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Comparative Evaluation Of Random Forest Regressor-Based DG Integration On IEEE 32-Bus Network With And Without Active Power Loss Sensitivity Index

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ABSTRACT

Comparative evaluation of Random Forest Regressor RFR) model-based multiple DG integration on IEEE 32-Bus Network with and without Active Power Loss Sensitivity Index (APLSI) is presented. The multiple DG integration is approached in two ways; in the first case, the APLSI was used for the DG location determination and then the RFR model is used for the DG capacity placement on the buses. In the second case, the RFR model was used both to determine and rank the candidate buses and also to determine the optimal DG capacity for each of the candidate buses on the IEEE 32-bus PDN. The load flow analysis was done using the Fast Decoupled Load Flow (FDLF) method. The results show that without the DG integration, the mean APSLI is 0.879, the mean is 0.838 when RFR model alone was used for DG integration while the mean was 0.0.713 when APSLI and RFR model were used for DG integration. Essentially, the lowest mean APSLI of 0.0.713 was realized when APSLI and RFR model were used for DG integration. Again, the results show that the case when the APSLI and RFR model were used for the DG integration gave the lowest power loss percentage of 8.025 % whereas when only the RFR model was used, the power loss was 8.376 %. In essence, the use of the APSLI in the DG location determination was better than using the RFR model alone.

KEYWORD: IEEE 32-Bus network, Random Forest Regressor Model, Distributed Generator (DG), Active Power Loss Sensitivity, Power Distribution Network (PDN)

1. INTRODUCTION

In recent decades, there has been global quest to mitigate the damaging effect of fossil fuel and other non-green energy source and non-renewable energy sources [1,2]. This has led to the development of renewable green energy solutions. In this regard, the wind energy, the solar energy, the tide energy and other green energy solution have attracted the attention of the experts in the power industry [3,4,5]. In addition, the advent of smart grid system has facilitated the integration of these diverse energy source to the grid thereby enabling further inclusion of such energy sources to the already existing power distribution system [6,7,8].

In addition, several governments across the globe have given support or incentives for self-generation of energy and the export of excess self-generated energy onto the national grid [9,10,11]. This approach has also added to the growing population of green energy solutions that are witnessed across the globe. However, integration of these diverse energy generating solution to a common grid is not a straight solution, it throw up issue that need to be addressed [12,13]. Especially, the introduction of such energy solution to a radial power network upsets the radial nature of the network and careful location of the distributed generator (DG) and proper sizing of the DG are required to ensure efficient operation of the network in the face of DG integration [14,15,16]. Moreover, when multiple DGs are to be installed power distribution network like the IEEE 33-bus network, the specific buses for the multiple DG installation need to be carefully selected and the DG capacities for each candidate bus is also selected for optimal performance [17,18,19]. These issues are addressed in this work by applying Random Forest Regressor (RFR) model and Active Power Loss Sensitivity Index (APLSI) [20,21]. The study focus is on the determination of the best option, one using the RFR model alone to locate and size the DGs or to use the APLSI to locate the DGs and then use the RFR model to size the DGs based on the identified bus locations for their installation. The ideas presented in this work is expected to assist the power industry to enhance service delivery to their teeming consumer population.

2. METHODOLOGY

2.1 The research procedure used for the distributed generator (DG) integration on IEEE 32-bus power distribution network

In the present work, distributed generator (DG) integration on IEEE 32-bus power distribution network (PDN) is considered. At the same time, the study is for multiple DG integration. The DG integration is approached in two ways; in the first case the Active Power Loss Sensitivity Index (APLSI) was used for the DG location determination and then Random Forest Regressor (RFR) model for the DG capacity placement on the buses. In the second case, the Random Forest Regressor (RFR) model was used both to determine and rank the candidate buses and also to determine the optimal DG capacity for each of the candidate buses on IEEE 32-bus PDN. The flow diagram for the research work is presented in Figure 1.

When the IEEE 32-bus is modelled and the line and bus data are read in, as shown in Figure 1, then the Fast Decoupled Load Flow (FDLF) method, as shown in Figure 2, is used to conduct the load flow analysis. The Active Power Loss Sensitivity Index (APLSI), as expressed in Equation 1 is used to determine the candidate buses which are also ranked based on their APLSI values, starting with the highest APLSI value on the top to the lowest APLSI value.

The Random Forest Regressor (RFR) model (Figure 3) is then used (as shown in Figure 1) to determine the capacity of the DG for each of the candidate buses. The FDLF method, is used to conduct the load flow analysis for this first case. The effeteness of the DG location and sizing in this first case is evaluated in terms of the power loss and voltage profile obtained from the load flow analysis.

Again, as shown in Figure 1, the second approach did not include the use of the APLSI, rather, only the RFR model is used, first to determine and rank the candidate buses and next to assign appropriate DG capacity to each of the candidate bus. In this wise, the RFR model is used to predict the APLSI value for each of the buses and hence use the predicted APLSI to rank the candidate buses. Again, the FDLF method, is used to conduct the load flow analysis for this second case. The effeteness of the DG location and sizing in this second case is evaluated in terms of the power loss and voltage profile obtained from the load flow analysis. The performance of the system in the first and second cases are compared and the approach which satisfied the voltage profile requirements and maintained lower overall percentage power loss is considered the best option.

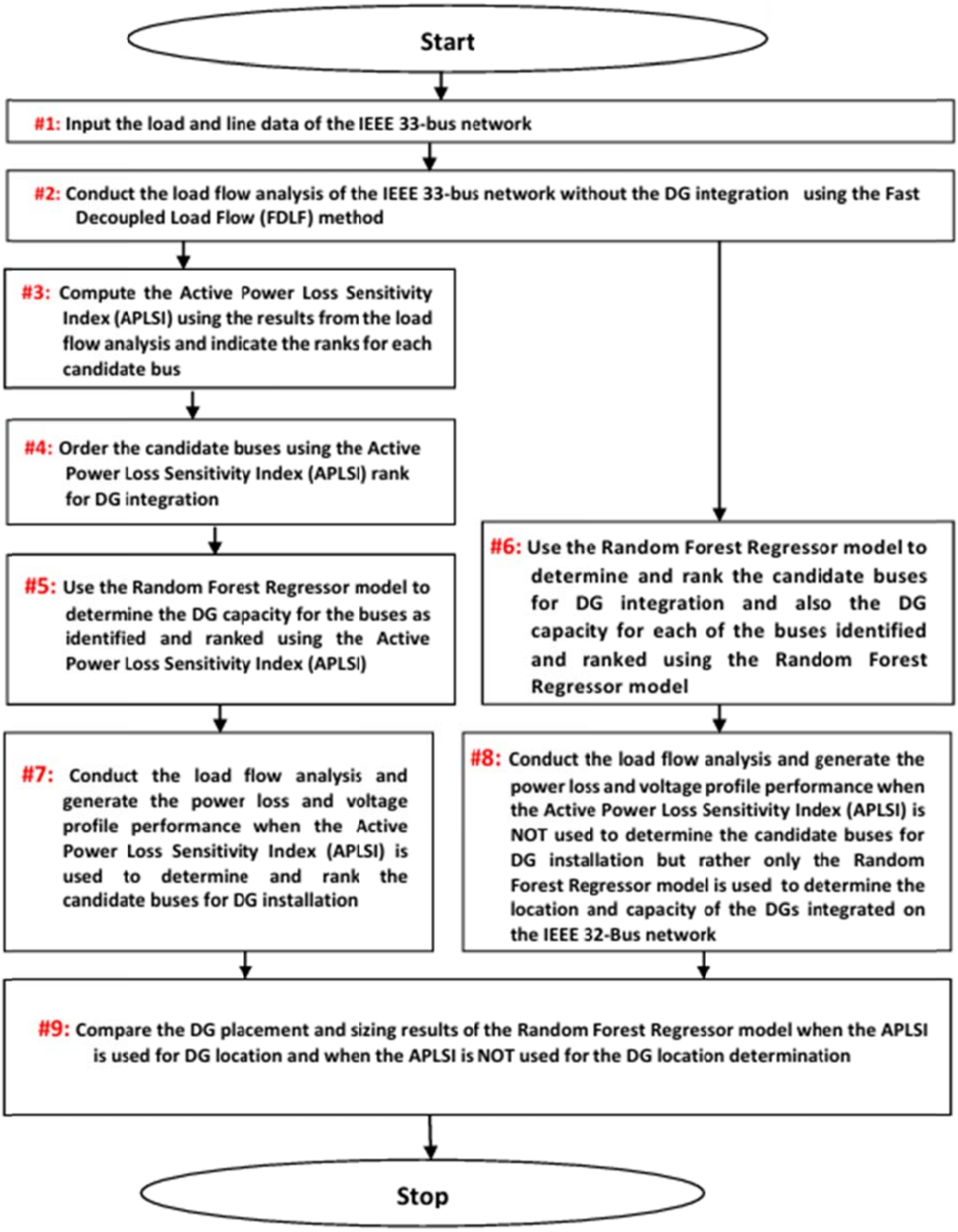

Figure 1 The flow diagram for the Random Forest Regressor-based DG integration on IEEE 32-Bus Network with and without Active Power Loss Sensitivity Index

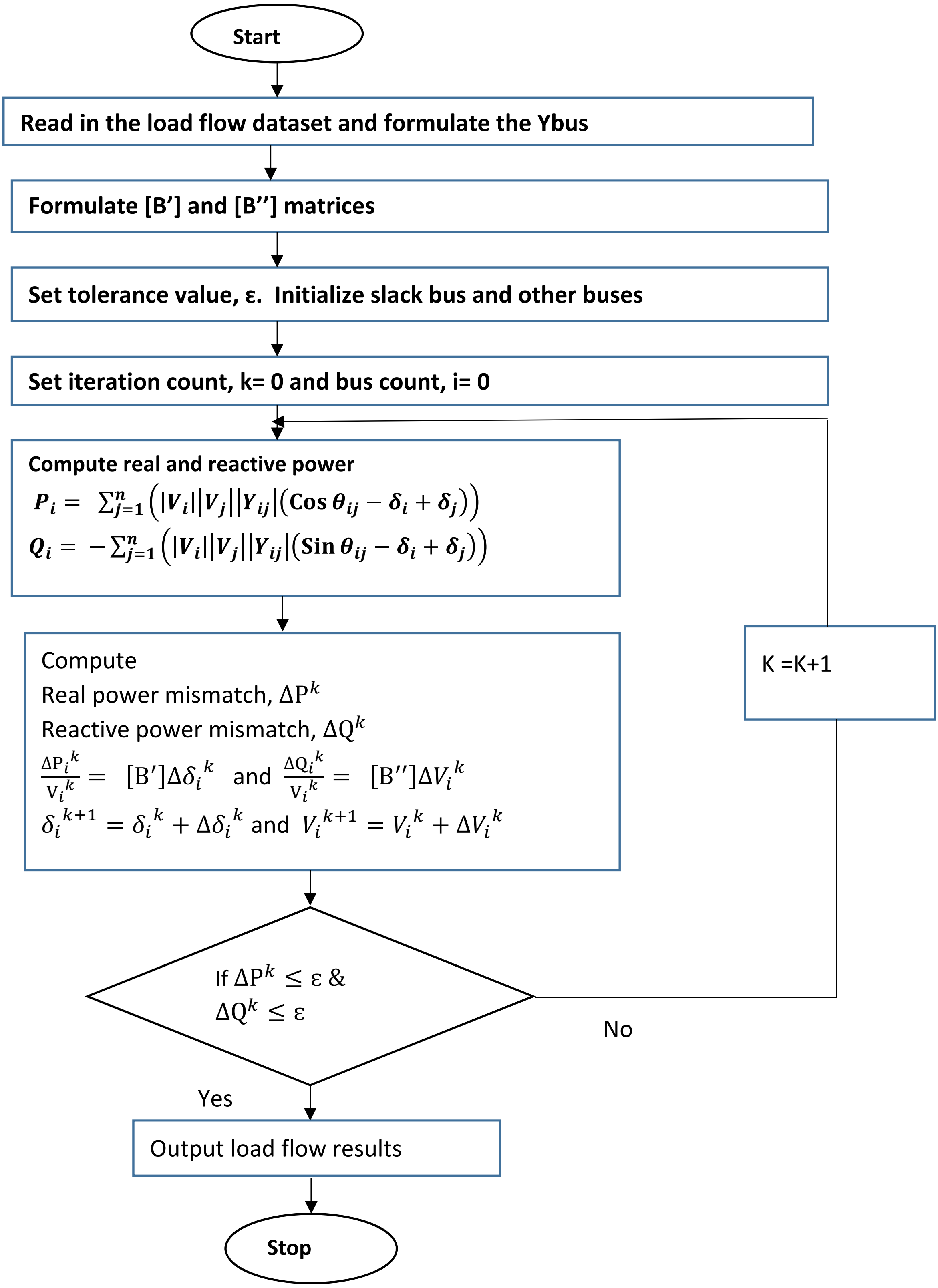

Figure 2 The Fast Decoupled Load Flow (FDLF) method flow diagram [22]

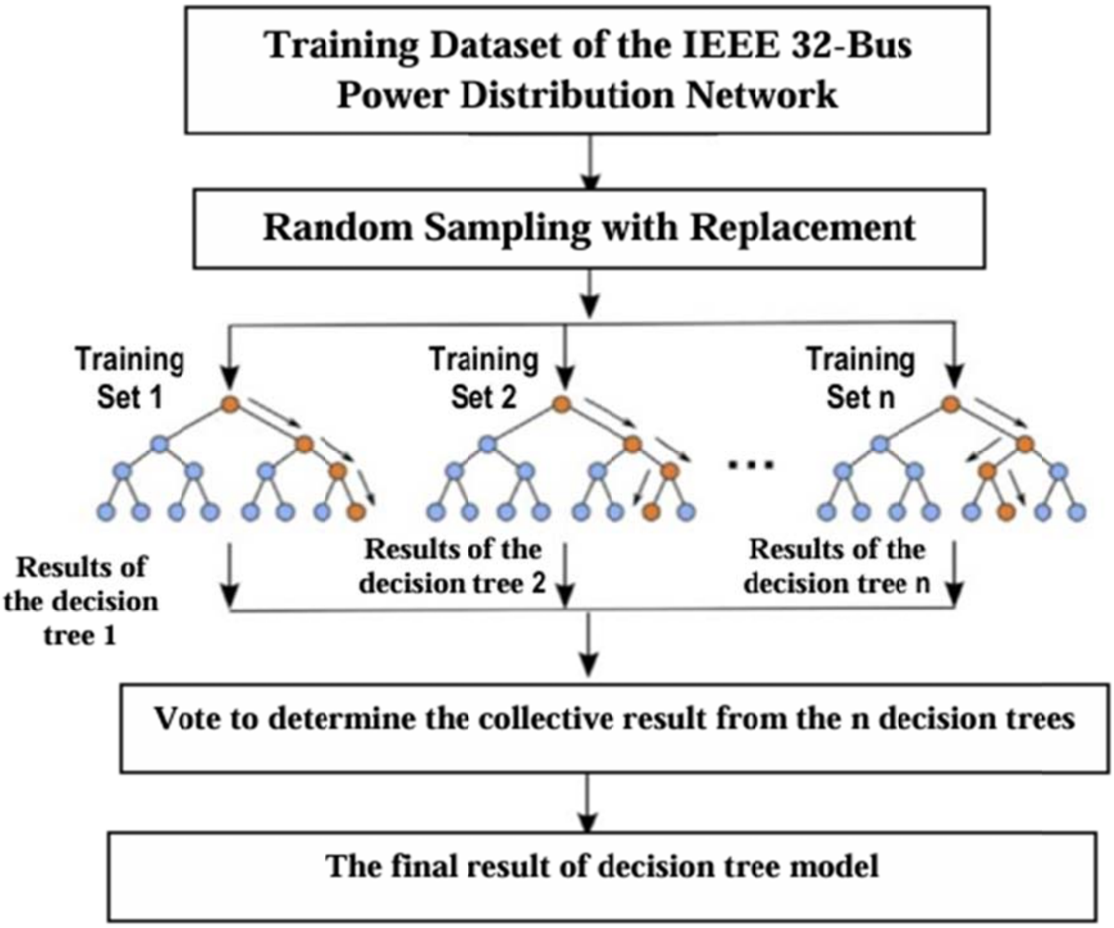

Figure 3 The architecture of the Random Forest Regresssor Model for the DG integration on the IEEE 32-bus network

2.2 Active Power Loss Sensitivity Index (APLSI)

Active Power Loss Sensitivity Index (APLSI) is determined for each bus in the IEEE 32-bus network and it is used to rank the bus starting with the highest APLSI bus on top and the lowest APLSI bus on the bottom of the ranking. The expression for computing the APLSI is given as **[23];**

$$APLS_{i,i+1} = \frac{2Q_{i+1,eff}R_k}{|V_{i+1}|^2} \tag{1}$$

Where $Q_{\text{i+1,eff}}$ denotes the reactive power which is the load consumed and the line k resistance is denoted by R_k, the V_i is the bus i voltage. The normalized voltage $V_{\text{norm (i)}}$ of the buses are also determined as follows **[24];**

$$V_{\text{norm}}(i) = \frac{|V(i)|}{V_{\text{threshold}}} \tag{2}$$

Where $V_{threshold}$ is 0.95.

3. RESULTS AND DISCUSSION

The results of the Active Power Loss Sensitivity Index (APLSI) obtained when there was no DG integration, when the DG is integrated using the APLSI and RFR model and when the DG integration, when the DG is integrated using the RFR model alone are shown in Figure 4. The results show that without the DG integration, the mean APSLI is 0.879, the mean is 0.838 when RFR model alone is used for DG integration while the mean is 0.0.713 when APSLI and RFR model are used for DG integration. Essentially, the lowest mean APSLI of 0.713 is realized when APSLI and RFR model are used for DG integration.

The results of the Active Power Loss Sensitivity Index (APLSI)-based ranking of the buses obtained when there was no DG integration, when the DG is integrated using the APLSI and RFR model and when the DG integration, when the DG is integrated using the RFR model alone are shown in Figure 5. It can be seen in the Figure 5 that the two DG integration scenarios have similar bus ranking trend after the 11th candidate bus ranking.

The power loss percentage of the two DG integration approaches are presented in figure 6. The results show that the case when the APSLI and RFR model are used for the DG integration gave the lowest power loss percentage of 8.025 % whereas when only the RFR model is used, the power loss is 8.376 %. In essence, the use of the APSLI in the DG location determination is better than using the RFR model alone. Also, the bus voltage plot for the two cases is plotted in Figure 7 and the graph showed that in both cases, the voltage profile of all the buses fall with the acceptable bus voltage threshold values.

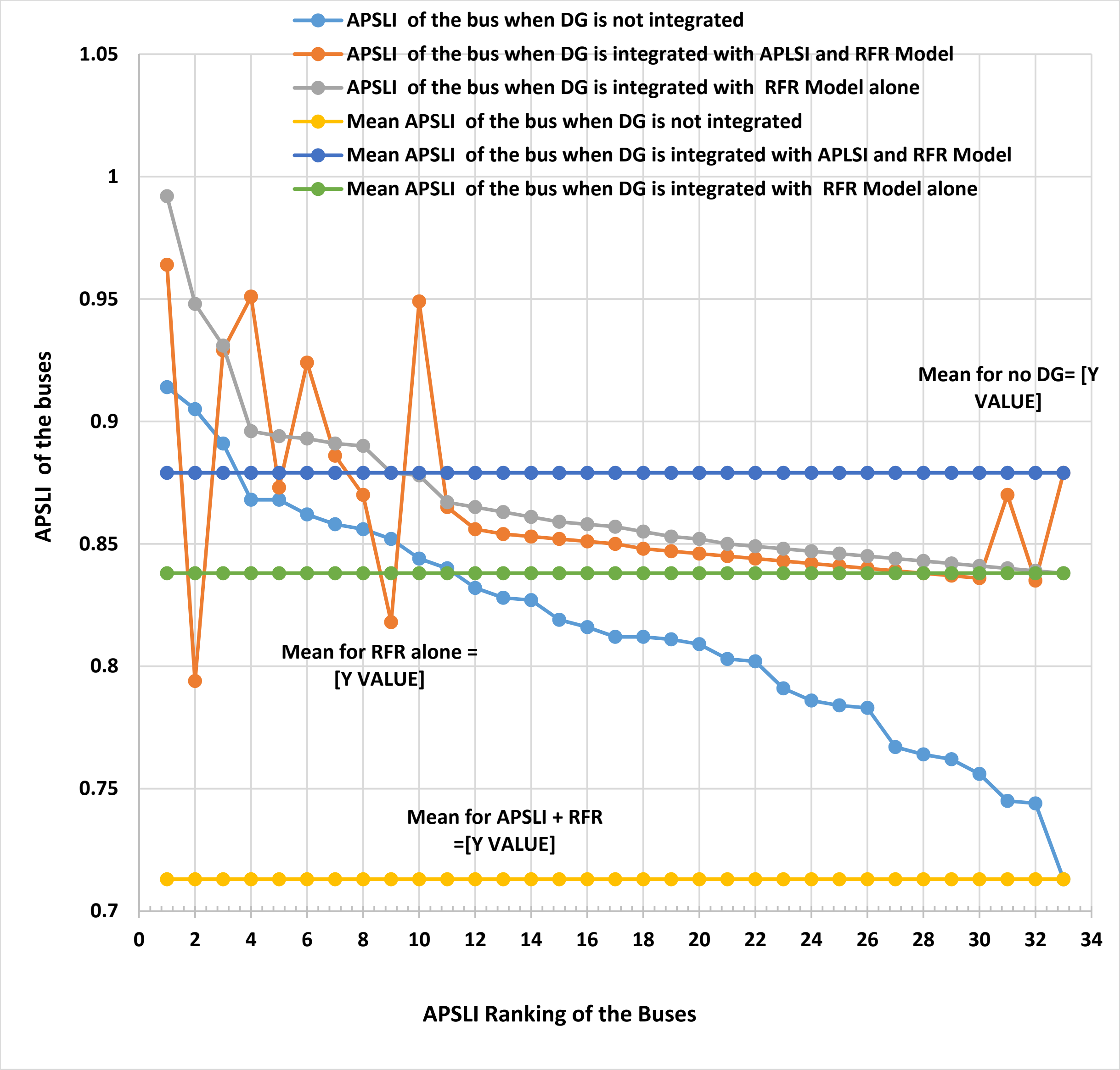

Figure 4 The APSLI values for the buses in the three scenarios, no DG, DG with APSLI and RFR model, DG with RFR model alone

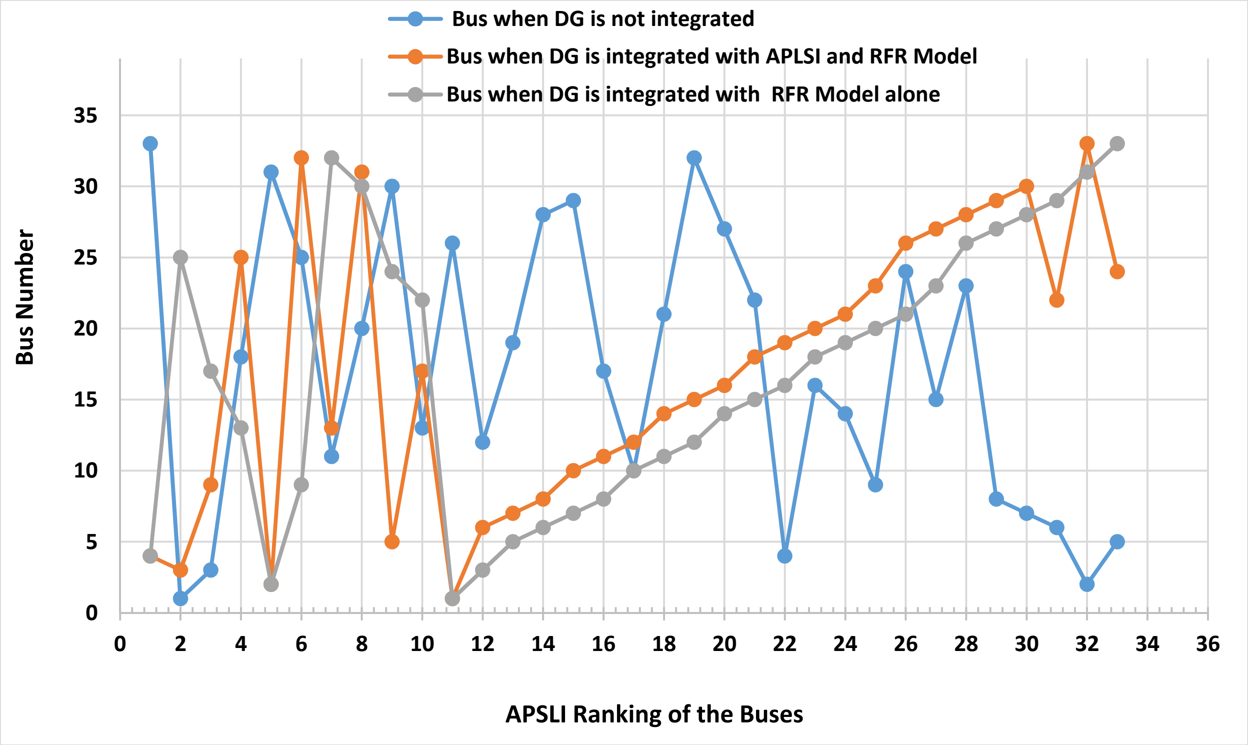

Figure 5 The APSLI based ranking of the buses in the three scenarios, no DG, DG with APSLI and RFR model, DG with RFR model alone

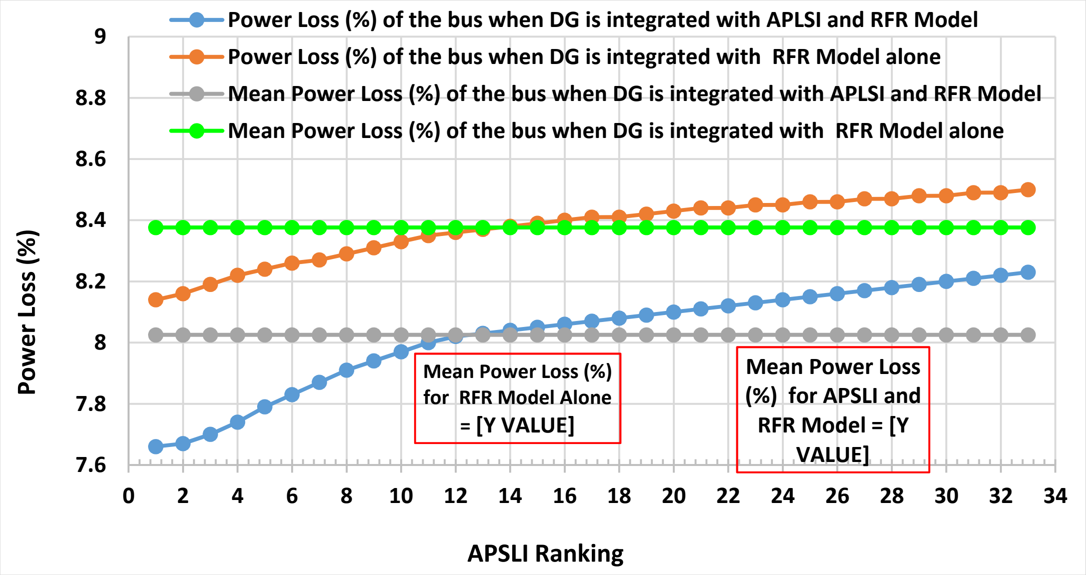

Figure 6 The power loss percentage of the two DG integration approaches

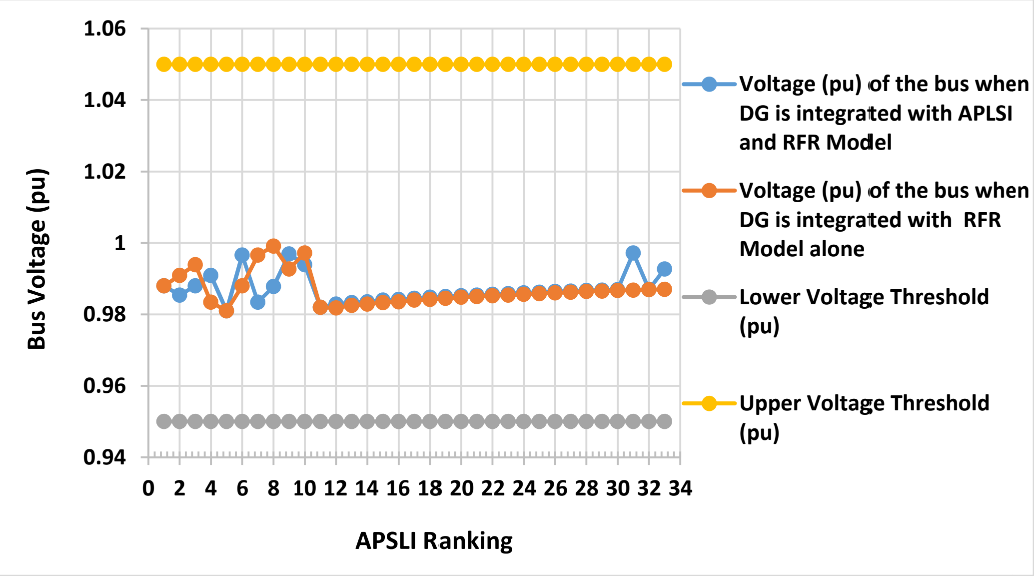

Figure 7 The bus voltage of the two DG integration approaches

Table 1 The comparison of the performance of the two DG Integration approaches

Mean of the key Performance Metrics	Value when DG is integrated with RFR Model alone	Value when DG is integrated with APLSI and RFR Model	Percentage Improvement of the APLSI Approach (%)
Mean of the Active Power Loss (kW)	120.6618	118.6294	1.684
Mean of the Reactive Power Loss (kVAR)	166.4152	164.4424	1.185
Mean of the Voltage Deviation Index (VDI)	0.0054	0.0054	0.000
Mean of the Bus Voltage (pu)	0.9997	0.9998	0.010
Mean of the Phase Angle Spread (deg)	7.7718	7.7161	0.056
Mean of the Power Loss Percentage (%)	8.3761	8.0252	0.351

4. CONCLUSION

The integration of DG on IEEE 33-bus network is presented. The use of Active Power Loss Sensitivity Index (APLSI) to locate the buses for the DG installation and then use random Forest Regressor (RFR) model for the sizing of the DGs on each of the buses is presented. Also, a second option where the DG location and sizes are determined using the RFR model alone is presented. The performance of the two approaches are compared using the power loss percentage. The results show that the use of the APLSI improved the power loss reduction by about 0.351 %

REFERENCES

1. Ghosh, Bablu K., et al. "Net zero emission and sustainable development in electricity: emerging Asia’s Bangladesh context in global perspective." *Progress in Energy* 6.4 (2024): 042001.
2. Afshan, Sahar, Ilhan Ozturk, and Tanzeela Yaqoob. "Facilitating renewable energy transition, ecological innovations and stringent environmental policies to improve ecological sustainability: evidence from MM-QR method." *Renewable Energy* 196 (2022): 151-160.
3. Bin Abu Sofian, Abu Danish Aiman, et al. "Machine learning and the renewable energy revolution: Exploring solar and wind energy solutions for a sustainable future including innovations in energy storage." *Sustainable Development* 32.4 (2024): 3953-3978.
4. Khare, Vikas, and Miraj Ahmed Bhuiyan. "Tidal energy-path towards sustainable energy: A technical review." *Cleaner Energy Systems* 3 (2022): 100041.
5. Androniceanu, Armenia, and Oana Matilda Sabie. "Overview of green energy as a real strategic option for sustainable development." *Energies* 15.22 (2022): 8573.
6. Cavus, Muhammed. "Advancing Power Systems with Renewable Energy and Intelligent Technologies: A Comprehensive Review on Grid Transformation and Integration." *Electronics* 14.6 (2025): 1159.
7. Ohanu, Chibuike Peter, Salihu Ahmed Rufai, and Ugbe Christiana Oluchi. "A comprehensive review of recent developments in smart grid through renewable energy resources integration." *Heliyon* 10.3 (2024).
8. Singh, Surender, and Saurabh Singh. "Advancements and challenges in integrating renewable energy sources into distribution grid systems: A comprehensive review." *Journal of Energy Resources Technology* 146.9 (2024): 090801.
9. Mir-Artigues, Pere, and Pablo del Río. "Prosumers’ Behavior under a Regulation That Encourages Strict Self-Sufficiency. The Case of Spanish Photovoltaic Micro-Generation." *Energies* 14.4 (2021): 1114.

10. Komen, George K. *A Comparative Tariff Assessment between Grid Electricity and Own Consumer Generation: A Case Study of Kenya*. Diss. University of Nairobi, 2022.
11. Yadav, Shubham, et al. "Benefits of Decentralized Residential Batteries for System-Level Energy Management." *Battery-Integrated Residential Energy Systems*. CRC Press, 2024. 161-180.
12. Iweh, Chu Donatus, et al. "Distributed generation and renewable energy integration into the grid: Prerequisites, push factors, practical options, issues and merits." *Energies* 14.17 (2021): 5375.
13. Shafiullah, Md, Shakir D. Ahmed, and Fahad A. Al-Sulaiman. "Grid integration challenges and solution strategies for solar PV systems: A review." *IEEE Access* 10 (2022): 52233-52257.
14. Salimon, Sunday Adeleke, et al. "Impact of distributed generators penetration level on the power loss and voltage profile of radial distribution networks." *Energies* 16.4 (2023): 1943.
15. Saxena, Vivek, et al. "Navigating the complexities of distributed generation: Integration, challenges, and solutions." *Energy Reports* 12 (2024): 3302-3322.
16. Barker, Philip P., and Robert W. De Mello. "Determining the impact of distributed generation on power systems. I. Radial distribution systems." *2000 Power Engineering Society Summer Meeting (Cat. No. 00CH37134)*. Vol. 3. IEEE, 2000.
17. Prabha, D. Rama, and T. Jayabarathi. "Optimal placement and sizing of multiple distributed generating units in distribution networks by invasive weed optimization algorithm." *Ain Shams Engineering Journal* 7.2 (2016): 683-694.
18. El-Zonkoly, A. M. "Optimal placement of multi-distributed generation units including different load models using particle swarm optimisation." *IET generation, transmission & distribution* 5.7 (2011): 760-771.
19. Lakshmi, GV Naga, A. Jayalaxmi, and Venkataramana Veeramsetty. "Optimal placement of distribution generation in radial distribution system using hybrid genetic dragonfly algorithm." *Technology and Economics of Smart Grids and Sustainable Energy* 6.1 (2021): 9.

20. Rajakumar, P., et al. "An integrated approach using active power loss sensitivity index and modified ant lion optimization algorithm for DG placement in radial power distribution network." *Scientific reports* 15.1 (2025): 10481.
21. Palanisamy, Rajakumar, and Senthil Kumar Muthusamy. "Optimal siting and sizing of multiple distributed generation units in radial distribution system using ant lion optimization algorithm." *Journal of Electrical Engineering & Technology* 16.1 (2021): 79-89.
22. Ukut, U. I., Okpura, N., & Umoette, A. T. (2023). Comparison Of Load Flow Analysis On IEEE 33 Bus System Based On Newton Raphson And Fast Decoupled Methods. *Science and Technology Publishing (SCI&TECH)*, *7*(2).
23. Rajakumar, P., Balasubramaniam, P. M., Aldulaimi, M. H., M, A., Ramesh, S., Alam, M. M., & Al-Mdallal, Q. M. (2025). An integrated approach using active power loss sensitivity index and modified ant lion optimization algorithm for DG placement in radial power distribution network. *Scientific reports*, *15*(1), 10481.
24. Murthy, K. R., Raju, M. R., Rao, G. G., & Rao, K. N. (2010, December). Comparison of loss sensitivity factor & Index vector methods in determining optimal capacitor locations in agricultural distribution. In *Proc. 16th National Power System Conference* (No. 6, pp. 26-30).