Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 11 Issue 1, January - 2024

Evaluation Of Ant Colony Optimisation-Based Distributed Generation Sizing And Location On IEEE 33 Bus Network

Agbaji Adai Samuel[1]
Department of Computer Engineering
University of Uyo, Uyo
Akwa Ibom State, Ngeria
agajisam@yahoo.com

Ezuruike Okafor S. F. [2]
Department of Electrical/Electronic Engineering
Imo State Polytechnic, Omuma,
Imo State, Nigeria

Uduaka Etim Udoka[3]
Department of Computer Engineering
Akwa Ibom State Polytechnic Ikot Osurua,
Ikot Ekpene, Akwa Ibom State

***Abstract*— The study focused on evaluation of ant colony optimisation-based distributed generation sizing and location on IEEE 33 bus network. The single line diagram of the case study IEEE 33-Bus network was along with the flow diagram of the improved Backward/Forward Sweep method used to carry out the power flow analysis from which the power losses, voltage profile and Voltage Deviation Index (VDI) were determined for the base case when no distributed generation system was included in the IEEE 33 bus network. The results showed that for the baseline case, the total real power loss of 202.4 kW and the total reactive power loss of 135.1 kVar were realized and the losses amount to 5.448183042 % of the total real power and 5.873913043% of the total reactive power with Voltage Deviation Index (VDI) of 11.64 %. The maximum voltage was 0.997 pu which occurred at bus number 2 and the minimum voltage was 0.9134 pu which occurred at bus number 18. The results obtained from the ACO placement and sizing of DG on the IEEE 33 bus showed that the reduction in real power losses with respect to the baseline (no DG) for the three scenarios were 42.1 % for 1 DG, 52.2 % for 2 DG and 54.1 % for 3 DG. Also, the reduction in reactive power losses with respect to the baseline (no DG) for the three scenarios were 39.1 % for 1 DG, 50.4 % for 2 DG and 53.9 % for 3 DG.**

Keywords— Ant Colony Optimisation, Power Losses, Voltage Profile, IEEE 33 Bus Network, Voltage Deviation Index, Distributed Generation Sizing And Location

1. INTRODUCTION

Over the years, studies have shown that optimal placement and sizing of Distributed Generation (DG) units in the power distribution systems play a significant role in maximising the advantages and minimising undesirable effects [1,2,3]. DG integration can lead to reduction in power losses, improvement of voltage stability, improvement in resilience, and improvement in the capacity to serve increasing demand [4,5,6]. To overcome this difficult optimisation problem, there is need to employ a range of approaches, including conventional methods, AI-like approaches, hybrid solutions [7,8]. Without optimal DG placement, the system suffers from more losses and lower performance, so getting the right placement is important [8,9,10].

Consequently, in this paper, Ant Colony Optimization (ACO) is presented for DG sizing and placement on IEEE 33 bus. ACO is a metaheuristic technique that mimics the ants' foraging behaviour by applying artificial pheromone trails in the solutions computation **[11,12,13].** ACO employs probabilistic algorithm to generate candidate solutions based on the available pheromone information and heuristic data [12,13,14,15]] The application of ACO in power systems span across different topics; it has been used to tackle problems like minimization of fuel cost, enhancement of voltage profile as well as voltage stability improvement [16,17,18]**.** The ACO technique was successfully applied to economic dispatch problems which entails generation costs minimization for a given load **demands [19]** Given the capabilities of ACO technique, this work employs the ACO DG sizing and placement algorithm to minimize power loss while at the same time enhancing the voltage stability. The study specifically, applied the ACO algorithm under DG different configurations so as to evaluate the effect of different number of DGs on the power loss and voltage stability of the IEEE 33 radial power distribution network.

2. METHODOLOGY

The Ant Colony Optimisation (ACO) algorithm is employed to determine the optimal size and location of Distributed Generation (DG) on IEEE 33 bus network. The single line diagram of the case study IEEE 33-Bus network is depicted in Figure 1. The graphical plot of the line data of the 33 bus network is presented in Figure 2 while the load demand data of the network is also presented in Figure 3. The Improved Backward/Forward Sweep method of power flow analysis (shown in Figure 4) is applied to determine the power losses, voltage profile and Voltage Deviation Index (VDI) for the base case where no distributed generation system is included in the IEEE 33 bus network. The Ant Colony Optimisation (ACO) algorithm used for the DG sizing and placement is captured using the ACO Pseudocode presented in Section 2.1. The Ant Colony Optimisation (ACO) algorithm control parameters as used in this study are shown in Table 1.

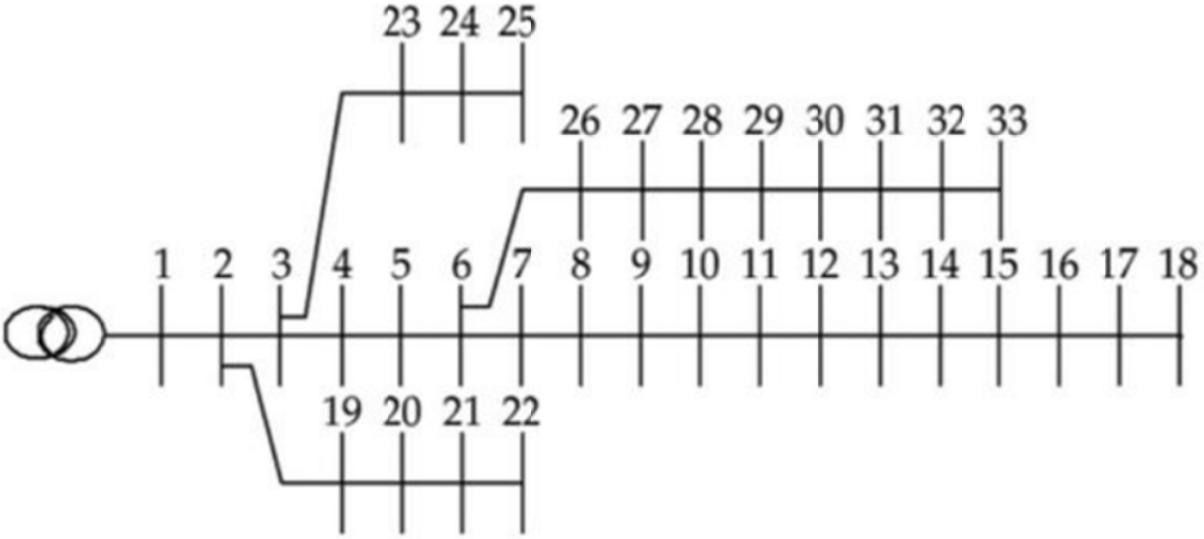

Figure 1. The single line diagram of the case study IEEE 33-Bus network [20,21]

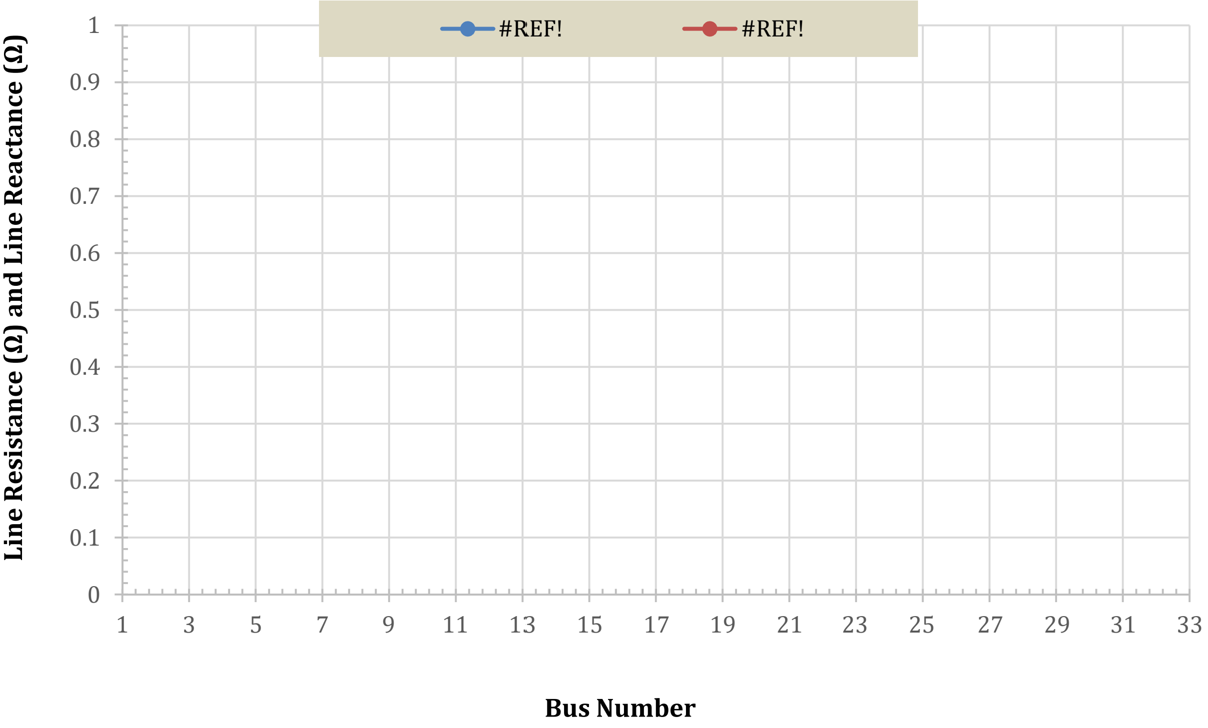

Figure 2 IEEE 33 bus test system line data

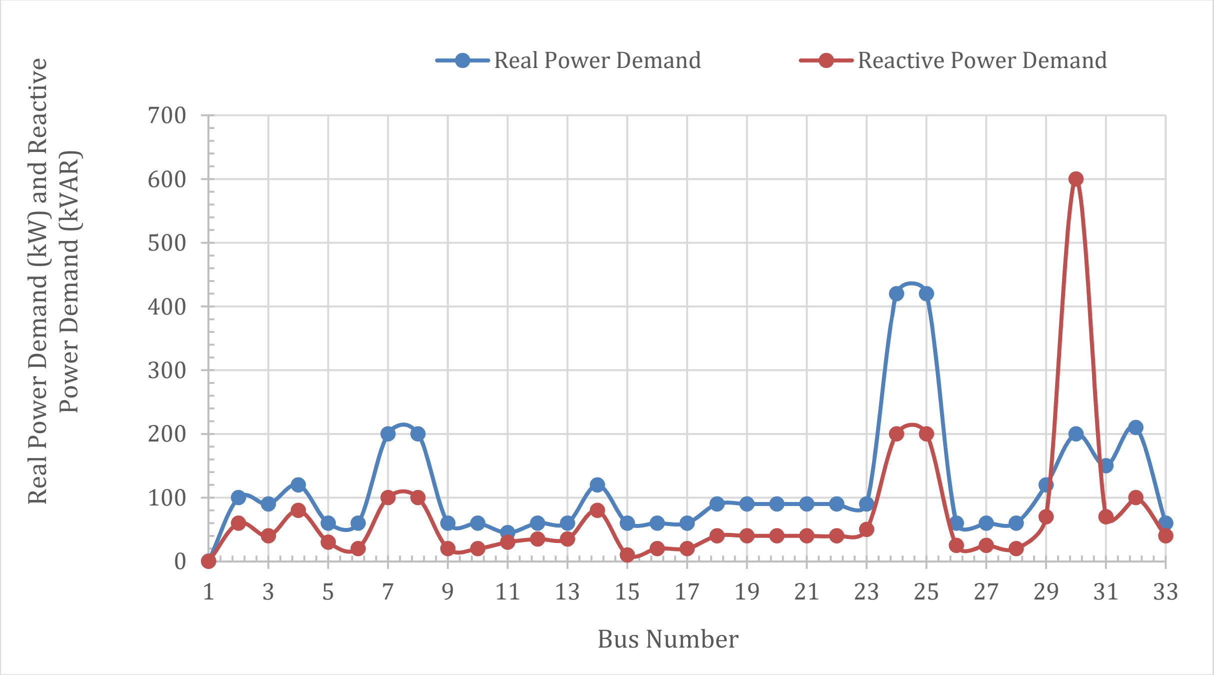

Figure 2 IEEE 33 bus test system load demand data

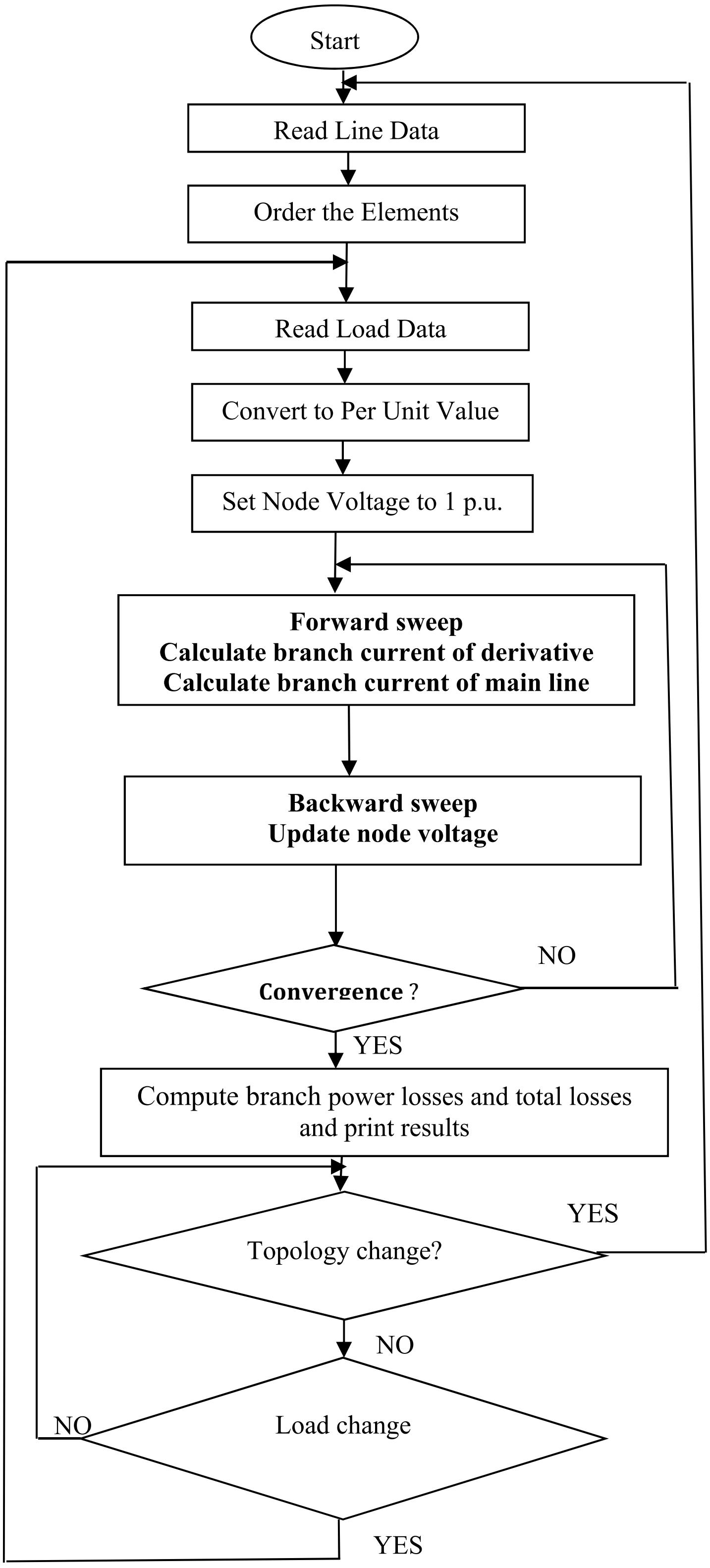

Figure 1 Flow diagram of Improved Backward/Forward Sweep method of Power Flow analysis

2.1 The Ant Colony Optimization (ACO) Pseudocode for DG placement and Sizing

```
i.    Initialize necessary parameters, pheromone trials, and candidate locations for DG;
ii.   while not termination do:
iii.  Generate ant population;
iv.   for each ant do:
v.    Select a candidate location for DG based on pheromone trials and heuristic information;
vi.   Determine the size of DG at the selected location;
vii.  end for
viii. Evaluate the fitness of each solution (i.e., power loss and voltage stability for the given DG placement and sizing);
ix.   Update pheromone trials based on the quality of solutions;
```

```
x.    end while
xi.   Return the best solution found;
xii.  end procedure.
```

Table 1: The Ant Colony Optimization (ACO) algorithm control parameters as used in the this study

Parameters	Values	Explanation
Population size	50	This defines the number of search ants exploring the solution space concurrently.
Maximum iterations	100	This sets the maximum number of times the ACO loop (ant movement and pheromone update) will be executed. It monitors convergence behaviour during simulations.
Alpha (α)	0.1	This parameter controls the relative importance of pheromone trails in guiding ant movement.
Beta (β)	1.0	This parameter controls the relative importance of the heuristic information (objective function value) in guiding ant movement.
Rho (ρ)	0.9	This parameter controls the rate of pheromone evaporation. Higher values lead to faster decay of pheromone trails, encouraging exploration of new areas.

3. RESULTS AND DISCUSSIONS

The results obtained from the load flow analysis conducted using Improved Backward/Forward Sweep method are shown in Table 2. The results (in Table 2 and Figure 2) are for the case of no DG in the network. In this case, the total real power loss of 202.4 kW and the total reactive power loss of 135.1 kVar are realized without DG and the losses amount to 5.448183042 % of total real power and 5.873913043% of total reactive power with voltage deviation index (VDI) of 11.64 %. The maximum voltage obtained is 0.997 pu which occurred at bus number 2 and the minimum voltage obtained is 0.9134 pu which occurred at bus number 18.

Table 2 The results obtained from the load flow analysis for the base case where there is no DG

Parameters	Base Case	Parameters	Base Case
Total real power demand (kW)	3715	Minimum voltage (pu)	0.9134
Total reactive power demand (kVAR)	2300	Minimum voltage bus number	18
Total real power loss (kW)	202.4	Maximum Voltage (pu)	0.997
Total reactive power loss(kVAR)	135.1	Maximum voltage Bus number	2
Voltage deviation Index, VDI (%)	11.64	Voltage deviation index (%)	11.64

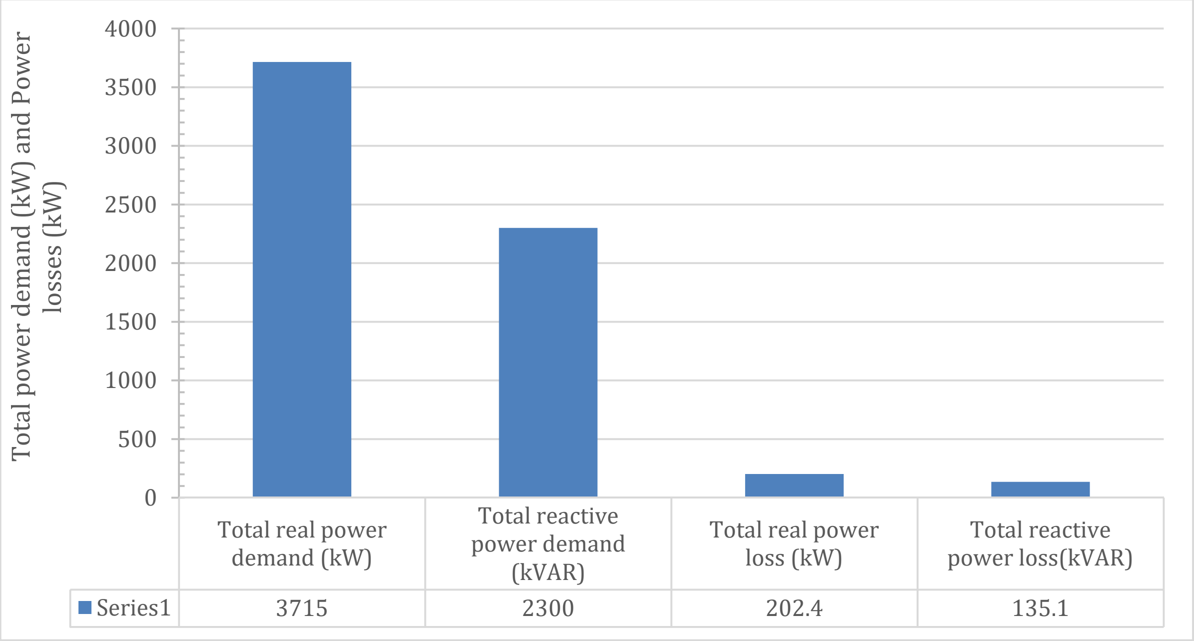

Figure 2 The total power demand and power losses in the bus for the case without DG

The results obtained from the ACO placement and sizing of DG on the IEEE 33 bus are presented in Table 3, Figure 3 and Figure 4. The results presented in Table 2 is from the ACO optimized DG placement in the case study power distribution network with 30% penetration. The bar chart in Figure 3 illustrates the impact of DG placement on power losses within a distribution network using the ACO) algorithm with 30% penetration and it is implemented in four scenarios: the base case (without DGs) and after the placement of one, two, and three DGs. It is shown in Figure 3 that the power losses reduce as more DGs are optimally sized and located in the bus network. The reduction in real power losses with respect to the baseline (no DG) for the three scenarios are 42.1 % for 1 DG, 52.2 % for 2 DG and 54.1 % for 3 DG. Also, the reduction in reactive power losses with respect to the baseline (no DG) for the three scenarios are 39.1 % for 1 DG, 50.4 % for 2 DG and 53.9 % for 3 DG.

Table 3: ACO-Optimized DG Placement Results (30% Penetration)

Parameter	Base Case	1 DG	2 DGs	3 DGs
Total real power loss (kW)	201.891	117	97	93
Total reactive power loss (kVAR)	134.641	82	67	62
Real power loss reduction (%)	-	42.1	52.2	54.1
% Reactive power loss reduction	-	39.1	50.4	53.9
Minimum voltage (pu)	0.9134	0.932914	0.933221	0.940068
Minimum voltage bus number	18	18	18	18
Maximum voltage (pu)	0.9834	0.997818	0.997832	0.997806
Maximum voltage bus number	2	2	2	2
Voltage deviation index (%)	11.28	6.24	4.86	4.49
DG Location (Bus No.)	-	26	30, 33	31, 11, 31
DG Real Power Size (kW)	-	1043	546, 502	366, 303, 351
DG Reactive Power Size (kVAR)	-	381	105, 232	171, 67, 59

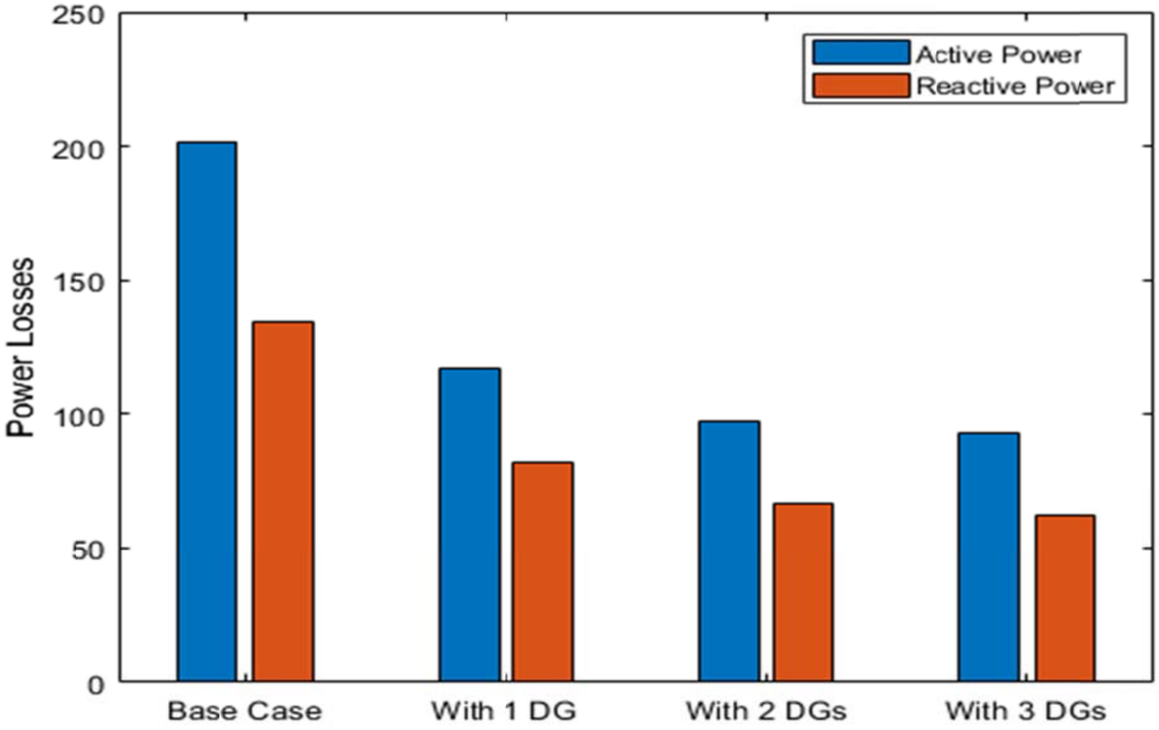

Figure 3:Real and reactive power losses for all scenarios using ACO.

The graph in Figure 4 presents a comparison of voltage profiles across different bus numbers in a power distribution network. The comparison is based on the base case scenario (no DG) and scenarios with 1, 2, and 3DGs integrated into the system, optimized using the ACO algorithm. This clearly illustrates that increasing DG penetration, optimized using the ACO algorithm, significantly improves the voltage profile across the distribution network. Notably, the results also showed that the VDI reduced from 11.28 % for the baseline case to 6.24 for the 1 DG. to 4.86 % for 2 DG and 4.49 % for the 3 DG. Essentially, the ACO method effectively determines optimal DG placement to achieve these improvements.

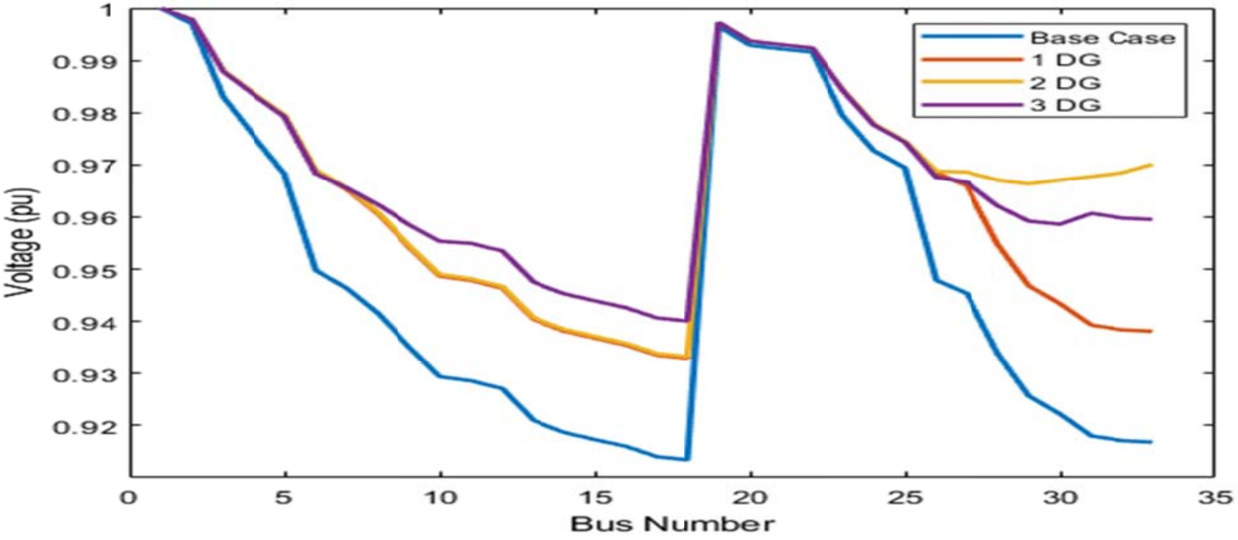

Figure 4: Voltage profile comparison with increasing DG penetration using ACO.

4. CONCLUSION

The ability to minimize the power losses and improve the voltage profile of IEEE 33 bus network using Ant Colony Optimisation (ACO) algorithm is presented. The load flow analysis to determine the power loss and voltage profile of the IEEE 33 bus network in the base case where there is no Distributed Generation (DG) installed in the network. The ACO is used to implement the DG integration for the cases of 1 DG, 2 DG and 3 DG and the results showed that the 3 DG scenario had the best power loss reduction value and also the bets voltage profile with the lowest voltage deviation index. In all, the ACO approach can effectively be used to optimally size and locate DGs on the IEEE 33 bus network.

REFERENCES

1. Kumar, A., Verma, R., Choudhary, N. K. and Singh, N. (2023). Optimal placement and sizing of distributed generation in power distribution system: a comprehensive review. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 45(3), 7160-7185.
2. Akorede, M. F., Hizam, H., Aris, I., & Ab Kadir, M. Z. A. (2010). A review of strategies for optimal placement of distributed generation in power distribution systems. *Research Journal of Applied Sciences*, *5*(2), 137-145.
3. Doagou-Mojarrad, H., Gharehpetian, G. B., Rastegar, H., & Olamaei, J. (2013). Optimal placement and sizing of DG (distributed generation) units in distribution networks by novel hybrid evolutionary algorithm. *Energy*, *54*, 129-138.
4. Rudresha, S. J., & Ankaliki, G. S. (2017). Voltage stability improvement with integration of DG into the distribution system. *International Journal of Emerging Trends & Technology in Computer Science (IJETTCS)*, *6*(5), 196-200.
5. Rudresha, S. J., Ankaliki, S. G., & Ananthapadmanabha, T. (2019). Voltage stability analysis and loss minimization with integration of different types of DGs into the distribution system. *IJSDR*, *4*(12), 185-189.
6. Khasanov, M., Kamel, S., Nazarov, F., Rizayeva, M., & Shodiyeva, N. (2023). Optimal distributed generation allocation in distribution system for power loss minimization and voltage stability improvement. In *E3S Web of Conferences* (Vol. 401, p. 03071). EDP Sciences.
7. Kaur, P., Kaur, S. and Khanna, R. (2016, July). *Optimal placement and sizing of DG comparison of different techniques of DG placement*. Delhi, India, 4p.
8. Mahesh, K., Nallagownden, P. and Elamvazuthi, I. (2016). Optimal configuration of DG in distribution System: An Overview. *MATEC Web of Conferences*, 38: 01007.
9. Daneshvar, M., Abapour, M., Mohammadi-ivatloo, B., & Asadi, S. (2019). Impact of optimal DG placement and sizing on power reliability and voltage profile of radial distribution networks. *Majlesi Journal of Electrical Engineering*, *13*(2), 91-102.
10. Remha, S., Chettih, S., & Arif, S. (2017). Optimal DG location and sizing for minimum active power loss in radial distribution system using firefly algorithm. *Int. J. Energetica*, *4*, 6-10.
11. Dorigo, M., Stützle, T. (2019). Ant Colony Optimization: overview and recent advances, pp311-351. *In:* M. Gendreau and JY. Potvin (Editors) *Handbook of Metaheuristics. International Series in Operations Research and Management Science*, Springer, Cham, Switzerland 624p.
12. Stützle, T. (2009). *Lecture Notes on Ant Colony Optimization,* Universit´e Libre de Bruxelles (ULB), Brussels, Belgium, 1p. https://link.springer.com/content/pdf/10.1007/978-3-642-01020-0_2.pdf (Retrieved on 7th July, 2024).
13. Dorigo, M., & Socha, K. (2018). An introduction to ant colony optimization. In *Handbook of approximation algorithms and metaheuristics* (pp. 395-408). Chapman and Hall/CRC.
14. Dorigo, M., & Stützle, T. (2003). The ant colony optimization metaheuristic: Algorithms, applications, and advances. *Handbook of metaheuristics*, 250-285.
15. López-Ibáñez, M., Stützle, T., & Dorigo, M. (2015). Ant Colony Optimization: A Component-Wise Overview.
16. Qasim, A. and Al-Bahrani, L. T. (2020). Constraint optimal power flow based on ant colony optimization. *Journal of Engineering and Sustainable Development*, 24:274–283.
17. Gasbaoui, B., and Allaoua, B. (2009). Ant colony optimization applied on combinatorial problem for optimal power flow solution. *Leonardo Journal of Sciences*, 14: 1-17.
18. Soares, J., Sousa, T., Vale, Z. A., Morais, H., and Faria, P. (2011). *Ant colony search algorithm for the optimal power flow problem*. 2011 IEEE power and energy society general meeting, Detroit, MI, USA, 9p.
19. Musirin, I., Ismail, N.H.F., Kalil, M.R., Idris, M.K., Rahman, T.K.A. and Adzman, M.R. (2009). Ant colony optimization (ACO) technique in economic power dispatch problems. Pp191-203. *In:* PK., Wai, X., Huang and SI. Ao. (editors) *Trends in Communication Technologies and Engineering Science*. Springer, Dordrecht, Holland, 365p.
20. Santoso, D. B., Sarjiya, S. and Sakti, F. P. (2018). Optimal sizing and placement of Wind-Based distributed generation to minimize losses using flower pollination algorithm. *JTERA (Jurnal Teknologi Rekayasa)*, *3*(2):167-176.
21. Saad Ouali and Abdeljabbar Cherkaoui ( ) An Improved Backward/Forward Sweep Power Flow Method Based on a New Network Information Organization for Radial Distribution Systems