

Design Simulation of a Rooftop Solar Power System Using PVSyst for Eco-Friendly Energy Supply at Hospital

I Made Sajayasa^{1*}, I Gede Suputra Widharma², I Gde Nyoman Sangka³,
I Nyoman Mudiana⁴, I Nengah Sunaya⁵, I Ketut Suryawan⁶
Politeknik Negeri Bali

Corresponding Author: I Made Sajayasa madesajayasa@pnb.ac.id

ARTICLE INFO

Keywords: Solar Photovoltaic System, PVSyst Simulation, Renewable Energy, Eco-Friendly, Hospital Power Distribution

Received: 2, September

Revised: 23, September

Accepted: 24, October

©2025 Sajayasa, Widharma, Sangka, Mudiana, Sunaya, Suryawan: This is an open-access article distributed under the terms of the [Creative Commons Attribution 4.0 International](https://creativecommons.org/licenses/by/4.0/).



ABSTRACT

Solar energy is one of the most promising renewable energy sources and has the highest potential among other alternatives to address global energy challenges while maintaining environmental sustainability. This study presents the design of a rooftop photovoltaic (PV) system at the Hospital Distribution Substation using the PVSyst software. The proposed system aims to supply electrical energy for existing substation equipment, including 20 KV cubicles, RTU, LED lighting, and power outlets. The design employs a 5.339 kWp PV array covering an area of 26 m², integrated with a Generic 3 kW Hybrid Solar Inverter to ensure stable and efficient power conversion. Simulation results using PVSyst indicate that the proposed system can generate an average of 18.398 kWh per day, demonstrating adequate energy yield and reliability under local solar irradiance conditions. The findings emphasize the potential of small-scale hybrid PV systems to enhance energy independence, operational reliability, and carbon reduction in public service institutions such as hospitals.

INTRODUCTION

Electrical energy is a primary need to support daily activities, particularly in the healthcare sector, which requires a stable and continuous power supply.[1] As electricity demand increases, the use of renewable energy sources such as solar energy is becoming an environmentally friendly and efficient alternative solution. Solar panels can convert solar energy into electrical energy, thereby helping reduce dependence on fossil fuels and supporting the reduction of carbon emissions.

In an electricity distribution system, distribution substations play a crucial role in delivering electrical energy to consumers. One of the main devices supporting distribution substation operations is the Remote Terminal Unit (RTU) and the Cubicle. The RTU functions to automatically monitor and control the electricity network.[3] While the Cubicle functions as a divider, breaker, connector, controller, and safety device for the electricity distribution system.[4] The electricity supply for the RTU and Cubicle generally comes from the PLN electricity network. However, under certain conditions, such as power outages or network disruptions, the PLN supply becomes unstable, which can affect the performance of the RTU and Cubicle in accurately monitoring the electricity system.

Nyitdah Hospital, as a healthcare facility operating 24/7, urgently requires a reliable electricity supply to support the operation of medical equipment and other supporting infrastructure. Power outages to devices such as the RTU (Residential Unit) and cubicles have the potential to disrupt healthcare services, impacting patient safety. Therefore, the use of solar panels as the primary power source is expected to be an alternative solution to maintain a continuous power supply to these devices.

Based on the aforementioned issues, the author designed a solar panel system as the primary power source for the RTU and cubicles at the Nyitdah Hospital distribution substation. If the primary power source (solar panels) for the RTU and cubicles fails, the backup power will be drawn from the PLN grid. The results of this research are expected to improve the reliability of the electrical system, reduce dependence on PLN electricity supply, and support the use of renewable energy in sustainable healthcare services.

LITERATURE REVIEW

Solar Panel System

The use of renewable energy, particularly solar power through the installation of solar panels, has become a primary focus of various research and implementations in Indonesia. Solar panels are semiconductor devices that directly convert sunlight into electrical energy. They consist of photovoltaic cells that generate electricity when exposed to sunlight. The average daily sunlight intensity in Indonesia ranges from 4.5 to 4.8 kWh/m²/day, demonstrating the significant potential for developing solar energy as a renewable energy source.

The integration of solar panels as the primary power source in Remote Terminal Units (RTUs) and cubicles in distribution substations, as planned for Nyitdah Hospital, offers numerous benefits. In addition to improving the reliability of electricity supply, this step also contributes to reducing greenhouse

gas emissions and supporting sustainable development. The use of renewable energy in electricity distribution systems not only reduces dependence on fossil fuels but also supports environmental conservation and energy efficiency efforts.

Globally, the use of renewable energy has become a key agenda for achieving energy security and environmental sustainability. Indonesia, with its wealth of natural resources, has great potential to develop various types of renewable energy, including solar power, to meet national energy needs and support environmentally friendly economic growth.



Figure 1. Solar panel system

Solar panels, also known as photovoltaic cells, are devices that convert sunlight energy into electrical energy through the photovoltaic effect. These devices consist of semiconductor materials that, when exposed to sunlight, produce direct current (DC). The resulting electrical energy can be used immediately or stored for future electricity needs. According to research published in *Teknika STTKD: Jurnal Teknik, Elektronik, Engine*, solar panels can convert solar energy into direct current (DC) electricity.

The use of solar panels as an alternative energy source is highly relevant, especially in areas not yet covered by conventional electricity grids. Furthermore, the use of solar panels contributes to reducing greenhouse gas emissions and supporting environmental sustainability. A study published in the *Jurnal Emitter* states that solar panels can be utilized by communities requiring electrical energy, especially in areas not yet connected to the state electricity company (PLN).

Array Area (PV Area) calculation formula:

$$PV\ Area = \frac{EL}{Gav \times TCF \times \eta_{PV} \times \eta_{Out}} (m^2) \quad (1)$$

with:

- EL : Energy generated (kWh/day)
- PV Area : Solar panel surface area (m²)
- Gav : Daily sunlight intensity (W/m²/day)
- TCF : Temperature coefficient factor (%)
- η_{PV} : Solar panel efficiency (%)
- η_{Out} : Output efficiency (%) is usually 75–85%

Calculation of power generated by the solar power plant:

$$P \text{ Wattpeak} = \text{PV Area} \times \text{PSI} \times \eta_{\text{PV}} \quad (2)$$

with:

- PV Area : Solar panel surface area (m²)
- PSI : Peak solar insolation is 1,000 W/m²
- η_{PV} : Solar panel efficiency (%)

Calculation of the number of solar panels used:

$$\text{Solar panel} = \frac{P \text{ wattpeak}}{PMPP} \quad (3)$$

with:

- P Wattpeak : Power generated (Wp)
- PMPP : Maximum power output of the solar panel (Watt)

Solar Panel Direction and Tilt Angle: In the discussion of shadow analysis, we briefly explained the changing position of the sun relative to the observer's position on Earth. Besides being related to the shadow effect, this also affects the optimization of sunlight absorption for conversion into electrical energy. Two parameters that must be considered are as follows:

The tilt angle significantly affects the amount of solar radiation received by the PV module surface, which is at a fixed angle. To obtain maximum power throughout the year, the tilt angle of the PV module should be adjusted to the latitude of the installation location. The control system in a solar power plant plays a crucial role in maintaining efficient and reliable power generation. This control can be done manually, by always pointing the panel towards the sun, or automatically using electronic circuits, especially in remote areas. However, from a practical and maintenance standpoint, the most efficient and economical method is to install the panels at a fixed position and at a specific angle. The direction and tilt angle must be adjusted to the geographic location, so that the PV panels face the equator and receive optimal sunlight. In equatorial regions (latitude 0°), horizontal panel installation (0° inclination) can produce maximum energy.

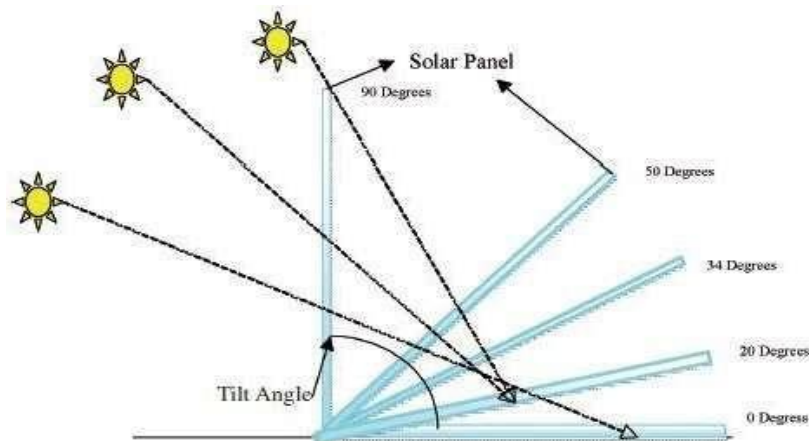


Figure 2. Comparative performance solar panel angle

In the design of a Solar Power Plant (PLTS), the azimuth angle refers to the direction the solar module faces towards north or south. To avoid disturbing shadows, solar modules in PLTS locations south of the equator should be directed north (azimuth 0°). Conversely, if the PLTS location is north of the equator, the module should face south (azimuth 180°). If the module's orientation does not comply with these provisions, for example, it still faces north even though it is located north of the equator, losses will occur due to a suboptimal inclination angle. The following figure clarifies how the azimuth angle is considered in solar panel placement.

Designing

The PVsyst application is an application specifically designed to assist in designing, simulating, and analyzing photovoltaic (PV) solar power systems. This application is used to determine the number of solar panels, the type of inverter, and to calculate the potential energy that can be generated based on location and weather conditions.



Figure 3. Distribution in the Hospital

Low-voltage surge protection equipment or Surge Protection Device (SPD) functions as a safety device for electrical systems by limiting transient voltages that arise due to voltage surges, such as those caused by lightning or switching disturbances. SPDs work by diverting or limiting the surge current to the grounding system, thereby preventing damage to electrical and electronic equipment connected to the system, as well as maintaining the reliability and safety of the electrical installation as a whole.

A Remote Terminal Unit (RTU) is a critical device in a Supervisory Control and Data Acquisition (SCADA) system, serving as an interface between field equipment and the Master Station control center. The RTU collects operational data from various sensors and field equipment, such as voltage, current, and equipment status, and then transmits this information to the Master Station for remote monitoring and control. Furthermore, the RTU receives commands from the Master Station to operate specific equipment, such as opening or closing circuit breakers, enabling efficient, real-time control of the electric power system.

In the context of distribution substations, RTUs are deployed to monitor and control substation activity, ensuring the continuity and reliability of electrical energy distribution to consumers. With an RTU, operators can easily monitor network conditions and take corrective actions remotely through the control center, without the need for a direct presence at the substation.

RTU development continues in line with technological advances. One innovation is the development of Internet Protocol (IP)-based RTUs, which enable faster communication and integration with various modern systems. This type of RTU consists of an embedded controller, microcontroller, and input/output modules designed to collect data and send it to the Master Station via an IP-based network. This increases flexibility and efficiency in managing the electric power distribution system. Integrating Solar Panels with Electricity Distribution Systems.

Benefits of Solar Panel Integration

Integrating solar panels with distribution substations offers several significant advantages, including energy efficiency, environmental sustainability, and economics. One of the primary benefits of implementing this system is increased reliability of electricity supply, especially for critical facilities such as hospitals that require a stable and continuous source of electricity. By using solar panels as the primary or backup power supply, the risk of power outages can be reduced, allowing devices such as Remote Terminal Units (RTUs) and cubicles in distribution substations to operate optimally.

Furthermore, the use of solar panels also contributes to long-term operational cost reductions. According to research published by the Ujung Pandang State Polytechnic, utilizing renewable energy in electricity distribution systems can reduce electricity consumption from the main grid by up to 30%, thereby lowering electricity bills and increasing power efficiency.

The design of the solar panel system for the main power supply to the Remote Terminal Unit (RTU) and cubicles at the Nyitdah Hospital distribution substation was carried out in the following stages:

- a. Energy Requirements Analysis
- b. Selection of Main Components
- c. One-line Diagram

Solar panel performance is influenced by various factors that can affect the efficiency and energy output produced. The following are some of the main factors affecting solar panel performance:

- a) Sunlight Intensity: The higher the intensity of sunlight received by the solar panel, the more electrical energy it can produce. Optimal light intensity allows the solar panel to operate at its maximum capacity.
- b) Temperature Increase: Temperature increases significantly affect the output voltage of solar panels. Solar panels operate optimally at a standard temperature of 25°C. Temperature increases above this value can cause a decrease in voltage and panel efficiency. Every 1°C increase in temperature above 25°C can significantly reduce solar panel efficiency.

- c) Wind Speed Factor: Wind speed around solar panels can help cool the panel surface, maintain low operating temperatures, and increase efficiency. Sufficient wind can reduce overheating in the panels, thus maintaining optimal panel performance.
- d) Dirt on Solar Panels: Dust, dirt, and pollutants that accumulate on the surface of solar panels can block the absorption of sunlight, reducing efficiency and energy output. Losses resulting from dirt and dust vary for each solar panel. The amount of loss due to dirt and dust is 5%.
- e) Solar Panel Tilt: The direction the solar panels face, and their installation angle, also affect the panel output. If they are not positioned at the optimal angle and direction, the panels will not produce the measurable output for that location. The most optimal solar panel orientation is towards the equator. The optimal solar panel angle ranges from 10° to 20° depending on the solar panel installation location.

METHODOLOGY

There are three methods in this research to solving the problem in designing a rooftop simulation based on PVSyst software.

1. Literature Study Method

In writing this thesis, the author studied references from various sources such as books, journals, articles related to the research that the author is researching. The various references used by the author to create this final assignment and other references related to the research.

2. Discussion or Interview Method

Collecting data by conducting direct discussions with expert

3. Observation Method

4. The author obtains data by coming directly to the field to observe and record the data needed to complete the thesis.

The research method used in this study is a quantitative research method because this method contains measurements, analysis of numerical data related to the performance of the solar panel system in supplying power to the Remote Terminal Unit (RTU) and cubicles at the Nyitdah Hospital distribution substation.

This study implements software to design rooftop solar panel system with eco-friendly technology. The system consists of 20 kV cubicles, RTU, LED lighting, and power outlets. Data sources consist of primary and secondary data. Primary data is data collected directly through experiments and surveys for quantitative research. Secondary data, on the other hand, is pre-existing data collected indirectly. Primary data is obtained directly through measurements, observations, interviews, and other means. In this study, primary data from sunlight intensity measurements using the Pvsyst application.

Secondary data is obtained indirectly in the form of reports, profiles, manuals, or literature. In this study, secondary data consists of:

- a. RTU and Cubicle Nameplates
- b. RTU and Cubicle Data

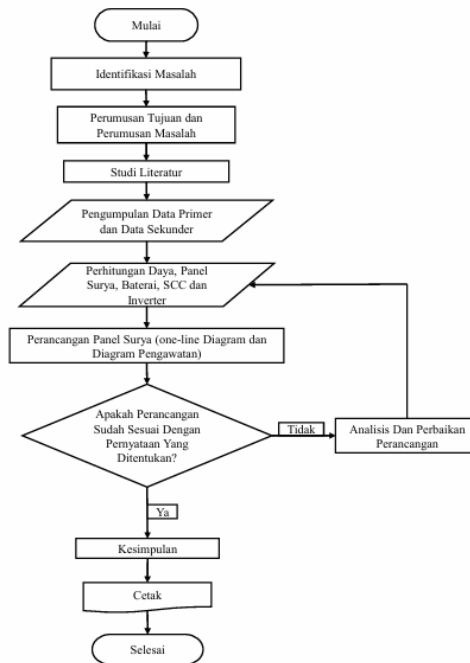


Figure 4. Research Flowchart

Data obtained through direct measurements and the assistance of existing data. Data collection will assist in the data analysis process.

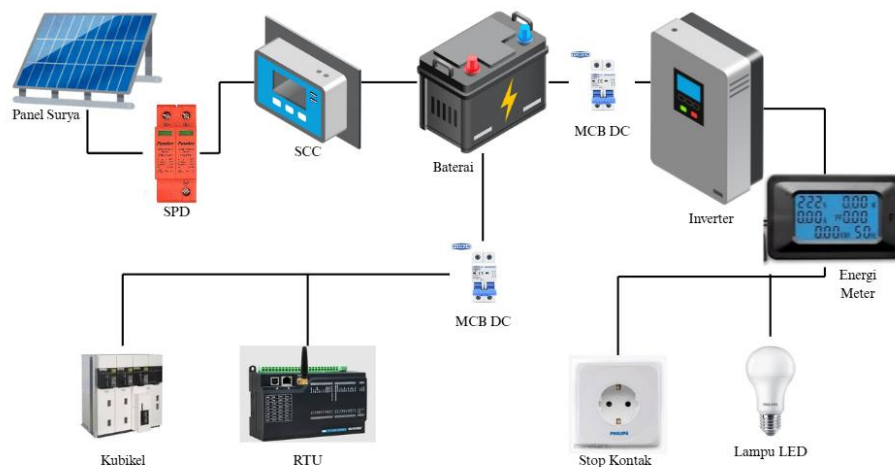


Figure 5. Single Line Diagram in Hospital

Components of a 20kV TM Cubicle (20kV Medium Voltage), consist of:

1. RMU (Ring Main Unit, a part of the cubicle that uses SF6 gas for insulation and circuit breaker, which functions as a circuit breaker and connector and protects the power distribution system). The RMU is defined as:
 - a. PMT (functions as a circuit breaker and connects the electrical flow)
 - b. PMS (separator), functions as an electrical circuit separator under no-load conditions
2. Busbar (functions to collect and distribute electrical energy at a specific voltage)
3. VT (functions to reduce the voltage from high to low voltage)

4. Fuse (functions as a control circuit safety)
5. Cable (functions as a connector and channel for electrical current)
6. Indicator light (functions to indicate cubicle operation)
RTU (Remote Terminal Unit) Components, consist of:
 1. Central Processing Unit (CPU)
 2. Memory
 3. Input/Output (I/O) Module
 4. Power Supply Module
 5. Telemetry (TM) The signal coming from the CT and VT is connected directly to the analog input module via a transducer.
 6. Telesignals (TS) coming from GI equipment (PMT, PMS, ES, transformers, etc.) are connected directly to the digital input module.
 7. Digital telecontrol (TC) output from the analog output module is connected to generating equipment or substations (PMT, PMS, ES, etc.) equipped with drive motors to be controlled from the control center.
 8. Analog telecontrol (TC) output from the analog output module is connected to the Generating Unit, where the load can be adjusted.

RESEARCH RESULT

Energy Consumption at the Nyitdah Hospital Distribution Substation

Based on data obtained from observations and load calculations, the daily electricity consumption at the Nyitdah Hospital Distribution Substation, including loads such as RTUs, RMU cubicles, lighting, and electrical outlets, averages approximately 18,398 kWh.

Table 1. Data in Hospital Distribution Substation

No	Beban Listrik (DC)	Merk	Jumlah	Daya Beban (W)	Total Daya (W)	Jam Operasi (h / day)	Energi Beban Harian (kWh)
1	RTU	SCHNEIDER	1	9,6	9,6	24	230,4
2	RMU Kubikel IN (Input dari P. Nyitdah)	ABB	1	144	144	24	3456
3	RMU Kubikel OUT (Output ke P. Pandak)	ABB	1	144	144	24	3456
4	RMU Kubikel Pelanggan (supply ke jaringan instalasi pelanggan)	ABB	1	144	144	24	3456
No	Beban Listrik (AC)	Merk	Jumlah	Daya Beban (W)	Total Daya (W)	Jam Operasi (h / day)	Energi Beban Harian (kWh)
5	Lampu LED	Philips	2	10	20	6	120
6	Stop Kontak	Schneider	1	1300	1300	6	7800
Total					1742		18398

Table 2. Data in Global Horizontal Irradiation a Year

Month	<i>Global Horizontal Irradiation (W/m²/day)</i>
January	4,307
February	4,099
March	4,439
April	4,260
May	4,044

Month	Global Horizontal Irradiation (W/m ² /day)
June	3,700
July	3,670
August	3,638
September	4,012
October	4,392
November	4,340
December	4,307
Average	4,070

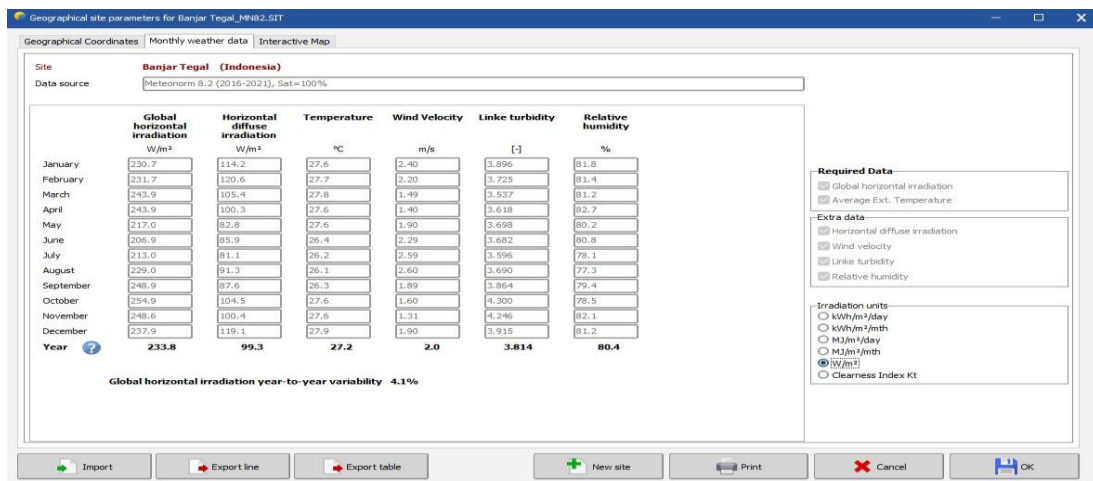


Figure 5. PVsyst to Measure Solar Irradiation and Temperature

Solar Panel Tilt Using the PVsyst App if azimuth is 0° (the equator is facing north) with tilt 10°.

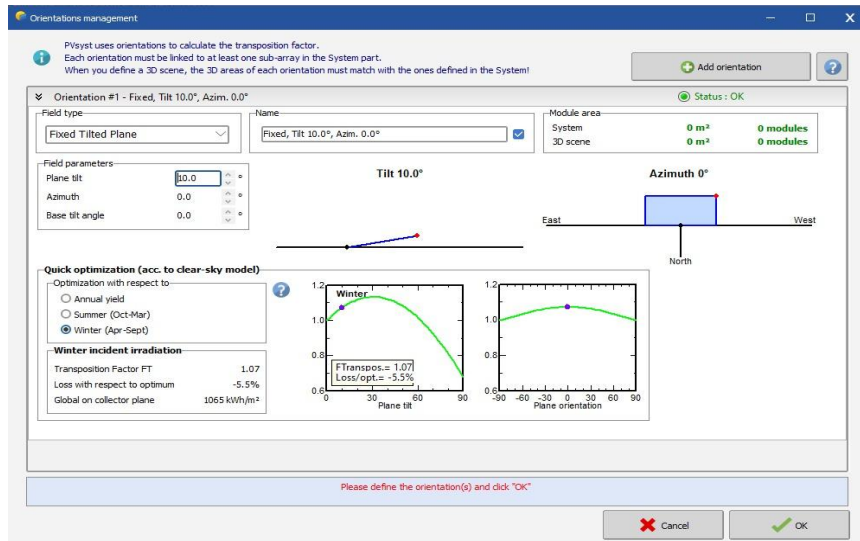


Figure 6. Azimuth 0°, tilt 10°

At an azimuth of 0°, a tilt of 10°, the resulting solar radiation is 1065 kWh/m².

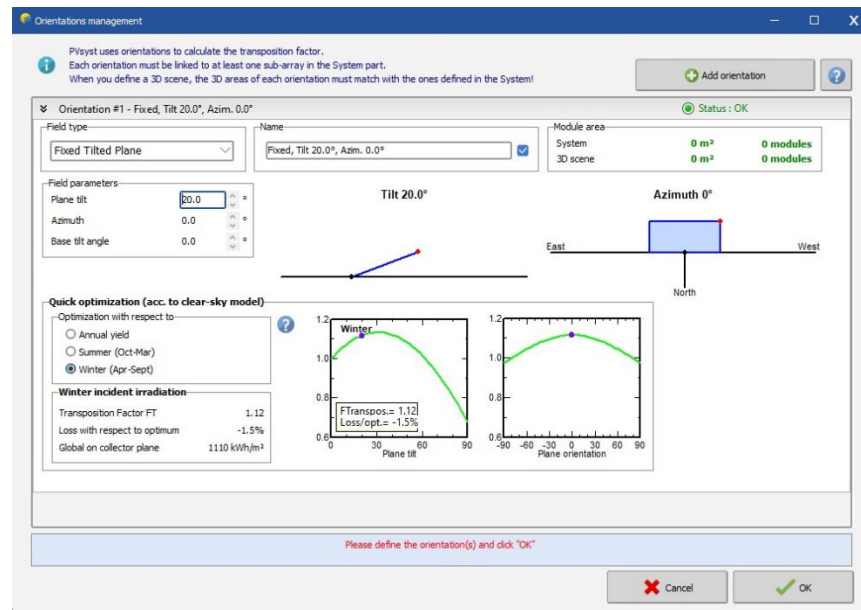


Figure 6. Azimuth 0°, tilt 20°

At an azimuth of 0°, a tilt of 20°, the resulting solar radiation is 1110 kWh/m².

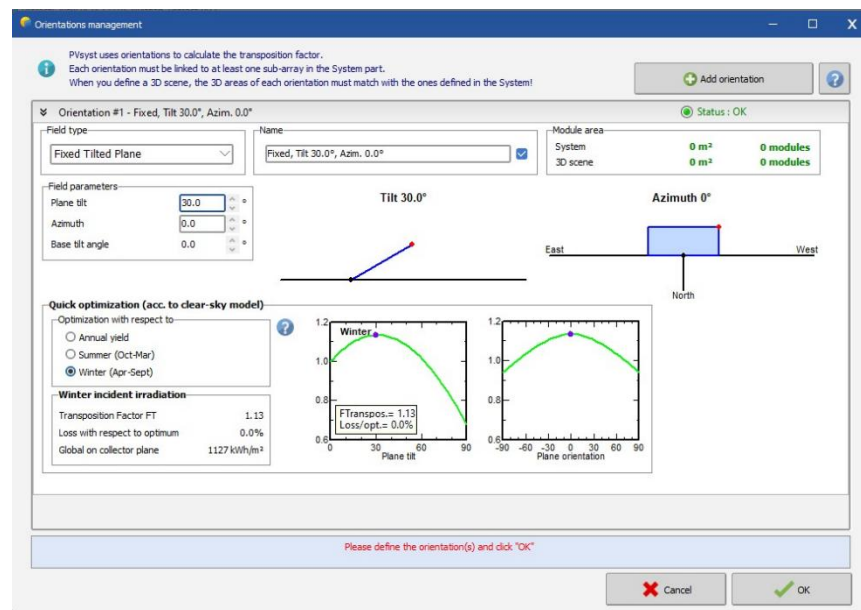


Figure 7. Azimuth 0°, tilt 30°

At an azimuth of 0°, a tilt of 20°, the resulting solar radiation is 1127 kWh/m².

DISCUSSION

This system is designed using solar panels as the primary source of environmentally friendly and efficient electrical energy. The solar panels capture sunlight and convert it into direct current (DC) electricity. This DC electricity is then channeled to a Surge Protective Device (SPD) to protect the solar panels and

related equipment from sudden voltage and current surges, which can be caused by lightning or power grid disruptions. It then flows to the Solar Charge Controller (SCC), which plays a crucial role in optimally regulating the battery charging process. The SCC also protects the battery from overcharging or overdischarging, thus extending battery life and increasing system reliability.

The electricity generated by the panels is then stored in batteries, which serve as a backup energy source when sunlight is unavailable, such as at night or on cloudy days. This stored power is used to supply the primary loads, namely the RMU (Ring Main Unit) Cubicle and RTU (Remote Terminal Unit) devices, which play a crucial role in the operation and monitoring of the distribution substation.

The DC electricity from the battery then flows into the inverter, a device that converts DC current to alternating current (AC) so it can be used by standard electrical equipment, such as lights and power outlets.

To ensure system safety, each component path is equipped with a Miniature Circuit Breaker (MCB). The MCB functions as a safety device against overcurrent or short circuits, minimizing the risk of damage to the equipment.

The processed AC electricity through the inverter is distributed to final equipment, such as lights and power outlets, which are used to support the operation of the Nyitdah Hospital Distribution Substation, including lighting, control devices, and monitoring. This system ensures the substation remains operational even if the main power supply is disrupted, ensuring the reliability and continuity of electricity distribution services.

CONCLUSSION AND RECOMMENDATION

Based on the design of the solar power plant at the Nyitdah Hospital distribution substation, the following conclusions can be drawn:

1. The solar power plant at the Nyitdah Hospital distribution substation is designed for 5339 Wp, with a required installation area of 26 m². The inverter used is a 3000 W Generic 3kW Hybrid Solar Inverter, and the solar panels used are VERTEX 500Wp, with 11 solar panel modules connected in parallel.
2. This design aims to supply the equipment in the Nyitdah Hospital distribution substation, as there is no DC supply from PLN. The existing equipment includes a 20kV cubicle (RMU), a Remote Terminal Unit (RTU), electrical outlets, and LED lights.

ADVANCED RESEARCH

After designing the solar power plant at the Nyitdah Hospital distribution substation, the author has the following suggestions utilizing batteries as electrical energy storage to store the power generated by the solar power plant system. This way, in the event of a power outage, the energy stored in the batteries can be used as a backup source.

ACKNOWLEDGMENT

This section we say thanks to our colleagues who provided suggestions for our paper: Electro Engineering Department in Politeknik Negeri Bali, foundation

of Cita Widya Suhita, Engineering in Ganesha Indonesia, South Hills and Communication Studies in UHN IGB Sugriwa Denpasar.

REFERENCES

- Arthadi, IP, MD PP, GFS, Dimas, DN, Widharma, IGS. (2017). Paket Program Aplikasi: Analysis and Mapping. Politeknik Negeri Bali.
- Bialevich, V.; Zachleder, V.; Bišová, K. (2022). The Effect of Variable Light Source and Light Intensity on the Growth of Three Algal Species. Cells
- IGS. Widharma, IN. Sunaya, IGN. Sangka, IP. Sutawinaya, IM. Sajayasa, IGK. Abasana, IGK. Sri Budarsa. (2025). Integrating Digital Technology in the Study of Rooftop Solar Panel Planning for Hospital by Using Software. AJNS 4 (2).
- Jatmiko, Hasyim Asy'ari, Mahir Purnama. (2011). Pemanfaatan Sel Surya dan LED untuk Perumahan. Seminar Nasional Teknologi Informasi & Komunikasi Terapan.
- Nurjaman, HB; Purnama, T. (2022). Pembangkit Listrik Tenaga Surya (PLTS) Sebagai Solusi Energi Terbarukan Rumah Tangga. Jurnal Edukasi Elektro, Vol. 06 (02).
- Rochadiani, TH; William, W.; Santoso, H; Natasya, Y; Ariqoh, UDN; Rahayu, RAS. (2022). Penerapan IoT Untuk Pemantauan Kualitas Air Kolam Peternak Ikan Di Kampung Kalipaten. Prosiding PKM-CSR, Vol. 5
- Sunaya, I Nengah, Sajayasa, I Made, Suputra Widharma, I Gede. (2017). Analisis Posisi Recloser Terhadap Keandalan Kinerja Penyulang Sempidi Berbasis Software ETAP Powerstation. Matrix 17 (3)
- Supriadi, M, Sunaya, IN, Widharma, IGS. (2019). Simulasi Pengendalian Kecepatan Putar Ceiling Fan Berbasis Arduino. Jurnal Vastuwidya 2 (2)
- Suputra Widharma, IG, Sunaya, IN. (2017). Analisis menentukan keandalan sistem distribusi dengan pemanfaatan aplikasi algoritma genetika berbasis pemrograman Matlab, Jurnal Matrix 5 (1)
- Suputra Widharma, IG, Sunaya, IN. (2017). Aplikasi Sistem Akuisisi Data Pada Sistem Fire Alarm Berbasis Sistem Mikrokontroler. Jurnal Logic 14 (2).
- Widharma, IGS, Lalu, FN. (2022). Buku Ajar Mikrokontroler dan Aplikasi.

Penerbit Wawasan Ilmu, Banyumas, Jawa Tengah.

Widharma, IGS, Sunaya, IN; Sajayasa, IM; IGN Sangka; Darminta, IK; Anggreni, AAMD. (2021). Effect of Heating Light on Lamps to the Behaviour of Tilapia Seedlings Sourced from Solar Panels. Proceedings iCAST-ES 2021, pages 1305-1311.