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Designing an On-grid Solar Power Plant at the Women's Dormitory Building of Aviation Polytechnic Jayapura

Markus Bernandos[1], Andi F. Perangin Angin[2], Faridh Surya Pratama[3]
[1,2,3]Aviation Polytechnic Jayapura, Indonesia

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ABSTRACT

Despite the abundance of solar energy potential in Indonesia, the utilization has not been optimal. PLN, as the state power grid provider, can not meet the increasing electricity demand in all regions of Indonesia. This research will discuss utilizing the potential of the On-Grid system PLTS planning on the Rooftop of the Jayapura Aviation Polytechnic Women's Dormitory Building in Tanjung Ria District, North Jayapura City. This PLTS design uses PvSyst programming to measure and analyze data from a complete solar PV system, aided by SketchUp Pro, to demonstrate 3D plan views. The result is data on the potential annual production of electrical energy, including the total energy produced, the energy distributed, and the value of the PLTS work ratio with data output. The configuration installed at the Poltekbang Jayapura women's dormitory is an AC Coupling On-Grid PLTS with 400 Wp Photovoltaic modules. From the PvSyst simulation that has been carried out, it can be obtained that the potential for electrical energy in the Jayapura Aviation Polytechnic Dormitory Building is 323,905 kWh / year with a PLTS capacity of 230 kWp with a Performance Ratio of 0,829.

Corresponding Author:

Markus Bernandos
Airport Electrical Engineering Study Program
Jayapura Aviation Polytechnic
99117 North Jayapura, Papua, Indonesia
Email: markusbernandos@gmail.com

INTRODUCTION

Indonesia is a tropical region where solar energy is very abundant with an average solar radiation intensity of 4.8 kWh/m^2, these solar energy sources have not been fully utilized. The need for electrical energy is increasing every day, and electricity from PLN will not be able to meet every need in all parts of Indonesia (Roza, 2019).

Citizens can adapt on-grid, Off-Grid, and Hybrid systems to preserve the earth by producing electrical energy to minimize the negative impact of non-renewable power plants that are commonly used today. Based on this premise, the problem to be researched can be formulated on how to plan the estimation of load requirements in the Jayapura Aviation Polytechnic Women's Dormitory Building, how to prepare the On-Grid PLTS system in the building using PV-Syst 7.3 software starting from photovoltaic modules, Solar Charge Controller and batteries, and simulate the performance of a PLTS (Solar Power Plant) on-grid system in the Taruni dormitory building using PVSyst 7.3 software (Hani, 2020). Aside from achieving the objectives, the purpose of this research is to plan the PLTS (Solar

Power Plant) On-Grid system, simulate the performance of the Solar Power Plant on-grid system, obtain a power supply system with high economic value, and investigate Hybrid PLN - Solar Cell renewable energy.

In this study, the method of taking primary data (hardcopy) directly from the Jayapura Aviation Polytechnic Dormitory building project to inspect and ensure the building construction project is in accordance with the drawing or blueprint. After the data is obtained, the next step is to design a PLTS model using PvSyst 7.3 software starting from modeling the shape of the building, modeling the photovoltaic module array, determining the azimuth angle and simulation.

Power generation is rapidly growing, especially in the government's efforts to achieve an electricity ratio of >70% by 2022. With this need, the role of photovoltaic power is crucial. Photovoltaic technology is widely used because the location to be electrified can sometimes be remote and isolated, such as the outer islands, and separated by mountains and hills, which makes it technically very difficult to pull the electricity network from the existing power grid.

Due to their simple design and low cost, distributed solar power generation systems (CSP) and SHS (Solar Home Systems) are widely used in rural areas far from cities. Nowadays, solar power plants (SHS) are combined with wind energy, hydropower, diesel and other forms of energy to produce hybrid SHS, also known as hybrid solar power plants. These hybrid solar farms aim to produce more energy and are currently used in residential neighbourhoods to provide backup power during a PLN power outage.

THEORETICAL FOUNDATION

An innovation that utilizes photovoltaic cells to convert sunlight (sun-based) into electrical energy that can be directly used to stack (self-utilization) or approach matrix solar power plants in addition to charging batteries, and the rest will be diverted into PLN coverage. This framework has the advantage of being smarter than the Off-Grid framework, considering that the latter requires more power generation components that depend on the load demand of the consumers. On the other hand, the On-Grid system needs a reliable system as it switches between PLN and solar PV within the time limit set by the control system. Therefore, On-Grid systems can also be more complicated and require a good and reliable control system (Priatam, 2021).

Generally, two types of PLTS system configurations are used: the AC connection system or AC coupling and the DC Connection or DC coupling (Merta, 2019).

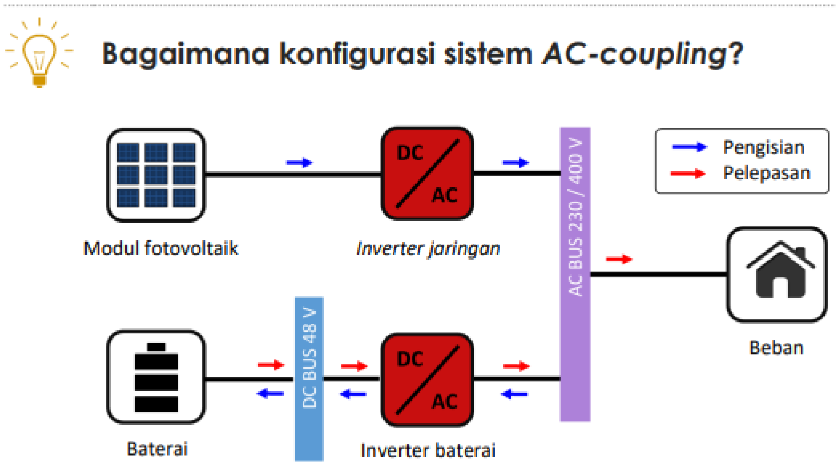

Figure 1 Sistem AC-Coupling

The matrix inverter is the part that recognizes the AC coupling framework from DC coupling. Photovoltaic modules and batteries are connected to the AC bus in an AC coupling configuration through the grid and battery inverter. The photovoltaic modules are connected to the grid inverter, where the voltage is converted from DC to AC. Like the charge controller, the grid inverter has an MPPT device to maximize energy absorption. During the day, the load can use the power from the photovoltaic module array directly, and the extra power is used to charge the battery simultaneously through the battery inverter (Ramadhani, 2018).

The power output of a solar cell or module is expressed in watt peak (Wp) and is calculated using Standard Test Conditions (STC), a set of worldwide testing guidelines. This standard applies to sunlight with an intensity of 1000 W/m2 shining perpendicularly on the solar cell at 25°C. Current and voltage are correlated in photovoltaic modules. Open circuit voltage (Voc) is the voltage at the cell when the resistance is infinitely variable (open circuit), the current is zero, and the voltage at the cell is at its highest point (Hamdani, 2019).

METHOD

The method used in seeking the performance of the solar power plant design in the residential building of the women's dormitory is qualitative and quantitative, which utilizes data and theory as an initial reference in the hope that the final results are in accordance with the theory and can be applied. The authenticity of the data in a research or inspection action is expected in order to obtain the accuracy and validity of the data with the initial pre-design data, in this case, the blueprint of the building in the accuracy of the installation of the number of solar panels on the roof of the building. Data authenticity techniques are taken by researchers based on the results of observations, reviews, evaluations, and assessments of data sources, as well as equations obtained in the PVSyst 7.3 software program. Figure 2 depicted a flow chart on this research process.

Figure 2 Research Flow Chart

In this study, the data required from various sources are as follows:

- Primary data (Hardcopy) taken directly from the Jayapura Aviation Polytechnic dormitory building project to review and ensure the building construction project is in accordance with the drawings or blueprints obtained from the head of the project owned by PT Sumber Rejeki Pramesti Lus KSO.
- AutoCAD soft file of the Jayapura Aviation Polytechnic Girls Dormitory Building blueprint.
- The geographical location of Jayapura Aviation Polytechnic Girls Dormitory Building was obtained from Google Earth and Meteonorm 7.2, which is available directly in PVSyst 7.3 software.
- Solar potential data from NASA (National Aeronautics and Space Administration) and Meteonorm 7.2 are available directly in PVSyst 7.3 software.
- References on Renewable Energy and PLTS Hybrid PLN - Solar Cell Planning.

Planning is done using PVSyst 7.3 programming by considering the information just obtained. Building the Jayapura Aviation Polytechnic Women’s Dormitory Building according to the blueprint, building a photovoltaic energy power generation system, building an energy storage system, energy management, photovoltaic shading management, determining the orientation of photovoltaic panels, and conducting economic evaluation are the first steps in the design process. In addition, the data is automatically processed and analyzed, resulting in a comprehensive report. PVSyst software is used in the simulation to determine the maximum output power value that solar panels can generate at the research site. Analyzing the examination of the output power produced by the original sunlight-based charger from direct estimation with the maximum output power according to the place obtained from the simulation results of the PVSyst program. Simulations were conducted using the PVSyst program to obtain the highest output power value equipped to be completed by the sunlight-based charger at the research site. Comparing the actual output power generated by the solar panels based on direct calculations with the maximum output power determined by the installed location based on the simulation results of the PVSyst software.

RESULTS AND DISCUSSION

Based on the calculation of the estimated electrical power obtained, the electricity consumption of the Jayapura Aviation Polytechnic Dormitory Building is 221.41 kWh, with details of electricity consumption per load determined previously. The highest electricity consumption is for air conditioners, with a total power per day of 198.45 kWh. The need for electrical energy in the Jayapura Aviation Polytechnic Princess Dormitory Building is detailed in Table 1, and the division of power based on the duration of the PLTS in Table 2.

Table 1 Electrical Power Requirement of Jayapura Polytechnic Girls Dormitory Building

No.	Load	Amount	Power/Load (Watt)	Total Power (kWh)	Time (hours)	Daily Energy (kWh)
1.	Lampu Lorong	96	10 W	0.96 kWh	8	7.68 kWh
2.	Lampu dalam Kamar	90	17 W	1.53 kWh	6	9.18 kWh
3.	Lampu Kamar Mandi	90	7 W	0.63 kWh	2	1.26 kWh
4.	Lampu Balkon	45	11 W	0.495 kWh	8	3.96 kWh
5.	Lampu Tangga	11	10 W	0.11 kWh	8	0.88 kWh
6.	Air Conditioner	45	735 W	33.07 kWh	6	198.45 kWh
	Total	**377**	**790**	**36.795**	**38**	**221.41 kWh**

Table 2 Power Distribution Based on Duration in Solar Power Plant

No.	Load	Total Power	Time (hours)		Power(kWh)	
			PLN	PLTS	PLN	PLTS
1.	Lampu Lorong	0.96 kWh	0	8	0	7.68
2.	Lampu dalam Kamar	1.53 kWh	0	6	0	9.18
3.	Lampu Kamar Mandi	0.63 kWh	0	2	0	1.26
4.	Lampu Balkon	0.495 kWh	0	8	0	3.96
5.	Lampu Tangga	0.11 kWh	0	8	0	0.88
6.	Air Conditioner	33.07 kWh	2	4	66.14	132.28
	Total	**36.795**	**2**	**37**	**66.14**	**155.24**

Electricity demand of solar power plant = $\frac{155.24}{221.41}$ x100% = 70.12%

PLN electricity demand = $\frac{66.14}{221.41}$ x100% = 29.87%

The results of the above calculations show that PLTS is expected to serve 170.27 kWh of electricity (67.88%), while PLN is 80.54kWh (32.10%) of the total building electricity demand of 250.84 kWh.

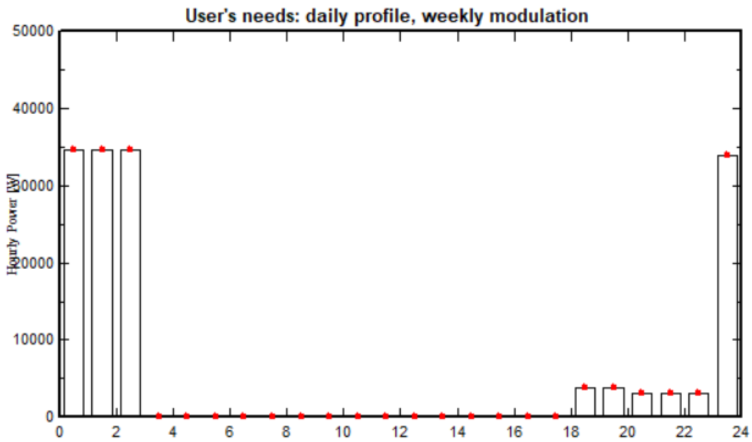

Figure 3 load curve based on service hours

The Gav value used when designing this solar power plant is the minimum average Gav value. The ηPV value is the efficiency of the solar panel, which is 18.1%. For the inverter efficiency value of 95%, assuming the battery efficiency and pollution on the surface of the solar panel is 95%, the ηout value is:

$$\eta\ Out = 0{,}95 \times 0{,}95 \times 0{,}95 = 0{,}85$$

The optimal temperature that solar panels can use is 25°C (Tiyas, 2020). In comparison, the highest average temperature in Jayapura city reaches 29°C. Then the temperature increase from 25°C to 29°C is 4°C. Therefore, before determining the number of photovoltaic panels, you must first know the array area with the following formula:

$$\begin{aligned} \text{Psaat t naik °C} &= 0{,}5\% \times \Delta t \times P_{MPP} \\ &= 0{,}5\% \times 4 \times 400 \text{ Watt} \\ &= 8 \text{ Watt} \end{aligned}$$

Therefore, the power released by the solar panel at an ambient temperature of 25°C is:

$$\begin{aligned} P_{MPP}\ \textit{saat naik menjadi t °C} &= P_{MPP} - \text{P } \textit{saat t naik °C} \\ &= 400\text{W} - 8 = 392 \text{ Watt} \end{aligned}$$

Determining the TCF(*Temperatur Correction Factor*):

$$\text{TCF} = \frac{\text{PMPP saat naik menjadi t °C}}{\text{PMPP}} = \frac{392}{400W} = 0{,}98$$

(Bonifacio, 2023) The surface area of the roof used is 1187 m^2, so the maximum installed capacity of the solar power plant is 230 kWp. The design specifications for the solar power system are presented in the figure. The solar panel used is a Canadian solar brand with a Pmpp of 400 Wp.

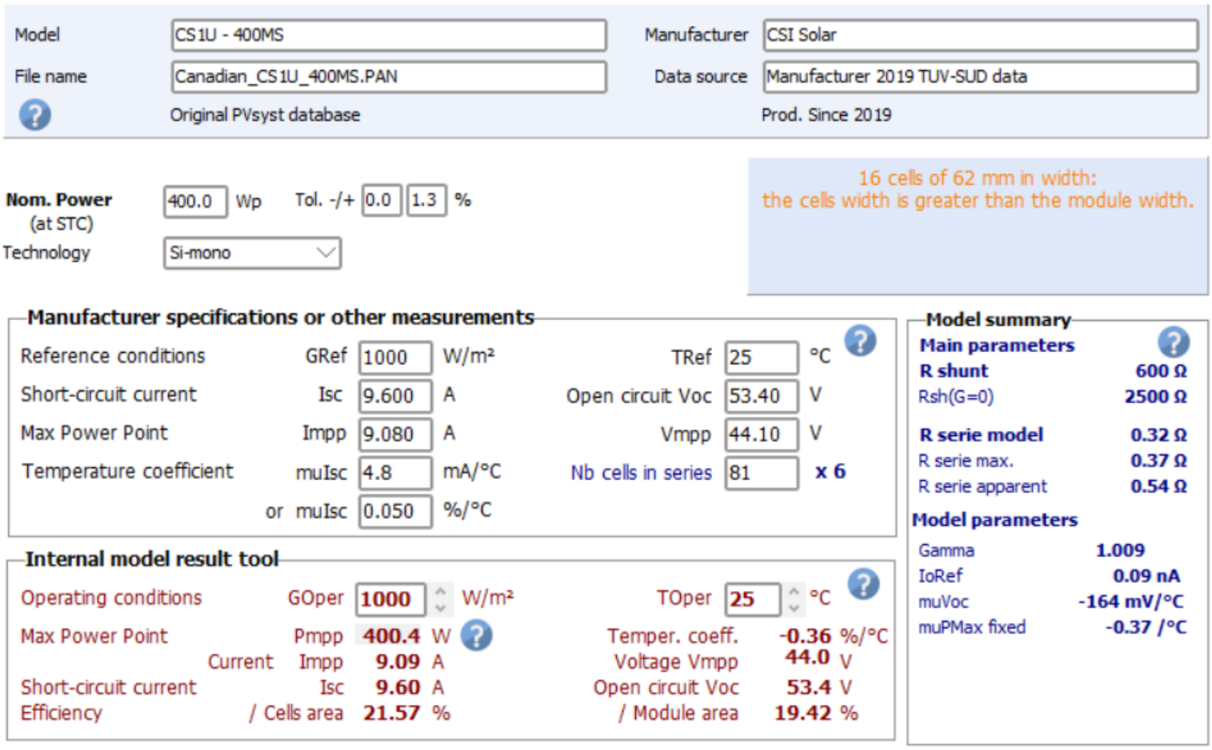

Figure 4 Solar panel specifications

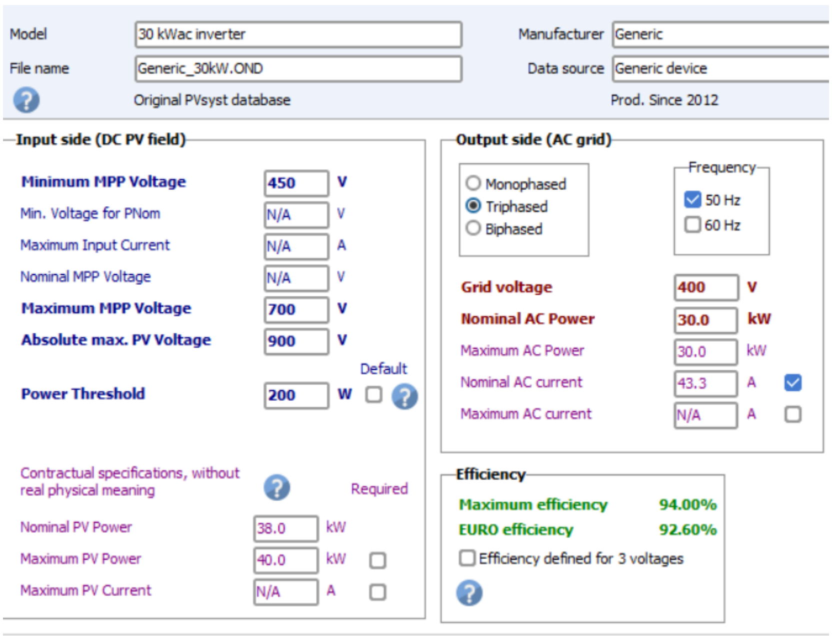

Figure 5 Inverter Specifications

Power generated is calculated as follows:

$$
\begin{aligned}
Pwp &= \text{Area Array x PSI x } \eta PV \\
&= 1187 \text{ x } 1000W/m^2 \text{ x } 0{,}194 \\
&= 230.278 = 234.400 \text{ Watt Peak}
\end{aligned}
$$

Then the number of photovoltaic modules is :

$$\text{Number of modules PV=}\frac{PWp}{Pmpp}=\frac{230400}{400}=576$$

The results above show that the number of photovoltaic modules required to serve the electricity demand of 155.24 kWh is 576 units (Iskandar, 2020).

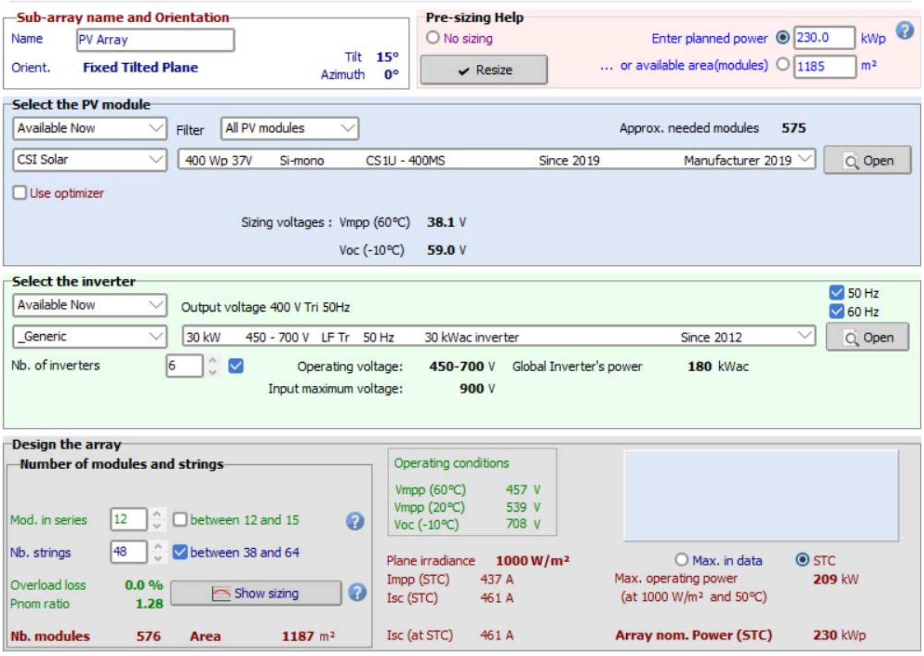

Figure 6 Solar System Parameters

Next is designing the installation of solar panels on the roof using PvSyst 7.3 software and Sketch Up Pro (Budiarta, 2021).

Figure 7 Configuration of solar panel installation on the roof of the building

Based on the PLTS simulation carried out using PvSyst 7.3, to meet 67.88% of the building's electricity needs of 155.24 kWh / day, which must be served by PLTS, a PLTS system is obtained with a total of 576 units of PV modules of the Canadian solar brand with a Pmpp of 400 Wp which is divided into 48 strings with the type of PV / azimuth tilt orientation, namely, 15 ° / 0 ° with a total Pmpp of 230 kWp. This PLTS system uses six units of SCC Inverter with Pnom 30 kW AC / unit, output voltage 450-700 V, and frequency 50Hz, so the overall total Pnom Inverter is 210 kW AC..

The graph of the main simulation results shows that the solar power system produces 323,905 mWh/year of electrical energy, with a breakdown of 1,405 kW/kW/year of electricity production. It shows that the solar power system meets the basic design requirements for a solar power plant.

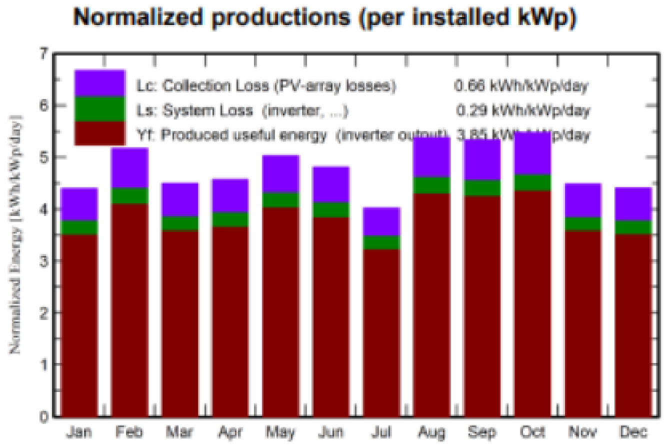

Figure 8 Electric Energy Production Chart

The electricity production in kWh/kWp/day for one year and every month is depicted in the graph above. The red variation emphasized 9 (Yf) in the figure above shows the prepared AC electrical energy, which is the output power from the inverter; the green variation highlight (Ls) is the losses in the PV module cells. The solar PV system achieved the highest Yf in October, about 5.3 kWh/kWp/day, and the lowest Yf in July, about 4 kWh/kWp/day, according to the above graph. In addition, the average value of electrical energy that can be harvested every day is determined to be Yf = 3.85 kWh/kWp/day and LC = 0.66 kWh/kWp/day.

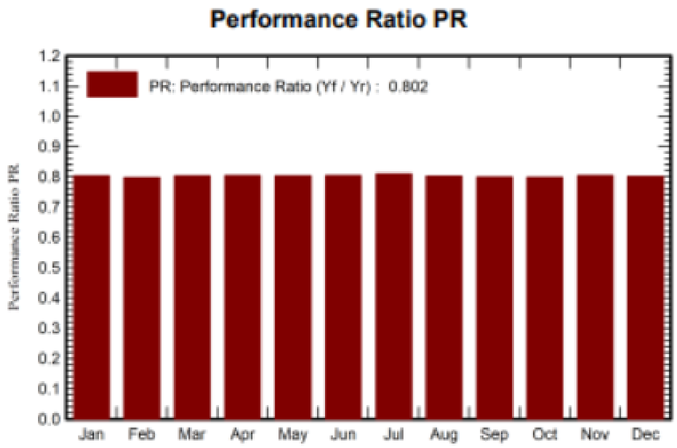

Figure 9 Perfomance Ratio Chart

The monthly performance of the solar system for one year is depicted in the graph above. The Performance Ratio is inversely proportional to the losses; the system performance will decrease along with the losses in the system (Karuniawan, 2023). Based on the graph above, the solar PV system experienced its best performance in July and its worst performance in October. In terms of what is needed typically in 1 year, the presentation of the solar PV framework is 0.802 or with a rate of 80.2%.

CONCLUSION

Based on the results of the simulation and design of the On-Grid PLTS of the Jayapura Aviation Polytechnic Dormitory Building using PvSyst 7.3 software, the following conclusions can be drawn:

1. The On-Grid Rooftop PLTS system at the Jayapura Aviation Polytechnic Dormitory Building has a potential electrical energy of 329,905 kWh/year or 903.85 kWh/day with a PLTS capacity of 230 kWp. It shows that the On-Grid Rooftop PLTS at the Jayapura Aviation Polytechnic Building can produce significant electrical energy to meet energy needs in the building.
2. Five hundred seventy-six solar modules are needed, with a total installed capacity of 230 kWp and a performance ratio of 80.2%.
3. This PLTS design uses 6 Inverter units with a total capacity of 30 kW. This division is done so there is a backup system in case of disturbances in one of the inverters.

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