A Novel Approach for evaluation of location and size of Distributed Generation in a Microgrid Environment

Gousia Sultana[1]
Research scholar, EEE Department, Visveswaray Technological University, PES research Centre, Bangalore, India[1]

Dr. B.K.Keshavan[2]
EEE Department, PES University, Bangalore, India[2]

Abstract: *In the present development of energy sector the importance is given to the renewable energy power generation, microgrid and Distributed Generation (DG). The placement and sizing of DG in a distribution network is most critical aspect as the improper placement and sizing of DG may lead to the inefficient performance, higher system losses, low reliability and increase in cost. In this paper a novel approach is proposed to obtain the optimal siting and sizing of DG in a microgrid. The protective devices like fuse, disconnectors are also considered in the distribution network. This approach gives the placement and sizing of DG for improved reliability, lower transmission losses, improved voltage profile and hence better performance of the distribution.*

Keywords: **Distributed Generation (DG), microgrid, renewable energy sources (RES), power flow analysis, and reliability.**

1. INTRODUCTION

The main aim of the distribution system is to supply the uninterrupted power supply to all the load points in the complete network. For the improvement in the system reliability the Distributed generators can be included in the distribution system planning. There are various types of distributed generators including photovoltaic's, wind turbines, fuel cell, batteries etc., the main advantage of having distributed generators is in improving overall reliability of system, peak shaving, improvement in voltage profile and reducing the transmission line losses of the system.

Optimal sizing and siting of DG is an important factor to get the above benefits. The improper placement of DG may lead to reduction in system performance and economic considerations thus proper planning has to be done for placement and sizing of DG.
The main protective devices involved in the distribution network are fuses, disconnectors, isolators, relays and circuit breakers. The reliability of the system depends on the failure rates, repair rates and unavailability of each component of the distribution system. The load point indices improve with the addition of protective devices and thus improve the overall system reliability.

2. Power Flow Analysis

One of the common techniques used for power flow analysis is newton raphson method. It is an iterative technique used for solving the n number of set of nonlinear equations with n number of unknowns. The standard power flow equations of a power system are shown below

$$S_i = P_i + jQ_i \tag{1}$$

$$S_i = V_i \sum_{k=1}^{n} V_{ik} V_k \tag{2}$$

$$P_i = \sum_{k=1}^{n} (V_i V_k Y_{ik}) \cos(\delta_i - \delta_k - \theta_{ik}) \tag{3}$$

$$Q_i = \sum_{k=1}^{n} (V_i V_k Y_{ik}) \cos(\delta_i - \delta_k - \theta_{ik}) \tag{4}$$

$$\Delta P_i = P_{i(specified)} - P_{i(calculated)} \tag{5}$$

Where i=1,2……….n;
i must not represent slack bus

$$\Delta Q_i = Q_{i(specified)} - Q_{i(calculated)} \tag{6}$$

Where i=1,2……….n ;
i must not represent slack bus and PV bus

The above equations can be written in matrix form as shown below

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N \\ M & L \end{bmatrix} \begin{bmatrix} \Lambda\delta \\ \Delta V \end{bmatrix} \tag{7}$$

$$\Delta P_i^r < \varepsilon \tag{8}$$

$$\Delta Q_i^r < \varepsilon_1 \tag{9}$$

The values of Δδ and Δ|V| obtained in the above step are used to update the values of voltage magnitude and phase angle at all load buses by the equations shown below.

$$|V_i^{r+1}| = |V_i^r| + \Delta|V_i^r| \tag{10}$$

$$\delta_i^{r+1} = \delta_i^r + \Delta\delta_i^r \tag{11}$$

3. Optimal Power Flow Analysis

The optimal power flow aims to minimize the overall generation cost in the power system. The objective function is represented as:

$$min_x\, f(x)$$

Subject to: $$g(x) = 0$$

$$h(x) \leq 0$$

$$x_{min} \leq x \leq x_{max}$$

Where
f(x) is the objective function which consists the polynomial cost of generator injections. g(x) corresponds to the equality constraints representing the power balance equations.
h(x) corresponds to the inequality constraints representing the branch flow limits.
x_{min} and x_{max} limits include reference bus angles, bus voltage magnitudes and generator injections.
The objective function f(x) is a summation of cost functions f_P^i and f_Q^i of real and reactive

power injections, respectively, for each generator:

$$f(P_g, Q_g) = \sum_{i=1}^{n_g} f_P^i\,(P_g^i) + f_Q^i(q_g^i) \tag{12}$$

The equality constraints are the 2 sets of n_b nonlinear real and reactive power balance equations

$$g_P(\theta, V_m, P_g) = P_{bus}(\theta, V_m) + P_d - C_g P_g = 0 \quad (13)$$

$$g_Q(\theta, V_m, Q_g) = Q_{bus}(\theta, V_m) + Q_d - C_g P_g = 0 \quad (14)$$

The inequality constraints consists of two sets of n_l branch flow limits as nonlinear functions of the bus voltage angles and magnitudes, one for the from-end and one for the to-end of each branch

$$h_{f(0,V_m)} = |F_f(0, V_m)| \quad F_{max} \leq 0 \quad (15)$$

$$h_{t(\theta,V_m)} = |F_t(\theta, V_m)| - F_{max} \leq 0 \quad (16)$$

The variable limits include an equality constraint on any reference bus angle, upper and lower limits on all bus voltage magnitudes, real and reactive generator injections.

$$\theta_i^{ref} \leq \theta_i \leq \theta_i^{ref}, \qquad i \in I_{ref}$$

$$v_m^{i,min} \leq v_m^i \leq v_i^{i,max}, \qquad i = 1 \ldots \ldots n_b$$

$$P_g^{i,min} \leq P_g^i \leq P_g^{i,max}, \qquad i = 1 \ldots \ldots n_g$$

$$q_g^{i,min} \leq q_g^i \leq q_g^{i,max}, \qquad i = 1 \ldots \ldots n_g.$$

4. Reliability Analysis

The reliability associated with a power system is a measure of its ability to provide an adequate supply of electrical energy for the period of time intended under the operating conditions encountered. The reliability of the distribution system can be measured in terms of load point indices and system reliability indices. The load point indices are Failure rate, repair rate and average outage time. These load point indices are evaluated by using the given below equations

Failure rate $\lambda_s = \sum_{i=1}^{n} \lambda_i$ (17)

Average outage time $U_s = \sum_i^n \lambda_i r_i$ (18)

Repair time $r_s = \frac{U_s}{\lambda_s} = \frac{\sum_i^n \lambda_i r_i}{\sum_{i=1}^n \lambda_i}$ (19)

The total system indices are given by

System Average Interruption Frequency Index

$$SAIFI = \frac{Total\ number\ of\ customer\ interruption}{Total\ number\ of\ Customers\ served}$$

$$SAIFI = \frac{\sum \lambda_i N_i}{\sum N_i} \quad (20)$$

System average interruption duration index

$$SAIDI = \frac{Sum\ of\ customer\ duration\ interruption}{Total\ number\ of\ Customers\ served}$$

$$SAIDI - \frac{\sum U_i N_i}{\sum N_i} \tag{21}$$

Customer average interruption duration index

$$CAIDI = \frac{Sum\ of\ customer\ duration\ interruption}{Total\ number\ of\ Customers\ interruption}$$

$$CAIDI = \frac{\sum U_i N_i}{\sum \lambda_i N_i} \tag{22}$$

Average service availability index

$$ASAI = \frac{Customer\ hours\ of\ available\ service}{Customers\ hours\ demand}$$

$$ASAI = \frac{\sum N_i\ X\ 8760 - \sum U_i N_i}{\sum \lambda_i\ X\ 8760} \tag{23}$$

Total Energy not supplied by the system

$$ENS = \sum L_{ai}\ X\ U_s \tag{24}$$

5. Methodology Adopted

In this paper the novel approach for the optimal placement and sizing of DG under microgrid environment is proposed. The optimal placement and sizing of DG is taken care to reduce the line losses, improving system reliability, enhancement of voltage profile.

The importance given is for improvement of reliability indices, managing voltage profile and reduction in line losses. In this approach the load flow analysis, optimal power flow and reliability analysis has been considered for optimal siting and sizing of DG.

The newton raphson method of power flow analysis is implemented to evaluate the voltage profile and line losses of the system. OPF analysis is also performed for the evaluation of the same. The Reliability analysis is carried out to evaluate the load point and system point indices.

A proposed algorithm to obtain the optimal siting and sizing of DG in grid-connected mode of microgrid is as follows:

Step-1: Place Distributed Generation (DG) at one location feeder wise.
Step-2: Set the size of DG.
Step-3: Evaluate the load point indices and total system indices.
Step-4: Run the power flow and evaluate line flows, voltage profile and line losses.
Step-5: Vary the size of DG and Check the DG size for maximum value.
Step-6: If not reached its maximum value then go to step-3.
Step-7: Run the optimal power flow.
Step-8: Placing the DG at next bus and then repeating the process from step 2 until all the sizes and siting is covered.

Step-9: Optimal position and size of DG is selected by comparing the results of reliability, PFA and OPF in each case for lower losses and/or higher reliability.

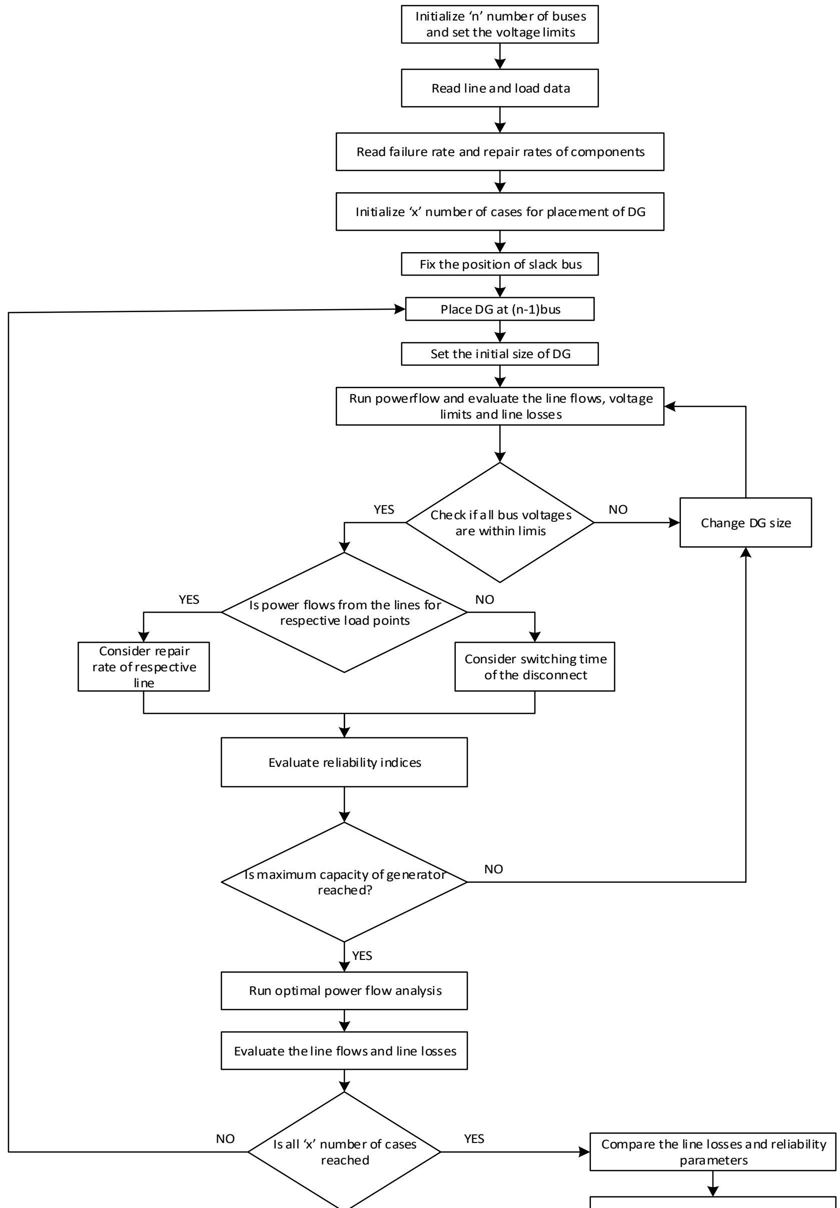

Figure. 1. Flow chart

6. Test System

The test system used for this research work is the distribution system of RBTS Bus-2 and feeder-1 and feeder-2 of RBTS Bus-4 system[1]. These systems consider all the main elements found in the actual distribution network. The protective elements used are disconnectors, fuses and circuit breakers.

The feeder-2 of RBTS bus-2 and bus-4 system are used for small user loads connected at high voltage side and the transformer is customer property. The other loads are on the low voltage side and the transformer is provided by the utility and included in the analysis.

The normally open sectionalizing points are provided between the feeders. These are used to interconnect the feeders to form a mesh network. In case of any fault occur in the feeder, the ring main units allow the customers to be supplied from alternative supply points.

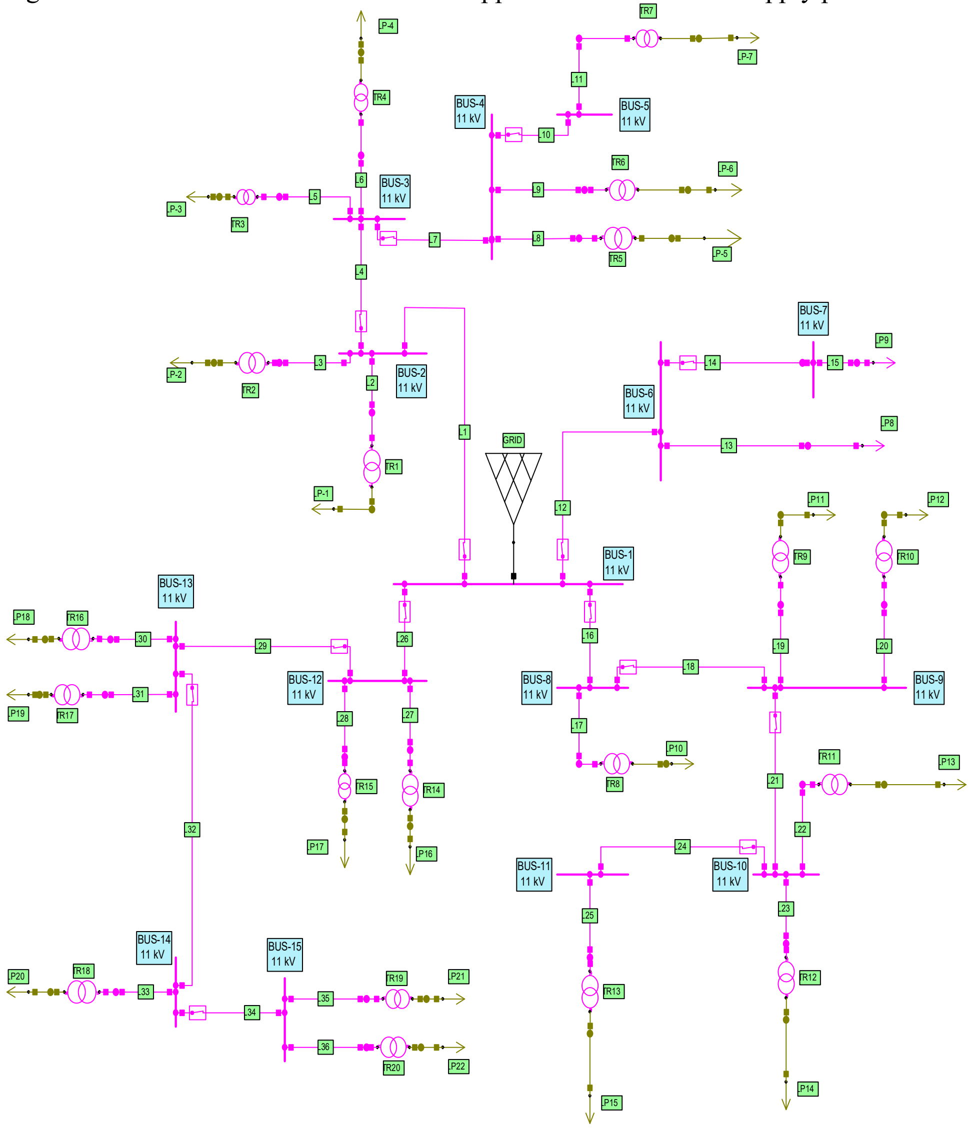

Figure. 2. RBTS BUS-2 SYSTEM

7. RESULTS & DISCUSSION

The evaluations are done and the results shown in this paper are the optimal results obtained from various sizes and placement of DG. The results are shown for all four feeders of RBTS Bus-2 system and two feeders of RBTS Bus-4 system.

The unavailability of each load point is evaluated considering the position of DG and the lines in which power flows to the respective load points. The switching time of the disconnectors are considered as 1sec. The disconnectors play major role in improving the reliability indices in case of main transmission lines. Likewise fuses improve the reliability of the load points with respect to lateral lines, thus the usage of the disconnectors and the fuses improves the reliability indices.

The voltage limits of each bus in the network are considered as 0.97p.u to 1.03p.u.

7.1 RBTS BUS-2: Feeder-1

The optimal siting of DG at feeder-1 for various positions is shown below in Table 1. The voltage profile of each bus with the placement of DG are shown from Figure 3 to Figure 7.

Table. 1 Optimal siting of DG at Feeder-1

Location of DG	LFA: Ploss(kW)	Reliability: ENS(MWh/yr)	OPF: Ploss(kW)
NO DG	18	13.2	19
Bus-2	9	12.9690	11
Bus-3	4	12.9630	7
Bus-4	4	12.9790	5
Bus-5	10	13.067	6

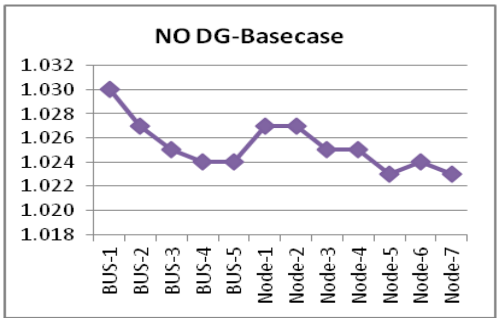

Figure. 3. Voltage magnitude without placing DG

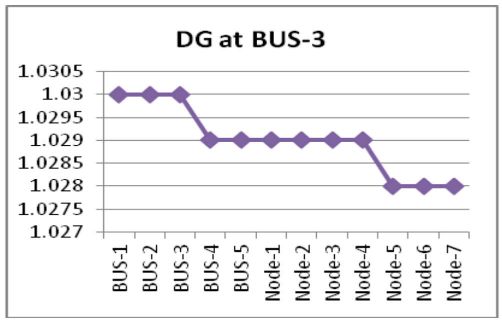

Figure. 5. Voltage magnitude for DG at Bus-3

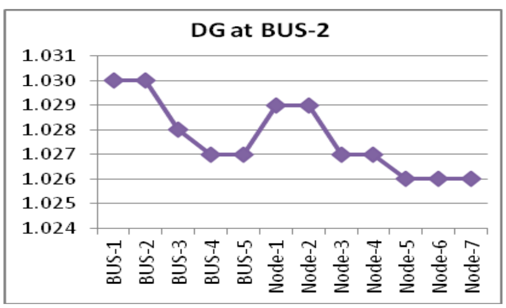

Figure. 4. Voltage magnitude for DG at Bus-2

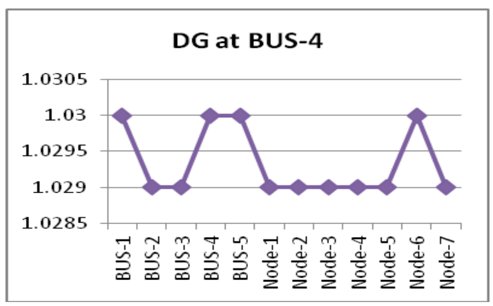

Figure. 6. Voltage magnitude for DG at Bus-4

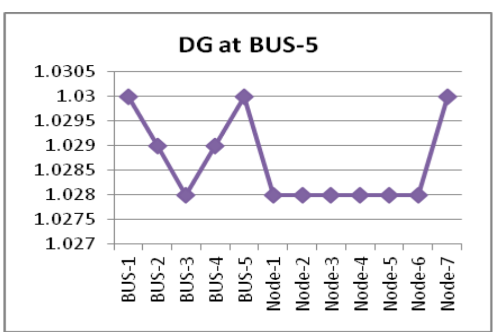

Figure. 7. Voltage magnitude for DG at Bus-5

Figure 8 shows the optimal results of lowest energy not supplied, lowest line losses as per power flow analysis and optimal power flow analysis of placement of DG at various buses of feeder-1.

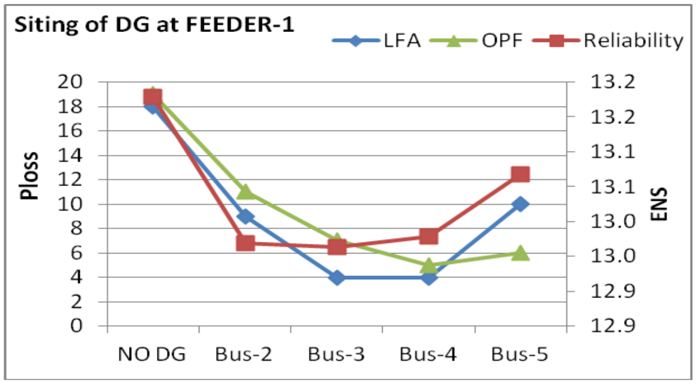

Figure. 8. Siting of DG at Feeder-1

According to the voltage stability, the better choice of DG location is at bus- 4. As per the reliability evaluation the improved reliability (ENS, SAIDI, CAIDI, ASAI, ASUI, AENS) is at bus- 2 and bus-3, but at bus-2 location the losses are higher than the losses at bus-3 and bus-4. Comparing the reliability at bus-3 and bus-4 the variation of ENS is 0.01Mwh/yr. Hence the optimal location of DG for feeder-1 is chosen as Bus-4.

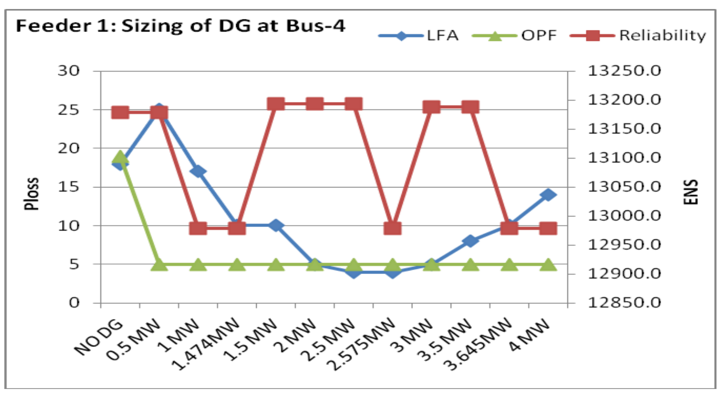

Figure. 9. Sizing of DG at Bus-4 for feeder-1

The optimal size is arrived after evaluation is done for various sizes of DG at bus-4 as shown in Figure 9. From the above chart the size of DG should be 2.575MW.

7.2 RBTS BUS-2: FEEDER-2

The optimal siting of DG at feeder-2 for various positions is shown below in Table 2. The voltage profile of each bus with the placement of DG for feeder-2 of RBTS bus-2 system are shown from Figure 10 to Figure 12.

Table. 2 Optimal siting of DG at Feeder-2

DG Location	LFA: Ploss(kW)	Reliability: ENS(kWh/yr)	OPF: Ploss(kW)
NO DG	7	1115.0	7
BUS-6	2	927.60	3
BUS-7	2	904.20	2

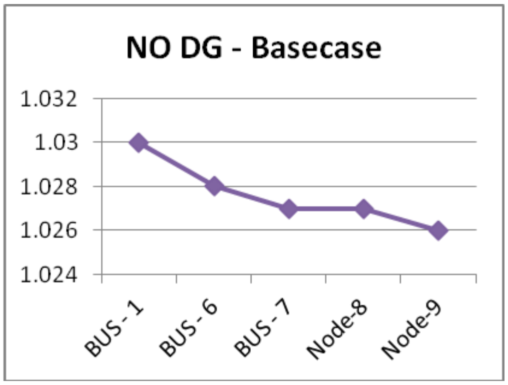

Figure. 10. Voltage magnitude without DG

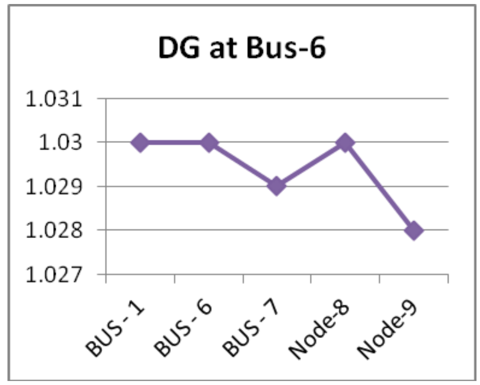

Figure. 11. Voltage magnitude for DG at Bus-6

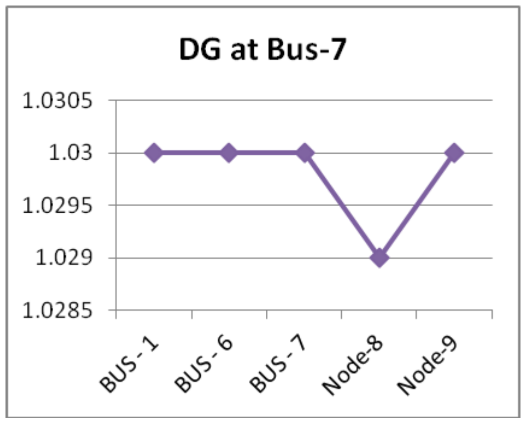

Figure. 12. Voltage magnitude for DG at Bus-7

The Figure 13 shows the optimal results of lowest energy not supplied, lowest line losses as per power flow analysis and optimal power flow analysis of placement of DG at various buses of feeder-2.

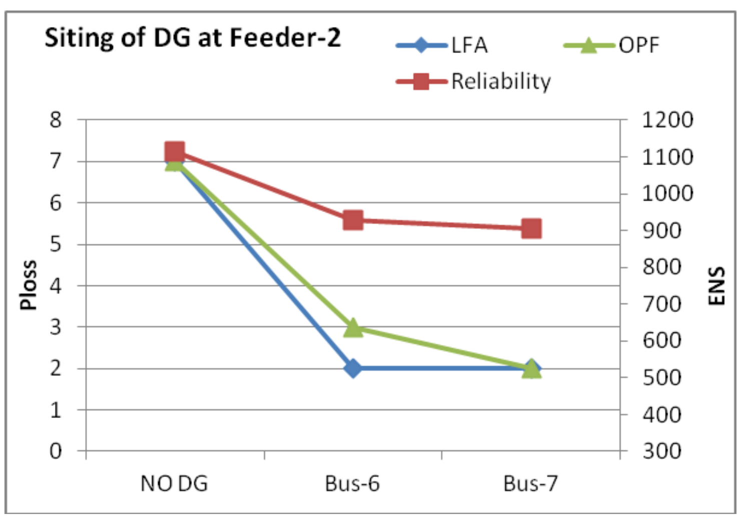

Figure. 13. Siting of DG at feeder-2

According to the voltage stability, the better choice of DG location is at bus-7. As per the reliability evaluation the improved reliability (ENS, SAIDI, CAIDI, ASAI, ASUI, AENS) is also obtained at bus- 7 and lowest losses are obtained when DG is placed at bus-7. Hence the optimal location of DG for feeder-2 is chosen as bus-7.

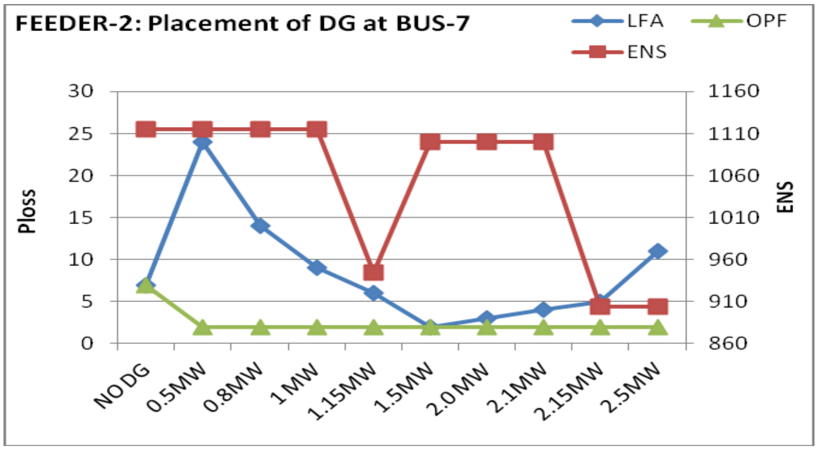

Figure. 14. Sizing of DG at Bus-7 for feeder-2

The location and size is arrived after evaluation is done for various sizes of DG at bus-7 as shown in Figure 14. From the above chart the size of DG should be 2.15MW.

7.3 RBTS BUS-2: Feeder-3

The optimal siting of DG at feeder-3 for various positions is shown below in Table 3. The bus voltage magnitudes of each bus with the placement of DG are shown from Figure 15 to Figure 19.

Table. 3 Optimal siting of DG at Feeder-3

DG location	LFA: Ploss(kW)	Reliability: ENS(kWh/yr)	OPF: Ploss(kW)
NO DG	9	11210.2	10
Bus-8	5	11102.00	6
Bus-9	2	11002.00	3
Bus-10	1	10979.00	3
Bus-11	3	11112.00	3

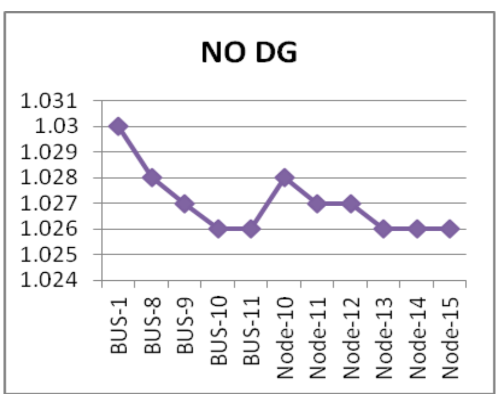

Figure. 15. Voltage magnitude without DG

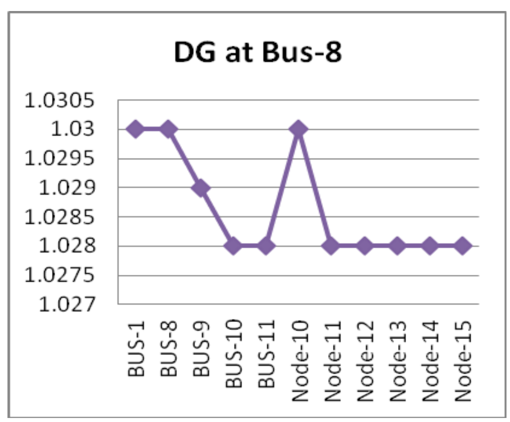

Figure. 16. Voltage magnitude for DG at Bus-8

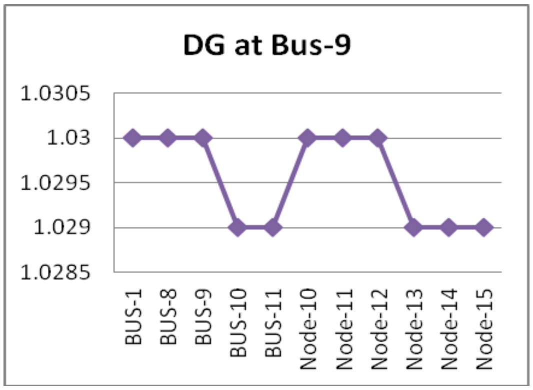

Figure. 17. Voltage magnitude for DG at Bus-9

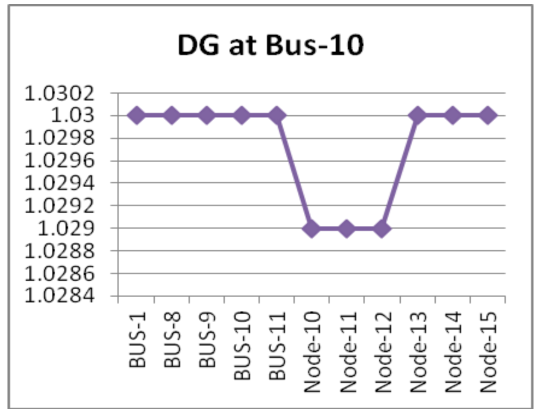

Figure. 18. Voltage magnitude for DG at Bus-10

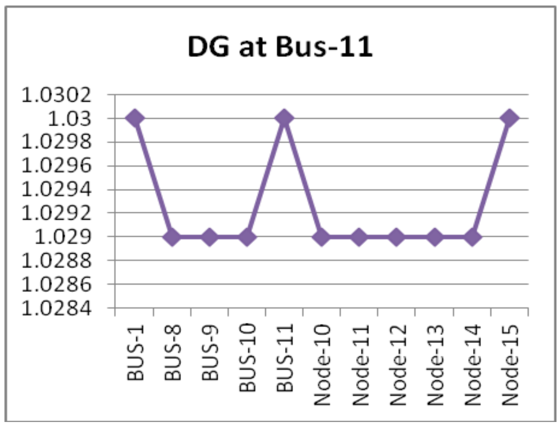

Figure. 19. Voltage magnitude for DG at Bus-11

Figure 20 shows the optimal results of lowest energy not supplied, lowest line losses as per power flow analysis and optimal power flow analysis of placement of DG at various buses of feeder-3 of RBTS bus-2 system.

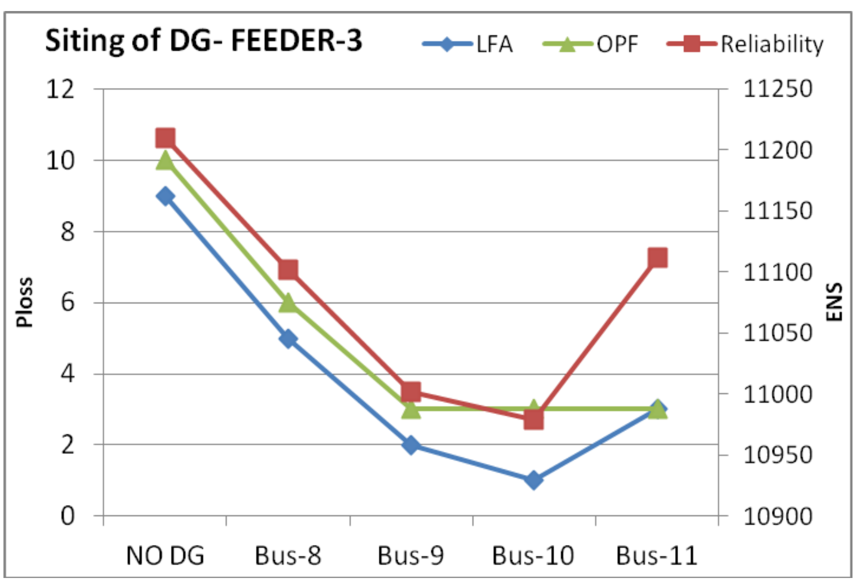

Figure. 20. Siting of DG at Feeder-3

According to the voltage stability, the better choice of DG location is at BUS- 9, or Bus-10 or Bus-11. According to the reliability evaluation the improved reliability (ENS, SAIDI, CAIDI, ASAI, ASUI, AENS) is at bus-10 and next better option is bus-9. According to OPF and LFA the lower losses is obtained at bus-10 and next is bus-9. Hence bus-10 is chosen as the optimal location of placement of DG.

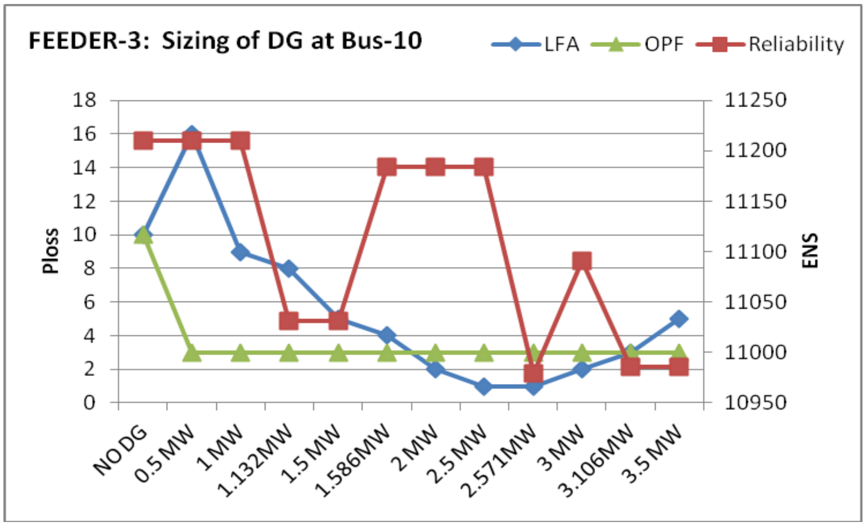

Figure. 21. Sizing of DG at Bus-4 for feeder-3

The location and size is arrived after evaluation is done for various sizes of DG at bus-10 as shown in Figure 21. From the above chart the size of DG should be 2.571MW.

7.4 RBTS BUS-2: Feeder-4

The optimal siting of DG at feeder-4 for various positions is shown below in Table 4. The bus voltage profile of each bus with the placement of DG are shown from Figure 22 to Figure 26.

Table. 4 Optimal siting of DG at Feeder-4

DG location	LFA: Ploss (kW)	Reliability: ENS(kWh/yr)	OPF: Ploss(kW)
NO DG	9	12258.34	10
Bus-12	5	12059.00	6
Bus-13	2	12060.00	3
Bus-14	1	12125.00	3
Bus-15	3	12065.00	3

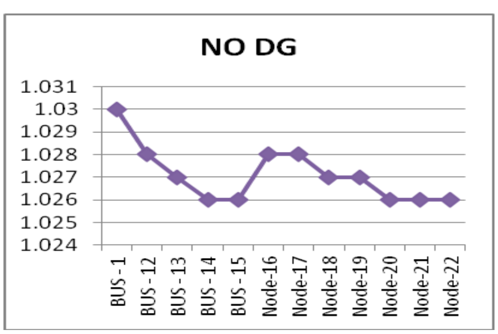

Figure. 22. Voltage magnitude without DG

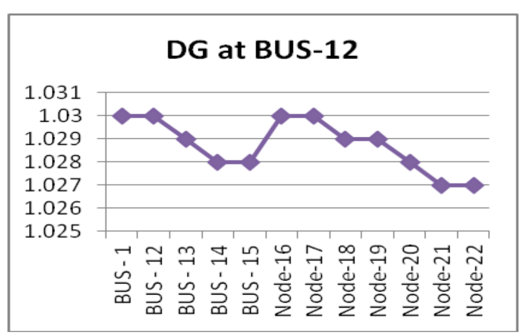

Figure. 23. Voltage magnitude for DG at Bus-12

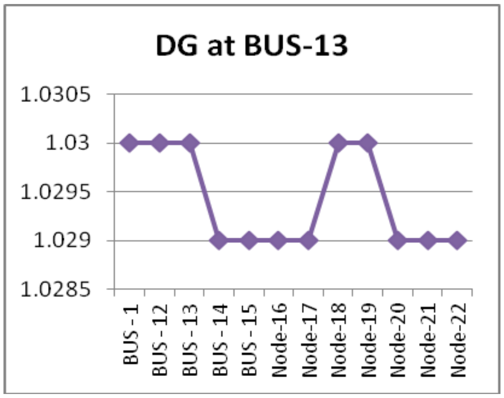

Figure. 24. Voltage magnitude for DG at Bus-13

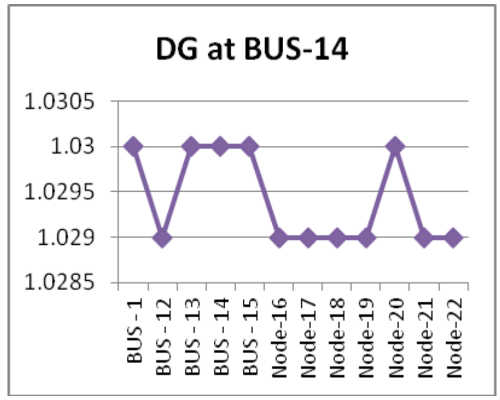

Figure. 25. Voltage magnitude for DG at Bus-14

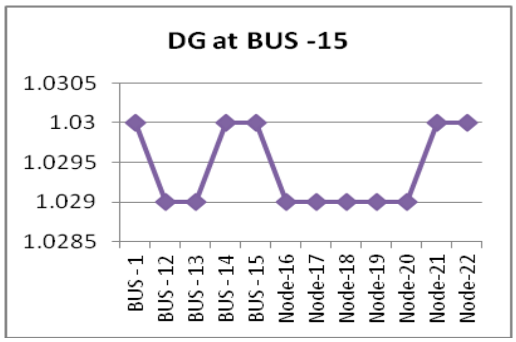

Figure. 26. Voltage magnitude for DG at Bus-15

Figure 27 shows the optimal results of lowest energy not supplied, lowest line losses as per power flow analysis and optimal power flow analysis of placement of DG at various buses.

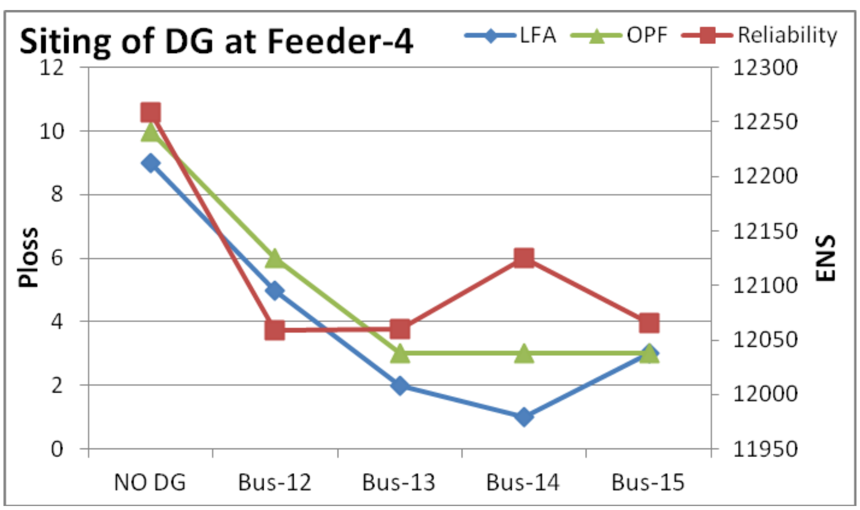

Figure. 27. Siting of DG at Feeder-4

According to the voltage stability, the better choice of DG location is at bus- 13, or bus-14 or Bus-15. According to the reliability evaluation the improved reliability (ENS, SAIDI, CAIDI, ASAI, ASUI, AENS) is at bus-13. According to OPF and LFA the lower losses is obtained at bus-14 and next is Bus-13, but at bus-14 even though there is lower losses but there is increase in 50kWh/yr energy not supplied compared to bus-13. Hence bus-13 is chosen as the optimal location for the placement of DG.

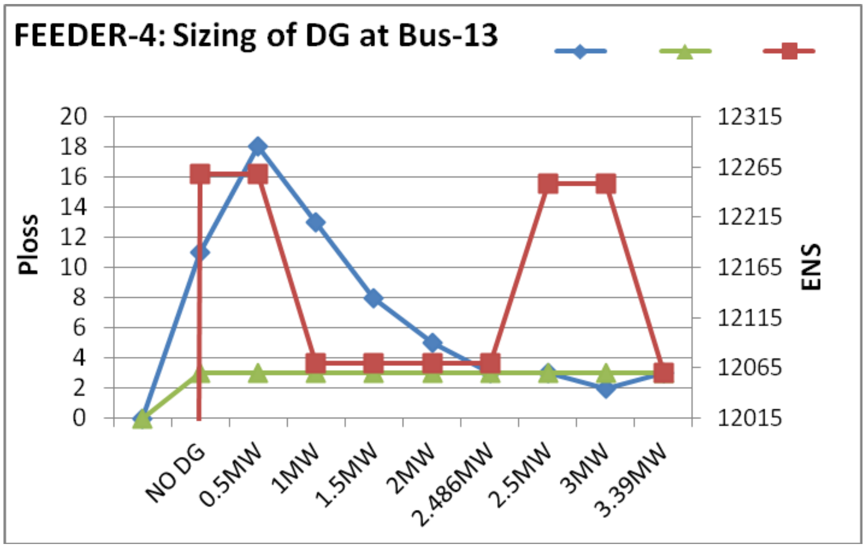

Figure. 28. Sizing of DG at Bus-13 for feeder-4

The location and size is arrived after evaluation is done for various sizes of DG at bus-13 as shown in Figure 28. From the above chart the size of DG should be 2.486MWor 3.39MW.

7.5 RBTS BUS-4: FEEDER-1

The Figure 29 shows the network of feeder-1 of RBTS bus-4 system. The optimal siting of DG at feeder-1 for various positions is shown below in Table 5. The bus voltage magnitudes of each bus with the placement of DG are shown from Figure 30 to Figure 35.

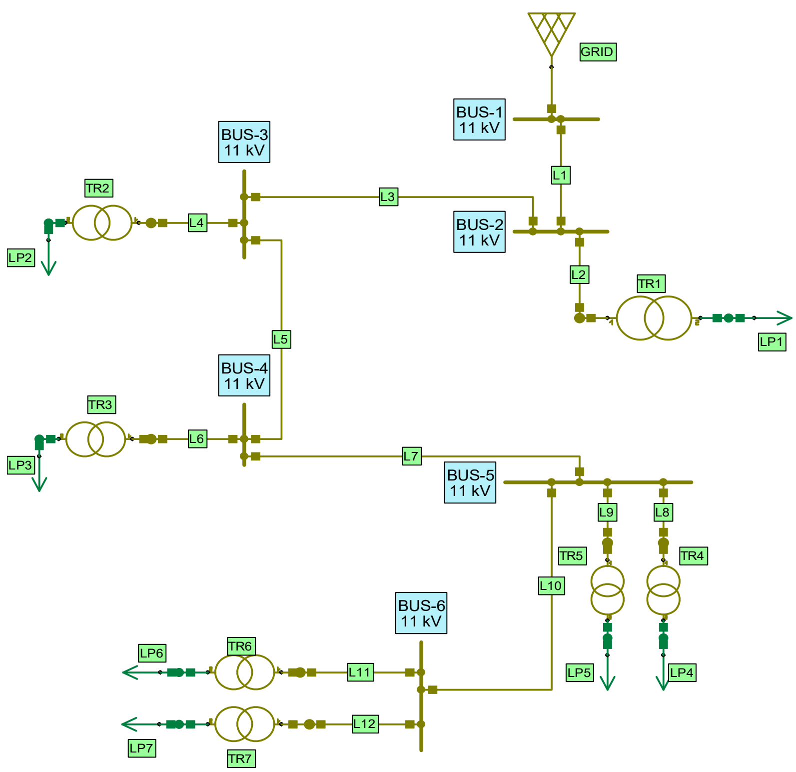

Figure. 29. Feeder-1 of RBS Bus-4

Table. 5 Optimal siting of DG at Feeder-1

PLACEMENT	LFA: losses(Kw)	Reliability: ENS(MWh/yr)	OPF: losses(Kw)
NO DG	25	12863.6000	25
BUS-2	16	12646.6900	18
BUS-3	9	12721.9000	12
BUS-4	5	12721.9000	8
BUS-5	3	12601.0400	6
BUS-6	5	12607.5800	6

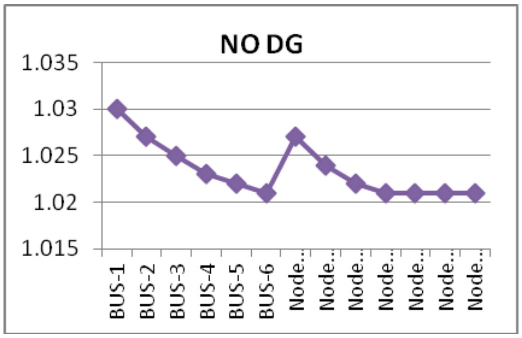

Figure. 30. Voltage magnitude without DG

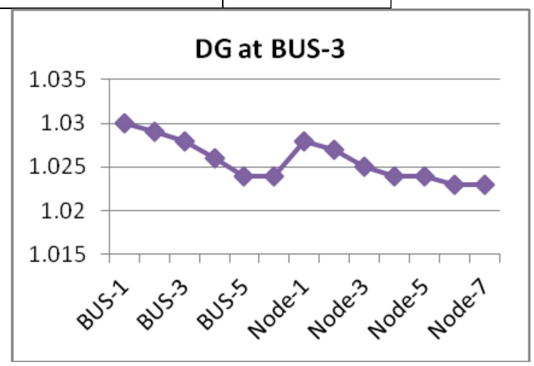

Figure. 32. Voltage magnitude for DG at Bus-3

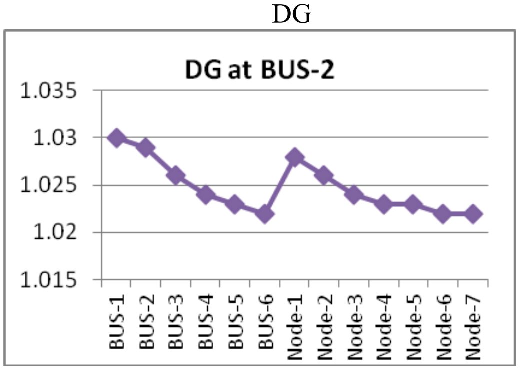

Figure. 31. Voltage magnitude for DG at Bus-2

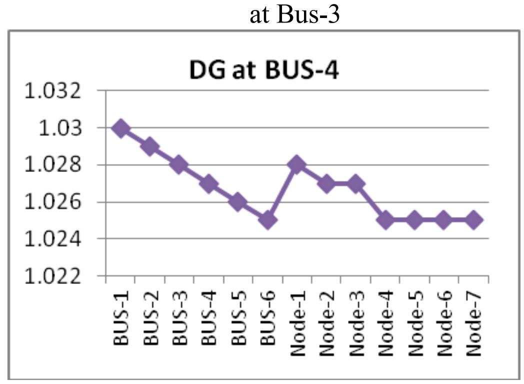

Figure. 33. Voltage magnitude for DG at Bus-4

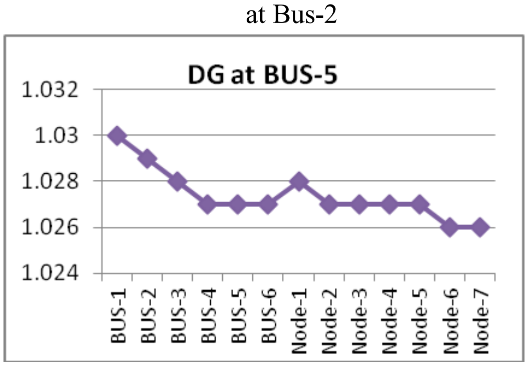

Figure. 34. Voltage magnitude for DG at Bus-5

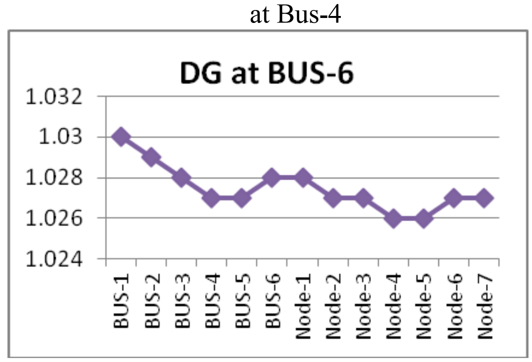

Figure. 35. Voltage magnitude for DG at Bus-6

Figure 36 shows the optimal results of lowest energy not supplied, lowest line losses as per power flow analysis and optimal power flow analysis of placement of DG at various buses.

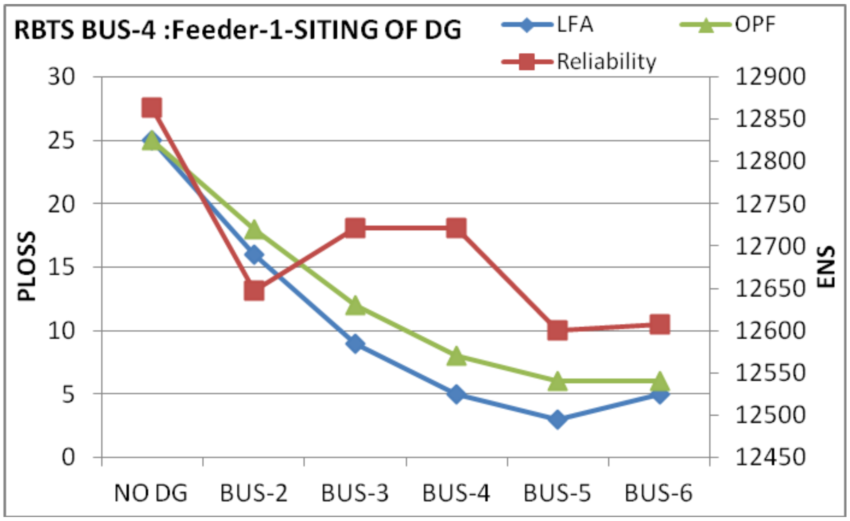

Figure. 36. Siting of DG at Feeder-4 of RBTS Bus-4 system

According to the voltage stability, the better choice of DG location is at bus-5. According to the reliability evaluation the improved reliability (ENS, SAIDI, CAIDI, ASAI, ASUI, AENS) is at bus-5 and next better option is bus-6. According to OPF and LFA the lower losses is obtained at bus-5. Hence bus-5 is chosen as the optimal location for the placement of DG

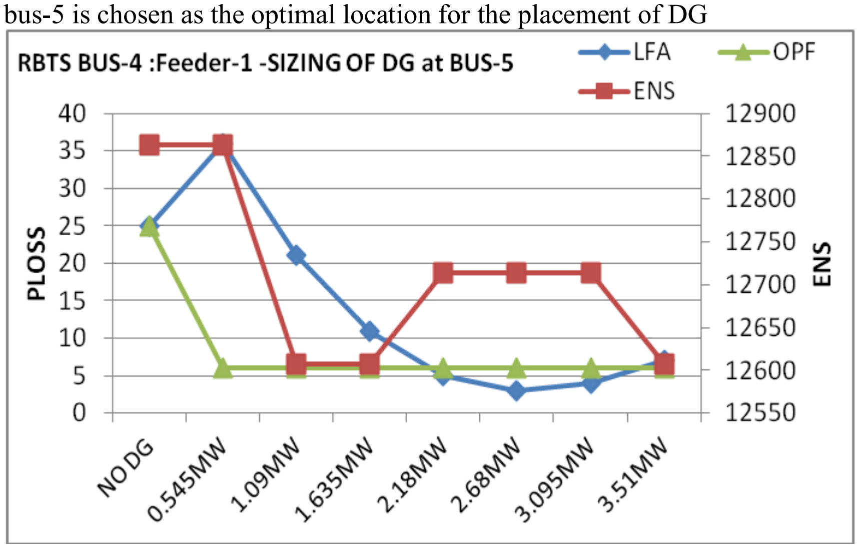

Figure. 37. Sizing of DG at Bus-3 for feeder-4 of RBTS Bus-4 system

The location and size is arrived after evaluation is done for various sizes of DG at bus-5 as shown in Figure 37. From the above chart the optimal size of DG should be 1.635MW or 3.51MW.

7.6 RBTS BUS-4: FEEDER-2

The Figure 38 shows the network of feeder-2 of RBTS bus-4 system. The optimal siting of DG at feeder-2 for various positions is shown below in Table 5. The bus voltage magnitudes of each bus with the placement of DG are shown from Figure 30 to Figure 35.

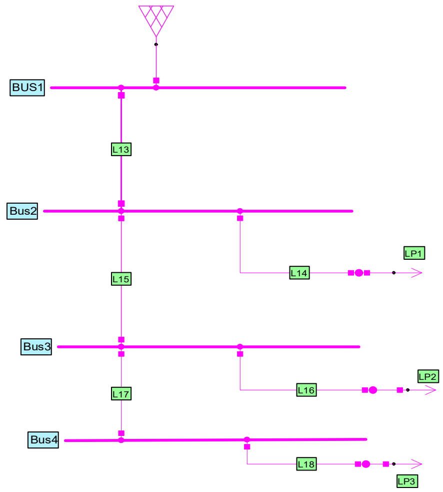

Figure. 38. Feeder-2 of RBS Bus-4

Table. 6 Optimal siting of DG at Feeder-2 of RBTS bus-4

PLACEMENT	LFA: losses(Kw)	Reliability: ENS(MWh/yr)	OPF: losses(Kw)
NO DG	4	1999.000	4
BUS-2	2	1791.00	2
BUS-3	2	1687.00	1
BUS-4	1	1765.00	1

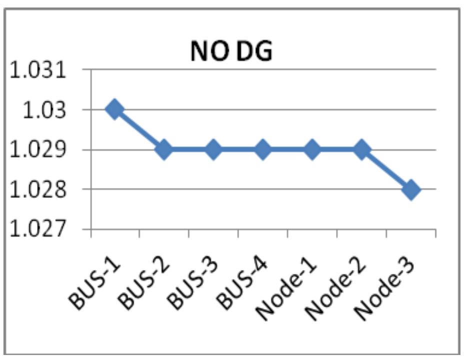

Figure. 39. Voltage magnitude for without DG

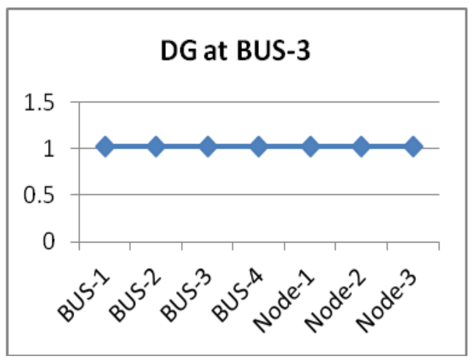

Figure. 41. Voltage magnitude for DG at Bus-3

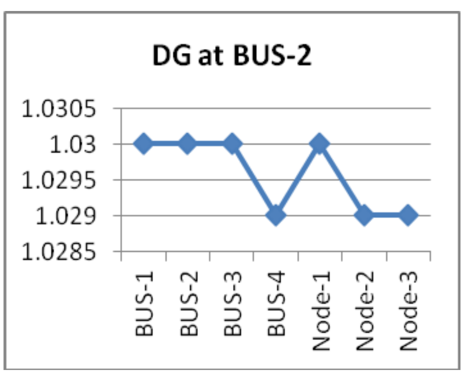

Figure. 40. Voltage magnitude for DG at Bus-2

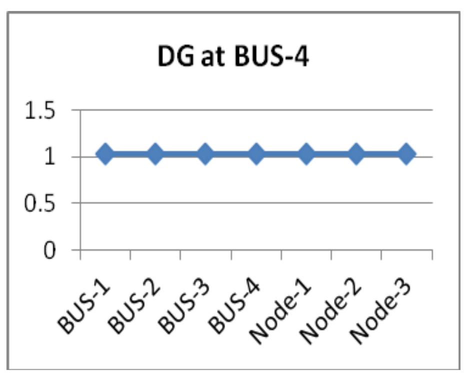

Figure. 42. Voltage magnitude for DG at Bus-4

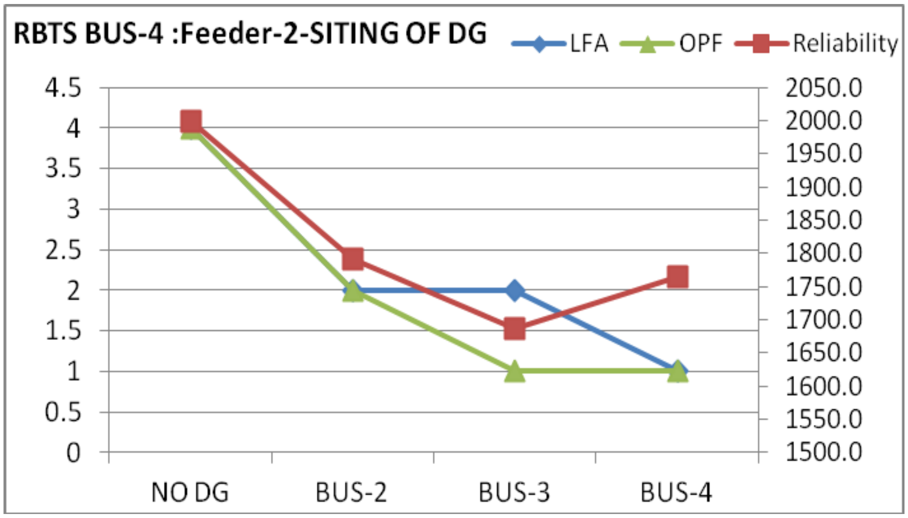

Figure. 43. Siting of DG at Feeder-2 of RBTS Bus-4

According to the voltage stability, the better choice of DG location is at bus-3 and bus-4. According to the reliability evaluation the improved reliability (ENS, SAIDI, CAIDI, ASAI, ASUI, AENS) is at bus-3. According to OPF the lower losses is obtained at Bus-3 and Bus-4 and from LFA the lower losses are at bus-4. Hence bus-3 is chosen as the optimal location for the placement of DG

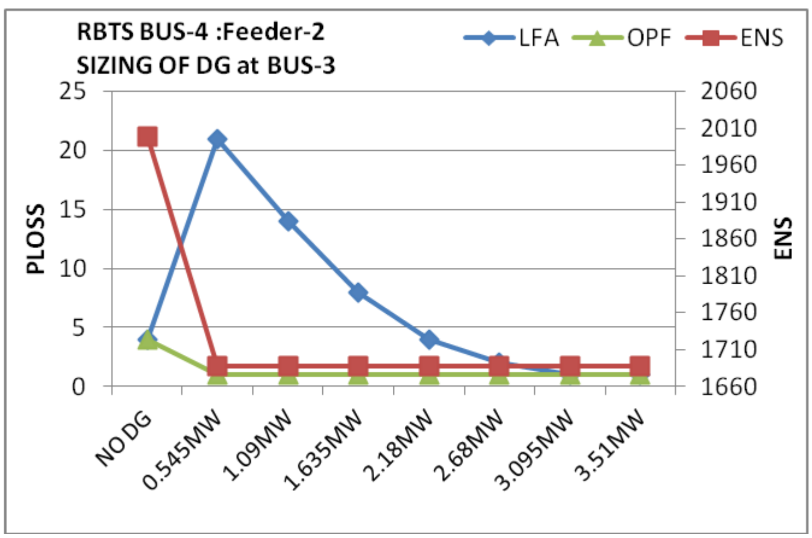

Figure. 44. Sizing of DG at Bus-3 for feeder-2 of RBTS Bus-4 system

The location and size is arrived after evaluation is done for various sizes of DG at bus-3 as shown in Figure 44. From the above chart the size of DG should be 2.68MW and above.

8. CONCLUSION

The approach proposed in this research work provides us the optimal solution for siting and sizing of DG in a microgrid. The results show the improvement in the reliability, reduction in line losses and enhancement in the voltage stability of the complete system. It has been observed from the results that the improper sizing and placement of DG leads to increase in total system losses. The reliability is further improved with the addition of protective devices in a network. The approach given performs the power flow analysis, optimal power flow as well as reliability evaluation. The proposed approach is evaluated for RBTS bus-2 and RBTS bus-4 system. The percentage of loss reduction for each feeder of RBTS bus-2 system with DG are 77.77%, 71.42%, 88.88% and 77.77% respectively. The percentage of reduction in Energy not supplied for each feeder of RBTS bus-2 system with DG are 1.67%, 18.90%, 2.062% and 1.618% respectively. The percentage of loss reduction for each feeder-1 & feeder-2 of RBTS bus-4 system with DG are 88% and 50% respectively. The percentage of reduction in Energy not supplied for feeder-1 &2 of RBTS bus-4 system with DG are 2.04% and 15.60% respectively.

REFERENCES

Journal Article

[1] *Roy Billinton and SatishJonnavithula., "A Test System For Teaching Overall Power System Reliability Assessment", IEEE Transactions on Power Systems, Vol. 1, No. 4, November 1996.*

[2] *R. N. Allan, R. Billinton, I. Sjarief, L. Goel, and K. S. So, "A reliability test system for educational purposes—Basic distribution system data and results," IEEE Trans. Power Syst., vol. 6, no. 2, pp. 813–820, May 1991.*

[3] *Gousia sultana, Keshavan B.K,"Power System Reliability in Distributed Generation Environment: A Review", Power research journal CPRI, ISSN: 0973-0338, Vol. 14, DOI : 10.33686/pwj.v14i1.142173, June 2018.*

[4] *Gousia sultana, Keshavan B.K, "Evaluation of Performance and Reliability Indices of a Micro-Grid with Distributed Generation" 2020 IEEE REGION 10 CONFERENCE (TENCON), DOI: 10.1109/TENCON50793.2020.9293700, Osaka, Japan, Dec 2020*

[5] *Gousia sultana, Keshavan B.K,"Reliability evaluation with siting and sizing of dg for a distribution system with disconnects" Journal of Xi'an University of Architecture & Technology, Volume XIII, Issue 8, Pp259-268, DOI:10.37896/JXAT13.8/313677, Aug 2021.*

[6] *Singh and Balwinder Singh Surjan "Microgrid: A Review" IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.*

[7] *Quanyuan Jiang, Meidong Xue, and Guangchao Geng, "Energy Management of Microgrid in Grid-Connected and Stand-Alone Modes" IEEE Transactions on Power Systems, Vol. 28, No. 3, August 2013.*

[8] *K.H. Kim, Y.J. Lee, S.B. Rhee, S.K. Lee and S.K.You, "Dispersed generator placement using fuzzy-GA in distribution system" IEEE PES Summer Meeting, Vol. 3, pp. 1148-1153, 2002.*

[9] *Shouxiang Wang, Zhixin Li, Qun Xu, Zuyi Li, "Reliability Analysis of Distributed System with DGs", 4th International Conference on Electric Utility Deregulation and Restructuring and Power Technologies (DRPT), IEEE Conference, 2011, DOI: 10.1109/DRPT.2011.5993855.*

[10] *Abdulaziz. A. Alkuhayli, Srinath Raghavan, Badrul H. Chowdhury, "Reliability Evaluation of Distribution Systems Containing Renewable Distributed Generations", 978-1-4673-2308-6/12/2012 IEEE*

[11] *M.Boonthienthong, N.Rugthai charoencheep, S. Auchariyamet, "Service Restoration of Distribution System with Distributed Generation for Reliability Worth", 47th International Universities Power Engineering Conference (UPEC), IEEE Conferences, 2012.*

[12] *Chengming Wu a, Jie Liub and Yabin Wuc, "The Impacts of Micro-grid on the Reliability of Distribution System" 2015 International Symposium on Smart Electric Distribution Systems and Technologies (EDST), IEEE Conference, 978-1-4577-1415-3, 2012.*

[13] *Dongmei Zhao, Yafei Li, Yanhua Liu, "Optimal design and sensitive analysis of distributed generation system with renewable energy sources" IEEE, 10.1109/CICED.2014.6991749.*

Book

[1] Roy Billinton, Ronald N. Allan "Reliability Evaluation of Power Systems", second edition, plenum press, newyork and London,1994.

[2] Roy Billinton, Ronald N. Allan "Reliability Evaluation of Engineering Systems", second edition, Springer Science+Business Media,1992.