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RESEARCH ARTICLE

Techno–Economic Feasibility Analysis of a Solar Photovoltaic System for Optimized Power Distribution Network

Rayes Ahmad Lone [1,2,] *, Sheikh Javed Iqbal [1], Ahmed Sharique Anees [2]

ABSTRACT: This study presents a comprehensive techno-economic feasibility analysis of a solar photovoltaic (PV) system integrated into a 7-bus power distribution network. By employing an improved analytical technique, the research strategically determines the optimal placement and sizing of distributed generation (DG) units to minimize power losses and enhance voltage profiles. The analysis focuses on a single-location deployment of a solar PV system with a capacity of 7678 kW, positioned at bus-2. The study compares the system's economic performance with conventional grid-supplied power over a projected 25-year lifespan, considering variables such as fixed charges, variable energy charges, taxes, and a 10% annual inflation rate. Initial power losses without DG integration amount to 128.05 kW, which are reduced to 55.00 kW after incorporating the PV system—a 57.05% reduction. The system operates for 8 hours daily, with an alternative scenario of 5 hours to account for practical limitations. Transmission losses of 10% are considered, emphasizing the system's ability to meet local demand while reducing dependency on centralized grids. The economic analysis reveals significant savings in operational costs, supported by a tariff rate of Rs. 3.10/kWh ($0.037). The findings indicate that the optimized solar PV system not only enhances technical performance by reducing power losses and improving voltage profiles but also proves to be a cost-effective and sustainable alternative to conventional power sources. This work demonstrates the potential of well-planned solar PV systems in addressing the dual challenges of energy efficiency and economic sustainability in modern power networks.

Keywords: Solar Photovoltaics, Distributed Generation, Power Losses, Distribution Network, Voltage Profile.

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1. INTRODUCTION

The incorporation of distributed generations (DGs), particularly solar photovoltaic (PV) systems, into distribution networks has gained significant attention due to their potential to enhance network performance and sustainability. Solar PV systems utilize semiconductor materials to directly convert sunlight into electricity, providing a renewable and sustainable energy source. Technological advancements have led to significant improvements in the efficiency of solar panels, making them a competitive choice for electricity generation [1]. The cost-effectiveness of solar PV systems has improved considerably due to reductions in the cost of solar panels and other associated technologies [2]. Distributed generation (DG) has increased the share of renewable energy generation owing to its closeness to load centres, rapid installation, and utilization of existing roofs for PV systems [3]. DGs can address challenges like power loss, low reliability, poor power quality, and transmission congestion, while meeting energy needs [4]. However, improper deployment can cause issues like reverse power flow, poor protection coordination, voltage imbalance, and increased losses [5]. Additionally, improper placement and size of DG can affect power quality and fault current at the point of common coupling (PCC) [6]. Thus, optimizing DG use is crucial to maximizing its benefits, requiring a strategic approach to planning and deployment. This involves identifying the most effective installation locations, selecting the appropriate types of DG systems, and correctly sizing

[1] National Institute of Technology, Srinagar, India
[2] Islamic University of Science and Technology, Kashmir, India.

* Author to whom correspondence should be addressed:
rayes.lone@islamicuniversity.edu.in (R. A. Lone)
jvd@nitsri.net (S. J. Iqbal)
shariq.anees@islamicuniversity.edu.in (A. S. Anees)

them to meet energy demands efficiently. That's why the integration of solar PV systems into power distribution networks requires effective optimization strategies to maximize their technical and economic benefits [7]. Various algorithms have been developed to enhance the placement and sizing of solar PV systems, addressing challenges such as power losses, voltage stability, and others. The improved grey wolf optimizer, has been utilized to optimize the placement of solar PV systems, resulting in significant performance improvements [8]. Similarly, the crow search algorithm has been employed to reduce power losses and enhance voltage stability by optimizing PV integration [9].The study by Godha et al. uses the ant colony optimization (ACO) technique to integrate DG into a distribution system, minimizing the techno-economic objective function (TEOF), which includes power loss, voltage deviation, and operating costs [10]. Moradi and Abedini presents a unique hybrid genetic-particle swarm optimization (GA-PSO) technique for the positioning and sizing of DG units [11]. Hung et al. used an analytical technique (AT) for the placement of various DG units in various types of distribution networks to reduce power losses [12]. A novel approach based on loss sensitivity factors (LSF) and bacterial foraging optimization algorithm (BFOA) is employed by Injeti et al. to determine the placement and size of DGs units [13]. Other techniques, such as teaching-learning-based-optimization (TLBO) [14], firefly algorithm (FA) [15], multi-objective taguchi technique (MOTA) [16], ant lion optimization algorithm (ALOA) [17], elephant herding optimization (EHO), [18], fuzzy based multi-objective PSO [19], have also been utilised to find the number of DGs, their optimal size and placement in order to enhance the voltage profile and minimize the power losses. These optimization strategies are crucial for the successful integration of solar PV systems into power distribution networks, ensuring both technical efficiency and economic sustainability.

In addition to the application of optimization techniques, numerous techno-economic analyses have been conducted to assess different types of distribution networks. These analyses focus on evaluating the economic viability and technical performance of various network configurations [20]. By examining factors such as cost efficiency, reliability, and scalability, these studies provide valuable insights into the most effective strategies for improving distribution network performance. The study by Mongkoldhumrongkul aims to design and assess a photovoltaic rooftop system by evaluating its economic feasibility, energy costs, and carbon dioxide compensation [21]. For evaluating grid-connected photovoltaic panels for residential use, [22] assesses rooftop solar systems in three cities. It uses PVsyst software to analyze technical, economic, and environmental factors, including energy output, net present value (NPV), internal rate of return (IRR), levelized cost of energy (LCOE), and lifecycle emissions. Similarly, a techno-economic assessment of rooftop solar systems in Iraq was conducted by Falih et al, assuming a hybrid connected photovoltaic (PV) solar system [23]. Similar analysis has been done for Bangkok, Thailand [24], Delhi, India [25], Nablus, Palestine [26], Kathmandu, Nepal [27], Madhya Pradesh, India [28], Botswana, South Africa [29], Jeddah, Saudi Arabia [30] and at various locations in Bangladesh [31].

Despite the existing techno-economic assessments of distribution networks, significant research gaps remain, particularly concerning the evaluation of optimized networks. The aforementioned studies focus on un-optimized configurations, overlooking the real-world challenges. Conducting economic analysis without calculating the optimal location and size of various DG sources can lead to several disadvantages. These include increased power losses due to reverse power flow, increased costs, and various integration issues. This may also result in energy inefficiencies, voltage instability, and higher maintenance expenses, undermining the economic viability of proposed solutions. Addressing these gaps in the literature is crucial for developing more accurate and practical models that reflect the complexities of actual distribution networks.

The rest of this paper is organized as follows: Section II presents the results of the improved analytical technique. Section III discusses the various assumptions and provides the initial information for the techno-economic analysis. In Section IV, the economic analysis is carried out for the first case with Solar PV Generation for 8 hours, followed by the analysis for 5 hours. Section V presents the findings and conclusions.

2. METHODOLOGY

This study applies an improved analytical approach using equivalent current injection (ECI) to identify the optimal placement and sizing of single and multiple DG units [32]. The aim is to strategically place the DG sources into the distribution network apart from minimization of power losses and enhancing the voltage profile of the distribution network. By placing the optimal size calculated for DG at the optimal location, the analysis is carried out for a 7-bus distribution system [33]. The analysis encompasses key factors including solar power generation, power loss reduction, transmission loss reduction, and overall financial implications. In recognizing the increasing importance of sustainable energy solutions, the study aims to provide a comprehensive understanding of the economic feasibility and benefits associated with the incorporation of solar PV systems. It also explores the technical aspects of solar photovoltaic systems, clarifying their benefits and functioning principles. The study is based on assumptions and preliminary information, taking into account variables like solar PV capacity, initial power loss, tariff rates, and working hours. The economic calculations go through into detailed computations, including solar power generation revenue, power loss reduction savings, transmission loss reduction compensation, and return on investment (ROI) [34]. The topology of the network is shown in Figure 1, having 6 lines operating at 23 kV. The active and reactive power demand of the system is 8650 kW and 5180 kVAr respectively [35]. The results obtained using the improved analytical technique (IAT) are summarized in Table 1, which highlights the impact of DG placement and sizing on power losses and the average voltage profile for both single and multiple DGs based on simulation outcomes. A comparison between the outcomes obtained with the proposed approach and those reported in [35], which use the mixed-integer nonlinear programming methodology, is also shown in Table 1. The losses have decreased to 55 kW from the base-case loss of 128.05 kW with a single DG of size 6361 kW, representing a loss reduction of 57.05 %. There is also a notable improvement in average voltage profile of the network from 0.9856 to 0.9930.

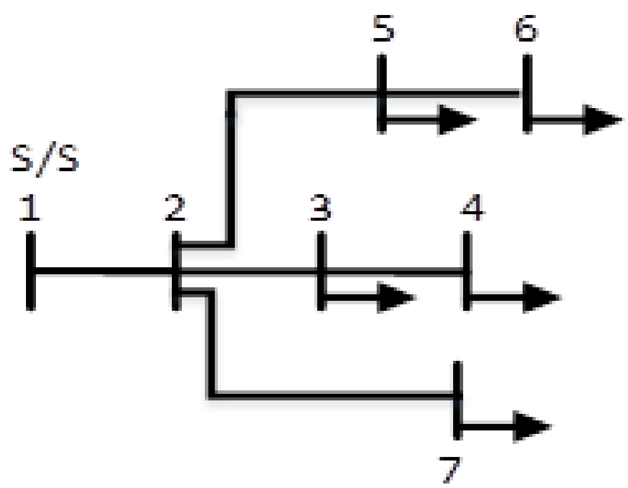

Fig. 1. A 7-bus distribution network.

The results in Table 1 will be utilized to conduct an economic analysis, comparing the installation and operational costs of the proposed system with those of conventional grid-supplied power. The analysis of the annual electricity costs, encompasses the fixed charges, variable energy charges, and taxes. The total expenditure is projected over 25 years, accounting yearly inflation rate of 10%. The MW rating for connection is determined by the power injected from DG and the savings in losses during DG operation. Here we are going to have the economic analysis for single location only which can later be implemented for multiple locations.

3. ASSUMPTIONS AND INITIAL INFORMATION

The analysis is based on several key assumptions and initial parameters. The solar photovoltaic (PV) system under consideration has a capacity of 7678 kW, selected as the optimal size for a single DG unit to be deployed at bus-2 within the 7-bus distribution network. This capacity is determined using an improved analytical technique designed to minimize power losses and enhance voltage profiles. The system's initial power loss, without DG integration, is recorded at 128.05 kW. To assess economic feasibility, a tariff rate of Rs. 3.10/kWh ($0.037) is used, reflecting competitive pricing relative to conventional grid electricity. The system operates for two scenarios: 8 hours daily for a standard operational period and 5 hours daily to accommodate practical limitations. A 10% transmission loss is incorporated into the analysis to simulate real-world conditions. These parameters form the foundation for evaluating the system's technical and economic performance, enabling a comprehensive comparison with grid-supplied power. By incorporating these assumptions, the study aims to provide realistic insights into the potential benefits and challenges associated with deploying solar PV systems in modern power distribution networks.

4. CASE-1: SOLAR PV GENERATION FOR 8 HOURS

The techno-economic analysis for case-1 is summarized in Table 2.

Table 1. Performance Analysis of a 7-bus System.

Case	Technique	Optimal Bus for DG	DG Size at each Bus (kW)	Total DG Capacity (kW)	Power Loss (kW)	% Loss Reduction	% DG Penetration	Average Voltage Profile
Base Case		-	-	-	128.05	-	-	0.9856
MINLP [35]	MINLP	3	6361	6361	56.95	55.52	63.09	-
Single DG	IAT	2	7678	7678	55.00	57.05	76.15	0.9930
Two DGs	IAT	2	4698	7678	41.81	67.35	76.15	
		4	2980					0.9941
Three DGs	IAT	2	3943	7678	39.29	70.09	76.15	
		4	2225					0.9942
		5	1510					

Table 2. Techno-economic analysis of a 7-bus system (8-Hours).

S. No	Item	Calculation	Result
1.	Annual Energy Production from Solar PV	7678 kW * 8 hours/day * 30 days/month * 12 months/year	22,112,640 kWh
2.	Annual Revenue from Solar Energy Generation	22,112,640 kWh * $0.037/kWh	$818,170
3.	Total Energy Production from Solar PV (25 years)	22,112,640 kWh/year * 25 years	552,816,000 kWh
4.	Total Revenue from Solar Energy Generation	552,816,000 kWh * $0.037/kWh	$20,454,192
5.	Power Loss Reduction	128.05 kW - 55 kW	73.05 kW
6.	Annual Power Loss Reduction	73.05 kW * 8 hours/day * 30 days/month * 12 months/year	210,384 kWh
7.	Annual Saving from Power Loss Reduction	210,384 kWh * $0.037/kWh	$7,784.2
8.	Total Power Loss Reduction	73.05 kW * 8 hours/day * 30 days/month * 12 months/year * 25 years	5,259,600 kWh
9.	Total Saving from Power Loss Reduction	5,259,600 kWh * $0.037/kWh	$194,610
10.	Initial Investment for Installing 7678 kW Solar PV	7678 kW * $600/kWp	$4,606,800
11.	Total Load Demand	-	8650 kW
12.	Annual Transmission Loss Reduction Compensation (10%)	865 kW * 8 hours/day * 30 days/month * 12 months/year * $0.037/kWh	$92,173
13.	Total Transmission Loss Reduction Compensation (25 years)	$92,173/year * 25 years	$2,304,325
14.	Total Saving from Installing DG at Bus 2	$20,454,192 + $194,610 + $2,304,325 - $4,606,800	$18,346,327

In Case-1 of the economic analysis, a single DG unit with a capacity of 7678 kW is connected at bus No. 2, operating in conjunction with a solar photovoltaic (PV) system for 8 hours daily. The theory explores the financial implications and benefits over a 25-year period. The initial investment for installing the 7678 kW Solar PV system is computed at $600 per kWp, totalling $4,606,800. The economic benefits extend to transmission loss reduction compensation, calculated annually and cumulatively over 25 years. The total savings from installing the DG at bus No. 2 are determined by summing the total revenue from solar energy generation, savings from power loss reduction, and transmission loss reduction compensation while subtracting the initial investment, resulting in a substantial total saving of $18,346,327. This comprehensive economic analysis showcases the financial viability and advantages of integrating a DG system with solar PV at a specific bus location.

5. ROI: RETURN ON INVESTMENT CALCULATIONS

The Return on Investment (ROI) calculations over a 25-year period provide a comprehensive analysis of the financial performance of the distributed generation (DG) system integrated at bus-2. The Table 3 outlines various financial metrics and showcases the net savings accrued over each year. The total revenue will be generated from solar power generation, power loss reduction, and transmission loss reduction. In Table 3, it is evident that during the 6th year of the ROI calculations, the negative sign in column E indicates a significant financial milestone. It reflects that the total savings, encompassing solar power generation revenue, power loss reduction, and transmission loss reduction compensation, surpass the initial investment cost. This negative sign signifies the recovery of the total installation cost, highlighting the point at which the accumulated savings offset the initial investment. In the 6th year, the negative value of -$901,960 in column E demonstrates that the total savings have not only covered the installation cost but have resulted in a surplus. This surplus represents the net financial gain, showcasing the economic viability and profitability of the distributed generation system integrated at bus No. 2.

6. CASE-2: SOLAR PV GENERATION FOR 5 HOURS

Table 3. Return on Investment (ROI) Calculations for 25-years.

Years	Solar power generation revenue-A ($)	Revenue from power loss reduction-B($)	Revenue from Transmission loss reduction-C ($)	Initial Investment-D ($)	Total Saving from installing DG at bus 2 (E) ($) E=D-(A+B+C)
1	818170	7784.2	92173	4606800	3.6887e+06
2	1.6363e6	0.0156e6	0.1843e6	4606800	2.7705e+06
3	2.4545e6	0.0234e6	0.2765e6	4606800	1.8524e+06
4	3.2727e6	0.0311e6	0.3687e6	4606800	9.3429e+05
5	4090850	38921	460865	4606800	16164
6	**4.9090e6**	**0.0467e6**	**0.5530e6**	**4606800**	**-9.0196e+05**
7	5.7272e6	0.0545e6	0.6452e6	4606800	-1.8201e+06
8	6.5454e6	0.0623e6	0.7374e6	4606800	-2.7382e+06
9	7.3635e6	0.0701e6	0.8296e6	4606800	-3.6563e+06
10	8181700	77842	921730	4606800	-4574472
11	8.9999e6	0.0856e6	1.0139e6	4606800	-5.4926e+06
12	9.8180e6	0.0934e6	1.1061e6	4606800	-6.4107e+06
13	1.0636e7	0.0101e7	0.1198e7	4606800	-7.3289e+06
14	1.1454e7	0.0109e7	0.1290e7	4606800	-8.2470e+06
15	12272550	116763	1382595	4606800	-9165108
16	1.3091e7	0.0125e7	0.1475e7	4606800	-1.0083e+07
17	1.3909e7	0.0132e7	0.1567e7	4606800	-1.1001e+07
18	1.4727e7	0.0140e7	0.1659e7	4606800	-1.1919e+07
19	1.5545e7	0.0148e7	0.1751e7	4606800	-1.2838e+07
20	16363400	155684	1843460	4606800	-13755744
21	1.7182e7	0.0163e7	0.1936e7	4606800	-1.4674e+07
22	1.8000e7	0.0171e7	0.2028e7	4606800	-1.5592e+07
23	1.8818e7	0.0179e7	0.2120e7	4606800	-1.6510e+07
24	1.9636e7	0.0187e7	0.2212e7	4606800	-1.7428e+07
25	20454250	194605	2304325	4606800	-18346380

Table 4. Techno-economic analysis of a 7-bus system (5 Hours).

S. No	Item	Calculation	Result
1.	Annual energy production from solar PV	7678*1000*5*30*12	13820400kWh
2.	Annual revenue from solar energy generation	13820400*0.037	$511350
3.	Total energy production from solar PV (25 years)	13820400*25	345510000kWh
4.	Total revenue from solar energy generation	345510000*0.037	$12783870
5.	Power loss reduction = Initial power loss – Power loss after DGs	(128.05 – 55) kW	73.0500 kW
6.	Annual power loss reduction	73.05*5*30*12	131490 kWh
7.	Annual saving from power loss reduction	-	$4.8651e+03
8.	Total power loss reduction	3287250 kWh	-
9.	Total saving from power loss reduction	-	$1.2163e+05
10.	Initial investment for installing 7678 kW Solar PV	($600/kWp) *7678	$4606800
11.	Total Load demand	8650 Kw	
12.	Annual Transmission loss reduction compensation	$(865*5*30*12*0.037)	$57609
13.	Total transmission loss reduction compensation	57609*25	$1440225
14.	Total saving from Installing DG at bus 2	$12783870 + $1.2163e+05 + $1440225 - $4606800	$9738925

The techno-economic analysis for case-2 is summarized in Table 4. Given the variability inherent in solar PV generation, Case-2 explores the economic analysis considering their restricted operational hours. In this context, the annual energy production from the solar PV system, with a capacity of 7678 kW, is calculated, considering the reduced operational hours (5 hours per day). Similar to the analysis conducted in Case-1, a detailed assessment of the return on investment over the 25-year period was carried out like Table 3, revealing varying financial outcomes. The first eight years showcase a positive trend in savings resulting from solar power generation revenue, power loss reduction, and transmission loss reduction. However, starting from the 9th year, a negative sign reflects that the accumulated savings surpass the initial investment, essentially signifying the completion of the DG installation cost.

7. CONCLUSION

The study concludes that the integration of an optimized solar photovoltaic (PV) system into a power distribution network is both technically and economically viable. By employing an improved analytical technique, the research identifies the optimal placement and sizing of distributed generation (DG) units, significantly reducing power losses and improving voltage profiles. The analysis for a 7-bus distribution network reveals that the incorporation of a 7678 kW solar PV system at bus-2 reduces power losses from 128.05 kW to 55.00 kW, achieving a 57.05% reduction. Additionally, the voltage profile improves from 0.9856 to 0.9930. These technical benefits translate into substantial economic advantages. Over a 25-year analysis period, the system demonstrates reduced operational costs compared to conventional grid electricity, with savings amplified by a low tariff rate of Rs. 3.10/kWh ($0.037). By considering real-case scenarios, such as 5-hour daily operation and a 10% transmission loss, the study emphasizes the robustness and reliability of the proposed system. The findings underscore the importance of strategic optimization in maximizing the benefits of solar PV systems. Moreover, the results demonstrate the scalability of the approach, with potential applicability to multiple locations beyond the single-site deployment analyzed in this study. The integration of solar PV systems, when optimized effectively, offers a sustainable solution to energy challenges, balancing technical efficiency with economic feasibility. This work highlights the critical role of optimization techniques in advancing renewable energy adoption and achieving long-term energy sustainability.

DECLARATIONS

Ethical Approval

We affirm that this manuscript is an original work, has not been previously published, and is not currently under consideration for publication in any other journal or conference proceedings. All authors have reviewed and approved the manuscript, and the order of authorship has been mutually agreed upon.

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Conflicts of Interest

The authors declare that they have no financial or personal interests that could have influenced the research and findings presented in this paper. The authors alone are responsible for the content and writing of this article.

Authors' contributions

All authors contributed equally in the preparation of this manuscript.

REFERENCES

[1] Victoria, M., Haegel, N., Peters, I.M., Sinton, R., Jäger-Waldau, A., del Canizo, C., Breyer, C., Stocks, M., Blakers, A., Kaizuka, I. and Komoto, K., **2021.** Solar photovoltaics is ready to power a sustainable future. *Joule*, *5*(5), pp.1041-1056.

[2] Obaideen, K., AlMallahi, M.N., Alami, A.H., Ramadan, M., Abdelkareem, M.A., Shehata, N. and Olabi, A.G., **2021.** On the contribution of solar energy to sustainable developments goals: Case study on Mohammed bin Rashid Al Maktoum Solar Park. *International Journal of Thermofluids*, *12*, p.100123.

[3] Nadeem, T.B., Siddiqui, M., Khalid, M. and Asif, M., **2023.** Distributed energy systems: A review of classification, technologies, applications, and policies. *Energy Strategy Reviews*, *48*, p.101096.

[4] Iweh, C.D., Gyamfi, S., Tanyi, E. and Effah-Donyina, E., **2021.** Distributed generation and renewable energy integration into the grid: Prerequisites, push factors, practical options, issues and merits. *Energies*, *14*(17), p.5375.

[5] Kharrazi, A., Sreeram, V. and Mishra, Y., **2020.** Assessment techniques of the impact of grid-tied rooftop photovoltaic generation on the power quality of low voltage distribution network-A review. *Renewable and Sustainable Energy Reviews*, *120*, p.109643.

[6] Lone, R.A., Javed Iqbal, S. and Anees, A.S**., 2024.** Hybrid technique for optimal placement and sizing of distributed generation units considering real and reactive power injection. *International Journal of Green Energy*, *21*(9), pp.2084-2101.

[7] 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), pp.7160-7185.

[8] Ansari, M.M., Guo, C., Shaikh, M.S., Chopra, N., Haq, I. and Shen, L., **2020.** Planning for distribution system with grey wolf optimization method. *Journal of Electrical Engineering & Technology*, *15*, pp.1485-1499.

[9] Ansari, M.M., Guo, C., Shaikh, M.S., Chopra, N., Haq, I. and Shen, L., **2020.** Planning for distribution system with grey wolf optimization method. *Journal of Electrical Engineering & Technology*, *15*, pp.1485-1499.

[10] Godha, N.R., Bapat, V.N. and Korachagaon, I., **2022.** Ant colony optimization technique for integrating renewable DG in distribution system with techno-economic objectives. *Evolving Systems*, *13*(3), pp.485-498.

[11] Moradi, M.H. and Abedini, M., **2012**. A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems. *International Journal of Electrical Power & Energy Systems*, *34*(1), pp.66-74.

[12] Hung, D.Q. and Mithulananthan, N., **2011.** Multiple distributed generator placement in primary distribution networks for loss reduction. *IEEE Transactions on Industrial Electronics*, *60*(4), pp.1700-1708.

[13] Injeti, S.K. and Kumar, N.P., **2013.** A novel approach to identify optimal access point and capacity of multiple DGs in a small, medium and large scale radial distribution systems. *International Journal of Electrical Power & Energy Systems*, *45*(1), pp.142-151.

[14] Mohanty, B. and Tripathy, S., **2016.** A teaching learning based optimization technique for optimal location and size of DG in distribution network. *Journal of Electrical Systems and Information Technology*, *3*(1), pp.33-44.

[15] Boukli Hacene, M.E.A., Laroui, R., Rozale, H. and Chahed, A., **2023.** Thermal simulation of the ground source heat pump used for energy needs of a bioclimatic house in Tlemcen City (western ALGERIA). *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *45*(2), pp.5425-5439.

[16] Meena, N.K., Swarnkar, A., Gupta, N. and Niazi, K.R., **2017.** Multi-objective Taguchi approach for optimal DG integration in distribution systems. *IET Generation, Transmission & Distribution*, *11*(9), pp.2418-2428.

[17] Ali, E.S., Abd Elazim, S.M. and Abdelaziz, A.Y., **2017.** Ant Lion Optimization Algorithm for optimal location and sizing of renewable distributed generations. *Renewable Energy*, *101*, pp.1311-1324.

[18] Meena, N.K., Parashar, S., Swarnkar, A., Gupta, N. and Niazi, K.R., **2017.** Improved elephant herding optimization for multiobjective DER accommodation in distribution systems. *IEEE Transactions on Industrial Informatics*, *14*(3), pp.1029-1039.

[19] Kamel, S., Selim, A., Ahmed, W. and Jurado, F., **2020.** Single-and multi-objective optimization for photovoltaic distributed generators implementation in probabilistic power flow algorithm. *Electrical Engineering*, *102*(1), pp.331-347.

[20] Iqbal, S.J., Showkat, S., Mohammad, S.S., Gajra, V., Ali, A. and Lone, R.A., **2023,** December. A New Data-Analytic Approach for the Design, Operation and Control of Residential Solar PV Systems. In *2023 International Conference on Power Energy, Environment & Intelligent Control (PEEIC)* (pp. 214-220). IEEE.

[21] Mongkoldhumrongkul, K., **2023.** Techno-economic analysis of photovoltaic rooftop system on car parking area in Rayong, Thailand. *Energy Reports*, *9*, pp.202-212.

[22] Hai, T., Jaffar, H.A., Taher, H.H., Al-Rubaye, A.H., Said, E.A., Hussein, A.H.A., Alhaidry, W.A.A.H., Idan, A.H. and Salehi, A., **2024.** Techno-economic and environmental analysis of a grid-connected rooftop solar photovoltaic system in three climate zones. *International Journal of Low-Carbon Technologies*, *19*, pp.1725-1739.

[23] Falih, H., Hamed, A.J. and Khalifa, A.H.N., **2022.** Techno-economic assessment of a hybrid connected PV solar system. *International Journal of Air-Conditioning and Refrigeration*, *30*(1), p.3.

[24] Jamroen, C., Vongkoon, P. and Ma, T., **2024.** Techno-economic assessment of grid-connected residential photovoltaic systems considering overvoltage-induced generation curtailment. *Energy Reports*, *11*, pp.5059-5068.

[25] Jamil, M., Anees, A.S. and Rizwan, M., **2012.** SPV based water pumping system for an academic institution. *American Journal of Electrical Power and Energy Systems*, *1*(1), pp.1-7.

[26] Ibrik, I.H., **2020.** Techno-economic assessment of on-grid solar PV system in Palestine. *Cogent Engineering*, *7*(1), p.1727131.

[27] Poudyal, R., Loskot, P. and Parajuli, R., **2021**. Techno-economic feasibility analysis of a 3-kW PV system installation in Nepal. *Renewables: Wind, Water, and Solar*, *8*, pp.1-18.

[28] Dwivedi, A. and Pahariya, Y., **2023.** Techno-economic Feasibility Analysis of Optimized Stand-alone PV and Hybrid Energy Systems for Rural Electrification in INDIA. *Journal of The Institution of Engineers (India): Series B*, *104*(4), pp.911-919.

[29] Kassem, Y., Gokcekus, H. and Agila, F.A.R., **2023.** Techno-Economic Feasibility Assessment for the promotion of Grid-Connected Rooftop PV Systems in Botswana: A Case Study. *Engineering, Technology & Applied Science Research*, *13*(2), pp.10328-10337.

[30] Imam, A.A. and Al-Turki, Y.A**., 2019.** Techno-economic feasibility assessment of grid-connected PV systems for residential buildings in Saudi Arabia—A case study. *Sustainability*, *12*(1), p.262.

[31] Ali, M.F., Sarker, N.K., Hossain, M.A., Alam, M.S., Sanvi, A.H. and Syam Sifat, S.I., **2023.** Techno-economic feasibility study of a 1.5 MW grid-connected solar power plant in Bangladesh. *Designs*, *7*(6), p.140.

[32] Lone, R.A., Javed Iqbal, S. and Anees, A.S., **2024.** Optimal location and sizing of distributed generation for distribution systems: an improved analytical technique. *International Journal of Green Energy*, *21*(3), pp.682-700.

[33] Lone, R.A., Iqbal, S.J. and Anees, A.S., **2023,** February. Multi-objective optimal siting and sizing of distributed generation units by Grid-Search Algorithm. In *2023 International Conference on Power, Instrumentation, Energy and Control (PIECON)* (pp. 1-6). IEEE.

[34] Jamil, M. and Anees, A.S., **2016.** Optimal sizing and location of SPV (solar photovoltaic) based MLDG (multiple location distributed generator) in distribution system for loss reduction, voltage profile improvement with economical benefits. *Energy*, *103*, pp.231-239.

[35] Montoya, O.D., Gil-González, W. and Grisales-Noreña, L.F**., 2020.** An exact MINLP model for optimal location and sizing of DGs in distribution networks: A general algebraic modeling system approach. *Ain Shams Engineering Journal*, *11*(2), pp.409-418.

