Street Lighting Design and Management Using Solar Cells Along The Perimeter Inspection Road At Binaka Gunungsitoli Airport

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Keywords:
Airport, Perimeter, Solar Cell, Street lights

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Abstract: Airports play an important role in the transportation system, connecting flights with land transportation and supporting the global economy. Flight safety is a top priority, and one important aspect to ensure it is optimizing the perimeter in the airport airside area. The perimeter is the boundary of land or territory under the control of the airport. This boundary surrounds the airport area. At Binaka Gunungsitoli Airport, there is no lighting on the Perimeter Inspection Road, this can cause major problems for officers who want to patrol at night. So, there are several ways that can be done, namely by installing streetlights using solar cells. This study uses primary data, data in the form of observations and direct interviews with Binaka Gunungsitoli aviation security personnel. In this study, it was found that many factors caused the security function in the Perimeter Street lighting of Runway 09 and Runway 27 of Binaka Gunungsitoli Airport to not be optimal, thus affecting the safety of ongoing flights, so that security on the perimeter of Runway 09 and Runway 27 is controlled, thus supporting flight safety until the implementation of safe, smooth, comfortable, effective flight operations. Therefore, Binaka Gunungsitoli Airport installed Perimeter streetlights, to comply with standard operational procedures..

INTRODUCTION

At Binaka Gunungsitoli Airport there are several things that are of concern, one of which is the lack of lighting on the Perimeter Inspection Road due to the complete absence of lighting, which can cause major problems for officers who want to patrol at night. Therefore, Binaka Gunungsitoli Airport installed Perimeter streetlights using solar cells.

Article 1 paragraph 1, namely, street lighting equipment is street lighting that functions to provide lighting in traffic spaces. The importance of public street lighting is to realize safety, security, order, and smooth traffic and convenience for road users in traffic, especially at night. Public street lighting at airports is usually used to provide lighting on public roads around the airport and to facilitate airport operations at night (Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 27 of 2018, Concerning Street Lighting Equipment).

Solar cells are devices that convert sunlight energy into electrical energy through the photovoltaic effect process, therefore they are also called photovoltaic cells. In a solar module, there are photovoltaic cells where the photovoltaic effect occurs. If several solar modules are assembled, a solar power generation system will be formed (Determination of Solar Cell and Battery Capacity Against Electrical Load Characteristics, Adi Rezkyanto, 2019).

Solar Charger Controller or commonly called SCC is an electronic device used to limit the direct current that enters the battery and is taken from the battery to the load. SCC prevents excessive charging and protects the battery from excess voltage. In addition, SCC also prevents the battery from being drained (discharged) until it runs out. SCC will regulate overcharging or excess charging because the battery is full and excess voltage from the solar panel (Analysis and Efficiency of Public Street Lighting Installation Power Using Solar Cells in Lamongan Regency BR, 2017).

Batteries are one of the most commonly used power storage methods. Batteries are an important component that affects the overall centralized PLTS system. The batteries used in the PLTS system are rechargeable batteries. The chemical reaction that occurs is reversible, so after use this battery can be recharged (charged) by providing an electric current from outside. Batteries have two important purposes in the photovoltaic system, namely to provide electrical power to the system when power is not provided by the solar panel array, and to store excess power generated by the panels whenever the power exceeds the load. The battery undergoes a process of storing and releasing, depending on the presence or absence of sunlight (Design and Realization of Battery Capacity Requirements for 125 Watt Water Pump Load Using Solar Power Plants, Djaufani et al., 2015).

RESEARCH METHOD

This journal writing uses qualitative methods. Qualitative methods are research methods that emphasize in-depth observation to understand phenomena in natural social contact. Qualitative data and analysis. Data collection was carried out before the installation of perimeter inspection street lighting.

1. Determine the capacity of the solar panel

In determining the capacity of solar panels, the effective hours of sunlight on the solar panels in one day. With the energy load usage. Then the formula for the capacity of the solar panel needed:

$$P_{pv} = \frac{P_{Load}}{t}$$

Information:

P_{pv} = Solar Panel Capacity (Wp)

P_{Load} = Load Energy (Wh)

t = Irradiation Time

2. Calculating Battery Capacity

The condition for the battery to work normally is that the current stored in the battery must not be drained more than 25%, so that DOD (Deep Of Discharge) = 100% - 25% = 75%, In one day. Reserve power for the load if the solar panel cannot receive sunlight or in one day the weather is cloudy, for the load with the following formula (Planning of Public Street Lighting Using Solar Power for Alternative Street Lighting Talang Pete Plaju Darat Sukma et al., 2021):

$$\text{1 day load reserve} = \frac{E_{Load}}{v}$$

So, to find the capacity of a solar battery, use the following formula:

$$i_b = \frac{\text{1 day load reserve (Ah)}}{\text{DOD} \times \eta_{battery}}$$

Battery power,

$$P_{battery} = V \times I$$

Information:

i_b = minimum battery capacity (Ah)

$P_{battery}$ = battery power (Wh)

V = battery voltage (Volt)

I = battery current (Ah)

So, to calculate the one-day load reserve for 12 hours of use, use the following formula:

$$t_{Load} = \frac{P_{battery}}{P_{Load}}$$

Information:

t_{Load} = battery fully charged (hours)

P_{Load} = lamp load (Watt)

To calculate the power of the battery, you can use the following formula equation:

$$P_{reserve} = P_{battery} - (P_{load} \times t_{load})$$

Information:

$P_{reserve}$ = battery reserve (Wh)

t_{load} = length of time the load is used (hours)

3. Solar Charge Controller (SCC)

The type of solar charge controller is Maximum Power Point Tracking Charge Controller (MPPT), PWM in terms of utilizing the full power of solar panels to charge the battery. To determine (SCC) using the following formula (Planning of Public Street Lighting Systems and Parks in the USU Campus Area Using Solar Power Technology, Sihombing & Kasim, 2013):

$$I = \frac{W}{V}$$

Information:

I = current rating of the solar charger (Amper)

W = power on the solar panel (Watt)

V = voltage on the battery (Volt)

4. Light Intensity Calculation

Technical planning by conducting observations, such as calculating existing formulas to adjust the Indonesian National Standard (SNI) reference. Observations are made to obtain a proper, protected, and durable security system. (Street lighting specifications in urban areas, SNI, BSN) A lamp is a tool consisting of a light source, so that it can light up and will consume energy while the lamp is on. The conditions used to calculate how much energy is used by light are determined by:

$$\text{Total load} = \text{power} \times \text{usage time}$$

Information:

E_{load} = Energy required or load (Wh / Watt hour)

P_{load} = Load or lamp power (Watt)

t = Length of use of load or lamp in one day (hour)

5. Ornamental handlebar angle

To determine the angle of the handlebar ornament, this function is so that the lighting point is directed towards the middle of the road, which can be written with the following formula:

$$t = \sqrt{h^2 + C^2}$$

After getting the t value, the following formula is obtained:

$$\cos\varphi = \frac{h}{t}$$

Information:

h = pole height

c = horizontal distance of lamp to the middle of the road

t = distance of lamp to the middle of the road

6. Light Intensity

Luminous intensity is the luminous flux per unit of room angle in the direction of the light beam, expressed in candela units and can be written in the following formula:

$$I = \frac{\varphi}{\omega}$$

Information:

I = Light intensity in the window (cd)

φ = Luminous flux in lumens (lm)

ω = Room angle (steradian)

7. Calculate the illumination at the end point of the path

Determining the illumination at the end of the road as follows, we must calculate the distance from the lamp to the end of the road using the illumination formula or light intensity expressed in Lux units:

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

Information:

I = road width

h = pole height

From the results above, it can be used for illumination at the end of the road with the following formula:

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

Information:

r = end of path illumination

I = luminous intensity in candela (cd)

8. Determine the number of light points

We can determine the number of light points on a road by using the following formula:

$$T = \frac{L}{S}$$

Information:

T = number of light points

L = length of road

S = distance between poles

Through this formula, the value of each component that we use for perimeter inspection street lighting at Binaka GunungSitoli Airport will be known. As a reference for the capacity of the object to be used.

RESULT AND DISCUSSION

The load borne by the solar cell is a 150 Watt LED lamp, where this solar cell can process a load of 150 Watt for 12 hours. To find out the load energy as follows:

Total load = Power × usage time

Total load = 150 Watt × 12 Jam

Total load = 1.800 Wh

1. Determine the capacity of the solar panel

In determining the capacity of solar panels, the minimum effective hours of sunlight hitting the solar panels in one day for 4 hours, with a load energy of 1,800 Wh, the following formula is used :

$$P_{pv} = \frac{P_{Load}}{t}$$

$$P_{pv} = \frac{1.800}{4}$$

$$P_{pv} = 450\ \text{Wp}$$

By paying attention to the calculation results, a capacity of 450WP for one panel was selected, the solar panel or photovoltaic selected was from 450WP Monocrystalline solar cells.

Table 1: Specification Monocrystalline Solar Panel 450 WP

Max. Power (Pmax)	450W
Max. Power Voltage (Vmp)	41.4V
Max. Power Current (Isc)	10.88A
Open Circuit Voltage (Voc)	50.0V
Short-Circuit Current (Isc)	11.47A
Weight	24 Kg
Dimension (mm)	209.5cm x 1039cm x 3.5cm

2. Calculating battery capacity

The condition for the battery to work normally is that the current stored in the battery must not be drained more than 25%, so that DOD (Deep of Discharge) = 100% - 25% = 75%, In one day, for a load with the following formula:

$$1\ \text{day load reserve} = \frac{E_{Load}}{V}$$

$$1\ \text{day load reserve} = \frac{1800\ \text{Wh}}{12\ \text{V}}$$

$$1\ \text{day load reserve} = 150\ \text{Ah}$$

So, to find the capacity of a solar battery, use the following formula:

$$i_b = \frac{1\ \text{day load reserve (Ah)}}{\text{DOD} \times \eta_{\text{battery}}}$$

$$i_b = \frac{150\ \text{Ah}}{0{,}75 \times 0{,}9}$$

$$i_b = 222{,}22\ \text{Ah}$$

So, the minimum battery current capacity is 222.22 Ah and 2 batteries with a capacity of 12 V 150 Ah are taken, where 2 batteries are arranged in parallel, then, 2 parallels x 150 Ah = 300 Ah.

Table 2: Specification Battery VRLA 12V/150AH

Merk	Zanetta
Nominal Voltage	12V
Rated Capacity	150Ah
Model	VRLA/SHS Battery
Weight	37Kg

Two batteries in parallel are:

$$P_{battery} = V \times I$$

$$P_{battery} = 12V \times 300Ah$$

$$P_{battery} = 3.600 \text{ Wh}$$

The power of the two batteries used is 3,600 Wh. So to calculate the load reserve in one day for 12 hours is to use the following formula :

$$t_{load} = \frac{P_{battery}}{P_{load}}$$

$$t_{bload} = \frac{3.600 \text{ Wh}}{150 \text{ Watt}}$$

$$t_{load} = 24 \text{ Hours}$$

From the calculation above, it is found that when the battery is fully charged it can light up the lamp load for 24 hours. If in a day the load is only on for 12 hours, from 18:00 to 06:00 then the battery still has a load reserve of up to 12 hours. To calculate the power on the battery, you can use the following formula equation:

$$P_{Reserve} = P_{battery} - (P_{load} \times t_{load})$$

$$P_{Reserve} = 3.600 \text{ Wh} - (150 \text{ Watt} \times 12 \text{ Hours})$$

$$P_{Reserve} = 3.600 - 1.800$$

$$P_{Reserve} = 1.800 \text{ Wh}$$

So the battery capacity that will be used is two 12 V 150Ah batteries. In the calculation above, the two batteries have a load reserve of up to 12 hours, to face the rainy season conditions, the batteries that will be used are two 12 V 150 Ah batteries, as a power supply for the load if the solar panel cannot receive sunlight or in one day the weather is cloudy or rainy.

3. Solar Charge Controller (SCC)

Here is the solar charge controller data used on the Solar Panel: The type of solar charge controller is the Maximum Power point Tracking Charge Controller (MPPT) whose efficiency is above PWM in terms of utilizing the full power of the solar panel to charge the battery. PWM limits its output to ensure that the battery is not overcharged. When the weather is sunny, the PWM will again receive more current from the solar panel using the following formula :

$$I = \frac{W}{V}$$

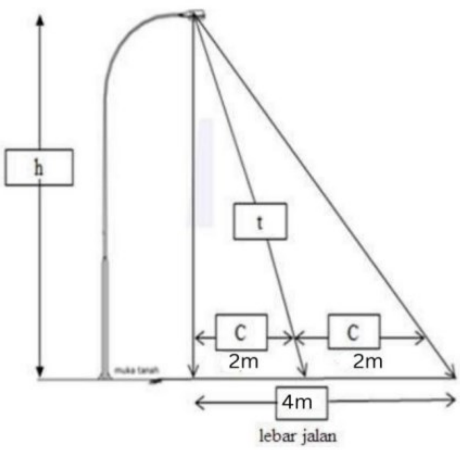
$$I = \frac{450}{12}$$

$$I = 37{,}5$$

So, the SCC used is 40 Ah to be the safety of the SCC.

4. Determine the angle of the ornament handlebars

The angle of the ornament bar is useful for producing a point of light directed to the middle of the road. Determining the angle of the ornament bar is very important, because the slope of the ornament bar affects the intensity value of the lighting produced.



Picture 1: Street Light Pole Image

The height of the pole is known to be 8 meters, and the width of the road is 4 meters, so to find the angle of the handlebar ornament as follows:

$$t = \sqrt{h^2 + C^2}$$

Pole height (h) = 12 meters

Horizontal distance of the lamp to the middle of the road (c) = 2 meters

Then:

$$\cos \varphi = \frac{h}{t}$$

$$\cos\varphi = \frac{12}{12{,}16}$$

$$\cos\varphi = 0{,}98$$

$$\varphi = \cos^{-1} 0{,}98$$

$$\varphi = 11^{0}$$

So, the angle of the ornament handlebar is 11^{0}

5. Calculating Light Intensity

The light intensity for a 150 Watt LED lamp can be calculated using the following formula:

$$\mathrm{I} = \frac{\varphi}{\omega}$$

φ = 110 lm/watt x 150 Watt = 16.500 cd

Then:

$$\mathrm{I} = \frac{16.500}{12{,}56}$$

$$\mathrm{I} = 1.313{,}69 \text{ Cd}$$

6. Calculate the illumination at the end point of the path

Before determining the illumination of the end point of the road, first determine the distance of the lights to the end of the road using the following formula :

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

$$r = \sqrt{12^2 + 4^2}$$

$$r = \sqrt{144 + 16}$$

$$r = \sqrt{160}$$

$$r = 12{,}64\, meters$$

So, the illumination to the end of the road when using a 150 Watt LED can be obtained using the following formula:

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

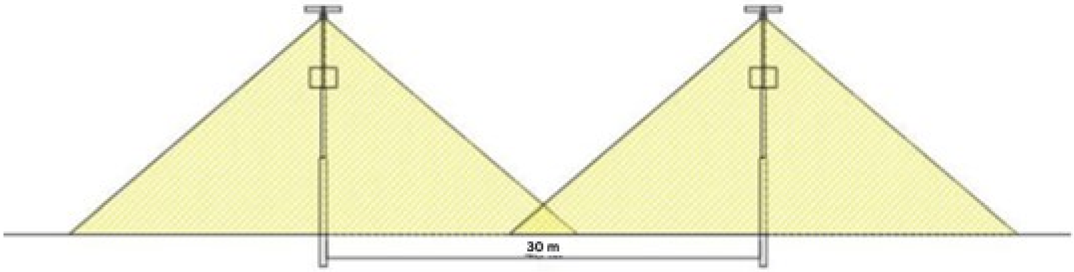
$$E = \frac{1.313{,}69}{12{,}64^2} \times \frac{12}{12{,}64}$$

$$E = \frac{1.313{,}69}{159{,}76} \times \frac{12}{12{,}64}$$

$$E = 8{,}22 \times 0{,}94$$

$E = 7,72\ Lux$

In the calculation above, the height of the pole is 12 m and 7.72 Lux will get a distance between poles of 40 m. where the end of the light meets another light, as illustrated below.



Picture 2: Distance between poles

7. Determine the number of light points

Determining the number of waypoints in the planning of a flight path along the Perimeter Inspection Road and the New Housing Complex at Binaka Gunungsitoli Airport, with the distance between poles following the existing street lights at Binaka Gunungsitoli Airport, which is 30 meters. We can determine the number of light points on a road using the following formula:

A. Along the perimeter inspection road, runway 27 has a road length of 1,500 meters.

$$T = \frac{L}{S}$$

$$T = \frac{1.500}{30}$$

$$T = 50\ Titik\ lampu$$

Picture 3: Inspection Road Perimeter Runway 27 Binaka Airport Gunungsitoli

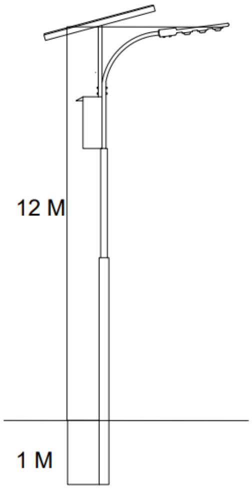
B. Along the perimeter inspection road, runway 09 has a road length of 1,390 meters.

$$T = \frac{L}{S}$$

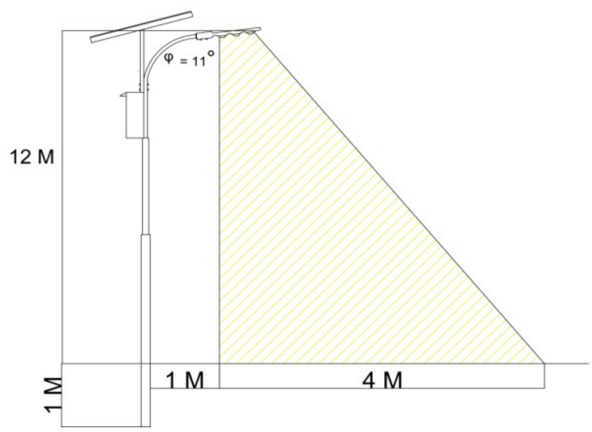
$$T = \frac{1.390}{30}$$

$$T = 46{,}3 \approx 46\,Titik\ lampu$$

Picture 4: Inspection Road Perimeter Runway 09 Binaka Airport Gunungsitoli



Picture 5: Single Pole Street Light



Picture 6: Distance from Pole to End of Road

CONCLUSION

The results of this study produce data for designing and managing street lighting using solar cells along the perimeter inspection road at Binaka Gunungsitoli Airport with the results of installing perimeter inspection street lighting, before the installation of perimeter inspection street lighting caused many major problems for officers patrolling at night, after the installation of perimeter inspection street lighting, it was found that with a pole height of 12 m and a road width with 150 Watt LED lights, the angle of the ornament bar was $11o$ and Illumination was 7.72 Lux. With Illumination of 7.72 Lux, the distance between poles is 30 M and for officers patrolling at night, they get good lighting for flight safety. For flight safety at Binaka Gunungsitoli Airport, it is necessary to install street lighting at Binaka Gunungsitoli Airport using solar cells.

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