Distributed Generation Planning using Voltage Stability Index

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Abstract— This paper presents an algorithm for allocation of DG to minimizing the active power loss based on voltage stability Index. The active power loss is mitigated with proper sizing and allocation of DG. The location of DG is found with the help of voltage stability index (VSI) and DG capacity is varied in small steps to corresponding power loss minimization. A direct distribution load flow method using BIBC and BCBV matrices for installing DG units is used. By proper sizing and allocation of Distributed Generation in IEEE 33-bus Radial Distribution system, the transmission losses are minimized and voltage stability problems are mitigated. This algorithm shows considerable loss reduction and voltage stability improvement.

Key words: Load Flow, Distributed generation (DG), Voltage Stability Index

I. INTRODUCTION

Electric utilities are now seeking upcoming new technologies to provide acceptable power quality and higher reliability to their customers in restructured environment. Non-conventional generation is growing more rapidly around the world, for its low size, low cost and less environmental impact with high potentiality. Distributed Generation is an emerging technology in this new era and it provides clean electric power. Distributed Generation should be located at or near an electrical load Centre. Installation of Distributed Generation at optimal places provides the clean electric power to the customer [1].

The key element of a new arena in electric power system is to operate several DG units near load centers instead of expanding central generation station. DG may come from a variety of sources and technologies. DGs from renewable sources, like wind, solar and biomass are often called as 'Green energy'. In addition to this, DG includes micro-turbines, gas turbines, diesel engines, fuel cells, and internal combustion reciprocating engines.

A group of advantages of DG such as economical, environmental and technical presented. The economical advantages are reduction of transmission and distribution cost, electricity price and saving of fuel. Environmental advantages entail reductions of sound pollution and emission of green house gases. Technical advantages cover wide varieties of benefit, like, line loss reduction, peak saving, increased system voltage profile and hence increased power quality and relieved transmission and distribution congestion as well as grid reinforcement. It can also provide the stand-alone remote applications with the required power. So, optimal placement of DGs and optimal sizing attract active research interests. Several researchers have worked in this area [2, 3]. Wang and Nehrir have shown analytical approaches for optimal placement of DG in terms of loss [3]. Gozel and Hocaoglu [4] employed a loss sensitivity factor for the determination of the optimum size and location of distributed generation to minimize total power losses. Keane and O'Malley [5] used linear programming to determine the optimal allocation of embedded generation.

The load flow will be imperative for the investigation of distribution networks, to research the issues identified with planning, outline and the operation and control. A few provisions like ideal distributed generation placement in distribution networks and distribution automation networks, obliges rehashed load flow result. Numerous systems such Gauss-Seidel, Newton-Raphson are generally appeared for convey the load flow of transmission networks [6]. The utilization of these systems for distribution networks may not be worthwhile in light of the fact that they will be generally focused around the general meshed topology of a normal transmission networks although most distribution networks structure are likely in tree, radial or weakly meshed in nature. R/X ratio of distribution networks is high respect to transmission system, which cause the distribution networks to be badly molded for ordinary load flow techniques [6-7]. Some other inborn aspects of electric distribution networks are (i) radial or weakly meshed structure, (ii) unbalanced operation and unbalanced distributed loads, (iii) large number of nodes and branches, (iv) has wide range of resistance and reactance values and (v) distribution networks has multiphase operation.

The effectiveness of the optimization problem of distribution networks relies on upon the load flow algorithm on the grounds that load flow result need to run for ordinarily. Thusly, the load flow result of distribution networks time proficient qualities. A technique which can discover the load flow result of radial distribution networks specifically by utilizing topological normal for distribution system [8-10] is utilized. In this strategy, the plan of tedious Jacobian matrix or admittance matrix, which is needed in customary techniques, is stayed away from.

In this paper, an algorithm for DG unit installation to reduce transmission losses by losses allocation criteria and improve the voltage stability of the system. A simple distribution system load flow approaches has been formulated. Optimal location of DG is identified by using voltage stability index (VSI) and to demonstrate the efficiency of proposed techniques a clear and detailed analysis of performance has been carried out on IEEE-33 Radial Distribution System.

II. LOAD FLOW OF RADIAL DISTRIBUTION NETWORK

A feeder brings power from substation to load points/nodes in radial distribution networks (RDN). Single or multiple radial feeders are used in this planning approach. Basically, the RDN total power losses can be minimized by minimizing the branch power flow or transported electrical power from transmission networks (i.e. some percentage of loads is locally meeting by local DG). To determine the total power loss of the network or each feeder branch, minimum Voltage stability index and the maximum voltage deviation are determined by performing load flow. A direct load flow methodology based on the bus-injection to branch-current (BIBC) matrix and the branch-current to bus-voltage

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(BCBV) matrix [8]. In this area, the advancement methodology will be depicted in subtle element. Load flow for distribution networks under balanced operating condition with constant power load model can be under remained through the accompanying focuses.

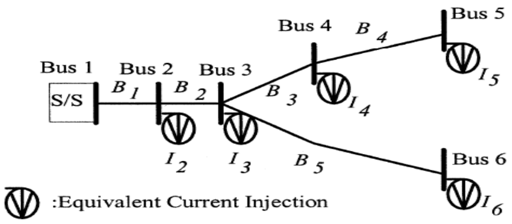

Fig. 1: A Simple Distribution system

III. SOLUTION METHODOLOGY

The development of BIBC and BCBV matrices investigate the topological structure of distribution networks. Basically the BIBC matrix is making an easy relation between the node current injections and branch currents. These relations give a simple solution for branch currents variation, which is occurs due to the variation at the current injection nodes, these can be obtained directly by using BIBC matrix. The BCBV matrix builds an effective relation between the branch currents and node voltages. The concern variation of the node voltages is produced by the variant of the branch currents. These could be discovered specifically by utilizing the BCBV matrix. The relations between the node current injections and node voltages could be communicated as:

$$[\Delta V] = [BCBV].[BIBC].[I] \quad (1)$$

Now $$[\mathrm{BCBV}] = [\mathrm{BIBC}]^{\mathrm{T}}.[\mathrm{ZD}] \quad (2)$$

$$\therefore [V] = [\mathrm{BIBC}]^{\mathrm{T}}.[\mathrm{ZD}].[BIBC].[I] \quad (3)$$

$$[DLF] = [BCBV][BIBC] \quad (4)$$

$$\therefore \quad [DLF] = [\mathrm{BIBC}]^{\mathrm{T}}.[\mathrm{ZD}].[BIBC] \quad (5)$$

Therefore, $$[V] = [DLF][I] \quad (6)$$

The iterative solution for the distribution system load flow can be obtained by solving equations given as:

$$I_i^k = I_i^r(V_i^k) + jI_i^i(V_i^k) = \left(\frac{P_i + jQ_i}{V_i^k}\right)^* \quad (7)$$

$$[\Delta V]^{k+1} = [DLF][I^k] \quad (8)$$

$$[V]^{k+1} = [V^0] + [\Delta V^{k+1}] \quad (9)$$

The new definition as illustrated uses just the DLF matrix to take care of load flow problem. Subsequently this strategy is extremely time efficient, which is suitable for online operation and optimization problem of distribution networks.

IV. ALGORITHMS FOR DISTRIBUTION NETWORKS IN LOAD FLOW ANALYSIS

The algorithm steps for load flow solution of transmission networks are given below:

- Step 1: Read the transmission networks line data and bus data.
- Step 2: Calculate the each node current or node current injection matrix. The relationship can be expressed as:

$$[I] = \left[\frac{S}{V}\right]^* = \left[\frac{P - jQ}{V^*}\right] \quad (10)$$

- Step 3: Calculate the BIBC matrix.
- Step 4: Evaluate the branch current by using BIBC matrix and current injection matrix (ECI). The relationship can be expressed as:

$$[IB] = [BIBC].[I] \quad (11)$$

- Step 5: Form the BCBV matrix by using steps given in section 3. The relationship therefore can be expressed as:

$$[\Delta V] = [BCBV].[IB] \quad (12)$$

- Step 6: Calculate the DLF matrix by using the equation (6). The relationship will be:

$$[DLF] = [BCBV][BIBC] \quad 13)$$

$$[V] = [DLF][I]$$

- Step 7: Set Iteration k = 0.
- Step 8: Iteration k = k + 1.
- Step 9: Update voltages by using equations (7), (8), (9) as –

$$I_i^k = I_i^r(V_i^k) + jI_i^i(V_i^k) = \left(\frac{P_i + jQ_i}{V_i^k}\right)^*$$

$$[\Delta V]^{k+1} = [DLF][I^k]$$

$$[V]^{k+1} = [V^0] + [\Delta V^{k+1}]$$

- Step 10: If max $\left((|\mathrm{V(k+1)}| - |\mathrm{V(k)}|) > \mathrm{tolerance}\right)$ go to step 6.
- Step 11: Calculate branch currents, and losses from final node voltages.
- Step 12: Display the node voltage magnitudes and angle, branch currents and losses.
- Step 13: Stop.

A. *Incorporation of DG into Load Flow:*

Assume that a single-source radial distribution networks with N_L branches and a DG is to be placed at node *i* and α be a set of branches connected between the source and node *i*. It is known that, the DG supplies active power ($P_{G_i}^{DG}$) to the systems, but in case of reactive power ($Q_{G_i}^{DG}$) it is depend upon the source of DG, either it is supplies to the systems or consume from the systems. Due to this active and reactive power an active current ($I_{DG_i}^r$) and reactive current ($I_{DG_i}^i$) flows through the system, and it changes the active and reactive component of current of branch set α. The current of other branches (∉=α) are unaffected by the DG.

Total Apparent Power at i^{th} node:

$$S = S_{Di} = \sum P_{Di} + j\sum Q_{Di} \quad \text{i=1,2......} N_B \quad (14)$$

Current at i^{th} node:

$$I_D = I_{Di}^{without\ DG} = \left(\frac{S_{Di}}{V_i}\right)^* \quad (15)$$

To incorporate the DG model, the active and reactive power demand at i^{th} node at which a DG unit is placed, is modified by:

$$P_{Di}^{with\ DG} = P_{Di}^{without\ DG} - P_{Gi}^{DG} \quad (16)$$

$$Q_{Di}^{with\ DG} = Q_{Di}^{without\ DG} \mp Q_{Gi}^{DG} \quad (17)$$

DG power at i^{th} node:

$$S_{DGi} = \sum P_{Gi}^{DG} \pm jQ_{Gi}^{DG} \quad \text{i= 1,2,..........} N_B \quad (18)$$

Total new apparent power at i^{th} node:

$$S = S_{Di} - S_{DGi} \quad (19)$$

So, new current at i^{th} node:

$$I_D = I_{Di}^{with\ DG} = \left(\frac{S_{Di} - S_{DGi}}{V}\right)^* \quad (20)$$

Now the updated network power can be expressed in matrix form

$$[S] = [S_{Di}] - [S_{DGi}] \quad (21)$$

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B. Voltage Stability Index:

A system experiences a state of voltage instability when there is a progressive or uncontrollable drop in voltage magnitude following a disturbance, increase in load demand or change in operating condition. It is usually identified by an index called voltage stability index of all the nodes in radial distribution system [11].

$$VS_i = |V_j|^4 - 4[P_i r_{i,j} + Q_i x_{i,j}]|V_j|^2 - 4[P_i x_{ij} - Q_i r_{i,j}]^2 \quad (28)$$

where P_i, Q_i are the net active and reactive power, respectively, at the i^{th} bus; $r_{i,j}$ and $x_{i,j}$ are the resistance and the reactance of the distribution line connected between the $i^{th}$and the j^{th} bus; V_i, V_j are the bus voltages at the i^{th} and the j^{th} bus, respectively; VS_i is the voltage stability index of the i_{th} bus.

By using VSI, stability level of radial distribution networks can be measured and a suitable action can be taken if VSI represents a poor stability level. All nodal voltages and branch currents will be obtained after the load flow study, and hence P_i and Q_i can be calculated easily. Thus one can calculate the voltage stability index easily at each node. Node with minimum VSI value is more sensitive to collapse in voltage. The effectiveness of this technique has been explained using 33Radial Distribution System.

In order to obtain optimal DG size, below steps should be followed:

- A node with minimum VSI should be found first and then the DG is placed at that node.
- Assuming Distributed generation power factor as constant, size should be varied in constant steps from a minimum value to a maximum value (feeder loading capacity) till minimum losses are obtained
- The size of DG which produces minimum loss is considered as optimal size.

V. RESULTS AND DISCUSSION

To analysis the effect of DG on the Distribution system, the standard IEEE 33Bus radial distribution system has been considered here. The single line diagram of 33-bus radial distribution system is shown in Fig. 2 with rated voltage of 12.66 kV. The system has total active and reactive power loads of 3.72MW and 2.3 MVar respectively. In the first case, load flow without DG is analyses and bus voltages magnitudes and total power loss of the network in RDS are computed. Without installation of DG, the power loss due to active component of current is 210.998 kW and power loss due to reactive component of the current is 143 kVAR. VSI at various buses is also calculated.

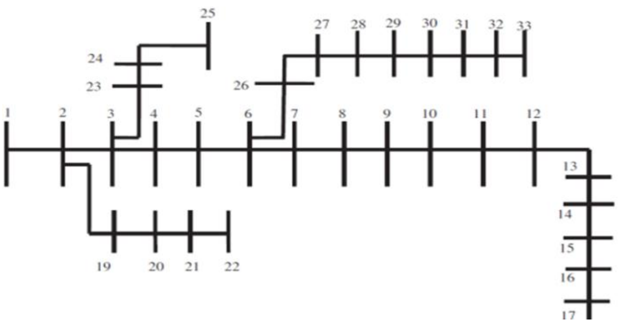

Fig 2: Single line diagram of 33-bus radial distribution system.

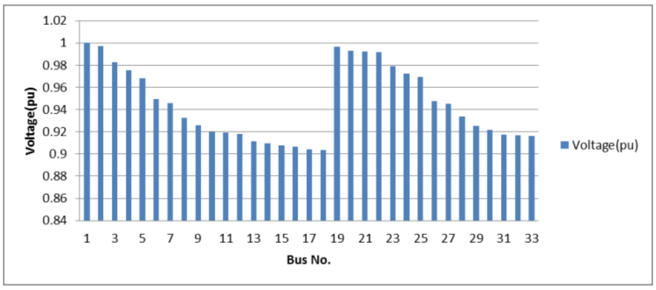

Fig. 3: Base case node Voltage magnitudes.

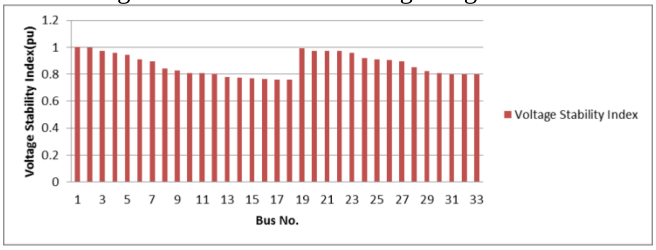

Fig. 4: Base case Voltage Stability Index.

From the analysis, we found that the bus 18 is having lowest VSI value of 0.7576. Hence, bus 18 is optimal location for placing DG. For analysis consider DG operating at unity power factor. For finding the optimal size of DG, the DG size is varied from 0.5 MVA to 4.0 MVA in step of 0.5 MVA. From the test result we observe that power losses are non-linearly varying with capacity of generator. First the power losses are decreased up to some minimum values and then start increasing with DG capacity increment. The optimal size obtained is 0.85 MVA. The Base case load solution given in Table 1. Simulation results are shown in figure 3 and figure 4. Table 1 contains the node voltage magnitudes, the angle in radian of the converged load flow solutions and voltage stability index. Table 2 shows improvement in system performance.

VI. CONCLUSION

The proposed algorithm has been implemented for optimal DG unit's allocation and sizing based on Voltage stability index. The results of case study performed on IEEE 33 bus for minimize total real power loss and allocations of DG shows that, integration of DG is effective in reducing total real power losses and improvement of voltage stability of the system. The proposed algorithm is simple, robust and easy to implement.

Bus No.	Voltage(pu)	Angle deviation(degree)	Voltage Stability Index
1	1	0	1
2	0.9970	0.0136	0.9952
3	0.9829	0.0958	0.9721
4	0.9754	0.1619	0.9569
5	0.9680	0.2290	0.9434
6	0.9495	0.1349	0.9103
7	0.9460	-0.0967	0.8970
8	0.9323	-0.2501	0.8411
9	0.9260	-0.3246	0.8288
10	0.9201	-0.3888	0.8100
11	0.9193	-0.3814	0.8086
12	0.9178	-0.3697	0.8033
13	0.9116	-0.4628	0.7814
14	0.9093	-0.5430	0.7744

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15	0.9079	-0.5815	0.7715
16	0.9065	-0.6052	0.7668
17	0.9044	-0.6840	0.7591
18	**0.9038**	**-0.6938**	**0.7576**
19	0.9965	0.0028	0.9929
20	0.9929	-0.0642	0.9746
21	0.9922	-0.0836	0.9751
22	0.9916	-0.1039	0.9715
23	0.9793	0.0648	0.9582
24	0.9726	-0.0239	0.9217
25	0.9693	-0.0676	0.9094
26	0.9476	0.1744	0.9045
27	0.9450	0.2305	0.8951
28	0.9336	0.3135	0.8535
29	0.9253	0.3914	0.8241
30	0.9218	0.4967	0.8097
31	0.9176	0.4123	0.7970
32	0.9167	0.3892	0.7965
33	0.9164	0.3815	0.7969

Table 1: Load Flow Solution Of 33-Bus Rds

Parameters	Without DG	With DG
Active power losses (in KW)	210.998	145.700
Reactive power losses (in KVAr)	143.000	100.700

Table 2: Improvement in system performance

REFERENCES

[1] homas Ackermann, Goran Andersson, Lennart Soder," Distributed Generation: a definition", Electric Power Systems Research,Vol.No.57, pp.195–204, 2001.
[2] Rau NS, Wan YH "Optimum location of resources in distributed planning" IEEE Trans Power System 1994; 9: 2014–20.
[3] Wang C, Nehrir M Hashem. "Analytical approaches for optimal placement of distributed generation sources in power systems". IEEE Trans Power System 2004; 19(4):2068–76.
[4] Gozel T, Hocaoglu MH. "An analytical method for the sizing and siting of distributed generators in radial systems". Electric Power System Res 2009;79 (6):912–8.
[5] Keane A, O'Malley M. Optimal allocation of embedded generation on distribution networks. IEEE Trans Power System 2005; 20 (3):1640–6.
[6] R. E. Brown, electric power distribution reliability, CRC press, 2008.
[7] S.H. Horowitz, A.G. Phadke, Power System Relaying, 2nd Ed. Baldock: Research Studies Press Ltd, 2003.
[8] J. H. Teng, "A Direct Approach for Distribution System Load Flow Solutions," IEEE Transactions on Power Delivery, vol. 18, no. 3, pp. 882-887, 2003.
[9] Dharmasa, C. Radhakrishna, H.S. Jain, and S. Ravi, "Non-iterative Power Flow Method for Radial Distribution Networks with Parameter Uncertainties," TENCON – IEEE Conference, 23rd-26th Jan. 2009, pp. 1-7, Singapore.
[10] B. Venkatesh and R. Ranjan, "Data Structure for Radial Distribution Load Flow Analysis," IEE Proceedings in Generation, Transmission and Distribution, vol 150, no. 1, pp. 101-106, January 2003.
[11] Borghetti A. A mixed-integer linear programming approach for the computation of the minimum-losses radial configuration. IEEE Trans Power Syst 2012;27(3):1264–73.
[12] Kashem MA, Ganapathy V, Jasmon GB, Buhari MI. A Novel Method for Loss Minimization in Distribution Networks. Int Conf Electr Utility Deregu Restruct. Power Technologies 2000, City University, London, 4–7 April 2000. p. 251–56.