

## Integrating Digital Technology in the Study of Rooftop Solar Panel Planning for Hospital By Using Software

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### ARTICLE INFO

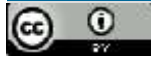
*Keywords:* Renewable Energy, PVSystem, Solar Panel, Rooftop, Digital Technology

*Received :* 11, April

*Revised :* 22, April

*Accepted:* 21, May

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### ABSTRACT

Electric energy is a vital need in daily life. Solar panel is a renewable energy technology that converts direct sunlight into electricity. Hospital has high electricity demand, especially in special rooms such as the emergency room, operating rooms, and inpatient rooms. This study aims to design a rooftop solar panel system for hospital. The design was carried out manually and simulated using integrating digital technology and simulator of software. This solar panel system uses capacity of 550 WP. Using inverter and batteries. The simulation results show that the energy produced by the solar panel reaches 16,375.05 kWh per year. The maximum efficiency of the solar panel will increase if the angle when the sun is shining is always at 90° and the angle of the sun's declination is about 74.99° and after knowing the value of  $\alpha$ , the angle of inclination of the solar panel can be found using the formula is about 15.01° facing northeast because the location is south of the equator. With these results, the off-grid solar panel design at hospital is considered feasible for implementation.

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## INTRODUCTION

Electric energy is a vital need in daily life. These days using fossil petroleum as energy supply is still the first priority. Renewable energy is from nature like sunlight, wind, water sustainable and environment friendly. The sun is a big and eternal energy supplier can be use everywhere. Solar panel is a renewable energy technology that converts direct sunlight into electricity. Solar cell has function as main component to generate electric energy in the solar panel system. Solar cell activity can be evaluated by checking its output power. The result is according to component materials, material resistance, temperature, and intensity of irradiance.

This research is focused to the hospital that has high electricity demand, especially in special rooms such as the emergency room, operating rooms, and inpatient rooms. There was many room that need electric energy constantly so that the electric consumption will be increase. However, hospital still using power sourced from government (PLN) as the main power, with gen-set as back up power. Hospital building has wide rooftop with pyramid dimension. Hospital that using kWh with power 20kVA and average consumption every month about five million rupiahs and often got trip caused by overload at the night suddenly. So that, must be look for best solution to using energy efficiently in operational like for AC, refrigerator, computer, lighting, exhaust and some other medical tools. Based on this problem, this study of planning to build the rooftop solar panel for hospital must be taken and focused to VIP room only. This study aims to design a rooftop solar panel system for hospital. The design was carried out manually and simulated using PVsyst software. The result of this research is give solution to afford overload in the same time with using the rooftop solar panel to VIP room. Beside that, using analysis comprehensive will be helpful to identified data and problems to answer the questions how to design rooftop solar panel for hospital by integrating digital technology.

The results of this study are expected to help overcome overload at the same time by focusing the supply of rooftop solar power plants with off-grid systems to inpatient rooms, especially in the VIP class. In addition, conducting a thorough technical analysis will help identify the advantages, difficulties, and practicality of implementing this system as a whole. Research to provide a useful contribution to the search for sustainable energy options in the health care industry in Bali.

## LITERATURE REVIEW

### *Solar Panel (PLTS) Design*

In research on the synthesis of micro-algae micro-samples using light sourced from solar panels (PLTS) technology, results were obtained on the design of PLTS so that it can supply lamps and aerator to supporting the synthesis in photosynthesis process in synthesis medium, as well as the results from the synthesis of micro-algae micro-samples. In this research, designing of solar panel using components like solar panel 550 WP, accumulator, SCC MPPX, MCB 6A, and Inverter. Solar cells receive solar radiation in one day varies greatly. This is because sunlight has a greater intensity when it is daytime

compared to the morning. To find out the capacity of the generated power, measurements are made of current (I) and voltage (V) on the arrangement of solar cells called modules. Solar modules, consisting of semiconductor materials, are devices that convert sunlight into electrical energy. The mechanism of this solar module is, semiconductors are made of semi-metals where there are electron-proton particles, if exposed to external energy it will result in the release of electrons, so that this will result in an electric current. Sunlight has electromagnetic waves or photo energy. When sunlight is absorbed by the solar module, the photon energy will produce kinetic energy and result in the release of electrons to the conduction band, thereby producing electrical energy. The selection of solar modules in this system affects the performance of the PLTS system.

In its application, Solar Power Plants (PLTS) consist of several types. These types of PLTS are distinguished by several supporting components in the operation of the PLTS system, including:

1. *Off-grid PLTS system*

Off-grid Solar Power Plant (PLTS) technology is a power generation technology that is suitable for remote or rural locations that do not have PLN network coverage. This self-sufficient system only relies on solar energy as the only source of electricity. This system is an optimal method for supplying electricity to remote areas by utilizing solar energy and converting it into electricity to meet the electricity needs of the community.

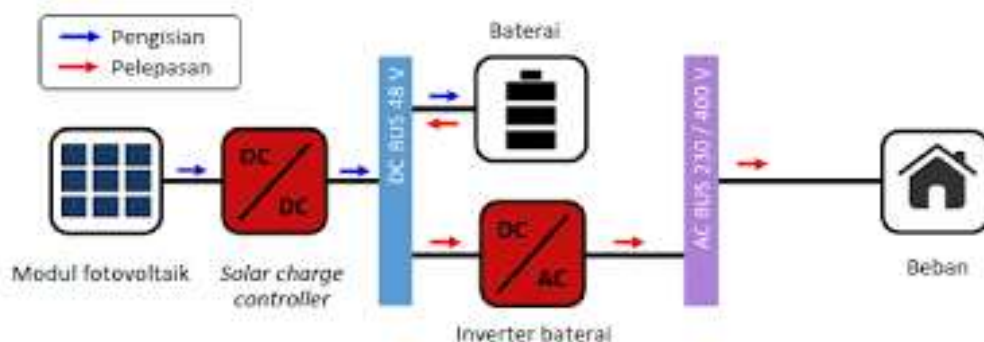


Figure 1. Off-Grid PLTS System

2. *On-grid PLTS system*

This technology utilizes photovoltaic panels to produce environmentally friendly and emission-free electricity. This technology will reduce residential electricity costs and offer other benefits to its owners. This system will remain connected to the PLN network by utilizing solar panel energy efficiently to maximize electricity production. In general, this system and the hybrid system have similarities, namely that they are effective in meeting the needs of offices and factories, where the application of this system is used for areas that are still covered by the PLN network. In addition, the implementation of the on-grid system does not require battery components, while the hybrid system requires batteries.

### 3. Hybrid PLTS System

This system refers to the use of two or more power generation systems that rely on different energy sources. Common production technologies used for hybrid vehicles include generators, PLTS, micro-hydro systems, and wind power. This system is an alternative power generation system that is very suitable for use in remote areas where access to electricity grid systems such as the PLN network is difficult. This hybrid system uses renewable energy as the main source, equipped with a generator or alternative source as a secondary energy source. As the electricity approaches common consumption centers, the electrical energy transmitted through the medium-voltage network is reduced from MV to low voltage (LV) by a step-down transformer at the distribution substation. The voltage is then stepped down to 230V and 380V, which is subsequently distributed to consumers via the low-voltage network through the distribution substation.

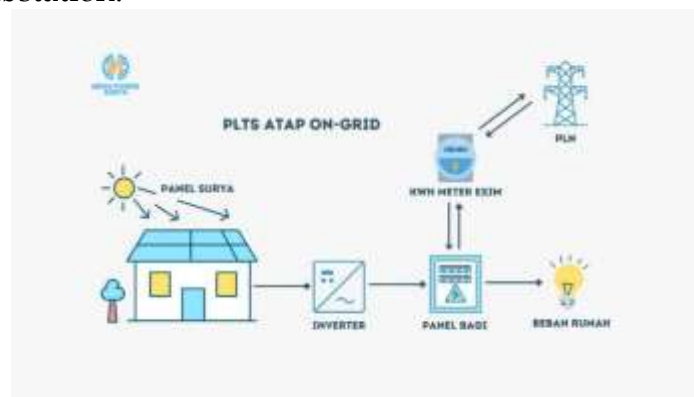


Figure 2. On-Grid PLTS System

Solar Charge Controller (SCC) is a tool in the PLTS system that aims to control the direct current that will be distributed to the load. SCC also aims to regulate if there is excess voltage from the solar panel and excess battery charging when it is full. This control is so that the battery can be used for a long time. Some of the functions of the SCC are:

- When the battery charging voltage reaches the maximum level, the controller will stop the flow of electric current to the battery to avoid overcharging, thereby extending the life of the battery.

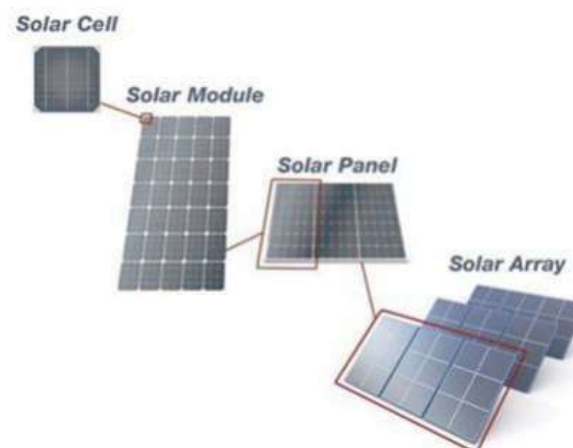


Figure 3. Solar Cell Process

- When the battery voltage is low, the controller operates to prevent the load from drawing electric current from the battery. When the battery voltage drops to about 10% of the remaining voltage, the controller cuts off the flow of current to the load. This serves to protect the battery and prevent damage to its cells.
- User text is bullet points. Some controllers are equipped with sophisticated digital meters that provide comprehensive indicators, allowing accurate detection of various conditions in the PLTS system.

An inverter is an electronic component that functions to convert DC voltage from a series of solar panel modules into AC voltage, either for direct use or for storing excess power in batteries. Like SCC, this device is also equipped with MPPT to optimize power utilization from a series of solar panel modules. "In special situations where there is available grid voltage, the inverter will be synchronized with the grid voltage and frequency to connect to the AC grid, convert the power that has been converted from the solar panels into AC power, and forward it to the grid. The inverter also functions as a safety measure to prevent a state of being active when the power grid goes out, and this is done to maintain grid stability and optimize power transfer from the solar panel series to the battery with the help of the MPPT algorithm.

Batteries are an integral component of the PLTS system that provides backup storage of electrical energy. "Batteries function to store electrical energy generated by solar panels as direct current or DC current. The energy stored in the battery serves as a reserve. Batteries function as a backup power source when the solar panels are unable to generate electricity, such as at night or during cloudy weather. In addition, it helps maintain a consistent voltage output to the system. The energy capacity stored in a battery is measured in ampere hours (Ah), which represents the maximum current that the battery can deliver over a period of one hour. However, in the discharge process, in order to extend the battery life, the battery should not be discharged to its maximum point, or at least not reduce the service life specified by the manufacturer. The discharge limit of a battery is generally only about 80% of the total usable capacity. Using battery power beyond this limit can affect battery life.

### *Integrating Digital Technology*

The efforts for integrating digital technology within derive from the mythical idea that people will communicate what is in the digital. In fact (and perhaps unfortunately) this is not the case. Digital authorities' belief in the 'myth of the digitalize: the idea is that, once clearly stated in the system and in technology, learning objectives and contents become objects that are easy to learn or teach. This utilitarian view of the digitalize is often adopted by people while planning lessons and it becomes one of the many existing myths. Myths play a major role in people's lives. They help organize experiences even when they don't portray real problems or solutions. People often take myths to support and legitimate actions and decisions. However, as engineers or educators we must question and deconstruct myths inherent.



Figure 4. Integrating Digital Technology

The myth of the digital technology as driving force for learning is well established in teaching. In fact, objectives, contents and teaching methods that constitute the digital documents are mere rectification of teaching practices that shouldn't be taken as the source of learning. Most myths about the integration of digital technology in the digital results from unproblematic and oversimplified visions of digital technology in system of its forms and application strategies and from the ed-problematical of its use at large in society. In contrast, students bring meanings and practices from outside system which are diverse, powerful and one step ahead of the systems' view of digital technology in society. Those two rather different mindsets the system-rules based perspective and the extra-system everyday context perspective stand in tension with each other and tend not to feed each other but to radicalize and get closed in their own boxes. A key element that should contribute to manage that tension is the way teachers use the system digital as a mediating artefact in their teaching practices. An open view of the role of digital technology in system requires engineers to address what happens in larger structures inside the social organization of the system. Engineers as digital developers would bring them to operate inside their professional community, seeing themselves as a transforming agent. The model of successful practising is the way a child learns to talk, a process that takes place without deliberate and organized practising, the goal set is very different. System as an artificial and inefficient process environment that society has been forced to invent because its informal environments fail in certain essential practising domains, such as writing or system formulas. The computer presence will enable us to so modify the learning environment outside the system that much if not all the knowledge systems presently try to practise. In a distribution substation, a distribution transformer is typically used to reduce the electrical voltage from the high-voltage distribution network to a usable voltage for the low-voltage distribution network (step-down transformer), for example, from 20kV to 380/230V. Meanwhile, transformers used to increase electrical voltage (step-up transformers) are only utilized in power generation plants to ensure that the voltage distributed through long transmission lines does not experience

significant voltage drops, meaning that it does not exceed the allowable voltage drop limit of 5% from the initial voltage.

### The PVsyst Software

PVsyst is a software for simulation, analysis, and optimization of photovoltaic (PV) systems. It is widely used in the solar energy industry by engineers, designers, and researchers to assess the performance and feasibility of solar power installations. Some of its main functions include the software provides tools to assess solar resources at a given location, taking into account factors such as geographic coordinates, meteorological data, and shading analysis. Users can design a PV system by selecting various components, including solar modules, inverters, trackers, and batteries. PVsyst helps in determining the optimal configuration and size of these components based on specific project requirements.

Project summary			
<b>Geographical Site</b> Banjar Dukuh Indonesia	<b>Situation</b> Latitude Longitude Altitude Time zone	-8.54 °S 115.12 °E 122 m UTC+8	<b>Project settings</b> Albedo 0.20
<b>Meteo data</b> Banjar Dukuh Meteonorm 8.0 (2010-2014), Sat=100% - Synthetic			

System summary			
<b>Stand alone system</b> <b>PV Field Orientation</b> Fixed plane Tilt/Azimuth 16 / 45 °	<b>Stand alone system with batteries</b> <b>User's needs</b> Daily household consumers Constant over the year Average 68 kWh/Day	<b>System information</b> <b>PV Array</b> Nb. of modules 24 units Pnom total 13.20 kWp	<b>Battery pack</b> Technology Lithium-ion, NMC Nb. of units 85 units Voltage 259 V Capacity 765 Ah

Figure 5. The PVsyst Software

The software allows users to model the electrical characteristics of a PV system, including wiring, cabling, and electrical losses. It can also simulate the behavior of different inverter topologies and provide detailed electrical reports.

### METHODOLOGY

In conducting this research, the author employed several data collection methods to obtain the necessary data for completing this final project. The methods used include the literature study method is a series of activities related to the collection of library data, reading and taking notes, as well as processing research materials. This method is conducted to reveal various theories relevant to the problem being studied, serving as a reference in discussing the research findings. The author conducted on-site visits to observe and record the necessary data for completing this final project. In this research on the planning of the Hospital Rooftop Solar Power Plant, there are several types of data collected, including:

### **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 include: Regulation of the Minister of Energy and Mineral Resources, PLN Provisions, and other references related to the research.

### **Discussion or Interview Method**

Collecting data by conducting direct discussions with the hospital

### **Observation Method**

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

## **RESEARCH RESULT**

### **Steps to test results**

Technical design is a detailed design of technical aspects. In the context of solar panel capacity, installation configuration, selection of equipment and components needed, and installation and interconnection plans. The technical design also includes in-depth calculations and simulations to ensure the solar power system works optimally according to local energy needs and environmental conditions. This includes analysis of potential solar irradiation, planning the placement of solar panels, selection of components such as inverters and batteries.

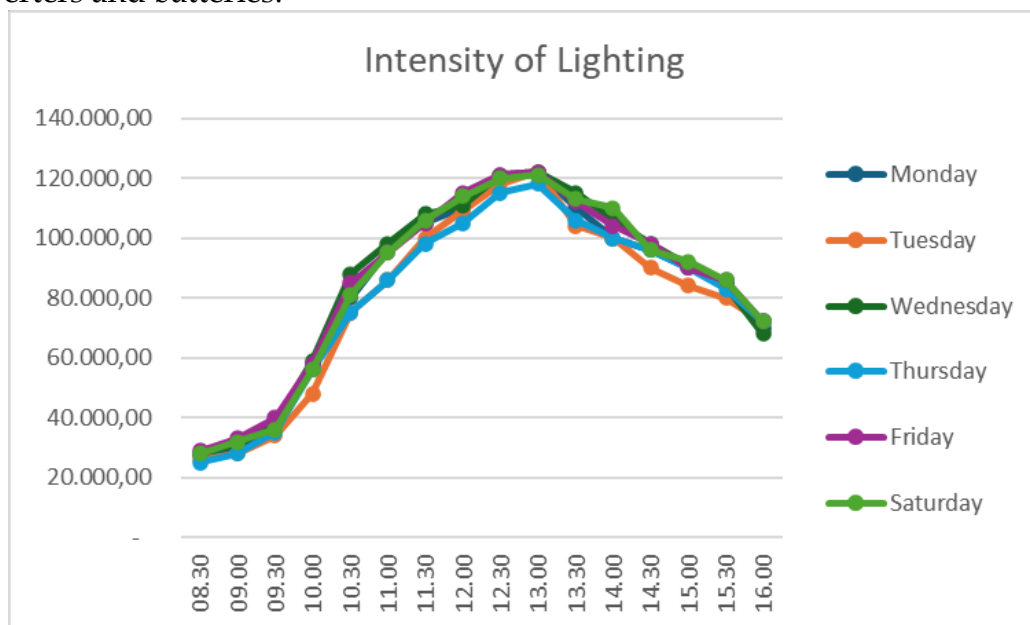


Figure 6. Intensity of Lighting in One Week

Location data including geographic coordinates, is used to determine factors such as the angle of incidence of the sun and shadows that can affect the performance of the PV system. This helps in determining the orientation and placement of solar panels on the roof of the Hospital.

Solar irradiation data refers to information that describes the intensity of sunlight received in the PV installation area over a certain period of time. This data provides estimates or historical values of the amount of solar energy reaching the earth's surface. Temperature data for PV installation refers to information regarding the air temperature in Tabanan, which is the place where the PV installation is used as a reference in designing and operating the Installed Solar Panel system. Air temperature data is usually collected through meteorological stations or trusted weather data sources in the area, but this time the author uses the help of the PVsyst application to find out the air temperature at the research location.

Energy consumption data in hospitals is important information to understand the electricity needs of the hospital, where the data taken is the load data in the VIP class. This data helps in determining the right size and capacity for the PV system, as well as to estimate how much energy savings can be achieved. Energy consumption data is calculated using a kWh meter. Where, this data is measured with a period of 2 x 24 hours. The results of the data will be divided equally to obtain daily electricity consumption. So that researchers are able to obtain daily energy from daily load consumption at the Hospital to design technical aspects in determining the capacity and components of rooftop PLTS.

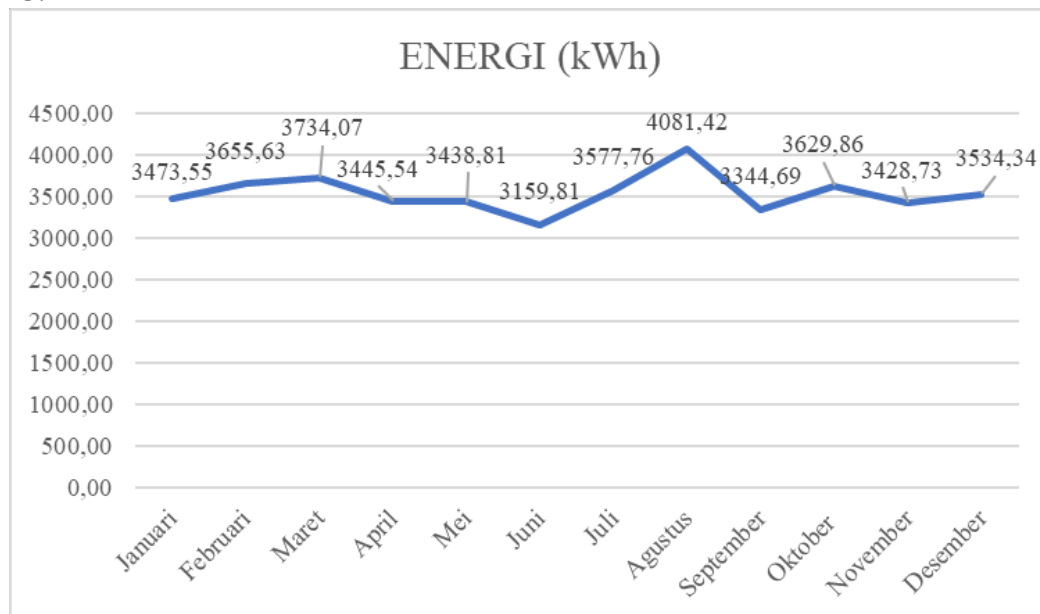


Figure 7. Energy Consumption for One Year

Based on the results of the data, it shows that the highest energy reached 4,0811.42 kWh, which was recorded in May 2024. Graphically, the energy usage data at the Hospital can be seen in the image.

This study to design, requires average solar radiation data on hospital buildings, so researchers use meteorological data from the PVsyst application. In this study, the solar conditions in the Tabanan-Bali area are quite high. The data was obtained using PVsyst simulation. The data can be seen in table 4.2 below.

Table 1. Comparison Irradiation with Others Factor

Year	Global Horizontal Irradiation kWh/m2/day	Global Diffuse Irradiation kWh/m2/day	Temperature °C	Wind Velocity m/s	Linke Turbidity [-]	Relative humidity %
January	5,52	2,39	24,8	1,70	4,052	82,0
February	5,40	2,62	24,8	1,70	3,954	82,1
March	5,71	2,60	25,0	1,19	3,648	80,9
April	6,00	2,06	24,8	1,09	3,687	82,8
May	5,16	2,10	24,8	1,40	3,693	79,6
June	4,77	1,81	23,7	1,80	3,687	80,1
July	4,97	1,77	23,4	2,00	3,619	77,2
August	5,52	2,00	23,4	3,10	3,756	75,0
September	6,07	2,23	23,8	1,61	3,913	76,7
October	7,01	2,11	25,1	1,60	4,354	75,8
November	6,69	2,29	25,1	1,20	4,396	80,5
December	6,36	2,23	25,0	1,39	4,106	81,7
	5,77	2,18	24,5	1,6	3,905	79,5

**DISCUSSION**

In this study, technical analysis of off-grid PLTS is carried out with calculations to determine the PV Area, Type of Solar Panel to be used, number of Solar Panels to be used, Determining the Solar Panel Circuit, Inverter Capacity, Battery Capacity. The calculation steps for designing an off-grid PLTS system can be explained as follows.

To determine the capacity of the PLTS, there are several factors that affect the panel output and efficiency of the solar panels. All of these factors must be considered when calculating solar power. The following are the types of losses that affect the output power of the PLTS. Solar panel manufacturers generally have an output tolerance of around +/- 3%. This means that the solar panels produced can have a deviation in output power of 3% from the watt value stated in the specifications.

Dirty or dusty solar panels can affect the performance of the solar panels. Losses resulting from dirt and dust vary for each solar panel. The amount of losses due to dirt and dust is 5%. Extreme temperatures or temperatures that are too high will also affect the performance of the solar panels, because solar panels only work with irradiation from the sun. Solar panels are affected by temperature where their efficiency can decrease when the panel temperature increases. In this study, every 1oC increase in temperature (from its standard temperature) of the solar panel, then it will cause the power generated by the solar panel to decrease by about 0.5%. The temperature obtained is 25.1 °C indicating that there is a temperature increase of 0.1 °C from the standard temperature, so it can be calculated using the following equation:

Inverters convert direct current (DC) generated by solar panels into alternating current (AC) which is used to power electricity. This process is not 100% efficient, with inverters typically having energy losses of around 5-8%. The length of the cable and the connections along the cable network affect the occurrence of cable installation losses. These DC cable losses range from 1-2%. AC cables and connections between the inverter and the panel box can experience a voltage drop that causes losses in system efficiency. These AC cable losses range from 2%. Shading or shadows on the surface of the solar

panel will affect the power output of the solar panel. Some types of solar panels are more affected by shading than others. Losses due to shading are between 3-4%.

The vast range of energy forms that can be generated from electrical energy, combined with the rapid advancement of technology, has made every aspect of human life dependent on electricity. As a result, society's demand for electricity continues to rise. The Indonesian government has been continuously expanding the electrical grid to meet this growing demand. This can be seen from the numerous power plants that utilize various energy sources as their initial driving force.

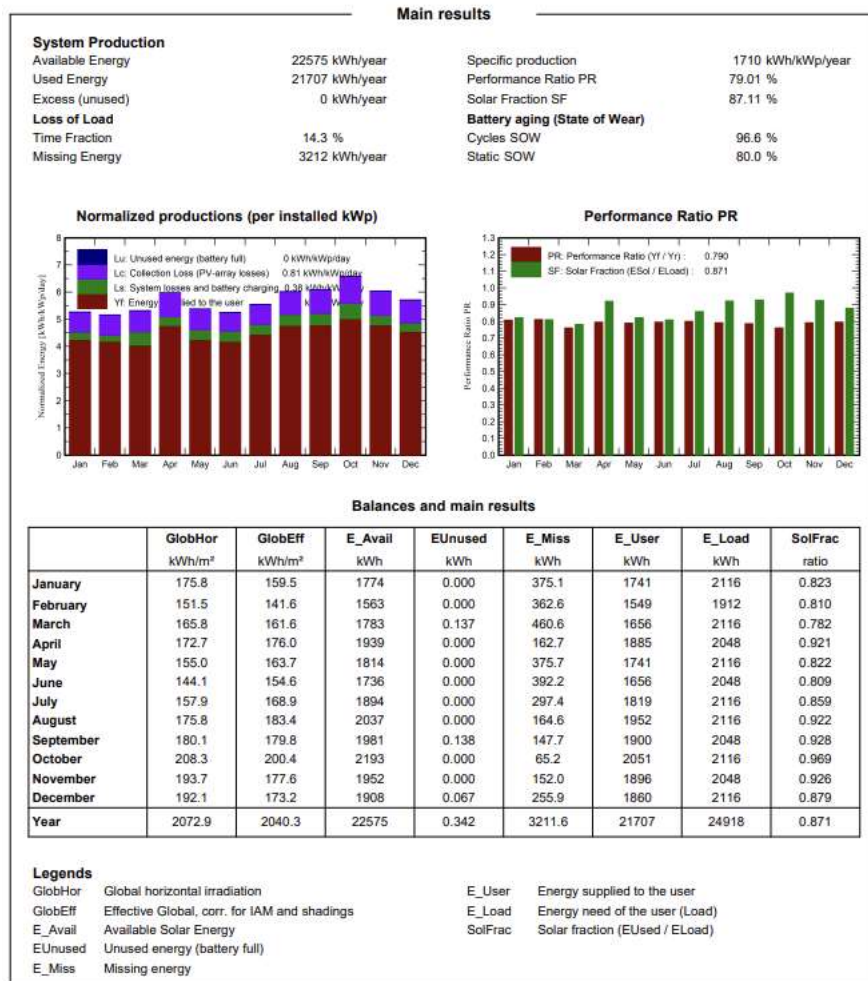


Figure 8. Analysis with PVSyst Software

The direction the solar panel faces, and the angle at which it is mounted, also affect the output of the panel. If it is not positioned at the optimal angle and direction, the panel will not produce measurable output for that location. The most optimal direction of solar panels is towards the equator. The optimal angle of solar panels ranges from 10° -20°, depending on the location of the solar panel installation. Losses due to the tilt of the solar panel average 0.4% for every 1° increase in the optimal angle. Every 1°C increase in temperature from the standard temperature of the solar panel can cause a decrease of about 0.5% in the power produced by the solar panel. The maximum efficiency of the solar

panel will increase if the angle when the sun is shining is always at  $90^\circ$ . To find out the maximum height of the sun (in degrees) when the sun reaches the sky ( $\alpha$ ), then it can be calculated lat is the latitude of the location of the installed solar panel installation (in degrees), and the angle of the sun's declination ( $23.45$ ) is about  $74.99^\circ$  and after knowing the value of  $\alpha$ , the angle of inclination of the solar panel ( $\beta$ ) can be found using the formula is about  $15.01^\circ$ . Based on the calculation of the orientation of the solar panel tilt that has been carried out, the optimal tilt angle obtained is  $15.01^\circ$  facing northeast because the location is south of the equator.

Roof Tilt Angle of the Hospital Building where the solar panel is planned to be installed on the roof. Where the angle of the installed solar panel follows the slope of the roof to be installed. It is known that the roof where the solar panel will be installed faces northeast and the results of the roof slope measurement are  $30^\circ$ . It is known that the optimal angle of the solar panel is  $15.01^\circ$ , which has a difference of  $14.99^\circ$ . From the calculations that have been carried out, the design of the rooftop PLTS with an on-grid system has been designed for this hospital.

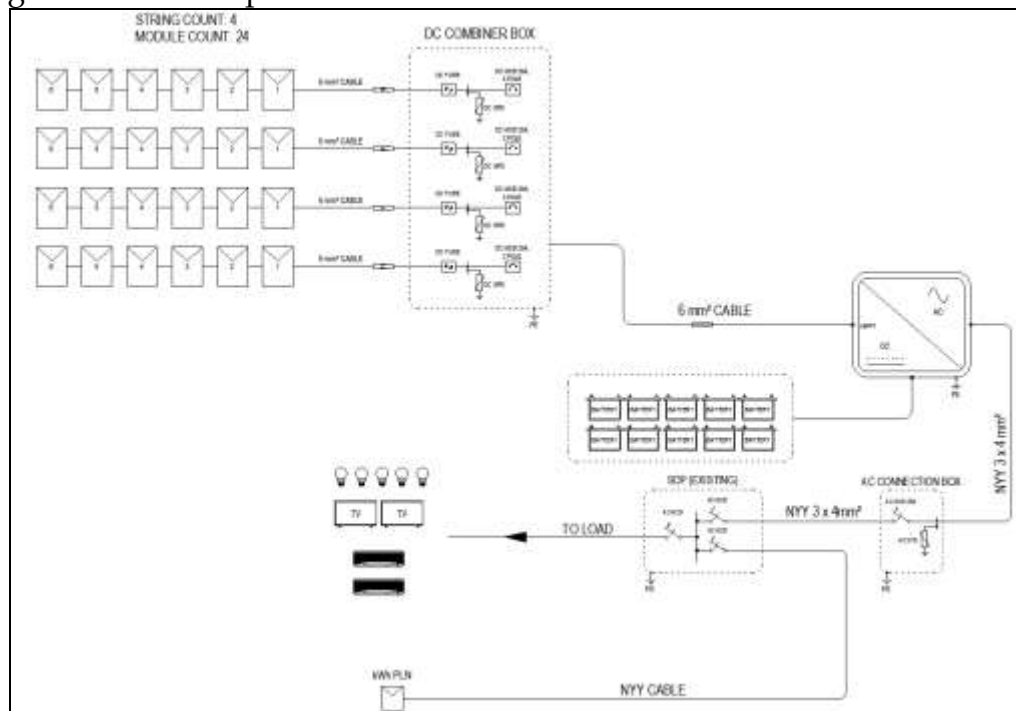


Figure 9. The Design of the Rooftop PLTS

## CONCLUSIONS AND RECOMMENDATIONS

Based on the results of calculations and simulations using software, the following conclusions can be drawn.

Rooftop PLTS with an off-grid system that has been manually designed and simulated in PVsyst software at the Hospital from the results of a total of 24 panels with a capacity of 550 Wp. The PV panel array configuration is arranged with a total of 4 strings, PV modules are arranged in series as many as 6 units, so that the maximum DC input voltage is 293.4 Volts, the output voltage is 3 phase AC 380 VAC using 1 inverter. While the number of batteries used is 10

units with a capacity of 100Ah each, with a voltage of 48V arranged in series as many as 5 units, so that the inverter input system voltage is 250VDC. Based on the simulation results in PVsyst, the annual energy produced by PLTS reaches 16,375.05 kWh and is able to support the electrical load in the Hospital by 42%. The maximum efficiency of the solar panel will increase if the angle when the sun is shining is always at 90° and the angle of the sun's declination is about 74.99° and after knowing the value of  $\alpha$ , the angle of inclination of the solar panel can be found using the formula is about 15.01° facing northeast because the location is south of the equator. With these results, the off-grid solar panel design at hospital is considered feasible for implementation.

Based on the results of the study above, there are several suggestions that can be given to improve the sustainability and effectiveness of this research and provide further contributions to the development of renewable energy. The following are suggestions from researchers. It is better to be more careful in manual calculations when calculating and selecting components so that they are more optimal and can increase the selling value of the PLTS. In order to be more accurate in designing, it is better to use a comparison of software that supports PLTS design in the future.

#### **ADVANCED RESEARCH**

Each study has limitations; thus, we can describe about development of this research to integration with digital communication technology, smart system, and sustainable tourism based on local wisdom here and briefly provide suggestions for further research.

#### **ACKNOWLEDGMENT**

This section gives us the opportunity to thank our colleagues who provided suggestions for our paper: Electrical Department in Politeknik Negeri Bali, Engineering Maintenance in in LPK Ganesha Indonesia, and Communication Science in UHN IGB Sugriwa Denpasar.

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