Cost Analysis and Feasibility Study for Off-Grid Solar Power Plants (PLTS) in Pinggir Laut Village, Rokan Hilir Regency

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Abstract

Power facilities that use solar radiation to generate electricity are known as solar power plants. As an alternative energy source, using the sun for energy demands has a lot of promise in today's world. The energy generated or released by a light source is the sun. As is well known, the sun provides a significant portion of the world's illumination energy. In this situation, solar energy may be used in conjunction with other machinery that contributes and has the ability to convert solar radiation into electrical energy through the use of solar panels, which are apparatuses that transform solar radiation into electrical energy. Apart from that, solar panels are the most promising and have the most potential when compared to other energy sources. It can be argued that solar panels are the primary factor in optimising the potential of solar energy reaching the earth. The weather affects solar panel performance. Solar panels must constantly be pointed in the direction of the sun's rays in order to work well, as the sun's location on the surface of the planet varies with time. From the explanation above, a plan was made for a solar power plant in Pinggir Laut Village, Rokan Hilir Regency complex using 60 units of 200 WP panels, 56 units of 12V 100 Ah batteries, 2 units of 8000W inverter, and 2 units of a charger controller with a voltage rating of 120 Ampere.

***Keywords**: Feasibility, PLTS, Planning, Photovoltaic, Power plants.*

I. INTRODUCTION

Electricity is a primary need for human life. Without electricity, electronic equipment cannot be used or function properly. Electricity is also a source of light for human life and is a basic need for all activities. The increasing need for conventional or PLN electricity can result in an electricity crisis occurring at any time. To prevent this crisis from occurring, currently many are starting to switch to using alternative energy sources. One of the most widely used alternative energy sources is Solar Power Plants or better known as PLTS. This power plant can be the best solution for those of you who want to be more energy efficient and cost effective.[1]. Utilization of solar energy sources is very supportive in tropical islands.

Rokan Hilir Regency is a tropical area where solar radiation reaches 94% which is very good for utilizing renewable energy, especially solar energy or also known as Solar Power Plants (PLTS) [2].

The application of solar power technology for electricity needs in the Kampung Pinggir Laut housing complex can be done by designing a PLTS, selecting a PLTS system that is designed to operate as a whole to meet the needs of the community around the housing, and can use additional energy such as water and wind. In distributing power to the Kampung Pinggir Laut housing complex in large quantities and dividing it into sub-divisions in the housing complex, a panel is needed which functions as a controller for the electrical power itself. The panel itself also functions to control the electrical power in the housing.

Therefore, we carried out "*Cost Analysis and Feasibility Study for Off-Grid Solar Power Plants (PLTS) in Pinggir Laut Village, Rokan Hilir Regency*" to calculate and analyze the needs and costs required to build a PLTS. In this research, we discuss the cost analysis and feasibility of PLTS.

II. LITERATURE REVIEW

2.1. Solar Power Plant (PLTS)

Solar Power Plants (PLTS) are power plants that utilize energy from sunlight to produce electrical energy. The main components of PLTS are solar panels, batteries, solar charger controller and inverters. Figure 1 shows the working principle of PLTS.

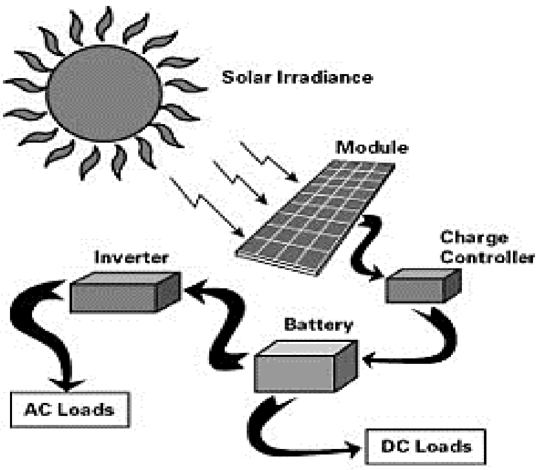

Figure 1. Working principle of PLTS

There are two types of systems for solar power plants, including on-grid and off-grid systems. On-grid is one of the PLTS systems, this system is a PLTS system that is connected to the PLN network. The advantage of this type of PLTS is that it can channel the electricity produced to PLN. This type of PLTS uses will be a special electricity meter, namely net metering where this electricity meter can allow electricity produced by PLTS to be sold to PLN and enable the electricity buying and selling process. Compared to other systems, this on-grid system is a fairly simple system and requires smaller costs. On-grid PLTS has the main components, namely solar panels and an inverter. This type of PLTS can be reduces electricity costs. On-grid PLTS components do not require.

This system has a drawback, namely that if a blackout occurs, the residence will also be cut off, because the on-grid PLTS system depends on PLN electricity. The on grid system is the simplest and most cost-effective system for installing solar panel energy, but this system does not provide backup power during grid outages.

Factors that need to be considered when installing an on-grid PLTS system include locations that have 24-hour access to PLN electricity, urban locations and surrounding areas which are ideal installation locations, home locations, business buildings, offices, government and service buildings and others who are interested in efficiency , locations that have or will have an SLO certificate for installed connections, locations that have installed kWh meters EXIM (export-import) which will be and are currently in the process of installing kWh meters.

Off-grid PLTS is a PLTS system that can operate itself without assistance from PLN because this type of PLTS allows storing electricity produced by PLTS using batteries which is then used at night. Because this type of PLTS is stand-alone, it cannot carry out the export-import process to PLN.

The main advantage of the off-grid system when compared to off-grid is that when there is a power outage by PLN, PLTS with an off-grid system will still provide electricity. This off-grid system has There is a weakness in terms of cost due to the cost of batteries which are expensive and require a large number. This type of PLTS has components, namely solar panels, charge controller, inverter, and batteries. The inverter used in the off-grid system is different from the on-grid system. The inverter used in the off-grid system is an inverter with possible bi-directional capabilities charging the battery and taking electricity from the battery. In an off-grid PLTS system, the arrangement of the solar panel array and the number of batteries used is very complex. Details of the electricity requirements are really needed in the planning and the system. This is because the battery used should not be too big or too small and the battery is also a dangerous component so it is needed extra attention in handling it. Besides that, the battery is an expensive component both in terms of purchasing and in terms of maintenance.

From both on-grid and off-grid systems, it can be seen that off-grid systems have many additional components so that the cost of installing an off-grid solar PV system is higher. The cost of off-grid PLTS can reach twice the cost of on-grid PLTS with the same capacity.

2.2. Solar Charge Controller

The solar charge controller is one of the important components for making a PLTS, where this component stabilizes the input voltage from the solar panels to the battery. The solar charge controller will charge the battery to a predetermined voltage, then if the voltage drops then the solar charge controller works to charge the battery again then this component can also regulate the current from the battery to prevent discharge and overvoltage and monitor the temperature of the battery if it is too hot, automatically turns off charging.

Solar controllers use pulse width modulation (PWM) technology to regulate the battery charging function and discharge current from the battery to the load. Several solar controller (SCC) functions include regulating the current for charging the battery from the solar panel, avoiding overcharging, avoiding overvoltage and monitoring battery condition. Figure 2 shows the Solar Charge Controller (SCC).

Figure 2. Solar Charge Controller (SCC)

2.3. Battery

The battery is one of the main components in PLTS, and its function is to store electrical energy produced from solar panels so that it can be used to provide load when needed. Each battery has a positive terminal (cathode) and a negative terminal (anode) as well as an electrolyte that functions as a conductor. The 12Volt battery used in designing a PLTS is useful for storing electrical energy through the process of solar panels. When the battery is fully charged, the solar charge controller automatically stops charging.

A charged battery can power electronic devices by changing the voltage from DC 12 Volt to AC 220 Volt using an inverter. Figure 3 shows the batteries used in PLTS.

Figure. 3. Batteries used in PLTS

2.4. Inverters

An inverter is an electronic device that functions to convert direct current (DC) into alternating current (AC) with an adjustable voltage and frequency. The output of an inverter is an AC voltage in the form of a square wave, modified sine wave, and pure sine wave. The inverter accepts a DC voltage source as an input voltage which can be obtained from an accumulator (battery), solar power, or other DC voltage source, with a switching process from the semiconductor components in the inverter circuit. In Solar Power Plants (PLTS), an inverter is needed to provide an AC current source for electrical devices such as lights, televisions, water pumps, and so on. In the discussion about inverters here, only 2 types of inverters will be discussed, namely Modified Sine Wave Inverters and Pure Sine Wave Inverters. Figure 4 shows the use of inverters in PLTS

Figure. 4. Inverters

2.5. *Design and selection of supporting components*

In designing PLTS, a mounting system and lightning protection are needed. Mounting system on PLTS components which functions as a place to place solar panels safely by considering the direction of the sun.

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The mounting system can be applied in various places according to the needs and applications of PLTS. Things that must be considered in the mounting system are determining the installation location for the Off-Grid Centralized PLTS System and the design of the solar module support construction system for the Off-Grid Centralized PLTS Solar Module.

Lightning protection is needed in every Off-Grid Centralized PLTS System. This tool functions to protect against lightning strikes or lightning shocks before they hit system equipment which can have fatal consequences. The system design and construction used in this research adapts to the Centralized Off-Grid System PLTS lightning protection design designed in the Off-Grid System Centralized PLTS technical design module by the Ministry of Energy and Mineral Resources.

3. RESEARCH METHODS

This research was carried out in kampung pinggir laut housing in Bangko District, Rokan Hilir Regency, Riau Province. The implementation time is approximately 6 months. The components and materials used in this research are 200 watt peak (Wp) solar panels, 120 A Solar Charger Controller (SCC), 12 Volt 100 Ah Li-Po battery and pure sine wave inverter. The research procedure carried out consists of the following stages.

Calculating component requirements, especially calculating the Array Area (PV Area) using the following formula:

$$\text{PV area} = \frac{E_L}{G_{av} \times TCF \times \eta PV \times \eta out}\,[m^2] \quad (1)$$

Calculate the power generated by PLTS (peak watts) using the following formula:

$$P_{wattpeak} = \text{PV area} \times PSI \times \eta PV\ [\text{watt}] \quad (2)$$

Charge controller capacity using the following formula:

$$\frac{Demand\ watt \times safety\ factor}{system\ foltage}[ampere]. \quad (3)$$

Battery capacity can be calculated with the following formula:

$$C = \frac{N \times E_d}{V_s \times DOD \times y}\,[Ah] \quad (4)$$

Inverter capacity can be calculated using the following formula:

$$\text{Cap.inv} = \text{Demand watt} \times \text{Saft factor [watt]} \quad (5)$$

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The initial investment costs for centralized PLTS housing in Kampung Pinggir Laut include costs such as: General costs, mechanical and electrical work costs, and civil work. These costs are the contract value for the construction of centralized PLTS housing in Kampung Pinggir Laut.

The annual maintenance and operational costs (M) for PLTS to be developed are as follows:

$$M = 1\% \times \text{Investation Cost Total[Rp]} \quad (6)$$

Life cycle costs (LCC) are calculated using the following formula:

$$LCC = \text{Life cycle cost (life cycle Cost)} \quad (7)$$

The present value of annual costs that will be incurred in the next few years (during the life of the project), with a fixed amount of expenditure, is calculated using the following formula:

$$M_{PW} = A\left[\frac{(1+i)n - i}{i(1+i)n}\right] \quad (8)$$

Diskonto Factor is a factor that translates expected financial profits or costs in a future year into present value. The diskonto factor formula is as follows:

$$DF = \frac{1}{(1+i)^n} \quad (9)$$

The capital recovery factor is calculated using the following formula:

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

Where, n is the period (age) of the project.

The formulation of energy costs is as follows:

$$COE = \frac{ICC \times CRF}{AKWH} \quad (11)$$

Where, COE is , ICC is , CRF is and AKWH is.

4. EXPERIMENTAL RESULTS AND DISCUSSION

4.1. Radiation Data

Table I shown Solar Radiation Data in the village of Pinngir Laut based on the Global Solar Atlas application.

TABLE I
SOLAR RADIATION DATA IN THE VILLAGE OF PINNGIR LAUT BASED ON THE GLOBAL SOLAR ATLAS APPLICATION

Variables	Parametric	Values
Direct Normal Irradiation	DNI	2.245 kWh/m2 per day
Normal Horizontal Irradiation	GHI	4.512 kWh/m2 per day
Diffuse Horizontal Irradiation	DIF	2.631 kWh/m2 per day
Global Oblique Irradiation At Optimal Angles	GTI opta	4.549 kWh/m2 per day
PV Module Slope	OPTA	6°
Air temperature	TEMP	27 °C

Temperatures in the village of Pinngir Laut is shown in Figure 5.

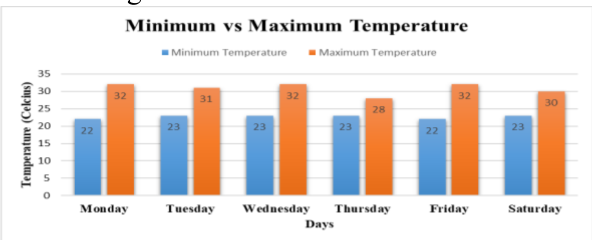

Figure 5. Temperatures in the village of Pinngir Laut

The burden on housing in seaside villages, Bangko sub-district, Rokan Hilir district, is shown in Table II.

TABLE II
BURDEN ON HOUSING IN PINGGIR LAUT VILLAGE, BANGKO SUB-DISTRICT, ROKAN HILIR DISTRICT

Load Requirements	Total Load Power (Wh)
Housing area	29000
Street Lighting	1800
Total A	30800
Energy Reserves = 30% x Total A	9240
Total B = Total A + Energy Reserves	40040
System Losses + JTR = 30% x Total B	12012
Total Amount = Total B + System Losses	52052

Electricity needs in Pinggir Laut village are shown in Table III.

TABLE III
LOAD REQUIREMENTS ON HOUSING

Load Type	Quantity	Total Load Power (Wh)
Housing area	20 x 1450	29000
Street Lighting	10 x 180	1800
	Total:	30800

To anticipate a decline in the performance of PLTS components, energy is reserved at 30% of the total energy generated. Likewise, to anticipate system and distribution network losses, system and JTR losses are assumed to be 30% of the total energy and reserve energy. The total load requirements are shown in Table IV.

TABLE IV
TOTAL LOAD REQUIREMENTS

Room	Power (Watt)	Load Time (hour)	Watt hours (Wh)
Porch Lights	10	11	110
Taillight	10	11	110
Family Room Lights	15	5	75
Kitchen Lights	15	5	75
Bedroom Lights 1	15	5	75
Bedroom Lights 2	15	5	75
Fan	20	4	80
Rice Cookers	300	2	600
TV	50	5	250
		Total:	1450

Based on the total results, the total PLTS load requirement is 48.165 Wh, including housing load requirements. In calculating the component requirements for the components that will be used, global oblique irradiation data is needed at the optimal angle of the solar panels in the new village resettlement housing. Data collection was carried out using the global solar atlas application to obtain a value of 4,549 kW/m2 per day.

4.2. Calculation Results on PLTS Components

PLTS component specifications are shown in Table V below.

Components	Specification	Quantity
Solar Panel	Type: monocrystalline Pmax: 220 watt Vpm: 35.9 Ampere Powertolerance 5% Efeciency: > 15% Maximum System Voltage: 1000V	64
Solar MPPT Control	Type: powmr MPPT Max charging current: 120A MPPT Volt: 64 – 116 VDC	2
Inverter	Type: Pure Sine Wave Inverter Input voltage: 48 VDC Output voltage: 220 VAC Frequency: 50 Hz	2

Battery	Type: Li-FePo4 Capacity: 100 Ah Voltage: 12 Volt	60

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4.3. PLTS Construction Cost Budget

After calculating the component requirements that will be used in the construction of PLTS, both main components such as solar panels, controllers, inverters, batteries and supporting components such as bolts, panel boxes and others, the next step is to calculate the draft budget (RAB) to support the construction process PLTS. Complete data on the components that will be used in the construction of PLTS is shown in Table VI below.

TABLE VI
PLTS COST BUDGET DRAFT

Components	Quantity	Price/Item (IDR)	Total Price (IDR)
200Wp Monocrystalline Solar Panel	64	2.400.000	153.000.000
12 Volt 100 Ah Battery	56	1.900.000	114.000.000
120 A MPPT	2	3.200.000	6.400.000
8000 Watt Inverter	2	13.400.000	26.800.000
Cable NYA 1.5 mm	4	335.000	1.340.000
Cable NYA 2.5 mm	40	197.000	7.880.000
Cable NYAF 4 mm	12	312.000	3.744.000
30 A MCB DC	6	165.000	990.000
40 A MCB DC	2	70.000	140.000
Isolation	40	10.000	400.000
Bolt	200	500	100.000
Box Panels	2	300.000	600.0000
		Total:	315.994.000

4.4. *Maintenance, Operational and Life Cycle Costs*

The maintenance and operational costs (M) per year for the PLTS to be developed are IDR 3.159.940/year.

The centralized PLTS in Pinggir Laut village is assumed to operate for 25 years. Determination of the life of this project refers to the guarantee (guarantee) issued by the solar panel manufacturer. The discount rate (i) used to calculate the present value in this study is 4.25%. The present value for maintenance and operational costs (Mpw) of PLTS centralized in seaside villages during the 25 year project with a discount rate of 4.25% is IDR 48.084.806.

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The capital recovery factor for converting all life cycle cost (LCC) cash flows into a series of annual costs, is calculated at 0.0675. The estimated electrical energy need for Pinggir Laut village is 52,052 kWh per day, so the annual energy use of centralized PLTS in Pinggir Laut village is calculated at 18,998 kWh. The cost of energy (COE) for centralized PLTS in Pinggir Laut village is IDR 1.259,07.

5. CONCLUSION

Based on the results of this planning, namely conducting a literature study used as a reference in conducting research, field studies to find out the research location, then continuing with calculating the need for public facilities, as well as calculating the planned cost budget that will be used with a total cost is IDR 298.794.000 of the total electrical energy requirement of 48.165 Wh.

In the centralized PLTS in Pinggir Laut village, it is planned that there will be 2 (two) series of arrays so that the total panels required are 60 units. When selecting solar power plant (PLTS) components, pay attention to the price of each component at a cheaper price but still pay attention to quality, so that the total investment costs and operational costs of replacing the battery can be cheaper.

Based on the results of research conducted in Pinggir Laut village, Bangko sub-district, Rokan Hilir district, it is said that it is feasible to build an off-grid solar power plant, because the survey data shows that the intensity of sunlight is quite good for a seaside village that has minimal electricity from PLN..

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