STUDY AND DESIGN OF STREET LIGHTING SYSTEMS USING SOLAR PANEL

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Abstract—Due to scarcity of fossil fuel, alternative energy has been used upon renewable energy. This research discussed about street lighting plan at PT. Haraka Erfi Kosmetindo Abadi which used solar panels as an alternative energy. The study aims to determine design the capacity of solar panels, batteries and inverters to meet the needs of road lights. Basically, reference study and calculation load are the basic method used. The results show that 7 solar panels of 100 Wp are needed, along with 3 units of batteries with a capacity of 100 Ah, 1 unit of PWM type Solar Charge Controller with a capacity of 60 A, and 1 unit of Modified Sine Wave type inverter with a capacity of 500 W. Furthermore, an efficiency of 14.37% was obtained from this system.

Keywords: solar panels, street lighting, solar energy, design, renewable energy

1. INTRODUCTION

Street lighting is an additional building part that can be placed/installed on the left and right sides of the road and used to illuminate the road and its surroundings. A luminaire is intended as a complete unit consisting of a light source (lamp) and optical components (reflector, refractor, and diffuser), electrical components (connectors to the power supply, and so on) and a supporting structure. [1]

Energy needs in the era of globalization require renewable alternative energy sources, including the need for electrical energy sources. In general, electrical energy is very dependent on the availability of natural resources that can be used to generate electricity, such as fossil fuels (oil), geothermal heat, sea water, wind, solar power, and others. energy sources that can be used as generators, but up to now Indonesia is still trapped and dependent on fossil fuels (oil) to be used as a source of electricity generation. [2]

The use of solar energy as an alternative energy source to overcome the energy crisis, especially the oil pandemic which has caused an epidemic since the 1970s, has received considerable attention from many countries in the world. Apart from being in unlimited quantities, its use also does not cause pollution that can harm the environment. Sunlight can be converted into electricity using solar cells or photovoltaic technology.

The potential for solar energy in Indonesia is very large, around 4.8 kWh/m2 or equivalent to 112,000 GWp, but only around 10 MWp has been utilized. Based on data compiled by the National Research and Innovation Agency (BRIN) and the Meteorology, Climatology and Geophysics Agency (BMKG), it is known that the intensity of solar radiation in the West Java region, especially Bogor and Bandung, has quite high radiation, namely an intensity of around 2 kWh/m2 . [3]

The use of lamps is currently supported by the availability of energy-saving lamps on the market at competitive prices. Utilization of renewable energy sources depends on the potential energy sources available at the location where the lighting system is installed. One of the locations for the street lighting system is the lighting in the PT parking lot. Haraka Erfi Kosmetindo Abadi is located just to the right and left of the gate and the outside leads to the resident's road where it will be installed.

This location was chosen because it is a rest area for employees as well as a parking area and the outside area is used as an access road for residents. Installing solar panels here takes advantage of the empty space above the employee toilet. The reason for choosing this location is because the area gets direct sunlight and in the lower area there is a panel house which can be used as a place to install other components such as batteries and controllers.

2. METHODS

The design scheme for a solar panel street light can be seen in Figure 1. The controller and inverter play an important role in controlling battery charging which has an impact on battery life. The energy supply from the sun is not constant due to easily changing weather factors, while batteries require constant power. This is a challenge for the controller. Due to restriction for movement and area construction, solar panel tracking is not available.

ISSN 2549-2888

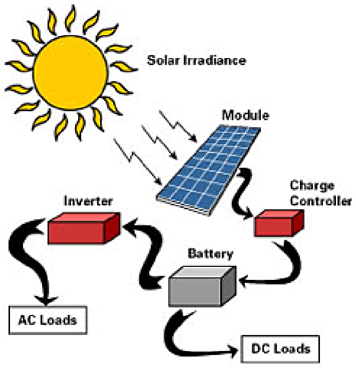

Figure 1. Street Light Design with Solar Panels

In this research, collecting precise and accurate data is very important to plan and design a solar panel system effectively. These include the following:

1. Field Survey: Researchers conduct field surveys to collect geographic and topographic data on research locations, such as information about location, size of available land, direction of the sun and so on. This survey helps in planning and designing a proper solar panel installation.
2. Secondary Data Analysis: Secondary data such as historical weather data and electricity usage data, can be accessed from government sources, electricity companies or research institutions. This data helps in understanding electricity consumption patterns and climate conditions at the research location.
3. Literature Study: researchers conduct research on similar research that has been carried out in other areas. This study helps in understanding the implementation of similar projects, the obstacles faced, and the lessons that can be taken for development in this research.
4. Direct Measurements: Direct measurements are carried out at the research location to obtain data such as sunlight intensity, temperature, and the potential for solar energy that can be produced at that location.

Furthermore, the data collected is divided into two types, namely:

1. Primary Data Collection: Primary data collection is data collection through measurement. Measurements carried out included measuring the roof area of PT employee toilets. Haraka Erfi Kosmetindo Abadi and measuring the lighting load on the panel with the aim of knowing the values related to the implementation of the research.
2. Secondary Data Collection: Secondary data collection is data collection through data from books, journals, and other related institutions to find out data including peak sun hour (PSH) data, solar radiation, and solar panel component specifications related to research implementation.

2.1 Lighting System

A lighting system is a collection of devices and components used to provide sufficient brass light so that the environment can be seen clearly, especially at night or in rooms with minimal natural light. Some of the main components in a lighting system are lights, fixtures, ballasts and drivers, reflectors, cables and connectors, control panels and spare batteries. Each component in the lighting system plays an important role in providing sufficient, safe and efficient light for daily activities. [4]

2.2 Energy and Types of Energy

The definition of energy is essentially the effort to produce work or action. Energy cannot be seen but its impact can be felt. Energy can be converted from one form to another. In fact, according to the definition of energy, energy is divided into two types, namely non-renewable energy and renewable energy. [5]. Non-renewable and renewable energy sources are needed for daily human needs. Non-renewable energy sources have a very limited supply, so if they run out then the energy source cannot be renewed. Non-renewable energy sources are energy sources that come from fossil products. Renewable energy is a natural energy source that can be utilized directly and freely. In addition, the available renewable energy sources are unlimited and can be utilized continuously. Examples of renewable energy include wind, solar, tidal sea water, geothermal, biofuel, water and biomass. [5]

2.3 Solar Energy

Solar energy is energy that comes from solar radiation. This radiant energy is used directly as a source of electrical energy generation using technology called photovoltaics or commonly known as solar energy. Solar energy used to produce electrical energy is called a solar power plant or PLTS. [6]

Average Solar Irradiance is determined as the amount or average length of sunlight in 1 day, by equation 1, it can be used to calculate the average solar radiation [7].

$$\frac{\mathrm{GHI}}{\mathrm{GCTC\ x\ 365}} \quad (1)$$

PSH is peak sun hour, GHI is Global Horizontal Irradiance (kWh/m2) and GSTC is Global Horizontal Irradiance in STC (W/m2).

Daily Energy Consumption or DEC is calculated to determine power consumption along 12 hour as equation 2. While surface area is defined by equation 3

$$8 \text{ h solar panel to load x} \frac{4 \text{ h battery to beban}}{\eta} \text{ x } 20\% \quad (2).$$

$$\text{PV module capacity x } 1.3 \quad (3)$$

2.4 Solar Panels

Solar energy can be directly converted into electrical energy using solar cells (photovoltaic cells). In these cells, a small electrical voltage is generated when the sun hits the meeting point between a metal and a semiconductor (for example silicon) or the meeting point between two different semiconductors.

When photons produced by solar energy hit solar cells, they knock electrons loose from their atoms. If conductors are installed on the positive and negative sides of the cell, an electric circuit will be formed. When electrons pass through the circuit, they produce electricity. Several cells are arranged into a solar panel, and several panels (modulation) can be combined to form a solar array. The more solar panels installed, the more energy that can be produced. To calculate the number of solar cell used is defined by equation 4.

$$\frac{\text{Total Hour in dailly}}{\text{PV module capacity x effective hour}} \quad (4)$$

2.5 Solar Panel Installation

Solar panels use sunlight to produce electricity. DC (Direct current), which can be converted into AC (alternating current) electricity if necessary, so when it is cloudy and the light intensity is low, solar panels can still produce electricity. Solar panels are basically power supplies (devices that provide power), and can be designed to supply small to large electricity needs, either independently or in a hybrid manner. To define watt peak capacity, it uses equation 5.

$$\frac{\text{Total dailly need (wh)}}{\text{peak}-\text{hour}} \quad (5)$$

Batteries are energy storage devices that can be used to operate electronic devices. Batteries are an important component in PLTS, because PLTS can only actively produce electricity during the day. Therefore, batteries are very important as an energy storage device for charging needs at night. During the day, the battery will store excess energy from the solar panels that is not absorbed by the load, so that when the PLTS does not produce maximum power due to bad weather, the battery can be used as a backup solution. Equation (6) and (7) define the capacity and the number of batteries [9].

$$\frac{\text{Power need (w)}}{\text{deep of discharge (DOD)}} \quad (6)$$

$$\frac{\text{Total battery capacity}}{\text{battery spesification}} \quad (7)$$

The use of a Solar Charge Controller (SCC) is required to be able to charge electrical energy to the battery. The presence of SCC can extend the life of the battery because SCC can control the voltage and charging current of the battery so that it does not over charge. SCC is defined by equation (8). [9]

$$ISC \times NPanel \times 125\% \quad (8)$$

Short circuit current (Isc) of solar panels, Npanel is Number of Solar Panels. An inverter is an electronic device that converts a direct voltage (DC) system into back and forth (AC). In a PLTS system, the inverter will be connected to a battery with direct current (DC) voltage and will produce an alternating electric voltage (AC) of 220 V, 50 Hz.

This output voltage is similar to the PLN voltage system so it will make it easier to integrate PLTS in households that are connected to the PLN network and there is no need to replace the electrical devices used. Based on the waveform produced, inverters are divided into three, namely inverters with square, modified and true sine wave output waves. The best inverter is one that is capable of producing pure sinusoidal waves or true sine waves, namely the wave form of PLN electricity. The choice of inverter type depends on the type of load used.

3. RESULT AND DISCUSSION

At this stage, component calculations are carried out to meet daily electricity data needs. Calculation of components which include Solar Panels, Solar Charge Controller, batteries and inverters.

Calculation of load requirements used for this research is the load of lights in employee toilets, street lighting around the parking lot and street lighting for residents. PLTS is designed to meet these load requirements. The detail load is described in detail in Table 1.

Tabel 1. Load Installed for Power Consumption

No	Load	pcs	Power(W)	Total(W)
1	LED TL	5	12	60
2	LED	13	8	104
3	LED	1	18	18
4	LED	1	30	30
		20		212

Total power consumption for a day is $212 \; watt \times 12 \text{ hour} = 2544 \; Wh$.

To determine the need for solar panels. The total energy requirement for one day of use, which from solar radiation measurements is assumed to be 4 hours, is the peak of solar radiation at 10.00 – 14.00 WIB (the maximum of one day-4 h). By using equation 5 ($\frac{2544)}{4}$), the watt peak capacity is 636 Wp.

Battery capacity could be defined by using equation 4. For the calculation, it is determined based on the energy required, namely 2544 Wh and a battery voltage of 12 volts, so the battery capacity is as follows:

$$\frac{2544}{12\text{ h x }75\%} = 282{,}67\text{ Ah}$$

The number of batteries could be described :

$$\frac{282.67\text{ Ah}}{100\text{ Ah}} = 2.82\text{ Ah } \approx 3\text{ Ah}$$

100 Ah is specified of battery used for this research.

Solar Charge Controller (SCC), it can be seen in the panel's technical data, usually there is a short circuit current (Isc) in amperes (A). The solar panel used has a current (Isc) of 5.87 A. In this case the oversize factor for the solar charge controller is 125%, so that Iscc could be obtained as follows:

$$I_{scc} = I_{sc} \times N_{panel} \times 125\%$$
$$I_{scc} = 5{,}87\, A \times 7 \times 125\%$$
$$I_{scc} = 51{,}36\, A$$

Hence, Scc used is 60 A. In this study, monocrystalline solar panels were used because these solar panels have greater efficiency than other types of solar panels, have good resistance to extreme environmental and weather conditions and have a long service life as Figure 2. The average efficiency of these solar panels is 14% - 16% as in Table 2.

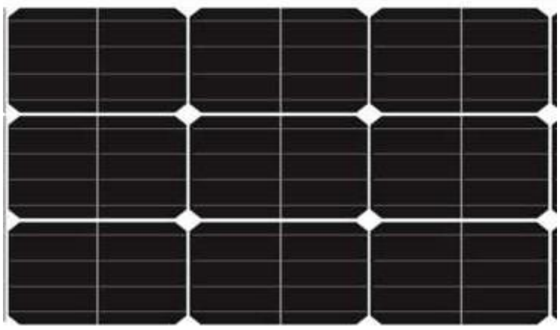

Figure 2. Mono-Crystalline Solar Panel

Table 2. Specifications of 100 Wp Solar Panel [6]

No	Load	Description
1	P_{max}	100 W
2	I_{sc}	5.87 A
3	I_{max}	5.48 A
4	V_{oc}	22.4V
5	V_{max}	1000V(Dc)
6	V_{maxP}	18.3 V
7	Temp	-40 -85 C
8	Dimension	1030 mm x670 mm x 30 mm
9	weight	7.74 kg

In the solar-based battery street light scheme, electricity can be transferred or used directly on the battery. So the battery is selected based on calculating the number of loads and the number of charges. Suitable battery specifications are shown in table 3.

Table 3. Specifications of battery

No	Load	Description
1	V	12 V
2	Rated Capacity(20Hr)	100 A
3	Dimension	328 mm x171 mm x 214 mm
4	weight	29.0 kg

The condition for a battery to work normally is the current stored in the battery must not be drained by more than 25%, so that DOD (depth of discharge) = 100%-25% = 75%. Load reserve is a power reserve for the load (lights), if the solar panels cannot receive sunlight or one day the weather is cloudy, usually a reserve is made for the load in one day. For this battery itself, the selection is made based on calculations of the amount of load, the amount of charging, and the amount of reserve energy.

Inverter specifications was done by looking at the consumption load used in this solar panel system, namely the lamp load of 212 watts. Because the load used in this system is feared that there will be a change in lamps to a larger capacity, the inverter capacity used is one inverter with a capacity of 500 W, modified sine wave type. The choice of modified sine wave inverter is because the components are common on the market and their use is suitable for LED lights compared to other types of inverters

Table 4. Sine Wave Inverter Specifications[6]

Session	Load	Description
	P	500 W
Peak	Peak P	1000 W
	DC In	12 V
	DC Op	9.5 V-15.5 V
	DC Low	9.2 V-9.8 V
Input	Dc low Voltage	10.2-10.5 V
	Over-Voltage	>15 V
	Fuse	35*2
Output	Wave	Sine
	Voltage	220 V
	Freq	50-60 Hz

monocrystalline type solar panels because these solar panels have greater efficiency than other types of solar panels. To calculate the efficiency of solar panels could be obtained as the following:

$$FF = V_m \times I_m / (V_{oc} \times I_{sc}$$
$$FF= 18{,}3\,V \times 5{,}48\,A/(22{,}4\,V \times 5{,}87\,A)$$
$$FF = 0{,}763$$

Total surface are of solar panel is about 4,83 m^2
Hence efficiency of solar panel is

$$\frac{Voc \times Isc \times FF}{Sx\,F} x100$$

$$\frac{22{,}4\,V \times 41{,}09 \times 0{,}763}{4{,}83 \times 1010{,}2}\,x100 = 14{,}39\,\%$$

In terms of battery charging time, time for charging is greatly influences the amount of daily load and weather conditions. By considering, the amount of power will be constant upon peak condition. Charging time (CT)will be obtained as follow:

$$\frac{BC \times V}{Wp} = \frac{300 \times 12}{100} = 5{,}14\ h$$

Where BC is battery capacity and total load is 212 W, while discharging time (DT) could be calculated as the following:

$$(BC \times V \times 0{,}75)/212{=}300x12x0.75/212{=}12.74\ h$$

4. CONCLUSION

From this study it can be shown that solar panels are able to supply the energy needs of street lights. So that the company's electricity bill can be minimized.

Even though the efficiency is still low compared others which is only 14% due to weather and power fluctuation, it could be increased by implemented some optimization algorithm in order to maintain power during charging[10][11][12]. Solar tracking is another way to increase the efficiency, however, it requires larger area for solar panel movement.

Determination of solar panel components based on the power load for 12 hours per day is 2544 watts. It requires solar panels with a total power requirement of 630 Wp with 7 units of monocrystalline type modules, batteries with a requirement of 282.67 Ah with a voltage of 12 V, 3 units of batteries with a capacity of 100 Ah.

1 unit of a PWM type Solar Charge Controller is required with a specification of 60 A, and 1 unit of a Modified sine wave model inverter with a capacity of 500 watts. It is concluded the efficiency of this solar panel system is 14.39%. The charging time of battery per unit is 5.14 hours and will run out in 12.74 hours whenever the power is cut-off.

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