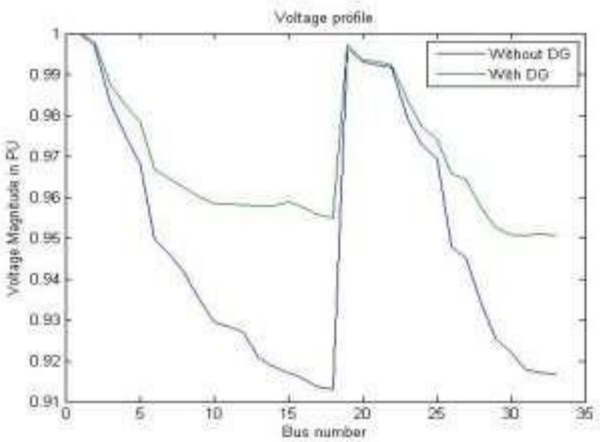

Fig 2.Voltage profile improvement with and without installation of DG

CONCLUSION

Distribution Generation (DG) is a renewable energy in small scale located near to the load in distribution system. (DG) has various technical & economic benefits, when integrated in distribution system. These benefits always depend on placement and sizing of DG. To maximize the benefits it is necessary to find optimal allocation of DG in radial distribution system.

The proposed methodology was tested on 33 bus distribution system. The problem was formulated as an optimization problem and solved with the help of loss sensitivity factor optimization technique. For load flow, Newton-Raphson method is used to calculate the power losses and voltage magnitude. LSF is used for installing the DG into the distribution system, power loss of the system is reduced and voltage profile is improved.

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