Technical Design and Financial Projection of Solar Power Plant on Grid 119.5 kWp in Sendang Sari Hotel

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***Abstract*—The productivity of a solar power plant is influenced by environmental factors such as the amount of irradiation captured, the amount of dust attached to it, and the ambient temperature. Therefore, it is very important to pay attention to the technical design of solar power plant, such as the installation location, tilt angle, and number of solar modules per series. In addition to a good technical design, it is also necessary to pay attention to its economic aspects, because solar power plant requires high costs, so it is necessary to make financial projections for the next few years, so that the economic value of the technical design can be determined. At this writing, the location is taken at Sendang Sari Hotel with coordinates -6.905910357088127, 109.72448291981084, installed power is 120kVA with the aim of the installation is for savings without exporting power to the grid. Based on the load analysis, the designed PLTS capacity is 119.5 kWp. Then, a simulation was carried out using the Helioscope which produced an energy yield of 161.8 MW with a performance ratio of 82.1%. Based on the simulation, a 25-year financial projection is obtained with an NPV of 580,943,546 IDR, an IRR of 6.09%, a payback period of 13.89 years, and an LCOE of 735.4 IDR/kWh.**

Keywords*— *solar power plant, financial projection, energy yield

I. Introduction

Renewable energy is energy that is renewable and also more environmentally friendly than fossil fuels. Some examples of the application of new and renewable energy include solar power plant, wind power plants, hydro power plants, geothermal power plants. Among all the renewable energy power plants that are being accelerated so that their use is increased is the Solar Power Plant because it has the greatest energy productivity potential of 3,294 GW[1].

Solar Power Plants are power plants that are able to convert photon energy from solar light into electrical energy using solar panels. The weakness of using solar energy is the weather and location factors which greatly affect the efficiency of solar power plant[2]. For that we need a good design. Good design or design, not only from a technical point of view but also from an economic point of view, because solar power plant requires a large amount of money and has a long investment period. The technical design of solar power plant can be analyzed with the help of energy simulations produced by solar power plant, after the solar power plant technical design is sufficiently efficient, then the next step is financial analysis in the form of financial projections for the next few years, to find out whether the installation of solar power plant is feasible or not [4].

II. Methods

A. *Solar Power Plant*

Solar Power Plant is a power generation system that originates from solar radiation through the conversion of photovoltaic cells. The solar power plant work system is very dependent on solar radiation so that the higher the solar irradiation received by the photovoltaic cells, the greater the electrical energy that can be produced by the solar power plant [3]. located in the tropics and traversed by the equator so that it gets sunlight throughout the year. In addition, data from the Ministry of Energy and Mineral Resources for 2021 shows that Indonesia has potential for solar energy of up to 400 GW.

B. *Solar Module*

Components that can convert solar energy into electrical energy are called solar modules, a collection of several solar modules is called a solar panel. Solar modules utilize the photovoltaic effect to work, that is, when silicon is exposed to sunlight, electrons will flow from the emitter to the collector[4].

C. *Inverter*

The electricity generated in the PLTS system is in the form of direct current electricity or DC electricity. However, most household or industrial loads use alternating current or AC electricity. Therefore, it is necessary to convert electricity from direct current to alternating current. The component to do this is an inverter [5].

In general, there are two types of inverters, namely on-grid inverters and off-grid inverters. An on-grid inverter is an inverter that is capable of converting direct current into alternating current and equalizes its frequency, voltage and polarity with electricity from the grid, so that electricity from PLTS can be connected to electricity from the grid. This inverter cannot operate without a supply from the grid because it needs a reference voltage [6].

Meanwhile, an off-grid inverter is an inverter that is used for off-grid systems, this inverter cannot synchronize with the PLN grid, but this inverter is able to convert DC current into AC current to supply the load and is able to charge the battery by adjusting the voltage[7].

D. *Helioscope*

Helioscope is a software platform for the solar panel industry. Folsom Labs developed HelioScope, this solar PV sales & design tool with powerful and detailed features. HelioScope is able to simplify the solar panel project engineering process by integrating easy layout tools with reliable performance modeling. HelioScope offers layouts with CAD caliber, remote shadow analysis, and reliable energy yield calculations[8].

E. Net Present Value

The net present value or NPV is the difference between the value of cash inflows now and outgoing during a certain period of time.[9] Capital budgeting and investment planning use NPV as a method of determining profit or profitability. Usually for business investments and projects that are just ideas to be proposed. A positive NPV value indicates that the planned investment can generate profits. So this alternative investment is feasible to implement[10].

$$NPV = \sum_{t=1}^{N} \left(\frac{R_t}{(1+i)^t} \right) \quad (1)$$

F. Internal Rate of Return

The Internal Rate of Return (IRR) is a metric used in financial analysis to estimate the potential return on an investment. The IRR is the discount rate that makes the Net Present Value (NPV) of all cash flows equal to zero in a discounted cash flow analysis. The IRR calculation relies on the same formula as the NPV[11].

G. Payback Period

Payback Period analysis basically aims to find out how long (period) the investment will be able to be returned when the principal return condition occurs. The length of the payback period (k) when the BEP condition is[12].

$$PP = \frac{Total\ investation}{profit + depreciation} \quad (2)$$

H. Solar Module

LCOE or Levelize Cost of Energy is the price of electricity for each kWh unit, this price is the reference for financing electricity consumed by electricity customers[13].

$$LCOE = \frac{Total\ Expenses}{Total\ Energy\ Production} \quad (3)$$

I. Location Identification

The PLTS on grid design location is at the Sendangsari hotel, the hotel is located on Jl. Jendral Sudirman No.29, Kasepuhan, Kec. Batang, Batang Regency, Central Java 51216 This hotel has a potential roof area in three areas 1.124,62 m², 846,92 m² dan 3.061,39 m².

Fig. 1 Location of Sendang Sari Hotel

This hotel building is connected to the PLN electricity network with a capacity of 120000 VA which is subject to a usage fee of IDR 1,444.70/kWh. Building owners use PLTS to get savings on electricity bills by using electricity supplied from PLTS without any power being exported to PLN. The coordinates of the location are -6.905910357088127, 109.72448291981084.

J. Load Analysist

Load analysis is carried out by observing the kWh meter owned by the building, then recording it every hour for 10 hours from 07.00 to 17.00, this is to find out how much electricity consumption during the day is when the PLTS is operating.

This load analysis aims to determine the capacity of PLTS which can be designed so that the energy produced during the day is not exported to PLN. To calculate the maximum capacity so that PLTS can be exported, use the following formula:

$$AC\ capacity = \frac{Total\ load\ at\ day}{Measurement\ duration} \quad (4)$$

$$AC\ capacity = \frac{1.019.000\ W}{10\ H} = 101.9\ kWAC$$

DC capacity = AC capacity x DC/AC ratio (5)
= 101.9 x 1.2 =122.2 kWp

The total load during the day is the electricity load when the PLTS can operate, this is obtained from the load at 07.00 to 17.00. The DC/AC ratio is the ratio between solar panel capacity and inverter capacity, this value is either 1.15 to 1.25. DC capacity is the capacity of solar panels, the value of 122.2 kWp is the maximum capacity that can be designed so that the energy produced by PLTS is not excessive so that it is exported to the PLN electricity network.

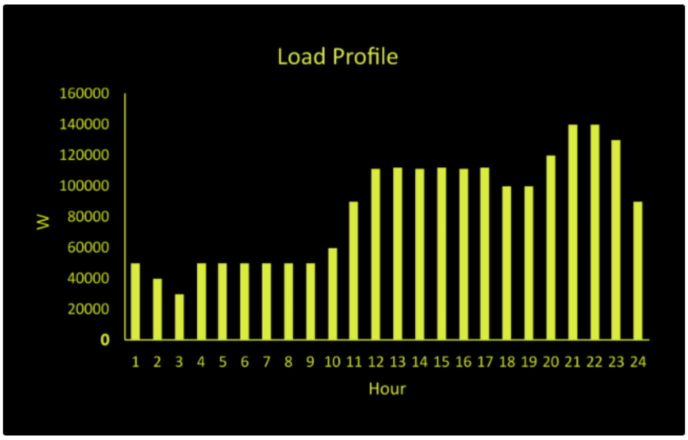


Fig.2 Load profile

K. *Electrical System*

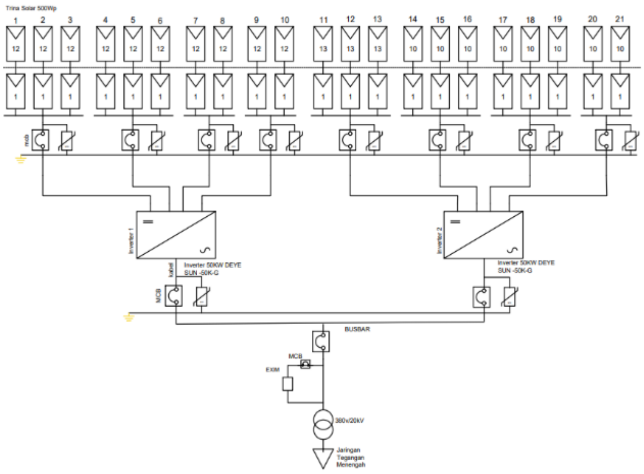


Fig. 3 PV Module and Inverter Interconnection

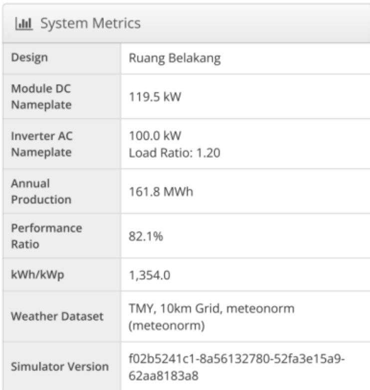
The image above is an overall electrical image of the on grid PLTS system. The image above is used as a guide when carrying out construction with the component specifications derived from a predetermined formula. The system uses 239 solar modules with each string numbering 10-13 solar modules with 2 to 3 parallels per string. 2 inverters are used with a capacity of 50kW each.

PV Layout is a layout of the arrangement of solar modules on the roof of a building. The PV layout must be designed on a roof that has the greatest potential, namely there is no shading and facing north so that the intensity of sunlight can be maximized. In addition, the shading on the PV module must be minimized, so the energy yield can be maximized[14]. The highest efficiency of energy yield in a solar power plant can be obtained with the optimal angle[15], but in this case, the tilt angle is designed to resemble the slope of the roof, so there is no need to add a structure that can cause additional costs. The total number of these modules is 239 with a capacity of 500 Wp and the area of each module is 2.1 x 1.1 meters. So that a roof area of approximately 660 square meters is required to install 239 solar modules.

Fig. 4 PV layout

III. Results and Discussion

A. *Helioscope Simulation*



System Metrics	
Design	Ruang Belakang
Module DC Nameplate	119.5 kW
Inverter AC Nameplate	100.0 kW Load Ratio: 1.20
Annual Production	161.8 MWh
Performance Ratio	82.1%
kWh/kWp	1,354.0
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	f02b5241c1-8a56132780-52fa3e15a9-62aa8183a8

Fig 5. Helioscope simulation

Heliocope will take estimated irradiation data for the next one year and weather data for meteonorms to calculate the estimated PLTS energy. The simulation results are in the form of estimated production of electrical energy for the next year.

Based on these simulations, it was found that the design has a performance ratio of 82.1%, meaning that the design can be said to be quite efficient. The total energy generated by this design for a year is 161.8 MWh. By using the degradation of solar modules every year, you will get a reduction in energy every year, so you can get an energy estimate for 25 years that can be used for financial projections.

By considering the four factors that affect the Performance Ratio and also data retrieval through PVsyst simulation. The estimation result of the Performance Ratio from the rooftop PV mini-grid design is 82.4%. This value has met the minimum standard for the Performance Ratio value. Simulation results using software still need to be checked because the data used in the software is still not updated so it does not provide a good level of simulation accuracy.

TABLE I. SYSTEM SPECIFICATION

Rooftop wide	1.124,62 m², 846,92 m², 3.061,39 m²
Total PV Module	239 pcs
DC Nameplate	119.5 kWp
AC Nameplate	100 kWac
PV Module Brand	Trina Solar Vertex DE18M(II) 500Wp
Inverter Brand	DEYE SUN-50 K-G

B. *Financial Projection*

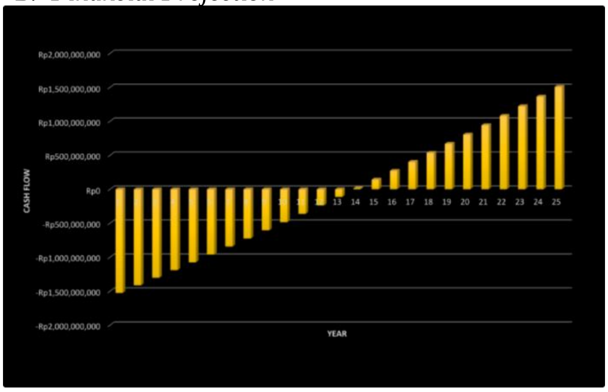


Fig.6 Financial projection

The picture above is a graph of cumulative cash flow in rupiah units against time in years. The graph shows that in the first 13 years income is negative, this is due to the large initial expenditure value of Rp. 1.634.137.912

TABLE II. FINANCIAL PROJECTION

Parameter	Value
CAPEX	1.634.137.912 IDR
NPV	580.943.546 IDR
IRR	6,09%
Payback Period	13,89 year
LCOE	735,4 IDR/kWh
Saving Estimation	1.047.467.356 IDR (25 year)

This design requires CAPEX of IDR 1,634,137,912. The NPV obtained for this design is IDR 580,943,546, this value is said to be good for investment because it has a positive value. The IRR obtained is 6.09%, this figure is said to be good for an investment if it is greater than the interest rate issued by the bank. The bank's own interest rate is 4.25%, meaning that the IRR of this solar power plant design is considered good.

The payback period of this design is 13.89 years, which means that during this period the investment capital will return, this time is when the cumulative cash flow is 0. LCOE is the electricity price per kWh that this design has at 735.4 IDR/kWh, this price is said to be good because it has a cheaper price than PLN electricity, which is 1,444.4 IDR/kWh. Meanwhile, the estimated saving on electricity bills over a period of 25 years is IDR 1,047,467,356.

IV. CONCLUSION

The technical design of a solar power plant is about determining the total capacity of solar power which needs to be installed, PV and inverter capacity, DC/AC ratio, tilt and azimuth angle, shading analysis, and a number of modules per string. The helioscope helps engineers to design and simulate an on-grid solar power plant. Including energy yield estimation in one year, and losses analysis. According to the load profile, the total capacity that must be installed is 119.5 kWp. That produces 161,8 MWh with a performance ratio of 82,1%. Besides the technical design, economic aspects must be considered. According to the energy yield, financial projections can be acquired within 25 years. NPV 580.943.546 IDR, IRR 6,09%, payback period 13,89 years, and LCOE 735,4 IDR/kWh. NPV is good if it has a positive value, and IRR is good if it has more than the interest rate, this projection uses a 4,25% of interest rate. LCOE must be smaller than the grid LCOE (1,444.4 IDR/kWh). Meanwhile, the payback period is prohibited for more than 15 years.

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