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Design of Public Street Lighting for Solar Power Plants (PLTS) in Bukit Bio-Bio Village

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***Abstract*— This design was motivated by the need to reduce dependence on fossil energy in the village of Bukit Bio-Bio. Although most villages are starting to consider renewable energy, there are still shortcomings in the application of technologies such as solar power plants to meet the needs of street lighting at night. This design proposes the installation of street lighting with solar power plants, as a solution to take advantage of existing solar energy. Thus, this idea aims to provide a sustainable and environmentally friendly alternative in meeting the needs of street lighting in Bukit Bio-Bio village. The research method includes surveys and direct observations in Bukit Bio-Bio Village to find out how long the road, the area of the road that will be designed for the installation of solar power plant (PLTS) street lighting in Bukit Bio-Bio Village, to find out how many light points will be installed and the distance between poles to other poles, and to find out how many panels are installed, as well as other components such as solar charger controllers (SCCs) and batteries. The results of the study show that in Bukit Bio-Bio village, 53 street lighting points are needed, in order to achieve good lighting and according to needs.**

***Keywords*— Solar Power Plant (PLTS), Bukit Bio-Bio Village Street Lighting, Renewable Energy, Survey, and Observation.**

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I. INTRODUCTION

Street lighting is one of the important aspects in creating a safe and comfortable environment for road users, especially at night. However, conventional street lighting systems that rely on electricity from the PLN network often face several challenges, such as high operational costs and dependence on fossil energy sources that negatively impact the environment. Therefore, there is an urgent need to find alternatives that are more efficient and environmentally friendly.

New and Renewable Energy (NRE) is the use of environmentally friendly energy with energy sources derived from sunlight, wind, water, and biomass [1]. The use of solar renewable energy (solar) in Indonesia has enormous potential. The use of NRE is able to reduce greenhouse gas emissions and climate change[2], energy needs (electricity, oil, and gas) will continue to increase along with the growth of the population in Indonesia. The amount of national energy consumption increased from 2018 to 2019 by 9%. Energy consumption in the industrial and construction sectors is 46%, households are 29%, transportation is 18%, and others are 7% [3]. Energy and Infrastructure Conditions of Bukit Bio-Bio Village, which is located in Kenagarian Sikucua Utara V Koto, Kampung Dalam Padang Pariaman, is an area with minimal street lighting. This is often a major challenge in ensuring access for rural communities.

Along with the development of technology and awareness of the importance of renewable energy, solar energy is becoming a potential solution to meet the needs. The basic need in the village is street lighting. Limited accessibility and minimal lighting can result in limited safety and mobility issues for villagers, especially at night. The design of the solar power plant in Bukit Bio-Bio Village aims to improve electricity accessibility in the village, especially for street lighting. By utilizing solar energy, it is hoped that it can provide sufficient and affordable lighting for the local community, as well as support social and economic activities in the village

II. METHODS

A. Flowchart

Research on the design of public street lighting in Bukit Bio-Bio Sikucua Utara was carried out using the Quantitative Method, namely in this Literature Study it was carried out to be able to search for theories, findings, and materials from relevant previous research, including books, journals, and other references on solar power plant planning, which will help researchers in the research process. In addition, this field survey was carried out to determine the location of the building that will use solar power and to calculate the required electricity load.

After performing these steps, the calculations are done using formulas to find out how many panels to use, etc. If there is an error in the analysis, repeat the calculation carefully. If the results of the calculation have correctly determined the capacity and type of components that will be used for solar power plants in lighting and can perform RAB calculations to find out the planned cost expenditure. To make it easier to understand what will be done in this study, a flowchart is used as shown in figure 1.

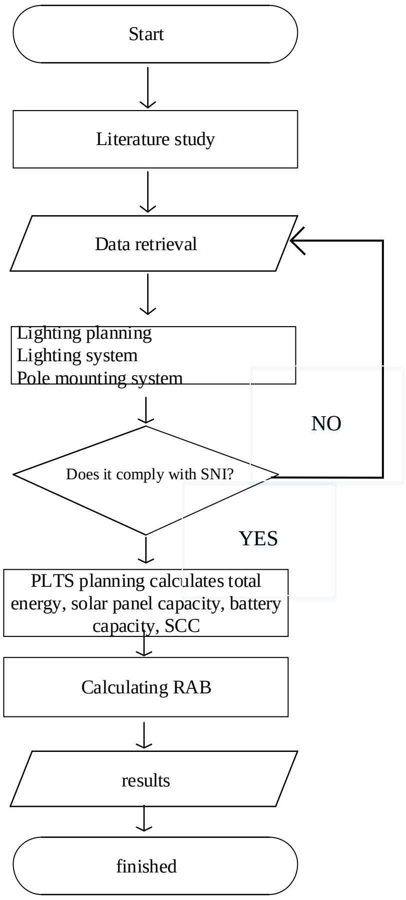

FIGURE 1. Block Diagram of System Planning

B. Research Venue

FIGURE 2. Bio-Bio Hill Location Plan

This research is to plan a more environmentally friendly PJUTS and the location of this research was carried out in Bukit Bio-Bio Village which is located in North Sikucua District, Kec. V Koto Kampung Dalam, Padang Pariaman Regency which has a track length of 2630 m with a road width of 4 meters where this road still uses sources from PLN or conventional street lighting. Many points do not light up and there are points where the lights do not work or are damaged.

C. Calculations to be discussed

The calculation of the lighting system includes light flux, lighting intensity, lighting intensity, lamp height and distance between poles. The calculation of a solar power plant includes the total energy needed, panel capacity, battery capacity, SCC capacity. Then calculate the investment cost needed for PJUTS.

D. Technical data

The road used as a case study in the study is a road in Bukit Bio-Bio Village, V Koto District, a village in Padang Pariaman Regency. The condition of street lighting at night is not good because of uneven lighting and there are several light points that do not work, seen in figure 3 is a comparison photo between afternoon and night conditions in Bukit Bio-Bio Village and can be seen in table 3.1 is the specification of the road in Bukit Bio-Bio Village

FIGURE 3. Day and Night Conditions at Bio-Bio Hill

TABLE I
Types of roads.

Information	Specifications
Street Name	Bukit Bio-Bio Village Road
Road Length	2630 m
Road Width	4 M
Number of Lines	One Lane
Road Function	local
Street Class	Primary

Calculation Formula

1. *Formula for calculating the angle slope of an ornamental handlebar*

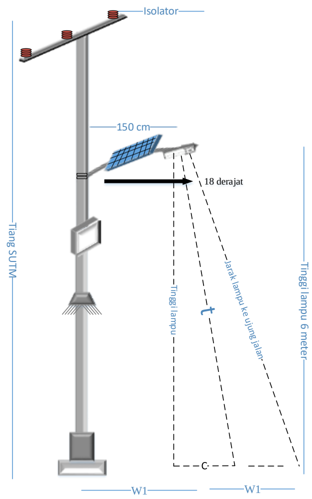

FIGURE 4. Calculating the angle slope of an ornamental handlebar

$$t = \sqrt{h^2 + c^2} \quad (1)$$

Where:
h = pole height
t = distance of light to the middle of the road
c = horizontal distance of the headlights
W1 = pole to lamp tip distance
W2 = horizontal distance of light to the end of the road

2. *Determining the number of light points*

To find out the number of light points installed or the number of light points needed for planning, if formulated as follows:

$$T = \frac{L}{s} + 1 \quad (2)$$

Where: T = Number of light points

L = Road length (m)
S = Distance from the pole pole (m)Determining the Capacity of the Solar Charge Controller

3. *Light Flux*
Light flux is the amount of light emitted by a light source. The light flux symbol is F/Φ and the unit is lumens (lm). To calculate the intensity of light, you can use the following equation:

$$F = \omega.l \quad (3)$$

Where: Φ = light flux (lm)
ω = angle of space in steradian
l = light intensity (cd)

From the light flux equation above, the light intensity equation is obtained as follows:

$$l = PV \quad (4)$$

4. *Light Illumination Intensity*
To calculate the intensity or intensity of lighting or lighting can use the following equation:

$$E\_(average) = (\varphi.\eta.MF)/(WS) \quad (5)$$

Where:
E (installments) = Average Exposure in Lux (Lx)
F = light flux (lumens)
MF = maintenance factor
MF = 0.7- 0.9 (SNI)
At = Road width
S = distance between poles the = 0.35 (SNI)

5. *Determining the Efficacy of Average Light*
Efficacy is the range of numbers compared between the luminous flux (lumens) and the electrical power of the light source (watts), in lumens/watts

$$K = \emptyset/p \quad (6)$$

Where:
K = light efficacy (lm/watt)
Ø = light flux in lumens (lm)
P = lamp power (watts)

6. *Calculating Lighting*
Lighting is the sum of light intensity per unit area. It is a measure of the brightness of an object. Lighting that is too large will dazzle the eyes. It is formulated by the following equation:

$$L = \frac{I}{(4\pi r^2 cos\theta)} \quad (7)$$

Where:
L = Lumination (cd/m^2)
Axle = Field area (m^2)
I = intensity (cd)

With

$$As = A \cos\theta \quad (8)$$

I = The angle between the incoming rays and the normal line

III. RESULT OF THE SOLAR CELL TESTS

A. Calculation Results

The design of this tool has resulted in the creation of a dual-axis solar tracker with a water pump load, which is intended for use as a plant watering mechanism. In order to track the solar cell system, a framework that can be moved in all directions is required. The framework of the dual-axis solar tracker employs angle iron and holo iron, which are capable of supporting the weight of solar panels. The solar tracker system necessitates the utilisation of two actuators for the purpose of moving the frame, with input derived from the LDR sensor. This sensor has been programmed by the Arduino Mega microcontroller with a 5-volt 4-channel relay output, thereby facilitating the activation of the aforementioned actuator.

From the results of determining the specifications of public street lighting poles that have been determined predetermined, namely with a pole height of 6 m and an ornamental handlebar length of 1.5 m, the pole specification parameters can be used to calculate the slope of the ornamental handlebar

Known:
h = 6 meters
a = 1.5 meters
$t = \sqrt{h^2 + c^2}$
$= \sqrt{6^2 + 2^2} = 6.32$ meters

After obtaining the t-value, then to determine the slope of the ornamental handlebars using the equation

$cos\ \theta = \frac{h}{t}, \quad cos\ \theta = \frac{6}{6{,}32}$

$= \theta cos^{-1}\frac{6}{6{,}32}$

$= \theta 18{,}31°$

So the slope of the ornamental handlebar is rounded to 18°.

B. Light Intensity Calculation

$= \frac{k\ x\ p}{w}$

Where:

k = lumens/watts

p = lamp power

at = 4π

$l = \frac{k\ x\ p}{w}$

$l = \frac{90x\ 40}{4x3{,}14}$

$l = \frac{3600}{12{,}56}$

286.6 cd $l =$

C. Calculation of Lighting Intensity

For the value η = 0.35 (SNI)[4] and for the MF value = 0.7- 0.9 (SNI)[4] the middle value for the MF value is 0.8, then obtained:

E_(installments) = $\frac{3571x0{,}35x0{,}8}{4.42}$

E_(installments) = $\frac{999{,}8}{168}$

E_(installments) = 5.9 lux

To find out the illumination at a point/coordinate (P) the equation is used:

E== $\frac{1}{r^2}$ Cosϕ

As a sample, it was taken at the end of the pavement with the value of h = 6 m and W2 = 4 m

r = $\sqrt{h^2 + w2^2}$

r = √(6^2+4^2)

r = 7,2

Once you know the value of r, put it into the equation that will be

E = $\frac{l}{r^2}$ Cosϕ

E = $\frac{286{,}6}{7{,}2^2}$ Cosϕ

E = $\frac{286{,}6}{51{,}84}$

E = 5.5 lux

So the lighting value at the point/coordinate of the end of the sidewalk is 5.5 lux

D. Lighting Calculation

L = $\frac{L}{(4\pi r^2 cos\theta)}$

= $\frac{286{,}6}{4x3{,}14x7{,}2^2x0{,}83}$

= 0.83 cd/m

E. Efficacy Calculation

K = $\frac{\emptyset}{p}$

= $\frac{3571}{40}$

= 89.2 lm/watt

F. Calculation of the Pole Point

T= L/s + 1
T = 2630/50 + 1
T = 53 points

G. Design Analysis and SNI

TABLE II
Analyze the Planning Results

Parameters	Account	SNI
E Average	5,9	2- 5 lux
E Min	5,5	3 lux
L Average	0,83	0.50 cd/m2

To ensure that the design The public street lighting in this study is in accordance with the applicable standards, so it is necessary to analyze the planning results using the national standards that have been set in Indonesia. The following are the results of the planning of the Indonesian National Standard (SNI) and

H. Determination of Solar Specifications

In this study, the amount of power used is 40 W. The load in question is a light load that is commonly used for 12 hours a day,

ET = P (L x t)
= 40 x 12
= 480 watts

Panel Capacity: $\frac{E_T}{isolasi}\ x\ 1{,}1$

$= \frac{480}{4{,}31}\ x\ 1{,}1$

=122.5

So the total capacity of the panel is 122.5 Wp

Emodul = Pmodul x digging factor
Emodul = 120 WP x 4 H
Emodul = 480 Wh

Module $\sum = \frac{E_t}{E_{modul}}$

Module ∑ =480/480
Module ∑ = 1 unit

I. Battery Calculation

$$I_{Ah} = \frac{E_T}{V_S}, \qquad I_{Ah} = \frac{480}{12}$$

$I_{Ah} =$ 40 Ah

$$I_{Ah} Total = \frac{I_{Ah}}{DOD}$$

$$= I_{Ah} Total \frac{40_{Ah}}{80\%}$$

$$= 50\ \text{Ah} I_{Ah} Total$$

$$\Sigma_{baterai} = \frac{I_{Ah\ total}}{kapasitas\ batrai\ perunit}$$

$$\Sigma_{baterai} = \frac{50}{50}$$

$$\Sigma_{baterai} = 1\ unit$$

J. SCC Calculation

The SCC is the central point connecting the load, solar panels, and battery. Then the maximum current at SCC is

$$I_{SCC} = \frac{P_{total}}{V_S}$$

$$I_{SCC} = \frac{40}{12}, \qquad I_{SCC} = 3{,}3\ A4\ \text{A}$$

K. RAB Calculation

TABLE III
RAB Calculation

Material type	Many	Unit Price	Entire
Ornamental lid	1	IDR 500.00	IDR 500,000
Solar Panel	1	IDR 550,000	IDR 500,000
Battery	1	IDR 500,000	IDR 500,000
12V LED	1	IDR 250,000	IDR 250,000
SCC	1	IDR 200,000	IDR 200,000
Timer switch	1	IDR 95,000	IDR 95,000
MCB	1	IDR 40,000	IDR 40,000
Cable	4 meters	IDR 5000	IDR 20,000
Box panel	1	IDR 250,000	IDR 250,000
Installation cost	1 point	IDR 800,000	IDR 800,000
	IDR 3,150,000		

To find out the total investment cost of public street lighting, the number of points is multiplied by the cost per point
Total cost = T x Cost per point
Total cost = 53 x IDR 3,150,000 So the total cost that must be incurred for solar-powered public street lighting is IDR 166,950,000
Total cost = IDR 166,950,000

IV. CONCLUSION

In the design of the lamp height of 6 meters with an ornamental handlebar slope of 18°, the length of the ornamanet handlebar is 1.5 meters, for the octagonal pillar type the distance between the pillars is 53 meters and the length of the road is 2630 meters with a width of 4 meters. The number of solar panels used on each street lighting pole is 1 unit with a capacity of 120 Wp. The number of batteries used on each street lighting pole is 1 unit with a capacity of 50 Ah. As for the SCC on each lighting pole, it has at least a current capacity of 4 A. The type of lamp used is a 40-watt led, with a voltage of 12 vdc with 3571 lumens, with an average lighting of 5.59 lux, a minimum lighting of 5.5 lux, and an average lighting of 0.85 cd/m. The cost of installing the pole is Rp 3,150,000.

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