# Impact of integrating solar and wind DGs on voltage profiles and power losses in a practical distribution system

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**ABSTRACT**

The rising inclusion of renewable energy sources into distribution networks has accelerated the adoption of distributed generation (DG) technologies such as solar photovoltaic (PV) and wind turbines. This paper explores the effect of solar and wind DG integration on voltage profiles, power losses, and economic performance in a practical 41-bus radial distribution system. Using the Power World Simulator (PWS) software, the load flow analysis is performed to evaluate different DG placement strategies and penetration levels using the loss sensitivity factor (LSF) method. The results indicate that optimal placement of solar and wind DGs notably improves voltage stability and effectively reduces both real and reactive power losses in the distribution system. Furthermore, the economic analysis demonstrates annual savings of ₹29.08 lakhs for solar DG and ₹33.40 lakhs for wind DG, with payback periods of approximately 11 years, indicating strong technical and financial feasibility. The findings highlight that strategic DG planning can simultaneously enhance system reliability, efficiency, and economic viability in modern distribution systems.



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## 1. INTRODUCTION

Electricity is conventionally transmitted from large central power stations to consumers through successive voltage reductions [1]. Thus, power is supplied at high voltages, while lower voltage levels passively receive and distribute it to consumers [2]. This has started to change in recent years as more and more generation capacity is being connected at low and medium voltage levels. These distributed generation (DG) technologies can help achieve the future electricity system's aims for lowering greenhouse gas emissions and boosting supply security, particularly if they use renewable energy. Additionally, DG can be locally connected with transportation and heating systems to take advantage of potential flexibility through the storage of electricity or heat in the batteries of vehicles [3].

Growing global concerns about electricity's environmental impact have accelerated the integration of renewable energy sources (RES) into creative and practical microgrid (MG) solutions. Microgrids are compact, semi-autonomous power systems that typically combine conventional generators, RES (such as solar, wind, and biomass), energy storage systems (ESS), and electronic power converters [4]. These systems support a variety of applications, including renewable-powered industrial setups like electric vehicle (EV) charging stations utilizing solar panels, wind turbines, hydrogen fuel cells, or biomass combustion.

Microgrids can function either independently (off-grid) or connected to the utility network. RES converts natural flows, sunlight, and wind into usable energy, primarily electricity [5].

Electrical grids must also dynamically control the complete production-to-consumption cycle in order to ensure overall stability. There are numerous ways to integrate renewable energy generation methods into electrical systems. Among these are wind, solar, and combined heat plants [6]. Problems with regulation, protection, power quality, and voltage control may arise from the addition of a huge quantity of DG. Thus, creative approaches to these issues are essential [7].

According to earlier research, DG could have a number of positive technical and financial effects on the growth and operation of transmission and distribution networks. DG may be able to lower network losses if it is positioned carefully throughout the system [8]. DG may also help delay investments in network capacity at the transmission and distribution levels [9], though this depends on the DG's capacity to generate electricity during periods of high demand.

However, integrating DG capacity also presents challenges, primarily because the majority of distribution grids were designed to move electricity from higher voltages that were fed into the grid to lower voltage consumers [10]. Problems like components being overloaded or difficulties maintaining voltage within permitted bounds can result from an increase in DG [11]. It's critical that research clarifies the best way to strike a balance between the advantages of DG and the expenses necessary to overcome these obstacles [12]. Preview study [13] teaching–learning-based optimization (TLBO) algorithm is applied to solve the optimal power flow (OPF) problem in a system that integrates solar photovoltaic, wind turbines, and tidal energy.

The viability of substituting all conventional plants with RES is emphasized by the authors of [14]. The significance of switching to RES, its benefits, and the potential for additional advancements were all covered in detail. Tafilah of Jordan was the subject of a real-time project in [15]. The authors suggested using the life cycle assessment (LCA) method to investigate the environmental effects of integrating wind power.

In some circumstances, the addition of RES to the grid will cause an imbalance in the power system. The methodology for load flow solution for variable load situations has been proposed by Alabri and Jayaweera [16] through the integration of solar electricity into the grid. These days, it is also noted that the distribution system is experiencing RES penetration. Rudresha *et al.* [17] analyzed the practical distribution system for voltage and losses with the integration of solar DG in the system.

Zdiri *et al.* [18] and Said *et al.* [19] made a contribution and put forth a novel approach to tackling the load flow problem in a radial distribution system with RES inclusion. Preview study [20], the voltage analysis on the HV transmission line is conducted in the presence of a hybrid solar and wind energy system. Researchers in [21] and [22] discuss challenges and recent advances in renewable energy system design and integration as the shift from fossil fuels accelerates. Researchers in [23], [24] evaluate the effects of a compact hybrid renewable polygeneration system in which biogas from anaerobic digestion drives an internal combustion engine, while electricity is simultaneously generated using photovoltaic modules and a wind turbine [25]. The major intention of this work is to analyze a real distribution feeder in Shivamogga, Karnataka, India, that experiences poor voltage profiles, high energy losses, frequent interruptions, and congestion, and to improve its performance by optimally placing and sizing DG units to decrease losses, improve voltage levels, and retain voltage stability across the feeder.

## 2. PROBLEM STATEMENT

This study considers a practical distribution feeder originating from the 110/11 kV Alkola substation in Shivamogga, Karnataka, India. The feeder supports a peak load of 1.987 MW and 0.626 MVAR, and serves 41 distribution transformers (DTCs). With the continual raise in population, the load demand on the distribution system also rises. If the system is unable to meet this growing demand, it results in a voltage fall and increased power losses due to higher current flow. Consumers connected at the extreme end of the feeder are predominantly affected, often experiencing voltage instability, where the voltage falls outside acceptable limits, thereby diminishing the overall effectiveness and performance of the distribution network. To address these issues, the integration of DG units near the load centers, particularly at the consumer end, can help to improve voltage profiles and reduce total system losses. This paper analyzes the key challenges faced in the studied distribution system i.e voltage drops and high-power losses. The existing voltage at the feeder is illustrated in Figure 1. For this analysis, a standard voltage deviation range of ±6% is adopted, corresponding to $V_{min}$ = 0.94 p.u. and $V_{max}$ = 1.06 p.u. The following sections of this paper demonstrate how the optimal sizing and strategic placement of DG units can enhance voltage levels across interconnected buses in the network.

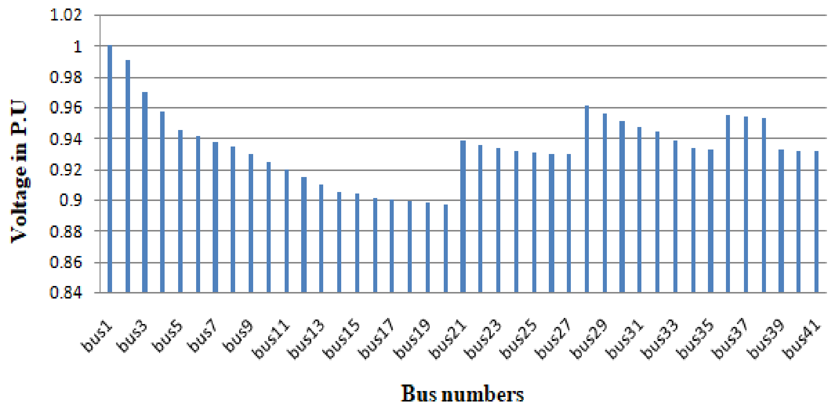


Figure 1. Variation of voltage across the selected distribution feeder

## 3. PROPOSED METHODOLOGY

In this study, the LSF method is applied to determine the optimal size and placement of distributed generation (DG) units using PWS software. The objective is to lower system losses and to get a better voltage profile across the distribution network, thereby ensuring better voltage stability. For a particular system, once the DG size is changed from $P_{DG1}$ to $P_{DG2}$, subsequently, the resulting power loss changes from $P_{L1}$ to $P_{L2}$, then the sensitivity factor can be determined using the formula:

$$LSF = \frac{P_{L1} - P_{L2}}{P_{DG1} - P_{DG2}}$$

This factor indicates the rate of change in power loss with respect to a change in DG size, and helps to identify the most effective DG configuration for system performance improvement. Figure 2 outlines the computational procedure followed in this study.

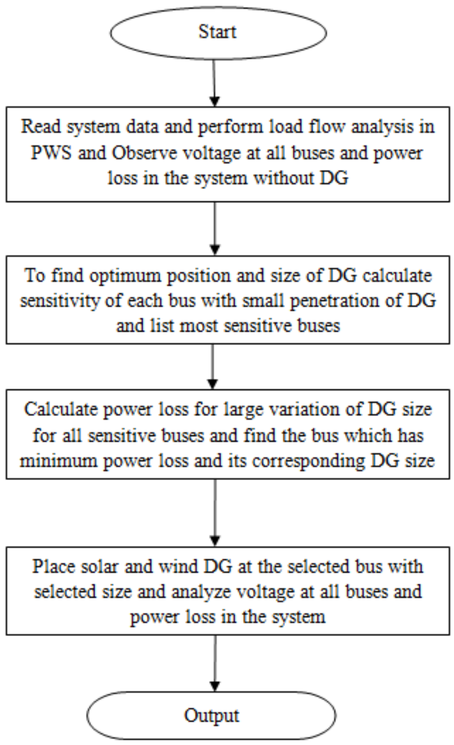


Figure 2. Stepwise computation of the proposed approach

To reduce the computational search space, sensitivity factors are first calculated for all buses in the system using the aforementioned equation. The bus with the highest sensitivity factor is identified, and additional buses with sensitivity values close to this maximum are shortlisted for further evaluation. At each of these chosen buses, the DG size is varied in relatively large steps to observe the corresponding power loss. The bus that results in the minimum power loss across different DG sizes is considered the optimal position for DG placement, and the associated DG size is identified as the optimal generation capacity [17].

## 4. SIMULATION RESULTS

The practical feeder depicted in Figure 3 is an 11 kV, 41-bus distribution system with Bus-1 as the slack bus. It has been modeled and simulated in PWS software to evaluate voltage stability along with system losses, both with and without DG integration. The system is analyzed under the following different scenarios: i) Case-1: without DG integration; ii) Case-2: with integration of solar DG; and iii) Case-3: with integration of wind DG.

– Case-1: Without DG integration
  In this case, the distribution system is analyzed under normal operating conditions without the integration of any DG units. The simulation results specify that the total real power loss in the network is 0.1334 MW, while the reactive power loss amounts to 0.096 MVAR. Furthermore, the least bus voltage recorded across the feeder is 0.8967 p.u, which occurs under maximum load conditions.
– Case-2: With integration of solar DG
  The practical 41-bus feeder with a solar DG is modeled and simulated in PWS software as shown in Figure 4. Using the projected LSF method, the best DG position and sizing are determined. The solar DG, supplying only active power, is optimally located at Bus-18 with a capacity of 0.633 MW, equivalent to 30% of the entire generation from the central grid. Table 1 summarizes the results before and after DG integration. Real power loss reduces from 0.1334 MW to 0.0783 MW, reactive power loss drops from 0.096 MVAR to 0.0589 MVAR, and the minimum bus voltage improves from 0.8977 p.u. to 0.9401 p.u. In general, DG placement reduces real and reactive power losses by 41.30% and 38.54%, respectively, while maintaining voltage levels in the feeder within tolerable limits, thereby enhancing system voltage stability and performance.
– Case 3: With integration of wind DG
  In this case, wind DG is connected in place of solar DG as shown in Figure 5, which supplies both active and reactive power. The optimal size of DG is 0.633 MW and 0.214 MVAR at bus-18, which is obtained from the loss sensitivity factor (LSF) method. As indicated in Table 1, following wind DG installation, the real and reactive power losses in the selected feeder reduce by 48.85% and 44.12%, respectively. The low bus voltage is enhanced to 0.9452 p u from 0.8646 p u.

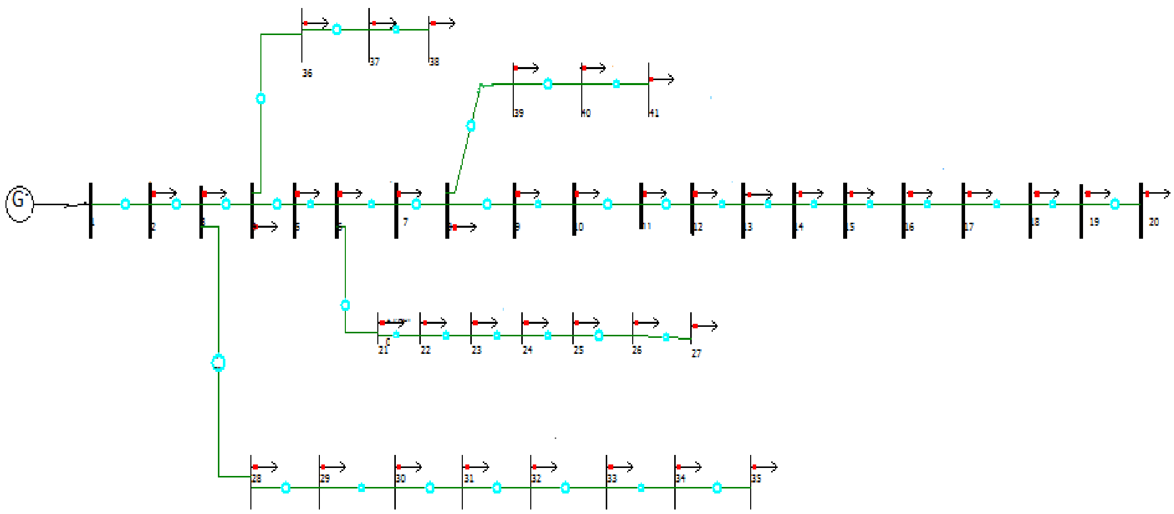


Figure 3. 41-bus practical distribution feeder

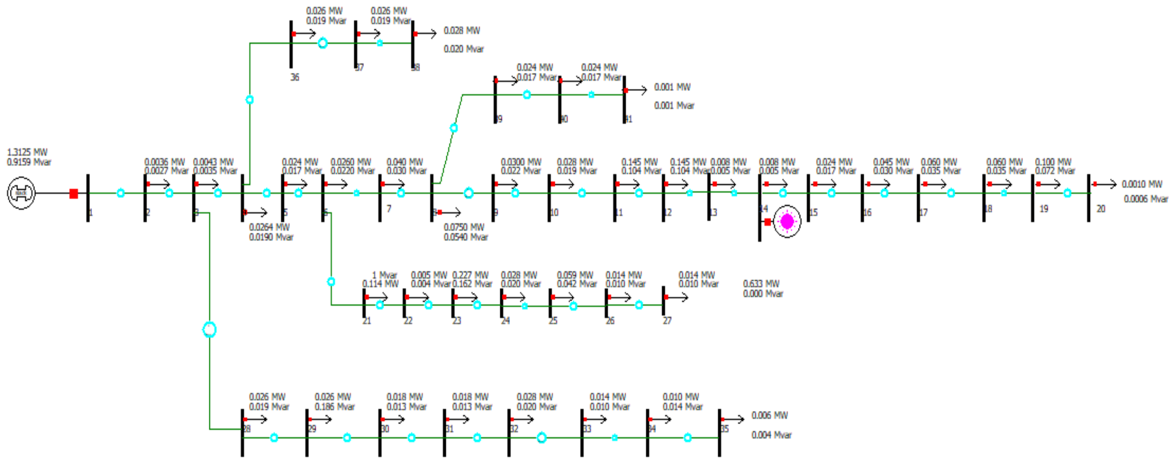

Figure 4. Practical system is modelled in PWS with integration of solar DG

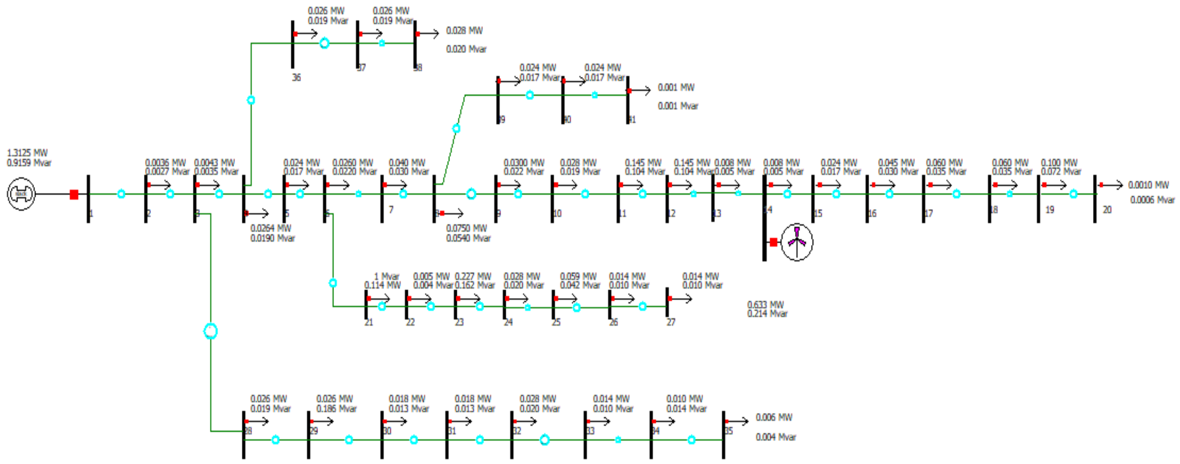

Figure 5. Practical system is simulated in PWS with integration of wind DG

Table 1. Loss reduction assessment

| Cases | Without DG | With solar DG | With Wind DG |
|---|---|---|---|
| DG installation at bus | - | 18 | 18 |
| DG active power (MW) | - | 0.636 | 0.636 |
| DG reactive power (MVAr) | - | - | 0.216 |
| Active power loss (MW) | 0.1334 | 0.0783 | 0.0701 |
| Reactive power loss (MVAr) | 0.096 | 0.0589 | 0.0532 |
| P Loss drop in % | - | 41.30 | 47.45 |
| Q Loss drop in % | - | 38.64 | 44.58 |

The comparisons of voltage profiles for the 41-bus practical distribution system under different operating conditions are illustrated in Figure 6. It can be clearly observed from the figure that when solar and wind-based DG units are integrated at their optimal locations with appropriately determined capacities, the voltage profile across all buses significantly improves. Each bus voltage remains within the permissible voltage limits, demonstrating enhanced voltage stability and overall system performance. Figures 7 and 8 illustrate real and reactive power losses for different cases. The results indicate that the greatest decrease in both power losses is obtained when a wind DG, delivering both active and reactive power, is placed at its optimal location.

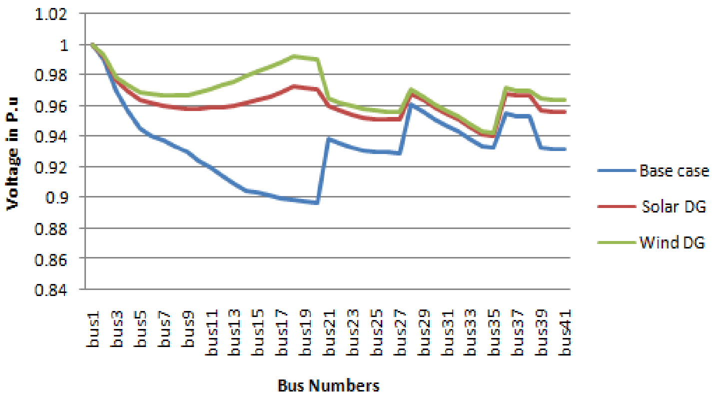


Figure 6. Voltage profile under different case studies

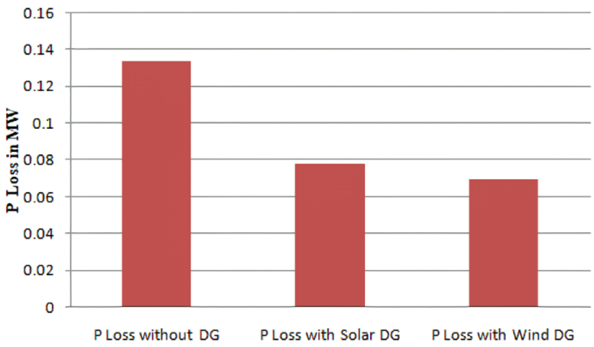


Figure 7. Real power loss of the selected distribution system in different cases

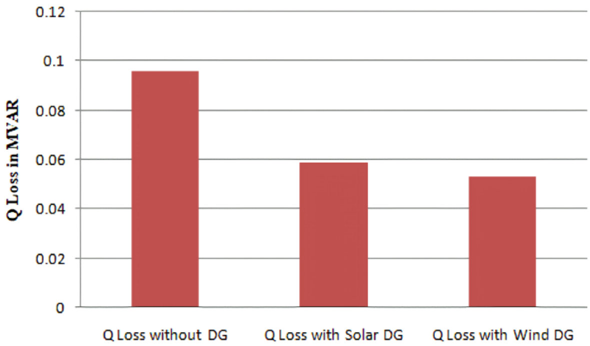


Figure 8. Reactive power loss for different case studies

## 5. ECONOMIC ANALYSIS

The economic analysis evaluates the cost–benefit impact of adding solar and wind DG units to the 41-bus practical distribution system. The objective is to estimate the potential energy cost savings and return on investment (ROI) resulting from the reduction in real power losses due to optimal DG placement.

### 5.1. Cost savings due to loss reduction

From the simulation results, the real power loss for the base case (without DG) is 0.1334 MW, which is reduced to 0.0783 MW with solar DG and 0.0701 MW with wind DG. Assuming an average electricity cost of ₹6 per kWh and continuous operation for 8,760 hours per year, the annual energy loss cost can be estimated as follows:

$$Annual\ energy\ loss\ cost\ =\ PLoss\ x\ 8760\ x\ Tariff\ rate$$

The economic analysis without DG, with solar and wind DG, is summarized in Table 2. As shown in the table, the savings in cost are obtained with the placement of wind and solar DG due to loss reduction as compared to the system without DG in the system. Hence, installing solar DG at the optimal placement results in an annual saving of approximately ₹29.08 lakhs, while wind DG provides about ₹33.40 lakhs per year due to greater loss reduction.

Table 2. Economic analysis for various cases

| Cases | Real power loss (MW) | Annual energy loss (MWh) | Annual cost (₹ lakhs) | Savings (₹ lakhs/year) |
|---|---|---|---|---|
| Without DG | 0.1334 | 1169.58 | 70.18 | - |
| With solar DG | 0.0783 | 685.01 | 41.10 | 29.08 |
| With wind DG | 0.0701 | 613.08 | 36.78 | 33.40 |

### 5.2. Investment and payback analysis

The installation costs for solar PV systems and wind turbines vary depending on scale and site conditions. Based on current Indian market data, the installation cost of solar and wind is as follows: i) solar PV installation cost ≈ ₹ 5 crore / MW, and ii) wind turbine installation cost ≈ ₹ 6 crore / MW. For the optimal DG capacity of 0.633 MW, the estimated capital investment and the corresponding economic performance for both solar and wind-based DG systems are summarized in Table 3. The table presents a comparative evaluation of the installation cost, annual energy savings derived from reduced power losses, and the resulting payback period for each technology. This analysis clearly highlights the economic viability of integrating renewable DG units into the distribution network, demonstrating that both solar and wind systems can recover their initial investment while continuing to provide sustained financial and technical benefits over their operational lifespan.

Table 3. Investment and payback analysis for solar and wind DG

| DG type | Installed capacity (MW) | Installation cost (₹ crore) | Annual savings (₹ lakhs) | Payback period (years) |
|---|---|---|---|---|
| Solar DG | 0.633 | 3.165 | 29.08 | 10.9 |
| Wind DG | 0.633 | 3.798 | 33.40 | 11.4 |

## 6. CONCLUSION

This study analyzed a practical 41-bus radial distribution feeder using an LSF method to select the best position and sizing of solar and wind DG units. Two renewable DG types are evaluated, the first one solar PV (providing only active power) and wind turbines (providing both active and reactive power), with the aim of minimizing overall system losses and enhancing the voltage profile throughout the system. Results show that solar DG reduced real and reactive power losses by 41% and 38%, while wind DG, supplying both active and reactive power, achieved greater reductions of 47% and 44%, respectively. All bus voltages remained within acceptable limits, ensuring improved voltage stability.

Economic analysis indicates annual savings of about ₹29.08 lakhs for solar DG and ₹33.40 lakhs for wind DG, with a payback period of around 11 years, proving both options to be technically effective and economically viable. Thus, optimal DG integration enhances system efficiency, voltage stability, and cost-effectiveness of the distribution network.


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## AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| Gopinath Harsha Rajappa |  | ✓ |  |  |  | ✓ |  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| Kiran Kumar Gama Ramaiah | ✓ | ✓ | ✓ | ✓ |  |  |  |  |  | ✓ | ✓ |  | ✓ |  |
| Shekhappa G. Ankaliki |  | ✓ |  | ✓ |  |  |  |  |  | ✓ | ✓ | ✓ | ✓ |  |
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

## CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

## DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author, [RSJ], on request.

## REFERENCES


[1] T. A. Hamed and A. Alshare, "Environmental impact of solar and wind energy-a review," *Journal of Sustainable Development of Energy, Water and Environment Systems*, vol. 10, no. 2, pp. 1–23, 2022, doi: 10.13044/j.sdewes.d9.0387.

[2] D. Gayen, R. Chatterjee, and S. Roy, "A review on environmental impacts of renewable energy for sustainable development," *International Journal of Environmental Science and Technology*, vol. 21, no. 5, 2024, doi: 10.1007/s13762-023-05380-z.

[3] K. Kumar, A. M. Soomro, M. Kumar, L. Kumar, and M. Arici, "Sustainable on-grid solar photovoltaic feasibility assessment for industrial load," *Journal of Central South University*, vol. 30, no. 11, pp. 3575–3585, 2023, doi: 10.1007/s11771-023-5488-0.

[4] S. O. Sanni, A. I. Abdullateef, O. O. Mohammed, M. N. Aman, A. K. Raji, and I. D. Fajuke, "Investigating the impact of solar PV and wind energy systems on the strength of a longitudinal power grid," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 8, p. 100593, 2024, doi: 10.1016/j.prime.2024.100593.

[5] M. M. R. Ahmed *et al.*, "Mitigating uncertainty problems of renewable energy resources through efficient integration of hybrid solar PV/wind systems into power networks," *IEEE Access*, vol. 12, pp. 30311–30328, 2024, doi: 10.1109/ACCESS.2024.3370163.

[6] S. Singh and S. Singh, "Advancements and challenges in integrating renewable energy sources into distribution grid systems: a comprehensive review," *Journal of Energy Resources Technology, Transactions of the ASME*, vol. 146, no. 9, p. 90801, 2024, doi: 10.1115/1.4065503.

[7] A. Sharma, "Current trends and future directions in renewable energy systems," *International Journal for Research Publication and Seminar*, vol. 15, no. 2, pp. 186–198, 2024, doi: 10.36676/jrps.v15.i2.1408.

[8] E. Ejuh Che, K. Roland Abeng, C. D. Iweh, G. J. Tsekouras, and A. Fopah-Lele, "The impact of integrating variable renewable energy sources into grid-connected power systems: challenges, mitigation strategies, and prospects," *Energies*, vol. 18, no. 3, p. 689, 2025, doi: 10.3390/en18030689.

[9] S. Algarni, V. Tirth, T. Alqahtani, S. Alshehery, and P. Kshirsagar, "Contribution of renewable energy sources to the environmental impacts and economic benefits for sustainable development," *Sustainable Energy Technologies and Assessments*, vol. 56, p. 103098, 2023, doi: 10.1016/j.seta.2023.103098.

[10] K. H. Bachanek, W. Drożdż, and M. Kolon, "Development of renewable energy sources in Poland and stability of power grids—challenges, technologies, and adaptation strategies," *Energies*, vol. 18, no. 8, p. 2036, 2025, doi: 10.3390/en18082036.

[11] M. Lv, K. Gou, H. Chen, J. Lei, G. Zhang, and T. Liu, "Optimal design of wind-solar complementary power generation systems considering the maximum capacity of renewable energy," *Energy*, vol. 312, p. 133650, 2024, doi: 10.1016/j.energy.2024.133650.

[12] M. Swadi, D. J. Kadhim, M. Salem, F. M. Tuaimah, A. S. Majeed, and A. J. Alrubaie, "Investigating and predicting the role of photovoltaic, wind, and hydrogen energies in sustainable global energy evolution," *Global Energy Interconnection*, vol. 7, no. 4, pp. 429–445, 2024, doi: 10.1016/j.gloei.2024.08.009.

[13] A. Maheshwari, Y. R. Sood, and S. Jaiswal, "Investigation of optimal power flow solution techniques considering stochastic renewable energy sources: review and analysis," *Wind Engineering*, vol. 47, no. 2, 2023, doi: 10.1177/0309524X221124000.

[14] P. Moriarty and D. Honnery, "Feasibility of a 100% global renewable energy system," *Energies*, vol. 13, no. 21, p. 5543, 2020, doi: 10.3390/en13215543.

[15] M. R. Gomaa, H. Rezk, R. J. Mustafa, and M. Al-Dhaifallah, "Evaluating the environmental impacts and energy performance of a wind farm system utilizing the life-cycle assessment method: a practical case study," *Energies*, vol. 12, no. 17, p. 3263, 2019, doi: 10.3390/en12173263.

[16] W. Alabri and D. Jayaweera, "Voltage regulation in unbalanced power distribution systems with residential PV systems," *International Journal of Electrical Power and Energy Systems*, vol. 131, p. 107036, 2021, doi: 10.1016/j.ijepes.2021.107036.

[17] S. J. Rudresha, S. G. Ankaliki, T. Ananthapadmanabha, and V. Girish, "Integration of solar photovoltaic generation in a practical distribution system for loss minimization and voltage stability improvement," in *Lecture Notes in Electrical Engineering*, 2022, pp. 237–246. doi: 10.1007/978-981-16-1642-6_19.

[18] M. A. Zdiri, F. Ben Salem, H. H. Abdallah, Z. Alaas, and B. Dhouib, "Load flow analysis and the impact of a solar PV generator in a radial distribution network," *Engineering, Technology and Applied Science Research*, vol. 13, no. 1, 2023, doi: 10.48084/etasr.5496.

[19] T. R. Said, B. Kichonge, and T. Kivevele, "Optimal design and analysis of a grid-connected hybrid renewable energy system using homer pro: a case study of Tumbatu Island, Zanzibar," *Energy Science and Engineering*, vol. 12, no. 5, 2024, doi: 10.1002/ese3.1735.

[20] E. A. Etukudoh, A. Fabuyide, K. I. Ibekwe, S. Sonko, and V. I. Ilojianya, "Electrical engineering in renewable energy systems: a review of design and integration challenges," *Engineering Science & Technology Journal*, vol. 5, no. 1, pp. 231–244, 2024, doi: 10.51594/estj.v5i1.746.

[21] R. Figaj, "Energy and economic sustainability of a small-scale hybrid renewable energy system powered by biogas, solar energy, and wind," *Energies*, vol. 17, no. 3, p. 706, 2024, doi: 10.3390/en17030706.

[22] J. P. Mahato, Y. K. Poudel, R. K. Mandal, and M. R. Chapagain, "Power loss minimization and voltage profile improvement of radial distribution network through the installation of capacitor and distributed generation (DG)," *Archives of Advanced Engineering Science*, vol. 3, no. 4, pp. 1–9, 2024, doi: 10.47852/bonviewaaes42022031.

[23] N. C. Ugwoke *et al.*, "Impact of large-scale solar photovoltaic integration on weak power grids," in *2024 IEEE PES/IAS PowerAfrica, PowerAfrica 2024*, 2024. doi: 10.1109/PowerAfrica61624.2024.10759386.

[24] P. P. Chinaris, G. N. Psarros, and S. A. Papathanassiou, "Hybridization of wind farms with co-located pv and storage installations," *Renewable Energy*, vol. 240, p. 122057, 2025, doi: 10.1016/j.renene.2024.122057.

[25] S. A. Adegoke, Y. Sun, A. S. Adegoke, and D. Ojeniyi, "Optimal placement of distributed generation to minimize power loss and improve voltage stability," *Heliyon*, vol. 10, no. 21, 2024, doi: 10.1016/j.heliyon.2024.e39298.

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