Type of Contribution:
Research Paper
Review Paper
Case Study

ENERGY: JURNAL ILMIAH ILMU-ILMU TEKNIK
Vol. 15, No. 1 (2025) pp 26-42
DOI: 10.51747/energy.v15i1.1513

E-ISSN: 2962-2565

This article contributes to:

SUSTAINABLE DEVELOPMENT GOALS
7 AFFORDABLE AND CLEAN ENERGY

Technical Feasibility Study and Design of 60 kWP On-Grid Solar Power Plant at Joint Lecture Building-5, University of Muhammadiyah Malang

Nabila Ayu Febrianti[1], **Machmud Effendy**[1,2*], **Basri Noor Cahyadi**[1]

[1] Engineering Profession, University of Muhammadiyah Malang, 65144, **Indonesia**

[2] Electrical Engineering, University of Muhammadiyah Malang, 65144, **Indonesia**

*machmud@umm.ac.id

Abstract

The problem of dependence on fossil energy which has an impact on the energy crisis and the environment. The current renewable energy mix is still at 14% which is far from the 23% target in 2025, encouraging the need for the development of Solar Power Plants (SPP) as part of the New Renewable Energy (NRE) mix in Indonesia. This research aims to design an On-Grid Solar PV system with a capacity of 60 kWp at the Joint Lecture Building-5 (JLB) of Muhammadiyah University of Malang (UMM) and analyze the technical and economic feasibility. The methods used include electrical load survey, climate and radiation data collection, and system design simulation using PVsyst software. The simulation results show an annual Performance Ratio (PR) value of 0.839 with an annual energy production of 105,000 kWh. Energy production analysis shows stable system performance with total losses below 2 kWh/kWp/day. However, based on the economic analysis, the 20-year Net Present Value (NPV) is negative at - IDR 646,841,211, indicating the project is not financially viable without incentive support. Nonetheless, the project is considered technically feasible and can serve as a reference for the implementation of higher education-scale solar power plants.

Keywords: SPP-On-Grid, JLB_UMM, Performance Ratio, NPV

Article Info
Submitted: 2025-04-02
Revised: 2025-05-13
Accepted: 2025-05-27

Publisher
Universitas Panca Marga

1. Introduction

Solar energy is one of the energies utilized in New Renewable Energy (NRE) because of its abundant and unlimited amount. However, in its application, fossil energy still dominates the world. Long-term use of fossil energy has a negative impact on glass emissions and ecosystem damage [1], [2]. Considering this, the Indonesian government through the National Energy Policy (KEN) has set an ambitious target for the new renewable energy mix of 23% which must be achieved by 2025. Coal contributes 61% of electricity generation considering the large coal reserves and PLTU dominated by coal. Indonesia as the largest energy consumer country in Southeast Asia, has low utilization of NRE and more than 85% of energy sources are dominated by fossil energy [3], [4]. According to the Director General of New Renewable Energy and Energy Conversion of the Ministry of Energy and Mineral Resources, fossil energy reserves are increasingly depleted. Data shows that current coal reserves are around 7.3-8.3 billion tons which are predicted to run out in 2026 [5].

The National Energy Policy issued in 2014 stipulated that 23% of Indonesia's renewable energy mix target must be achieved by 2025 – two years from now, and 31% by 2050. The current renewable energy mix is still at 14%, which is far from the target of 23% in 2025 [6]. The Indonesian government continues to strive to encourage the development of SPP, namely by issuing Ministerial Regulation No. 49 of 2018 concerning the use of rooftop SPP that can be connected to the On-Grid network [7]. In addition to having abundant solar energy potential, SPP in Indonesia is a power generation system that is relatively easy to build. In addition, the Indonesian Government continues to strive to encourage the development of SPP, namely by issuing Ministerial Regulation No. 49 of 2018 concerning the use of rooftop SPP that can be connected to the On-Grid network [8], [9].

Many studies related to the feasibility study of SPP and the implementation of SPP have been conducted. Research on the investigation of the feasibility of a rooftop SPP system in the Bandung area has been conducted [10]. This study uses HOMER and Helioscope software, where the 450VA electrical load can be supplied by SPP energy. The results of the study showed that the SPP system was successfully implemented in meeting the daily electricity needs, and the need for a home electricity load of 42% of the total electricity needs can be covered by the SPP system. Further research on the feasibility study of the use of diesel, wind turbines, inverters, and batteries for backup power plants in hotels [11]. To assist in engineering and economic design, this study uses HOMER to assist in the realization process. The results of this research show that the combination of using wind power plants and diesel engines can save operational costs when compared to only using diesel engines as backup power plants to anticipate when national electricity experiences a blackout.

Other research related to the use of SPP has also been able to supply electricity needs in lecture buildings such as on campus [12]-[14]. And from the results of these studies, the strategy of using SPP can reduce electricity costs from national electricity. In addition, it can help the government in reducing carbon emissions so that it can create a healthy and comfortable campus.

In this study, a study of the technical and economic feasibility of on-grid SPP in JLB-5 UMM was conducted. This study uses PV-syst software to determine the productivity, performance, and design of the SPP system. The designed SPP capacity refers to the recommendations of the simulation results and the potential for solar irradiation that can be utilized with the SPP system. Several electrical parameters that will be calculated include SPP energy, technical feasibility, and economic analysis in terms of net present value (NPV).

2. Methods

2.1 Methodology

The stages of this research are shown in **Figure 1** below.

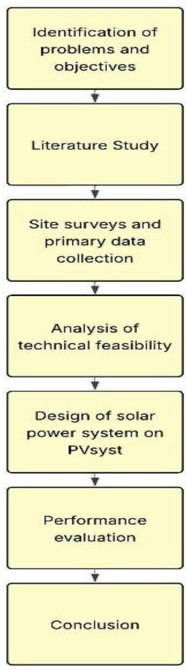

Figure 1. Research Methods Diagram

The image above explains the preparation of the research which begins with identifying the problems and objectives containing energy problems and potential SPP and the objectives of installing On-Grid SPP. The second step is to conduct a literature study by reviewing several things including, aligning the definition of On-Grid SPP and its components, conducting a technical and regulatory feasibility study (Ministry of Public Works and Public Housing standards regarding solar pvroof roof technology). After conducting a literature study, primary data collection and location survey by taking several data including, rooftop area, irradiance data, local climate data, and university electricity load. The fourth step is to design the On-Grid SPP system by calculating the number of strings, panel layout design, inverter selection, and connection scheme to the PLN network. The design and simulation of On-Grid SPP is carried out using PVSyst with production and efficiency estimates. The last step is to draw conclusions regarding technical feasibility along with implementation recommendations.

2.2 Electricity Loading at the University of Muhammadiyah Malang

Before determining the PV power capacity, a load analysis was conducted on the Joint Lecture Building-5 of the University of Muhammadiyah Malang. The electrical distribution system is designed starting from the Low Voltage Main Distribution Panel (LVMDP) as the main panel. The entire load is then distributed to each Sub Distribution Panel (SDP) spread across various areas of the building (as shown in **Figure 2**). Each SDP supplies specific loads such as lights, air conditioners, lifts, pumps and laboratory equipment. This is done to separate the types of loads so that loads with different characteristics are not mixed in one distribution line. In addition, it makes it easier for maintenance engineers to localize the source of the disturbance without turning off the entire system. The LVMDP at the Joint Lecture Building-5 operates with a 3-phase system, 220/380 Volt voltage with a standard frequency of 50 Hz divided into 3 groups of Divider Panels (PP) as follows: PP-hydrant, PP-lift, and PP-ph (as shown in **Table 1**). Further distribution to SDP with a total of 2 SDPs and pp-plumbing (as shown in **Table 2**).

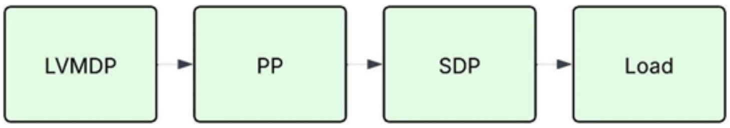

Figure 2. JLB-5 Loading Diagram

The following are the specifications of the LVMDP loading table and at JLB-5, University of Muhammadiyah Malang:

Table 1. LVMDP loading

Group No.	Panel Name	Load Services	Connected Load(Watt)		
			R	S	T
1	PP-Hydrant	*Electric Pump*1x115 kW *Jockey Pump*1x4.5 kW *Diesel Pump*1x2.5 kW	122000	122000	122000
2	PP-Lift	*Lift Service*	3500	3500	3500
		PC PF	1166	1166	1166
3	PP-PH	*Power House*	1844	3000	2100
Total Sub (Watts)			128510	129666	128766
Sub Total (VA)			151188	152548	151486
Sub Total (Amp)			248	248	248

Table 2. SDP Loading

Group No.	Panel Name	Load Services	Connected Load(Watt)		
			R	S	T
1	SDP-1	Normal Load and AC Load	80852	80865	78887
2	SDP-2	Normal Load and AC Load	77292	77082	77187
3	PP-Plumbing	*Diesel Pump*1x2.5 kW	12315	12566	12165
	Total Sub (Watts)		178459	178513	176869
	Sub Total (VA)		209951	210015	208081
	Sub Total (Amp)		339	339	336

2.3 String Count Calculation

Installing PV in quantities of more than 2 requires calculating the effectiveness of the number of strings required. The calculation is done in the following manner,

$$Min.seri\ per\ string = \frac{V\min inverter}{Voc\ PV} \quad (1)$$

with Vmin inverter as the minimum DC voltage of the inverter and Voc PV as the open circuit voltage of the solar panel. [13]

$$Max.seri\ per\ string = \frac{V\max inverter}{Voc\ PV} \quad (2)$$

with Vmax inverter as the maximum DC voltage of the inverter and Voc PV as the open circuit voltage of the solar panel.

$$Max.paralel\ per\ string = \frac{I\max inverter}{Isc\ PV} \quad (3)$$

with Imax inverter as the maximum DC current input of the inverter and Isc PV as the open circuit current of the solar panel.

$$Total\ String = \frac{Total\ PV}{Total\ PV\ seri\ per\ string} \quad (4)$$

2.4 Determining the Capacity of Solar Power Plants

The design of the SPP goes through the capacity determination stage through the following calculations,

$$Capacity\ Load = \frac{Daily\ Load}{(PSH\ x\ Efficiency)} \quad (5)$$

with daily load as the total load per day (kWh), Peak Sun Hours (PSH) as the effective hours of sunlight per day (in Indonesia the average is 5 hours), and system efficiency as the overall efficiency value of the load (with a value of 0.8).[14]

2.5 Economic Analysis of Solar Power Plants

The economic analysis of SPP consists of several cost indicators, including initial investment costs, operational and maintenance costs, component replacement costs (Replacement Present Worth), life cycle costs (Life Cycle Cost), factor conversion costs (Cost Recovery Factor), and SPP energy costs (Levelized Cost of Energy).[15]

$$O\&M = 1\% \; x \; S \qquad (6)$$

with O&M as operational and maintenance costs in 1 year. Cleaning costs along with PV installation are assumed to be 1% according to the Directorate General of EBTKE – Ministry of Energy and Mineral Resources. Parameter S as the initial investment cost.

$$O\&Mpw = \frac{O\&M}{(1+i)^n} \qquad (7)$$

with O&Mpw as the annual O&M cost during the project life (Operation & Maintenance Present Worth). O&M as the operational and maintenance cost in 1 year. Parameter i as the interest rate. Parameter n as the project life (lifetime).

$$Rpw = F \; x \; DF \qquad (8)$$

with Rpw as the component replacement cost, F as the initial component purchase cost, and DF as the component Discount Factor.

$$LCC = S + O\&Mpw + Rpw \qquad (9)$$

with LCC as the cost over the life of the system (Life Cost Cycle), S as the initial investment cost, O&Mpw as the annual O&M cost over the life of the project, and Rpw as the component replacement cost.

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \qquad (10)$$

with CRF as a factor to convert the investment value into fixed annual payments over the life of the project (Cost Recovery Factor) and n as the project age (lifetime).

$$LCoE = \frac{LCC \; x \; CRF}{A \; kWh} \qquad (11)$$

with LcoE as the average energy production cost per kWh (Levelized Cost of Energy), CRF as a factor to convert the investment value into fixed annual payments during the project life (Cost Recovery Factor), and A kWh as the annual energy production value of the SPP (kWh/year).

2.6 Net Present Value Feasibility Method

Net Present Value(NPV) is a method of calculating the net value at the present time. This method uses the Discounted Cash Flow (DFC) technique to calculate the time value of money from all project cash flows.[12]

$$NPV = \sum_{t=1}^{n} \frac{NCFt}{(1-i)^t} - S \qquad (12)$$

with NCF as the net cash flow from year 1 to year n, S as the initial investment, i as the interest rate, and n as the project lifetime.

The decision-making criteria using NPV are based on the final NPV results with details that if NPV > 0, then the investment is said to be feasible, whereas if NPV < 0, then the investment is said to be unfeasible.

2.7 Performance Ratio

Performance Ratio (PR) is defined as the ratio between the AC electrical energy produced by the generator and the theoretical calculation result that would be produced by the generator if the module converted the received irradiance into electrical energy based on the generator's capacity.[8]PR calculates the overall effect of system losses on a PV system, including losses caused by modules, temperature, low light efficiency reduction, inverter, installation, cables, shading and fouling.[16]

$$PR = \frac{Yf}{Yr} \quad (13)$$

with Yf as the net electrical energy produced by the system and Yr as the total irradiation energy received. If PR is in the range of 0.75 - 0.85, then the system is said to be very good or has met the On-Grid SPP system standards. PR is > 0.9, then the system is very efficient. PR is <0.7, then the system needs to be evaluated for design due to shading, temperature, or inverter factors.

3.Results and Discussion

3.1 PV Module and Inverter Specifications

The selection of solar panel modules can be done before determining the number of strings. In this study, the solar panel uses the Solterra brand produced in Cikarang, Indonesia. The following are the specifications of the PV modules used in GKB V Universitas Muhammadiyah Malang (as shown in **Table 3**). The inverter consists of 1 with 4 MPPT of 60 kW with the following specifications (as Shown in **Table 4**).

Table 3. PV specifications

Parameter	Value
Rated maximum power	550W
Maximum power voltage	40.9 V
Maximum power current	13.45 A
Open circuit voltage	49.62 V
short circuit current	14.03 A
Module efficiency	21.33%

3.2 Determining the Number of Strings

In Based on the PV and inverter specifications obtained with a minimum inverter voltage of 200 Volts, a maximum inverter voltage of 1000 Volts, a maximum inverter current of 60 Ampere, a PV open circuit voltage of 49.62 Volts, and a PV short circuit current of 14.03 Ampere. Thus, the following calculations are obtained:

$$Min.\,seri\;per\;string = \frac{200\;Volt}{49.62\;Volt}$$

$$Min. seri\ per\ string \approx 4\ pcs$$

$$Max. seri\ per\ string = \frac{1000\ Volt}{49.62\ Volt}$$

$$Max. seri\ per\ string \approx 20\ buah$$

$$Max. paralel\ per\ string = \frac{60\ Ampere}{14.03\ Ampere}$$

$$Max. paralel\ per\ string \approx 4\ pcs$$

The maximum number of solar module series that need to be connected to the inverter is around 20 units to achieve the maximum input voltage of the inverter of 1000 Volts. However, in the application, the total maximum number of solar module series installed is 15 units so that the number of strings produced is 8 strings with the following formula calculation,

$$Number\ of\ string = \frac{116}{5}$$

$$Number\ of\ \ string = 8\ strings$$

So, the current produced will not reach a maximum of 1000 volts:

$$V\ total\ per\ string = 15\ x\ 49{,}62\ volt$$

$$V\ total\ per\ string = 744\ Volt$$

The formation of the number of PV modules per string less than the maximum number is done as a protection or to ensure that the string voltage remains within a safe range even if there are variations in environmental conditions such as high temperature or module performance discrepancies.

Table 4. Inverter Specifications

Parameter	Value
Model	SI-60K-3PH
MPPT voltage range	200-1000 VDC
Max. short circuit input current	2 x 60 A DC
Rated AC grid voltage	3L/N/PE/ 230/400V
Rated AC grid frequency	50/60 Hz
Rated AC output power	60 W

3.3 Determination of SPP Capacity

Determining the capacity of a solar power plant requires daily load data, peak sun hours, and system efficiency.

$$Capacity\ \ of\ \ SPP = \frac{Beban\ harian}{(PSH\ x\ Efisiensi)}$$

$$Capacity\ of\ SPP = \frac{192\ kWh/hari}{(4\ x\ 0.8)} = 60kWp$$

Thus, SPP JLB-5 UMM designs a SPP capacity of 60 kWp.

3.4 Technical Design of On-Grid SPP at JLB-5 UMM

This research is a study that focuses on the design of the JLB-5 UMM On-Grid SPP using a 60 kW capacity inverter to convert direct current (DC) from solar panels to alternating current (AC) and distributed through the LVMDP (Low Voltage Main Distribution Panel). The GKB-5 UMM SPP uses an On-Grid configuration with an inverter without a battery backup. This system will run if it gets current from the grid (PLN network). The PV module on the JLB-5 UMM is composed of cells produced from semiconductor materials. If sunlight consisting of photons illuminates the cell, the electrons in the semiconductor material will move and produce direct current or Direct Current (DC).

The current will flow to the DC panel with several components, one of which is the Surge Protection Device (SPD) which functions as protection or protection from over voltage due to lightning and the Miniature Circuit Breaker (MCB) functions as protection to protect the system from excess current (over current) or short circuit (short circuit). The SPD and MCB are arranged to adjust the number of strings. Next, the current flows through the inverter by changing the Direct Current (DC) to Alternating Current (AC). The SPP inverter system used in JLB-5 UMM is designed without using batteries (as shown in Figure 3). This system will not run if the grid (PLN network) is blacked out. The design is done by mapping and discussing what components are used based on the specifications and output to be produced.

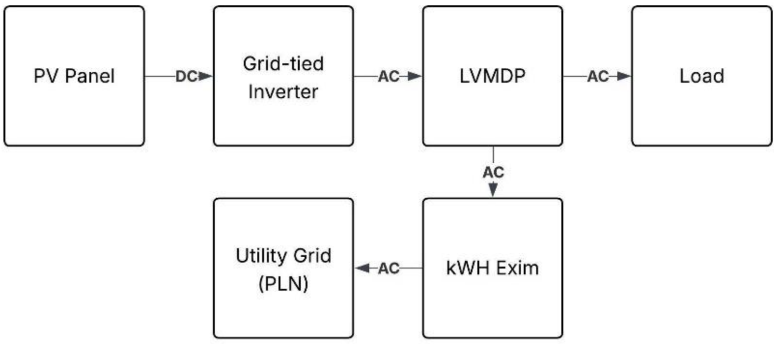

Figure 3. Design of SPP components

In designing PV technical, location coordinate points are needed that can be seen through Google Maps (as shown in Figure 4). The coordinate points of JLB-5 UMM latitude are -7.926144139799383 and longitude are 112.59916471320234. PV is placed on the roof of the auditorium on the 5th floor with a roof length of 28 meters and a roof width of 20 meters. Plane tilt angle is 1° and 15°.

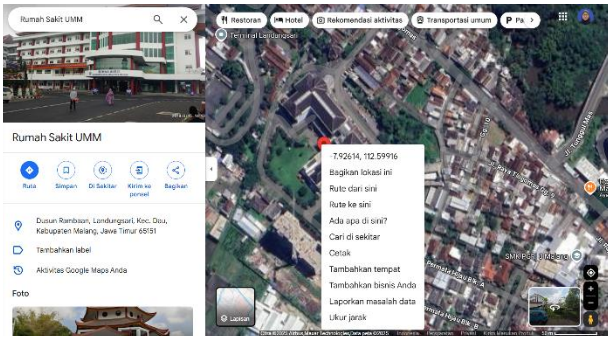

Figure 4. Coordinate Points of JLB-5 UMM

Design using PVSyst can render 3D views with pre-set specifications. The 3D shows at 12.00 WIB where the gray panel indicates that the panel is exposed to near shading more often with lower electricity production. In Figure 5, The yellow panel indicates that some of the panels are shaded, still quite effective but not optimal, while the blue panel indicates that the panel is not shaded, the optimal location, and gets full radiation throughout the day.

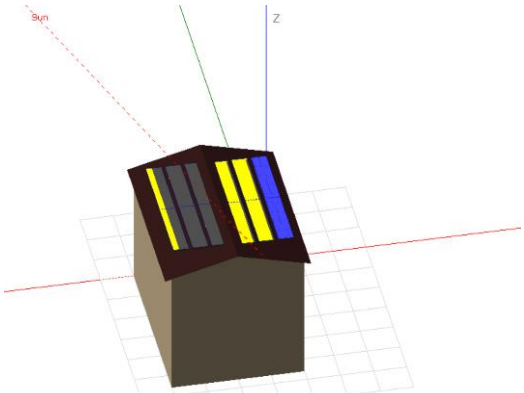

Figure 5. Near Shading SPP

3.5 Performance Ratio (PR) SPP at JLB-5 UMM

The performance ratio results on the JLB-5 UMM SPP have an annual PR value of 0.839, which means that the system produces 83.9% of optimal energy (as shown in Figure 6). The monthly PR range is stable at around 0.83 - 0.84 throughout the year. PR between 0.75 - 0.85 is considered very good for the On-Grid SPP system. There are almost no major fluctuations indicating a stable and consistent system. There are no months that have a drop value, so technically the design and installation of the system are ideal.

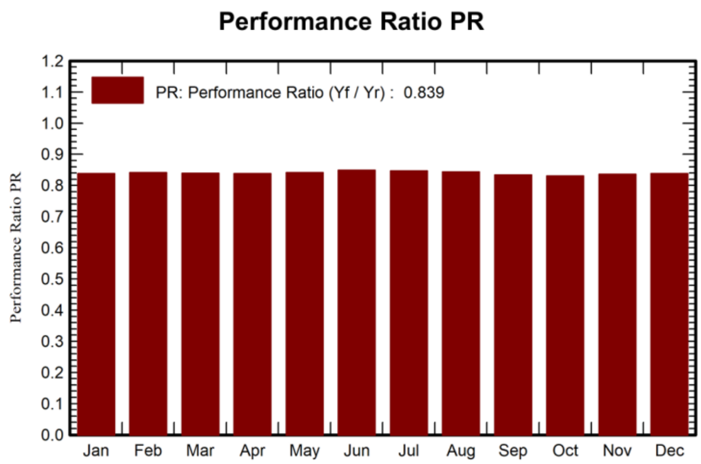

Figure 6. Performance Ratio of SPP

3.6 Analysis of Normalized Productions PV

In Figure 7, the dark red indicator shows the net electrical energy used (Yf), green shows system losses (Ls), and purple shows collection losses (Lc). The data shows that the analysis in January to March showed quite high production in the range of 5 - 5.5 kWh / kWp / day, but experienced slightly larger losses. In April to June, production decreased to around 4.5 kWh / kWp / day with a temporary analysis that in that month range the rainy season dominates. In July to October, production returned to optimal, even approaching the peak in September to October with a value of 5.2 - 5.5 kWh / kWp / day. In November to December, production decreased slightly, but was still above the annual average.

The Yf value is quite stable throughout the year approaching 5 kWh/kWp/day indicating a well-performing and balanced system. The Lc value is in the range of 0.8 – 1.2 kWh/kWp/day adjusting to Indonesia's tropical climate. The Ls value is small in the range of 0.1 – 0.2 kWh/kWp/day indicating the inverter and installation are very efficient. Total losses are still within reasonable limits with a total of <2 kWh/kWp/day.

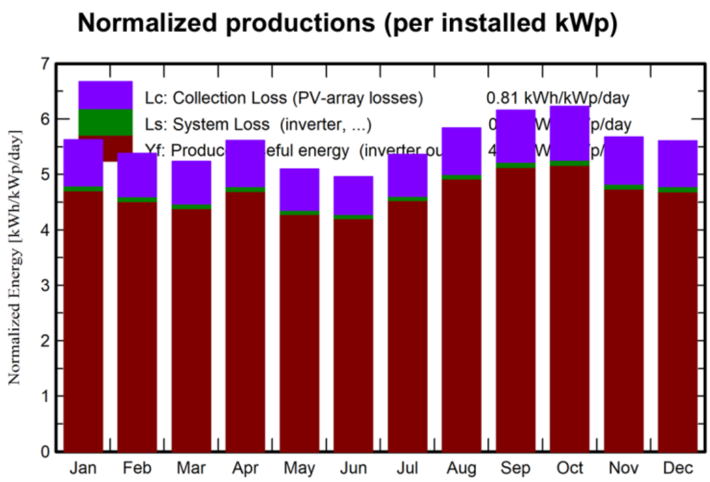

Figure 7. Normalized SPP Production

3.7 Economic Analysis and Feasibility of On-Grid SPP at JLB-5 UMM

Table 5. Initial Investment Costs

Parameter	Unit	Unit price	Total Price
Solar photovoltaic	116 units	3,600,000	417,600,000
Inverter	1 unit	64,500,000	64,500,000
Mounting structure	1 lot	106,400,000	106,400,000
Panel accessories	1 lot	122,800,000	122,800,000
SLO	1 lot	34,700,000	34,700,000
Installation + testing + training services	1 lot	72,700,000	73,700,000
Sub-Total			819,700,000
VAT 11%			90,167,000
Total + VAT			909,867,000

It is known that the initial investment cost (including 11% VAT according to Law Number 7 of 2021 concerning Harmonization of Tax Regulations) is worth IDR 909,867,000 (as shown in **Table 5**). So, to get the operational & maintenance value, the following results are obtained,

$$O\&M = 1\%\ x\ S$$

$$O\&M = 1\%\ x\ 909.867.000$$

$$O\&M = 9{,}098{,}670$$

Thus, the operational & maintenance value obtained is Rp. 9,098,670,-

The next step is to calculate the Operation & Maintenance Present Worth with an estimated 20-year project and an interest rate of 5.75% per April 2025 according to Bank Indonesia (as shown in **Table 6**). The following is the calculation of O&Mpw in the first year,

$$O\&Mpw = \frac{O\&M}{(1+i)^n}$$

$$O\&Mpw = \frac{9.098.670}{(1+5,75\%)^1}$$

$$O\&Mpw = 8.603.943$$

PV has a warranty value of 12 years and inverter has a value of 5 years. In determining the discount factor based on the warranty, the following calculation is required,

$$DF\ PV = \frac{1}{(1+i)^n}$$

$$DF\ PV = \frac{1}{(1+5,75\%)^{12}} = 0,5113$$

$$DF\ Inverter = \frac{1}{(1+i)^n}$$

$$DF\ Inverter = \frac{1}{(1+5,75\%)^5} = 0,7561$$

The DF value of PV is 0.5113, which means that Rp 1 in the 12th year is only worth around Rp 511 as of April 2025 if discounted at an interest rate of 5.75%. Likewise, the DF of the Inverter which is worth 0.7561 means that Rp 1 in the 5th year is worth around Rp 756 today if discounted at an interest rate of 5.75%.

Table 6. O&Mpw calculation

Year (n)	Interest Rate (i)	O&M	O&Mpw
1	5.75%	9,098,670	8,603,943
2			8,136,117
3			7,693,727
4			7,275,392
5			6,879,803
6			6,505,724
7			6,151,985
8			5,817,480
9			5,501,163
10			5,202,046
11			4,919,192
12			4,651,718
13			4,398,788
14			4,159,610
15			3,933,438
16			3,719,563
17			3,517,317
18			3,326,068
19			3,145,218
20			2,974,202

The total value of O&Mpw is Rp. 106,512,494,-

$$Rpw\ PV = F\ x\ DF$$

$$Rpw\ PV = 3.600.000\ x\ 0,5113 = 1.840.680$$

$$Rpw\ Inverter = 64.500.000\ x\ 0,7561 = 48.768.450$$

Total Rpw is Rp 50,609,130,- with the addition of PV and inverter component replacement costs.

$$LCC = S + O\&Mpw + Rpw$$

$$LCC = 909.867.000 + 106.512.494 + 50.609.130$$

$$LCC = 1.066.988.624$$

Thus, the calculation results obtained show that the life cycle costs that must be paid for the GKB V UMM On-Grid SPP for 20 years are IDR 1,066,988,624.

PVsyst V8

Project: GKB V
Variant: New simulation variant

Cost of the system

Installation costs

Item	Quantity units	Cost IDR	Total IDR
PV modules			
Solterra	116	3600000.00	417600000.00
Inverters			
60 kWac string inverter	1	64500000.00	64500000.00
Other components			
Accessories, fasteners	1	122800000.00	122800000.00
Studies and analysis			
Permitting and other admin. Fees	1	34700000.00	34700000.00
Installation			
Global installation cost per inverter	1	72700000.00	72700000.00
Mounting Structure	1	106400000.00	106400000.00
Taxes			
Local taxes	1	0.00	90167000.00
Total			909867000.00
Depreciable asset			604899952.00

Operating costs

Item	Total IDR/year
Total (OPEX)	0.00
Including inflation (3.00%)	0.00

System summary

Total installation cost	909867000.00 IDR
Operating costs (incl. inflation 3.00%/year)	0.00 IDR/year
Produced Energy	105 MWh/year
Cost of produced energy (LCOE)	682.524 IDR/kWh

Figure 8. Cost Simulation Results Through PVSyst

In the simulation results on the PVSyst software (as shown in **Figure 8**), the LCoE value obtained was Rp 683/kWh with the value of produced energy or clean electrical energy produced by solar panels after considering inverter efficiency, panel degradation, and other factors of 105 MWh/year or 105,000 kWh/year.

$$Cash\ in = produced\ energy\ x\ LCoE$$

$$Cash\ in = 105.000\ x\ 683 = 71.715.000$$

Thus, the cash inflow obtained is Rp 71,715,000. The net cash value is obtained by subtracting the cash inflow with the component replacement cost (Rpw) of Rp 50,609,130.

$$NCF = 71.715.000 - 50.609.130$$

$$NCF = 21.105.870$$

The total value of the NPV for 20 years is Rp 263,025,789 by adding up **Table 7** Net Present Value Results in 20 Years. As the initial investment of Rp 909,867,000, it has an NPV value <0 because,

$$NPV = 263.025.789 - 909.867.000 = -646.841.211$$

Thus, based on the feasibility analysis through Net Present Value, the planned SPP does not yet have feasibility from an economic perspective. This is in accordance with the statement that if NPV < 0, then the investment is not feasible (unfeasible) to be realized because it is unprofitable.

Table 7. Net Present Value Results in 20 Years

Year (n)	Discount	NCF	Df	NPV
1	0.05	21,105,870	0.95	20,100,829
2			0.91	19,143,646
3			0.86	18,232,044
4			0.82	17,363,851
5			0.78	16,537,001
6			0.75	15,749,525
7			0.71	14,999,548
8			0.68	14,285,284
9			0.64	13,605,032
10			0.61	12,957,173
11			0.58	12,340,165
12			0.56	11,752,538
13			0.53	11,192,893
14			0.51	10,659,899
15			0.48	10,152,284
16			0.46	9,668,842
17			0.44	9,208,421
18			0.42	8,769,925
19			0.40	8,352,309
20			0.38	7,954,580

4. Conclusion

This study successfully designed an On-Grid SPP system with a capacity of 60 kWp at JLB-5 UMM based on technical and economic analysis using PVSyst software. The simulation results show that the system has an annual Performance Ratio (PR) of 0.839, indicating that the system is capable of producing 83.9% of its optimal energy potential. The PR value is stable throughout the year with minimal fluctuations, meaning that the design and installation of the system have been carried out efficiently and according to standards. Normalized energy production analysis shows that the highest production occurs in September–October (around 5.5 kWh/kWp/day), and the lowest production in May–June (around 4.3 kWh/kWp/day), which is still above the reasonable threshold for tropical regions. Losses System and Losses Collection (Lc and Ls) remain within the tolerance limit of <2 kWh/kWp/day, indicating excellent system performance. However, from an economic perspective, the calculation results show that this project is not yet financially feasible. The Net Present Value (NPV) for 20 years is negative at Rp 646,841,211, which means that the total cash inflow is less than the total investment and operational costs of the system. With an LCoE of Rp 683/kWh and a total energy output of 105,000 kWh/year, this investment is still not profitable from a conventional financial perspective. Technically, this SPP project is very feasible and can be used as a model for implementing EBT in the education sector. However, financially, the project will be more attractive if there is additional support in the form of government incentives, tax cuts, or an increase in electricity sales rates through a net-metering scheme.

Authors' Declaration

Authors' contributions and responsibilities - The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation, and discussion of results. The authors read and approved the final manuscript.

Funding - No funding information from the authors.

Availability of data and materials - All data is available from the authors.

Competing interests - The authors declare no competing interest.

Additional information - No additional information from the authors.

References

[1] Effendy, M., Ashari, M., & Suryoatmojo, H. (2022). Load Sharing and Voltage Restoration Improvement in DC Microgrids with Adaptive Droop Control Strategy. International Journal on Engineering Applications (IREA), 10(4), 233.https://doi.org/10.15866/irea.v10i4.21483

[2] Sari, DP, Kurniasih, N., & Fernandes, A. (2020). Utilization of Solar Power as an Electricity Supply to Power Water Pumps for the Community of Cilatak Hamlet, Sukadana Village, Ciomas District, Serang Regency, Banten. Terang, 3(1), 68–79.https://doi.org/10.33322/terang.v3i1.1019

[3] G. Lahope, K. Kunci, EB Renewable, K. Energy, and T. Energy, "Implementation of Indonesia's National Energy Policy (KEN) Towards 23% New and Renewable Energy (EBT) Mix Target 2025," J. Darma Agung, no. 2024, pp. 124–135, 2024. https://dx.doi.org.10.46930/ojsuda.v32i1.3945

[4] Handayani, YS, Alex Surapati, & Fitrilina. (2022). Implementation of Small SPP in Charging Houses as an Effort to Develop Tourism in Rindu Hati Village. Dharma Raflesia: Scientific Journal of Development and Application of IPTEKS, 20(2), 352–364.https://doi.org/10.33369/dr.v20i2.24535

[5] RA Aprilianto and RM Ariefianto, "Opportunities and challenges towards net zero emission (NZE) using variable renewable energy (VRE) in the electricity system in Indonesia," J. Paradig., vol. 2, no. 2, pp. 1–13, 2021. https://doi.org/10.22146/jpmmpi.v2i2.70198

[6] Ilham R. (2023). Impact Analysis of Rooftop Solar Power Plant Implementation Policy on Government Buildings Using Projection Scenarios. ELKOMIKA: Journal of Electrical Energy Engineering, Telecommunication Engineering, & Electronic Engineering, 11(4), 834. http://dx.doi.org/10.26760/elkomika.v11i4.834

[7] Candra Erawan, IN, Setiawan, IN, & Sukerayasa, IW (2023). Analysis Of Carbon Emission Mitigation And The Economics Of On-Grid Rooftop Solar

Power Plants (Spp) 463.25 Kwp In A Pharmaceutical Company In The Pt Jakarta Industrial Estate Area, Pulogadung, East Jakarta. Spektrum Journal, 10(3), 29.https://doi.org/10.24843/spektrum.2023.v10.i03.p4

[8] M. Effendy et al., "Technical and Economic Feasibility Study of Rooftop Solar Power Plant at Rayz Hotel, University of Muhammadiyah Malang," Techné J. Ilm. Elektrotek., vol. 23, no. 1, pp. 95–106, 2024, doi: 10.31358/techne.v23i1.455.

[9] Republic of Indonesia (2018). Regulation of the Minister of Energy and Mineral Resources No. 49 of 2018 concerning the Use of Rooftop Solar Power Generation Systems by Consumers of PT Perusahaan Listrik Negara (Persero)

[10] BSAprillia and MAFoury Rigoursyah, "Design On-Grid Solar Power System for 450 VA Conventional Housing using HOMER Software," IOP Conf. Ser. Mater. Sci. Eng., vol. 771, no. 1, 2020, doi: 10.1088/1757-899X/771/1/012011

[11] H. Mubarok and TK Yoga, "Economic Studies of the Wind Turbine Diesel Hybrid Power Generation System (Case Study at: Queen of the South Beach Resort Hotel, Yogyakarta, Indonesia)," in 2018 International Seminar on Application for Technology of Information and Communication, 2018, pp. 591–596.

[12] R. Rafli, J. Ilham, and S. Salim, "Planning and Feasibility Study of Rooftop Solar Power Plant at Faculty of Engineering Building, UNG," Jambura J. Electr. Electron. Eng., vol. 4, no. 1, pp. 8–15, 2022, doi: 10.37905/jjeee.v4i1.10790.

[13] H. Gusmedi, RP Putra, AS Samosir, U. Lampung, and KB Lampung, "DESIGN OF 60 KWP ON-GRID SOLAR POWER PLANT (SPP)," vol. 13, no. 1, pp. 129–137, 2025.

[14] ERMAPL Pinky Kartikasari, Azmain Noor Hatuwe, "Theoretical Design Of Centralized Spp As An Alternative To Electricity Supply For Sucker Rod Pump Needs Pinky," J. Mech. Eng. (JME)., vol. 2, no. 3, pp. 105–114, 2024.

[15] SDA Febriani and CT Rani, "Techno-Economic Study of On-Grid System in Smart Greenhouse," J. Tech. Ap., vol. 3, no. 1, pp. 1–9, 2024, doi: 10.25047/jteta.v3i1.33.

[16] Wahyu Syahrir, "Analysis Of Solar Power Plant Planning (Spp) With On Grid System In Port Office Building Of Pt.Pupuk Kalimantan Timur," J. Syntax IDEA, vol. 6, no. 1, pp. 471–486, 2024.