Scientific Journal Impact Factor (SJIF): 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745 ISSN (PRINT) : 2393 - 8161

OPTIMAL PLACEMENT OF DG IN RADIAL DISTRIBUTION SYSTEM USING CLUSTER ANALYSIS

MUDDA RAJARAO[1]
[1]*Assistant Professor*
Department of Electrical & Electronics Engineering,Dadi Institute of Engineering and Technology, Anakapalle; Visakhapatnam (Dt); A.P, India

Abstract-This paper proposes the application of clustering analysis technique to find the optimal size and optimum location for the placement of DG in the radial distribution networks for active power compensation by reduction in real power losses and enhancement in voltage profile. The analytical expression is based on exact loss formula.The optimal size of DG is calculated at each group using the exact loss formula and the optimal location of DG is found by using the loss sensitivity factor, voltage sensitivity factor and cost function. Three groups are created by considering cluster analysis. The proposed technique is tested on standard 33-bus test system.
Keywords—cluster analysis; lsf; vsi; ct; dg

I. INTRODUCTION

The objective of power system operation is to meet the demand at all the locations within power network as economically and reliably as possible. The traditional electric power generation systems utilize the conventional energy resources, such as fossil fuels, hydro, nuclear etc. for electricity generation. The operation of such traditional generation systems is based on centralized control utility generators, delivering power through an extensive transmission and distribution system, to meet the given demands of widely dispersed users. Nowadays, the justification for the large central-station plants is weakening due to depleting conventional resources, increased transmission and distribution costs, deregulation trends, heightened environmental concerns, and technological advancements. Distributed Generations (DGs), a term commonly used for small-scale generations, offer solution to many of these new challenges. CIGRE define DG as the generation, which has the characteristics (CIGRE, 1999): it is not centrally planned; it is not centrally dispatched at present; it is usually connected to the distribution networks; it is smaller then 50-100MW. Other organization like, Electric Power Research Institute define distributed generation as generation from few kilowatts up to 50MW. Ackermann *et al.* have given the most recent definition of DG as: “DG is an electric power generation source connected directly to the distribution network or on the customer side of the meter.” Using DG can enhance the performance of a power system in many aspects. Employing DG in a distribution network has several advantages as (Khoa et al, 2006), reduction in line losses, emission pollutants, overall costs due to improved efficiency & peak saving. Improvement of voltage profile, power quality, system reliability and security and the disadvantages are (Illerhsus et al, 2000), reverse power flow, injected harmonics, Increased fault currents depending on the location of DG units. DG also has several benefits like energy costs through combined heat and power generation, avoiding electricity transmission costs and less exposure to price volatility (Ghosh et al, 2010).

II. MATHEMATICAL FORMULATION

The load flow of a single source network can be solved iteratively from two sets of recursive equations. The first set of equations for calculation of the power flow through the branches starting from the last branch and proceeding in the backward direction towards the root node. The other set of equations are for calculating the voltage magnitude and angle of each node starting from the root node and proceeding in the forward direction towards the last node. These recursive equations are derived as follows.

The fig. 1 shows the representation of 2 nodes in a distribution line. Consider a branch 'j' is connected between the nodes'i' and 'i+1'.

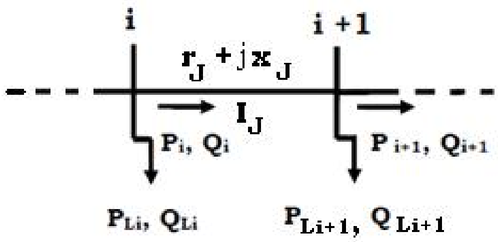

Fig.1. Representation of two nodes in a distribution line

The effective active (P_i) and reactive (Q_i) powers that of flowing through branch 'j' from node 'i' to node 'i+1' can be calculated backwards from the last node and is given as,

$$P_i = P^1{}_{i+1} + r_j \frac{(P^{1\ 2}_{i+1} + Q^{1\ 2}_{i+1})}{V^2_{i+1}}$$

$$Q_i = Q^1{}_{i+1} + x_j \frac{(P^{1\ 2}_{i+1} + Q^{1\ 2}_{i+1})}{V^2_{i+1}}$$

Where $P^1_{i+1} = P_{i+1} + P_{Li+1}$ & $Q^1_{i+1} = Q_{i+1} + Q_{Li+1}$

P_{Li+1} & Q_{Li+1} Are the loads that are connected at node 'i+1'

P_{i+1} & Q_{i+1} Are the effective real and reactive power flows from node 'i+1'

The voltage magnitude and angle at each node are calculated in forward direction. Consider a voltage $V_i \langle\delta_i$ at node i and $V_{i+1} \langle\delta_{i+1}$ at node i+1, then

$$V_{i+1} = [V_i^2 - 2[P_i r_j + Q_i x_j] + [r_j^2 + x_j^2] \frac{[P_i^2 + Q_i^2]}{V_i^2}]^{\frac{1}{2}}$$

And angle at each bus is

$$\delta_{i+1} = \delta_i + \tan^{-1}\left(\frac{[Q_i r_j - P_i x_j]}{[V_i^2 - (P_i r_j + Q_i x_j)]}\right)$$

The real and reactive power losses at branch j can be calculated as

$$P_{loss}(j) = r_j \frac{[P_i^2 + Q_i^2]}{V_i^2}$$

$$Q_{loss}(j) = x_j \frac{[P_i^2 + Q_i^2]}{V_i^2}.$$

2.1 Loss sensitivity factor:

The loss sensitivity factor is used for the placement of DG is explained as, the real power loss in the system is given by (1).This formula is popularly referred as "Exact Loss" formula (Elgerd, 1971; Kazemi et al, 2009).

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}[\alpha_{ij}[P_i P_j + Q_i Q_j] + \beta_{ij}[Q_i P_j + P_i Q_j]]$$

Where,

$$\alpha_{ij} = \frac{r_{ij}}{V_i V_j}\cos(\delta_i - \delta_j)$$

$$\beta_{ij} = \frac{r_{ij}}{V_i V_j}\sin(\delta_i - \delta_j)$$

And $Z_{ij} = r_{ij} + jx_{ij}$ is the ij th element of [Zbus] matrix.

$P_i = P_{Gi} - P_{Di}$ And $Q_i = Q_{Gi} - Q_{Di}$

P_{Gi} & Q_{Gi} Are powers injection of generator to the bus.

P_{Di} & Q_{Di} Are the loads.

P_i & Q_i Are active and reactive powers of the buses

The sensitivity factor of real power loss with respect to real power injection from the DG is given by

$$\alpha_i = \frac{\partial P_L}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{j=1}^{N}\sum_{j\neq i}[\alpha_{ij}P_j - \beta_{ij}Q_j]$$

Sensitivity factor are evaluated at each bus by using the values obtained from the base case load flow. The bus having highest loss sensitivity factor will be best location for the placement of DG (Acharya et al, 2006).

2.2 voltage stability index

For a distribution line model, given in fig.1, the quadratic equation which is mostly used for the calculation of the line sending end voltages [11] in load flow analysis can be written in general form as

$$VSI_{i+1} = |V_i|^4 - 4[P_{i+1}x_j - Q_{i+1}r_j]^2 - 4[P_{i+1}r_j + Q_{i+1}x_j]|V_i|^2$$

Where i is sending end bus and i+1 is receiving end bus

In this study the above simple stability criterion, given in eq.5, is used to find the stability index for each line receiving end bus in radial distribution networks. The node, at which the value of the stability index is at minimum, is the most sensitive to the voltage collapse.

2.3 Cost Function

The fuel cost of generator at bus i can be represented as a
Quadratic function of power generation (P_i)

$$C_i = \alpha_i + \beta_i P_i + \gamma_i P_i^2$$

Where $\alpha_i, \beta_i, \gamma_i$ are the cost coefficients of generator i

$$(\alpha\frac{Rs}{h}, \beta\frac{Rs}{mwh}, \gamma\frac{Rs}{mwh^2})$$

Find cost function of each bus, and the bus where less
Cost function value is suitable to place DG.

2.4 optimal sizing of DG

The total power loss against injected power is a parabolic function and at minimum

Volume 03, Issue 02, [February – 2016] ISSN (Online):2349–9745; ISSN (Print):2393-8161

losses, the rate of change of losses with respect to injected power becomes zero [9].

$$\frac{\partial P_L}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{j=1}^{N}\sum_{j\neq i}[\alpha_{ij}P_j - \beta_{ij}Q_j] = 0$$

It follows that

$$P_i = \frac{1}{\alpha_{ii}}[\sum_{j=1}^{N}\sum_{j\neq i}[\alpha_{ij}P_j - \beta_{ij}Q_j]]$$

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

$$P_i = [P_{DGi} - P_{Di}]$$

Where P_{DGi} the real power injection from DG is placed at node i, and P_{Di} is the load demand at node i. By combining
The above we get

$$P_{DGi} = P_{Di} - \frac{1}{\alpha_{ii}}[\sum_{j=1}^{N}\sum_{j\neq i}[\alpha_{ij}P_j - \beta_{ij}Q_j]]$$

The above equation gives the optimum size of DG at buses i for the loss to be minimum. Any size of DG other than P_{DGi} placed at bus i, will lead to higher loss.

III. CLUSTER ANALYSIS

3.1 Introduction and Summary

The objective of cluster analysis is to assign observations to groups so that observation within each groups are similar to one another with respect to variables or attributes of interest, and the groups them-selves stand apart from one another. In other words, the objective is to divide the observations into homogeneous and distinct groups

In contrast to the classification problem where each observation is known to belong to one of a number of groups and the objective is to predict the group to which a new observation belongs, cluster analysis seeks to discover the number and composition of the groups. There are so many methods among those

3.2 Hierarchical Algorithm

Hierarchical clustering group's data over a variety of scales by creating a cluster tree or *dendrogram*. The tree is not a single set of clusters, but rather a multilevel hierarchy, where clusters at one level are joined as clusters at the next level. This allows you to decide the level or scale of clustering that is most appropriate for your application.

Let the distance between clusters *i* and *j* be represented as d_{ij} and let cluster *i* contain n_i objects. Let ***D*** represent the set of all remaining d_{ij}. Suppose there are *N* objects to cluster.

1.Find the smallest element $d_{ij\ remaining}$ in ***D***.

2.Merge clusters *i* and *j* into a single new cluster, *k*.

3.Calculate a new set of distances $d_{km..}$Here *m* represents any cluster other than *k*

4.Repeat steps 1 - 3 until ***D*** contains a single group made up off all objects. This will require *N-1* iterations.

3.3 K-Means Cluster Algorithm

This nonhierarchical method initially takes the number of components of the population equal to the final required number of clusters. In this step itself the final required number of clusters is chosen such that the points are mutually farthest apart. Next, it examines each component in the population and assigns it to one of the clusters depending on the minimum distance. The centroid position is recalculated every time a component is added to the cluster and this continues until a l the components are grouped into the final required number of clusters.

3.4 Test system

This methodology is tested on test system contains 33 buses and 32 branches as shown in fig.2. It is a radial system with a total load of 3.72 MW and 2.3 MVAR (Kashem et al, 2000). A computer program is written in MATLAB 2010a.

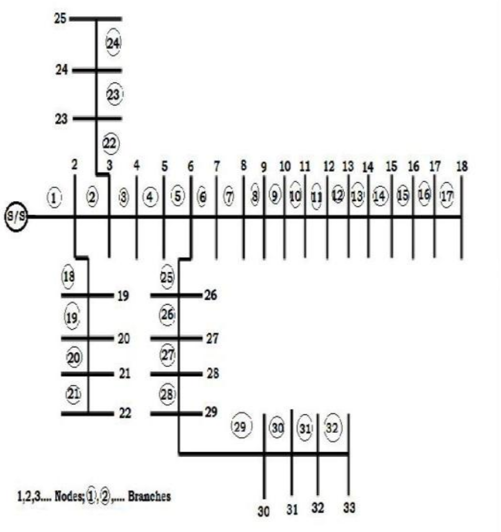

Fig 2: A 33 distribution radial system

IV. RESULTS AND DISCUSSIONS

Here we considering vsi and lsf and cost function for optimal location. By using optimal location we go for hierarchal and k-means clustering and the results are as follows

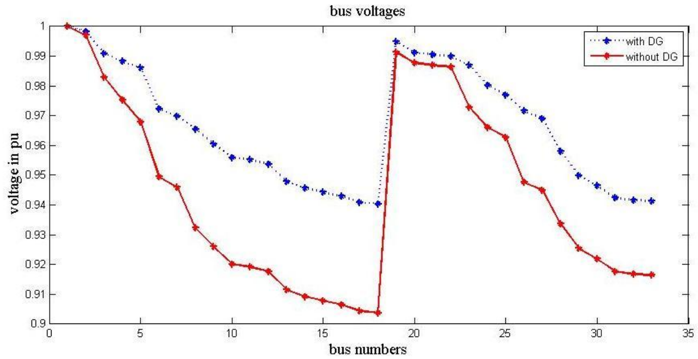

Fig 3: voltage deviation with and without DG placement (33-bus)

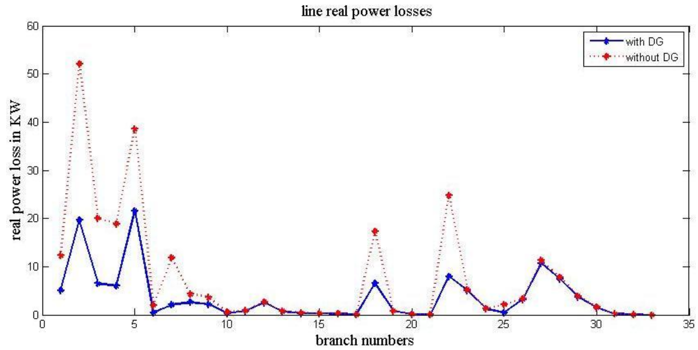

Fig 4: real power loss with and without DG

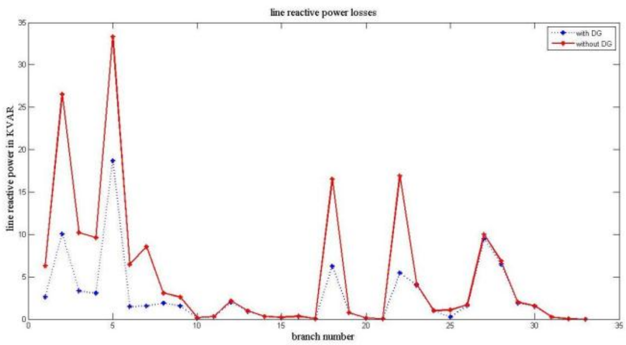

Fig 5: reactive power loss with and without DG (33-bus)

And the variation of results both real and reactive losses are shown in bellow table.

Description	Total Loss		Minimum Voltage and it's node number
	Real power (kW)	Reactive power (kVAr)	
With out DG	249.29	173.95	0.9038at 18
With DG	203.66	144.01	0.911 at 18

Table 1: Comparision Table

V. Conclusion

The iterative techniques commonly used in transmission networks are not suitable for distribution power flow analysis because of poor convergence characteristics. In this work the distribution power flow is carried out by the backward and forward propagation iterative equations. The effective branch powers are calculated in backward propagation. In forward propagation voltage magnitudes at each node are calculated. By placing DGs at optimal three groups voltage profile is improved and losses are reduced.

REFERENCES

[1] .W.Tinney and C.Hart, "Power Flow Solution by Newton's Method", IEEE Transactions on Power Apparatus and Systems, Vol.PAS-86, no.11, pp.1449- 1460, November. 1967.
[2] B.Stott and O.Alsac, "Fast Decoupled Load-flow", IEEE Transactions on Power Apparatus and Systems, Vol.PAS-93, no.3, pp.859-869, May 1974.
[3] F. Zhang and C. S. Cheng, "A Modified Newton Method for Radial Distribution System Power Flow Analysis",IEEE Transactions on Power Systems, Vol.12, no.1,pp.389-397, February 1997.
[4] H. L. Nguyen, "Newton-Raphson Method in Complex Form", IEEE Transactions on Power Systems, Vol.12, no.3, pp.1355-1359, August 1997.
[5] Whei-Min Lin, Jen-HaoTeng, "Three-Phase Distribution Network Fast-Decoupled Power Flow Solutions", Electrical Power and Energy SystemsVol.22, pp.375-380, 2000.
[6] Chowdhury S, Chowdhury SP, Crossley P.2009. Micro grids and Active Distribution Networks. 1st ed. London.IET Renewable Energy Series.
[7] Willis H. L, 2000. Analytical methods and rules of thumb for modeling DG distribution interaction. IEEE Proc. PES summer meeting, vol.3, pp. 1643-1644.
[8] Wang C, and Nehrir MH. 2004. Analytical approach for optimal placement of distributed generation sources in power systems. IEEE Trans. PWRS, 19(4), pp. 2068-2076.
[9] Griffin T, Tomosovic K, Secrest D, and Law A. 2000 Placement of Dispersed Generation systems for reduced losses. In proceedings of 33rd Annual Hawaii International conference on systems sciences, Maui, Hawaii , pp. 1-9. IEEE Region 10 Conference, 3: 331-34.
[10] . NPTEL videos

