ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 11, November 2016

Optimal Location of DG Units using Sensitivity Analysis

[1] P S Divya [2] Dr.T.Gowri Manohar
[1] PG Student [2]Associate Professor
[1][2]Dept of EEE, S V University College Of Engineering, Tirupati .

Abstract: **-- Now a days the usage of electrical power is increasing enormously and it is also becoming highly impossible in the future world without the electricity. One of the techniques for maintaining the continuous supply i.e., by generating the electrical power in the distribution is presented . Distributed generation (DG) play an important role in distribution networks. Among many of their merits, loss reduction, THD reduction and voltage profile improvement can be the salient merits of DG. If the placement of the DG is done in non-optimal locations with non-optimal sizes of DG units may lead to increased losses, poor voltage profile and injection of harmonics in large quantity which in turn implies in increased cost of the system. In this paper, Sensitivity Analysis is used to determine the location of DG and Particle Swarm Optimization (PSO) is used to determine the size of DG to minimize the power losses in the distribution networks.The proposed PSO based approach is tested on standard IEEE 33 bus test system. The results so obtained show the improvement in voltage profile, reduction of real power loss using MATLAB.**

Index Terms**:- Distributed generation, Optimal location and size, Exact loss formula, Sensitivity analysis, Particle swarm optimization (pso)**

I. INTRODUCTION

Distributed generation is an electricity generating technology installed by a customer or independent electricity producer that is connected at the distribution system level of the electric grid[1]. The share of distributed generators in the power systems has been increasing in the last few years. It can be said that DG is associated with the use of small generation units. The effects of DG on voltage profile, line losses and power transfer capability are to be evaluated separately before installing it in a distribution network. The achievement of such benefits depends much on how optimally these distributed generators are installed. Studies have indicated that approximately 13% of generated power is consumed as loss at distribution level.

Along with the power losses and voltage drops, the increasing growth in the electricity demand requires upgrading the infra structure of distribution system. So as to reach these targets, loss reduction and voltage profile improvement, planning of the electric system with the presence of DG requires the definition of several factors such as the best technology to be used, the number and the capacity of the units, the best location, the type of network connection and the problem of DG location and sizing is of great importance. The installation of DG units at non-optimal places with non-optimal sizing can result in an increase in system losses, voltage flicker, protection, therefore having an effect opposite to the desired [2],[3]. For this reasons the use of an optimization method capable of indicating the best solution for a given distribution network is mandatory.The optimum DG allocation can be modelled as optimum active power loss compensation. Location of DG in radial systems to minimize power loss is done by sensitivity analysis.In this paper, particle swarm optimization technique is used for sizing of DG in distribution networks in order to loss reduction in distribution network. The IEEE 33-bus test system is selected to test the proposed method and the results are mentioned in the paper.

II. PROBLEM FORMULATION

The real power loss reduction and voltage profile improvement in a radial distribution system is requiredfor efficient power system operation. The loss in the system can be calculated by equation (1) [4],

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n}\left(\alpha_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}\left(Q_iP_j - PiQj\right.\right. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The Real Power Loss given by equation (1) is known as Exact Power Loss.
where,

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

where, $P_i$and $Q_i$are net real and reactive power injection in bus *'i'* respectively, $r_{ij}$is the line resistance between bus 'i' and 'j'$r_{ij}+jx_{ij}=Z_{ij}$ are the ij[th] elements of [Z_{bus}] matrix V_i and δ_i are the voltage and angle at bus 'i' respectively.

III. LOAD FLOW SOLUTION

The main aim of this work is to develop a new formulation for load flow method. The proposed load flow algorithm requires formation of Bus Injection to Branch Current (BIBC) matrix with 1's & 0's as elements and Branch Current to Bus Voltage (BCBV) matrix with primitive impedances as elements and Distribution Load Flow (DLF) matrix where DLF matrix is obtained as product of BCBV & BIBC matrices. The distribution load flow method[5] is robust, time-efficient and needs very less memory even for a large size distribution system.

A. *Algorithm For BIBC Matrix*

Step 1 : For a system with m branch sections and an n-bus ,the dimension of the BIBC matrix is m×(n-1).

Step 2: If the line section (branch) B-k is located between Bus i and j , copy the column of the i-th bus of BIBC matrix to the column of the j-th bus and add 1 to the k-th row and the j-th bus column.

Step 3: Repeat step (2) until all the sections are included in the BIBC matrix.

B. *Algorithm For BCBV Matrix*

Step 1 : For a system with m number of branch sections and an n number of bus ,the dimension of the BCBV matrix is (n-1)×m.

Step 2: If the line section (branch) B-k is located between Bus i and j , copy the row of the i-th bus of BCBV matrix to the row of the j-th bus and add primitive line impedance(Z-k) in position of j-th bus row and k-th column.

Step 3: Repeat step (2) until all the sections are included in the BCBV matrix.

IV.SENSITIVITY ANALYSIS

DG location and sizing has a vital role in the distribution systemsfor the location of DG, the sensitivity analysis is used. The main objective is to minimize the total real power loss of the system in radial distribution system. If the DG is placed in non-optimal location with an undetermined size, the losses aresaid to be high. Hence it is obligatory to place the DG with obtained size at the desired location to achieve the desired objective. This method is tested on IEEE 33Bus standard test system.

Sensitivity factor method is based on the principle of linearization of original nonlinear equation around the initial operating point, which assistance to reduce the number of solution space. Loss sensitivity factor has been widely used to solve the capacitor allocation[6] problem. Its application in DG allocation is new in the field[7].

The loss sensitivity factor is obtained by differentiating real power loss with respect to real power injection of DG, which is given by

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

The total power loss against injected power is a parabolic function and at minimum losses, the rate of change of real power loss with respect to real power injection becomes zero.

$$\alpha_i = \frac{\partial P_L}{\partial P_i} = 2\sum_{j=1}^{n}(\alpha_{ij}P_j - \beta_{ij}Q_j) = 0 \ldots\ldots\ldots\ldots\ldots (3)$$

which follows the

$$P_i = \frac{1}{\alpha_{ii}}\left[\beta_{ii}Q_i + \sum_{j=1,j\neq i}^{n}(\alpha_{ij}P_j - \beta_{ij}Q_j)\right] \ldots\ldots(4)$$

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.

$$P_i = P_{DGi} - P_{Di} \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where P_{DGi} is the real power injection from DG placed at node i, P_{Di} is the load demand at node i, combining 4 & 5 we get

$$P_{DG_i} = P_{D_i} + \frac{1}{\alpha_{ii}}\left[\beta_{ii}Q_i - \sum_{j=1,j\neq i}^{n}(\alpha_{ij}P_j - \beta_jQ_j)\right](6)$$

The above equation determines the size of the DG to be placed at the particular bus. By arranging the list in ascending order based on the real power loss obtained from equation (1), the bus stood in the top is ranked as the first location of DG and further the process is repeated by placing the concerned size of DG at that particular location which generates the next location of DG. The process is said to be terminated when it repeats the same location or when the power loss is minimum.

A. *Algorithm For Sensitivity Analysis*

Step 1: Run the base case load flow.

Step 2: Find the optimum size(units) of DG for each bus using equation of (6).

Step 3: Compute the appropriate loss using equation(1) of exact loss for each bus throughplacing DG of optimum size obtained in step 2 for that bus. Add the injection fromDG for that bus and use base case values for state variables.

Step 4: Locate the bus at which the loss is minimum after DG placement. This is the optimumLocation for DG.

Step 5: Run load flow with DG to get the final result.

V.PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is a population-based optimization method first proposed by Kennedy and Eberhart in 1995, inspired by social behaviour of bird flocking or fish schooling [8]. The PSO [9] as an optimization tool provides a population-based search procedure in which individuals called particles change their position with time. In a PSO system, particles fly around a multidimensional in search space. During flight, each particle set its position according to its own experience (Pbest), and according to the experience of a neighbouring particle (Gbest), made use of the best position encountered by itself and its neighbour (Figure 1).

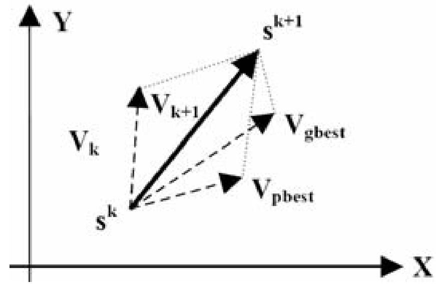

Figure 1: Concept of a searching point by PSO

This can be represented by the concept of velocity. Velocity of each agent can be modified by the following equation

$$v_{id}^{k+1} = \omega v_{id}^{k} + c_1\, rand^*\left(pbest_{id} - s_{id}^{k}\right) + c_2\, rand^*\left(gbest_{d} - s_{id}^{k}\right) \quad (7)$$

Using the above equation, a certain velocity, which gradually gets close off to pbest and gbest can be calculated. The current position (searching point in the solution space) can be modified by the following equation:

$$s_{id}^{k+1} = s_{id}^{k} + v_{id}^{k+1} \quad (8)$$

where s^k is current searching point, s^{k+1} is modified searching point, $v^k$is current velocity, $v^{k+1}$is modified velocity of agent i, v_{pbest} is velocity based on pbest, , v_{gbest} is velocity based on gbest, n is number of particles in a group, m is number of members in a particle, $pbest_i$ is pbest of agent i, $gbest_i$ is gbest of the group, ω_i is weight function for velocity of agent i, C_i is weight coefficients for each term.

A. *Algorithm For Finding Optimal Dg Sizing Using PSO*

Step 1: Read line and and bus data.

Step 2: Calculate the loss using distribution load flow.

Step 3: Randomly generates an initial population (array) of particles with random positions and velocities on dimensions (Size of DG and Location of DG) in the solution space. Set the iteration counter k = 0.

Step 4: For each particle if the bus voltage is within the limits, calculate the total loss in equation (1). Otherwise, that particle is infeasible.

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 11, November 2016

Step 5: For each and every particle, compare its objective value with the individual best. If the objective value is lower than Pbest, set this value as the current Pbest, and record the corresponding particle position.

Step 6: Choose the particle associated with the minimum individual best Pbest of all particles, and set the value of this Pbest as the current overall best Gbest.

Step 7: Update the velocity and position of particle using (7) and (8) equations respectively.

Step 8: If the iteration number reaches the maximum limit, go to Step 9. Otherwise, set iteration index k = k + 1, and go back to Step 4.

Step 9: Print out the optimal solution to the target problem. The best position includes the optimal locations and sizes of DG and the corresponding fitness value representing the minimum total real power loss.

VI. TEST SYSTEM & ANALYTICAL TOOLS

The system under study is a typical IEEE 33 bus test system, contains 33 buses and 32 branches as shown in the figure3. A computer program is written in MATLAB2009a to find the optimal location of DG's by using sensitivity analysis and also the optimal size of each DG were determined by using PSO.

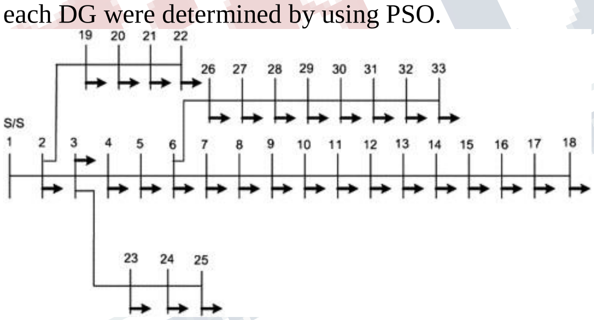

Figure 3: Single line diagram of IEEE 33 bus test system

The power factor of the load is $\cos\emptyset = 0.70$.The only supply source in the system is the substation at bus 1 as a slack bus with a constant voltage. All loads are treated as constant PQ spot loads. A Table1 & Table2 represents the input data of the test system.

Table 1: Line data of IEEE 33 bus test system

Branch number	**Sending end node**	**Receiving end node**	**Resistance in Ω**	**Reactance in Ω**
1	1	2	0.0922	0.0477
2	2	3	0.4930	0.2511
3	3	4	0.3660	0.1864
4	4	5	0.3811	0.1941
5	5	6	0.8190	0.7070
6	6	7	0.1872	0.6188
7	7	8	1.7114	1.2351
8	8	9	1.0300	0.7400
9	9	10	1.0040	0.7400
10	10	11	0.1966	0.0650
11	11	12	0.3744	0.1238
12	12	13	1.4680	0.1550
13	13	14	0.5416	0.7129
14	14	15	0.5910	0.5260
15	15	16	0.7463	0.5450
16	16	17	1.2890	1.7210
17	17	18	0.7320	0.5740
18	2	19	0.1640	0.1565
19	19	20	0.5042	1.3554
20	20	21	0.4095	0.4784
21	21	22	0.7089	0.9373
22	3	23	0.4512	0.3083
23	23	24	0.8980	0.7091
24	24	25	0.8986	0.7011
25	6	26	0.2030	0.1034
26	26	27	0.2842	0.1447
27	27	28	1.0590	0.9337
28	28	29	0.8042	0.7006
29	29	30	0.5075	0.2585
30	30	31	0.9744	0.9630
31	31	32	0.3105	0.3619
32	32	33	0.3410	0.5302

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 11, November 2016

Table 2: Load data of IEEE 33 bus system

Node	KW	KVAr
1	0	0
2	100	60
3	90	40
4	120	80
5	60	30
6	60	20
7	200	100
8	200	100
9	60	20
10	60	20
11	45	30
12	60	35
13	60	35
14	120	80
15	60	10
16	60	20
17	60	20
18	90	40
19	90	40
20	90	40
21	90	40
22	90	40
23	90	50
24	420	200
25	420	200
26	60	25
27	60	25
28	60	20
29	120	70
30	200	600
31	150	70
32	210	100
33	60	40

VII. RESULTS AND DISCUSSIONS

The proposed method for solving DG location as well as size problem is applied to IEEE 33-bus standard test system. All the results and the discussion are presented in this section. Firstly Radial Distribution Load Flow (RDLF) [10] is conducted on the standard IEEE 33 bus test system which consists of the formation of various matrices like Bus Injected to Branch Current (BIBC) matrix, Branch Current to Bus Voltage (BCBCV) matrix etc. The product of BIBC matrix and BCBV matrix represents output as RDLF matrix which is clearly explained in [10].

The real power loss of the test system before locating any DG in to the system is 245.5048KW. A program is written in MATLAB 2009a to calculate the loss saving, DG location and its desired size in MW. Now the sensitivity analysis program written in MATLAB is made run to determine the DG location as well as to reduce real power loss. For the first iteration the maximum loss saving is occurring at bus 6. The candidate location for DG is bus 6 with a loss saving of 120.9771 kW. The optimum size of DG at bus 6 is 2.6453 MW. By assuming 2.6453MW DG is connected at bus 6 of base system and is considered as base case.Then the optimal location obtained is bus 14 with appropriate DG size as 0.3546 MW. Again this size of DG is placed at bus 14 to know the next optimal location. Finally the next optimal location obtained is bus 29 with an appropriate DG size as 0.1983 MW. Again this size of DG is placed at bus 29 to know the next optimal location. Then the optimal location obtained is bus 24 with appropriate DG size as 0.2697 MW. Then after this size of DG is placed at bus 24 to know the next optimal location.The next location is bus 6 with the size as -0.6453 MW. This indicates that the size of DG at bus 6 is reduced from 2.6453 MW to 2.6453-0.6453=2.0000 MW to reduce the real power loss of the system.. The results are shown in table 3.

Table 3: Results from Sensitivity analysis

Iteration No.	Bus No.	DG size (MW)	Saving (KW)
1	6	2.6453	120.9771
2	14	0.3546	108.3542
3	29	0.1983	104.3803
4	24	0.2697	101.1924
5	6	-0.6453	98.3715

The solution obtained above is local optimum solution but not global optimum solution. The DG sizes

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 11, November 2016

corresponding to global optimum solution are determined using PSO method [9]. The candidate locations for DG placement are taken from Sensitivity analysis i.e., bus numbers 6, 14,29 and 24. With these locations, sizes of DGs are determined by using Particle swarm optimization (PSO) algorithm described in section 5. The sizes of DGs are dependent on the number of DG locations. The number of DG's to be installed for the test system is limited to 4 and brief explanation to this is given in the following three cases. Case 1 represents installation of only one DG in to the system, case 2 with two DG's and case 3 followed by three DG's. case 4 with four DG's .DG sizes in the four optimal locations, total real power losses before and after DG installation for four cases are given in Table 4. Due to the installation of the four DG's at the optimal locations with the corresponding determined at sizes, the total real power loss of the system is reduced from 245.5048 KW to 81.8774 KW with a maximum saving of 163.6274 KW.

The reduction in the loss associated with reactive component of the branch current is very small as it is already mentioned that placement of DG effects onlyactive component of branch current. Though the objective is to reduce the losses, the voltage profile is also substantially improved as well. The table 6shows the voltages profile after and before placement of DG.

Table 4:Analysis of Results obtained from PSO algorithm

Case	Bus loc	DG size (MW)	Total size (MW)	Losses before DG installation (KW)	Total Real Power loss After DG installation	Saving (KW)
1	6	2.8796	2.8796	245.5048	120.2103	125.2945
2	6	2.1568	2.8349		98.7795	146.7253
	14	0.6781				
3	6	1.2713	2.8090		86.5560	158.9488
	14	0.6781				
	29	0.8596				
4	6	1.0993	3.2758		81.8774	163.6274
	14	0.6781				
	29	0.8596				
	24	0.6388				

Table 6: Results for voltage profile before and after DG placement

Bus No.	Voltage Magnitude In P.U At Each Bus	
	With Out Dg	With Dg
1	1.0000	1.0000
2	0.9970	0.9990
3	0.9826	0.9954
4	09740	0.9933
5	0.9652	0.9913
6	0.9440	0.9850
7	0.9406	0.9839
8	0.9251	0.9768
9	0.9176	0.9743
10	0.9122	0.9736
11	0.9114	0.9737
12	0.9100	0.9740
13	0.9055	0.9762
14	0.9033	0.9765
15	0.9016	0.9775
16	0.9005	0.9765
17	0.8990	0.9751
18	0.8986	0.9747
19	0.9965	0.9985
20	0.9929	0.9949
21	0.9922	0.9942
22	0.9916	0.9936
23	0.9803	0.9949
24	0.9762	0.9945
25	0.9729	0.9949
26	0.9415	0.9837
27	0.9389	0.9828
28	0.9274	0.9778
29	0.9192	0.9744
30	0.9153	0.9736
31	0.9064	0.9653
32	0.9052	0.9641
33	0.9044	0.9633

VIII. CONCLUSION

Units of DG and location of DG plays a major role in the reduction of losses in primary distribution system. In this paper, the Sensitivity algorithm and PSO algorithm was tested on a 33-bus test system to find the ideal location and size of the DGs. The main objective is to minimize the total real power loss and the number of DG's to be installed. The Location of the DG is done by sensitivity algorithm and the Size of DG is found by using PSO algorithm. The proposed study for location and size selection correctly identifies the best location and size for DG placement in order to minimize the total power losses. Also, improvement of voltage profile and an increase in power transfer capacity are achieved by of best DG location and sizing.

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 11, November 2016

REFERENCES

[1] Thomas Ackermann, Goran Andersson, Lenart Soder, "Distributed generation: a definition," Electric Power Systems Research, Volume 57, Issue 3, Pages 195-204,20 April 2001.

[2] Rau N. S. and Wan Y. H. , "Optimum location of resources in distributed planning," IEEE Trans. on Power Systems, vol. 9, pp. 2014- 2020, 1994.

[3] M. Gandomkar, M. Vakili an, M. Ehsan, "Optimal distributed generation allocation in distribution network using Hereford Ranch algorithm ", Proceedings of the Eighth International Conference on Electrical Machines and Systems, 2005.Volume 2, pp. 916 - 918,27-29 Sept. 2005.

[4]. I.O. Elgerd, Electric Energy System Theory: an Introduction. McGraw Hill., 1971.

[5] K.Prakash, Member, IEEE, and M.Sydulu, Member , IEEE, "An Effective Topological and Primitive Impedance based Distribution Load Flow Method for Radial Distribution Systems".

[6]. Bala JL, Kuntz PA, Pebles MN. Optimum capacitor allocation using a distribution analyzer recorder. IEEE Trans PWRD 1997;12(1):464-9.

[7]. Grioin T. Tomosovic K Secrest D, Law A. Placement of dispersed generation for reduced losses. In proceedings of 33rd Hawaii international conferences on sciences, Hawaii,2000.

[8]. Kennedy J and Eberhart R, "Particle Swarm Optimizer," IEEE International Conference on Neural Networks (Perth, Australia), IEEE Service Center Piscataway, NJ, IV, pp1942- 1948, 1995.

[9] D. Sai Krishna Kanth, "Siting & Sizing of Dg for Power Loss & Thd Reduction, Voltage Improvement Using Pso & Sensitivity Analysis",e-ISSN: 2278-067X, p-ISSN: 2278-800X, Volume 9, Issue 6 (December 2013), PP. 01-071.

[10] K. Prakash and M.Sydulu, "An Effective Topological and Primitive Impedance based Distribution Load Flow Method for Radial Distribution Systems", DRPT 2008 6-9 April 2008 Nanjing China.