Analysis of Solar Panel Based Public Street Lighting Installations

Zuraidah Tharo[1*], Eddy Sutejo[2], Gavana Mustaqim SK[3]
[1,2,3]Fakultas Sains dan Teknologi, Universitas Pembangunan Panca Budi, Indonesia

*e-mail: zuraidahtharo@dosen.pancabudi.ac.id

ABSTRACT
Public Street Lighting is one of the public facilities that requires energy, so to meet these energy needs it is appropriate to utilize New Renewable Energy, a part from supporting government programs, it will also minimize the use of conventional electricity in accordance with ESDM regulation Number 14 of 2012 concerning Energy Management. Public Street Lighting is a public lighting installation and is usually installed on road medians, bridges, toll roads, arteries and collectors and certain places such as parks and other public places so as to provide a sense of security and comfort to the public when traveling/activities at night. To obtain effective and efficient Public Street Lighting, good and correct planning is required, including selecting the type of lights to be used. Calculating the need for solar panels, pole height and distance from one pole to the next is part of planning Solar Panel-based Public Street Lighting.

Keywords: Public_Street_Lighting, Renewable_Energy, Solar_Panel

Introduction

Public Street Lighting is one of the facilities and infrastructure included in the Regional Government Program to provide Social Services to the community so that street lighting is produced that can provide safety, smoothness and comfort for road users. (BSN, n.d.) Public street lighting is usually installed on road medians, bridges, toll roads, arteries and collectors and in certain places such as parks and other public places. (BSN, n.d.)

With advances in technology and efforts to reduce Green House Gas emissions as well as the use of New and Renewable Energy, the need for Electrical Energy for Public Street Lighting is designed with a Solar Energy source. However, in the development and planning of good PJUs, existing standards and regulations must be used so that public street lighting installations can operate properly according to their function and can be used in the long term. By using Solar Panel media as a means of converting sunlight into electrical energy, it will produce an energy source that can turn on lights in public street lighting. The problem is that using solar panels as an energy source must go through precise calculations so that the capacity of the electrical power produced can meet the expected needs. The purpose of this analysis is to obtain correct calculations in determining public street lighting installations using solar energy sources. The research was carried out using the Quantitative Method where calculations and experiments were carried out to obtain data and research results.

Public Street Lighting

The lighting lamp in question is a complete unit consisting of a light source (lamp/lumen), reflecting optical elements (reflector), diffuser, electrical elements, connectors, power source (power supply) and others. This also includes the supporting structure consisting of support arms, vertical support poles and light pole foundations. According to the IESNA (Illumination Engineering Society of North America) criteria, the main purpose of street lighting is to provide speed, accuracy and comfortable vision at night. The quality of visibility must be maintained, as well as making it easier for passing vehicles and pedestrians. (Shamin & Demak, 2018)

The function of roads according to Law No. 38 of 2004 states that roads are transportation infrastructure which includes all parts of the road including complementary buildings and equipment intended for traffic above ground level and below ground level and above the water surface, except railroad and cable roads. The grouping of road functions in Indonesia according to Law No.38 of 2004 is:

1. Arterial Road
   It is a public road that functions to serve the main transportation with the characteristics of long distance travel, high average speed, and the number of access roads is limited in an efficient manner.
2. Collector Street
   It is a public road that functions to serve collector or share transportation with the characteristics of medium distance travel, medium average speed, and a limited number of entrances.
3. Local Roads
   It is a public road that functions to serve local transportation with the characteristics of short distance travel, low average speed and unlimited number of entrances.
4. Neighborhood Road
   It is a public road that functions to serve environmental transportation with the characteristics of short distance travel and low average speeds (Pratama & Arifin, 2021).

The function of street lighting according to the specification book for Street Lighting in Urban Areas, Directorate General of Highways (2007) includes:

1. Produces contrast between objects and the road surface.
2. As a navigation aid for road users.
3. Increase the safety and comfort of road users, especially at night
4. Supports environmental safety
5. Provides beauty to the road environment
6. Improve traffic safety
7. Provides security from criminal acts.

Solar Power Plant

Solar Power Plants are a type of power plant that utilizes New Renewable Energy with the energy source being sunlight. Using Solar Panel media to convert solar energy into electrical energy. Solar energy is a renewable energy alternative with great potential, because the amount of energy sources is unlimited and is available in almost all parts of the world. (Tharo et al., 2022) With this working system, when the sun shines on the surface of a semiconductor device which is usually called a solar cell or solar panel, the photoemission process (photoelectric effect) occurs in the solar cell,

and the solar energy is directly converted into electrical energy. Sunlight hitting a semi-conductor (photovoltaic) medium causes electrons in the medium to be released from their bonds and flow/move, resulting in reverse current activity. This transfer is known as photovoltaic. All photovoltaic cells have at least 2 semiconductor layers, one with a positive charge and one with a negative charge. When a photovoltaic cell is exposed to sunlight, the electron charge will flow to a high potential charge. The connection between the two layers causes electricity to flow, generating a direct current. (Tharo et al., 2022) The use of sunlight in public street lighting follows the PLTS working system, using batteries as energy storage.

Public Street Lighting Poles

In general, the location of lamp poles intended for public street lighting can be seen from the following table:

Table 1. Layout of Public Street Lighting Poles

Road Conditions	Arrangement/Location Arrangement
One way street	a. Left or right of the road b. On the left and right of the road/zigzag c. On the left and right of the road/facing d. In the middle/median of the road
Two-way street	a. In the middle/median of the road b. Combination of left and right facing the middle/median of the road c. Catenation, in the middle of the road with the lights hanging
Crossroads	a. Can be done using tower lights with several lights, generally placed on islands, road medians and outside intersection areas.

(Pratama & Arifin, 2021)

The pole is a component used to support the lamp. Several types of poles used for street lights are iron poles and octanginal poles. There are several types of street lighting poles, including:

1. Single Arm light pole, generally placed on the left or right side of the road.

Figure 1. Single Arm Light Pole
Source: BSN

2. Double Arm Light Poles, specifically placed in the middle or median of the road provided that the condition of the road to be illuminated can still be served by one pole.

Figure 2. Double Arm Light Pole
Source: BSN

3. Armless Light Poles, needed to support tower lights, which are generally placed at road intersections or large areas such as interchanges, parking lots and so on.

Figure 3. Armless Light Pole
Source: BSN

Ornament Handlebar Tilt Angle

The angle of the ornamental handlebar is aimed so that the lighting point is directed towards the middle of the road, so first you have to know the distance between the lights and the middle of the road. The lamp tilt angle is a maximum of 30° with the following considerations:

a. The glare effect of light reflection on the road surface
b. Lamp life
c. Light spreading efficiency

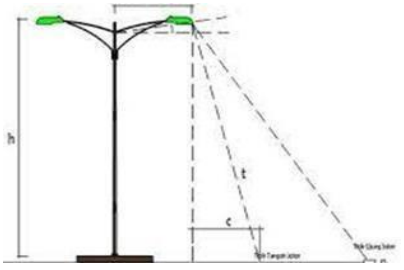

Figure 4. Ornament Handlebar Tilt Angle
(Effendi; & Aldifian, 2012)

The angle of the ornament's handlebars functions so that the lighting point is directed towards the middle of the road. The calculation results can be obtained using the following formula:

$$\text{Cos } \phi = \frac{h}{t} \quad (1.1)$$

After getting the angle of inclination of the ornament's handlebars, then calculate the distance from the lights to the middle of the road using the following formula:

$t = \sqrt{h^2 + c^2}$ (1.2)

Information:
h = Height of the pole
c = Horizontal distance of the light to the middle of the road
t = Distance from the light to the middle of the road

Light Intensity
Luminous intensity is the light flux per unit angle of space in the direction of light emission. The calculation results can be obtained using the following formula:

$I = \frac{\varphi}{\omega}$ (1.3)

Information:
I = Light intensity in candela (cd)
φ = Luminous flux in lumens (lm)
ω = Space angle (°)

Where the magnitude of the light flux φ in lumens can be found using the following formula:

φ = K x P (1.4)

Information:
K = Average light efficiency of the lamp
P = Electric power

Illumination

Illumination aims to determine the distribution of light intensity. The calculation results can be obtained by using the following equation:

$r = \sqrt{h^2 + l^2}$ (1.5)

Information:
h = Height of the pole
l = Distance from the light to the end of the road
r = Distribution of light intensity

So the illumination value can be obtained using the following equation:

$E = \frac{I}{r^2} \times \frac{h}{r}$ h = Height of the pole

Where:
E = Illumination strength
I = Light intensity
r = Distribution of light intensity

(1.6)

Lumens

Lumination aims to determine the light flux φ in lumens emitted by a light source, it can be calculated using the equation:

Lamp power x Number of lamps (1.7)

1. Methods

This research uses quantitative research and design methods where the results and data are provided through calculations and experiments carried out. This research aims to see the ability of solar panels to provide energy for public street lighting, and the capacity of the components that will be used in public street lighting. Thus, in this research, data collection techniques were obtained by observing and carrying out calculations. Research implementation from August to December 2023. The method used in data analysis is the Quantitative Research Analysis method, where the data obtained is based on measurements and experiments carried out, and aims to develop mathematical models related to natural phenomena. The research procedure can be seen in the following flow diagram:

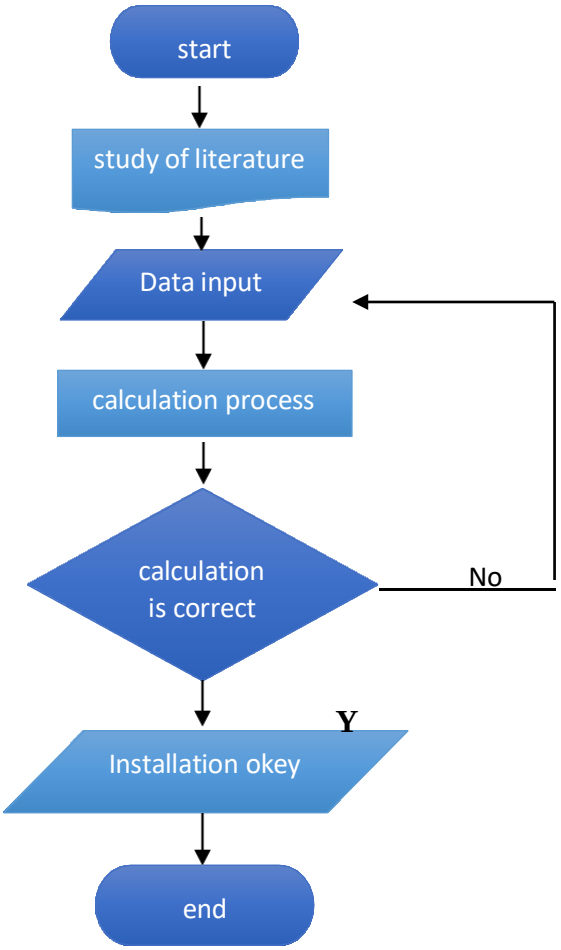

Figure 5. Research Flowchart

2. Results and Discussion

The research was carried out on Jalan Soekarno-Hatta, Binjai City, North Sumatra, this road is included in the Arterial and Collector Road types. By taking a road length of 1 km (1000 m), the road width is 6 m on the right and left sides of the road.

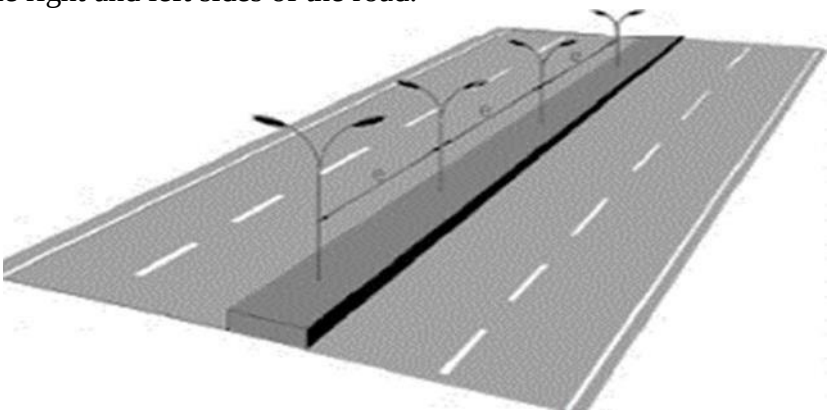

Figure 6. Illustration of Public Street Lighting
(Yolnasdi, 2017)

Type and Height of Pole

Pole Type

From the research carried out, the types of poles used in lighting lamps were obtained Public Roads are a type of Double Arm Pole that is installed on the road median.

Figure 7. Type of Double Arm Pole in the Road Median

Pole Height

The height, distance and number of poles are listed in the following table:

Table 2. Data on Public Street Lighting Lamp Poles

Component	Size
Pole Height	8 m
Distance Between Poles	30 m
Number of Poles	30 pieces

As an illustration, the location of public street lighting along Jalan Soekarno-Hatta, Binjai City is as follows:

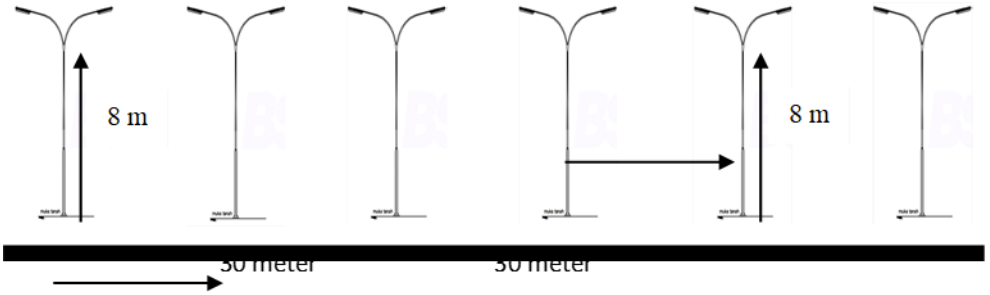

Figure 8. Illustration of Public Street Lighting in Binjai City (Effendi; & Aldifian, 2012)

Ornament Handlebar Tilt Angle

The angle of inclination of the ornament handlebar can be calculated using equation (1.1) by first finding the distance from the light to the middle of the road using equation (1.2). As seen in the following image:

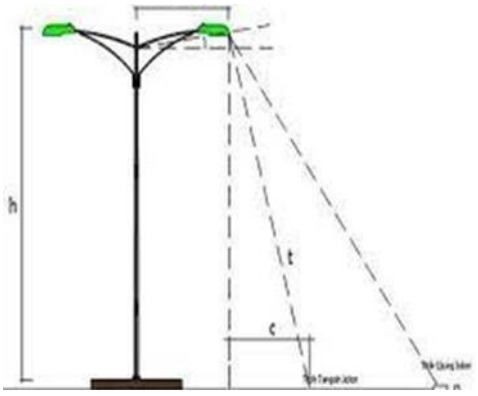

Figure 9. Distance From Lights to The Middle Of The Road (Effendi; & Aldifian, 2012)

Equation (1.2) is written as t = $\sqrt{h^2 + c^2}$

Where:
t = Distance from the light to the middle of the road
h = Height of the pole
c = Horizontal distance of the light to the middle of the road

From the measurement results, the pole height is 8m, the horizontal distance of the light to the middle of the road is 3m, then the distance of the light to the middle of the road can be calculated:

$$t = \sqrt{h^2 + c^2}$$
$$= \sqrt{8^2 + 3^2}$$
$$= \sqrt{64 + 9} = \sqrt{73} = 8{,}54 \text{ meters}$$

By obtaining the distance from the light to the middle of the road, the angle of inclination of the ornament handlebar can be calculated using equation (1.2)

$$\cos \varphi = \frac{h}{t}$$
$$= \frac{8}{8{,}54} = 0.93$$

$$\cos^{-1} 0.93 = 21.56°$$

From the calculations above, the distance between the lights and the middle of the road is 8.54 meters and the angle of the ornamental handlebar is 21.56 degrees.

Light Illumination

Calculating illumination aims to determine the strength of the illumination and the distribution of light. The calculation results can be obtained using the following equation (1.5):

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

dimana:
r = Sebaran cahaya
h = Tinggi tiang
l = Lebar jalan

By substituting the pole height = 8 meters and the road width of 6 meters, the light distribution is obtained as follows:

$$r = \sqrt{h^2 + l^2}$$
$$= \sqrt{8^2 + 6^2}$$
$$= \sqrt{64 + 36}$$
$$= 10 \text{ meters}$$

After the light distribution is obtained, then calculate the lighting strength using equation (1.6), namely:

$$E = \frac{I}{r^2} \times \frac{h}{r}$$

Where:
E = Illumination strength
I = Light intensity

r = Light distribution

h = Height of the pole
Before calculating Illumination, first calculate the light intensity using equation (1.3) below:
$I = \frac{\varphi}{\omega}$
Where :
I = Light intensity φ
= Luminous flux ω
= Space angle
The magnitude of the light flux φ in lumens can be found using the following equation (1.4):
φ = K x P
Information:
K = Average light efficiency of the lamp
P = Electric power

If the average light efficiency value for LED lamps is 120 lm/W (standard for LED lamps), and the lamp power is 43 Watts and the room angle is 4π, then we get:
$I = \frac{K \times P}{\omega}$
$= \frac{120 \times 43}{4\pi} = 410.61$ Cd

Once the parameter values are known, the Illumination can be found by entering these values into the equation:
$E = \frac{I}{r^2} \times \frac{h}{r}$
So we get:
$E = \frac{I}{r^2} \times \frac{h}{r}$
$= \frac{410.61}{100} \times \frac{8}{10} = 3.28$ lux.

From the calculations, the amount of illumination obtained is only 3.28 Lux, this figure is still very low if seen from the standard set by SNI, namely 15-20 Lux.

Power Used

Calculating power aims to determine the power required based on the LED lights used with a power of 43 Watts, so the power flowing in public street lighting can be calculated using the following equation:
P = Lamp Power x Number of Lamps
= 43 Watts x 60 Light bulbs (double arm pole)
= 2,580 Watts (2.58 kW).
Meanwhile, the energy used is:
E = P x t
Information:
E = Energy
P = Lamp power
t = Length of operation of the lamp in 1 day (Yolnasdi, 2017)
If the lights are active for 12 hours from 18.00 to 06.00 then the energy can be calculated:
E = 43 Watts x 12 hours

= 516 Wh/Day.

For energy used for 1 month (30 days) then:
E = 516 Wh/Day x 30 Days
= 15,480 Wh/Month.
= 15.48 KWh/month

Solar Panel Requirements

Each light pole requires two solar panels, each with a capacity of 60 Wp, a 20 Amper Solar Charge Controler and a 150 Ah 12 V Battery.

3. Conclusion

From the research and calculations carried out, it was obtained that 2 x 60 Wp Solar Panels, 20 Amper Solar Charge Controler and 150 Ah 12 Volt DC Battery, can supply energy for a 43 Watt LED Public Street Lighting with a double arm lamp pole which means 2 LED lights are used. n this case, we don't use an inverter because the light load is LED, which is Direct Current (DC). Because Public Street Lighting only operates from 18.00 to 06.00 (12 hours), So the energy absorbed by a lamp per day is 516 Watthour (Wh), so that for a lamp post the energy absorbed is 43 x 2 x 12 which equals 1,032 Wh.

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