International Journal of Engineering & Technology, 7 (4.22) (2018) 236-240

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

DG Placement Using Loss Sensitivity Factor Method for Loss Reduction and Reliability Improvement in Distribution System

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Abstract

The electrical power distribution system is designed to provide a reliable electrical supply to its consumers as economically as possible. The key factor in any electrical power system is the power loss due to resistance during transmission and distribution. However the power loss in the distribution network is more than in the transmission network because of high R/X ratio. To minimize these losses in the distribution system, now a days, Distribution Generators (DG's) are introduced in the network. The addition of DG's in the radial distribution system provides many technical and cost benefits to both utilities and customers. However, improper placement of these DG's may cause negative impacts on the overall system performance. Hence an optimum location of DG's in the radial distribution system plays vital role.

In this paper, an analytical method to calculate optimal size and to identify optimal location of DG's is considered to minimize the power losses and to improve voltage profile and Reliability in distribution systems. The methodology is applied to IEEE 33-bus Radial Distribution System and the obtained results are compared.

Keywords: *Distribution Generation, Loss sensitivity Factor, Reliability Indices, Radial Distribution System.*

1. Introduction

Reliability calculation is an important tool for distribution system planning and operation**.** By performing this analysis it is easy to evaluate past performance and predict future performance of the distribution system. Basic Probability Indices and Performance Indices are defined in (1,2). Reliability evaluation techniques for Distribution system planning studies and operation are presented in (3). Optimum location of DG was considered in (4) for reduction of losses. Optimal placement of different types of DG sources using PSO is given in (5,6). In this paper, Optimum size and location of DG using LSF for both loss reduction and Reliability improvement has been considered. Problem formulation is discussed in section 2. Sensitivity analysis for DG location and size is described in section 3. Result analysis is presented in section 4 and conclusions are given in section 5.

2. Problem Formulation

The objective is to reduce the losses and improve Reliability with DG placement. The fitness function considered for minimization of total active power losses (P_L), given by the equation

$$F = \min\left(P_L = \sum_{i=1}^{N} |I_i|^2 R_i \right) \tag{1}$$

where
I is the line current in branch i
R is the resistance of the branch i
N is the total number of branches

2.1. Constraints

2.1.1 Equality Constraints:

The equality constraint is the power balance condition given by Eqn. (2).

$$\sum_{i=1}^{N} \left(P_{Gi} + P_{DGi} \right) = P_{Di} + P_L \tag{2}$$

2.1.2 Inequality Constraints :

Voltage at each bus should be within upper and lower voltage bounds given by Eqn. (3)

$$V_{i,\min} \le V_i \le V_{i,\max} \tag{3}$$

Where V_{min} and V_{max} are the minimum, maximum permissible node voltages

2.1.3. Reliability indices are defined as follows:

The customer orientated performance indices that are defined in [1] as :

(i) System Average Interruption Frequency Index

$$SAIFI = \frac{\text{total number of customers interruptions}}{\text{total number of customers served}}$$

$$\mathrm{SAIFI} = \frac{\sum_{i=1}^{k}\lambda_i N_i}{\sum_{i=1}^{k} N_i} \text{ f/yr} \tag{4}$$

(ii) System Average Interruption Frequency Index

$$\mathrm{SAIDI} = \frac{\text{Sum of customer interruption duration}}{\text{total number of customers served}}$$

$$\mathrm{SAIDI} = \frac{\sum_{i=1}^{k} U_i N_i}{\sum_{i=1}^{k} N_i} \text{ hr/yr} \tag{5}$$

(iii) Customer Average Interruption Duration Index ,

$$\mathrm{CAIDI} = \frac{\text{Sum of customer interruption duration}}{\text{total number of customers interruptions}}$$

$$\mathrm{CAIDI} = \frac{\sum_{i=1}^{k} U_i N_i}{\sum_{i=1}^{k} \lambda_i N_i} \text{ hr} \tag{6}$$

(iv) Average service availability index,

$$\mathrm{ASAI} = \frac{\text{Customer hours of available service}}{\text{Customer hours demanded}}$$

$$\mathrm{ASAI} = \frac{\sum_{i=1}^{k} 8760\, N_i - \sum_{i=1}^{k} U_i N_i}{\sum_{i=1}^{k} 8760\, N_i} \tag{7}$$

Where N_i is number of customers at load point i, λ failure rate and U outage time

(v) Average Service Unavailability Index

$$\mathrm{ASUI} = 1 - \mathrm{ASAI} \tag{8}$$

Reliability constraints

$0 < \mathrm{SAIFI} < (\mathrm{SAIFI})_b$;
$0 < \mathrm{SAIDI} < (\mathrm{SAIDI})_b$;
$0 < \mathrm{CAIDI} < (\mathrm{CAIDI})_b$;
$0 < \mathrm{ASUI} < (\mathrm{ASUI})_b$;

Where $(\mathrm{SAIFI})_b$,$(\mathrm{SAIDI})_b$,$(\mathrm{CAIDI})_b$,$(\mathrm{ASUI})_b$ are base case indices and SAIFI, SAIDI, CAIDI, ASUI are indices after DG placement.

3. Loss Sensitivity Factor Method

This method is used for identifying the optimal location and sizing of DG.

3.1 Loss Sensitivity Factor

Sensitivity factor method is based on the principle of linearization of original nonlinear equation around the initial oper ating point, this helps to reduce the number of solution space.

The real power loss in the system is given by Eqn.(9). This formula is popularly referred as "Exact Loss" formula (7).

$$P_{Loss} = \sum_{j=1}^{N}\sum_{i=1}^{N} \alpha_{ij}\left(P_i P_j + Q_i Q_j\right) + \beta_{ij}\left(Q_i P_j - P_i Q_j\right) \tag{9}$$

where

$$\alpha_{ij} = \frac{R_{ij}}{V_i V_j}\mathrm{Cos}(\delta_i - \delta_j)\ \beta_{ij} = \frac{R_{ij}}{V_i V_j}\mathrm{Sin}(\delta_i - \delta_j) \tag{10}$$

$Z_{ij} = r_{ij} + jx_{ij}$ are the ij^{th} element of $[Z_{bus}]$ matrix

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

$$\alpha_i = \frac{\partial P_{Loss}}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{j=1, j\neq i}^{N}\left(\alpha_{ij}P_j - \beta_{ij}Q_j\right) \tag{11}$$

3.2 Optimal Location of DG

The following steps are used to identify the optimal location for the DG:

1. Determination of real power loss sensitivity w.r.t. active power injection at each bus using Eqn. [11].
2. Arrange the buses in descending order of their sensitive ties.
3. The bus having highest real power loss sensitivity w.r.t. real power injection is the candidate bus for DG location.

3.3 Optimal Size Of DG

The total power loss against injected power is a parabolic function using Eqn. (11) and minimum losses occurs at which, the rate of change of losses with respect to injected power becomes zero.

$$\frac{\partial P_{Loss}}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{j=1, j\neq i}^{N}\left(\alpha_{ij}P_j - \beta_{ij}Q_j\right) = 0 \tag{12}$$

Computing the equation (12) yields

$$P_i = -\frac{1}{\alpha_{ii}}\sum_{j=1, j\neq i}^{N}\left(\alpha_{ij}P_j - \beta_{ij}Q_j\right) \tag{13}$$

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

$$P_i = P_{DGi} - P_{Di} \tag{14}$$

P_{DGi} is the real power injection from DG placed at node i. P_{Di} is the load demand at node i. Based on the LSF priority list for each bus the DG is placed and size is varied from minimum (0MW) to a higher value until minimum system losses is found with DG size. Optimal size of DG is given by

$$P_{DGi} = P_{Di} - \frac{1}{\alpha_{ii}}\sum_{j=1, j\neq i}^{N}\left(\alpha_{ij}P_j - \beta_{ij}Q_j\right) \tag{15}$$

3.4 Steps Involved for The Implementation of Sensitivity Factor Method To Find Optimal Size of DG

Optimal location and size of DG is proposed for distribution system which reduces the total power losses and improvement in reliability indices

The algorithm is considered as follows

Step1: Run the base case load flow and perform reliability analysis.
Step2: Place the single DG at bus as per priority list and run the load flow
Step3: Check whether all the bus voltages are within specified tolerance limits or not.
$V_{i,\min} < V_i < V_{i,\max}$ if so go to step 5
Step4: Adjust the size of DG in "small" steps and go to step 2
Step5: Calculate power loss
$0 < P_{Loss\ new} < P_{Loss\ old}$
If so, store the best value and discard the previous value otherwise go to step 4

Step6: Store the DG size that gives minimum loss

Step7: Repeat step 3 to step 5 for all busses in the priority list. The Flow chart for optimal location and size of DG is shown in Figure 1.

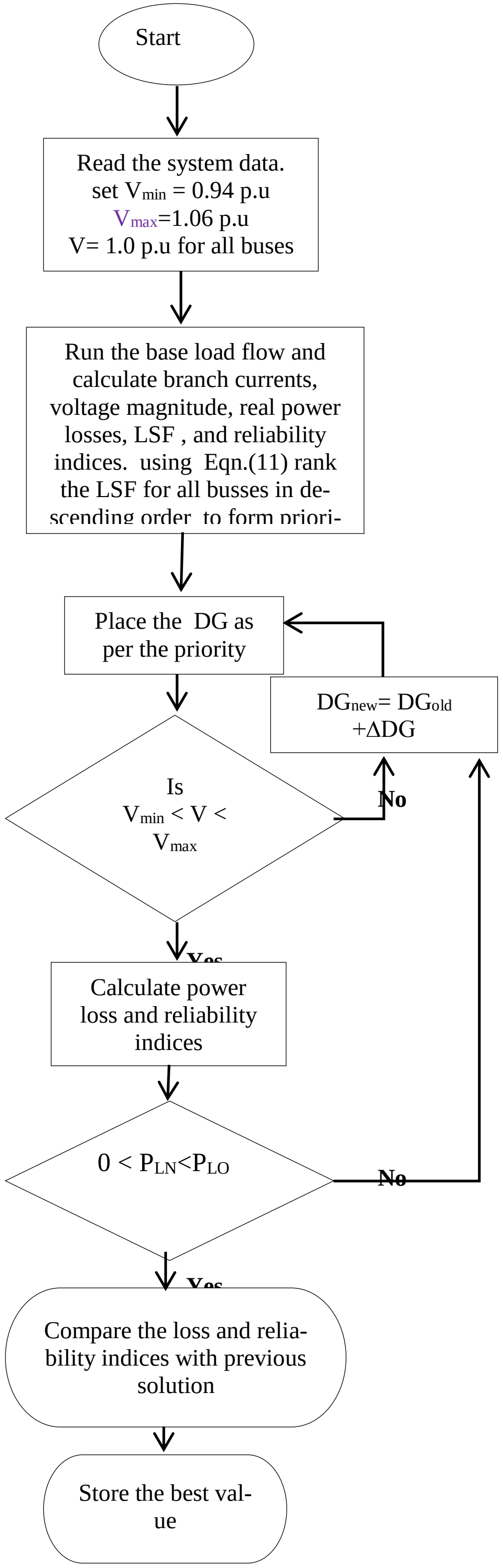

Fig 1:The Flow chart for optimal location and size of DG is shown

4. Results and analysis

Results of 33-bus RDS losses, voltage and reliability indices are analyzed.

4.1 Test System Description

Load flow results have been obtained for IEEE -33 RDS as shown in Fig.2 using Forward and Backward Sweep method. The base MVA and base kV taken as 100 MVA and 12.66 kV respectively.

4.2 Assumptions and constraints

The capacity of system is 100MVA and V_{base}= 12.66kV.
Only one DG operate with unity power factor
The capacity of DG size is limited to 2.5 MW.

4.3 Power Loss Analysis

For 33-RDS without installation of DG real power losses are 202.3 kW. Using LSF method placing DG size of 2.49 MW at bus 6 obtain the total real power loss of 104 kW and reduction percentage of real power loss is 48.06%.Comparison of Power loss and Vmin are given in Table 1

Table 1: Comparison of losses and minimum voltage and before and after DG placement

Method	Repeated load flow [4]		LSF Method	
	Without DG	With DG	Without DG	With DG
Losses(kW)	202.3	111.1	202.3	104
DG size (MW)	-	2.6	-	2.49
DG Location	-	6		6
Vmin (p.u)	-	-	0.9131	0.949

4.4 Comparison of voltage magnitudes and power loss

The values of voltage magnitudes and Line real power losses its Comparison for the base case and after placement of DG of 33-bus RDS is given in Table 3,4 and Fig.3 and Fig.4

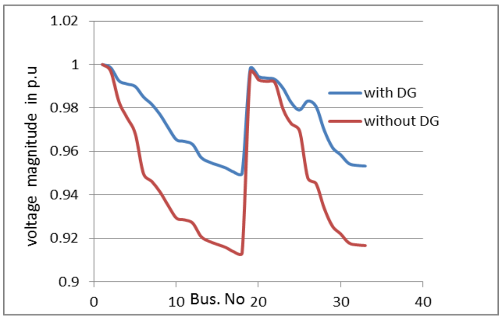

Fig. 3: Comparison of voltages before and after DG placement

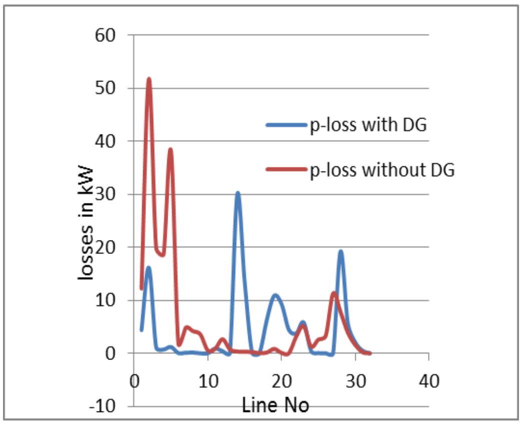

Fig. 4: comparison of Active power losses before and after DG placement

IEEE 33-Bus RDS with DG at bus 6 is shown in Figure.2

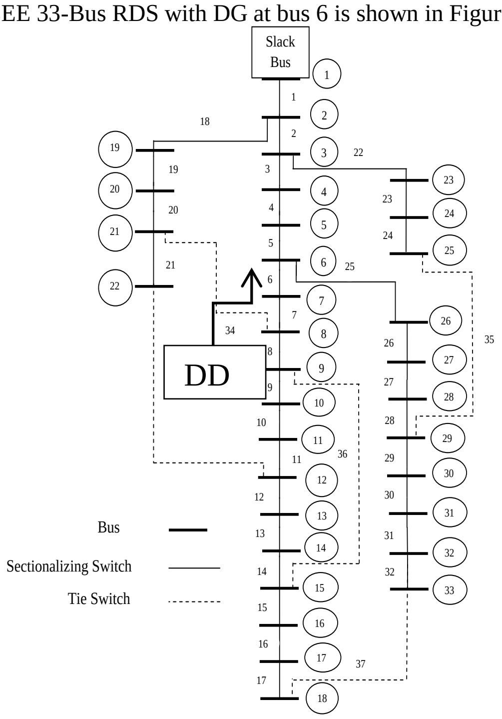

Fig. 2: IEEE 33-Bus RDS with DG at bus 6

4.5 Reliability indices

The reliability indices of IEEE 33 Bus RDS before and after connecting the DG at 6th bus are calculated using cutset approach and are given in Table 2. Reliability and Load data is given in Table 5 and 6. From Table 2 and Figure.5 it is found that improvement of reliability after DG connected at optimal location.

Table 2: Comparison of reliability indices before and after DG placement

Index	**Before DG**	**After DG (at 6th BUS)**	**% Decrease**
SAIFI	2.41	2.096	13.02
SAIDI	2.04	1.726	15.33
CAIDI	0.85	0.823	3.17
ASUI	2.33E-4	1.971E-04	15.4

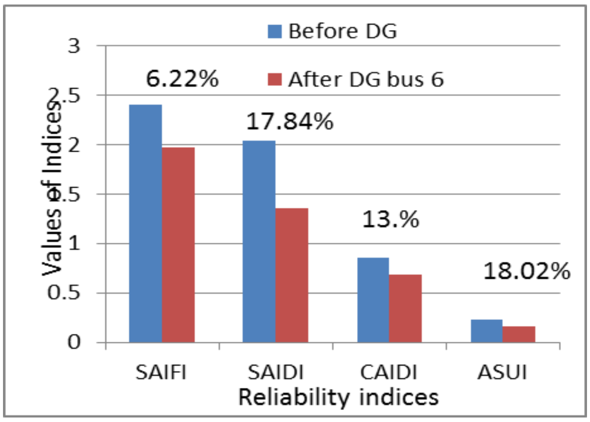

Fig. 5: Comparison of reliability indices before and after DG placement

5. Conclusions

The inclusion of DG into Distribution system yields many benefits such as line loss reduction, increasing Reliability and improved voltage profile. LSF method is used to find the optimal size and optimal location of the DG unit and implemented on IEEE 33 RDS. The system voltage profile has been significantly improved. The Customer Reliability indices are also improved after DG is connected at the optimal location. The results presented indicated that the DG placement is an important factor in the analysis.

Table 3: Voltage magnitudes before and after DG

Bus no	with DG (bus 6)	without DG (base)
1	1	1
2	0.99854	0.99703
3	0.99252	0.98295
4	0.99102	0.97548
5	0.98986	0.96808
6	0.98503	0.9497
7	0.98168	0.94621
8	0.97702	0.94137
9	0.97099	0.93511
10	0.9654	0.9293
11	0.96457	0.92844
12	0.96313	0.92694
13	0.95725	0.92083
14	0.95507	0.91857
15	0.95372	0.91715
16	0.9524	0.91579
17	0.95045	0.91376
18	0.94987	0.91316
19	0.99801	0.99651
20	0.99444	0.99293
21	0.99374	0.99222
22	0.9931	0.99159
23	0.98897	0.97936
24	0.98237	0.97269
25	0.97907	0.96937
26	0.98318	0.94777
27	0.98071	0.94521
28	0.96971	0.93378
29	0.96181	0.92556
30	0.95839	0.92201
31	0.95439	0.91785
32	0.95351	0.91694
33	0.95323	0.91665

Table 4: Line real power Loss before and after DG

Line no	Real power loss with DG	Real power loss without DG
1	4.258	12.2229
2	16.57	51.7171
3	6.35	19.8654
4	6.14	18.6668
5	12.92	38.1913
6	1.77	1.9119
7	4.47	4.8312
8	3.86	4.1745
9	3.29	3.5559
10	0.51	0.5529
11	0.81	0.8799
12	2.46	2.6625
13	0.67	0.7282
14	0.32	0.3565
15	0.26	0.2811
16	0.23	0.2513
17	0.04	0.0531
18	0.16	0.1609
19	0.82	0.8321
20	0.1	0.1008
21	0.04	0.0436
22	3.11	3.1807
23	5.04	5.1422
24	1.26	1.2871
25	2.4	2.5968
26	3.07	3.3238
27	10.45	11.2847
28	7.24	7.8228
29	3.6	3.8905
30	1.47	1.5915
31	0.19	0.2129

32	0.01	0.0132

Table 5: Reliability data for IEEE-33 RDS

LINE No	SE BUS	RE BUS	Failure rate f/yr	Repair time (hrs)	No.of Customers
1	1	2	0.05	1	500
2	2	3	0.3	1	400
3	3	4	0.22	1	600
4	4	5	0.23	1	350
5	5	6	0.51	1	350
6	6	7	0.11	1	1000
7	7	8	0.44	1	1000
8	8	9	0.64	1	550
9	9	10	0.65	1	550
10	10	11	0.12	1	400
11	11	12	0.23	1	300
12	12	13	0.91	1	400
13	13	14	0.33	1	550
14	14	15	0.36	1	300
15	15	16	0.46	1	450
16	16	17	0.8	1	300
17	17	18	0.45	1	400
18	2	19	0.1	0.5	450
19	19	20	0.93	0.5	350
20	20	21	0.25	0.5	450
21	21	22	0.44	0.5	550
22	3	23	0.28	0.5	450
23	23	24	0.56	0.5	1500
24	24	25	0.55	0.5	1300
25	6	26	0.12	0.5	300
26	26	27	0.17	0.5	500
27	27	28	0.66	0.5	300
28	28	29	0.5	0.5	600
29	29	30	0.31	0.5	900
30	30	31	0.6	0.5	800
31	31	32	0.19	0.5	1050
32	32	33	0.21	0.5	300

Table 6: IEEE 33 Bus and Line Data

LINE NO	**SE BUS**	**RE BUS**	**R in (OHM)**	**X in (OHM)**	**P_L (kW)**	**Q_L (kVAr)**
1	1	2	0.0922	0.0477	100	60
2	2	3	0.4930	0.2511	90	40
3	3	4	0.3660	0.1840	120	80
4	4	5	0.3811	0.1941	60	30
5	5	6	0.8190	0.707	60	20
6	6	7	0.1872	0.6188	200	100
7	7	8	0.7114	0.2351	200	100
8	8	9	1.0300	0.7400	60	20
9	9	10	1.0440	0.7400	60	20
10	10	11	0.1966	0.0650	45	30
11	11	12	0.3740	0.1238	60	35
12	12	13	1.4680	1.1550	60	35
13	13	14	0.5410	0.7129	120	80
14	14	15	0.5910	0.5260	60	10
15	15	16	0.7460	0.5450	60	20
16	16	17	1.2890	1.7210	60	20
17	17	18	0.7320	0.5740	90	40
18	2	19	0.1640	0.1565	90	40
19	19	20	1.5040	1.3554	90	40
20	20	21	0.4040	0.4784	90	40
21	21	22	0.7080	0.9373	90	40
22	3	23	0.4510	0.3083	90	50
23	23	24	0.8980	0.7091	420	200
24	24	25	0.8960	0.7011	420	200
25	6	26	0.2030	0.1034	60	25
26	26	27	0.2840	0.1447	60	25
27	27	28	1.0590	0.9337	60	20
28	28	29	0.8040	0.7006	120	70
29	29	30	0.5070	0.2585	200	600
30	30	31	0.9740	0.9630	150	70
31	31	32	0.3110	0.3619	210	100
32	32	33	0.3410	0.5302	60	40
33	21	8	2.0	2.0	0	0
34	9	15	2.0	2.0	0	0
35	12	22	2.0	2.0	0	0
36	18	33	0.5	0.5	0	0
37	25	29	0.5	0.5	0	0

References

[1] R.Billiton,R N Allan, *Reliability Evaluation of Power Systems*, Second Edition, Springer International Edition, Reprinted in India, BS Publications,(2007), pp.229-231.

[2] V Sankar, System *Reliability Concepts*, Himalaya Publishing house,(2015), pp.239-27.

[3] T Lantharthong, N Phanthuna, “Techniques for Reliability Evaluation in Distribution system planning", *World Academy of Science, Engineering and Technology*, Vol.64,(2012),pp.16-21.

[4] Naresh Acharya et.al , “An analytical approach for DG allocation in primary distribution network”, *Electrical Power and Energy Systems*, 28 (2006), 669–678

[5] Satish Kansal, B.B.R. Sai, Barjeev Tyagi, Vishal Kumar, “Optimal placement of distributed generation in distribution networks”, *International Journal of Engineering Science and Technology*, Vol. 3, No. 3, 2011, pp. 47-55.

[6] Satish Kansal, B.B.R. Sai, Barjeev Tyagi,”Optimal placement of different type of DG sources in distribution networks”, *Electrical Power and Energy Systems*, 53 (2013) 752–760.

[7] Elgerd I.O, “Electric energy system theory: an introduction”, *McGraw-Hill*, (1971).