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Operational Analysis Of Rooftop Solar Power Plant (PLTS) At GMIT Jemaat Paulus Kupang

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ABSTRACT

Rooftop Solar Power Plant (PLTS) is one of the renewable energy solutions that support energy efficiency and environmental sustainability. East Nusa Tenggara is one of the areas that has sunlight potential that supports the utilization of solar energy both on a large and small scale, moreover, the relatively low operational costs of rooftop PLTS can reduce the cost of electricity bills. The purpose of this research is to analyze the performance and effectiveness of the rooftop solar power system installed at the GMIT Jemaat Paulus Kupang church. Measurements were made using tools such as Digital Multimeter and Ampere Pliers. This research uses descriptive and quantitative methods, which describe the variables analyzed supported by data in the form of numbers generated from measurements there is PLTS and includes collecting references from journals and articles related to PLTS as well as direct measurements in the field to obtain primary and secondary data related to geographical and weather conditions. The results show that the performance of rooftop solar power plants has decreased significantly due to factors such as solar radiation intensity, ambient temperature, and the physical condition of solar panels and inverters. During one week, GMIT Jemaat Paulus Kupang used a total of 561.396 kWh of electrical power to meet load requirements. Of this amount, PLTS supplied 499.2468 kWh of power, while the remaining 62.1492 kWh was supplied by PLN. The excess power generated by the PLTS, because it is greater than the total load demand, is exported back to the PLN network.

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1. INTRODUCTION

Energy is one of the basic needs in human life. Along with the increasing population and technological development, the need for energy is also increasing. Conventional energy sources such as petroleum, natural gas, and coal, which have been the mainstay, have limitations in availability and have a negative impact on the environment. Therefore, alternative solutions are needed in the form of new energy sources that are environmentally friendly and sustainable. One alternative energy source that has great potential to be developed is solar energy, which is considered a clean energy source because it does not pollute the environment in the production process.

Solar power generation system (PLTS) is a technology that utilizes energy from sunlight to be converted into electrical energy. This system is becoming one of the renewable energy solutions that are increasingly in demand amid global efforts to reduce dependence on fossil energy sources and reduce greenhouse gas emissions. In the Indonesian context, the government targets to increase the utilization of renewable energy in

the national energy mix to 23% by 2025 and 31% by 2050, as stated in the National Energy Policy. One of the concrete steps to achieve these targets is the issuance of Minister of Energy and Mineral Resources Regulation No. 49/2018, which regulates the production of electrical energy using rooftop solar systems by PT PLN (Persero) consumers for various sectors, such as households, businesses, government, social, and industry [1].

Furthermore, the government also invites the public to actively participate in utilizing rooftop PLTS for personal use. This invitation is strengthened by the issuance of Minister of Energy and Mineral Resources Regulation No. 2 of 2024, which in Article 20 explains that prospective rooftop solar PV customers can build and install rooftop solar PV systems with a total capacity of up to 500 kW connected in one electrical power installation system.

Various studies related to solar power systems, especially rooftop solar power systems, have been conducted to assess their potential, design, and effectiveness. For example, research on the capacity of rooftop solar power plant in Graha Sewaka Dharma Building shows that the installed capacity of 188.8 kWp with 472 solar module units and 6 inverter units produces annual output energy of 306.2 MWh/year. Another study on the design of an on-grid solar PV system at Jami' Al-Muhajirin Mosque using PVSyst software showed that certain system variations can produce annual energy of 12.31 MWh with a performance ratio of 81.93%. However, from an economic point of view, other variations are more feasible as they have the highest NPV value and the fastest payback time of the initial investment [10][2][3]. In addition, research in Makassar shows that the use of on-grid solar PV or rooftop solar PV can save PLN electricity power by 39.9% to 110.5% [4]. In the long term, solar panels can reduce monthly electricity costs, increase the use of renewable energy, and reduce carbon emissions by 96.7%. Based on this, the purpose of this research is to find out how the operational performance and use of rooftop solar panels can reduce electricity consumption at GMIT Jemaat Paulus Kupang

2. RESEARCH METHODS

This research method analyzes the operation of the Rooftop Solar Power Plant (PLTS) at GMIT Jemaat Paulus Kupang. Figure 1 shows the block diagram of the existing electrical energy installation system at GMIT Jemaat Paulus Kupang using PV module components, DC Combiner panels, inverters, MDP and LVMDP which are shown to provide electrical energy that will be interconnected with the PLN network.

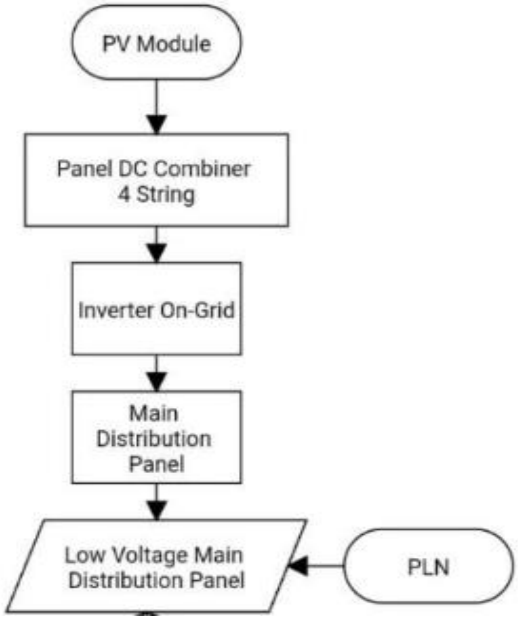

Figure 1. Block diagram of rooftop solar power plant

The tools used include Digital Multimeter DT-830B, Kyoritsu Ampere Pliers, and PC/Laptop Lenovo V14-ADA. The research data consisted of primary data, namely current and voltage, as well as secondary data which included geographical information, meteorology (tilt, azimuth, solar radiation, and temperature), solar radiation intensity, temperature, solar panel and inverter specifications, and the number of PLTS components. The research procedure includes collecting data on solar radiation intensity and daily temperature for seven days at 07:00-17:00 WITA using the Global Solar Atlas and NASA Power Data Access. Current and voltage measurements were taken at the Main Distribution Panel (MDP) and Low Voltage Main Distribution Panel

(LVMDP) at the same time, including currents and voltages from PLTS, PLN, and loads. The collected data were analyzed to assess the performance and efficiency of the rooftop solar power plant.

2.1 Research Flowchart

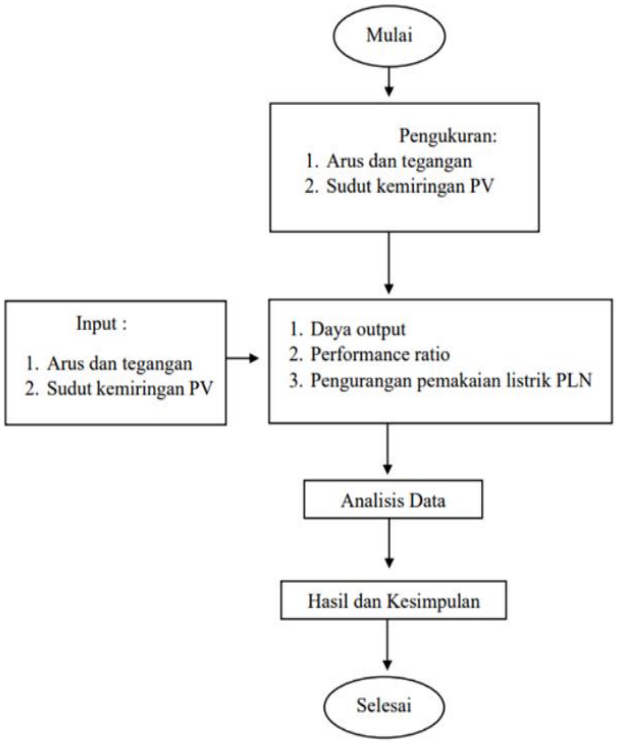

Figure 2. Research Flowchart

3. RESULTS AND DISCUSSION

3.1. Solar Radiation Intensity Data

The solar radiation intensity data used includes solar radiation data from the global solar atlas. The solar radiation intensity data in Table 1 is the average data in September 2024.

Table 1. Solar Radiation Intensity Data

Hour (WITA)	Solar Radiation (kWh/m^2)
07.00	2,646
08.00	7,841
09.00	12,134
10.00	15,113
11.00	16,738
12.00	17,341
13.00	16,839
14.00	15,386
15.00	12,564
16.00	8,631
17.00	4,007

Based on the data in Table 1, the intensity of solar radiation taken from the Global Solar Atlas shows that the maximum peak of solar radiation intensity occurs at 12:00 pm, with a solar radiation intensity of 17.341 kWh/m^2. During this period, the solar panel produces maximum power output. In contrast, in the morning (07.00-08.00 WITA) and afternoon (16.00-17.00 WITA), the radiation is very low, with values of 2.646 kWh/m² and 4.007 kWh/m² at 07.00 WITA, so the power output of the solar panel is very minimal at these times.

3.2. Temperature Data (°C)

The temperature measurement data in Table 2 is data taken from the Nasa Power Data Access.

Table 2. Temperature Data

Day/Date	Temperature (°C
Friday/ 20/ 09/ 2024	30
Saturday/ 21/ 09/ 2024	30
Sunday/ 22/ 09/ 2024	31
Monday/ 23/ 09/ 2024	30
Tuesday/ 24/ 09/ 2024	28
Wednesday/ 25/ 09/ 2024	28
Thursday/ 26/ 09/ 2024	29

Based on the data in Table 2, the temperature (℃) in the area around the rooftop solar power plant from 07.00 to 17.00 WITA for 7 days (Friday, September 20, 2024 to Thursday, September 26, 2024). From the data, it is obtained that the average maximum temperature occurred on Sunday at 31 ° C.

3.3. Calculation of Output Power Generated by PV

Based on the data obtained at GMIT Paulus Kupang congregation. the amount of solar power is 25 kWp, which is generated by a total of 76 panels. Where there are 4 *strings* as current and voltage output from solar panels. In accordance with the data collection method used in the field, the calculated power is the result of$P = V \times I$ on each *string*. The power will enter the On-Grid inverter which will then be the output of the inverter in the form of 3-phase AC current The calculated PV efficiency can be seen in table 3 which is the result of $.Efisiensi\ PV\ (\%) = \frac{Output\ Inverter\ (kW)}{Kapasitas\ PV\ (kWp)} \times 100$

Table 3 . Power Inverter Data and Maximum Efficiency

Day/Date	Hour (WITA)	Output Inverter AC(W)	Efficiency
Friday/ 20/ 09/ 2024	11:00	16220	64,88%
Saturday/ 21/ 09/ 2024	11:00	16840	67,36%
Sunday/ 22/ 09/ 2024	11:00	15030	60,12%
Monday/ 23/ 09/ 2024	12:00	18340	73,36%
Tuesday/ 24/ 09/ 2024	12:00	16390	65,56%
Wednesday/ 25/ 09/ 2024	10:00	14500	58%
Thursday/ 26/ 09/ 2024	12:00	17580	70,32%

Based on the data in table 3 taken through observation and calculation on the inverter to get power and efficiency every hour from 07:00 to 17:00 WITA. The data above shows that the maximum power output occurred on Monday at 12:00 WITA with a power of 18340 W. The total PV output power is greater than the AC output due to power losses in PV, power losses in the conductor, and power losses in the inverter. PV efficiency is the calculation data which finally found that the maximum PV efficiency occurred on Monday at 12:00 WITA with an efficiency of 73.36%. The solar PV system at GMIT Jemaat Paulus Kupang has an installed power of 25 kWp with 76 solar panels divided into 4 strings. The data taken records the power output from solar panels and inverters in AC form. The power output fluctuations throughout the day are influenced by the changing intensity of sunlight, with the highest output around 12:00 pm and the lowest output in the morning and evening. The power supplied by the solar power plant is more dominant compared to PLN.

3.4 Measurement Results of PLTS and PLN Power Supplies Against Load Requirements

Based on the measurement data obtained at the Rooftop PLTS at GMIT Jemaat Paulus Kupang on the *Low Voltage Main Distribution Panel* (LVMDP) get the total supply power from the PLTS, and the total power demand on the load. If the power supplied by the PLTS exceeds the power required by the load, then the power will be exported to the network. If the power supplied by the PLTS does not meet the power needs of the load, it will be imported from PLN. In accordance with the data collection method used in the field can be seen in table 4, then the export-import power obtained is the result of $.Exim = (PLTS + PLN) - Beban$

Table 4 . Average Power Supply to Load Data

Day/Date	PLTS (kW)	PLN (kW)	Load (kW)
Friday/ 20/ 09/ 2024	3,61	6,42	8,84
Saturday/ 21/ 09/ 2024	3,84	3,92	6,76
Sunday/ 22/ 09/ 2024	3,24	8,67	7,27
Monday/ 23/ 09/ 2024	3,82	0	7,65
Tuesday/ 24/ 09/ 2024	2,79	0,53	5,66
Wednesday/ 25/ 09/ 2024	3,33	1,09	4,94
Thursday/ 26/ 09/ 2024	3,92	3,65	4,81

Based on the data in Table 4, the data taken is measurement data on the Low Voltage Main Distribution Panel (LVMDP) to get the total average power from PLTS, PLN and load for each hour from 07:00 to 17:00 WITA. The maximum total average power supplied by PLTS occurred on Thursday of 3.92 kW while the maximum average power supplied by PLN occurred on Sunday of 8.67 kW while the peak demand on the load was on Friday with a total required power of 8.84 kW. If the power supplied by PLTS and PLN is greater than the load requirement, the remaining power will be exported to the network. Meanwhile, if the power supplied by PLTS and PLN is less than the load requirements, the load will take power from PLN. In this case, there is an export and import of power between PLTS and PLN

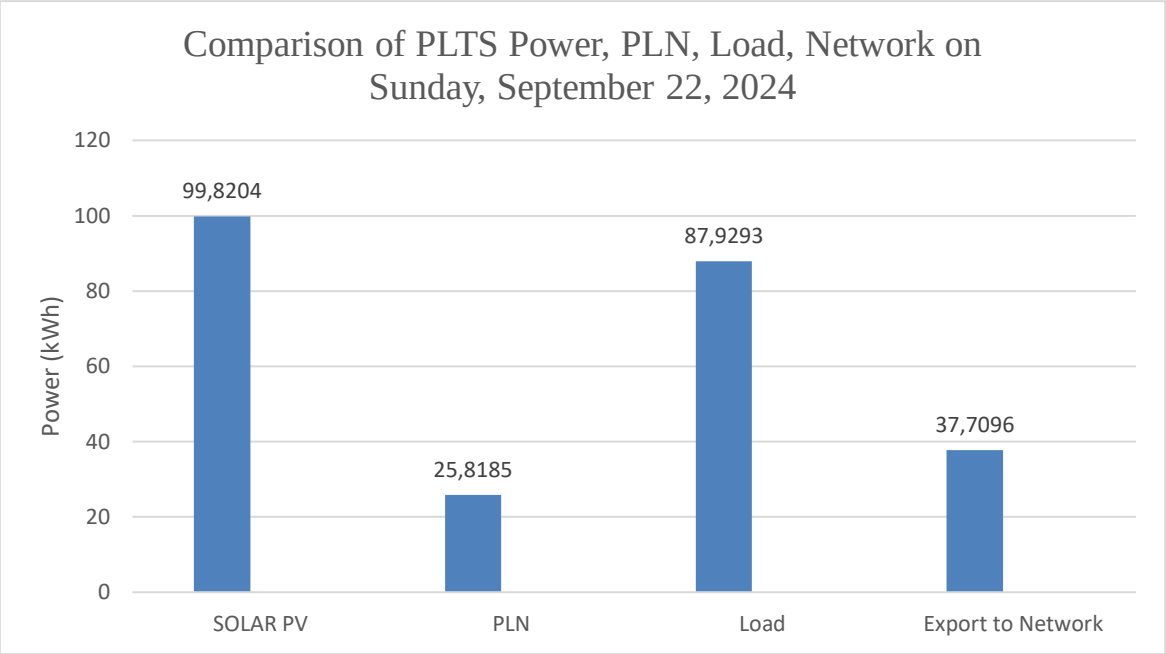

Figure 3 . Graph of Power Supply against Load Requirements

Figure 3 explains that on Sundays, the load power demand at GMIT Jemaat Paulus Kupang is recorded at 87.9293 kWh. The solar power plant installed at the location is capable of producing 99.8204 kWh of power, which is overall sufficient to meet the load requirements. However, there are certain times, especially when the weather conditions are unfavorable, where the PLTS cannot supply full power so that PLN must supply a power shortage of 25.8185 kWh to ensure electricity needs are still met. Conversely, when the power generated by the PLTS exceeds the load requirements, the excess power is exported to the grid with a total power of 37.7096 kWh. Thus, PLTS plays an important role in power supply by reducing dependence on PLN, although it still requires support from the grid under certain conditions. Other daily PLTS, PLN, Load, Grid Power Comparison charts can be seen in the appendix.

4. CONCLUSIONS

The operational performance of the Rooftop Solar Power Plant can be seen from the efficiency of the Rooftop Solar Power Plant at GMIT Jemaat Paulus Kupang which obtained the maximum value that occurred on Monday of 73.36%. Based on observations for seven days at GMIT Solar Power Plant, it shows variations in performance in meeting load requirements. The highest power production was recorded at 19.316 kW on the seventh day, while the lowest was 6.286 kW on the first day. The highest load demand of 15.5528 kW occurred on the seventh day, and the lowest was 11.3227 kW on the third day. In general, the solar farm can meet the load demand with the largest power surplus of 5.9785 kW on the fifth day. However, on the first day, there was a power shortage of 6.1915 kW, indicating that the PLTS was not optimal at some times. During one week, the total electrical power used by GMIT Jemaat Paulus Kupang to meet load demand reached 561,396 kWh. Of this amount, most of the power, namely 499.2468 kWh, was supplied by the Solar Power Plant (PLTS). Meanwhile, PLN supplies the rest, which is 62.1492 kWh. Since the power generated by the PLTS is greater than the total load demand of GMIT Jemaat Paulus Kupang, the excess power is exported back to the PLN network. This research can be further developed by conducting research related to the control system on the PLTS in order to find out the power losses in the PV, wiring, or in the inverter.

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