



Analysis of the utilization of led lighting systems using solar panels at PLTU PT. puncakjaya power

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Abstract

The Indonesian government aims to achieve a renewable energy mix target of 23% by 2025, this commitment is stated in the National Determined Contribution (NDC) document which was last updated in 2021. The potential for solar energy development in Indonesia is quite large at 4.8 Kw h/m². In this regard, the PT. Puncakjaya Power PLTU wants to contribute to energy savings using LED lights and the use of environmentally friendly solar energy for lighting at the PT. Puncakjaya Power PLTU. This is also one of the solutions in obtaining optimal lighting during a total blackout. In this study, by taking direct data on lighting power, it was obtained that the current electricity load consumption for lighting was 161.72 KWh converted using LED lights down to 79.5 KWh. For the utilization of PLTS using PV system simulation, the power obtained in PLTS on grid is 71.2 KWh and off grid is 8.3 KWh, the efficiency level of solar panels at standard test conditions (STC) is 20.43% and the temperature loss reaches 6.58%. In the economic analysis of Net Present Value, Benefit Cost Ratio (1.3 -1.5), and Payback Period (9.09-10.65) it can be concluded that PLTS ongrid is feasible, while for Off grid it is not feasible but in terms of operation and impact on the environment it is very helpful and needed at PLTU PT. Puncakjaya Power.

Keywords: PLTS, LED lamps, investment, pvsyst

Introduction

Steam-electric Power Station (PLTU) PT Puncakjaya Power is a steam power plant that is utilized for the provision of energy to PT Freeport Indonesia. It possesses an installed capacity of 3 X 75 MW and is situated in Portsita, Timika, Papua. The PLTU PT Puncakjaya Power sector is integrated into the pre-existing PLTD power grid system in Tembagapura, operating at a voltage of 230 KV. During operation, occasional interruptions occur that lead to a lack of electricity flow. Consequently, the lighting in the PLTU PT. Puncakjaya Power area is suboptimal due to the limited availability of emergency lights that rely on direct current (DC) power from the Accu. Some of this power is utilized for control and lubrication purposes. As a result, the start-up process for repairs is not fully optimized, limiting operator access in the field. Additionally, the recovery of power from Tembagapura PLTD to PLTU PT. Puncakjaya Power takes approximately 1-2 hours. The plant has demonstrated compliance with the relevant rules in Indonesia, both internally and in its interaction with the intricate power system.

Indonesia's objectives for the year 2045, as outlined by KLHK, demonstrate a strong dedication to mitigating greenhouse gas emissions and enhancing environmental conditions. Indonesia, being recognized as a nation susceptible to the impacts of climate change, has set a goal to decrease its greenhouse gas emissions by 29% through domestic initiatives and 41% with collaboration from international partners by the year 2030. The pledge is explicitly outlined in the National Determined Contribution (NDC) agreement, which underwent its most recent revision in 2021. Indonesia has set a goal to achieve a 23% share of renewable energy in its national energy portfolio by the year 2025, as part of its commitment to executing a clean energy transition.

The scarcity of fossil energy sources as a primary source of electrical energy has prompted extensive research and development efforts focused on improving energy efficiency and exploring other energy sources. One such alternative is the utilization of solar energy sources, specifically LED lights, for lighting purposes. The utilization of solar energy in Indonesia exhibits promising prospects, owing to its geographical location as a tropical nation situated along the equator, which confers favorable solar energy potential. The usage of solar power through photovoltaic conversion has been extensively implemented, encompassing both individual systems and hybrid systems that integrate conventional energy sources with renewable energy sources (Revolta, 2020; Kual *et al.*, 2022).

When subjected to sunlight of a specific intensity, the surface of this solar cell generates direct current (DC). When solar energy sources are effectively harnessed through the design of an energy converter system capable of meeting energy demands, they have the potential to significantly contribute to various sectors. The utilization of solar energy sources offers numerous benefits, such as the accessibility of cost-free energy sources, environmental sustainability due to its pollution-free nature, and the potential for endless deployment. Hence, it is important to undertake a comprehensive investigation to have a deeper understanding of the electrical system derived from this solar energy source. One of the challenges associated with the utilization of solar energy is the variability in energy generation, which is contingent upon seasonal and environmental factors. This phenomenon is particularly evident in regions characterized by significant variations in solar intensity. Hence, it is imperative to implement an energy storage mechanism, specifically an accumulator or battery. The utilization of solar energy derived from the sun enables the deposition of power into an accumulator, which can thereafter be immediately utilized.

In accordance with the above explanation, the researcher devised a system wherein solar panels were integrated with an automated charger to facilitate the charging of a battery, which serves as a reservoir for the electrical energy produced by the solar panels. The present system comprises solar cells, which serve as a means of generating electrical energy. Researchers at PLTU PT. Puncakjaya Power are now investigating the potential of a Solar Charge Controller (SCC) to serve as a standalone electricity source for lighting purposes. This system combines a controller, battery, and inverter to achieve this objective.

The objective of this research is to investigate the utilization of solar energy through the energy conversion process taking place in solar panels. Specifically, the focus is on utilizing the potential of solar energy to generate electrical energy, with the aim of achieving Indonesia's projected goal of incorporating 23% New Renewable Energy by 2025.

According to the given description, the researcher aims to address four objectives as follows:

1. Calculating the electrical energy consumption of lighting in the PLTU PT. Puncakjaya Power.
2. Analyze the optimal process of converting solar energy to electrical energy at the PLTU PT Puncakjaya Power.
3. Analyze the effect of changes in light intensity and temperature on the power of the Solar Cell.
4. Analyze the technical and economic feasibility of LED lighting systems using solar panels at the PLTU PT Puncakjaya.

Research method

Research type

The present research employs a quantitative research methodology. This study examines the implementation of solar-powered photovoltaic (PV) cells in LED lighting systems at PLTU PT. Puncakjaya Power. The research explores the potential of solar energy as an alternative energy source for lighting operations. In the design, modeling, and real energy production outcomes of Rooftop PLTS on buildings/facilities at PLTU PT. Puncakjaya Power, quantitative methodologies are employed. The findings indicate that the implementation of Rooftop PLTS and the utilization of LED lighting led to cost savings.

Research location and time

The research was carried out at the PT Puncakjaya Power Plant, a coal-fired steam power plant specifically designed to meet the electrical demands of PT Freeport Indonesia in the highland regions. The power plant has a total capacity of 3 X 65 MW and is in Amamapare Timika, Papua. To ensure smooth production, PT Freeport Indonesia as a mining company requires continuous electrical energy, so PT Puncakjaya Power, which consists of Diesel Power Plant (PLTD) and Steam-electric Power Plant (PLTU), tries to meet electricity needs optimally and handle quickly and precisely if there is a disturbance.

The research was conducted between August 2023 and August 2024. The research activities were segmented into distinct stages, including preparation, data gathering, analysis, and report production.

Data Type and Source

This research uses 2 types of data sources, namely:

1. Primary Data

Primary data refers to the outcomes derived from direct measurements and observations conducted in the field, which can serve as informative parameters. In the present research, the main data consist of the documentation regarding the area, structure, building area, and lighting spots.

2. Secondary Data

Secondary data refers to the supporting data that includes information on electricity usage, journals, articles, and climate data.

Data Collection Technique

The data collection techniques were carried out including the following steps:

1. Selection of the Research Site

2. Data Collection of the Lighting Usage

PLTU PT. Puncakjaya Power currently uses fluorescent, incandescent, halogen, HID type lighting. HPS (High Pressure Sodium) lamp power and fluorescent / fluorescent lamps that are converted to LED lights. Lights based on lumens per watt where HPS is 54.2 lumens: LED 105.7 lumen, while fluorescent / fluorescent lamps to led based on comparison, namely fluorescent / fluorescent lamps 23 Watt and LED 10 Watt.

3. Data collection of the intensity, radiation, and temperature of the solar panel

This data collection methodology employs web-based software or applications. At this stage, a field survey is conducted to observe and quantify the criteria employed in the design of rooftop solar power plants, encompassing roof conditions, shading potential, and the energy capacity allocated to buildings or facilities at PT Puncakjaya Power Plant. Geographical coordinates will be obtained by the utilization of GPS technology to ascertain the precise location, facilitating the acquisition of global irradiation data and the subsequent calculation of the roof area using the geotagging methodology. The precise determination of the roof area can be accomplished by the utilization of Google Earth software.

Data analysis technique

The initial stage of the PLTS design was an analysis of the prevailing conditions and availability of the area at the designated location. Moreover, the computation of the magnitude of potential energy that can be produced by the given area is performed. The subsequent phase involves the identification of the lighting region that requires access to crucial areas in the event of electricity interruption from the PLTU and PLTD. This is achieved by modifying the power source capacity of the PLTS, which is optimized based on the system mapping within the given area. The simulation process is conducted using PVsyst software to ascertain the most optimal power capacity that can be achieved.

Findings and discussion

The calculation of electrical energy consumption for lighting

The lighting lamps utilized at PLTU PT. Puncakjaya Power consist of HPS (High Pressure Sodium) lamps and fluorescent lamps, as indicated in table III.2. Data collection is conducted directly in the field, yielding a value of

161.717 KWatt. Subsequently, the conversion process is performed using LED lamps, which are known for their higher energy efficiency. The power obtained from HPS (High Pressure Sodium) lamps and fluorescent lamps is transformed into LED lights. In terms of lumens per watt, the HPS exhibits a lumen output of 54.2 lumens, while the LED demonstrates a lumen output of 105.7 lumens. When comparing fluorescent lamps to LEDs, it is observed that fluorescent lights output 23 Watts, while LED lamps produce 10 Watts. Consequently, the overall conversion result amounts to 79.499 KW. The lighting strategy employed at the WWT Building Plant area is as follows:

1. CA (HPS lamp type with power 250-Watt, voltage 120 Volt) = 28

Total Power = Power x number of lamps
 = 250-Watt x 28
 = 7000 Watt

Converted to LED lights based on lumens to be as follows:
 Power = 7000 x (54,2:105,7)
 = 3589.4 Watt

2. FA (Fluorescent lamp type, Voltage 120 Volts, 800 MA, Power (2X96) Watts) = 3

Total Power = Power x number of lamps
 = 192-Watt X 3
 = 576 Watt

Converted to LED lights based on lumens to be as follows:
 Power = 576 x (10:23)
 = 250,43 Watt

3. FC (Fluorescent lamp type, Voltage 120 Volts, 800 MA, Power (2X96) Watts) = 1

Total Power = Power x number of lamps
 = 192-Watt x 1
 = 192 Watt

Converted to LED lights based on lumens to be as follows:
 Power = 192 x (10:23)
 = 83,48 Watt

4. FD (Fluorescent lamp type, Voltage 120 Volts, 800 MA, Power (2X96) Watts) = 2

Total Power = Power x number of lamps

= 192-Watt x 2
 = 384 Watt

Converted to LED lights based on lumens to be as follows:
 Power = 384 x (10:23)
 = 166.96 Watt

Therefore, the aggregate power consumption of lighting at the WWT building plant can be represented as follows:

Total Power = CA power + FA power + FC power + FD power
 =7000+576+192+384
 =8152 Watt

Moreover, the aggregate power consumption of lighting infrastructure at the WWT building plant after the implementation of LED lighting is:

Total Power =3589.4 +250.43+83.48+166.96
 =4090.27 Watt

Data collection using PV SYST software

This research involved a comprehensive literature review on PLTS technology and a data search to determine the power load demands for lighting at PLTU PT. Puncakjaya Power, Timika Papua. Additionally, the study aimed to gather weather data and average solar radiation values within the PLTU PT. Puncakjaya Power operational region. The present study investigates the application of solar power plant-generated energy for the purpose of powering LED lights, employing 340 Wp solar panels. This study examines the utilization of two PLTS supply systems. The first system, known as on-grid PLTS, is employed when solar energy is available without any battery storage. The second system, referred to as off-grid PLTS, serves as a continuous power source for lighting for 24 hours. Its purpose is to enable the monitoring of critical equipment and provide access in the event of a blackout or complete blackout of the PLTU and PLTD network at PT Puncakjaya Power. The storage battery is utilized during periods when solar energy is unavailable, specifically during nighttime.

The following table presents the daily average solar radiation value of 4.88 kWh/m²/day at the study location. The data for the period of 2016-2021 was obtained from Meteonorm 8.1, with a synthetic sat value of 100% calculated at 0 km.

Table 1: Daily Average Data during 2016-2021

	Global horizontal irradiation kWh/m ² /day	Horizontal diffuse irradiation kWh/m ² /day	Temperature °C	Wind Velocity m/s	Linke turbidity [-]	Relative humidity %
January	5.54	2.68	27.1	1.30	3.373	86.6
February	5.46	2.60	27.0	1.39	3.361	86.4
March	5.54	2.58	27.0	1.30	3.285	86.6
April	5.08	2.43	26.8	1.01	3.343	88.4
May	4.62	1.99	27.3	1.00	3.665	85.8
June	3.97	2.40	26.6	1.09	3.836	86.9
July	4.07	2.35	27.0	1.19	3.812	82.1
August	4.54	2.41	26.9	1.20	3.944	80.9
September	4.57	2.50	26.8	1.10	4.085	83.3
October	4.98	2.75	27.3	1.18	4.308	84.1
November	5.12	2.59	26.9	1.00	4.028	87.7
December	5.08	2.72	27.2	1.09	3.544	87.7
Year	4.88	2.50	27.0	1.2	3.715	85.5

Table 2: Monthly Radiation Values during 2016-2021

	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature	Wind Velocity	Linke turbidity	Relative humidity
	kWh/m ² /mth	kWh/m ² /mth	°C	m/s	[-]	%
January	171.7	83.2	27.1	1.30	3.373	86.6
February	152.9	72.9	27.0	1.39	3.361	86.4
March	171.7	79.9	27.0	1.30	3.285	86.6
April	152.5	72.9	26.8	1.01	3.343	88.4
May	143.2	61.6	27.3	1.00	3.665	85.8
June	119.0	72.0	26.6	1.09	3.836	86.9
July	126.0	72.9	27.0	1.19	3.812	82.1
August	140.7	74.7	26.9	1.20	3.944	80.9
September	137.0	75.0	26.8	1.10	4.085	83.3
October	154.3	85.3	27.3	1.18	4.308	84.1
November	153.6	77.6	26.9	1.00	4.028	87.7
December	157.6	84.2	27.2	1.09	3.544	87.7
Year	1780.1	912.2	27.0	1.2	3.715	85.5

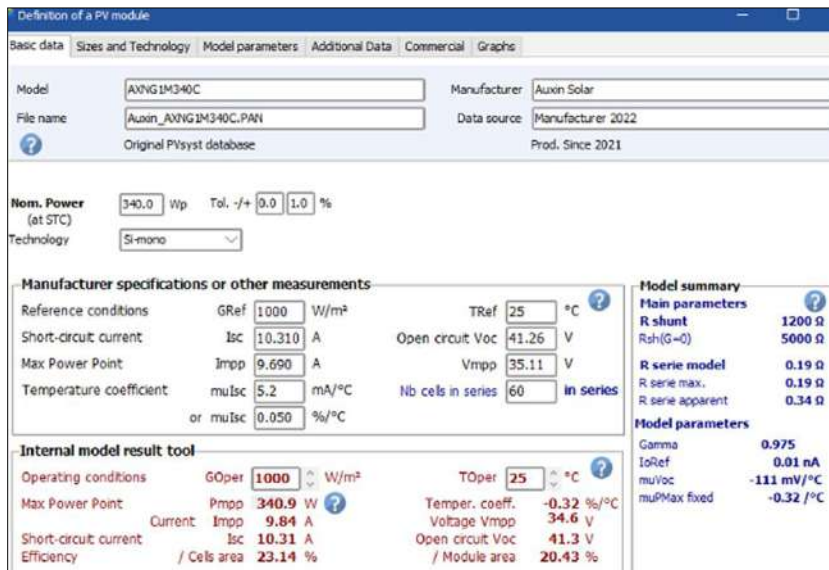


Fig 1: Auxin Solar AXNG1M340C Monocrystalline 340 Wp

The figure above shows the type of solar panel used, namely Auxin Solar AXNG1M340C Monocrystalline 340 Wp, Voc (41.3 V), Isc (10.31 A).

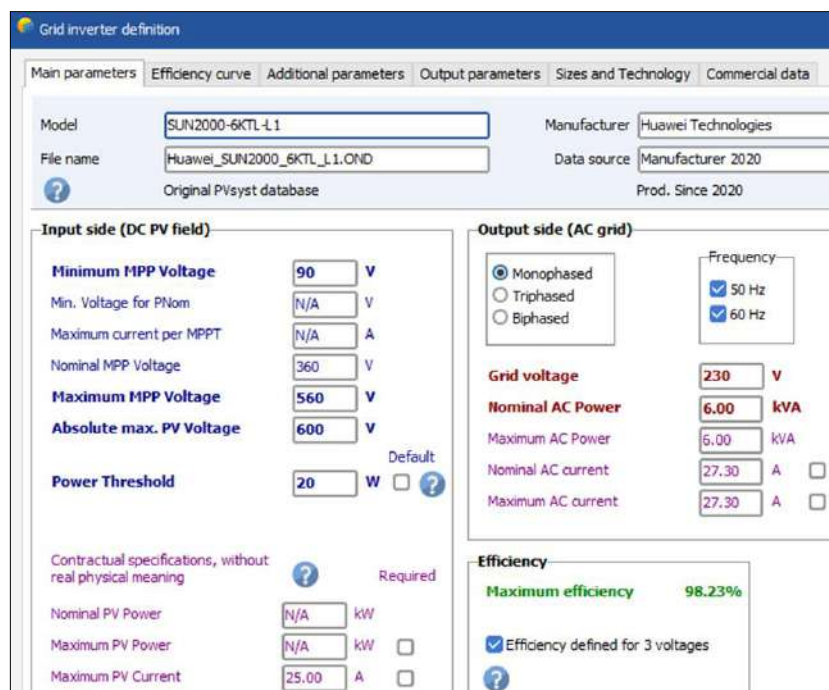


Fig 2: Huawei inverter SUN2000-KTL-L1

Figure 2 above illustrates the simulation of the photovoltaic (Pv) system, highlighting the utilization of the Huawei inverter SUN2000-KTL-L1 model.

The Demin rooftop ongrid solar power plant has been implemented to provide lighting in the Water Treatment Building Plant complex, generating a total power output of 4.09 kW. The Pvsyst software was used to simulate a solar panel system design with an asymptotic angle of 0 degrees

north and a slope of 7 degrees north. The system consisted of 16 units of 340 Wp monocrystalline panels arranged in parallel and series, with a total capacity of 5.44 kWp. Additionally, the Ongrid inverter had a capacity of 5 kWp and operated with 1 unit. The generation capacity of this system is 8236.64 kilowatt-hours per year.

The PVSyst simulation scenario is shown in the figure below.

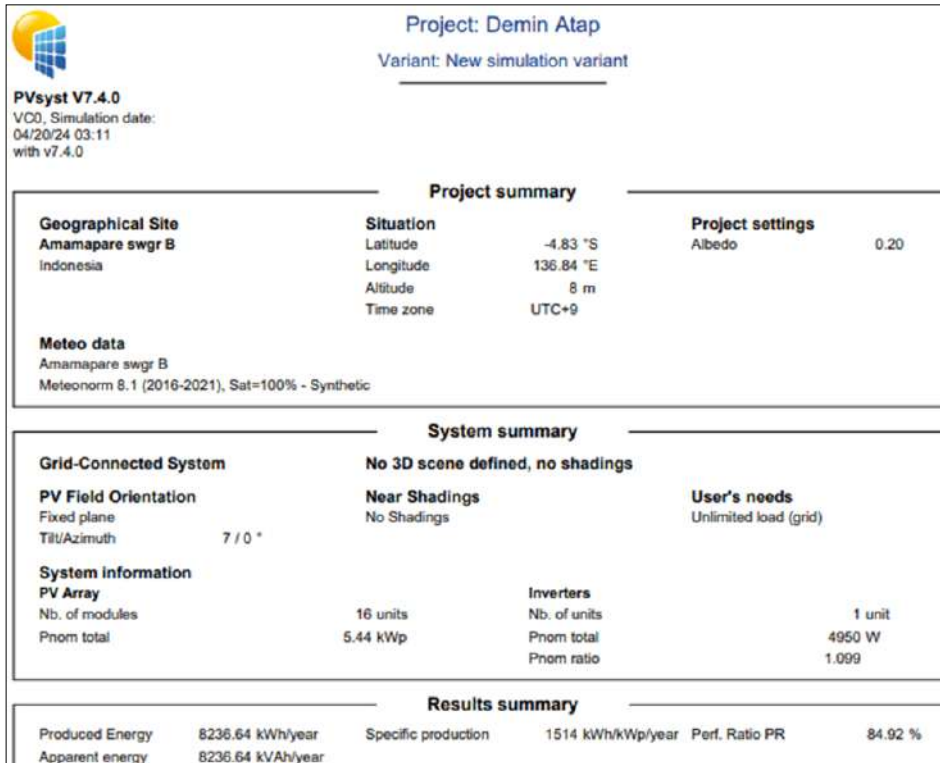


Fig 3: PVSyst simulation scenario on the Demin Roof

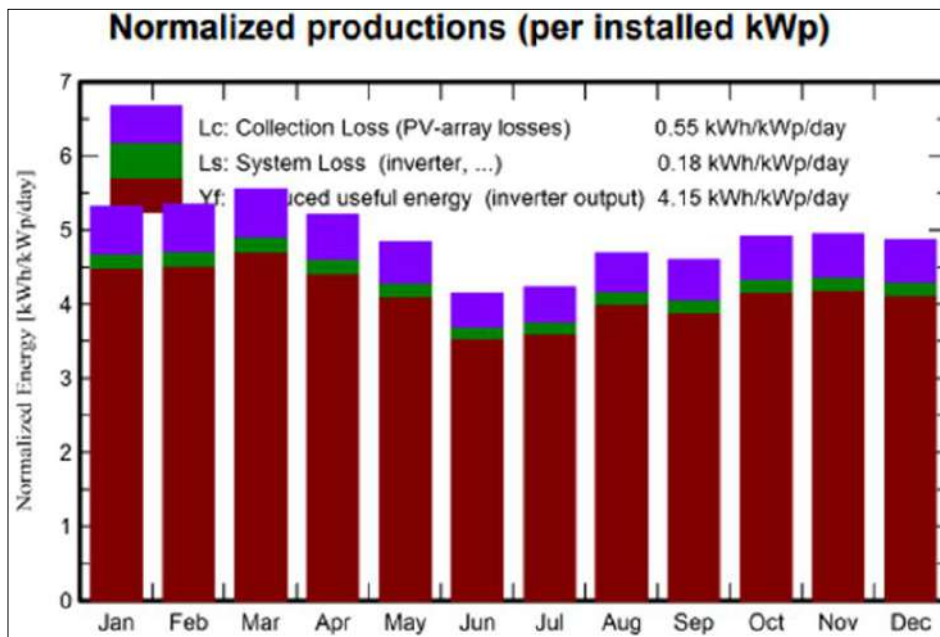


Fig 4: Electric energy generated on Demin Roof

In March, the observed peak in electrical energy production amounted to approximately 4.7 kWh/kWp/day. The mean daily electrical energy generation capacity is approximately 4.15 kilowatt-peak (kWp). Based on the solar panel's total

capacity of 5.44 kWp, the average daily electrical energy generation is estimated to be approximately 22.576 kWh/day.

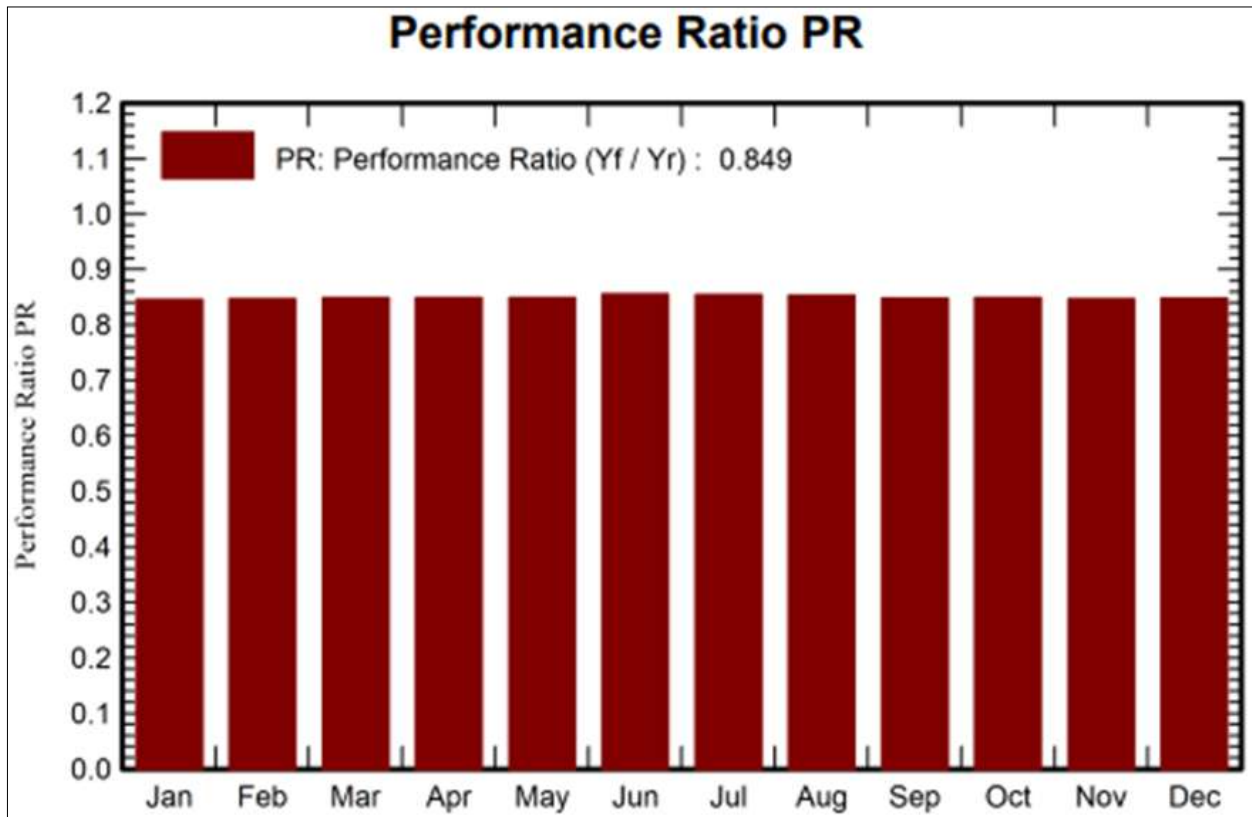


Fig 5: Performance Ratio

The simulated performance ratio, which represents the effective ratio of energy produced to energy required, is

depicted in Figure 5. The performance ratio of the solar photovoltaic (PV) system reached a stable value of 0.849.

Table 3: PVSyst Solar Energy Potential Simulation Results

Balances and main results								
	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray kWh	E_Grid kWh	PR ratio
January	171.7	83.11	27.10	164.8	160.1	791.1	758.4	0.846
February	152.8	72.84	26.97	149.6	145.9	719.2	689.1	0.847
March	171.7	79.85	27.01	172.1	168.3	828.9	794.5	0.849
April	152.5	72.87	26.84	156.1	152.4	752.6	721.2	0.849
May	143.2	61.58	27.29	150.1	146.6	723.3	692.7	0.848
June	119.0	72.03	26.63	124.2	121.0	603.4	577.7	0.855
July	126.0	72.93	26.96	131.1	128.1	636.2	609.0	0.854
August	140.8	75.24	26.93	145.3	142.2	704.4	674.6	0.854
September	136.8	70.24	26.78	137.9	134.5	664.7	636.3	0.848
October	154.3	87.59	27.31	152.3	148.5	733.5	703.0	0.848
November	153.6	75.26	26.95	148.6	144.8	714.8	684.8	0.847
December	157.6	81.23	27.22	150.9	146.5	725.7	695.3	0.847
Year	1780.2	904.76	27.00	1782.9	1738.8	8597.9	8236.6	0.849

Legends	
GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

Table 3 presents the available monthly electrical energy generation capacity of the solar panel system. The available data indicates that the month of March exhibits the largest electricity production, amounting to 794.5 kWh, accompanied by an irradiation value of 171.7 kWh/m².

Conversely, in June, the lowest power production is recorded, measuring 577.7 kWh, with an irradiation value of 119 kWh/m². The mean monthly electrical energy production was recorded as 686.38 kilowatt-hours (kWh).

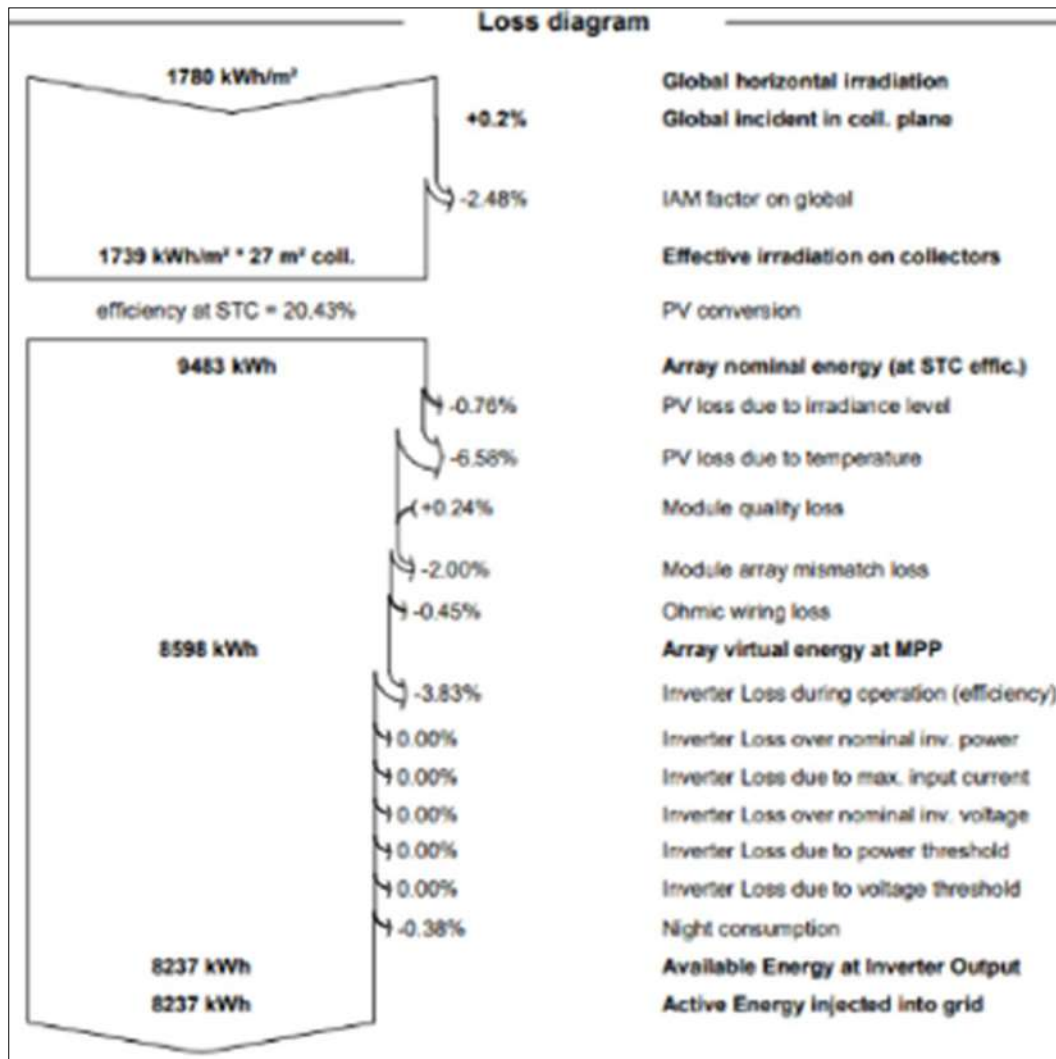


Fig 6: Energy losses in on-grid rooftop solar PV Demin

Within the solar panel system, there exists data pertaining to the Sun's potential energy, which is measured at 1780 kWh/m². Given the solar panel's efficiency level under standard test settings (STC) of 20.43%, the primary source of electrical losses in this solar panel system is attributed to temperature losses, which amount to 6.58%, along with various other losses as depicted in Figure 6. Hence, the aggregate load supply provided to the electrical grid annually amounts to 8236.6 kilowatt-hours (kWh).

Economic analysis of PLTS

1. Initial investment cost

The initial investment cost of PT Puncakjaya Power's rooftop solar power plant encompasses the expenses associated with the components of the PLTS system, as well as the costs incurred in the production of panel supports and necessary installation. The Rooftop PLTS facility of PT Puncakjaya Power is designed to operate on the grid or be connected to the PLN network or other electricity sources without the use of batteries. On the other hand, the offgrid PLTS system is not connected to the PLN network or any other electricity source. The initial investment costs of PT. Puncakjaya Power's ongrid PLTS system in the demin area were determined through a comprehensive analysis of surveys conducted among offline and online retailers affiliated with various e-commerce platforms in Indonesia.

2. Operation and maintenance costs

The annual operation and maintenance (O&M) costs of PT Puncakjaya Power's rooftop solar power plant is computed using the following formula: The maintenance costs were ascertained using Table IV.7. The annual operational and maintenance expenses for PT Puncakjaya Power's ongrid PLTS system in the demin area are typically determined as a conservative proportion of the overall initial investment expenditure for system components. Typically, the estimates encompass a range of 1 to 2% of the initial investment expenditure. In this scenario, the projected annual running expenses for the on-grid solar photovoltaic (PV) system may be determined by utilizing a specific proportion of the overall initial investment cost. This approach ensures that the resulting table closely aligns with the actual costs incurred in the Papua province region. The aggregate starting expenditure amounts to Rp. 4,509,176,560.00, while the yearly upkeep expenditure stands at Rp. 85,353,600.00.

3. Cash flow of plts investment in pltu pt. puncakjaya power

A comprehensive analysis of the feasibility of implementing the PT. Puncakjaya Power Plant involves the assessment of various components, including Cash Inflow, Cash Outflow, Present worth Benefit, Present worth Cost, and Present Interest Factor. The present study suggests that the PLTS is expected to operate for a duration of 25 years,

encompassing the economic lifespan of its constituent components. The study incorporates a discount rate of 6%, aligning with the interest rate set by BI bank for the year 2024. According to the power price administered by PT PLN (PERSERO) as of May 2024, the non-subsidized tariff for electricity stands at Rp.1,699.53 per kilowatt-hour (kWh). As of May 2024, the yearly inflation rate stands at 4.00%. The calculation of the Present worth Benefit value involves the multiplication of the cash input by the Present Interest Factor (FBP), whereas the Present worth Cost is derived by multiplying the cash outflow by the FBP.

4. The calculation of net present value (NPV)

The calculated Net Present Value (NPV) is derived by subtracting the Present worth Cost (PWC) from the Present worth Benefit (PWB) values. Table IV.11 presents the cash flow related to PT Puncakjaya Power's PLTS investment. The PWB value is recorded as Rp. 289,792,727.26, whilst the PWC value is reported as Rp. 193,783,083.33. The Net Present Value (NPV) value will be derived using the subsequent calculation:

$$NPV = PWB - PWC$$

$$NPV = Rp. 289,792,727.26 - Rp. 193,783,083.33$$

$$NPV = Rp. 96,009,643.93$$

In accordance with the stipulations of the computation, the investment is deemed viable and can be presumed to yield advantages if the net present value (NPV) exceeds zero. Conversely, in the event that the net present value (NPV) is less than zero, the investment is anticipated to lack the capacity to provide advantages, hence rendering it unviable. Based on the calculated net present value (NPV) of Rp. 96,009,643.93, it can be concluded that the execution of the PT Puncakjaya Power PLTS Demin area is deemed feasible.

5. The calculation of benefit cost ratio (BCR)

The calculation of the Benefit Cost Ratio (BCR) involves the division of the Present worth Benefit (PWB) by the Present worth Cost (PWC). The cash flow generated from the PLTS investment of PT Puncakjaya Power in the Demin area has a PWB value of Rp. 289,792,727.26, whilst the PWC value amounts to Rp. 193,783,083.33. Therefore, the BCR value can be derived in the following manner:

$$BCR = \frac{PWB}{PWC}$$

$$BCR = \frac{Rp. 289,792,727.26}{Rp. 193,783,083.33}$$

$$BCR = 1.5$$

The BCR value was determined to be 1.5. Therefore, based on the BCR value being more than 1, it may be concluded that the investment in PLTS PT. Puncakjaya Power's Demin region is technically viable.

6. The Calculation of Payback Period (PBP)

In order to determine the predicted repayment time, investors might employ the repayment time (PBP) value computation. The cumulative cash flow and net cash flow for the PLTS investment of PT Puncakjaya Power demin

region have been computed based on the data shown in Table IV.11. Thus, the calculation of PBP can be elucidated as follows:

$$PBP = n + \frac{\text{Cumulative cash flow for the year } (n - 1)}{\text{Net cash flow for the year } n}$$

$$PBP = 10 + \frac{\text{Cumulative cash flow for the year } (9)}{\text{Net cash flow for the year } 10}$$

$$PBP = 10 + \frac{-Rp. 3,748,854.27}{Rp. 16,695,717.64}$$

$$PBP = 10 + \frac{-Rp. 3,748,854.27}{Rp. 16,695,717.64}$$

$$PBP = 9.78$$

Based on the aforementioned calculations, the Payback Period value is determined to be 9.78. This indicates that the investment can be deemed viable as it falls below the specified project life value of 25 years. The capital investment in the Demin area of PT Puncakjaya Power PLTS is expected to yield a return on investment by the tenth year.

Conclusion

The utilization of PVSYST software enables the design of both ongrid and offgrid solar cell systems within the PT Puncakjaya Power PLTU building, with the aim of achieving the optimal capacity of solar panels. Consequently, the outcome of this analysis yields the following conclusions:

1. The electrical energy use for lighting at PT Puncakjaya Power PLTU amounts to a total of 161,717 kWh prior to the implementation of LED lights. However, when LED lights are utilized, the power consumption decreases to 79.50 kWh.
2. A grid-connected lighting system utilizing solar panels comprises a total of 262 units of photovoltaic type 340 Wp, together with 16 units of inverters with a capacity of 5 kW, 1 unit with a capacity of 3 kW, and 5 units with a capacity of 2 kW. The capacity of the system is sufficient to generate a cumulative annual electrical energy output of 127.34 MWh.
3. The proposed lighting system utilizes an offgrid configuration, employing photovoltaic technology with a total capacity of 47.6 kWp and 340 Wp type. The system consists of 140 units and utilizes Universal Controller MPPT Converter Technology. The storage capacity of the system is 180 battery units, with each battery having a voltage of 120 Volts and a power output of 2400 Ah. The system is sealed and features gel technology. The system has the capacity to generate a cumulative annual electrical energy output of 70.29 MWh.
4. After conducting an economic analysis using the Net Present Value (NPV) calculation method and the Benefit Cost Ratio (BCR) calculation, it has been determined that the investment in PLTS on all rooftops of PT Puncakjaya Power ongrid is viable.

Based on the economic analysis conducted using the Net Present Value (NPV) calculation method and the Benefit Cost Ratio (BCR) calculation, it can be concluded that the investment of PLTS on the roof of the PLTU PT. Puncakjaya Power offgrid system is not economically viable. This conclusion is drawn even though the payback period for the investment is 18 years, which does not account for the maintenance and operational costs, which would require 25 years. As observed from an operational perspective at Puncakjaya Power PLTU, the monitoring of important regions proves to be quite beneficial.

References

1. Aboagye B, Gyamfi S, Ofosu EA, Djordjevic S. Degradation analysis of installed solar photovoltaic (PV) modules under outdoor conditions in Ghana. *Energy Rep*,2021;7:6921-31.
2. Aryza S, Hermansyah H, Siahaan AP, Suherman S, Lubis Z. Implementation of solar energy as a supply source for portable farmer fertilizer dryer. *IT J Res Dev*,2017;2(1):12-8.
3. Asrori A, Yudianto E. Study of panel surface temperature characteristics on the performance of mono and polycrystalline type solar panel installations. *Flywheel J Teknik Mesin Untirta*,2019;1(1):68-73.
4. Azizah AN, Purbawanto S. Grid-connected hybrid power plant planning (PV and micro hydro) (Case study of Merden village, Padureso sub-district, Kebumen). *J Listrik Instrumentasi Elektronika Terapan*, 2021, 2(1).
5. Badan Standarisasi Nasional. Energy conservation in lighting systems. *Indonesian National Standard*, 2020, 1-38.
6. Banguero E, Aristizábal AJ, Murillo W. A verification study for grid-connected 20 kW solar PV system operating in Chocó, Colombia. *Energy Procedia*, 2017;141:96-101.
7. Booyesen MJ, Samuels JA, Grobbelaar SS. LED there be light: The impact of replacing lights at schools in South Africa. *Energy Build*,2021;235:110736.
8. Budiyanoto B, Setiawan H. Comparative analysis of the performance of vertical solar panels with flexible solar panels on monocrystalline types. *Resistor (Elektronika Kendali Telekomunikasi Tenaga Listrik Komputer)*,2021;4(1):77-86.
9. Cahyadi CI, Oka IGAAM, Kusyandi D. Battery recharger efficiency in solar power plants. *Edu Elekrika J*,2020;9(2):61-5.
10. Cohen JJ, Azarova V, Kollmann A, Reichl J. Preferences for community renewable energy investments in Europe. *Energy Econ*,2021;100:105386.
11. Dahliya D, Samsurizal S, Pasra N. Efficiency of a 100-wp solar panel under the influence of temperature and wind speed. *Sutet*,2021;11(2):71-80.
12. Ekici S, Gurbuz D, Ekici BB. Investigating the effect of dust and dirt on PV output energy. In: *International Conference on Energy and Thermal Engineering*, 2017, 46-469.
13. Fathurrahman F, Tsaqib N, Tarmizi T, Utami RS. Design of LED driver for public street lighting in solar power plant system by using boost converter. *KITEKTRO J Komput Inform Teknol Dan Elektro*,2023;8(1):49-55.
14. Fuaddin D, Daud A. Design of a 20 kWp on-grid solar power generation system for residential. *J Teknik Energi*,2021;10(1):53-7.
15. Hendarto D. Planning for solarcell-based public street lighting (PJUBS) installation in Cibadak Village. *Prosiding LPPM UIKA Bogor*, 2018.
16. Irfani KN, Windarta J, Handoko S. Study of solar power plant design at UMKM coffee shop in Semarang city in terms of technical feasibility analysis using PVSYST software. *Transient J Ilm Teknik Elektro*,2021;10(4):643-52.
17. Kadang JM, Sutanto H, Saptadi S. Optimizing the performance of photovoltaic power plants through the root cause analysis method.
18. Kariongan Y, Joni J. Planning and economic analysis of rooftop solar power plant with on grid system as supplementary power supply at Mimika Regency Hospital. *J Pendidik Tambusai*,2022;6(1):3763-73.
19. Kual M, Palintin AD, Sarungallo P, Elektro T, Teknik F, Papua U. Designing a rooftop solar power plant at the Faculty of Engineering University of Papua using PVSyst and EasySolar software. *J Inf Sci Technol*, 2022, 11(2).
20. Latupono NI, Rikumahu JJ, Parera LM. Planning of on-grid solar power plant on the roof of the Electrical Engineering Department building of Ambon State Polytechnic. *J ELKO (Elektrikal Dan Komputer)*,2023;2(2):165-74.
21. Lestari NMN, Kumara INS, Giriantari IAD. Review of solar panel status in Indonesia towards the realization of 6500 MW national solar PV capacity. *J Spektrum*, 2021, 8(1).
22. Mohammad L, Istiqomah A, Tahier ARH, Syamputra DNI. Evaluation of techno-economic performance results of solar power plants in higher education buildings in Indonesia. *Briliant J Riset dan Konseptual*,2023;8(2):496-510.
23. Nag SK, Gangopadhyay TK. Design of LED lighting system using solar powered PV cells for a proposed business complex. *Sci Rep*,2022;12(1):1-.
24. Purwoto BH, Jatmiko J, Fadilah MA, Huda IF. Efficiency of using solar panels as an alternative energy source. *Emitor J Teknik Elektro*,2018;18(1):10-4. <https://doi.org/10.23917/emitor.v18i01.6251>
25. Ramadhana RR, Iqbal M, Hafid A, Adriani A. Analisis PLTS On Grid. *Vertex Elektro*,2022;14(1):12-25.
26. Rega MSN, Sinaga N, Windarta J. Rooftop solar PV planning for PT Pagilaran Batang Tea Factory area. *ELKOMIKA J Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika*,2021;9(4):888.
27. Rudawin L, Rajabiah N, Irawan D. Analysis of photovoltaic working system based on tilt angle using monocrystalline and polycrystalline. *Turbo J Prog Studi Teknik Mesin*,2020;9(1):129-37.
28. Semaoui S, Abdeladim K, Taghezouit B, Hadj Arab A, Razagui A, Bacha S, Boulahchiche S, Bouacha S, Gherbi A. Experimental investigation of soiling impact on grid connected PV power. *Energy Rep*,2020;6:302-8.
29. Sinaga Y. Analysis of the utilization of solar energy as an energy source in automatic garbage dredging machines. *Cahaya Bagaskara J Ilmiah*.

30. Sukmajati S, Hafidz M. Design and analysis of a 10 MW on-grid solar power plant in Yogyakarta. *Energi & Kelistrikan*,2015:7(1):49-63.
31. Soedjarwanto N, Endah Komalasari E, Asyraf Fardhan S. Feasibility study of solar power plant (PLTS) with battery and grid connected in Nias, North Sumatra.
32. Sukma IB, Azis A, Pebrianti IK. Planning public street lighting using solar power (solar cell) for alternative street lighting Talang Pete Plaju Darat. *Teknika J Teknik*,2021:8(2):140-6.
33. Suprianto. Calculation analysis for solar home system installation. *Rele Rekayasa Elektrikal Dan Energi J Teknik Elektro*,2021:4(1):60-7.
34. Workala RC, Palintin AD, Stepanus JB. On-grid rooftop solar power plant (PLTS) design study at the University of Papua Rectorate building. *JISTECH J Inf Sci Technol*,2023:11(2):97-106.
35. Kurniawan EA, Sugiono FAF, Larasati PD, Adeguna PD, Pramurtri AR. Analysis of potential electrical power of rooftop PLTS in Directorate Building of Politeknik Negeri Semarang with PVSyst software. *J Energy Electr Eng*, 2023, 75(4).
36. Ritzky OS, Windarta J, Saptadi S. Economic feasibility study of 32 kWp rooftop solar power plant at PT KPJB office building, Tanjung Jati B Power Plant, Jepara Regency. *J Energi Baru Terbarukan*,2023:4(2):97-107.