Design of Solar Photovoltaic System at Language Center of Tanjungpura University using PVsyst

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ABSTRACT

West Kalimantan is widely available new renewable energy sources (RES) in the form of sufficient solar energy potential to become a Solar Power Plant (SPP) especially for areas that have high solar potential, such as in Pontianak which is located on the equator then. This study evaluates the Solar Power Plant which is located at the UPT Language of Tanjungpura University, Southeast Pontianak District, Pontianak City. The tool used to help solve the problems in this study is the PVsyst software. This tool is used to analyze the planning of SPP. The total load of electrical energy used consists of 6 electronic devices which is often used at the UPT Language of the University of Tanjungpura per day is 80,584 kWh/day, and for the need for electrical energy for 1 year of 29,010 kWh/year. For the results of energy production by a panel with a nominal capacity of 22 kW which is capable of producing a total energy of 32.904 kWh/year. From the results of the economic analysis in this study, the total NPV was obtained Rp.397,823,869, LCC Rp.555,807,731 for a COE of Rp.1.478/kWh for maintenance and operational costs of Rp.4,928,090,and Discount Payback Periode (DPP) 15.1 year is the result of 25 years of economic analysis obtained from the PVsyst software simulation source.

Keywords:
Renewable Energy
Solar Power Plant Planning
Software PVsyst
Electrical Energy
PLTS off grid

1. INTRODUCTION

Energy has been a major necessity throughout human civilization. An increase in energy demand can be an indicator of increased prosperity, but at the same time it poses a problem in the effort to provide it. With the depletion of petroleum reserves in Indonesia, the utilization of alternative non-fossil energy must be increased [1].

Indonesia as a tropical country has high solar energy potential with an average daily radiation (insolation) of 4.5 kWh/m2/day. This potential can be utilized as an alternative energy source that is cheap and available throughout the year. In addition, the geographical condition of Indonesia, which consists of thousands of islands, means that there are still many re Therefore, the application of Solar Power Plant (PLTS) technology to utilize the potential of solar energy available in these locations is the right solution. But especially to meet the needs of electrical energy at UPT Language Tanjungpura University with an off grid system using PVsyst software [3].

2. METHOD

An explanation of the research process chronologically, including the research design, the research methodology (whether algorithms, pseudocode, or other), and the testing and data acquisition processes. References should be provided to support the description of the course of research, so that the explanation can be accepted scientifically. Figures 1-2 and Table 1 are presented center, as shown below and mentioned in the manuscript.
2.1 Solar Power Plant

Solar power generation is a power generation technology that converts energy from solar radiation into electrical energy. To date, solar energy has been popular among other renewable energy sources mainly because of its plug and play feature, unlike other power sources that require mechanical support such as motors or generators (hydropower, wind, wave) or chemical support (biofuels) which are mostly state-oriented. Solar technology is new and evolving at a linear pace. Solar technology has been popularized since its application as an alternative energy source for pocket calculators. Now solar panels are used along north-south highways, telecommunication towers, and even for street lighting. This conversion of solar energy into electrical energy is done on solar panels consisting of photovoltaic cells.

2.2 Working System Configuration

PLTS is a module unit that can produce electrical energy by utilizing solar radiation. The amount of electrical energy that can be produced by the PLTS system is based on the intensity of the sun, so the PLTS system cannot work when there is no sunlight either at night or cloudy. The dominant PLTS system has a very large energy storage to store its energy, but some PLTS systems do not use energy storage so that they can only work when sunlight is adequate. Energy can generate electrical energy through a process called photovoltaic (PV).

2.2.1 PLTS Off Grid

In conducting research using the Off Grid Solar Power Plant System (PLTS) is a power generation system that utilizes solar radiation without being connected to the PLN network. Off Grid PLTS systems rely on solar radiation energy with the help of solar panels or photovoltaic. As the only source of electricity, it is safe from pollution or does not pollute the air. So it is feasible if done for UPT Language, with the scheme in Figure 1 as follows:

![Figure 1. Desain system for PLTS Off Grid at Upt Language](image)

2.3 Component PLTS

2.3.1 Monocrystalline

The physical characteristics of this type of monocrystalline solar cell are its segidelap shape, and darker color. The manufacture of this type of solar cell is quite complicated and requires expensive production costs, so the selling price is also higher. Despite the high price, this type of panel has a higher efficiency value than the others. In this PLTS planning using Mage Powertec Plus 250 WP.

2.3.2 Battery

Batteries are one of the most commonly used means of power storage. The battery is an important component that affects the overall centralized solar system. Battery maintenance, service life, power, and efficiency are battery parameters that affect the performance of centralized solar power plants. The most appropriate battery for a solar power system is one that has a Deep Discharge character type. This type of battery can be discharged until about 20% of the battery's storage capacity remains. (Batteries for starting motor vehicles are generally only allowed to be discharged until 80% of the battery's storage capacity.
remains. If discharged beyond this capacity, the battery life will be shorter. In this PLTS planning, a lead acid battery type NPP with 12v and 200 Ah is used.

2.3.3 Solar Charge Controller

Solar Charge Controller (SCC) is electronic equipment used as a regulator of the current charged to the battery and taken from the battery to the load. Solar Charge Controller (SCC) regulates overcharging and excess voltage from solar panels. In this PLTS planning using SCC smart solar 250 W / 100 A.

2.3.4 Inverter

An inverter is an electrical device used to convert direct current (DC) electricity into alternating current (AC) electricity. Inverters convert DC from devices such as batteries, solar panels / solar cells into AC. The use of inverters from within the Solar Power Plant (PLTS) is for devices that use AC (Alternating Current). The output voltage can be fixed or variable with a fixed or variable frequency as well. The variable output voltage can be determined by changing its DC input output voltage, in which case the gain of the inverter is kept constant. In this PLTS planning using the Must PV3500 PRO.

2.4 PVsyst

PVsyst is a comprehensive computer application software for solar systems that includes a set of tools for studying, rescaling, simulating and analyzing PVsyst system data. In this simulation stage, PVSyst software version 7.3 is used as the main tool to analyze the performance and potential for electrical energy generation. PVSyst is a software package used for the process of learning, sizing, and analyzing data from a complete solar power system.

2.5 Calculation PLTS

\[
P_{\text{Area}} = \frac{EL}{G_{\text{av}} \times TCF \times \eta_{PV}}
\]

(1)

Perhitungan Daya

\[
P_{\text{wattpeak}} = P_{\text{Area}} \times PSI
\]

(2)

Jumlah Panel Surya

\[
\text{Total Panel surya} = \frac{P_{\text{watt peak}}}{P_{\text{mppt}}}
\]

(3)

Kapasitas SCC

\[
SCC = \frac{\text{Daya yang dibangkitkan x Faktor keamanan}}{\text{Sistem Tegangan}}
\]

(4)

Kapasitas Inverter

Inverter Capacity = Maximum inverter power x Safety Factor

(5)

Kapasitas Baterai

\[
C = \frac{N \times E_{d}}{V \times \text{DOD} \times \eta}
\]

(6)

2.6 Ekonomi Aspek

Maintenance and Operational Costs

\[
M = 1\% \times \text{Total biaya investasi [Rp]}
\]

(7)

The present value of annual costs to be incurred in the coming years (over the life of the project), with a fixed amount of expenditure, is calculated using the following formula:

\[
M_{PW} = M \left[ \frac{(1+i)^n-1}{i(1+i)^n} \right]
\]

(8)

Life Cycle Cost

\[
LCC = C + M_{PW}
\]

(9)
Discount Factor
\[ \text{DF} = \frac{1}{(1+i)^n} \]  

Cost Of Energy
\[ \text{CRF} = \frac{(1+i)^n}{(1+i)^n - 1} \]  

Within being the period (life) of the project, the energy cost formulation is as follows:
\[ \text{COE} = \frac{LC \times CRF}{AKWH} \]  

2.7 Investment Feasibility Analysis

Net Present Value
\[ \text{NPV} = \sum_{t=1}^{n} \frac{NCFI}{(1+i)^t} \times C \]  

Profitability Index
\[ \text{PI} = \frac{\text{present value of cash flows}}{\text{initial investment}} \]  

Discounted Payback Period
\[ \text{DPP} = \text{The year before the final return} + \frac{\text{initial investment costs}}{\text{total net cash value}} \]  

3. RESULTS AND DISCUSSION

3.1 Place And Time Research

The first step is to determine the location of the project. In this research, the location of UPT Bahasa Tanjungpura University which is located on Jalan Professor Doctor H. Hadari Mawawi, Bansir Laut, Southeast Pontianak District, West Kalimantan Province is located at the point (00.054417 °LS, 109.34967 °BT). UPT Bahasa Tanjungpura University.

3.2 Solar Potential

In this study using the potential of solar energy for this system generator, namely solar irradiation data obtained by Meteonorm 8.1 data from the PVsyst program for UPT Bahasa Tanjungpura University as shown in Table 1.

<table>
<thead>
<tr>
<th>Month</th>
<th>Horizontal global irradiation kWh/m²/day</th>
<th>Horizontal diffuse irradiation kWh/m²/day</th>
<th>Temperature°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Januari</td>
<td>4.22</td>
<td>2.26</td>
<td>26.8</td>
</tr>
<tr>
<td>Februari</td>
<td>4.62</td>
<td>2.75</td>
<td>27.0</td>
</tr>
<tr>
<td>Maret</td>
<td>4.86</td>
<td>2.45</td>
<td>27.3</td>
</tr>
<tr>
<td>April</td>
<td>5.02</td>
<td>2.58</td>
<td>27.0</td>
</tr>
<tr>
<td>Mei</td>
<td>4.82</td>
<td>2.34</td>
<td>27.7</td>
</tr>
<tr>
<td>Juni</td>
<td>4.83</td>
<td>2.39</td>
<td>27.3</td>
</tr>
<tr>
<td>Juli</td>
<td>5.05</td>
<td>2.39</td>
<td>27.2</td>
</tr>
<tr>
<td>Agustus</td>
<td>4.90</td>
<td>2.75</td>
<td>27.5</td>
</tr>
<tr>
<td>September</td>
<td>4.20</td>
<td>2.62</td>
<td>26.9</td>
</tr>
<tr>
<td>Oktober</td>
<td>4.16</td>
<td>2.72</td>
<td>26.9</td>
</tr>
<tr>
<td>November</td>
<td>4.28</td>
<td>2.38</td>
<td>27.0</td>
</tr>
<tr>
<td>Desember</td>
<td>4.24</td>
<td>2.28</td>
<td>26.4</td>
</tr>
<tr>
<td>year</td>
<td>4.60</td>
<td>2.49</td>
<td>27.1</td>
</tr>
</tbody>
</table>
3.3 Electrical Load UPT Language

UPT Language requires electricity needs, especially lighting that requires electricity supply. Among them, lamps, PC, TV, dispensers, air conditioners, speakers for UPT Language to meet the electricity needs of UPT Language, an alternative energy is designed, namely a solar power plant with the following load data shown in Figure 2.

![Figure 2. User need’s](image)

3.4 Calculating Area Array (PV Area)

The amount of electrical energy usage (EL) UPT Bahasa that will be supplied by PLTS is 80,584 kWh. For the average daily solar insulation value (Gav) in 2023, which is 80.6 kWh/m2. Generally, solar panels (ηPV) only have an efficiency of around 20%. Every 1°C increase in temperature from the standard temperature of the solar panel will decrease by about 0.5%. The maximum temperature data for Pontianak in 2023 is 27.7°C. This temperature data shows that there is an increase of 2.7°C from the standard temperature (25°C) required by solar panels. The amount of power reduced at the standard temperature is calculated using the following formula:

\[
P_{\text{when riding}}^\text{2.7°C} = 0.5\% \times P_{\text{MPP}} \times \text{temperature rise (°C)}
\]

\[
= 0.5\% \times 250 \text{ W} \times 2.7\text{°C}
= 3.37 \text{ W}
\]

For the maximum output power of the solar panel when the temperature rises to 27.7°C, calculated by the formula:

\[
P_{\text{MPP when riding}}^\text{°C} = P_{\text{MPP}} \times P_{\text{when riding}}^\text{°C}
\]

\[
P_{\text{MPP when t=27.7°C}} = 250 \text{ W} - 2.7 \text{ W}
= 247.3 \text{ W}
\]

Based on the calculation of the maximum output power of the solar panel when the temperature rises to 27.7°C, the TCF value can be calculated using the following formula:

\[
\text{TCF} = \frac{P_{\text{MPP when riding}}} {P_{\text{MPP}}}
\]

\[
\text{TCF} = \frac{247.3 \text{ W}} {250 \text{ W}} = 0.98
\]

Gav is determined from the minimum value of solar irradiation of components that complete the PLTS such as: battery, change controller, and inverter. Because the PLTS that will be developed at UPT Bahasa is only equipped with an inverter, the value for ηout is determined based on the efficiency of the inverter, which is 0.9.

If the values of EL, Gav, ηPV, TCF are inserted into the formula, it will be obtained that:

\[
\text{EL} = 80,524 \text{ kWh}
\]

\[
\text{Gav} = 4.16
\]

\[
\text{TCF} = 0.98
\]

\[\eta_{PV} = 20\% / 0.2\]

\[\eta_{out} = 0.9\]

\[
\text{PV Area} = \frac{\text{EL}} {\text{Gav} \times \eta_{PV} \times \text{TCF} \times \eta_{out}}
\]

\[
\text{PV Area} = \frac{80,584 \text{ kWh}} {4.16 \times 0.2 \times 0.98 \times 0.9}
= 109.81 \text{ m}^2
= 109 \text{ m}^2
\]

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3.5 Calculating Power PLTS (Watt peak)
With an array area of 109 m², Peak Sun Insolation (PSI) is 1000 W/m² and solar panel efficiency is 20% then:

\[ P_{\text{Watt peak}} = 109 \text{ m}^2 \times 1000 \frac{\text{W}}{\text{m}^2} \times 0.2 \]
\[ = 21.800 \text{ Watt peak} \]

3.6 Calculating The Number of Solar Panels
The solar panels required as a reference are solar panels that have a P_MPP specification of 250 W per panel. So based on these specifications, the number of solar panels needed for the PLTS to be developed can be calculated by the formula.

\[
\text{Number of solar panel} = \frac{P_{\text{Watt peak}}}{P_{\text{MPP}}} = \frac{21.800 \text{ WP}}{250 \text{ W}} = 87.2
\]
\[ = 87 \text{ panel surya} \]

The number of solar panels is divided into 2 series of arrays, and the number of each array of solar panel installations is connected in series and parallel. While the results of the PVsyst software the number of panels determined is 85 solar panels mounted in series 5 and 17 in parallel.

3.7 Calculating Capacity of Battery
If the battery used is 200 Ah, then the number of batteries required is:
- Number of battery = \( \frac{35343}{200} = 176.7 \) = 176 battery
- Battery voltage capacity in series = 9 x 12 = 108 V
- Battery voltage capacity in parallel = 18 x 200 Ah = 3600 Ah

From the above calculations obtained 176 number of batteries, adjusting to the PVsyst program using 162 batteries installed 9 in series and 18 in parallel which are used in this PLTS planning.

3.8 Economic Calculation Of PLTS
This economic calculation is an investment cost plan that will be issued for the construction of Off Grid PLTS at UPT Bahasa Tanjungpura University. Where this cost is the cost of components that will be used in this planning is shown in Table 2.

<table>
<thead>
<tr>
<th>No</th>
<th>Component</th>
<th>Total</th>
<th>Price (Rp)</th>
<th>Total price (Rp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solar Module</td>
<td>85</td>
<td>1.400.000</td>
<td>119.000.000</td>
</tr>
<tr>
<td>2</td>
<td>Battery</td>
<td>162</td>
<td>2.000.000</td>
<td>324.000.000</td>
</tr>
<tr>
<td>3</td>
<td>Inverter</td>
<td>2</td>
<td>5.950.000</td>
<td>11.900.000</td>
</tr>
<tr>
<td>4</td>
<td>SCC</td>
<td>1</td>
<td>4.509.000</td>
<td>4.509.000</td>
</tr>
<tr>
<td>5</td>
<td>Panel support</td>
<td>42</td>
<td>200.000</td>
<td>8.400.000</td>
</tr>
<tr>
<td>5</td>
<td>Installation cost</td>
<td></td>
<td></td>
<td>25.000.000</td>
</tr>
<tr>
<td>6</td>
<td>Total</td>
<td></td>
<td></td>
<td>Rp.492,809.000</td>
</tr>
</tbody>
</table>

In accordance with the component price data table, according to the component price, it can be estimated that the initial investment in this study is:
Rp.492,809,000

3.8.1 Maintenance And Operating Cost
M = 1% x Total investment cost
\[ = 1\% \times \text{Rp.492,809,000} \]
\[ = \text{Rp.4,928,090/Year} \]

3.8.2 Calculating Life Cycle Cost
The PLTS UPT Bahasa is assumed to operate for 25 years. The determination of the project life refers to the warranty issued by the solar panel manufacturer. The amount of discount rate (i) used to calculate the present value in this study is 6%. The determination of this discount rate refers to the Bank Indonesia lending rate as of April 17, 2023. The present value for maintenance and operational costs (\(M_{\text{pw}}\)) of PLTS UPT Bahasa during the project life of 25 years with a discount rate of 6% is:

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3.8.3 Calculating The Energy Cost Of PLTS

The capital recovery factor for converting all life cycle cost (LCC) cash flows into a series of annualized costs is calculated as follows:

\[
CRF = \frac{(1+i)^n}{(1+i)^n - 1} \times \frac{0.06(1+0.06)^{25}}{0.2575 - 1}
\]

\[
= 0.07822
\]

The estimated electrical energy demand of UPT Bahasa is 80,524 kWh per day, so the annual energy of PLTS UPT Bahasa is calculated as follows:

\[
AKWH = kWh \times 365 \text{ [kWh]}
\]

\[
= 80,584 \times 365 \text{ [kWh]}
\]

\[
= 29,413 \text{ kWh/year}
\]

\[
COE = \frac{LCC \times CRF}{AKWH}
\]

\[
= \frac{Rp.555,807,731 \times 0.07822}{29,413}
\]

\[
= Rp.1,478,097/kWh
\]

\[
\approx Rp.1,478/kWh
\]

3.8.4 Feasibility Analysis Of PLTS Investment

The annual cash inflow of PLTS is generated by generating annual production of PLTS with energy costs of 29,143 kWh / year and energy costs of Rp.1,478 / kWh, then the amount of annual cash inflows is Rp.43,073,354. The cash outflow is Rp.4,928,090 / year derived from the annual maintenance and operational costs of PLTS.

3.8.5 Net Present Value

The total net cash flow value which is the result of multiplying the net flow is Rp.953,631,600, if the initial investment plus bank interest is Rp.555,807,731, then the NPV value can be calculated as follows:

\[
NPV = \sum_{t=1}^{n} \frac{NGPI}{(1+i)^t} - C
\]

\[
= Rp.953,631,600 - Rp.555,807,731
\]

\[
= Rp.397,823,869
\]

3.8.6 Profitability Index

With a total present value of net cash flows of Rp.953,631,600 and initial investment costs plus bank interest and maintenance costs of Rp.555,807,731, the PI value can be calculated as follows:

\[
PI = \frac{\text{present value of cash flow}}{\text{initial investment}}
\]

\[
= \frac{Rp.953,631,600}{Rp.555,807,731}
\]

\[
= 1.7157
\]

3.8.7 Discounted Payback Period

The present value of cumulative net cash flow is close to the initial investment value and bank interest of Rp.555,807,731, while the net cash flow value is Rp.953,631,600, so the time required is as follows:

\[
DPP = \text{Year before the final take} + \frac{\text{initial investment}}{\text{net cash flow value}}
\]

\[
= 15 + \frac{Rp.953,631,600}{Rp.555,807,731}
\]

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To consider the feasibility of investing in PLTS UPT Bahasa as a source of electricity at UPT Bahasa, it is necessary to conduct an economic analysis. The feasibility of the UPT Bahasa PLTS investment is determined based on the results of the calculation of Net Present Value (NPV), Profitability Index (PI) and Payback Period (PP), shown in Table 3 as follows:

Table 3. Investment feasibility analysis

<table>
<thead>
<tr>
<th>INVESTMENT FEASIBILITY ANALYSIS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PLTS Investment Costs</td>
<td>Rp.492,809,000</td>
</tr>
<tr>
<td>PLTS Operational and maintenance costs</td>
<td>Rp.4,928,090</td>
</tr>
<tr>
<td>Life Cycle Cost (LCC)</td>
<td>Rp.555,807,731</td>
</tr>
<tr>
<td>Project Age</td>
<td>25 Tahun</td>
</tr>
<tr>
<td>Cost of energy (COE)</td>
<td>Rp.1,478 kWh</td>
</tr>
<tr>
<td>Net Present Value (NPV)</td>
<td>Rp.397,823,869</td>
</tr>
<tr>
<td>Probability Index (PI)</td>
<td>1.7157</td>
</tr>
<tr>
<td>Discounted Payback Period (DPP)</td>
<td>15,1 Tahun</td>
</tr>
<tr>
<td>Bank interest</td>
<td>6%</td>
</tr>
</tbody>
</table>

4. CONCLUSION

The evaluation study conducted on the Solar Power Plant (PLTS) at UPT Bahasa Tanjungpura University, utilizing PVsyst Software, has yielded insightful findings. The estimated daily energy demand for the university is calculated at 80,584 kWh/day and 29,010 kWh/year. Manual calculations for PLTS power indicate 20.8 kWp, while PVsyst Software suggests 21.3 kWp. The planned PLTS configuration involves two series and parallel arrays, with manual calculations proposing 87 solar panels covering 109 m², and PVsyst indicating 88 panels covering 138 m². Battery numbers vary, with manual calculations suggesting 176 and PVsyst recommending 162 batteries arranged in 12 series and 9 parallel. The manual calculation for charge controller capacity is 90.6 Amperes, and the inverter capacity is 9.065 with a total of 2 inverters. The initial investment, inclusive of components and labor, is Rp.492,809,000, with an annual maintenance cost of Rp.4,928,090. Over a 25-year project life with 6% bank interest, the life cycle cost (LCC) is Rp.555,807,731. The cost of energy for UPT Bahasa PLTS is Rp.1,478/kWh, producing 28,207 kWh/year. The Net Present Value (NPV) is positive at Rp.397,823,869, the Profitability Index (PI) stands at 1.7157, and the Discounted Payback Period (DPP) is approximately 15 years and 1.2 months. These analyses collectively affirm the feasibility of implementing the UPT Bahasa PLTS investment.

REFERENCES

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