DESIGN AND SIMULATION OF A ROOFTOP PV SOLAR POWER SYSTEM FOR THE TRAINING ROOM AT PT. PUPUK ISKANDAR MUDA – ACEH

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Abstract

This study presents the design and simulation of an on-grid photovoltaic (PV) solar power system for the training room at PT. Pupuk Iskandar Muda (PT. PIM), located in North Aceh, Indonesia. As part of Indonesia's renewable energy goals, this research explores the potential of rooftop solar installations in supporting the country's energy transition. Using the PVSyst simulation software, the study assesses the technical and economic feasibility of deploying a solar power system tailored to the building's electricity demands and solar radiation characteristics. The design incorporates monocrystalline and polycrystalline solar panels, and system configurations are optimized based on factors such as panel capacity, inverter specifications, and site-specific conditions. The results indicate that a 2 kWp system can generate up to 2.91 MWh annually, with a performance ratio (PR) of 81.15%, demonstrating the system's feasibility for sustainable energy use. The findings contribute to understanding the practical applications of rooftop solar power in educational and industrial sectors, providing insights into the potential for broader adoption across similar contexts in Indonesia.

Keywords: ***Solar Power Plant (PLTS); Solar Roof System; Design and Simulation; Energy Efficiency; Economic Feasibility***

1. Introduction

The current government policies and targets regarding renewable energy utilization in Indonesia are primarily outlined in the General National Energy Plan (RUEN) and various presidential and ministerial regulations. Specifically, the aim is to increase the share of renewable energy in the national energy mix to 23% by 2025, with a target of expanding installed solar energy capacity to 3,600 MW by 2025, including the substantial development of rooftop solar power systems (1). The Indonesian government has positioned rooftop solar photovoltaic (PV) installations as a critical element in achieving these renewable energy goals, facilitating residential and commercial sectors to contribute to energy diversity and independence from fossil fuels (2). By promoting rooftop solar systems, the government aims not only to enhance energy security but also to mitigate greenhouse gas emissions, supporting its commitments to sustainability and climate action (3). As for the current installed capacity of solar power plants (PLTS) in Indonesia, recent data indicate that the installed capacity reached approximately 0.15 GW by the end of 2020 (2). This significantly trails behind the governmental target of 3,600 MW for rooftop PLTS by 2025, highlighting a substantial gap that needs addressing through strategic investments and policy implementation (2). Given Indonesia's estimated solar energy potential of around 207.8 GW, this gap underscores the urgent need for initiatives that encourage the rollout of both large-scale and distributed solar power projects to meet the ambitious targets set by the government (4). Previous studies focusing on the design of rooftop solar power systems, particularly in educational institutions, have revealed essential insights regarding site selection and performance optimization (5). For instance, building characteristics, geographical location, and solar radiation levels play a pivotal role in determining system efficacy (6). Implementations in various locations show that tailored designs specific to local climatic conditions can enhance energy production and cost-effectiveness. In urban settings such as educational institutions, maximizing the potential of rooftops through proper azimuth and tilt optimization can significantly increase energy capture and overall system performance (5).

Economic analyses used in prior studies to ascertain the viability of rooftop solar power systems often leverage methods such as net present value (NPV), internal rate of return (IRR), and payback period calculations (7). Findings consistently suggest that investments in rooftop solar yield financial benefits, such as reduced energy bills and the potential for income through feed-in tariffs, making them an attractive option for many households and businesses (8). These studies emphasize the possibility of achieving substantial cost savings and energy consumption reductions through well-planned solar installations, which could counterbalance initial setup costs within a relatively short payback period (2). Lastly, simulation and design tools like PVSyst are fundamental in evaluating and optimizing the performance of rooftop solar power systems. These tools allow for the modeling of various scenarios, enabling designers to analyze factors like solar irradiance, shading impacts, and system losses under different conditions, ultimately guiding decisions on system size and component selection for efficiency (4). Through comprehensive simulation studies, stakeholders can better understand how rooftop solar systems can be effectively integrated into the energy landscape of Indonesia, promoting a transition toward sustainable energy solutions (9). In this study, the design and feasibility simulation of an on-grid solar power system (PLTS) on the roof of the PT. PIM Training Room is conducted. The simulation is carried out using the PVSyst software. Subsequently, a feasibility analysis is performed from both the electrical and economic aspects.

2. Method

When designing an on-grid solar power system, both technical and economic criteria play crucial roles in determining its feasibility and implementation. From a technical standpoint, considerations include hosting capacity, power quality, and integration with existing grid infrastructure. Specifically, factors such as the capability of the distribution network to accommodate additional solar capacity are vital; analyses have shown that the inclusion of solar photovoltaic (PV) systems can significantly reduce active power loss and improve voltage profiles in distribution networks (10). Furthermore, compliance with grid connection codes, which govern the operational parameters for integrating PV systems into the national grid, is essential (11). These requirements address issues related to power quality and configuration, ensuring that new installations do not adversely affect the existing power infrastructure. Economically, the feasibility of an on-grid solar power system hinges on factors such as initial capital investment, operation and maintenance (O&M) costs, and revenue generation through mechanisms like net metering (12). For instance, net metering can incentivize residential solar installations by allowing homeowners to offset their electricity bills with excess energy fed back into the grid, thereby presenting a compelling financial rationale for adopting solar PV technology (13).

The selection of main components such as solar panels and inverters critically influences the performance, quality, and investment costs of an on-grid solar power system. Quality solar panels are correlated with higher energy yields and longer lifespans, which directly minimize the levelized cost of energy (LCOE) (14). Higher-efficiency panels can lead to reduced space requirements and enhanced overall system output, thereby improving the economic viability of solar installations. Similarly, the choice of inverters is paramount; grid-following inverter technology must ensure that solar generation aligns smoothly with grid requirements, which is essential for maintaining grid stability and compliance with quality standards (15). Moreover, the integration of advanced inverter technologies can significantly enhance system performance by managing various operational aspects efficiently, leading to long-term benefits (16). Economic analyses have consistently highlighted the benefits of investing in high-quality components. For example, systems with superior components typically exhibit lower maintenance costs and higher reliability, which are crucial for ensuring sustained financial returns over time (17). Moreover, the declining costs of key components like solar panels and inverters, due in part to technological advancements and increased manufacturing efficiency, reinforce the economic appeal of such investments, allowing for broader accessibility and adoption of solar technologies globally (18). The design process of the PLTS system is presented in Figure 1.

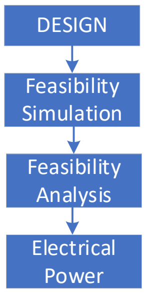

Figure 1. Solar Power Plant System Design Process

Solar panels work by converting solar energy into electrical energy through the photovoltaic effect, first discovered by Charles Fritts in 1883. Modern panels, such as monocrystalline and polycrystalline types, use silicon as a semiconductor to improve efficiency and power output (19). Monocrystalline panels, made from a single crystal, are more efficient, ranging from 18.5% to 23.5%, while polycrystalline panels, formed from multiple silicon fragments, have lower efficiency at 15.5% to 18% (20,21). Although monocrystalline panels generally perform better, polycrystalline ones can outperform under certain conditions, like higher temperatures (22), (23). Additionally, cost and aesthetic preferences influence consumer choices, with monocrystalline panels being more expensive due to higher manufacturing costs (24,25).

Location Identification

This study designs a grid-connected solar power system (PLTS) on the roof of the training building at PT. PIM, located in the PT. PIM complex, Jl. Medan - Banda Aceh (Arun Lhokseumawe Special Economic Zone), Tambon Baroh Village/Subdistrict, Dewantara District, North Aceh Regency, Aceh Province, with coordinates (05°13'46", 097°02'21"). The building features a gable roof, with each side having an area of 366.7 m². The gable roof's shape from the top is shown in Figure 2.

Figure 2. View of PT. PIM Training Room

Gathering of data

In this study, data collection was conducted through direct observation of the PT. PIM – Aceh training building. The aim of this observation is to gather essential information for designing a grid-connected solar power system (PLTS). The collected data includes solar radiation intensity received by the roof, electricity consumption of the building, roof area available for solar panel installation, and the costs of the components to be used in the PLTS system. This data is vital for determining the appropriate capacity of the solar system and calculating both the costs and energy efficiency it will generate.

Design of Solar Power System (PLTS)

The manual design is conducted to calculate several parameters that will be used in the PLTS system simulation. This theoretical calculation is important as an initial step to obtain the baseline values, which will then be compared with the results from the simulation using the PVSyst software. This approach helps gain a better understanding of how these parameters influence the overall system performance. The manual calculations also allow for the verification of simulation accuracy, ensuring that the designed system will perform as expected. The stages of the PLTS system design involve a series of steps, including energy needs analysis, component selection, calculation of the required solar panel capacity, and determining the overall system configuration. When determining the location for the installation of a Solar Power Generation System (PLTS), several physical factors must be considered to ensure the system operates optimally. These factors include the location's physical condition, geographic coordinates, and roof slope. Studies have shown that these elements significantly impact the efficiency and productivity of the PLTS system. Geographic coordinates play a crucial role in determining the solar radiation received, as it varies based on specific locations on Earth (OBARA & Utsugi, 2017). The roof slope is also vital for efficient sunlight absorption, with the optimal tilt angle depending on the local geographic and climatic conditions (Yılmaz et al., 2015).

Furthermore, a precise location analysis must consider environmental factors such as shading from nearby objects, which can reduce system efficiency (26). Technologies like Geographic Information Systems (GIS) can be used to provide spatial data necessary for evaluating and planning the installation site for the PLTS system (27). Therefore, conducting a thorough site survey is essential before system installation, including analyzing the surrounding environmental effects. Regarding the calculation of the PLTS system's capacity, system efficiency is often influenced by potential losses. An increase of 15–25% in the P_peak value is generally needed to account for losses due to real-world conditions that may not be fully captured during the planning phase (28), (29). These losses can arise from factors such as ambient temperature, humidity, and variability in sunlight, leading to a decrease in the performance of solar panels. In practice, this capacity calculation ensures that the designed system meets energy needs despite losses, guiding the determination of system size and type (30).

$$P_{\text{peak}} = \frac{\text{Energy per day}}{\text{Average solar radiation}} \quad (1)$$

Solar radiation is one of the most abundant renewable energy sources, particularly in areas near the equator, such as Indonesia. Solar radiation refers to the energy emitted by the sun, which reaches Earth's surface in the form of light and heat. The standard unit for measuring solar radiation is kWh/m²/day, reflecting the amount of solar energy received per unit area per day. In the Jabodetabek area, solar radiation intensity is estimated to range from 4.98 to 5.02 kWh/m²/day, indicating significant potential for solar energy use (31), (32). Common methods for measuring solar radiation include installing instruments like pyranometers to detect and record the amount of solar radiation received. Additionally, solar radiation data can be obtained from historical data analysis or using software programmed to estimate radiation values based on existing meteorological data (33). The accuracy of this data is crucial for determining the efficiency of renewable energy systems.

Regarding the use of the Meteonorm database, research by Indra et al. describes how solar radiation potential in Southeast Sulawesi was analyzed using data from Meteonorm software. The study showed that the generated radiation data is valuable for planning solar power plant development, with the global horizontal radiation ranging from 142.5 to 156.3 kWh/m² (34). The Meteonorm database provides comprehensive and reliable solar radiation information across various locations, assisting designers and researchers in obtaining accurate data for renewable energy projects. The selection of solar panels in the design of a Solar Power Generation System (PLTS) is crucial as it influences energy efficiency, overall system cost, and the optimal use of space. Key factors to consider when choosing solar panels include panel efficiency, module area, and design costs. Panel efficiency directly affects the energy output of the PV system. According to Majdi et al., monocrystalline panels typically offer higher efficiency than polycrystalline panels, making them more effective in generating power in smaller areas (35). Environmental factors such as temperature and wind speed also significantly impact efficiency. As noted by Nurhaida et al., increased temperatures can reduce the efficiency of solar panels (21). Therefore, selecting the appropriate panel type is essential for maximizing energy production.

The area of the modules must also be considered, as solar panels require sufficient space to optimize the sunlight they receive, which also relates to the overall system cost (36). A well-designed system can minimize land usage and maintain cost efficiency, although there is limited data available on how specific designs or panel efficiencies correlate with cost (37). Design costs are another primary consideration. Medford et al. argue that the integration of new technologies and materials into solar panel manufacturing can significantly contribute to the overall system cost, and a strategy that takes into account cost, lifespan, and practical effectiveness is essential for achieving sustainable energy policies (38). Regarding the calculation of the number of panels required in a PLTS system, the formula generally expressed is:

$$\text{Number of Panels} = \frac{\text{System Capacity (W)}}{\text{Panel Output Power (W)}} \quad (2)$$

In this context, choosing the right panel based on output power (Power Peak) and efficiency becomes highly relevant, as the power peak indicates their energy generation capacity under optimal conditions (39). Designing and implementing a photovoltaic solar power system (PLTS) requires careful consideration of several key factors, including selecting the right inverter, configuring solar panel arrays, and evaluating system performance using metrics like Performance Ratio (PR). The inverter must be chosen based on the system's designed capacity to ensure optimal functionality. Triyanto et al. emphasize that the inverter’s capacity should match the number and arrangement of solar panels to maximize sunlight utilization (40). Additionally, Akram et al. highlight the importance of determining appropriate inverter sizes and capacities to ensure synchronization with specific solar panel configurations, thereby maximizing efficiency (41). Properly matching the solar panel type with the inverter is also crucial for enhancing power output. Ariawan et al. show that selecting the right combination of solar modules and inverter capacities can improve system performance and longevity (42). Furthermore, Triyanto et al. provide formulas to determine optimal panel configurations in series and parallel to maximize energy output and minimize space usage (40). PR is a vital indicator of system efficiency, with Akram et al. and Sathiracheewin et al. demonstrating how operational factors influence its calculation and accuracy (41), (43). The formulas used for this research are as follows:

Formula for selecting inverter specifications:

Inverter Capacity = Numb. of Panels × Panel Cap. (3)

Formula for the configuration of the solar panel array system:

$$\text{Min. series} = \frac{V_{min}\text{Inverter}}{V_{oc}\text{ Solar panel}} \quad (4)$$

$$\text{Max. series} = \frac{V_{max}\text{Inverter}}{V_{mp}\text{ Solar panel}} \quad (5)$$

$$\text{Paralel} = \frac{I_{max}\text{ Input Inverter}}{I_{mp}\text{ Solar panel}} \quad (6)$$

3. Results and Discussion

Solar Radiation at the Research Location

The solar radiation potential obtained based on the coordinates of the PT. PIM – Lhokseumawe Aceh training building is presented in Table 1.

Table 1. Radiation Values at the PT. PIM Aceh Training Building

Month	Solar Radiation (kWh/m2/day)
January	5.18
February	5.47
Mart	5.58
April	5.43
Mei	5.28
June	5.32
July	5.29
August	5.13
September	5.08
October	4.10
November	4.30
December	4.05

Based on the obtained data, the highest solar radiation value occurs in March, which is 5.58 kWh/m²/day. This peak is due to March being the height of the dry season. The lowest solar radiation value is recorded in December, with a value of 4.05 kWh/m²/day. The average solar radiation throughout the year is 5.01 kWh/m²/day. The electricity load estimate for the PT. PIM Lhokseumawe – Aceh training building was derived from direct observations of the site and interviews with the building management. Based on these observations, the maximum estimated average daily electricity load in the building is 7,000 watts. The building has an electrical capacity of 66,000 VA. Although the estimated maximum load exceeds the installed capacity, in practice, the electrical load has never exceeded the installed capacity since the electrical loads are not all used at the same time, and the building is only used during training sessions.

Main Components of a Solar Power System (PLTS)

The main components used in a solar power system (PLTS) are solar panels and inverters. Before selecting the components, the system capacity must first be calculated. Using Equation (1), the minimum required capacity for designing the PLTS is determined to be 1.5 kWp. However, due to system losses, an additional 15% to 25% is added, resulting in a designed PLTS capacity of 1.875 kWp, which is then rounded up to 2 kWp. The solar panels used in the design of this on-grid PLTS system are of the monocrystalline and polycrystalline types, branded AEG, with capacities of 275 Wp and 335 Wp (polycrystalline). This is done to determine the total number of arrays. To calculate the number of solar modules required based on their type and capacity, calculations were performed according to Equation (2), resulting in the values shown in Table 2.

Table 2. Solar Panel Requirements Data

Type of solar panel	Solar panel capacity (Wp)	Total designed watt peak (kWp)	Total designed panels (pcs)
Monocrystalline	275	1.875	7
Monocrystalline	335	1.875	6
Polycrystalline	275	1.875	7
Polycrystalline	335	1.875	6

Equations (4), (5), and (6) are used to analyze the array circuit configuration of the PV system, which includes minimal series, maximal series, and parallel configurations. The resulting configurations are presented in Table 3. By using these equations, we can understand how each configuration affects the overall performance and efficiency of the PV system, which is crucial in determining the optimal arrangement of solar panel elements to maximize energy production.

Table 3. Array Circuit Configuration

Variasi	**Minimal series**	**Maximum series**	**parallel**
Monocrystalline 275 Wp	3	18	2
Monocrystalline 335 Wp	2	14	2
Polycrystalline 275 Wp	3	18	2
Polycrystalline 335 Wp	2	14	2

Referring to equation (3), it is obtained that the inverter used has a capacity of 2 kWp. This capacity ensures optimal inverter performance in supporting the system, providing high efficiency in power management, and ensuring stable and reliable energy supply for the intended application.

Simulation

In simulating the design of the PV solar power system for the PT. PIM Training Room using PVSyst, various data parameters are required, as they significantly influence the simulation output. The first key parameter is the tilt angle of the solar panels, which is set to 30°, facing south. This angle was chosen because the solar panels are mounted on the roof, aligning with the roof's slope. This alignment is crucial for maximizing solar exposure throughout the day. Additionally, the inverter used in the system is the ENF type EPV2KTL, selected for its reliability and compatibility with the designed system. The solar panels in the design vary in type, capacity, and configuration to optimize energy generation under varying environmental conditions. This variation allows for a more flexible and efficient system setup, taking into account different panel efficiencies and performance rates. The system is designed as a roof-mounted configuration, with fixed panel supports to ensure stability and durability, especially under harsh weather conditions. By selecting these specific parameters and configurations, the simulation can provide a more accurate prediction of the system's performance, ensuring that the designed PV solar power system will effectively meet the energy demands of the training room while maintaining efficiency and cost-effectiveness.

Variasi A

The first simulation conducted is a variation of the solar power system design using monocrystalline solar panels with a capacity of 275 Wp, consisting of 8 panels configured in a 1 string with 8 series connections. Based on the simulation results, the total energy produced by the on-grid solar power system is estimated to reach 2.91 MWh per year. Figure 3 shows the varying energy production pattern throughout the year, with the peak production occurring in June, reaching 450 kWh, while the lowest production is recorded in December, at just 230 kWh. This simulation result highlights significant differences in energy production levels, influenced by weather conditions and sunlight duration each month. The high energy production in June is attributed to the longer duration of sunlight in that region, while the lower energy production in December is impacted by the shorter sunlight hours due to seasonal conditions. The Performance Ratio (PR) obtained for this variation of the solar system is 81.15%. This value indicates that the system performs well and efficiently converts sunlight into electrical energy. The high PR also suggests that this system is reliable and feasible for implementation on a larger scale, considering both economic factors and the availability of natural resources. Overall, the simulation results show that the selected solar system configuration has great potential in generating renewable, environmentally friendly, and sustainable energy.

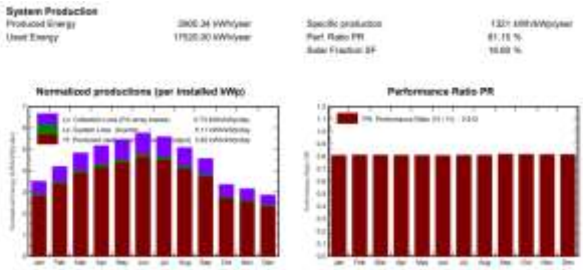

Figure 3. Graph of Simulation Results for the PLTS Varias 1 System

Variasi B

The second simulation involves a variation in the design of the photovoltaic power system (PLTS) using monocrystalline solar panels with a capacity of 335 Wp. A total of 6 panels are used, configured into 1 string with 6 panels connected in series. Figure 4 shows that the total energy produced by the on-grid PLTS system is predicted to be 2.71 MWh per year. The highest energy production occurs in June, reaching 470 kWh, while the lowest energy production is recorded in December at 270 kWh. The Performance Ratio (PR) achieved by this variation of the PLTS system is 82.99%, which is considered to meet the feasibility requirements for implementing the system, indicating that the system performs efficiently. This simulation provides valuable insights into the efficiency and output of a monocrystalline solar panel-based system, offering a practical view of its performance across different months of the year. The data demonstrates that seasonal variations play a significant role in energy production, with peak output observed during summer months when sunlight intensity is at its highest. On the other hand, lower production in December suggests that systems relying on solar energy are subject to fluctuations based on seasonal factors, which can be influenced by elements like weather and sunlight duration. The calculated PR of 82.99% signifies a well-functioning system, meeting industry standards for solar power systems in terms of performance. It ensures that the system is operating efficiently, with minimal losses in the conversion of solar energy to electrical energy. This result suggests that such a system would be viable for practical applications, offering a reliable source of renewable energy with consistent performance. Furthermore, the study highlights the importance of understanding energy output throughout the year for better planning and optimization of solar energy systems.

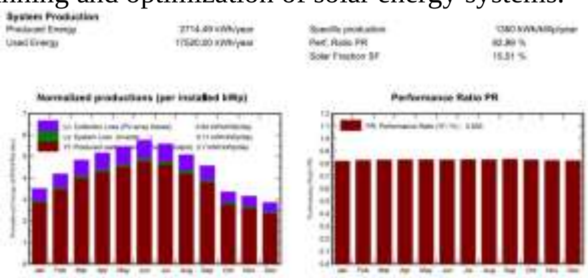

Figure 4. Graph of Simulation Results for the PLTS Varias 1 System

4. Conclusion

The simulation of the rooftop PV solar power system for the PT. PIM training room demonstrates that such systems can be technically and economically viable for meeting energy demands. The performance ratio (PR) of 81.15% and 82.99% for the two design variations indicates efficient energy conversion and system reliability. Additionally, the high energy output during peak months, such as June, further emphasizes the potential for solar energy systems in Indonesia. Despite lower energy production in December, the system's overall performance meets industry standards, making it a promising solution for renewable energy integration in both educational and commercial sectors. This study provides valuable insights for further implementation of rooftop solar systems, aligning with the Indonesian government's renewable energy targets.

REFERENCES

1. Ardianto K, Windarta J, Wardaya AY. Evaluation Analysis of Small Capacity Rooftop Solar Electricity (PLTS) Development Plans at PT Pertamina Gas. J Locus Penelit Dan Pengabdi. 2024;3(7):558–73.
2. Afif F, Martin A. Tinjauan Potensi dan Kebijakan Energi Surya di Indonesia. Vol. 6, Jurnal Engine: Energi, Manufaktur, dan Material. 2022. p. 43.
3. Windarta J, Denis D, Firmansyah AZ, Avinda AI, Kusuma IA. Technical Study of 1.2 KWP Solar Plant on Tanbihul Ghofilin Islamic Boarding School Banjarnegara. Iop Conf Ser Earth Environ Sci. 2022;969(1):12031.
4. Samsurizal S, Pasra N, Adewijaya SR. Design and Simulation of Solar Power Generation on Rooftops Towards Clean Technology. Eksergi. 2023;19(2):55.
5. DAMIRI DJ, LAMANIA RRL. Design and Simulation of on-Grid Rooftop Solar Power Plant (Rooftop PV) System on Office Buildings With a PLN Grid System. Elkomika J Tek Energi Elektr Tek Telekomun Tek Elektron. 2023;11(1):231.
6. KARADAN D, BİRİŞÇİ T. Solar Power Plants in Terms of Landscape Protection and Repair: Activities of Local Governments in İzmir. Ege Üniversitesi Ziraat Fakültesi Derg. 2024;60(4):595–610.
7. Akpolat AN, Dursun E, Kuzucuoğlu AE, Yang Y, Blaabjerg F, Baba AF. Performance Analysis of a Grid-Connected Rooftop Solar Photovoltaic System. Electronics. 2019;8(8):905.
8. Hisamatsu E. Challenges of Applying on-Site Photovoltaic System at Environmetally Friendly Buildings in Indonesia. J Appl Sci. 2021;3(2):26–36.
9. Fitrianingtyas P, Asy'ari MK, Elyawati N, Musyafa A. Reliability, Maintainability and Availability Analysis of Solar Power Plant in Pantai Baru Using Voltage Measurement Data. E3s Web Conf. 2024;479:5001.
10. Dahal S, Jha AK, Bhattarai N, Panjiyar AK. Determining the Hosting Capacity of Solar Photovoltaic in a Radial Distribution Network Using an Analytical Approach. J Adv Coll Eng Manag. 2019;5:15–25.
11. Abdalla OH, Mostafa AAA. Technical Requirements for Connecting Solar Power Plants to Electricity Networks. 2019;
12. Abeywickrama M, Sridarran P, Gowsiga M, Dilogini RAA. Strategies to Enhance the Applicability of Grid Power Solar Net Metering Concept in Sri Lanka. 2022;756–68.
13. Elmnifi M, Mhmood AH, Saieed ANA, Alturaihi MH, Ayed SK, Majdi HS. A Technical and Economic Feasibility Study for on-Grid Solar PV in Libya. Math Model Eng Probl. 2024;11(1):91–7.
14. Masrur H. Techno-Economic-Environmental Impact of Derating Factors on the Optimally Tilted PV System. 2020;
15. Saad E, Helmy S, Elkoteshy Y, Abou-Zayed U. Modelling of Grid-Following Current-Controlled VSC. J Phys Conf Ser. 2023;2616(1):12037.
16. Loutan C, Klauer P, Chowdhury S, Hall SG, Morjaria M, Chadliev V, et al. Demonstration of Essential Reliability Services by a 300-Mw Solar Photovoltaic Power Plant. 2017;
17. Rahmansyah A, Hiendro A, Khwee KH. Study of the Evaluation of 10 KWP on- Grid Solar Power System at PLTD Siantan. Telectrical. 2024;1(3):319.
18. Abanda FH, Manjia MB, Enongene KE, Tah JHM, Pettang C. A Feasibility Study of a Residential Photovoltaic System in Cameroon. Sustain Energy Technol Assessments. 2016;17:38–49.
19. Budiyanto B, Fadliondi F. The Improvement of Solar Cell Output Power Using Cooling and Reflection From Mirror. Int J Power Electron Drive Syst. 2017;8(3):1320.
20. Imu NJ, Ezeamama A, Matemilola S. Assessment of Energy and Emissions Saving Impact of Solar PV Modules: A Case Study of Bangladesh. Int J Build Pathol Adapt. 2021;40(4):608–21.
21. Nurhaida, Susanti I, Puspitasari DU. A Comparative Analysis of the Influence of Temperature and Wind Speed on the Efficiency of 100 WP Solar Panels of Monocrystalline and Polycrystalline Types at Sriwijaya State

Polytechnic. Int J Res Vocat Stud. 2023;3(3):63–73.
22. Özer T, Oğuz Y, Çimen H. Energy Flow Control With Using Arduino Microcontroller in Off-Grid Hybrid Power Generation System Including Different Solar Panels and Fuel Cell. Meas Control. 2017;50(9–10):186–98.
23. Taşçıoğlu A, Taşkın O, Vardar A. A Power Case Study for Monocrystalline and Polycrystalline Solar Panels in Bursa City, Turkey. Int J Photoenergy. 2016;2016:1–7.
24. Nerubatskyi V, Плахтій O, Hordiienko D, Khoruzhevskyi H. Study of the Energy Parameters of the System "Solar Panels – Solar Inverter – Electric Network." Iop Conf Ser Earth Environ Sci. 2023;1254(1):12092.
25. Pavlović T, Milosavljević D, Radonjić I, Pantić L, Radivojević A. Application of Solar Cells Made of Different Materials in 1 Mw Pv Solar Plants in Banja Luka. Contemp Mater. 2011;2(2):155–63.
26. Kesler S, Kıvrak S, Gurleyen H, Dinçer F, Yılmaz Ş, Özçalık HR. A Low Cost Shading Analyzer and Site Evaluator Design to Determine Solar Power System Installation Area. Int J Photoenergy. 2015;2015:1–9.
27. Choi Y, Suh J, Kim S-M. GIS-Based Solar Radiation Mapping, Site Evaluation, and Potential Assessment: A Review. Appl Sci. 2019;9(9):1960.
28. Dominguez A, Kleissl J, Luvall JC. Effects of Solar Photovoltaic Panels on Roof Heat Transfer. Sol Energy. 2011;85(9):2244–55.
29. Awoyinka TD, David TW, Somefun T, Somefun C, Orovwode H. I-v Response Test of 60–150 W Mono-Crystalline Solar Panel. Front Energy Res. 2024;12.
30. Wilson G, Al-Jassim M, Metzger WK, Glunz SW, Verlinden P, Xiong G, et al. The 2020 Photovoltaic Technologies Roadmap. J Phys D Appl Phys. 2020;53(49):493001.
31. Nisa AR, Riyanti A, Ramadhani GTA, Rahmadaniar I, Ghani MRA, Tambunan MRH, et al. Sound Record "Selamat Datang Di Curug Cikoneng" Dan Lampu Otomatis Berbasis Motion Gesture. Elektrika. 2024;16(1):45.
32. Pratama A, Yuniahastuti IT, Susilo D. Pembersih Panel Surya 50W Menggunakan Wiper Di Laboratorium Terpadu UNIPMA. Jasiek (Jurnal Apl Sains Inf Elektron Dan Komputer). 2023;5(2):147–56.
33. Ardiansyah D. Perbandingan Model Prediksi Radiasi Matahari Berbasis Mesin Pembelajaran Pada Stasiun Meteorologi Fatmawati Soekarno Bengkulu. Megasains. 2023;14(1).
34. Indra I, Musaruddin M, Mokui HT. Analisis Klasifikasi Potensi Radiasi Matahari Hasil Data Satelit Meteonorm Di Sulawesi Tenggara Sebagai Sumber Pembangkit Listrik Tenaga Surya. JMR. 2024;6(1):88.
35. Majdi HS, Younis A, Abdullah AR, Elmnifi M, Habeeb LJ. A Comparative Analysis of the Efficiency of Monocrystalline and Polycrystalline Photovoltaic Modules: CTI-80 and YHM-205-27P. Int J Des Nat Ecodynamics. 2023;18(4):775–82.
36. Siregar Y, Tial MKS, Purba YFS, Suherman S, Soeharwinto S. Design of Solar Cell Using Mirror, Cooling, Double Axis, and Solar Tracking. Indones J Electr Eng Comput Sci. 2022;28(3):1297.
37. Yağcı M. Economical and Technical Challenges of a Large Scale Solar Plant. Int J Intell Syst Appl Eng. 2017;2(5):70–5.
38. Medford AJ, Lilliedal MR, Jørgensen M, Aarø D, Pakalski H, Fyenbo J, et al. Grid-Connected Polymer Solar Panels: Initial Considerations of Cost, Lifetime, and Practicality. Opt Express. 2010;18(S3):A272.
39. Putri NA, Rahman A, Suryawan IWK. Exploring the Potential of Solar Energy in Mosque Buildings: A Case Study of Dumai Islamic Centre Mosque in Riau Province, Indonesia. J Presipitasi Media Komun Dan Pengemb Tek Lingkung. 2023;20(3):621–32.
40. Triyanto A, Rozak OA, Aditya A. Calculation Array Solar Panel Capacity of 50 kWP Pamulang University South Tangerang. Protek J Ilm Tek Elektro. 2023;10(3):193–8.
41. Akram I, Awais M, Bashir A, Khan RAJ, Iqbal J. Design and Analysis of 300MW Solar Configuration and Its Comparison With Quaid-E-Azam Solar Park. 2018;1–7.
42. Ariawan IGAJ, Giriantari IAD, Sukerayasa IW. Perancangan PLTS Atap Di Gedung Graha Sewaka Dharma. J Spektrum. 2021;8(3):9.
43. Sathiracheewin S, Sripadungtham P, Kamuang S. Performance Analysis of Grid-Connected PV Rooftop, at Sakon Nakhon Province, Thailand. Adv Sci Technol Eng Syst J. 2020;5(4):816–23.