Feasibility Study of Solar Power Plant in the Rectorate Building of Lampung University Using the On-grid System

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Abstract

This research aims to analyze the technical and economic feasibility aspects of the construction of solar power plants in the Rectorate building of Lampung University. Technical aspects are calculated how much electrical energy is generated, the number of components and systems used. Then the economic aspects are calculated using the net present value (NPV) and profitability index (PI) methods to determine profitable or detrimental investments in the future. The electrical energy generated by solar power plant is affected by solar radiation based on RetScreen data and the number of solar modules installed on rooftop buildings. The results of this study showed that the construction of solar power plant in the Rectorate building of the University of Lampung is feasible to build using ballast installation techniques and on-grid systems, based on economic aspect, it is feasible.

Keywords: *RetScreen, on-grid system, rooftop, solar modules.*

I. INTRODUCTION

Unila Rectorate Building has a large rooftop area that is currently untapped. It is located in an area illuminated by the Sun throughout the day and is not blocked by other objects. Rectorate Building has 5 floors which is the tallest building of the surrounding building. With the advantages of this building has great potential in developing large solar power plants [1].

In Indonesia, electricity is generally converted from energy that is not renewable and environmentally friendly. The total installed capacity based on the details of PLN data in 2019 is electric steam power plant 47.31%, gas and steam power plant 24.42%, diesel power plant 8.42%, gas engine for power generation 3.05%, hydroelectric power plant 8.17%, gas power plant 7.27%, geothermal power plant 1.32% and solar power plant and wind power plant only 0.04%. Based on data on such generating capacity, it was obtained that renewable energy and environmentally friendly power plants are relatively few, so the construction of renewable and environmentally friendly generating centers such as solar power plant must be improved [2].

Indonesia has great potential in developing solar power plants, because it is on the equator, so Indonesia is illuminated by sunlight throughout the year, especially in Bandar Lampung. Based on data from RetScreen, Bandar Lampung has a sunlight intensity of 4.76 kWh / m² / d. In addition, soalar power plant is an environmentally friendly power plant, because it does not produce gas emissions and includes sustainable energy, because solar power plant converts solar energy into electrical energy, so that dependence on fossil fuels can be overcome in thefuture [3].

Electricity consumption in Unila Rectorate building tends to increase, so alternatives are needed to meet these needs. Lampung University as a higher education institution in Lampung, so Lampung University must play an active role in developing renewable and environmentally friendly electricity such as solar power plant so that it becomes an example of another campus as well as a research center. At this time, the rooftop of the Unila Rectorate building has not been utilized, so it can be used as a solar power plant installation area [1,4].

The rooftop of the Rectorate unila building is on the 6th floor and directly illuminated by the Sun because of its high enough position from the building or trees around it. The power generated by solar power plant can be used to meet the needs of electrical load in buildings, especially during the day, while at night using power from PLN network (on grid).

Figure 1. Monocrystalline

Solar Power Plant is one of the renewable power plants that are environmentally friendly. Sunlight is the main energy source converted into electrical energy by solar panels. The intensity of solar radiation is obtained based on the annual average of the RetScreen software. The electrical energy produced is highly dependent on the intensity of sunlight, so it only operates when illuminated by sunlight. At night, solar power plant does not operate, but solar power plant can operate throughout the day if added batteries (storage) as a storage. Solar panels produce an electrical power output is DC (Direct Current) electricity, therefore it takes an inverter to convert DC electric current to AC (Alternating Current). The solar power plant image is shown in figure 1 [4].

The electrical energy produced by solar power plant is highly dependent on the intensity of solar radiation, because the lower the intensity of sunlight, the smaller the electrical energy and vice versa. Therefore, solar power plants can only operate during the day or only when solar panels are illuminated by sunlight [5].

The figure 2 shows the greater the intensity of the sun, then the power generated the greater or directly proportional. Power is the multiplication of current and voltage, so the maximum power generated by solar panels lies in the curve line on the curve.

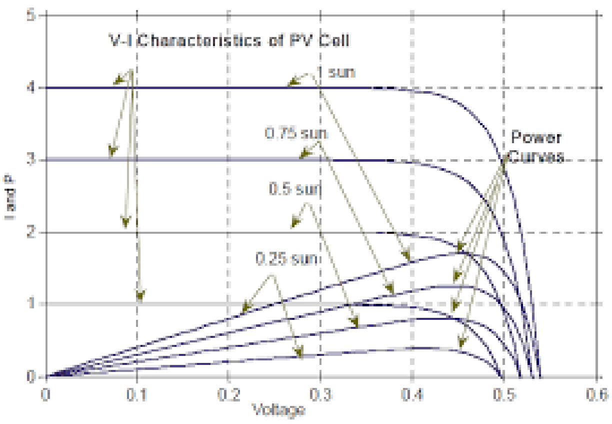

Figure 2 Characteristic curves of solar panels

II. Materials and Methods

Feasibility analysis is needed to determine what is the maximum power capacity in solar power plant that can be supplied and profitable or not economically. The data needed such as the area available and the intensity of sunlight and the specifications of each component [7].

The solar panel used is a type of monocrystalline 200 WP to maximize the available area, while the inverter capacity is 26 kW. The number of inverters adjusts to the number of solar panels that are stuck. After knowing the number of components used, the cost of the investment can be known in its entirety. Here's the type of analysis used.

A. System of Solar Power Plant

Solar power plant system used is *on grid*, so it does not use batteries and cannot operate when the solar module is not illuminated by sunlight. The installed solar power plant can be illustrated like figure 3. Based on figure 3 can be seen the solar power plant system used in this solar power plant using an *on grid*s ystem. The panel module is placed in an area illuminated by the Sun throughout the day, then connected with the optimizer mppt (maximum *power point tracker)*, so that the power generated by the panel module can be maximized by mppt. Furthermore, the output of mppt is connected to an *inverter* that serves to convert dc current (direct*current)* into AC current (alternating *current)*. Output produced by the inverter becomes a sinusoidal wave that has a voltage of 220 V and a frequency of 50 hz because it is adapted to the network that has been installed previously by PLN. The output of the inverter is compared to the PLN network in the distribution *box* by using a bus that is also connected to the rectorate building's power grid. The electricity network originating from PLN is added with kwh *exim* which serves to calculate the flow of currents in and out of solar power plant, so that when the production of solar power plant > load, power will be supplied to the PLN network and vice versa.[3]

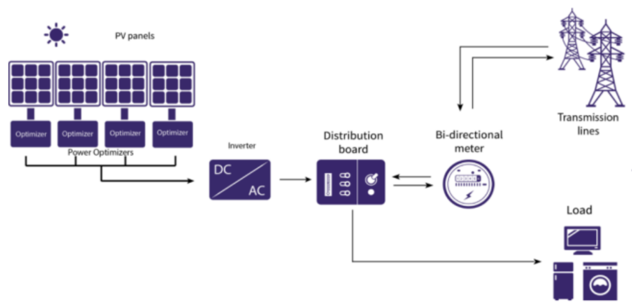

Figure 3.Ongrid system

B. NPV (Net Present Value)

Net present value is a method used to calculate the difference between the present value of an investment and the value of future net cash receipts. Proposed disqualification project plan is detrimental (NPV < 0) or beneficial (NPV > 0).

Each cash flow that enters per year is calculated one by one and then summed up the total to get the NPV value. After that it is reduced by the cost of the investment, if the result is positive then it is a good investment and if negative means the investment is not [8].

Net present value is a way of calculating the difference in present value of incoming cash flows with the present value of cash flows out over a given period of time [9].

C. Profitability Index (PI)

The Profitability Index analyst method is an equation to determine whether or not an investment will be profitable. This equation with the PI method calculates the comparison between the net cash flow of present value with the initial investment of the PI equation can be written in equation 1 [10]. The following is a diagram of the research flow can be seen in figure 4.

$$PI = \frac{\sum_{t-1}^{n} NCF_t\,(1-i)^{-t}}{IA} \quad (1)$$

where:
PI = Profitability Index
$\sum_{t-1}^{n} NCF_t\,(1-i)^{-t}$ = net cash flow of present value
IA = initial investment

III. RESULTS AND DISCUSSIONS

A. Area

Rectorate Building of Lampung University is located at Jl. Prof. Dr. Sumantri Brojonegoro No. 1, Gedong Meneng, Rajabasa, Bandar Lampung City, Lampung 35145, Indonesia. The administrative service center is all students from all faculties and at the same time the office room of the Rector and vice Rector. Activities in this building are mostly during the day. The view of the Unila rectorate building can be seen in figure 5.

The selection of the Rectorate building as a place for solar power plant to be built because it has a large rooftop area and illuminated by the sun throughout the day. The area available in this building is also not used for useful things, so the construction of solar power plant in this building is very possible.

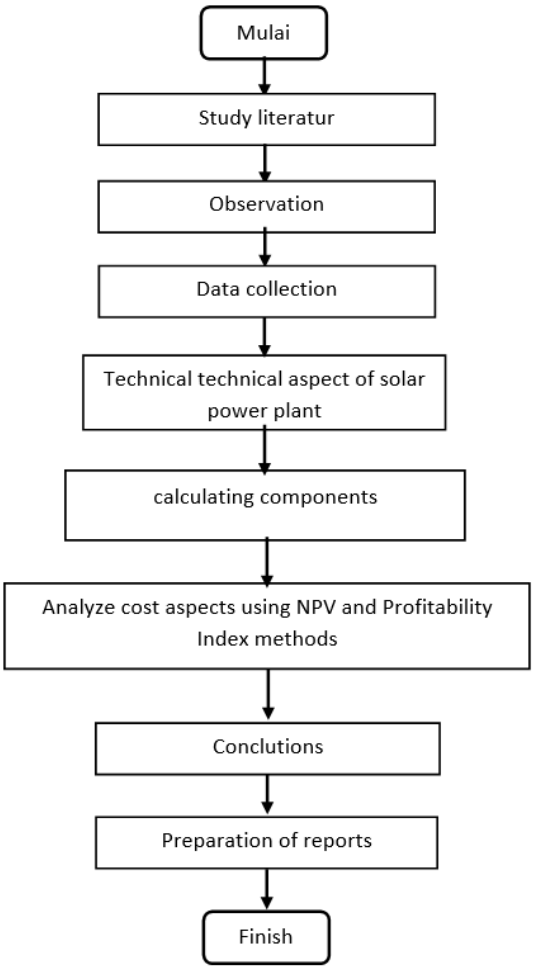

Figure 4. Research flowcart

Figure 5 View of the Rectorate Building

Rectorate Building of Lampung University has 5 floors and the roof is made of concrete. Compared to the surrounding buildings, this Rectorate building is the tallest so that the trees do not cover it. Solar lighting is optimal because there is no other object(shadow)that covers the roof of the Unila Rectorate building.

The land area in the Unila Rectorate building is 1296 m² with a length of 40.7 M and a width of 37.9 M but cannot be used all for the inclusion of panel modules because there is a building in the middle, down field to calculate the area of the rooftop of the rectorate building can be seen in figure 20. The rooftop area of the university rectorate building is very open which is illuminated by the Sun and has not been utilized.

B. Electricity Consumption in the Building

Electricity consumption in the Unila Rectorate building takes place at all times, especially during the day. Electricity use activities mostly take place during the day because work activities are carried out during working hours, but at night power tools are still turned on such as night guard lights. The load attached varies greatly from lights, elevators, computers and other electronic equipment. Electricity consumption in the Unila Rectorate building is relatively large, but the land available in the building is limited, so the target load supplied by solar power plant is 40% which is 469 kWh per day.

C. Angle of Slope of Module

The tilt of the installation of the solar module affects the power it generates, because the solar module only changes the radiation of sunlight that hits the surface of the module. The angle of tilt also produces shading, so it is not good if it is too large so as not to interfere with other modules. In addition, the solar module is positioned tilted because it makes it easier to clean its surface. This slope automatically drops dirt or dust attached to the surface of the module, including rainwater, so that there are no puddles or distracting objects on the surface of the module. The mounting slope of the module is 15º. This slope is based on a simulation of the software Pvsyst 7.1 [7].

D. Installation Techniques

Installation techniques are determined based on the condition of the land and also the objects around it. The land available in the Unila Rectorate building is not covered by other objects or there is no shadow that hits the area, so the entire area can be utilized and the rooftop is made of concrete. The installation of panel foundations cannot be planted or plugged into the surface of the land because it is made of concrete so that other objects are needed as a place to support iron. So, it takes concrete as the bottom foundation of the iron buffer from the solar module. The system used in solar power plant is called ballast installation system. Ballast installation technique can be seen in figure 6.

Figure 6. Installation Techniques

E. Number of Solar Panels and Inverters

The area of solar panels needed to meet 40% of electricity needs in unila rectorate building is 503 $m^2$the calculation can be seen in equation 2.

$$\text{PV Area} = \frac{E_L}{G_{av} \times \mu_{pv} \times TCF \times \mu_{out}} \quad (2)$$

$$\text{PV Area} = \frac{469\ kWh}{\frac{4{,}76\ kWh}{M^2} x\ 0{,}2 x\ 1\ x\ 0{,}98}$$

$$= 502{,}70\ m^2 \approx 503\ m^2$$

The amount of the required array area is already known, so the amount of power generated by the solar power plant (watt peak) can be calculated by the equation 3.

$$P_{watt\ peak} = \text{area array x PSI x } \mu_{pv} \quad (3)$$

$$P_{watt\ peak} = 503 \text{ x } 1000 \text{ W/ x } 20\%m^2$$

$$P_{watt\ peak} = 100.600 \text{ watt peak}$$

The power that can be generated by solar power plant is 103,800 watt peak, so it can be determined how many panel modules are needed. The number of solar panel modules needed can be seen in equation 4.

$$\text{Number of solar panels} = \frac{P_{watt\ peak}}{P_{MPP}} \quad (4)$$

$$\text{Number of solar panels } \frac{100.600}{200} = 503$$

Number of solar panels = 503 solar panels, as on Table 1 below.

Table 1 Initial investment

NO	Item	Quantity	Price	Cumulative
1.	Solar Panels	503	Rp.3.250.000	Rp1.634.750.000,00.
2.	Reverse + MPPT	4	Rp.30.723.000	Rp.122.892.000.00
3.	Installation and Maintenance	20% x Component cost	1 time	Rp.351.528.400.00
TOTAL				Rp.2.109.170.400.00

The number of solar panel modules needed to meet 40% of the rectorate building's electricity load is 503 solar panels.

Based on calculations in equation 3, the number of solar panel modules needed by solar power plant to meet 40% of the rectorate building's electricity needs is 503 solar panels. The inverter needed adjusts to the power generated by the solar power plant. One inverter has a capacity of 26 kW, so to convert 100,600 power is 4 inverters.

F. NPV analysis

The following is a cash flow calculation table on solar power plant shown in table 6 calculated over 20 years. Based on the NPV calculation shown in table 6, the calculation is done over a span of 20 years. The investment issued is Rp.2,109,170,400.00 and the return of capital in the 15th year.

The cash inflow is calculated based on the electrical power generated by the solar power plant to the load on the Unila Rectorate building. The use of electricity supplied by solar power plant is 40% of the total demand. The power supplied is 469 per kWh. The ability of solar power plant to supply power is reduced by 0.5% every year, so that every year the electrical power output of solar power plant is reduced.

The output of power produced every year is decreasing, so that the cash inflows from time to time continue to decline. The following is a table for calculating the cash flow in solar power plant as shown in table 6 which is calculated for 20 years. Based on the NPV calculation shown in table 6, the calculation is carried out over a span of 20 years.

Table 2 Cash flow

year	Initial Investment Cost	Cash Inflows	Cash OutFlow	Discount Factor	PVNCF	cumulative
	2,109,170,400					
1		281,517,156	21,091,704	0.9259	241,127,926	241,127,926
2		380,112,571	21,091,704	0.8573	307,788,589	548,916,515
3		278,707,987	21,091,704	0.7938	204,495,805	753,412,321
4		277,315,407	21,091,704	0.7350	188,324,422	941,736,742
5		275,886,813	21,091,704	0.6805	173,388,072	1,115,124,814
6		274,548,256	21,091,704	0.6301	159,702,973	1,274,827,788
7		273,173,683	21,091,704	0.5834	147,064,627	1,421,892,414
8		271,811,116	21,091,704	0.5402	135,438,626	1,557,331,040
9		270,454,552	21,091,704	0.5002	124,731,297	1,682,062,337
10		269,097,987	21,091,704	0.4631	114,851,710	1,796,914,047
11		267,753,428	21,091,704	0.4288	105,768,547	1,902,682,594
12		266,414,871	21,091,704	0.3971	97,417,830	2,000,100,424
13		265,082,316	21,091,704	0.3676	89,690,949	2,089,791,373
14		263,755,764	21,091,704	0.3404	82,602,846	2,172,394,219
15		262,441,217	21,091,704	0.3152	76,073,366	2,248,467,585
16		261,126,670	21,091,704	0.2918	70,042,203	2,318,509,788
17		259,818,125	21,091,704	0.2702	64,503,879	2,383,013,667
18		258,521,586	21,091,704	0.2502	59,404,956	2,442,418,624
19		257,231,049	21,091,704	0.2317	54,713,486	2,497,132,110
20		255,940,512	21,091,704	0.2145	50,375,069	2,547,507,179
TOTAL						2,547,507,179

G. Profitability Index (PI) Analysis

The profitability index (PI) is calculated with equation 17. Based on the results of the profitability index obtained a yield of 1.1671, which means that the investment in plts is worth continuing because the PI value more than 1.

$$PI = \frac{\sum_{t-1}^{n} NCF_t\,(1-i)^{-t}}{IA} \quad (6)$$

$$PI = \frac{Rp.2,461,777,179}{Rp.2.109.170.400}$$

PI = 1.1671

IV. Conclusions

Based on analysis and discussion, it can be concluded that the construction of solar power plants is feasible to be built with energy supplied by solar power plant of 469 kWh / day with an ongrid system. Investment costs worth RP.2,109,170,400, based on NPV analysis the investment can return after 15 years of operation and the value of profitability index of 1.1671.

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